Draft Final Feasibility Study Report
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TA-8547 TAJ: Wholesale Metering and Transmission Reinforcement

Draft Final Feasibility Study Report

Asian Development Bank TA-8547 (TAJ)
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Abbreviations	
ADM	Add-and-Drop Multiplexer
AEM	Advanced Energy Meter – Усовершенствованный счетчик
AMI	Advanced Metering Infrastructure ИУЭ Усовершенствованная инфраструктура учета потребления электроэнергии
AES	Advanced Encryption Standard - Новейший стандарт шифрования
AMR	Automated Meter Reading - Автоматизированное считывание показаний
ANSI	American National Standards Institute - Американский национальный институт стандартов
ATM	Asynchronous Transfer Mode
BPL	Broadband Power Line - Широкополосная линия электропередачи
BT	Barqi Tojik
BUNCC	Back-Up National Control Centre
CDMA	Code Division Multiple Access - Многостанционный доступ с кодовым разделением каналов
CEN	Comité Européen de Normalisation - ЕКС Европейский комитет по стандартизации
CENELEC	Comité Européen de Normalisation Electrotechnique - Европейский Комитет по Стандартизации Электротехники
COSEM	Companion Specification for Energy Meter - Набор правил, основанных на существующих стандартах, для обмена данными с электрическими счетчиками
CSD	Circuit Switched Data
CT	Current Transformer – Трансформатор тока
DC	Data Concentrator – Накопитель данных
DLC	Distribution Line Carrier - Канал связи на несущей распред. сети
DLMS	Device Language Message Specification - Спецификация языка общения с приборами учета электроэнергии
DSM	Demand Side Management – Рационализация спроса,
EBRD	European Bank for Reconstruction and Development – Европейский банк реконструкции и развития
EDM	Energy Data Management - Управление энергетическими данными
EIB	European Investment bank – Европейский инвестиционный банк
ELRP	Energy Loss Reduction Project
EMS	Energy Management System
EN	European Norm - Европейский Стандарт
EU	European Union – Европейский союз
FEC	Forward Error Correction - Упреждающая коррекция ошибок
FSK	Frequency Shift Keying - Частотная манипуляция
GDP	Gross Domestic Product – Валовой внутренний продукт
GIS	Geographical Information systems – Геоинформационная система
GoT	Government of Tajikistan – Правительство РТ
GSM	Global System Mobile - Глобальная система сотовой связи
GPRS	General Packet Radio Service – Общая служба пакетной радиопереда-

	чи
GWh	Giga Watt hours – Гига Вт.ч
HAN	Home Area Network - Домашняя Сеть
HSCSD	High speed circuit switched data
HF	High Frequency- Высокая Частота (ВЧ)
HSDPA	High Speed Data Packet Access - Высокоскоростная передача пакетов данных
HV	High Voltage – Высокое напряжение (ВН)
HPP	Hydro Power Plant – Гидроэлектростанция (ГЭС)
HVAC	Heating, Ventilation and Air Conditioning - Нагревание, вентиляция и кондиционирование воздуха
IEC	International Electrotechnical Commission - Международная электротехническая комиссия (МЭК)
IEEE	Institute for Electrical and Electronic Engineering - Институт инженеров по электротехнике и электронике
IP	Internet Protocol - Интернет-протокол
ISO	International Organisation for Standartisation - Международная организация по стандартизации
ITU-T	International Telecommunications Union – Telecommunications Международный союз по телекоммуникации - телекоммуникации
IT	Information Technique - Информатика
kbps	Kilo bit per second - Килобит в секунду
KV	Kilo Volt – Киловольт (кВ)
kWh	Kilowatt hour – Киловатт-часов (кВт.ч)
LAN	Local area Network – Локальная вычислительная сеть
LF	Low Frequency - Низкая Частота
LTE	Long Term Evolution *(4G LTE)*
LV	Low Voltage - Низкое напряжение
Mbps	Mega bit per second - Мегабит в секунду
M-Bus	Meter-Bus - Шина счетчика
MDM	Meter Data Management - Управление учетными данными (УУД)
MDCS	Meter Data Collection System – Система сбора данных со счетчиков
MSRCS	Multi Side Redundancy Concept by SCADA
MV	Medium Voltage - Среднее напряжение (СН)
MVA	Mega Volt Ampere – Мега вольт ампер (МВА)
MW	Mega Watt – Мега ватт (МВт)
M2M	Machine to Machine
NCC	National Control Centre
NMS	(Telecommunication) Network Management System
NOC	(Telecommunication) Network Operation Control Centre
OPERA	Open PLC European Research Alliance - Европейский исследовательский союз по ВЧ связи
OSHC	Open Stock Holding Company
OSI	Open Systems Interconnection - Взаимодействие открытых систем (ВОС)
PES	Territorial Distribution Enterprise - Территориальная распределительная организация (ПЭС)
PCM	Pulse Code Modulation
PDH	Plesiochronous (*plesio-synchronous*) Digital Hierarchy
PLC	Power Line Carrier - Связь по линии электропередачи

PoD	Point of Delivery – Конечная точка доставки
PSTN	Public Switched Telephone Network - Коммутируемая телефонная сеть общего доступа
RCC	Regional Control Centre
RES	District Distribution Branch - Районное распределительное отделение, РЭС
RF	Radio Frequency - Радио частота
RLP	Radio Link Protocol
RMR	Remote Meter Reading - Дистанционное считывание учетных данных
SCADA	Supervisory Control and Data Acquisition System
STM	Synchronous Transport Module
TA	Technical Assistance - Техническая помощь
TCP	Transmission Control Protocol - Протокол управления передачей
TOU	Time of use – Полезное время
UMTS	Universal Mobile Telecommunications System
USSR	Union of Soviet Socialist Republics – Союз Советских Социалистических Республик (СССР)
VPN	Virtual Private Network
VT	Voltage Transformer – Трансформатор напряжения
WAN	Wide Area Network – Глобальная вычислительная сеть
WiFi	Wireless Fidelity - Беспроводной доступ
WiMAX	Worldwide Interoperability for Microwave Access - Технология широкополосного доступа в микроволновом диапазоне
UMTS	Universal Mobile Telecommunications System - Универсальная мобильная телекоммуникационная система
PEN	Protective Earth Neutral - глухозаземленная нейтраль
TNC	Terre Neutre Combiné
TWh	Terra Watt hours
In the section “Poverty and Social Analysis” dedicated abbreviations are used. These abbreviations are listed separately at the beginning of the related section.	

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1. Executive Summary

1.1 Task 1 Wholesale Metering System

1.1.1 Present metering equipment and meter reading procedure

In the past the majority of the existing metering points including meters and metering transformers are originally designed for technical metering. The equipment follows technically the "Electrical Equipment Construction Rules" of the Ministry for Energy and Electrification of Soviet Union dated 1985. This concerns especially the accuracy classes for meters and instrument transformers.

The accuracy classes for meters differ depending on the associated power and voltage level and vary between classes 0.5 and 2.0 for meters and classes 0.2 up to 1.0 for voltage and current transformers. The meters installed are mostly of Soviet type dating back to the era before 1990, are more than 25 years old and basically have exceeded their useful technical live span anyhow. Certain replacement projects with different manufacturers, for example meters of the manufacturer Chint or Landis&Gyr have taken place since 2007.

The majority of the existing meters are unsuitable to meet the requirements of an automated commercial metering in a wholesale metering system because of their age, not fulfilling the accuracy classes, lack of memory and data communication function, missing possibilities of load profile recording and electric energy tariff settings.

Exceptions are the meters installed at the HV and MV substations in the SUDG Energy Loss Reduction Project which will be incorporated in the new wholesale Metering System.

The current meter reading process in the transmission and distribution systems is based on manual reading by the operating staff of

- Barqi Tojik’s generation departments
- Barqi Tojik’s departments “Electricity & Network”
- the respective Barqi Tojik’s departments “Interstate Energy Flow” together with the Customs and the representatives of the energy company of the concerned foreign countries on the borders

First consumptions and generation numbers and losses per transmission line, substation, and generation plant are calculated manually based on these readings by the meter readers.

The results are communicated via phone to the central “Distribution & Control” department of Barqi Tojik and for the meters on the borders to the central “Interstate Energy Flow” department.

The “Distribution & Control” department of Barqi Tojik calculates the countrywide consumption & losses and passes the figures to the “Accounting” department of Barqi Tojik. The “Interstate Energy Flow” department calculates the import or export values of the last period and passes the figures to the “Accounting” department.

The “Accounting” department creates corresponding entries in the financial system, converting the values of kWh into Tajik Somoni or United States Dollar (USD). Then invoices or credit vouchers are created and sent out. The manual procedures are time consuming and prone to errors.

1.1.2 Restructuring of Barqi Tojik

In the future Barqi Tojik will form the main business units such as (i) Generation, (II) Transmission, and (III) Distribution.

The following subjects will form the core business of the new business units:

- The generation business unit will be concerned only with power generation or combined heat and power. Assets allocated to the generation business unit will include plants that produce only electrical energy.
- CHP1 Dushanbe and Yavan while privately owned or being joint ownership power plants will remain separate businesses.
- The transmission business unit will transmit power, operate the transmission system including the exchange of power with the neighboring countries and have responsibility for system stability and generation dispatch. Transmission assets will include 500 kV, 220 kV and all 110 kV systems.
- Distribution will only be responsible for distributing power to customers. Distribution assets will consist of systems operating at voltages of 35 kV, 20 kV, 10 kV, 6 kV and 0.4 kV.

1.1.3 Scope of meter replacement

The determination of the project scope has been performed by the following priorities:

Priority 1 Commercial metering points

The project considers a replacement of the meters located in the part of the substations of the future transmission system at the 500 kV, 220 kV and 110 kV levels, in total including future extensions 199 substations.

Based on the commercial metering points the energy transported in the transmission system shall be balanced based on:

1. Energy received from the generation units
2. Energy received / delivered to the transmission system operators (TSO) in the
    - Republic of Uzbekistan,
    - Kyrgyz Republic,

- Islamic Republic of Afghanistan.

3. Energy delivered to the distribution unit
4. Energy consumed for transmission system operation and transmission system losses.

In order to improve the correctness of this commercial balance the exchange of CT and VT equipment for the commercial metering points has been in general considered on the 35 kV, 10 kV and 6 kV levels in the project scope.

Priority 2 Operational balancing points

For improvement of the operation of the transmission system several balancing calculations will be enabled as there are.

Asset	Purpose
HV Substations,	Balancing of energy delivered and received, SS power consumption, Unplanned outages.
HV Overhead lines,	Voltage drop > 95%, Unplanned outages
HV/MV transformers,	Transformer efficiency, Unplanned outages,
HV/MV Substations,	Balancing of energy received and delivered, Unplanned outages, SS power consumption.

For the calculation of the balances mentioned above the meters installed at commercial metering points and at the additional internal metering points will be used.

Because the metering results will be used for internal balancing purposes only the exchange of CT and VT does not have the highest priority and has not been considered for the 500 kV, 220 kV and 110 kV networks for the project.

The existing and new meters will consist of
4Q meter type: The meter is used for detecting active and reactive energy in two directions (bi-directional energy flow).

2Q meter type: The meter is used for detecting active and reactive energy delivered (one directional energy flow).

The following scope will be considered in the project:

Table 1-1 Scope for meter replacement

Voltage level	Meter type:	Accuracy cl.	Number
500 kV	4Q	0.2	23
230 kV / 220 kV	4Q	0.2	89
110 kV	4Q	0.2	40
35 kV	4Q	0.2	1
15.8 kV	4Q	0.2	0
10.5 kV / 10 kV	4Q	0.2	16
6 kV	4Q	0.2	0
total	**4Q**	**0.2**	**169**

Voltage level	Meter type:	Accuracy cl.	Number
230 kV / 220 kV	4Q	0.5	72
110 kV	4Q	0.5	133
35 kV	4Q	0.5	93
15.8 kV	4Q	0.5	13
10 kV	4Q	0.5	93
6 kV	4Q	0.5	57
0.4 kV	4Q with CT	0.5	52
0.4 kV	4Q direct	0.5	6
total	**4Q**	**0.5**	**519**

Voltage level	Meter type:	Accuracy cl.	Number
110 kV	2Q	0.5	7
35 kV	2Q	0.5	14
10 kV	2Q	0.5	76
6.3 kV / 6 kV	2Q	0.5	209
0.4 kV	2Q with CT	0.5	116
0.4 kV	2Q direct	0.5	7
total	**2Q**	**0.5**	**429**

In total the replacement of 1117 meters has been foreseen.

The scope for replacing the related current and voltage transformers at the future commercial interfaces will be as follows:

Table 1-2 Scope for CT and VT replacement

CT and VT at commercial points				
	CT single	CT complete	VT single	VT complete
35 kV	54	162	54	162
15.8 kV	13	39	13	39
10.5 / 10 kV	104	312	104	312
6 kV	71	213	71	213
0.4 kV	132	396		
total		1122		726

1.1.4 Meter data collection and structure of the new system

In the substations the meters are located in open racks in rooms for electrical equipment. For remote reading the new meters will be equipped with wireless and with a wired M-BUS interface.

The M-BUS interfaces (based on DLMS/COSEM protocol according IEC 62056) are recommended as an internationally accepted standard which allows an exchange of manufacturer for the meters connected.

The wired M-BUS interface will be connected to the data concentrator (DC). The wireless M-BUS interface may be used for manual reading with a handheld device during commissioning and during operation.

The data concentrator will perform the scheduled meter reading and collect and store the data of the meters connected. The data in the data concentrators will be read out by an AMI – Advanced Metering Infrastructure system.

Within the MDM module of the AMI the meter readings are converted to kWh. According to their location in the network

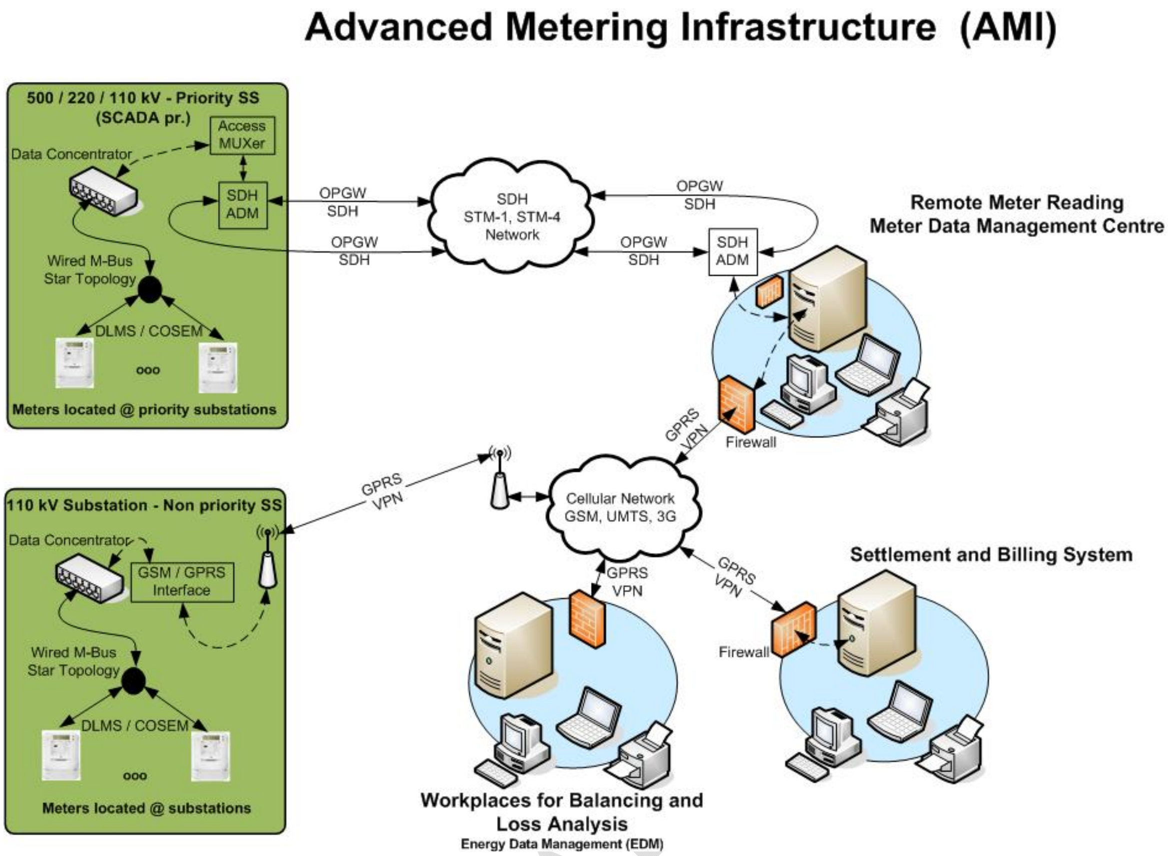
- the consumption of a DSO (Distribution System Operator) or
- the generation of a generation plant or
- the exchange on a border

can be aggregated by use of the concerned meter-related values

These aggregated values in kWh (per DSO / generation plant / border) will be passed to the settlement system.

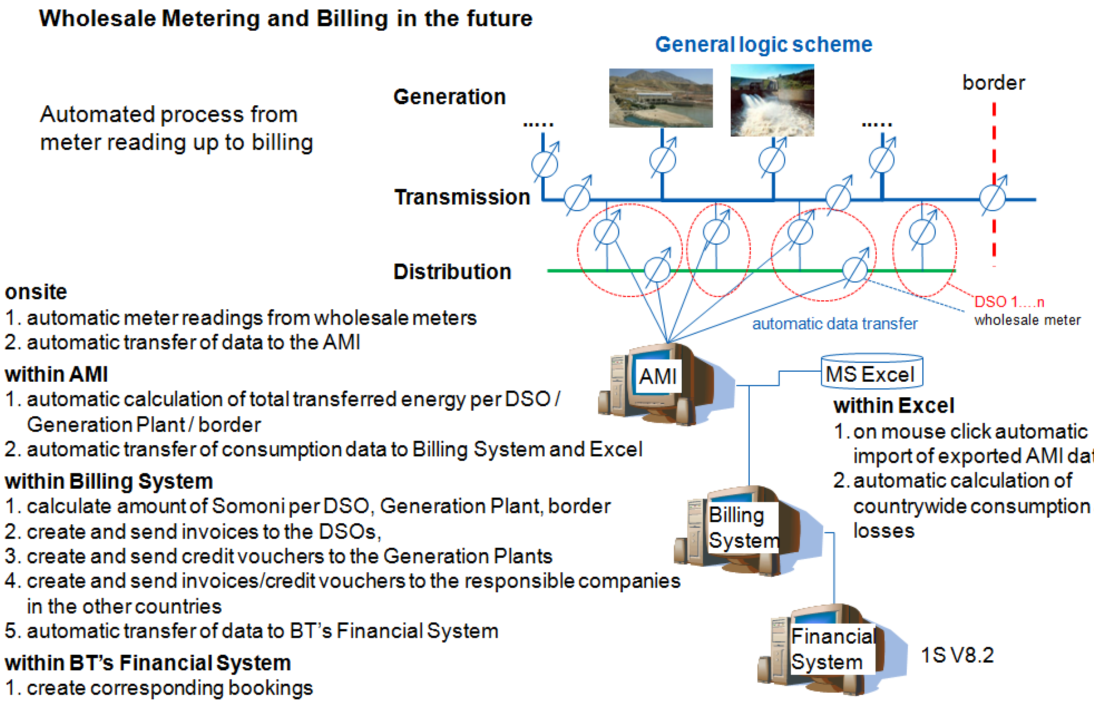
The structure of the overall proposed wholesale metering system is indicated in the next figure.

Figure 1-1Structure of the Wholesale Metering System



The automated dataflow of the metered and aggregated values is indicated in the next figure.

Figure 1-2 Way and Handling of the Meter Data and Respective Calculations in the Future



1.1.5 Required infrastructure for meter data communication

As outlined before the metered values will be collected by scheduled reading sequences by data concentrators via wired M-Bus. For reading out the data concentrator with the AMI a communication infrastructure is required.
In line with the upgrade of the SCADA system in the CAREC project the existing SDH network established with the installed OPGW network will be upgraded and extended for a total of 43 priority substations.
In these priority substations the SDH network shall be used for the transport of the metered data.
In the remaining substations the data concentrators will be equipped with GPRS modems. The network provided by the public communications service providers will be used for the transportation of the metered values
The existing power line communication (PLC) infrastructure is not appropriate for the transfer of metered data because this infrastructure is mainly used for transfer of protection signals and remote control signals.

1.2 Task 2 220 kV OHL and Substation Modifications

The feasibility study has been prepared for the following measures:

- 220 kV overhead line (OHL) between Ayni – Rudaki
- Rehabilitation of the 220 kV substation Rudaki
- Modification of the substation Ayni 220 kV

1.2.1 220 kV OHL from SS Ayni to SS Rudaki

Certain parts of the Tajikistan transmission grid still suffered from disconnection from the Central Asian Power System in November 2009.

Prior to the disconnection, the Penjikent Electrical network (PEN) with a population of 261,000, was supplied from two 220 kV OHL, type AC 400, from the Republic of Uzbekistan. From Penjikent (substation Rudaki) electricity was further transmitted to Ayni region with a population of 75,000.

From Penjikent to Ayni electricity was transmitted over 95 km through a 110 kV OHL, type AC 120, built in 1965 and with a maximum rating of 67 MW. After 2009, these two regions became isolated from the main transmission grid of the Republic of Uzbekistan.

A connection to the main transmission grid in Tajikistan has been established in 2012 with the commissioning of the new constructed substation Ayni 220 kV. This substation supplies electrical power to the regions of Ayni and Penjikent and 6 additional substations located in the valley of the river Zeravshan by using the existing 110 kV OHL.

Due to the limited capacity of the existing equipment and the lack of supply redundancy frequent load shedding does occur in the region of Penjikent. The existing limitation in the power supply is inhibiting the further growth of the industry.

Route Description

The newly to be constructed 220 kV single circuit line from Rudaki (Penjikent) to Ayni is running south- eastwards from Rudaki Substation parallel to two out of operation 220 kV lines to Uzbekistan up to the village of Chorvodor where all three lines will turn more to the south to run through a gap between Chorvodor and Yalokdzhar to reach the southern side of the road from Penjikent to Samarkand (Uzbekistan).

From there the line continues in open areas to the south and finally to the east. The line route passes north south of Zebon, Shurcha and Sabr, keeping a distance of approximately 8.5 km to the middle of the runway of Penjikent Airport and south of Kushtappa towards the east near to Gusar going around the agricultural area up to Navabad. From Navabad the line is running south of Dashthikazy and crossing the access road to a Tajik-Chinese Gold Mining Company.
In this section the line should run parallel but south to the existing 110 kV line from Ayni to Penjikent and continues by crossing a valley to reach the southern border of Koshana.

From Koshana the line runs further on the top of the hills to come down again south of the village of Uata.

From Uata the line is crossing two ridges of hills and continues on the hills bypassing Yavan and following a track to reach the main road Ayni – Penjikent. In this region the line is following this road for approx. 10 km where it again meets the existing 110 kV line.

At the SS Ayni 220 kV the lien will be connected to the existing gantry by crossing the existing 220 kV OHL with construction of two 90 degree tension towers.

The routing proposed has been developed by a joint site survey performed by the responsible expert of the Penjikent Electrical Network and the Consultant. Tower locations, which may be exposed to landslides, have been avoided by alternative routing and preferred locations of the towers at the crest of the mountains. Tower locations, which may be exposed to avalanches, will be protected by V-formed concrete protectors. Following the preliminary route identification a detailed route corridor has been defined by using digital satellite maps generated in June 2014 of the region with a resolution of 50 cm.

According to the routing defined the line will be approximately 94 km long.

Protected areas

There are two Nature Reserves (IUCN Category IV) and one Important Bird Area located in the investigation area. The Zerafshansky Nature Reserve is located north of the river Zeravshan and the city of Penjikent. This natural reserve is located in certain distance from the OHL and the project area.

The IBA Sarazm is located north of the SS Rudaki at both sides of the river. This IBA area is also not touched by the project but a certain part of the OHL will be equipped with bird protection equipment.

The Saivatinsky (Soy Vota) Natural Reserve is located in a south east direction of the village Uata. The northern border of reserve area is extended close to the banks of the river Zeravshan.

In collaboration with the responsible persons from the Forest Department in Ayni, with participation of a representative of ADB and the Consultant the border of the reserve have been identified during a field trip in the related OHL section (irrigation channel) and the final tower positions have been defined so that a crossing of the natural reserve area with the OHL is avoided.

Alternative routes

In the last section starting from substation Ayni 220 kV the 110 kV line is located in the narrow valley areas directly beside the road and the steep slope going down to the river. There is no possibility to bundle the route with the new 220 kV line. Furthermore where the 110 kV is running north of the river this line is crossing many residential areas, which should be avoided by the new line. When the 110 kV line was routed on the south side of the river a parallel routing was preferred.

At Penjikent the 110 kV line is running through the city to reach the Substation Rudaki and thereby crossing many houses.

For these reasons the new line is first leaving Penjikent to the west and turns later to the east, towards the substation Ayni 220 kV.

OHL Technical Design Data

The new OHL will be designed for the following data:

Nominal voltage U_n		**220 kV**
Maximum operating voltage U_s		245 kV
Power frequency		50 Hz
Basic insulation level design BIL (lightning impulse)		1050 kV_{peak}
Switching impulse withstand voltage phase - earth		460 $kV_{r.m.s.}$
Ratio of switching over-voltage phase- to-phase and phase to ground		1.5
System highest 1-phase short-circuit current level (1s)		25 kA
Short circuit current for thermal stability check of the OPGW (1s)		6 kA
Conductor type		ACSR 400 sqmm (“Zebra”)
Number of conductors per phase		1
Transmission Capacity of the Line (thermal)		300 MVA
Number and type of ground-wires		1 OPGW Steel $70mm^2$
Design creepage distance for medium pollution as per IEC 60815		31mm/kV (U_s)
Altitude above sea level		900 – 2.000 m

Additional wind and ice data derived from the climatic records are included in the related chapter of this report.

The OHL will be equipped with an optical ground wire (OPGW) with 24 single mode fibers. In the related area of the Penjikent airport the OHL will be equipped with an aircraft warning system compliant to the Convention on International Civil Aviation.

Towers

Towers may designed as PUE towers or alternatively following a new tower design (including type test). Further details regarding the tower and foundation design are included in the respective chapter of this report.

1.2.2 Modification SS Rudaki

The first part of 220/110/35/10 kV substation Rudaki was built 50 years ago and extended by 220 kV part more than 30 years ago. All installed equipment is old and at the end of the service life. The Rehabilitation of the complete substation is necessary but in this project only scheduled for the 220 kV part.

Location and Arrangement

The substation is located at the western part of the City of Penjikent. The area of the substation is limited at the north west side by the river side. Furthermore the substation is surrounded by housing areas at the northern and eastern direction. Only in the south west direction nearby the 110 kV part an area is used by a green house which is not used anymore. But the related properties are not belonging to Barqi Tojik anymore. As a consequence any extension of the substation will be limited by space constraints.

The existing 220 kV switchyard includes:
- 2 (two) OHL bays for the 220 kV OHL Sogdiana (Uzbekistan) and 220 kV OHL Sary Bazar (Uzbekistan).
- 2 (two) transformer bays 220/110/10 kV, 63 MVA each
- 2 (two) measuring bays

Rehabilitation concept

It has been decided that the rehabilitation of the 220 kV switchyard will replace one 220 kV OHL from Uzbekistan which is currently out of operation by the new line from Ayni and contain the following:

- Rehabilitation of OHL one (1) overhead transmission line bay to SS Ayni 220 kV (former OHL Line to Sogdiana, Uzbekistan)
- Rehabilitation of OHL one (1) overhead transmission line bay to Sari Bazar (Uzbekistan)
- Rehabilitation of one (1) transformer bay and replacement of one (1) autotransformer AT1 with 220/110/10 kV 125 MVA auto-transformer
- Rehabilitation of one (1) transformer bay and replacement of one (1) autotransformer AT2 with 220/110/10 kV 125 MVA auto-transformer

The new switchyard will be based on a ring bus bar system.

The rehabilitation work will also contain the removal of the existing HV equipment including structures and foundations, civil works and replacement of control equipment, protection equipment and communication equipment.

The concept proposed is to have a cost advantage compared to a double bus bar system; it can be realized with the existing space of the substations and avoids the acquisition of new land.

The replacement of the autotransformers is justified by the present consumption figures, the present load shedding and the load forecast given for the area.

The technical concept proposed may also allow the import and the export of power on the 220 kV level to the Republic of Uzbekistan.

Design data

The basic technical values have been selected in accordance with the existing system in Tajikistan and under consideration of the recommendations of IEC. For the 220 kV system the following basic technical values will be considered:

nominal system voltage:	220 kV
highest voltage for equipment:	245 kV

rated frequency:	50 Hz
standard lightning impulse withstand voltage:	1050 kV (peak value)
standard switching impulse withstand voltage:	460 kV (peak value)
creepage distance:	6,125 mm

For the 220 kV circuit breakers the SF6 type will be used. The SF6 breakers will be of the outdoor type, single pole, constructed according to IEC 60056 and other relevant IEC standards / recommendations as well as VDE regulations and DIN standards.

All insulators shall be equipped with motor drives, however, manual operation must also be possible. The isolators will be combined with manually operated interlocked earthing switches.

Voltage transformers shall be installed in all line feeders. The voltage transformers will be of capacitive type, single phase, with one end of the primary winding directly earthed and will be in-stalled on separate supports.

Current transformers shall be installed in all line and transformer feeders and shall be single-phase and directly installed on separate supports. For measuring and protection the same current transformers with multiple secondary cores will be used.

In the present high voltage system lightning arresters are installed only at the primary and secondary side of the transformers. There are no arresters at the entrance of the line feeder bays into the substations. However, most of the utilities in western countries have installed lightning arresters in line bays. The arresters provide an additional overvoltage protection for the switchyard equipment.

The substation control and monitoring system (SCMS) for the rehabilitated substations will be a digital control and monitoring system to supervise and operate the 220 kV switchyards completely in every respect for monitoring and control also the existing switchyards via existing distribution frame and existing control cubicles.

1.2.3 Modification SS Ayni

The Ayni 220 kV substation is a 220/110/10 kV substation and was commissioned in 2012. The technical conditions are good.

During the design and construction of the substation prearrangements for the connection of the 220 kV OHL to Rudaki for example with a space reserve for the additional bay has been made.

The 220 kV switchyard includes:

1(one) OHL bay to substation Shahristan
2 (two) transformer bays 220/110/10 kV
1 (one) coupling bay
2 (two) measuring bays

Modification works

For the connection of the new 220 kV OHL from the SS Ayni 220 kV to the SS Rudaki the following modification work will be required in the SS Ayni:

- Installation of one (1) overhead transmission line bay
- Installation of one (1) coupling between the existing OHL and the new OHL
- Modification of the control and protection system. The existing SCMS need to be extended with respect to the additional equipment.
- Modification of the communication system with respect to the extension of the OPGW respectively of the SDH network to the SS Rudaki.

1.3 Financial Analysis

In the framework of the consultancy project, Fichtner has prepared a financial analysis of the prospective investment within the Wholesale Metering and Transmission Reinforcement Project in accordance with ADB's "Financial Management and Analysis of Projects" (2005 and 2006) and "Financial Due Diligence - A Methodology Note'' (January 2009).

As starting point for the financial analysis data is sourced from project investment, financing and operating plans. Fichtner has prepared a preliminary investment and financing plan, the latter being subject to negotiations between lending and borrowing entities. Bothe plans are shown in the tables below.

Table 1-3 Preliminary Project Investment Plan

Table 1: Project Investment Plan
($ million)

Item		Amount [a]
A.	**Base Costs** [b]	
	1. Wholesale Metering	17.2
	2. Transmission Lines	36.9
	Subtotal (A)	54.1
B.	**Contingencies** [c]	8.1
C.	**Financing Charges During Implementation** [d]	4.8
	Total (A+B+C)	67.0

a Includes taxes and duties of [amount] to be exempted by the government.
b In mid-2014 prices.
c Physical contingencies computed at 10% of the base costs excluding taxes and duties. Price contingencies computed at 1.5% on foreign exchange costs and 7.0% on local currency costs: includes provision for potential exchange rate fluctuation under the assumption of a purchasing power parity exchange rate.
d Includes interest for sub-loan to Barki Tojik calculated at 5%. to be financed from Barki Tojik resources.
Source: Asian Development Bank and TA consultant estimates.

Table 1-4 Preliminary Financing Plan

Table 2: Financing Plan

Source	Amount ($ million)	Share of Total (%)
Asian Development Bank	54.0	80
Government	13.0	19
	67.0	**100**

Source: Asian Development Bank estimates.

Based on various assumptions for inflation in Tajikistan, exchange rate fluctuations between the Tajik Somoni and US$, cost of capital Tajikistan, project construction duration, terms and conditions of borrowing and taxes, Fichtner performed the financial analysis based on the discounted cash flow method.

The overall results are shown in the table below.

Table 1-5 Consolidate Financial Evaluation of the Project

Year	Period	Costs Investment costs	O&M costs	Replacment and Major Overhaul	Total Costs	Benefits	Net Cash Flow
2014	-4						
2015	-3	0.30			0.30		-0.30
2016	-2	1.20			1.20		-1.20
2017	-1	9.96			9.96		-9.96
2018	1	18.59			18.59		-18.59
2019	2	25.15			25.15		-25.15
2020	3	11.79	0.93		12.72	11.91	-0.81
2021	4		0.93		0.93	12.15	11.22
2022	5		0.93		0.93	12.40	11.47
2023	6		0.93		0.93	12.66	11.73
2024	7		0.93		0.93	12.91	11.99
2025	8		0.93	0.68	1.61	13.18	11.57
2026	9		0.93		0.93	13.45	12.52
2027	10		0.93		0.93	13.72	12.80
2028	11		0.93		0.93	14.01	13.08
2029	12		0.93		0.93	14.29	13.36
2030	13		0.93	0.68	1.61	14.58	12.98
2031	14		0.93		0.93	14.88	13.96
2032	15		0.93		0.93	15.19	14.26
2033	16		0.93		0.93	15.50	14.57
2034	17		0.93		0.93	15.81	14.89
2035	18		0.93	0.68	1.61	16.14	14.53
2036	19		0.93		0.93	16.47	15.54
2037	20		0.93		0.93	16.80	15.88
2038	21		0.93		0.93	17.15	16.22
2039	22		0.93		0.93	17.50	16.57
2040	23		0.93	0.68	1.61	17.85	16.24
2041	24		0.93		0.93	18.22	17.29
2042	25		0.93		0.93	37.14	36.21
FNPV		**59.09**	**14.32**	**1.76**	**75.17**	**236.78**	**161.61**
FIIR		**16.54%**					
WACC		**2.30%**					

The analysis of both components of the project as well as the consolidated project demonstrates that the overall project is financially viable by generating sufficient returns and positive net present values. A sensitivity analysis has confirmed this judgment.

1.4 Economic Analysis

The economic analysis has the objective to evaluate the overall impacts of the project on the welfare of the people of Tajikistan, and to confirm the economic viability of the project. The consultant looks at the project from a societal perspective and whether the project utilizes scarce resources in an optimal manner for society.

The methodology used for the economic analysis is similar to the financial analysis. The evaluation of the project is carried out in a four step approach. Cost and benefits of the project are:

- identified
- quantified
- expressed in monetary terms, and
- compared to each other to derive the net benefit of the project.

The financial investment costs are converted into economic costs by applying the shadow price approach. In the performed economic analysis, market prices can only be applied if they reflect the true marginal social costs to the economy. In most countries including Tajikistan this is not the case, because of government interventions into the competitive market process through various mechanisms.

The economic assessment – as well as the financial analysis - will use incremental costs and benefits, meaning that the with and without project situations is indirectly considered.

Fichtner has identified the following benefits:

Wholesale Metering:

- The economic benefits for the wholesale meters component are the incremental energy billed. By installing wholesale meters countrywide the measuring process becomes more effective and efficiency increases throughout the network. BT will have an incremental revenue resulting from additional energy billed.
- From the standpoint of the entire economy of Tajikistan, it is worth to consider that consumers once they are obliged to pay for electricity consumed, there will be increasing efforts of the same to save electricity by using low consumption equipment such as bulbs with low voltage and to avoid any wasting of electricity.
- Furthermore, the installment of such meters will indirectly avoid outages and reduce losses when BT will be able to measure it technical losses more precisely.
- When the process of energy saving is initiated by the installment of the concerned metering equipment, consequently other consumers will benefit from this process because their demand of electricity can be satisfied in a more reliable way. This is an important overall economic benefit for the Tajik society, which has a lot of consequential benefits such as extension of various business areas.
- Finally, the utility BT will have a better understanding and a more clear picture on the real demand of electricity in Tajikistan which facilitates the optimization of the whole electricity system.
- In the base case, it has been assumed that in 2020 an increase of energy billed of 1.5% has been assumed which reflects the aggregate of the economic benefits of the project.

Transmission Lines

The economic benefits for the transmission lines component are the incremental energy transmitted generated through the reduction of load shedding and improving the efficiency of the network. Any additional energy generated through the new transmission line will be used by the people in the Penjikent region because currently load shedding is significant during all periods.

In terms of numbers, the EIRR and ENPV have been calculated. The results are shown in the tables below

Table 1-6 Wholesale Meters component: Economic costs and benefits stream and Economic Internal Rate of Return

Year	Period	Costs: Economic Investment costs	Replacement costs	Total Costs	Benefits	Net Benefits
2014	-4				0	
2015	-3	0.00		0.00		0.00
2016	-2	0.53		0.53		-0.53
2017	-1	3.08		3.08		-3.08
2018	1	5.44		5.44		-5.44
2019	2	7.22		7.22	0.00	-7.22
2020	3	3.39		3.39	7.50	4.11
2021	4				7.55	7.55
2022	5				7.60	7.60
2023	6				7.64	7.64
2024	7				7.69	7.69
2025	8		0.16	0.16	7.74	7.57
2026	9				7.78	7.78
2027	10				7.83	7.83
2028	11				7.88	7.88
2029	12				7.93	7.93
2030	13		0.16	0.16	7.97	7.81
2031	14				8.02	8.02
2032	15				8.07	8.07
2033	16				8.12	8.12
2034	17				8.16	8.16
2035	18		0.16	0.16	8.21	8.05
2036	19				8.26	8.26
2037	20				8.31	8.31
2038	21				8.35	8.35
2039	22				8.40	8.40
2040	23		0.16	0.16	8.45	8.29
2041	24				8.50	8.50
2042	25				8.54	8.54
NPV		**10.61**	**0.09**	**10.69**	**30.53**	**19.84**
EIIR		**32.31%**				
Discount rate		**12%**				
B/C ratio:		**9.09**				

Table 1-7 Transmission Lines component: Economic costs and benefits stream and Economic Internal Rate of Return

Year	Period	Costs			Total Costs	Benefits	Net Benefits
		Economic Investment costs	O&M costs	Major Overhaul			
2014	-4						
2015	-3	0.00			0.00		0.00
2016	-2	0.85			0.85		-0.85
2017	-1	5.91			5.91		-5.91
2018	1	11.10			11.10	0.00	-11.10
2019	2	14.94	0.00		14.94	0.00	-14.94
2020	3	32	1.63		34.13	11.72	-22.41
2021	4		1.63		1.63	11.72	10.09
2022	5		1.63		1.63	11.72	10.09
2023	6		1.63		1.63	11.72	10.09
2024	7		1.63		1.63	11.72	10.09
2025	8		1.63	0.5	2.13	11.72	9.59
2026	9		1.63		1.63	11.72	10.09
2027	10		1.63		1.63	11.72	10.09
2028	11		1.63		1.63	11.72	10.09
2029	12		1.63		1.63	11.72	10.09
2030	13		1.63	0.5	2.13	11.72	9.59
2031	14		1.63		1.63	11.72	10.09
2032	15		1.63		1.63	11.72	10.09
2033	16		1.63		1.63	11.72	10.09
2034	17		1.63		1.63	11.72	10.09
2035	18		1.63	0.5	2.13	11.72	9.59
2036	19		1.63		1.63	11.72	10.09
2037	20		1.63		1.63	11.72	10.09
2038	21		1.63		1.63	11.72	10.09
2039	22		1.63		1.63	11.72	10.09
2040	23		1.63	0.5	2.13	11.72	9.59
2041	24		1.63		1.63	11.72	10.09
2042	25		1.63		1.63	28.12	26.48
NPV		**32.93**	**6.38**	**0.27**	**39.58**	**46.43**	**6.86**
EIIR		**14.93%**					
Discount rate		**12%**					
B/C ratio:		**2.73**					
LEC:		**1.87 US$ cents/kWh**					

1.5 Financial Management Assessment of Barki Tojik

The performed financial management assessment (FMA) of Open Joint Stock Holding Company Barki Tojik, the project executing agency for the Wholesale Metering and Transmission Reinforcement Project (the project), was based on the report prepared by the project preparatory technical assistance (TA) consultant who has reviewed and updated previous FMAs in order to avoid duplicating diagnostic work. The FMA for this project was prepared in accordance with ADB's "Financial Management and Analysis of Projects" (2005) and "Financial Due Diligence – a Methodology Note" (January 2009). The update for the project will also focus on work done earlier, however it focuses on Barki Tojik's efforts to overcome previously identified issues to demonstrate any improvements.

Barki Tojik's financial management capacity requires significant improvement. External auditing for fiscal years (FY) 2011 and 2012 based on international standards on auditing (ISA) both indicate major issues including i) valuation of inventory, ii) revaluation of assets, iii) records on account receivables and payables, and iv) data conciliation of revenues. However, substantial efforts are being made to strengthen the financial management capacity. Barki Tojik, funded by the World Bank, is in the process of recruiting international consultants to i) revaluate assets in accordance with the International Financial Reporting Standards (IFRS), and ii) assess the issues related to the account receivables and payables. Automated accounting and billing system are being introduced starting from major cities such as Dushanbe and Khujand. It is expected that there will be positive changes in Barki Tojik's accounting procedures, financial reporting and management reporting systems. This project will also contribute to resolving the issues related to accounts payable/receivable and revenue accounting through the introduction of wholesale metering.

The recent financial performance of Barki Tojik has been weak and unstable, generating losses for FY2007-2009, profits for FY2010-2011, and losses again in FY2012 and in FY 2013. The weak and unstable performance may be attributed to a low level of end-user tariffs (an average tariff at 2 cents/kWh), provisions required to accommodate increasing doubtful account receivables, and deteriorated performance of ageing assets. Continued efforts are necessary to steadily increase the tariff level, improve tariff collection efficiency with the adoption of computerized accounting and reporting systems, and modernize and rehabilitate productive assets through investments. It is expected that Bark Tojik's financial performance improves with the supports provided by international financial institutions including ADB and WB.

1.6 Initial Environmental Examination

Please refer for the executive summary of the initial environmental examination (IEE) to the related section in the report attached in the annexes.

1.7 Land Acquisition and Resettlement Plan (LARP)

Please refer for the executive summary of the land acquisition and resettlement plan (LARP) to the related section in the report attached in the annexes.

2. Authorization

The

ASIAN DEVELOPMENT BANK (ADB)
6 ADB Avenue
Mandaluyong City 1550
Metro Manila, Philippines
as Employer

appointed

FICHTNER GmbH and Co KG
P.O. Box 10 14 54
70013 Stuttgart / Germany
as Consultant

to perform the consulting services for the execution of the technical assistance (Technical Assistance) for the TA-8547 TAJ: Wholesale Metering and Transmission Reinforcement .

2.1 Objectives of the project:

The total installed generation capacity of Tajikistan is 5,055 megawatts (MW). In 2012 it generated 16.9 terra-watt hours (TWh) of which only 13.2 TWh was billed.

The difference is a sum of the power system's own consumption and losses. Total transmission/distribution system losses in Tajikistan are currently estimated at around 22%, of which transmission system technical losses accounted for 5% in 2012. Distribution system losses are 17% and have remained virtually unchanged since 2006.

Barqi Tojik does not recognize commercial losses and therefore applies technical losses "norms" to the amount of energy received into the distribution networks from transmission. These are unreliable figures and probably understated due to absence of proper methodology and relevant metering system.

Barqi Tojik is in the process of organizational restructuring to form three separate business units. The three business units will comprise generation, transmission and distribution. The transmission business unit will comprise 500/220/110 kV systems and distribution systems will comprise systems at 35 kV and below. Throughout the Barqi Tojik system 1073 existing wholesale metering points are installed.

Existing wholesale metering hardware within Barqi Tojik is an assortment of electronic and electromechanical meters. The present billing and settlement system relies on manual inputs and processing. To enable eventual establishment of commercial operations for each business unit, a modern metering and automated billing system is required.

At the same time, certain parts of the Tajikistan transmission grid still suffer from disconnection from the Central Asian Power System in November 2009.

Prior to the disconnection, the Penjikend region of Tajikistan, with population of 261,000 (39,122 customers), was supplied from two 220 kV lines from Uzbekistan (through 2x63 MVA transformers). From Penjikent (substation Rudaki) electricity was further transmitted to Ayni region with population of 75,000 (2,100 customers). Peak demands of Penjikent and Ayni are 75 MW and 20 MW, respectively. From Penjikent to Ayni electricity was transmitted over 95 km through 110 kV line built in 1965 and with maximum rating of 67 MW. After 2009, these two regions became isolated from the main transmission grid of Tajikistan.

For that reason and in consideration of the expected growth of the power demand in the Penjikent region, the present project with its reinforcement of the trans-mission system in combination with the loss reduction expected from the improvement of the new metering system is understood to be a further step to form an overall interconnected network within Tajikistan and to make the Tajik network more reliable.

Hence the aim of the consultants assignment is to undertake a technical, financial, economic, environmental and social due diligence and to prepare a feasibility study to ensure ADB financing of the Project.

2.2 Acknowledgement

The Consultant would like to thank all Government officials, the management and members of the Project Management Unit, Barqi Tojik personnel and the ADB regional office as well as other organizations for their fruitful cooperation in furnishing data and information and providing general support during local investigations.

3. Task 1: The wholesale metering component

3.1 Existing Metering System for calculation of countrywide consumption and losses

In the past the majority of the existing metering points including meters and metering transformers are originally designed for technical metering. The equipment follows technically the "Electrical Equipment Construction Rules" of the Ministry for Energy and Electrification of Soviet Union dated 1985. This concerns especially the accuracy classes for meters and instrument transformers.

The accuracy classes for meters differ depending on the associated power and voltage level and vary between class 0.5 and 2.0 for meters and class 0.2 up to 1.0 for voltage and current transformers.

The meters are mostly of Soviet type dating back to the era before 1990, are more than 25 years old and basically have exceed their useful technical live span anyhow.

These meters are unsuitable to meet the requirements of a commercial metering because of their age, not fulfilling the accuracy classes, lack of memory function, missing possibilities of load profile recording and electric energy tariff settings.

The meter reading is based on manual reading by the operation staff of

- BT generation departments of the respective HPP and Heating plants in the concerned plants
- the respective BT departments “Electricity & Network” in the substations and lines
- the respective BT departments “Interstate Energy Flow” together with the Customs and the representatives of the energy Company of the concerned foreign state on the borders

On the basis of these readings first consumptions/generation and losses per transmission line / substation / generation plant are calculated.

The values noted on the papers are communicated verbally via phone to a counterpart in the central “Distribution & Control” department of Barqi Tojik and for the meters on the borders to the central “Interstate Energy Flow” department.

The “Distribution & Control” department of Barqi Tojik calculates the countrywide consumption & losses and passes the figures to the “Accounting” department of Barqi Tojik. The “Interstate Energy Flow” depart-ment calculates the import or export values of the last period and passes the figures to the “Accounting” department.

The “Accounting” department creates corresponding bookings in the financial system, converting the values of kWh into Tajik Somoni or United States Dollar (USD). Then invoices or credit vouchers are created and sent to the foreign energy companies.

Figure 3-1 Process of calculation the countrywide consumption and losses

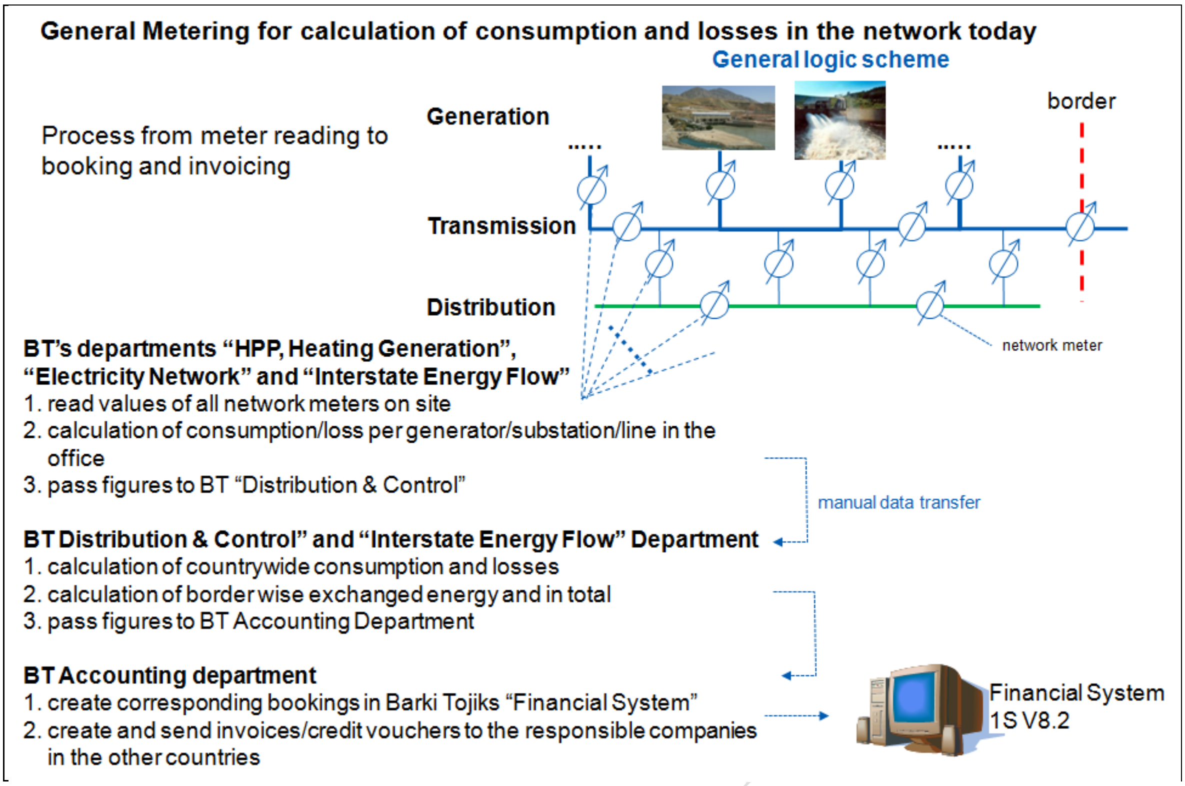
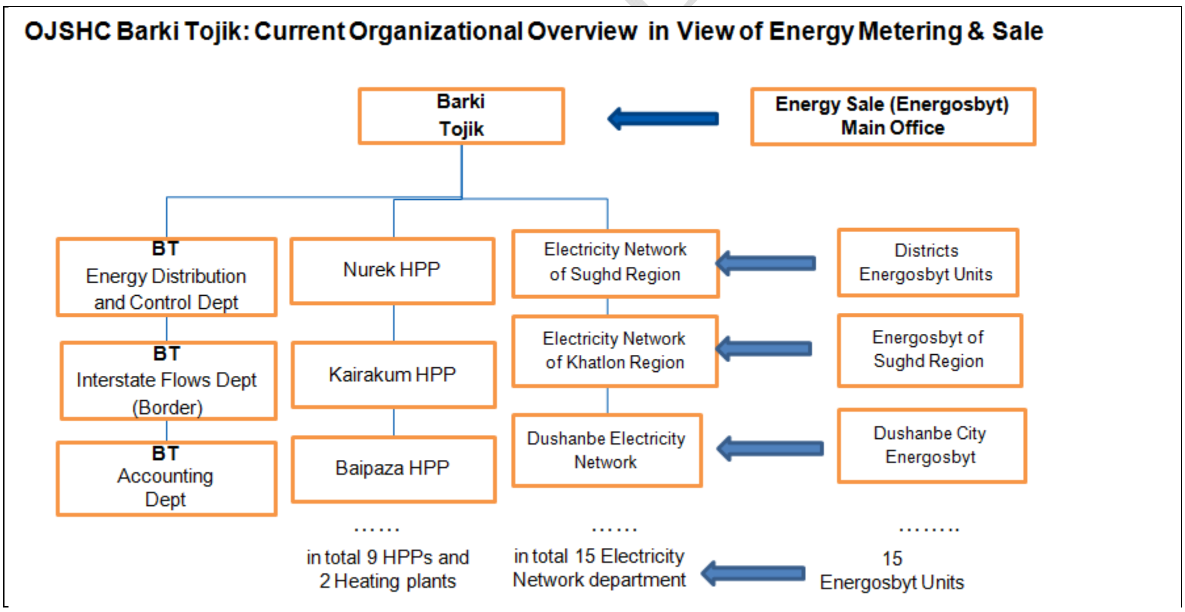


Figure 3-2: Organisational Units with respect to the network metering and calculation task



3.2 Review of projects related to metering, SCADA or communications.

3.2.1 Meter replacement projects

3.2.1.1 Supply by Landis & Gyr

In the period from 2002 to 2008 with a financing from a Swiss bank OSHC Barqi Tojik replaced the first lot of meters in their system.

Under the project, new energy meters have been supplied for cross-border energy exchange points, at major power stations and at the border points between the future business units for generation, transmission and distribution.

The supply and installation contract has been awarded to Landis & Gyr.

The current transformers (CT) and voltage transformers (VT) have not been exchanged under the project due to budget limitations.

In the period between 2009 to 2010 additional 320 meters have been supplied and installed. This project has been financed by the ADB grant 2303 TAJ.

Landis & Gyr meters

Three (3) different types of meters have been supplied under the project:

Type-A: Four quadrant meters for import and export of active and re-active energy
Type-B: Two quadrant meters for active and re-active energy metering in one direction only
Type C: One quadrant meter for active energy metering in one direction only

The meters installed are capable but not equipped for automatic meter reading and metering data transmission.

In total in the northern part 28 meters and in the southern part of the electrical network 67 meters have been installed.

The meters installed had the following characteristics:,

- type ZMQ202C.6r4f6, cl 0.2 and
- type ZMQ205C.6r4f6, cl 0.5
- 1A and 5 A,

The decision for replacing these electronic meters is based on the following facts:

- Lack of built in communication devices for remote meter reading,
- The meters are in operation since 2008 and will have reached more than 50% of their lifetime when the next phase of this project is due for execution.

3.2.1.2 Sugd Energy Loss Reduction Project

In October 2012 the contract for consultancy services for the Sugd ELRP commenced.

Based on the technical design the contracts for two lots for supply and install have been awarded. Both supply contracts commenced in May 2014.

The content of the supply lots will be follows:

Lot 1

The lot 1 comprises the supply and installation of grid and retail meters (end consumer meters), meter reading system, and auditable billing system in Khujand and surrounding municipalities.

Approximately 100,000 mechanical meters are to be replaced within the distribution grid of Khujand and surrounding municipalities.

Lot 1 will cover the supply and installation of retail and grid meters, low voltage overhead lines and underground cable products, meter boxes, distribution boards for houses, communication modems, data concentrators, current and voltage transformers where necessary and installation of accessories for different metering points:

(a) remote metered grid metering points enabling the creation of energy balances;
(b) remote metered important industrial and budget consumers which are indirectly measured ,
(c) remote metered small commercial and industrial consumers;
(d) remote metered residential consumers living apartment buildings; and
(e) remote metered residential consumers living in individual houses.

The lot 1 will also include:

(f) advanced metering infrastructure (AMI) functions like meter operating system, meter management and meter data management, data concentrators and additional communication infrastructure,
(g) Energy data management (EDM) and auditable billing system,
(h) Additional testing and certification equipment.

The AMI, EDM and the billing systems will support load limitation and remote disconnection of customers in the case of non-payment in order to enable a pre-payment function of the consumed energy. The pre-payment function will be based on online communication.

The supply, installation, commissioning and testing of the AMI will allow for remote meter reading of all grid meters supplied.

Lot 1 includes provisions for the training of the BT staff in operating, administrating and maintaining of the AMI system including the communication technologies used.

The EDM and billing system will cover the supply, installation, commissioning and testing of an auditable state of the art billing system and will include training for the BT staff as well.

The relocation of the customer meters mainly from inside of the houses to the low voltage line posts and the related replacement of the supply cables is one of the main actions to reduce the energy theft.

Presently the project completion for lot 1 is scheduled for April 2017.

The lot comprises the replacement of 190 pieces of 3-phase meters, U=100 V, I=5 A, (class

0.5) to be installed at HV and MV substations and distribution points.

It further comprises the supply and installation of 220 pieces of 3-phase meters, U=100 V, I=5 A (class 0.5) for MV customers (CT/VT) as well as the replacement of the related CT's and VT's at these customers.

The meters will be produced by Hexing Electronics, China, the type HXF300 is foreseen for operation with CT and VT in HV and MV substations.

The meters can be equipped with plug and play communication module (GPRS / PLC / RF / zigbee / M Bus). As per the standard in the Sugd ELRP the communication of the meters located in the substations to the data concentrator will be wired M-Bus in star topology.

The replacement of CT's and VT's at the HV and MV substations is part of the Sugd ELRP.

Even when the Sugd ELRP has only a small overlapping to the transmission system it is foreseen to integrate the meters supplied in Sugd ELRP project into the Wholesale metering project.

Lot 2

The lot 2 comprises measures for the rehabilitation of electric distribution networks. This includes the supply and installation of high, medium and low voltage equipment like substations, transformers and switchyards (110 kV Substation with transformers 110/10 kV, 6-10 kV transformers and switchyards and 0.4 kV equipment), buried cables as well as aerial bundled conductors (ABC).

The installation of the additional 110 kV substation in Nargornaya and the new installation of supply lines to the nearest existing transformer points will reduce the overload of the existing power supply network at the right bank area of the city of Khujand especially in the so called "Mira Street"-Area where approx. 27,000 customers are located and in the surrounding areas.

The additional infeed capacity of the Nagornaya substation will reduce the load in the presently overloaded 110/10 kV substations in Novaya and Zarachnaya. This improves the power quality and reduces technical losses as well as inaccuracies with respect to electricity consumption metering.

For the left bank area of Khujand City a replacement of MV cables and 8 transformer points is foreseen which will improve the power quality for approximately 20,000 customers.

In the "Dushanbe ELRP" it has been experienced that a significant number of end consumer meters were not working correctly due a very low voltage level.

The completion of the lot 2 is scheduled for November 2015.

3.2.1.3 Dushanbe loss reduction project

The Dushanbe ELRP has been developed and implemented to create a solid economic basis for the electricity sector in Dushanbe. The project comprises:

- provision of 160.000 energy meters at household and the distribution grid level together with auxiliary installation material,
- provision of meter testing and calibration equipment
- supply of different types of cables and wires required for installation of the meters and for partial network rehabilitation.
- the installation of a modern metering and billing system for electricity,
- technical assistance and training to OSHPC Barqi Tojik (BT)
- 3 Contracts for installation of the energy meters and cables.
- The project also had a component for GAS metering and billing which is not dealt with in this chapter.

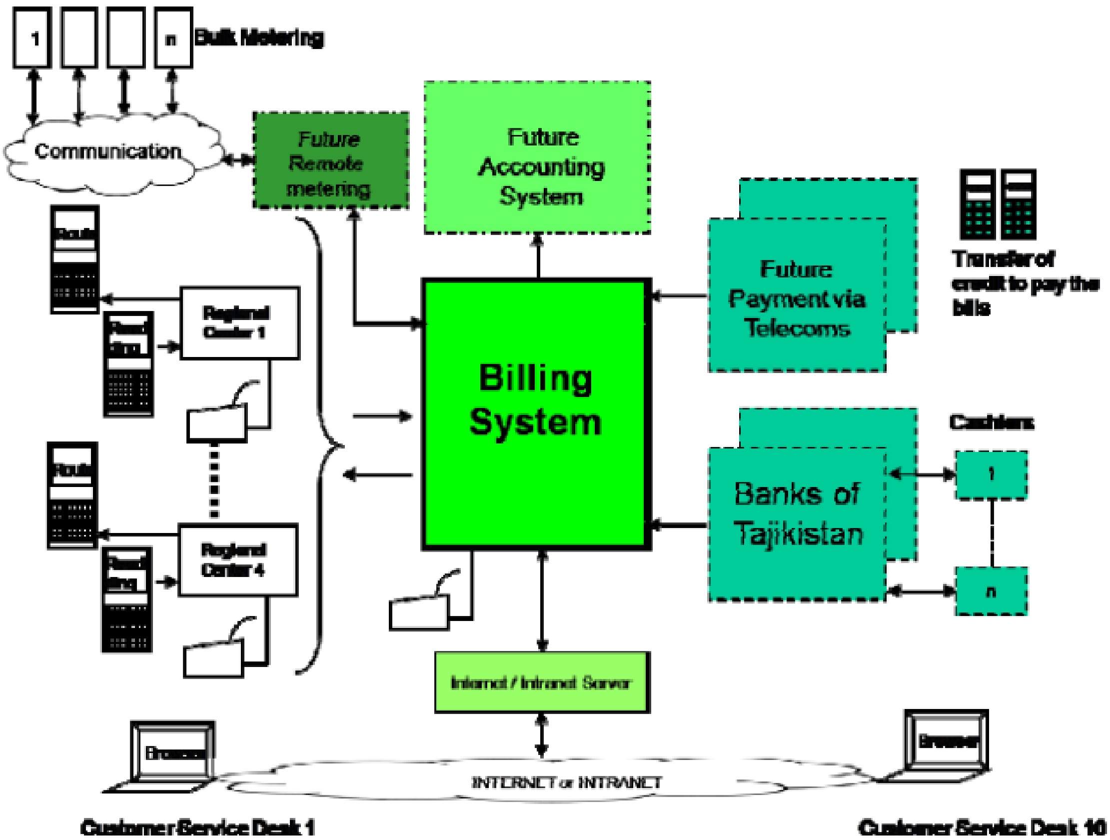
3.2.1.3.1 Short description of the project

The project covered design, supply and installation of a computerized Billing Metering System, training of the system operators and maintenance crew as well as after sales services. The billing metering system (essentially an IT system) was installed at Dushanbe city centre in existing premises of BT.

Meter readings are based on Hand Held Meter Reading Units (HMRUs) and remote metering for the Bulk Meters. Manual input should only be required in exceptional situation. The HMRUs were planned to interface with the Billing Metering System to:
(a) load the units with walk order and customer information before reading; and
(b) to extract and process the metered data after reading.

For Customer services task an Intranet / Internet server is implemented to support workstations at 4 regional offices and 10 workstations at Banks Cashiers in Dushanbe

Figure 3-3 Dushanbe Billing System Overview

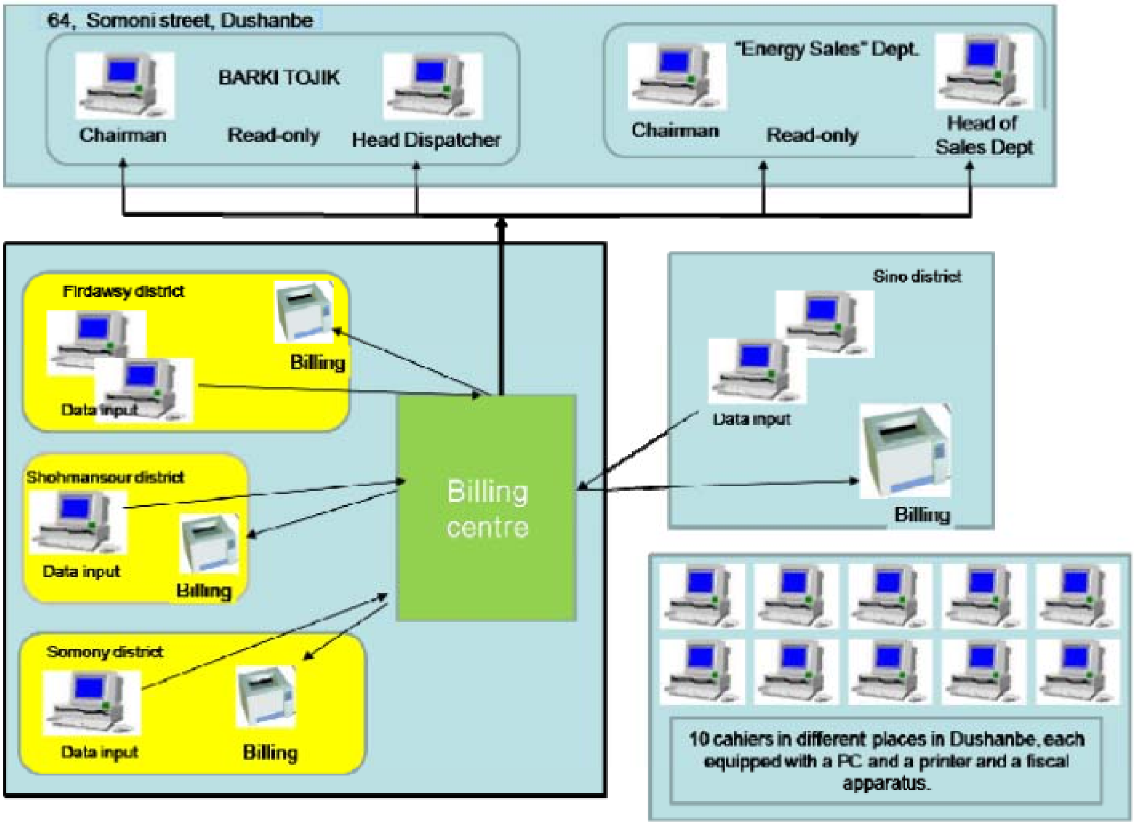


The graphic above shows the billing system environment. Consumption data are collected via handheld meter reading units. These units are loaded and unloaded with a reading system from the meter supplier (CHINT). The data are stored in a database. An Interface between the billing system and this meter reading software is provided. Payments are carried out via banks, the paper receipts are being processed manually.

The Contract with ASEM as the supplier of the Metering Billing system included options for:

- Interfaces with future remote meter reading system, future finance and accounting system and for electronic payment transfer with banks and telecoms.
- Customer Service desks

Figure 3-4 Overall system hardware configuration



The billing centre and three of the four districts are close together. Barqi Tajik's Head Quarters and the fourth district are located in another part of the city and the links to the billing system from these sites are realized via a web server (internet/intranet).

The handheld meter reading units are planned to be loaded and unloaded at the regional centers. The consumption data shall be saved into the database from where it can be exported to the billing system. The invoices shall be produced centrally and printed out in the regional centers.

Under a separate Contract the project covered supply of 160.000 electronic energy meters of different types including single and 3 phase meters for active and reactive energy, for active energy only, for direct connection with different base and maximum currents as well as for CT connection. Together with the meters auxiliary equipment such as new meter boxes, CTs, MCBs, seals etc required for meter installation was purchased.

Under this contract with CHINT of China handheld meter reading units, automatic meter testing and calibration stations and portable test tools for the meters were also purchased. The contract furthermore covers services such as training, documentation and factory testing. The contract was concluded in September 2007

Different type of cable products were purchased under another contract.

Installation of the new energy meters together with the meter boxes and cables was covered under 3 erection contracts with local companies.

Meanwhile, in October 2012, another contract was signed with CHINT for the supply of approximately 46.000 additional meters and respective auxiliary material.

Presently investigations are performed by the Consultant in order to complete the configuration of the SAP-IS-U billing system located in Dushanbe for the invoicing of the electricity consumed.

The tender documents shall be launched in the fourth quarter 2014.

3.2.2 Regional Power Transmission Project, Lot 3 SCADA project

In line with the Regional Power Transmission Project, Tajikistan, a Supervisory Control and Data Acquisition (SCADA) System in line with a National Control Center (NCC) in Dushanbe will be installed. The project is financed by the ADB Grant 0213-TAJ.

The SCADA project is implemented to enhance the general arrangement of the network, provide a more stable supply of electricity to customers, and better facilitate inter-regional export / import arrangements.

The project works consist of the following components:

5. Establishment of a new National Control Centre (NCC) at Barqi Tojik Head Office in Dushanbe
6. Establishment of a Back-Up National Control Centre (BUNCC) at the office of the Central Electrical Network near Novaya 220kV substation
7. Provision of Control Center hardware and software at both locations in a multi - redundancy configuration
8. Provision of SCADA and Energy Management (EMS) software for supervision and optimization of the power system in Tajikistan.
9. Provision of new RTUs and interfacing of existing Substation Automation systems at 43 Power Plants and Substations
10. Extension and upgrade of the existing Telecommunication System for
11. operation of the Tajik Power system.
12. Provision of control centre facilities at the location under item 1 and 2
13. incuding refurbishment of the control and equipment rooms and
14. provision of safe power supply, fire detection and fire fighting, back-up
15. HVAC system, access control and video survailance system (CCTV)
16. Comprehensive training program fur Barqi Tojik personnel
17. Spare parts and tools for maintenance of the installations

Project description

A new SCADA/EMS System shall be provided for operation of the National Power System in Tajikistan including Major Power Plants and the 500/220kV Transmission network.

Main purpose of the new SCADA/EMS System is to achieve a Multi-Side-Redundancy Concept by SCADA (MSRCS) with high availability, safety and transparency at first comprising 43 Priority Stations of Tajikistan.
This new redundant SCADA/EMS System enables remote-monitoring and remote-controlling the Priority Stations from one central location. Their operational status, local energy-loads as well as amount and direction of energy-flow (at generators) of the Transmission network will be known at the NCC and at its back-up at any time, hence.

The Energy Management System (EMS) to be implemented will additionally allow managing higher tasks. For example, in order to be able to take appropriate measures in advance, based on previous and current SCADA data the EMS will indicate forecasts about the status of the Transmission network to be expected within the next few hours or days.

All Priority-Substations which are all 500 kV / 220 kV Substations, nine distinguished 110 kV Substations, all water power plants and one thermal power plant are affected by the implementation of a new SCADA/EMS System.
All other roundabout 120 remaining 110 kV substations which have not been involved in this project can be upgraded and implemented successively into the new SCADA/EMS System later on.

As mentioned, due to high availability and safety reasons the new SCADA/EMS system will be a redundant backup-system, which will mainly consist of a new National Control Centre close to the Barqi Tojik Head Office in Dushanbe and its back-up Control Centre to be located about 400 m away from Novaya 220 kV substation.
Under normal circumstances, the back-up NCC near Novaya 220 kV substation shall act as the Regional Control Centre for the Electrical Network in the Central Region ex Dushanbe.
The NCC in Dushanbe as well as its back-up shall be designed for supervision of Tajikistan's entire Power System down to the transformers feeding into the 10kV and 6kV distribution network.
Additionally, there will be four Regional Control Centres controlling the City of Dushanbe, the Central Region ex Dushanbe, the North Region and the South Region. All of them as well as the NCC will be redundant, meaning that all data-transmission lines, devices, computers, servers, routers etc. and all data of all four Control Centres will always exist twice, being available at any time.

In case of emergency or failure of any Control Centre its dedicated back-up will be able to take over within 3 ms.

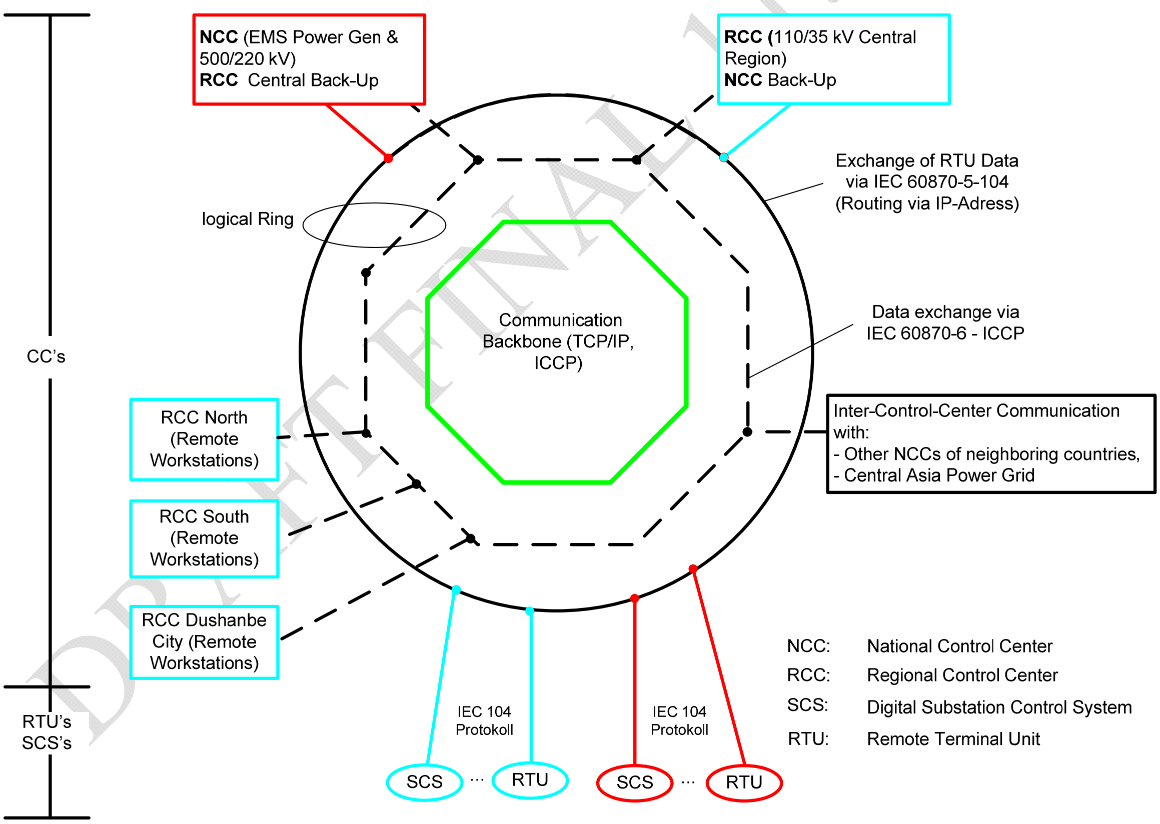
Location name	**appropriation for …**
NCC and back-up	Transmission (500kV, 200 kV) and all Power Generation Plants (monitoring only) as well as EMS of the whole country.
RCC Central and back-up	Sub-Transmission (110 kV) of Central Region without City of Dushanbe.

RCC Dushanbe and back-up	Sub-Transmission (110 kV) in the City of Dushanbe. Completely Back-up of NCC and any function in case of its failure.
RCC North and back-up	Sub-Transmission (110 kV) of the North Region
RCC South and back-up	Sub-Transmission (110 kV) of the South Region

A 1+1 redundant new fiber optics SDH telecommunication system on STM-1 and STM-4 level which is a guarantee for highest reliability and low latency and some new DPLC connections which is already existing and has partly to be deployed will be the heart of the new SCADA/EMS System, enabling any SCADA communication and any other data transfer service like Whole Sales Metering at all. The new telecommunication system will provide any communication between all Control Centres and Substations among each other as well as the Back-Up functionality of the NCC and the redundancy of all Control Centres.

The figure below in general shows the design / the basic system layout for the new SCADA/EMS System as well as its redundancy and telecommunication concept. Involved Priority Substations are principally indicated at the bottom of the circle.

Figure 3-5 Basic system layout of new SCADA System



Attachment 3-3: Basic System Layout for NCC/RCCs

In addition, generation and consumption of electrical energy of the Transmission network precisely can be related to power plants, power lines, locations or areas at a time by a new implemented Advanced Metering Infrastructure (AMI) respectively by Wholesale Metering which will also be implemented under this project. Being precisely related to locations and unique time-stamps all measurements of electrical power provided by Wholesale Metering can be compared with according measurements provided by SCADA. Hence, values gathered by Wholesale Metering allow precise analysis as well as precise Balancing and Billing of the entire Transmission network of Tajikistan, also with regard to the CAREC project and with regard to international energy exchange with adjacent Asian countries.

3.2.3 Restructuring of OSHC Barqi Tojik

In the process of restructuring OSHC Barqi Tojik it is intended to form the following main business units as (i) Generation, (II) Transmission, and (III) Distribution.

According to the Technical Separation Guidelines established by Corporate Solutions[1] the following subjects will form the core business of the new business units:

- The generation business unit will be concerned only with power generation or combined heat and power. Assets allocated to the generation business unit will include plants that produce only electrical energy.

- CHP1 Dushanbe and Yavan while privately owned or joint ownership power plants will remain separate businesses.

- The transmission business unit will transmit power, operate the transmission system including the exchange of power with the neighboring countries and have responsibility for system stability and generation dispatch. Transmission assets will include 500 kV, 220 kV and all 110 kV systems.

- Distribution will only be responsible for distributing power to customers. Distribution assets will comprise of systems operating at voltages of 35 kV, 20 kV, 10 kV, 6 kV and 0.4 kV.

The resulting commercial boundaries between the business units and the ideal meter locations are discussed in the following sections.

3.2.3.1 Substations for the metering part

This chapter will give an overview about the existing substations in the electricity network.

The first overview was prepared on the inventory list provided at Barqi Tojiks homepage[2] which is publishing an inventory list with a reference to the balance sheets dated 01.01.2012.

[1] Technical Separation Guidelines established with ADB GRANT NO: 0213 -TAJ, 02/2014
[2] http://www.Barqitojik.tj/index.php/en/ct-menu-item-49/ct-menu-item-51

Following several discussions with Barqi Tojik as per 01.01.2014 the following number of substations have been identified:

Table 3-1 Substation summary schedule

Substation Summary Schedule for Tajik Power System (Status 01.01.2014)					
Name of Utility Наименование предприятия	Future transmission system Будущая система передачи			Future distribution system Будущая система распределения	
	500 kV Substation /пс. 500 кВ	220 kV Substation/ пс. 220 кВ	110 kV Substation/ пс. 110 кВ	35 kV Substation/пс. 35 кВ	35-20-10-6/0,4 kV Substation/пс. 35-20-10-6/0,4 кВ
Southern Area of Tajikistan					
Central Electric Networks ЦЭС	2	6	28	33	1866
Tursunzoda's Electric Networks ЭС Турсунзаде		1		3	420
Rasht's Electric Networks ЭС Рашт			8	3	1090
Yavan's Electric Networks ЭС Яван		1		9	322
Southern Electric Networks ЮЭС		4	24	49	2564
Kulob's Electric Networks ЭС Куляб		1	11	22	1136
Dangara's Electric Networks ЭС Дангара		3	1	5	328
Kulob's City Electric Networks ГорЭС Куляб			3	6	440
Dushanbe's City Electric Networks ГорЭС Душанбе			25	9	1283
Kurgon-Teppa's City Electric Networks ГорЭС Курган-Тюбе					192
Subtotal for southern area Итого по югу	**2**	**16**	**100**	**139**	**9641**
Northern Area of Tajikistan					
Sugd's Electric Networks ЭС Сугд		5	28	53	1362
Khujand's Electric Networks ЭС Ходжент			4	5	337
Istaravshan's Electric Networks	1	4	16	16	1089

ЭС Истаравшан					
Penjikent's Electric Net-works ЭС Пенджикент		2	9	5	610
Chkalovsk's City Electric Networks Чкаловские ГорЭС			1	2	90
Isfara's Electric Networks Исфаринские ЭС			8	8	385
Subtotal for northern area	**1**	**11**	**66**	**89**	**3873**
Total	**3**	**27**	**166**	**228**	**13514**

In ongoing projects the following additional substations are under preparation:

Southern Network

Name of project	**SS Name and details**
CAREC Project	SS Geran 2, 220/110/10 kV, 2 x 16 MVA
CASA 1000 Project	SS Yujniy 500 kV
ROGUN PROJECT	SS Obi Garm-500 kV (future)

Northern Network

Name of project	**SS Name and details**
Sugd Energy Loss Reduction Project	SS Nagornaya 110/10 kV, 2 x 16 MVA

In total 199 substations will belong to the business unit for Transmission and will be considered in the Wholesale metering project.

The detailed inventory list prepared on the data received from Barqi Tojik for the existing electricity meters including the data for CT and VT installed are attached in the annexes:

The substations related to the Rogun HPP Project will be considered later when more detailed data will be available.

3.2.3.2 Strategy for the wholesale metering equipment arrangement

The wholesale metering equipment and the connected systems like the automated meter reading system (AMR), the energy data management system (EDM) and the settlement system shall support in future the commercial balancing of the transmission system, support the calculation of performance indicators as well as the determination of losses.

For these reasons the following priorities are identified for the metering equipment:

Priority 1 Commercial metering points

Based on the commercial metering points the energy transported in the transmission system shall be balanced based on:

1. Energy received from the generation unit
2. Energy received / delivered to the transmission system operators (TSO) in the
    - Republic of Uzbekistan,
    - Kyrgyz Republic,
    - Islamic Republic of Afghanistan.
3. Energy delivered to the distribution unit
4. Energy consumed for transmission system operation and transmission system losses.

In order to improve the correctness of this commercial balance the exchange of CT and VT equipment for the commercial metering points has been considered in general on the 35 kV, 10 kV and 6 kV level in the project scope.

The further need for replacement of CT and VT will be considered if the installed existing equipment is not compliant to the criteria stipulated in later sections.

Priority 2 Operational balancing points

For improvement of the operation of the transmission system several balancing calculations will be enabled as there are.

Asset	Purpose
HV Substations,	Balancing of energy delivered and received, SS power consumption, Unplanned outages.
HV Overhead lines,	Voltage drop > 95%, Unplanned outages
HV/MV transformers,	Transformer efficiency, Unplanned outages,
HV/MV Substations,	Balancing of energy received and delivered, Unplanned outages, SS power consumption.

The system shall allow combining the balances listed above.

For the balances mentioned above the meters installed at commercial metering points and installed at the additional internal metering points will be used.

Because the metering results will be used for internal balancing purposes only the exchange of CT and VT does not have the highest priority and has not been considered for the project.

The replacement of presently missing metering equipment will be influenced by:

- Space constraints, for example due to the existing arrangement.
- For introducing new CT's and VT's too much equipment need to be replaced, which is challenging the economics.

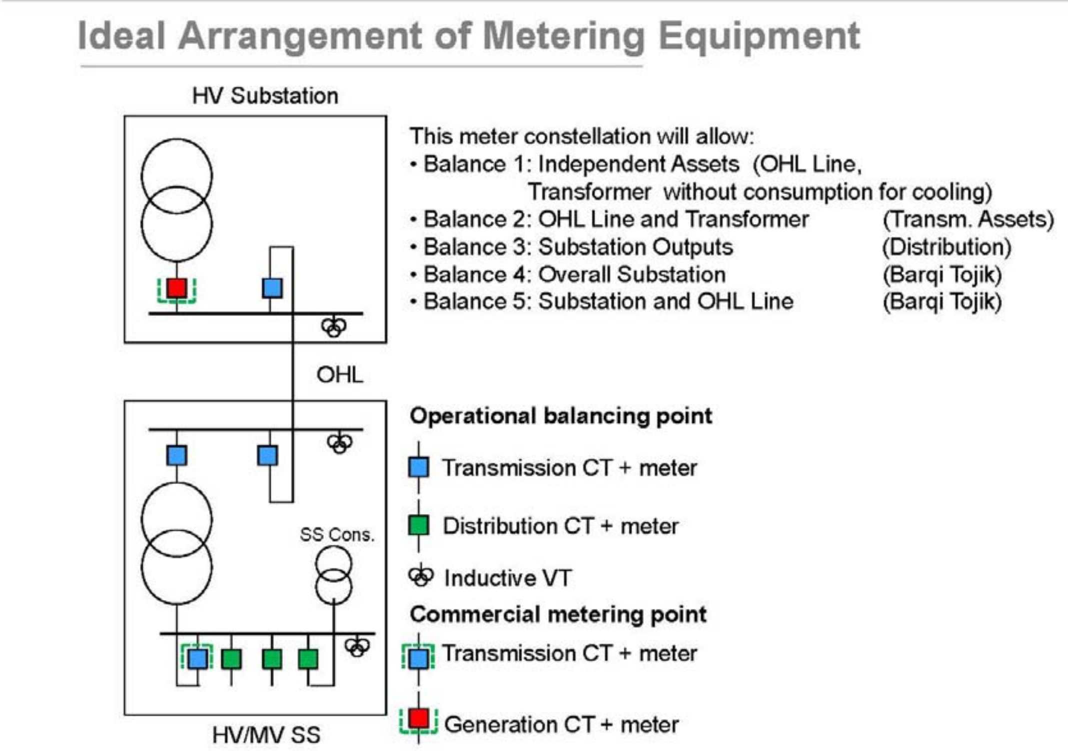
The next figure is indicating an ideal arrangement of the metering equipment in the substations.

The substations deviating from these requirements will be assessed. in reality the following discrepancies will occur:

- No VT at the incoming busbar
- No CT at the incoming OHL,
- No metering at all,

An overview about missing metering equipment compared to an ideal arrangement in the substations is attached in the annex.

Figure 3-6 Ideal Arrangement of metering equipment



3.3 Wholesale metering and billing in the future

3.3.1 Meter data collection

In the SS the meters are located in open racks in rooms for electrical equipment. The new meters will replace the existing ones.

For remote reading the new meters will be equipped with wireless and with a wired M-BUS interface.

The M-BUS interfaces (based on DLMS/COSEM protocol according IEC standards) are recommended as a international accepted standard which allows an exchange of manufacturer for the meters connected.

The wired M-BUS will be connected to the data concentrator (DC) in the substation in a star topology.

The wireless M-BUS interface may be used for manual reading with a handheld device during commissioning and later on during operation.

The data concentrator will perform the scheduled meter reading and collect and store the data of the meters connected.

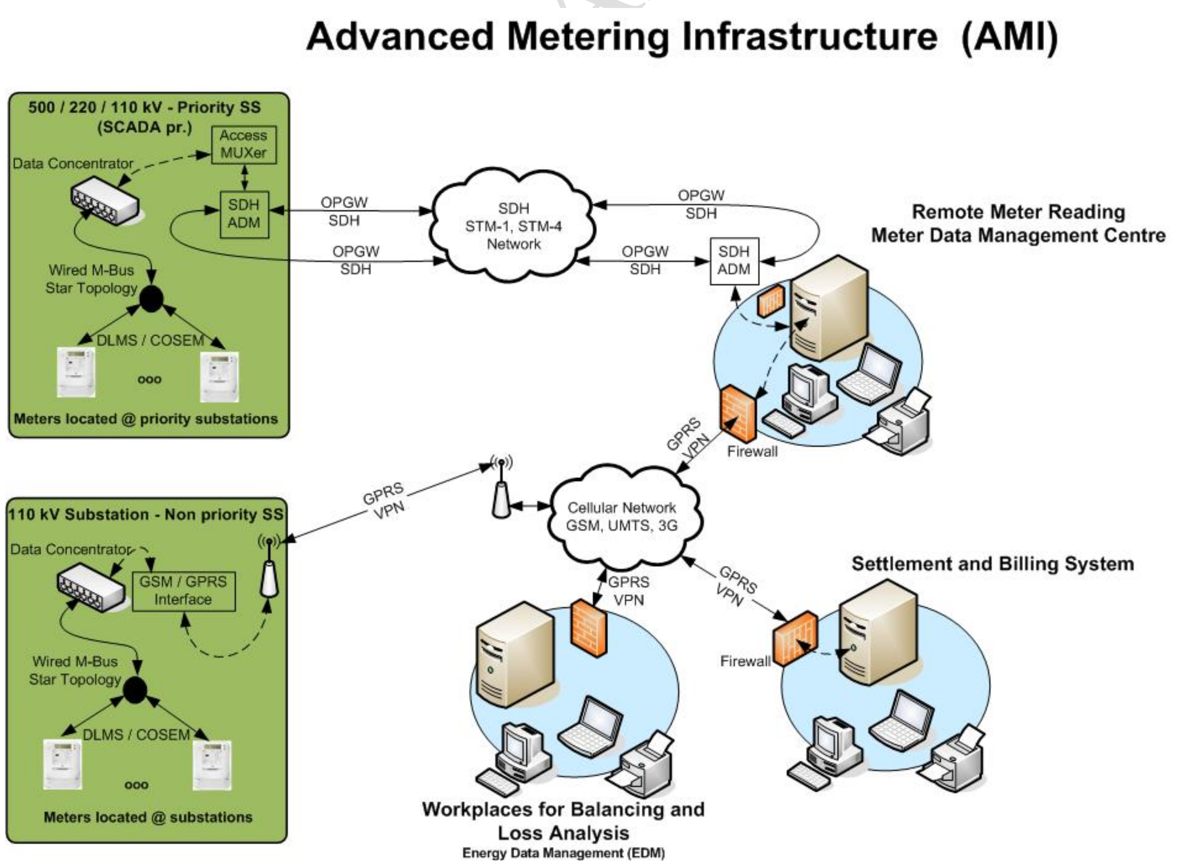
The data in the data concentrators will be read out by an AMI – Advanced Metering Infrastructure system. The data are read by the RMR or AMR (remote respectively automatic meter reading) module of the AMI.

With the MDM (Meter Data Management) module of the AMI the data calculates the kWh, here substitute values can be entered and plausibility checks are performed. Also aggregations can be made by help of the MDM module.

The MDM module will also have an interface to the settlement / billing system and for the calculation of the countrywide consumption and losses the respective data will be exported to a CSV file.

The structure of the overall proposed Wholesale metering system is indicated in the next figure.

Figure 3-7 Structure of the Wholesale metering system



The following workplaces (desktop PC, LAN equipment, A4 black and white printer, office software, etc.) will be established for the system:

- 3 desktop workplaces for the remote meter reading system,
- 3 desktop workplaces for balancing and loss analysis,
- 3 workplaces for the settlement and billing system.

The project will include the required LAN cabling.

3.3.1.1 Process from metering and billing supported by the different systems in the future

As described in the subchapter above, the meter values of the wholesale meters are automatically read and transferred to the AMI and managed there within the MDM module.

This approach is also foreseen for the meters on the borders. The process onsite has to be modified in cooperation with the Customs and the foreign energy companies.

Within the MDM module of the AMI the meter read-ings are converted to kWh and according to their loca-tion in the network

- the consumption of a DSO (Distribution System Operator) or
- the generation of a generation plant
- the exchange on a border

can be aggregated by use of the concerned meter-related values.

These aggregated values in kWh (per DSO / generation plant / border) will be passed to the Billing system.

Also the kWh values of all wholesale meters are ex-ported to a CSV file.

Within Excel in one sheet all exported data will be imported. This will be done by running a small makro, only reading the values from the CSV file into a dedicated sheet. In a calculating sheet the scheme for the calculation of the countrywide consumption and losses will be defined. After each import within this sheet automatically this calculation will performed to represent the status of the last period.

After the import of the data of the last period into the Billing System the invoice amounts for each DSO will be calculated in Somoni using respective tariffs.

The credit voucher values for the generation plants will be calculated in Tajik Somoni using respective tariffs.

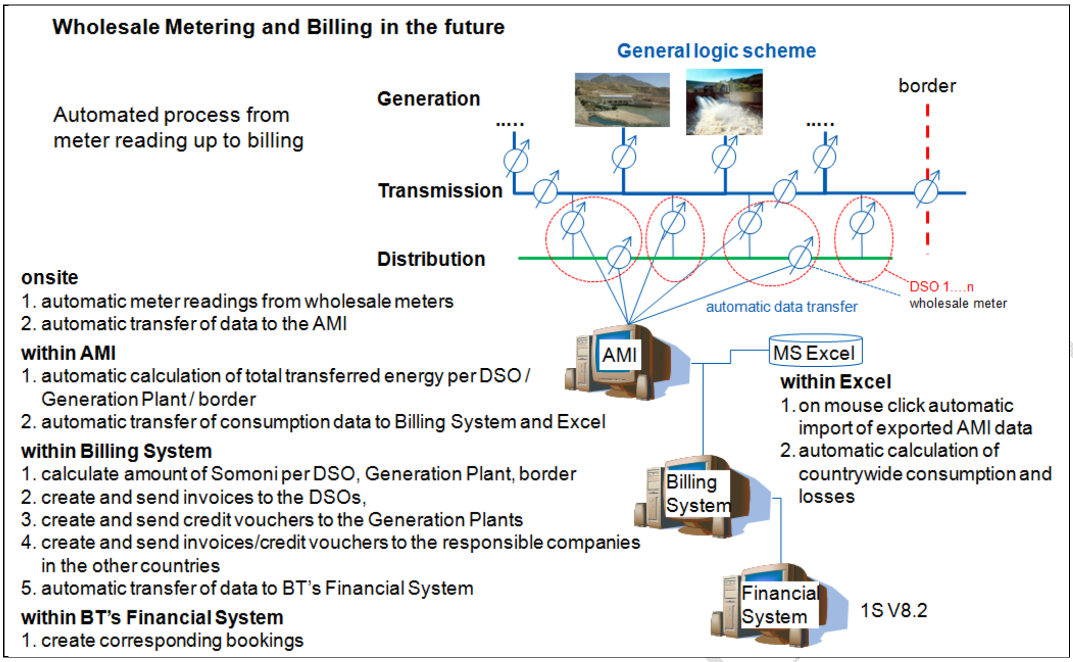
The invoice or credit voucher values for the foreign energy companies will be calculated in US $ using agreed tariffs.

All invoices or credit vouchers will be printed and sent to the respective party.

All financial figures will be transferred to the Financial system of BT holding.

Within BT's Financial System only corresponding bookings on the different accounts will be initiated.

Figure 3-8 Way and handling of the meter data and respective calculations in the future



3.3.1.2 Recommendation on technology and functionality of the AMI for Tajikistan

In relation to conventional electromechanical or electronic meters, AEM offer many additional benefits for Barqi Tojik including:

- improved synchronization of meter readings for wholesale meters and customer retail meters, allowing system losses to be accurately calculated.

- built-in tamper proof features can detect most forms of meter tampering.

Beside the automatic meter reading these functions shall be implemented in the Advanced Metering Infrastructure (AMI) for Tajikistan as they are required to meet the main goal of reduction of non technical and nontechnical losses and improvement of payment collection.

AMI includes the data storage at the meters and concentrators and the two way communication infrastructure required to provide advanced functionalities in the future such as:

- Energy conservation and demand side management (DSM) through time-of-use (TOU) tariff rates.
- load management
- outage management
- network condition monitoring and local power quality monitoring
- meter condition monitoring

AMI is advancing in technology and functionality. In combination with a data warehouse, settlement system and management processes, operational and economic benefits can be leveraged by the utility. These include:

- reduction of non-technical losses
- system fault identification
- more accurate and timely billing
- ability to introduce time of use tariffs
- improvements in load factor and loss factor
- data for system planning

A potential downside of AMI is the higher-level of technical and managerial capacity requirement and initial cost that needs to be expanded to leverage the true benefits of the technology.

Also, as technical standards are still evolving, careful evaluation of the technologies offered during the bidding process is critical to protect the long-term investment in AMI.

AMI can offer Barqi Tojik a solution towards reducing non-technical losses and provides strategic infrastructure for future load management. It is recommended that AEM technology is adopted (in place of conventional electromechanical and electronic meters) in order to fully leverage the benefits of an intelligent electricity system and to "future proof" that technology investment.

With the tender documents the consultant will specify the AMI system and equipment with appropriate IEC standards. The rationale for this relates to the fact that the underlying electricity system utilizes IEC standards, and the vast majority of AEM / AMI suppliers and service agencies have products and solutions that comply with IEC standards.

3.3.1.3 Hand Held Collection

Concept:
A handheld meter reading device is used equipped with one or several communication interfaces, e.g.:

- a keypad for key in the reading manually
- a wired connection
- an optical port (infrared, IR)
- a RFID based reader
- a built in or attached RF transceiver

to interrogate and collect meter readings from a Smart Meter.
The collected meter data stored in the handheld device is brought to the local office or Customer Service Center where the data is readout and transferred to the Metering Data Management Center. Alternatively, by using a handheld device enabled for cellular mobile communication, the meter reading data is directly transferred to the Metering Data Management Center via public cellular mobile networks. The meter data transfer may happen immediately or delayed if there is no coverage e.g. in the basement of a house.

With touch-based meter reading, a meter reader carries a handheld meter reading device with a wand or probe. The device automatically collects the readings from the meters by touching or placing the read probe in close proximity to a reading coil enclosed in the touchpad. When a button is pressed, the probe sends an interrogate signal to the touch module to collect the meter readings. The software in the reading device matches the serial number to one in the route database, and saves the meter reading for later transfer to Metering Data Management Center.

RF technologies covering sufficient distance, the reader does not need to enter the premises. UHF low power radio technologies operating in the 433/868 MHz ISM-bands, 2.4GHz Bluetooth, wireless M-Bus or ZigBee are appropriate standards to interrogate meters over a distance of several or several tens of meters.

Technologies

For handheld meter data collection the following wireless technologies are commonly available:

- Bluetooth
- ZigBee
- Proprietary or industrial radio standards

The transmit power can be in the mW range.
Different technologies for touch based or close proximity handheld meter reading are used, amongst other:

- M-bus (Meter bus) over twisted pair or radio
- standard RFID technologies
- inductive coupler
- Infrared

To transmit the handheld meter readings to the Metering Data Management Center the following communication technologies are commonly used:

For immediate transmission using mobile-enabled handhelds:

- Public cellular networks based on 2G/2.G GSM/HSDPA/ GPRS/EDGE
- Public cellular networks based on 3G UMTS

For transmission from the local office:

- PSTN
- Leased telecommunication channels (E1,E2, …)
- xDSL
- WAN

Conclusion/recommendation

This technology involves one way communication and utilizes the existing meter reading force. The handheld technology can be used to speed up the existing meter reading process thereby reducing manual errors and potential for fraud.

In the past, the touch concept has brought some benefits as it involved regular inspection of status and conditions of electrical installations and meters and thus increasing the likelihood of detecting fraud (e.g. meter tampering). In a modern AMI smart grid concept where energy flow is measured at different network levels and consistency is checked, this side effect may become less important but still not obsolete.

3.3.2 AMI System Functions

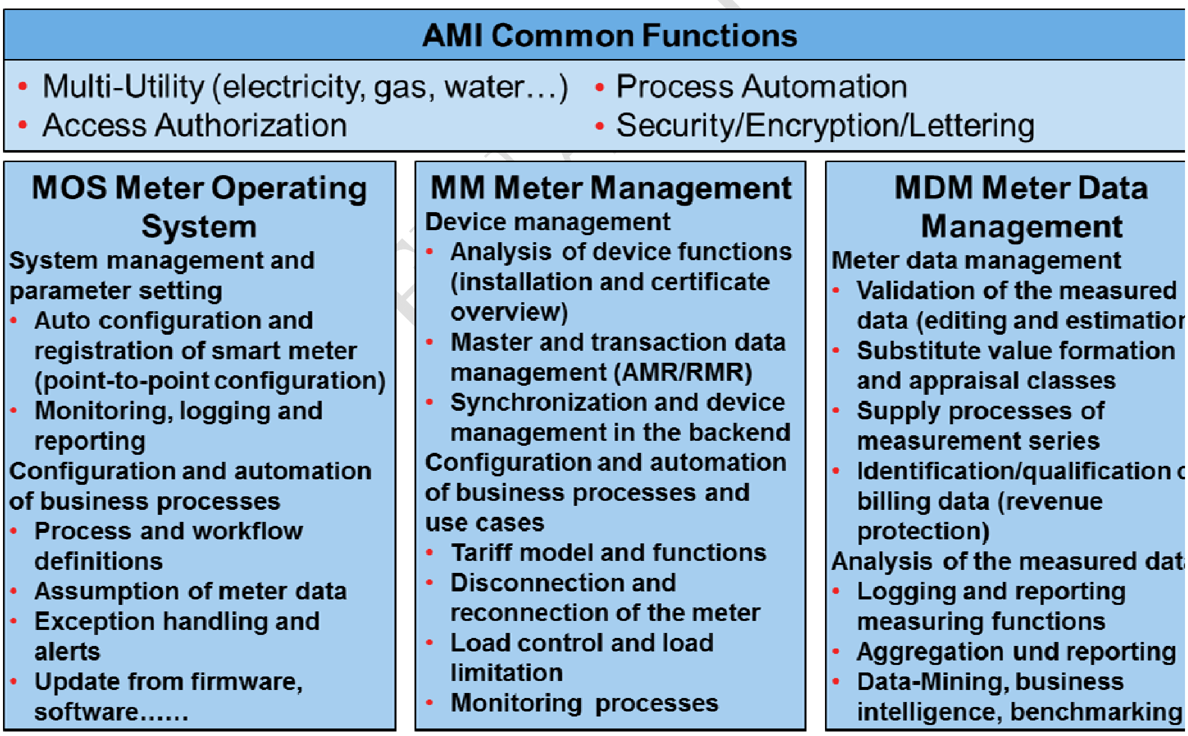
Advanced Metering Infrastructure (AMI) applies the technology used for automating collection of energy consumption data for the purposes of real-time billing and consumption analysis. At any given time, the AMI system gathers real-time data and transfers the information gathered to the central database through networking technology.

Technological advances had expanded the scope of AMI activities. Other possible uses for the AMI include monitoring for theft and detecting meter tampering. Consumer profiling (especially on such points as peak and lean periods of use) can be derived and analyzed.

3.3.2.1 AMI Common Functions

The generic functions of an AMI system are grouped and summarized below.

Figure 3-9 AMI Common Functions



3.3.2.1.1 AMI Administration Services

Fundamental requirements around the several meter administration services have to be fulfilled:

- The ability to develop, store, send and receive digital information concerning electricity use, costs, prices, time of use, nature of use, storage, or other information relevant to device, grid, or utility operations, to or from or by means of the electric utility system, through one or a combination of devices and technologies.

- The ability to measure or monitor electricity use as a function of time of day, power quality characteristics such as voltage level, current, cycles per second, or source or type of generation and to store, synthesize or report that in-formation by digital means.

- The ability to sense and localize disruptions or changes in power flows on the grid and communicate such information instantaneously and automatically for purposes of enabling automatic protective responses to sustain reliability and security of grid operations.

- The ability to detect, prevent, communicate with regard to, respond to, or re-cover from system security threats, including cyber-security threats, using digital information, media, and devices.

- The ability of any appliance or machine to respond to such signals, measurements, or communications automatically or in a manner programmed by its owner or operator without independent human intervention.

- The ability to remotely connect or disconnect smart meters.

3.3.2.1.2 Process automation

In order to support the usage of the data collected, a messaging infrastructure with integration technologies will be established. The AMI deployment will also consider the management of the “state” of meters throughout the lifecycle.

Due to the logistical complexity of the rolling out, it will be reduced by automating and orchestrating business processes that manages the optimal roll out and deployment of smart meters.

In the AMI System fully automated processes and workflows (e.g. switch process, Smart Meter rollout process) shall be implemented. Furthermore, AMI shall be provided with a complete visibility and control through monitoring display and analytical dashboards to show e.g. the continuous integration of meters in the system.

3.3.2.1.3 Access authorization of users connecting

It is required that applications developed for users shall be secure and free of any vulnerabilities through the following mechanisms:

- VPN and two factor authentications through secure tokens to reduce the risk of unauthorized access and modification

User administration with password protection

- various user levels by assigning user roles
- open configurability of user roles
- clientele processing entirely possible

- Use of Firewall and Anti-Virus software with latest signature configurations for effective and efficient prevention of network virus or worm outbreaks.

- Vulnerabilities are fixed through deployment of security patches, packages and hot fixes to be applied to infrastructure elements (servers, workstations, desktops, laptops, network devices, applications etc.) in order to protect against known vulnerabilities.

- Mobile computing policies and controls which outline requirements for use of mobile computing devices by employees from a location outside of designated normal access facilities.

- Implementation of security controls for system security, use of anti-virus protection and personal firewall on the computing device (PC, Notebook/Laptop Computers, etc.).

- Backup copies of information and software to be maintained and tested regularly for the purpose of data recovery in case of events such as system crash or accidental deletion of information.

- Threads shall be identified in risk assessments and risk mitigation strategies, with input from Barqi Tojik as supporting partner, related to such risks shall be developed in the detailed design stage.

3.3.2.1.4 Security, Encryption/ Signature, Lettering

Typical cyber practices used to meet regulatory requires are as follows:

- All type of data transmissions will require the data to be encrypted.
- All data and application source code backups will require to be encrypted.

Requirements for data encryption on server and PC clients residing within Barqi Tojik physical protection boundaries will be defined during final systems requirements identification activities. It will be a recommendation that all data will be encrypted when at rest, no matter what the platform, location, or media.

3.3.2.1.5 Meter Operating System

The connection management scenario will enable processes for connection and device management infrastructure at Barqi Tojik.

Beside the increasing demand for Advanced Meter Infrastructure (AMI) it will be essential to administrate and run remote and conventional meters in parallel. AMR and RMR functions shall be supported.

3.3.2.1.6 Meter and Device Installation

The management and classification of new devices and meters have to be performed in this business function.

The function shall be required to support to install meters and other devices. Barqi Tojik shall allocate the various devices and individual registers to each other, and thus will map the complete installation structure of the customer in the system. It shall be possible to replace installed devices, reprogram them, or change their rate data.

The meter and device installation process shall create and maintain meters and devices and monitors the installation, removal and replacement of meters and devices.

3.3.2.1.7 System Management

It is required to have a system management und parameter setting for auto configuration and registration of smart meters (point-to-point configuration) as well as the communication lines to these meters.
It will be necessary to have a meter operating system with the possibilities for configuration and automation of business processes, e.g. for

- Process and workflow definitions

- Assumption of meter data
- Exception handling and alerts and
- Remote firmware upgrades, programming or addition of new functions to the meter

3.3.2.1.8 Device Inspection

With this business function, the field service shall check the devices in different ways according legal and internal requirements:

- Periodic replacement shall enable them to manage all devices that have to be replaced in a certain year (due to legal requirements, for example).

- In the sample lot procedure, individual devices shall be inspected. These devices shall be representative of a group of devices. The function shall support them in compiling lots and drawing sample devices.

- In certification, Barqi Tojik (through TAJ-Standard Agency) shall certify individual devices.

Barqi Tojik shall also combine the different procedures, for example, by including devices from a sample lot in the periodic replacement.
The device inspection and retirement functions will help Barqi Tojik to ensure that technical installations and equipment will be checked as required by law and other regulations.

3.3.2.2 Meter Management

3.3.2.2.1 Device Management

It is required to have the following functions for operating the device management, e.g.:

- Analysis of device functions (installation and certificate overview)
- Master and transaction data management

- Synchronization and device management in the backend

It will be necessary to use a function for visualization of job reports.
The following reports shall be created during a job, and have to be viewed after the data transmission will be completed:

- status report
- error report
- transmission report
- decoder report
- data transfer report
- import report

3.3.2.2.2 Meter Management Automation

It is required to configure the data transmission system, e.g.:

- configuration of hardware components needed for data transmission
- launch and shut-down of data transmission software
- modification of configuration files relevant to data transmission
- modification of process list
- configuration and modification of communication lines between meter management system and the remote readout station to be fetched

Required functions for administration of basic fetch data:

- creation of new remote readout stations
- station data
- meter data
- connection data
- modification of basic fetch data
- various basic data views (sorted according to meter type, client, location, etc.)
- filtering of remote readout stations via a user-defined text filter
- creation and launch of test data transmission orders

Required functions for administration of data transmission orders:

- order creation
- order modification
- order start, interrupt, and stop
- deleting orders from the order list
- tabular overview of all meter management jobs including status, fetch period, last start time, next start time (for periodical orders),
- periodicity and type of data transmission
- easy modification of orders at a later point in time

The meter management system shall support automation of business processes and use cases, e.g.:

- Transfer of Tariff data and according functions
- Disconnection and reconnection of the meter
- Load control and load limitation
- Monitoring processes

3.3.2.2.3 Data Transfer including Tariff Data

A bi-directional flow of data from and to the grid will be enabled when the Smart meters are installed in the substations, providing information on consumption volumes and periods of consumption. This will open up the potential for Barqi Tojik to provide attractive and personalized tariff options to consumers and to encourage them to consume energy at off-peak times.

The increase of data received from consumers provides new opportunities to Barqi Tojik to derive detailed analytical information about consumption patterns. This data will be evaluated to derive patterns of energy consumption, which will be applied in many different ways, for example to detect fraudulent use of electricity. Marketing and product management personnel will be leveraged the data about consumption patterns to propose new products and services to consumers. It is required to have secure electronic data exchange, e.g.:

- Master data (customer, meter…)
- Contract Information
- Tariff Agreement/Tariff Model
- Billing Determination and mapping of various accounting grid and trader structures
- Time synchronization lead by GPS master clock installation

3.3.2.2.4 Load control and load limitation

Load management shall be used to monitor and control usage rates in the measuring periods.

One-minute advances in the integrated meter totals of the boundary element from Meter Management (MM) instruments or telecontrol installations will be generally used as the input vareable. From this data, the average usage rates in the 15-minute or 60-minute measuring period will be aggregated and controlled. The set points to be monitored will be preset in different versions until the reported registered schedules will be transferred.

Barqi Tojik’s requirements range from load shedding by deactivating electrical loads (under consideration of technical and contractual boundary conditions) to output adaptation through selective set points to the control of in-plant generation installations. Clear graphical display of the output or power curves shall provide the user a fast overview of the current load situation.

Automatic reading of load profiles and practically real-time consumption values from bulk meters and meters of large customers with telecontrol technology shall be provided for, e.g.;

- Complex meter links and proofs of use
- Transfer to the EDM system
- Load limitation
- Processing of the residual integral requirement from power supply systems
- Intranet/Internet customer information system
- Automatic dispatch of aggregated load profiles to the Transmission System Operator (TSO)
- Processing of schedules and (synthetic) load profiles for transit calculations
- Functions for the optimization and forecasting of transit and consumption data
- Integrated alarm and report management up to fault messaging through tele-alarm

3.3.2.2.5 Monitoring processes

For monitoring processes it will be necessary to use a Control Center for supervising and control all meter management activities like master and transaction data management. Various features like configuration, visualization of fetch data and reports, basic data maintenance, and the creation and initialization of data transmission orders, shall be provided via an Internet or Intranet-based web server.

Online monitoring shall be available and comfortable in use for representation of communication between meter management system and the remote readout station during a data transmission task (character level or hexadecimal) and status of the individual communication lines.

3.3.2.2.6 Meter Data Management

Metering data will become a key issue in determining energy consumption, developing customer-specific offerings, optimal power system control, as well as billing.

In case of periodic meter readings it is required to organize the collection of the data according to a defined schedule through the AMR/RMR or manually. Beside the periodic readings a-periodic readings will be requested. They have to apply a basic check when entering the metered data and provide the gathered data to other market participants.

Meter Data Management (MDM) is part of the AMI system for processing metering data collected from any customer type through various communication methods from potentially multiple meter systems. The MDM system rationalizes, cleans, and manages data to establish a "system of record" of meter and interval data, which can then be securely used in a variety of billing, analysis, and operational applications.

The MDM shall be highly customized and specifically coded for the needs of Barqi Tojik. The MDM shall to "talk to" the EDM and settlement system. The MDM/EDM system shall be fully integrated that means all components and modules communicate with each other without interfaces.

The MDM/EDM system shall assume the function of the central data hub for controlling and recording the data flows of the announced processes. The basic system (Kernel) shall operate as a central, company-wide time series data pool for equidistant time series of all kinds (electricity, gas, water, prices, temperatures, weather data, brightness, forecasts, schedules, products, businesses, ...). The time series shall be compressed to a high degree by means of special storage procedures compared to conventional database storage.

3.3.2.2.7 Managing Schedule Data for Metered Data Collection

The MDM shall provide managing schedule functions to determine when meters shall be periodically read. The MDM shall provide functions to define whether:

- the AMR/RMR takes the readings
- the readings are taken through the mobile devices
- the customer reads the meter
- an agent of the Barqi Tojik takes manual readings
- or whether the periodic meter reading is estimated

AEMs shall be allocated for scheduling through the installations (in the system), in which the relevant meters will be installed. Meter reading units shall be grouped together e.g. bay and voltage level in the substation. Barqi Tojik has to enter all the data relevant to the scheduling of the meter reading assigned to the specific meter reading method.

Processing Requests for Metered Data Collection
It is required to receive requests for a-periodic collection of metered data. In this case the Barqi Tojik to schedule the reading.

3.3.2.2.8 Performing Metered Data Collection

The function Metered Data Collection shall be provided in order to create and issue meter reading orders as a trigger for metering data collection. Devices shall be read periodically or a-periodically based on the requirements for data collection. The meter reading results shall be entered into the system. A basic data check shall be performed to guarantee data quality. The entire process of metered data collection shall also be monitored

3.3.2.2.9 Providing Collected Metering Data

The main purpose of this function is to send the collected metered data to market participants e.g. power supply and commercial customers. Therefore the recipient's information shall be determined and error handling during the communication process shall be performed. The supply processes for gaining measurement series shall be used for market communication within the company and for external recipients.

3.3.2.2.10 Metered Data Validation and Measurement Data Calculation

Processing Requests for Measurement Data
The Metered Data Responsible shall receive requests for measurement data from other organizations and authorities. These measurement data shall be a-periodic and not scheduled.

Validating, Calculating and Distributing Measurement Data
The provision of metered data shall either be scheduled or it shall be individually requested. Barqi Tojik shall validate these data using plausibility checks. If the data will be implausible the data shall be corrected. If metering data are missing they have to be estimated and substituted. The substitute value formation and appraisal classes to be created are a central task of the Meter Data Management (MDM) and shall be provided.

Based on the metering data Barqi Tojik will determine the consumption. The metering data and the consumption (measurement data) shall be sent to the responsible market participants. Based on the measurement data the grid usage bill (grid access provider) or the end customer bill (balance supplier) shall be created.

3.3.2.2.11 Energy Settlement and Aggregation

Measurement Data Aggregation and Settlement
It is required to use this business function for aggregation and reporting of measurement data. This shall include the monthly aggregation of customers within an operational area as well as the determining overtake and undertake amount.

Provision of Energy Capital Data
It is required to provide this function if the Metering Data Aggregator will create and manage energy forecasts in behalf of Third Parties or will provide data for energy forecasts to third parties.
Barqi Tojik will also use this function in the future if the Metering Data Aggregator manages an Energy Trading Platform or provides Data for Energy Trading.
Process Measurement Data Aggregation
With this function the Metering Data Aggregator shall receive measurement data from the Metering Data Responsible. The consumption of interval and non-interval measured customers shall be aggregated according to certain market rules. After this calculation, the information shall be sent to other market participants to further process this data. One example shall be the monthly aggregation of all customers within an operational area of a distribution network company. This information shall be calculated and sent separately for all supply / re-

tail companies acting in the operational area of the responsible distribution network company.

Determining Overload and Underload Amounts
It is required to automatically detect Overload and Underload amounts as well as their monetary value. At a second step it shall be necessary to identify and qualify the billing data. Together with the measurement data it shall be possible to prepare a pre-billing data set for accelerated processing in the billing system.

It shall be necessary to collect, aggregate, or distribute the information for settlement in an initial settlement run and make it available to the other departments or eventually market partners. The Barqi Tojik will transfer the positive or negative amounts to billing and value them using different prices.

Usage & Measurement
It is required to support the reading of submeters for multiple tenants or cost centers.
It is required to receive and process customer usage data in various formats (e.g., kW, kWh, hourly, pulse intervals, kVA, kVAR, etc.).
It is required to support the meter reading of unlimited registers within a meter and/or channels within a recorder.
It is required to support unlimited reads per meter taking into consideration the reset of kW.
It shall be necessary to aggregate any read from any entity on any schedule. This shall support combined, conjunctive, or totalized billing.

3.3.2.2.12 Functional Specification of Recommended AMI system

In addition to collecting and uploading hourly consumption information, the AMI would have certain present and future capabilities. These include:

a) Interoperability – if meters are procured from multiple vendors, then the meters shall conform to an interoperable communications protocol standard (e.g. IEC DLMS).

b) Time of Use Consumption – in the future, if Barqi Tojik elects to adopt time of use (TOU) electricity rates, the AMI shall be capable of recording hourly information by time of use rate blocks.

a) Russian language shall be used wherever practical for all documentation, training materials, and customer communications and bills. The AMI/Balancing/ Settlement and Archive system could be delivered immediately in Russian and English language, later on it will time to change the language for the front office work place.

3.3.3 Requirements for Metering equipment

3.3.3.1 Accuracy of meters

Requirements on AEM meters

In accordance with industry standards, AEM meters are available in following accuracies:

- Class 2 – Max error of +/- 2%
- Class 1 – Max error of +/- 1% (appropriate for residential revenue electricity metering)
- Class 0.5 – Max error of +/- 0.5%
- Class 0.2 – Max error of +/- 0.2%.

In general, the higher the accuracy class, the higher the cost. However, AEM meters (because they use digital measurements) provide higher accuracy for relatively low incremental cost.

Meters with accuracy of class 0.2 or 0.2S for active power and 0.5 or 0.5S for reactive power on the other hand are by far more expensive than class 1.0 meters.

Such meters are commonly used at the borders of utility companies or for very large customers e.g. >125MW load.

Time synchronization

Synchronized metering data reading at all metering points in the electrical grid is a basic prerequisite for accurate metering. Therefore according IEC 62052-21 / IEC 62054-21 the deviation of metering instant may not exceed a certain time period, which is defined as maximum deviation from the system time basis i.e. between 10 and 3 seconds for meters of class 1 to class 0,2S

The reference time will be defined by the meter management system and is based upon GPS-time. Meters shall be synchronized from the Meter Management System.

Check meter requirements

For the commercial boundaries between the business units Generation, Transmission and Distribution the metering system is considered as a trustworthy system. No check meters will be foreseen.

In case of discrepancies the energy balance calculation for the grid segment and for the substation may be referred and provide further information.

For independent power producers (IPP), for example Sangtuda HPP 1, Sangtuda HPP 2, Dushanbe TPP 1, Dushanbe TPP 2, check meters should exist.

But the installation of check meters will also be subject to the scope of supply of the IPP during construction and document approval process.

For power exchange through international borders a check meter configuration should be installed.

Barqi Tojik informed that at the borders two metering point do exist, one eat each side of the respective OHL.

If electricity is delivered to the Kyrgyz Republic, then the meter at the related SS premises in Aigul-Tash in the Kyrgyz Republic is used for billing.

If energy is vice versa delivered to Tajikistan, then the meter located in the SS Kanibadam in Tajikistan is used for billing.

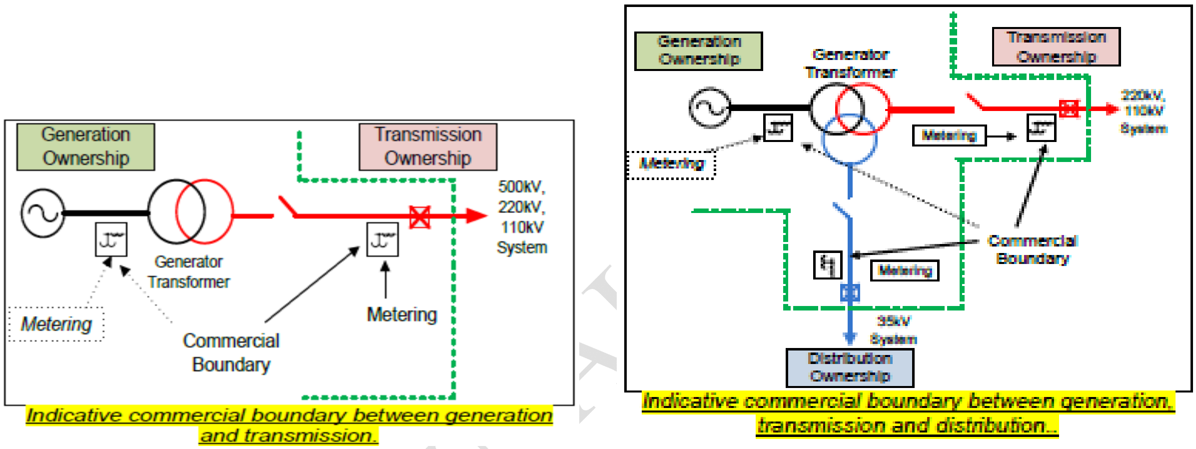
The settlement system shall support the existing solution.

3.3.3.2 Locations of commercial boundaries and number of wholesale metering points between generation and transmission

Except for the switchyards belonging to the power plants located in Nurek the interface will be the circuit breaker (CB) upstream of the step-up transformer. The CB will belong to Generation.

The interface is indicated in the following figures[3].

Figure 3-10 Commercial interfaces between generation and transmission



Main generation plants are the following locations:

Plant	Power	Status
Rogun HPP	3,600 MW	design
Shurob HPP	700 MW	design
Nurek HPP	3,000 MW	
Baypaza HPP	600 MW	
Sangtuda 1 HPP	670 MW	
Sangtuda 2 HPP	incl. above	design
Golovnaya HPP	240 MW	
Perepadnaya HPP	29.9MW	
Central HPP	15.1 MW	
Kayrakumskaya		

The meters related to these generation plants are listed in the annex 2.1 and tagged with generation.

The summary of the required new meters is provided in annex 2.1.1.

In the scope of the project the replacement of all meters downstream of the generator (15.8 kV

[3] Source: Corporate Solutions, Technical Separation Guidelines

level) with the related voltage and current transformers has been considered.

For the HPP 7 located in **Nurek**, 2 meters upstream of the 500 kV transformer and 2 meters upstream of the 220 kV transformer have been considered.

For the HPP 8 located in **Baypaza** according to the arrangement of the existing meters 4 meters upstream of the generator on the 15.8 kV level and two meters on the 6 kV level for determination of the own consumption have been considered.

For the **HPP Sangtuda 1** the internal metering, as there are:

- 4 meters ustream of the generator on 15.8 kV level
- 2 meters on 0.4 kV level for the determination of the own consumption
- 2 meters on the 220 kV level
- 2 meters on the 35 kV level

have been identified as internal meters and have not been considered.

For the commercial interface of the ower plant the replacement of the 2 meters located on the 220 kV (A1, A2) have been considered.

For the **HPP Golovnaya** meters at the step up transformer on the 220 kV level do not exist. All existing meters, which will be subject for replacement are located at the outgoing 220 kV lines.

The following metering points have been considered:

- 7 meters on 110 kV level as commercial points
- 2 meters on 35 kV level
- 8 meters on 10 kV level
- 4 meters on 6 kV level

For the **HPP Perepadnaya** 4 meters on 110 kV outgoing lines from the 110 kV switchyard have been considered. There are presently no meters upstream of the step-up transformer located. In addition 2 meters have been considered on the 35 kV level and 2 meters on the 6 kV level have been considered. The present meter arrangement does not consider the determination of the power consumption of the HPP.

For the Central HPP the following has been considered:

- 5 meters on 6 kV level
- 1 meter on 110 kV level upstream of the stepup transformer

For the HPP Kayrakumskaya the following has been considered:

- 4 meters on 220 kV level on outgoing lines
- 6 meters downstream of the generator on 10 kV level.
- Currently a metering upstream of step up transformer does not exist.

For the several small HPP the replacement of the meters included in the annexes have been considered. These HPP's are:

- Marzich HPP; 1 on 6 kV level (according SLD it should be 5)
- Tutak HPP; 1 for 10 kV level

- Yasmand HPP; 1 for 10 kV level

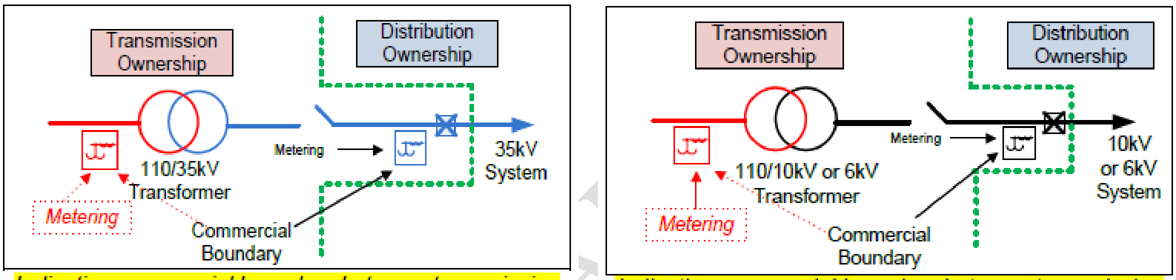
The exchange of the current transformers and voltage transformers at these metering locations for the voltage levels 110 kV, 220 kV and 500 kV locations is not foreseen due to space constraints and due to the cost impact.

3.3.3.3 Locations of all commercial boundaries and number of wholesale metering points between transmission and distribution

The interface between Transmission and Distribution will be the CB located at the low voltage side of the respective transformer feeding to the 35 kV, 20 kV, 10 kV and 6/0.4 kV network. The CB will belong to Transmission.

The interfaces in the 35 kV level and at the 10/6 kV level are indicated in the following figures[4].

Figure 3-11 Commercial interfaces between transmission and distribution (35 kV and 10/6 kV levels)



Indicative commercial boundary between transmission and 35kV distribution.

Indicative commercial boundary between transmission and 10kV or 6kV distribution.

The meters considered for replacement are included in the Annex 2.1.

The summary of the required meters are listed in annex 2.1.1.

3.3.3.4 Interfaces for interstate Energy exchange

The transmission grid in the Republic of Tajikistan is mainly connected on the 500 kV level and the 220 kV level with the Republic of Uzbekistan. On other voltage levels additional connections do exist. On the 220 kV a connection is also established to the Kyrgyz Republic.

The interfaces to foreign countries are indicated in annex 2.6 inter-republican connections.

Over and above the connections displayed in this annex the new connections to the Islamic Republic of Afghanistan need to be considered.

As informed by Barqi Tojik the metering interfaces established are as follows:

On both sides of the OHL line a meter is installed. Presently for balancing purpose the meter on the energy receiving side is used.

[4] Source: Corporate Solutions, Technical Separation Guidelines

When for example the energy flows from the Republic of Tajikistan to the Kyrgyz Republic, the meter located in the related substation in Kyrgyz Republic will be taken. When the energy is delivered from Kyrgyz Republic to the Republic of Tajikistan, the meter in Tajikistan will be used.

These new meters will be connected in the substations via wired M-Bus to a new data concentrator. The data concentrator will be equipped with a GPRS modem.

The related meters are included in the annex 2.1 and included in the summary in annex 2.1.1.

3.3.3.5 Suitability of existing electronic meters for reuse with the new wholesale metering system

As outlined above, the existing electronic meters have been installed stepwise from 2008 onwards in several contracts and different periods.

The meters which are going to be supplied in the SUGD Energy Loss Reduction Project in Khujand and surrounding municipalities are replacing existing meters and these new meters (manufacturer Hexing, China) are suitable for integration into the wholesale metering project.

For the following reasons the existing meters are found not being suitable for further usage in the overall wholesale metering system because:

1. Considering a start of the project installation works for the wholesale metering part at the beginning of 2017 a main part of the existing electronic meters have already passed a substantial part of their designed live time. Upgrades of these devices are not reasonable.

2. Some of the existing meters are not equipped with a communication technology which supports remote meter reading, for example the meters supplied by Landis & Gyr. The exchange of these devises is mandatory in order to reduce the human factor in meter reading and data processing.

3. Some of the existing meters are equipped with communication technologies suitable for communication with local devices only, for example the meters supplied by Chint. The exchange of these devices is necessary.

4. In the recent years the smart meter industry has made major progress and modifications in the design and in the applicable communication standards. A common metering technology and design will support the success of the project.

5. In some recent performed substation construction and rehabilitation work, for example SS Ayni 220 kV, different new meter types have been installed. Here are limited numbers of different makes and types available. In order to reduce the project impact caused by different technologies the present strategy is to replace these meters as well. During detailed design with the Contractor it may be decided to reuse these meters.

The new meters installed with the SUGD ELRP in the area of Khujand and surrounding areas and foreseen to be reused in future are not included in the annex 2.1.

3.3.3.6 Future use of existing free standing high voltage metering current transformers (CT) and voltage transformers (VT);

3.3.3.6.1 General

The accurate measurement of electric energy in electrical grids depends among other factors on three key components, the current transformer (CT), the voltage transformer (VT) and the advanced electricity meter (AEM meter).

Equipment to be replaced within the project shall comply with the requirements outlined below:

Requirements for voltage transformers

Voltage transformers shall fulfill the following precision classes according IEC 61869:

- for circuits with a nominal capacity above 125 MVA – class 0.2
- for circuits with a nominal capacity below and equal to 125 MVA – class 0.5.

Requirements on current transformers

Current transformers shall fulfill the following precision classes according IEC 61869:

- for circuits with a nominal capacity above 125 MVA – class 0.2S;
- for circuits with a nominal capacity between < 125 MVA and > 10 MVA – class 0.5S;
- for circuits with a nominal capacity below 10 MVA – class 0.5.

3.3.3.6.2 Assessment of existing equipment

The existing free standing high voltage metering current transformers (CT) and voltage transformers (VT) are in normal conditions in operation since construction of the substation.

The design of these devises in the 500 kV, 220 kV and 110 kV transmission systems is compliant to the actual technical requirements for such devices and for the metering purpose.

As indicated in annex 2.1 the accuracy for

- Voltage transformers vary between class 0.2 and class 0.5.
- Current transformers vary between class 0.2 and class 1. As an exception class 3 applies.

These accuracy classes are acceptable for the metering purpose (priority 2 equipment).

In general a replacement of high voltage equipment will be done on exceptional basis and financed from the project contingencies.

Barqi Tojik informed that no experience does exist regarding the current accuracy of existing CT and VT devices which are in the majority of the cases in use since the time of construction. Recalibration of the CT and VT in use in the high voltage areas has not been done so far.

Accuracy of instrument transformers (CT and VT as mentioned above) do change due to

- Aging
- Environmental effects like ambient temperature (above 40 Deg C), temperature cycling, humidity etc
- line transients and surges leading to insulation leakage, shorted turns
- fault currents leading to saturation of cores

Due to the history of the equipment, in the majority in operation since the date of construction in former times of the Soviet Union, the deterioration of the accuracy rate of the existing equipment is assumed as follows:

- The levelized accuracy of CT installed has changed from 0.5% to 1.5%. (±CT)
- The levelized accuracy of VT installed has changed from 0.5% to 1.5% (±VT)
- The levelized accuracy of the electricity meters has changed from 0.5% to 1%. (± meter)

The accuracy of the energy currently metered at the commercial interfaces to the distribution system can be calculated as follows:

$$\text{failure metred energy} = \pm\sqrt{(\pm CT)^2 + (\pm VT)^2 + (\pm meter)^2} = 2.35\%$$

Option

Following an request issued by Barqi Tojik the following equipment shall be considered for replacement:

Khujand Electrical Network (annex 2.4.1)

- 18 CT for 110 kV
- 18 VT for 110 kV

Dushanbe City Electrical Network (annex 2.5.1)

- 87 CT for 110 kV
- 90 CT for 110 kV

The related costs of these 213 items will sum up to approx. 2.3 Million USD.
It has been agreed that these items will not be included into the project.

3.3.3.6.3 Conditions of high voltage equipment containing metering CT's and associated VT's;

In the following figures an oil filled circuit breaker located at the SS Sovetskaya is displayed.

The insulators at the inlet and outlet are equipped with current transformers.

Figure 3-12 Oil filled circuit breaker with two CT's

These CT's are used for protection and also for metering purposes.

This equipment can only be replaced when the arrangement in the related part of the substation is reworked completely with resulting costs.

For this reason the replacement is not foreseen in the ongoing project.

3.4 Conditions of Power Line Carrier terminal and line equipment on the 220 kV system.

For Wholesale Metering purposes, existing and new digital meters (smart meters) shall be located in rooms for electrical equipment in substations, at generator stations and at the edges of different providers.

Digital meters (smart meters) allow a wide range of types of measurements which also can be read via telecommunication from remote.

Besides accurate measurements of active power, reactive power and apparent power, the direction of the according energy flow can be indicated and recorded at a time. De-pendent of the mode and type digital meters are able to store measurement data related to a time-stamp each from 190 to 1400 days from which the profile of load can be seen. Hence, the data transfer of readings can be performed at any time. Digital meters can be controlled and be read from remote and they are working with unique time-stamps. Any digital meter (smart meter) has to have the same time-stamp at a time.

For remote meter reading of electrical power, new digital meters (smart meters) will be equipped with a wireless M-BUS interface as well as with a wired M-BUS interface.

M-BUS interfaces are recommended as an international accepted standard which allows independency regarding vendors or manufacturers of digital meters.

EN 13757 defines the M-BUS including several physical media of its supporting lay-ers below, comprising drilled copper twin lines and the wireless M-BUS.

For the operation with drilled copper twin lines a data transfer rate of 2400 to 9600 Baud are normal.

Furthermore, M-BUS supports the standard protocols DLMS/COSEM, defined in IEC 62056 which is a communication protocol at application level, based on a client-server structure.

In order to measure any incoming and outgoing electrical power of BT’s electrical transmission network as well as to identify and to reduce or even avoid technical losses in the system, remote controlled digital meters will be located at the edges of the transmission network:

- at common edges of the transmission network and the distribution network on both sides,
- at the edges of different energy providers and
- at generators of the transmission network.

To avoid failures or arguments, at the edges of different providers two (2) digital meters will be deployed: one digital meter for each provider. In this way readings can be compared with each other.

In order to analyse measurements all digital meters can be related to their location and they will have one unique time stamp, provided by GPS.

The wired M-BUS interfaces of the new digital meters deployed in a substation will be directly connected to a data concentrator (DC) which is located in the same substation. The data concentrators needs to be compatible with standard protocols DLMS/COSEM (IEC 62056), hence.

Dependent of the site not more than two (2) types of intelligent and remote controllable data concentrators from not more than two (2) vendors will be needed:
On sites, which are connected to the SDH network DCs with appropriate interfaces for the SDH-ADMs and additional interface converters are required to be able to com-municate via the SDH network.
On sites without SDH, DCs with integrated GPRS interfaces are required. They need to be able to establish a GPRS VPN connection automatically and for safety reasons to communicate via GPRS VPN (Virtual Pri-vate Network) with the remote central meter data management system (MDM).

Data concentrators use the DLMS/COSEM communication protocol. Related data transfer rates can be assumed to 1200 Bit/s (half-duplex), hence.

Any communication matter related to remote meter reading respectively to data concentrators (DCs) will be managed, conducted and provided by the Contractor. In particular, the Contactor will guarantee a save communication technology (concerning GPRS for example the use of VPN and firewalls) and will ensure a documented and reliable integration of digital meters and data concentrators into BT’s IT-network.

The wireless M-BUS interfaces of the new digital meters may be used for manual reading with a handheld device during commissioning and later on during operation.

The data concentrator will perform scheduled and/or cyclic meter readings and it will collect and store all that data gathered from all connected digital meters. So, in the course of the time a big data volume might be stored in the data concentrator.
The figure below provides an overview for the architecture in general.

Measurement data which are between-stored in the data concentrators will be cyclically (or scheduled) acquired and read out by a remote central meter data management system (MDM).

Therefore, a suitable telecommunication system between the data concentrator and the central MDM is required. Subject of this chapter are feasible possibilities of telecommunication connections between data concentrators in the substations and the remote central MDM in Tajikistan.

For the current telecommunication within Barqi Tojik's power energy supply facilities, predominantly analogue PLC in operation frequency range from 40 kHz to 620 kHz is available, which is partly far over 30 years old. Even though widely 3 phases are capable to be used for teleproteciton and data transmission, a bandwidth of 4 kHz per channel and a maximum transfer rate of 1 to 4 kBit/s per channel is a realistic assumption for PLC currently deployed in Tajikistan.

In the scope of its bandwidth and its possibilities, PLC is first of all dedicated to ensure reliable teleprotection and to provide the data transfer of SCADA data as well as voice telephone - especially at power energy facilities in rural areas, far away from infrastructure where no reasonable means of telecommunications are available.
Moreover, in Tajikistan many of the available older PLC lines either have been put out of service a long time ago or they only still can be used for teleprotection, which has always highest importance.

At present Barqi Tojik operates digital PLC links (DPLC) on the following transmission line sections (see Annex 2-2):
- On 500 kV lines, Regar-500 – Dushanbe-500 – Sogd-500: two (2) DPLC links are installed for transmission of teleprotection signalling.
- On 220 kV lines, Nurek HPP – Rogun HPP: one (1) DPLC link is installed for transmission of teleprotection signalling.
- On 220 kV lines, Nurek HPP – Yavan TPP: one (1) DPLC link is installed with a tee-off to the Nurek substation for transmission of teleprotection signalling.
- On 220 kV lines, Nurek HPP – Lolazor:
one (1) DPLC link is installed with a tee-off to the Sebiston substation for transmission of teleprotection signalling.
- On 220 kV lines, Nurek HPP – Shar-shar:
one (1) DPLC link is installed for transmission of teleprotection signalling.
- On 220 kV lines, Nurek HPP – Orjonikidzeobod-2: one (1) DPLC link is installed with a tee-off to the Nurek-500 substation for transmission of teleprotection signalling.
- On 220 kV lines, Jangal – Baipaza HPP:
one (1) DPLC link is installed for transmission of speech, SCADA data and teleprotection signalling.
- On 220 kV lines, Golovnaya HPP – Kolhozobod: one (1) DPLC link is installed for transmission of speech, SCADA data and teleprotection signalling.
- On 220 kV lines, Kairakkum HPP – Kanibodom: one (1) DPLC link is installed for transmission of speech, SCADA data and teleprotection signals.
In the North of Tajikistan, the existing PLC network will be extended as follows, in order to protect, to monitor and to control the following sites/stations with teleprotection and with the new SCADA System:
- For the 220 kV transmission line Kairakkum HPP – Kanibodom (72.2 km) new DPLC equipment shall be provided for transmission of speech and SCADA data.
- For the 220 kV transmission line Sugh – Buston (24.0 km) new DPLC equipment shall be provided for transmission of speech and SCADA data.
- For the 110 kV transmission line Aini – Rudaki (100.0 km) new DPLC equipment shall be

provided for transmission of speech and SCADA data.

Existing and new PLC/DPLC lines concerning Priority stations see annex 2-3.

As outlined above, digital PLC (DPLC) is partly available in Tajikistan - and occupied for the use of teleprotection, SCADA and voice telephone.

In order to replace outdated PLC facilities, DPLC it will be deployed or extended in the scope of this project. But even DPLC offers only a limited bandwidth, which is already reserved for first priority applications, as already mentioned above.

Another limiting fact of PLC/DPLC is the unpredictability of data channel's behaviour which is highly dependent of environmental and disturbing influences.

Since teleprotection has always to have first priority, in case of active teleprotection there might be a disruption of data transfer at ser-vices with low priority like Metering.
Even with modern PLC/DPLC equipment it is not possible to guarantee a certain band-width and maximum transfer delay. More-over, in a wide area PLC/DPLC network, transmitting a packet from a source to a destination node which is not immediately reachable requires the packet relay of the intermediate nodes (repeaters). Due to the dynamic topology change and impossible pre-diction of power line attenuation and all disturbing influences in the power line, repeaters cannot be statically configured.

As already mentioned, PLC provides only a limited bandwidth as well as a limited data transfer rate. Even if there is a non-disturbed data transfer via PLC there is always a big data volume stored in each data concentrator to be transferred to the remote MDM, which will occupy PLC channels just for this data transfer. So, PLC could not be used for other purposes for a long time.

In those few cases that PLC could be used for data transmission, the data concentrators as well as their counterpart on the receiving side (MDM) will have to be capable to recognise any external forced disruption of data transfer, to store and to manage all stored data for the time being, repeatedly to initiate successful data transfers automatically as well as to guarantee their completeness and correctness at the receiving side (MDM) at any time.

Additionally, a suitable protocol interface converter between the data concentrator and the PLC multiplexer / terminal equipment will be required.

As a matter of fact, for the current situation PLC is not a realistic option for the data transfer of metering data.

Another possibility for the transfer of metering data is to realise their transport by SDH on fiber optic lines, which are already available at the most of the 43 Priority Substations - and which will be extended in the project.

Since SDH lines are available anyway, data transmission via SDH will not cause additional costs for the data transfer of metering data.

SDH technology in general

The advent of semiconductor circuits and a continuing demand for telephone capacity in the 1960s resulted in the development of the pulse code modulation (PCM) transmission method. With PCM (using a single line multiple times through digital time-domain multiplexing), the analog telephone signal is first sampled at a 3.1 kHz bandwidth, quantized and encoded and then transmitted at a 64 kBit/s rate. Collecting 30 such coded channels together into a frame along with the necessary signalling information can achieve a 2048 kBit/s transmission rate. Up to present, this 2048 kBit/s primary rate is used throughout the world except in the USA, Canada, and Japan, which use a 1544 kBit/s primary rate (formed by combining 24 channels). In the course of time the demand for greater bandwidth, however, resulted in the need for more multiplexing stages throughout the world. A practically synchronous — or plesio-synchronous — digital hierarchy (PDH) was developed in response. Slight differences in timing signals have required justification or stuffing to form the multiplexed signals.
Inserting or dropping an individual 64 kBit/s channel to or from a higher digital hierarchy requires a lot of complex and expensive multiplexer equipment.

Synchronous digital hierarchy (SDH) was introduced in the 1980s, paving the way for a worldwide, unified network structure. SDH is ideal for network providers and enterprises, because it delivers an efficient, economical network management system that easily adapts to accommodate band-width-consuming applications and services.

Compared to the older PDH system, low-bit-rate channels can be easily extracted from and inserted into the high-speed bit streams in SDH, eliminating the need for costly de-multiplexing and re-multiplexing the plesiochronous *(plesio-synchronous)* structure.

SDH enables network providers and enter-prises to react quickly and easily to their customers' respectively to their own requirements, such as switching leased lines just in minutes - dependent of the vendor automatically by software. Network providers or enterprises can use standardised net-work elements (NE) that they can control and monitor from a central location (Net-work Operation Control Centre = NOC) by a telecommunications network management system (TNM or NMS).

SDH networks include various automatic backup-circuit and repair mechanisms that management can monitor to cope with sys-tem faults so that link or NE failures do not lead to an entire network failure.

SDH is the ideal platform for a wide range of services including POTS, ISDN, mobile radio, and any data communications, such as SCADA, LAN, WAN. It can also handle more recent services such as triple-play, video on demand and digital video broad-casting via ATM.

SDH simplifies gateway setup between different network providers and to SONET systems. The SDH interfaces are globally standardised, making it possible to combine NEs from different manufacturers into a single network which reduces equipment costs.

An existing redundant SDH fiber optic mesh network is available with STM-1 (155 MBit/s) and STM-4 (622 MBit/s) lines, pro-viding far enough bandwidth, data channels and data transfer rates suitable for a reliable transport of metering data. The SDH net-work will be extended in this project on STM-1 level and on STM-4 level.
1 STM-1 signal transports 63 VC12 contain-ers respectively 63 E1s.
Since 1 E1 (2048 kBit/s) = 30 x 64 kBit/s,
1 STM-1 signal, for example is capable to transport 1890 x 64 kBit/s (= 1890 ISDN channels)

simultaneously.

At present, Barqi Tojik operates existing SDH fiber optic links as follows.

In the North of the country:
A STM-4 line between the existing 500kV substations Dushanbe – Sogd and between the existing 220kV substations Sogd – Shahriston – Aini.
An optical STM-1 ring between the sites Kairakkum HPP – Asht.

In the centre and in the South of the country:
STM-4 between the existing 500kV substa-tions Dushanbe – Regar.
An optical STM-1 ring connecting the sites Novaya – Barqi Tojik Headoffice – Dushanbe TPP – Jangal – Kurgan Tube – Lomonosova – Golovnaya – Sangtuda HPP-2– Sangtuda HPP-1 – Lolazor – Sebiston – Nurek HPP - Orjonikidzeobod-2.
An optical STM-1 ring between the sites Kurgan Tube– Pryadilnaya – Perepadnaya HPP – Centralnaya HPP.
An optical STM-1 ring between the sites Sangtuda HPP-1 – Geran – Rumi.
And an optical STM-1 ring between the sites Lolazor – Hatlon.

About the existing and the new SDH network concerning Priority stations see Annex 2.2.
The principle for the deployment of meters and data concentrators on the substations (sites) is the same as described above in this chapter.

Since the data transfer will not be affected by teleprotection or other external influences like PLC, data transfers in general will be reliable and predictable.

However, it is recommendable that data concentrators also will have to be capable to recognise any external caused disruption of data transfer, to store and to manage all stored data for the time being, repeatedly to initiate successful data transfers automatically as well as to guarantee their completeness and correctness at the receiving side (MDM) at any time.

Interfaces and protocols between the data concentrator and the tributary side of the SDH-Add-and-Drop Multiplexer (ADM) need to match with each other. For that reason, additionally a suitable protocol converter and/or interface converter between the data concentrator and the tributary side of the SDH-Add-and-Drop Multiplexer (ADM) might be required.

SDH equipment at Barqi Tojik's power energy facilities like SDH-ADMs, are predominantly made in China by Huawei. ADMs with Alstom labels are originally assembled by Huawei as well.

3.5 Suitability of mobile phone networks for transmission of metering data.

Today, mobile services are available almost everywhere making the cellular infrastructure extremely valuable for all kind of applications including AMR.

2G cellular mobile networks commonly provide data services at net data rates up to several kbps or several tens of kbps. These data services are optimally tailored to most telemetry and remote metering applications. Network operators also provide special data call numbers and data-only SIM cards for GSM data modem devices and offer data services at special tariffs.

GSM is the best infrastructure network deployed worldwide. As good as whole area covering data services are offered for time and volume tariffs.
Even for SCADA applications the usage of GSM as main connection or as backup connection is common. However, GSM's limited bandwidth widely excludes video applications.

For AMR applications, data is typically transmitted either via SMS or the circuit-switched non-transparent GSM data service (CSD) based on Radio Link Protocol (RLP) providing 9.6 kbps net throughput in both directions.

CSD (Circuit Switched Data) and HSCSD (High Speed Circuit Switched Data) are classical GSM data services, in which a narrow band point-to-point connection (with 9.6 kBit/s respectively with 43.2 kBit/s) with a guaranteed quality of service gets established with one fixed counter side.
Since the billing is dependent of the duration of connection these services are not permanently in use.

If higher transmission speed is required, HSCSD supporting multi-slot transmission and higher rate coding (FEC) schemes can be used. GPRS or EGPRS (EDGE) enhanced GSM networks can provide packet-oriented data services at even higher speed up to 80 kbps and 237 kbps, respectively, depending on link quality.

GPRS (General Packet Radio Service) and GPRS Edge are IP-based GSM data ser-vices, providing higher data transfer rates (depending of link quality up to 237 kBit/s) via internet and vareable coupling to multiple counter sides.

Since data services do have less priority than voice services, service providers cannot permanently guarantee constant quality of service for GPRS and GPRS Edge, which is disadvantageous. But since metering data are stored in the Smart meters as well as in the concentrators, the transfer time of metering data from the concentrators to the remote central meter data management system (MDM) is not scheduled neither fixed. So, this disad-vantage does not affect Wholesale Metering.

The ability to reach remote GPRS-data concentrators from the central meter data management system (MDM) or vice versa is provided by IPsec-, PPTP- or L2TP protocol via internet. Most of the service providers normally offer cheap additional services, which make it possible to reach GPRS-data concentrators (or GPRS-SCADA stations) as safe access points (VPN server) in the internet.

A GPRS connection provides a quasi permanent line. Accidental service disruptions as mentioned above easily can be compensated by an intelligent data storage and data transfer management of the data concentrators (or SCADA archive mechanism according to IEC 60870-5-104).

Similarly to 2G/2.5G technologies, the W-CDMA-based 3G/UMTS technologies and evolutions thereof (HDSDPA, HSUPA) are principally able to provide data-only services suitable for telemetry and metering applications. These services are normally packet oriented and IP based. Likely, operators could offer 3G data services at more economical conditions than 2G services.

The behavior of an UMTS network designed in cell structures is similar to the behavior of a GPRS connection - but UMTS regionally provides higher data transfer rates (up to 384 kBit/s). Also in this case a connection for the transfer of measurement data (or of SCADA process data) gets established by a saved VPN-tunnel via internet.
However, the territorial covering of UMTS is limited to areas with high population or to important traffic ways.

Availability of UMTS always individually has to be investigated before planning, hence.

Today, deployment of 3G networks operating at 2 GHz is still far behind 2G. This is particularly true in less populated and rural areas. This may however change in future, since 3G/UMTS is considered a strong candidate to provide broadband Internet access in those areas currently not served by xDSL and cable. Nevertheless, indoor penetration at 2 GHz must be considered less effective than at 900 MHz requiring house gateways or 2 GHz antennas to be mounted at well selected positions.

The main advantages with LTE are high throughput, low latency, plug and play from day one. LTE will support seamless connection to existing networks, such as GSM, CDMA and WCDMA. However LTE requires a completely new RAN and core network deployment and is not backward compatible with existing UMTS systems.

The 3GPP (LTE) is defining IP-based, flat network architecture as part of the System Architecture Evaluation (SAE) effort. LTE–SAE architecture and concepts have been designed for efficient support of mass-market usage of any IP-based service.

Nowadays the majority of the Machine to Machine (M2M) communication applications as mentioned above are based on the GSM data service GPRS (EDGE). The number of developed applications is still increasing. It can be expected that these services will be available for the next 15 to 20 years in the fast changing telecommunication technology business.

In Tajikistan there is currently an estimated coverage of about 70% for GSM and for GPRS. Related maps are included in the annexes. There are two main providers offering GSM respectively GPRS services in distinct parts of the country: Tcell (CJSC Indigo Tajikistan, CJSC JV Somoncom) and Beeline (Tacom LLC). So, substations which are not involved in the SDH telecommunication network easily can be connected to the central meter data management system (MDM) by GPRS. However, availability of GPRS and of its services individually has to be investigated before planning.

Among other service providers, Tcell provides GPRS service for mobile subscribers respectively wireless access to the internet at any time, which allows uploading and downloading of data at a maximum of 171.2 kBit/s.

In order to use GPRS service, subscribers at first need to connect and set the service. Data concentrators with integrated GPRS shall be capable to connect and to set the service by themselves. Furthermore, as mentioned in the last chapter, data concentrators must be able to communicate via VPN and be remotely controllable.

For the use of GPRS, subscribers will be charged only for the total amount of downloaded and uploaded data - subscribers will not be charged for airtime (the duration of the connection). Adding or cancelling GPRS services also will not be charged.

For GPRS Tcell currently offers 3 tariffs as follows:

Tariff	Service description	Price
Ajoib	per 1mb download and upload	2.32 TJS
AVVALIN/ City	per 1mb download and upload	1.75 diram
NEXT	up to 1 Mb (rounding up 1 Kb)	0.50 TJS
	over 1 Mb (rounding up to 1 Kb)	0.08 TJS

The coverage of Tajikistan with GSM, GPRS, UMTS and 3,5G HSDPA see Annex 2-3. Data concentrators of one (1) type and from one (1) vendor with integrated GPRS inter-face are advisable since they are usual and available on the market.

If available, in combination with VPN (virtual private network) data transfers by GPRS are much safer and much faster in comparison with “normal” GPRS without VPN or with the slower GSM.

The meters used for the determination of power supplied to neighbouring countries will be connected via wired M-Bus to a data concentrator. This data concentrator will be equipped with a GPRS modem.

The metered data will be transferred using the public communication networks to the AMI.

An intelligent communication management, which shall be a feature of the data concentrator, enables reliable data management, permanent transfer of current readings and of load profiles.

Following maximum data transfer durations are to be assumed as a scalable benchmark for 1 data concentrator serving 50 Smart Meters. Transfer durations mentioned below concern the transfer line between 1 data concentrator and the MDM.

The answer on a spontaneous request for current measurement data of 50 Smart meters (50 records) will last less than 180 seconds.

The time to transfer all data of 50 Smart meters stored in the data concentrator within 1 day will last less than 20 minutes, at constant measurement cycles of 15 minutes (480 records).

The time for other reactions like remote control features provided by the Smart meters will last less than 5 minutes.

3.6 Testing requirements for metering components including CT's

and VT's

Prior to the supply of the metering equipment, the equipment shall pass the following tests:

- Type tests at international certified laboratories
- Equipment registration at Tajik Standard
- Quality check at the manufacturer
- Factory acceptance tests at the manufacturer workshop prior to shipment
- If required, the quality of the production shall be supervised by a independent authority.

A subset of the supply lot shipped to Tajikistan, typically 1%, shall be forwarded after arrival to Tajik Standard for additional quality checks.

Testing of existing equipment built in in the substations, for example for CT and VT equipment, is not a usual practice and not required.

In order to enable Barqi Tojik to assess the required meter accuracy the supply contract will include a fully computerized meter test bench system for carrying out routine and acceptance tests as per IEC-61036.

The test system shall generate automatically error test reports with error curve for each and every meter.

Necessary minimum testing facilities should be available at the manufacturer’s works for carrying out tests such as:

- insulation resistance measurement
- no-load conditions
- starting current test
- accuracy requirement
- power consumption and voltage circuit
- M-Bus communication interface

The interface in the supply contact will be a existing power supply feeder. Up to this feeder all required work and supply will belong to the Contractor.

3.7 Workshop equipment for smart meters

The test system shall generate automatically error test reports with error curve for each and every meter.

Necessary minimum testing facilities should be available at the manufacturer’s works for carrying out tests such as:

- insulation resistance measurement
- no-load conditions
- starting current test
- accuracy requirement
- power consumption and voltage circuit
- M-Bus communication interface

The interface in the supply contact will be a existing power supply feeder. Up to this feeder all required work and supply will be-long to the Contractor.

3.8 Training Requirements

Due to the importance of the system for Barqi Tojik's business success it will be necessary to keep all functions fully operational and updated after completion of the project. A continuous supervision and maintenance of all elements by Barqi Tojik personnel will thus be required.

In order to qualify the employees for the level required, a training program will educate employees for the following qualification level:

User
Users will exist for the following systems: AMI, Loss analysis, and Settlement system.
A user will use the system sometimes during the day or week. The system will be an additional tool for executing the work tasks assigned to him. The functions used by a user are well established and documented routines, processes and applications.

Key User
Key users will be placed at and use the functions and access the Loss analysis and settlement system. For a key user the system will be an essential tool for executing his job because he will perform the majority of his work during a day by using the system. The functions used by a key user will be routine functions as well as specialized functions. A key user will have a dedicated knowledge of the system and all required components. A key user may be in the position to assign new lines, feeders and meters in the system or to analyze failures.

Expert User
A user on expert level is a key user with additional training on certain dedicated subjects. A small number of expert users are defined for the settlement system which may have experienced for example a dedicated training regarding the calculations required with respect to the balancing of the transmission grid or for the financial year closing and consolidation activities.

The key user/expert user will be an interface between the requirements in a business division and the IT administration. The key user/expert user will provide the 1st level of support to questions and problems with focus on customers and colleagues with user level qualification.

Administrator
The administrator is having a deep knowledge of the system configuration but with a focus on the services and functions operating in the background of the system. He will be in the position to add new users and key users as well as administrators in the system. In the following, typical profiles are given for a data base and a network administrator

Typical data base administrator profile:

- Installing and upgrading the Database server and application tools
- Allocating system storage and planning future storage requirements for the database system
- Creating primary database storage structures (table spaces) after application developers have designed an application
- Creating primary objects (tables, views, indexes) once application developers have de-

signed an application
- Modifying the database structure, as necessary, from information given by application developers
- Enrolling users and maintaining system security
- Ensuring compliance with the license agreement
- Controlling and monitoring user access to the database
- Monitoring and optimizing the performance of the database
- Planning for backup and recovery of database information
- Maintaining archived data on tape
- Backing up and restoring the database
- Contacting the Supplier or the data base software manufacturer for technical support

Typical network administrator profile:
- Troubleshooting LAN-, Security-, WAN- based on trouble ticket information
- Troubleshooting for interfaces with public communication system providers
- Reconfiguration of LAN-, Security- and WAN-Services
- Documentation of the data bases

Additional administrator qualifications
The qualification level required for the system administration will be based on three qualifications:
1. Supplier administration training courses
2. Some years of practical experience in the IT support field.
3. Dedicated knowledge level certified by leading system providers
4. Study with the theme focus on IT at an university

Administrators should be trained for the different systems like AMI, loss analysis, settlement, and Archive as well as on the supporting infrastructure network and communication technology. Over and above, these training sessions delivered by the supplier the employees working on the administration level should have an additional IT knowledge and experience. As a common business practice this experiences may be certified by the system providers.

The systems finally installed will be selected by the supplier according to his standard applications. In general the following qualification certificates would definitely be supportive for the employees working on administration level:

Retention program
It is clear that employees who enjoyed a company sponsored training and achieved the qualification mentioned are very attractive for other companies in the IT market. Due to the salaries and the job opportunities offered, the market is also attractive to the qualified employees.

It is thus recommended that Barqi Tojik shall setup a retention program before delegating employees to the training courses.

Supplier training
The Supplier shall propose the necessary training to assure that Barqi Tojik is fully prepared to assume responsibility for operating and troubleshooting their new systems, hardware, oper-

ating and application software (including third party software such as DBs, Application Server, Development tools, etc.) .

Classroom style courses with hands-on experience will be preferred.

For end user training, virtual classroom or Web-Based Training (WBT) courses shall be considered if required.

Number of recommended training courses and locations are indicated in the following tables.

Subject/Group **Тема/группа**	Number **Кол-во**	Duration / location of each event **Продолжитель-ность/местоположение каждого занятия**
Brief Management system presentation Руководство	2 events for 10 persons each 2 занятия для группы по 10 человек	1 day at BT's Headquarter in Dushanbe
Briefing on smart meter functions	1 Event, 20 persons	3 days at BT's Headquarter in Dushanbe
Briefing on meter installation Краткий курс по установке счетчиков	1 Event, 20 persons 1 занятие, группа из 20 человек	1 day at BT's Headquarter in Dushanbe 1 день
Communication training PLC /, GSM / GPRS, leased line, xDSL and VPN, SDH Обучение по систмам связи по ВЧ/GSM/GPRS, выделенным линиям/ xDSL и VPN	1 Events, 10 persons 1 занятие, группа из 20 человек	3 days at BT's Headquarter in Dushanbe 3 дня
User Обучение по профилю пользователя	3 Events for 10 persons each 1 занятие, группа из 20 человек	2 days at BT's Headquarter in Dushanbe 2 дня
Key User/ AMI Обучение по профилю ключевого пользователя системы AMI	1 Event, 10 persons 1 занятие, группа из 10 человек	2 week at BT's Headquarter in Dushanbe 2 недели
Key User loss analysis, settlement and Archiving, Обучение по профилю ключевого пользователя систем EDM, биллинга и архивирования	1 Event, 10 persons 1 занятие, группа из 10 человек	2 weeks at BT's Headquarter in Dushanbe 2 недели
Expert workshop loss analysis and settlement, Archiving eg. focus line and substation balancing, financial closing at the year end, special data report and items Семинар по системам EDM/биллинга, архивирования и т.д, с упором на процедуры закрытия финн. отчетов, подготовке статистических отчетов и их данных	1 event for 10 persons 1 занятие, группа из 10 человек	1 week at BT's Headquarter in Dushanbe 1 неделя
System Administrator Обучение по профилю системного администратора	1 Event, 6 Persons 1 занятие, группа из 6 человек	2 weeks at Manufacturer 2 недели на заводе-изготовителе
System Administrator Обучение по профилю системного администратора	1 Event, 6 Persons 1 занятие, группа из 6 человек	2 weeks at BT's Headquarter in Dushanbe 2 недели в ХЭС

3.9 Recommendation for Task 1

The introduction of the new wholesale metering system is linked to the following advantages for Barqi Tojik:

- The overall assessment of the electrical system will reduce the sources for unmetered energy supply. Additional meters will be installed in order to reduce unbilled delivery in the future.
- The Automated Meter Reading System will speed up the collection of metered data and the balancing of the energy generated, exported, and transported to the Distribution System and will form the basis for the related invoicing and an improved cash flow.
- The automated transfer of data will reduce the human interface and accordingly related failures as well as manipulation.
- The additional information collected with the meters will support the operation of the network with respect to load flow analysis, detection of overloaded system, reduction of system losses, etc. The information will form a basis for network extension planning in the future.
- A reliable balancing of the energy transported is necessary for a successful establishment of the new business units and will support the reduction of non technical losses.

As outlined in section 3.3.3.6.2 currently the failure rate of the energy transported is not less than ±2.5% based on the deterioration of the accuracy of the equipment used for metering.

With the new equipment foreseen within the project the related accuracy of the equipment will improve as follows:

- The levelized accuracy of CT installed will change to 0.5% (±CT new)
- The levelized accuracy of VT installed will change to 0.5% (±VT new)
- The levelized accuracy of the electricity meters will change to 0.5% (± meter new)

According to the formula used in the chapter 3.3.3.6.2 the new system will determine the energy transported with an overall accuracy of:

$$\text{failure metred energy new} = \pm\sqrt{(\pm CT\ new)^2 + (\pm VT\ new)^2 + (\pm meter\ new)^2} = \pm 0.87\%$$

The difference between the existing and new accuracy rate will be 1.5% which will be equal to increase of additional energy billed.

4. Task 2: Transmission component

4.1 Need of the proposed transmission line and substation expansion

4.1.1 Existing studies and reports

Because neither existing studies nor existing reports have been made available to the Consultant it is assumed that these documents do not exist.

Detailed load flow data and projections have been submitted in the answers to the questionnaire no. 2 by Barqi Tojik and in a letter addressed to the Consultant. The information handed over is attached in annex 3.8.

4.1.2 Historic load data

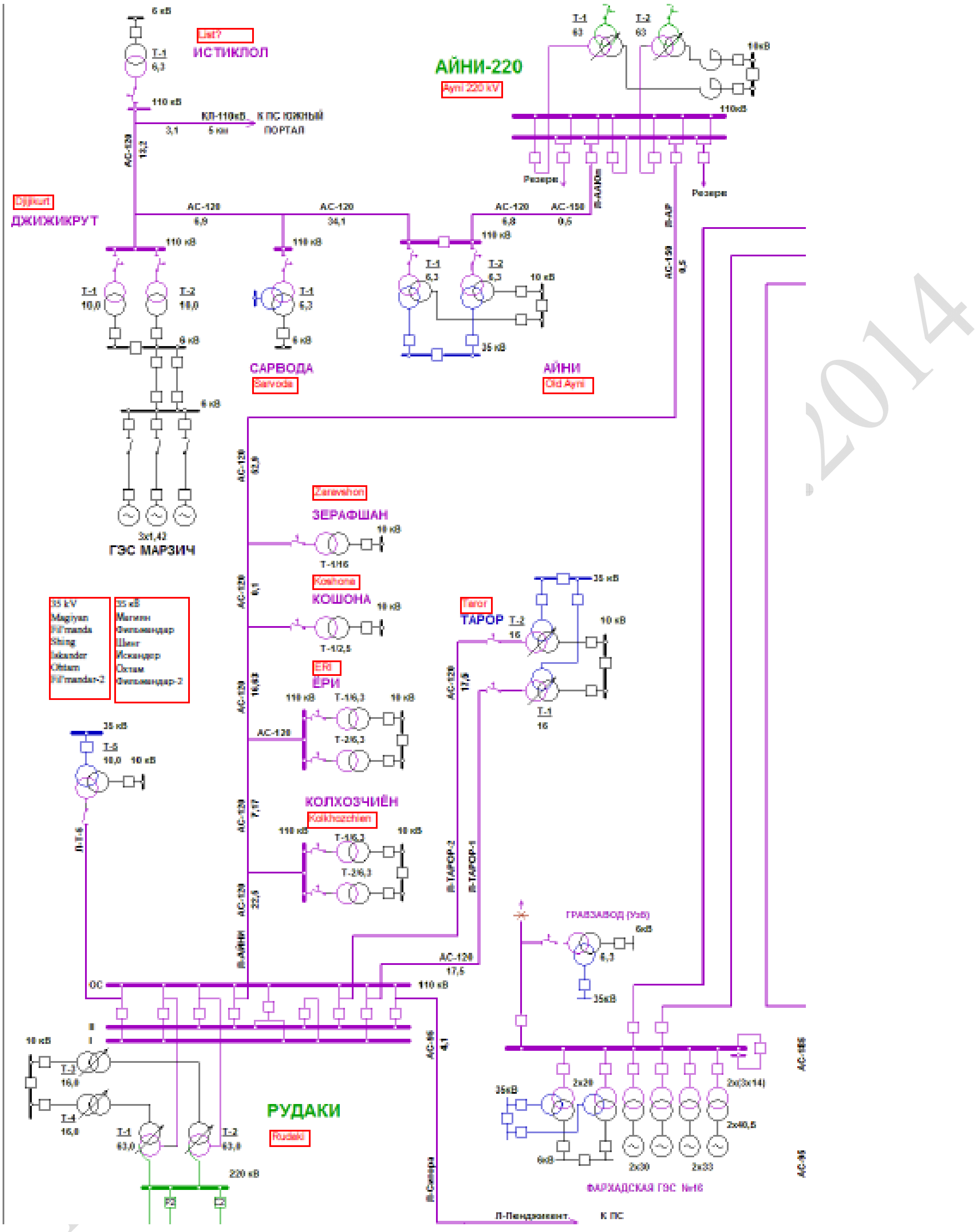
Barqi Tojik informed about the load figures in the years prior to the disconnection as follows:

Table 4-1 Historic load figures for the Penjikent EN

Historic load figures for the Penjikent EN					
Year	**2005**	**2006**	**2007**	**2008**	**2009**
220 kV OHL from SS Sogdiana (MWh)	287,2	290,7	268,0	250,8	256,4
220 kV OHL from SS Sari Bazar (MWh)	214,6	211,6	206,5	217,5	247,5
Total Quantity (MWh)	501.8	502.3	474.5	468.3	503.9
average monthly peak load (MW)					
220 kV OHL from SS Sogdiana	62	65	68	70	72
220 kV OHL from SS Sari Bazar	32	34	30	35	36
total (MW)	94	99	98	105	108

It need to be observed that the figures above are indicating the complete consumption of the Penjikent and Ayni regions which consists of the following substations connected to the existing 110 kV OHL:
The structure of the Penjikent Electrical Network (basically 110 kV level) is indicated in the next figure:

Figure 4-1 Structure of Penjikent Electrical network



Also included in the figures indicated in Table 4-1 Historic load figures for the Penjikent EN are the consumption of the consumers connected to the following substations:

SS Name	Habitants	Consumers
Zeravshon	61,586	8,776
Koshona	incl. in Zeravshon	incl. in Zeravshon
Eri	not available	not available
Kolkhozchien	61,965	6,825

Also included in the figures above is the consumer with large consumption, the Tajik Chinese Gold mining company, which is feed by the substation Taror.

Dedicated figures about the energy forwarded to the SS Ayni (SS Old Ayni) have not been made available.

The monthly breakup of the electricity consumption of the Penjikent region in 2013 is indicated in the following table:

Table 4-2 Monthly electricity consumption

	Penjikent		Zeravshon		Eri		Kolkhozchien	
2013 Month	Quantity (kWh)	average monthly load (MW)	Quantity (kWh)	average monthly load (MW)	Quantity (kWh)	average monthly load (MW)	Quantity (kWh)	average monthly load (MW)
January	24,132,240	32.4	1,134,720	1.5	x	x	1,418,760	1.9
February	20,322,560	31.1	1,231,080	1.8	x	x	1,435,020	2.1
March	23,141,360	31.1	2,869,800	3.9	x	x	2,766,720	3.7
April	19,507,840	27.1	2,897,040	4.0	2,897,040	4.0	2,645,280	3.7
May	17,361,520	23.3	2,760,600	3.7	288,360	0.4	3,134,580	4.2
June	16,899,520	23.5	2,729,280	3.8	852,960	1.2	2,867,580	4.0
July	16,793,040	22.6	2,860,800	3.8	706,100	1.0	2,005,040	2.7
August	17,201,360	23.1	2,742,600	3.7	664,920	0.9	2,814,960	3.8
September	16,463,040	22.8	25,779,600	3.6	1,045,920	1.5	2,470,560	3.4
October	19,387,280	26.1	2,756,160	3.7	x	x	2,787,900	3.7
November	19,559,760	27.2	1,376,160	1.9	x	x	1,460,940	2
December	22,205,920	29.8	1,271,640	1.7	x	x	1,384,760	1.8

4.1.3 Current Load shedding

The estimated electricity supply deficit in 2013 is as follows[5]:

Penjikent

- In the summer month 104,226,320 kWh with a corresponding missing capacity 23,7 MW.
- In the winter month 129,359,120 kWh with a corresponding missing capacity of 56,1 MW. The number of hours with load shedding was given with **1,452 hrs**.

[5] Based on the replies provided to questionnaire no. 2

Zeravshon

- In the summer month 16,568,280 kWh with a corresponding missing capacity 3.8 MW.
- In the winter month 10,639,560 kWh with a corresponding missing capacity of 7.3 MW. The number of hours with load shedding was given with **2,912 hrs.**

Eri

- In the summer month 6,455,400 kWh with a corresponding missing capacity 1.5 MW.
- Data for the winter month have not been provided.

Kolkhozchien

- In the summer month 15,938,000 kWh with a corresponding missing capacity 3,63 MW.
- In the winter month 11,204,100 kWh with a corresponding missing capacity of 7.7 MW. The number of hours with load shedding was given with **2,912 hrs**.

Tajik-Chinese Gold Mining Company

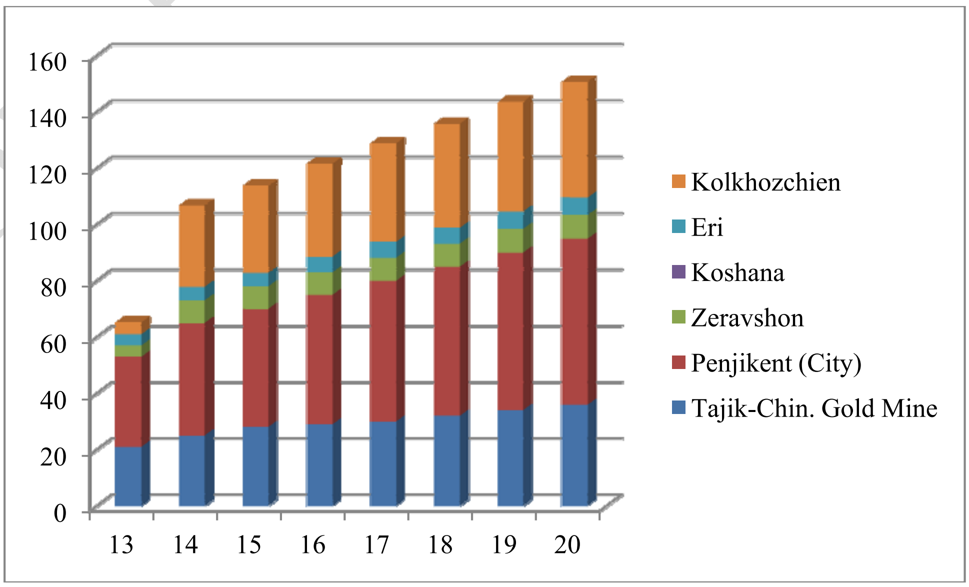
- In the summer month 57,753,465 kWh with a corresponding missing capacity 13,1 MW.
- In the winter month 64,158,270 kWh with a corresponding missing capacity of 14.7 MW. Information regarding load shedding has not been provided.

4.1.4 Load forecast for the period between 2014 to 2020

Barqi Tojik informed about the load forecast in the area for the years 2014 to 2020.

The data provided are displayed in the following figure:

Figure 4-2 Load forecast for Penjikent EN (2014 to 2020)



4.2 Proposal for design and line routing

4.2.1 Location

Route Description

The newly to be constructed 220 kV single circuit line from Rudaki (Penjikent) to Ayni is running south- eastwards from Rudaki Substation parallel to two out of operation 220 kV lines to Uzbekistan up to the village of Chorvodor where all three lines will turn more to the south to run through a gap between Chorvodor and Yalokdzhar to reach the southern side of the road from Penjikent to Samarkand (Uzbekistan).

From there the line continues in open areas to the south and finally to the east. The line route passes north south of Zebon, Shurcha and Sabr, keeping a distance of approximately 8.5 km to the middle of the runway of Penjikent Airport and south of Kushtappa towards the east near to Gusar going around the agricultural area up to Navabad. From Navabad the line is running south of Dashthikazy and crossing the access road to a Tajik-Chinese Gold Mining Company.
In this section the line should run parallel but south to the existing 110 kV line from Ayni to Penjikent and continues by crossing a valley to reach the southern border of Koshana.

From Koshana the line runs further on the top of the hills to come down again south of the village of Uata.

From Uata the line is crossing two ridges of hills and continues on the hills bypassing Yavan and following a track to reach the main road Ayni – Penjikent. In this region the line is following this road for approx. 10 km where it again meets the existing 110 kV line.

The new 220 kV line will be kept always south of the existing 110 kV line to avoid un-necessary crossings. The line will be kept at the southern side of the river opposite side of Vishkent crossing two hills up to Khayrabat.

From Khayrabat the route will be located again on the ridge of hills until it reaches Dardar.

The route is going around of the southern edges of Zerabad up the hills to avoid unstable soil condition (landslides) through a valley and again uphill to come down to the Ayni – Panjikent road, which is just under reconstruction, and reaches after approx. 500 m the Substation Ayni 220 kV.

Detailed maps about the recommended route are attached in the annexes.

Protected areas

There are two Nature Reserves (IUCN Category IV) and one Important Bird Area located in the investigation area.

The Zerafshansky Nature Reserve is located north of the river Zeravshan and the city of Penjikent. This natural reserve is located in certain distance from the OHL and the project area.

The IBA Sarazm is located north of the SS Rudaki at both sides of the river.

The Saivatinsky (Soy Vota) Natural Reserve is located in a south east direction of the village Uata. The northern border of reserve area is extended close to the banks of the river Zeravshan.

In collaboration with the responsible persons from the Forest Department in Ayni, with participation of a representative of ADB and the Consultant the border of the reserve have been identified during a field trip in the related OHL section (irrigation channel) and the final tower positions have been defined so that a crossing of the reserve with the OHL is avoided.

Special efforts have been undertaken to obtain a detailed map of the reserve and to align the routing of the OHL at the border of this reserve (please refer to the annex).

Assessment of alternative routes

In the last section starting from SS Ayni 220 kV the 110 kV line is located in the narrow valley areas directly beside the road and the steep slope going down to the river. There is no possibility to bundle the route with the new 220 kV line. Furthermore where the 110 kV is running north of the river this line is crossing many residential areas, which should be avoided by the new line. When the 110 kV line was routed on the south side of the river a parallel routing was preferred.

At Penjikent the 110 kV line is running through the city to reach the Substation Rudaki and thereby crossing many houses.
This was the reason that the new line is first leaving Penjikent to the west to turn later to the east, towards Ayni.

In the Rudaki SS the existing feeder of the old 220kV line to Sogdiana (Uzbekistan) will be used for the new line to SS Ayni 220 kV. The new line will run in the first section westwards to go parallel to the existing old 220kV lines to Uzbekistan to avoid any house crossing before the line route turns to the east towards Ayni.

At Ayni SS the outgoing line towards Rudaki SS can be done in the following ways:

1. The connection from the existing free gantry to the Terminal tower at the south-west side of the substation area can be done by 220kV cable to cross under the incoming line from Khujand.

   This solution requires two sets of steel construction to accommodate the three cable sealing ends and surge arresters at the terminal tower side and at the gantry side inside the substation plus approx. 3 x 150m of 220kV cable.

   The steel construction with the cable sealing ends and the surge arresters under the terminal tower which is located outside the substation area should be fenced-in for safety reasons.

2. The connection from the free gantry can be done by using two 90 degree angle towers crossing over the slack span of the incoming line from Khujand.

   This solution requires two special terminal towers with full tension on both sides with an angle of 90° and the three cross-arm only on one side, one above the other.

   In this solution it is required to perform construction work above the line in operation.

3. A further solution is to reroute the existing 220 OHL a certain distance and approach the SS with a newly constructed Terminal Tower located according to the currently empty gantry. For the realization of this solution the power supply will be interrupted for a certain period of time for the complete Penjikent Electrical Network. This fact disqualifies the solution for further consideration.

The advantages and disadvantages of both solutions have been discussed between Barqi Tojik and the Consultant. Barqi Tojik advised at the presentation of the draft design that the design shall consider the two 90 degree angle towers.

In order to avoid any line crossings at the substation surroundings the Consultant recommends basing the design on a cable connection.

A layout drawing of the substation is attached in the annexes.

4.2.2 Line Design

The Bidder can offer either newly designed towers or the standard PUE towers. The Client will regard either approach as technically equal. The design of new towers may enable savings on steel, while application of existing PUE towers will represent savings in design and testing of tower prototypes.

Most of transmission lines existing in Tajikistan were designed and erected in accordance to the Former Soviet Union Energetiki & Elektrifikatii Ministry Norms named PUE - PRAVILA USTROISTVA ELECTROUSTANOVOK.

PUE standards define the wind pressures and ice loading on line elements based on a defined return period time for all the territory of the former Soviet Union. There are seven meteorological wind areas and five ice accumulation areas (Annex).

In these specifications we have used recent climatic data to specify wind and ice zones applicable to this entire project.

The standard PUE foundations are then selected to suit the specific soil capacity and tower type, or they can be designed after development of maximum foundation loads acting from particular type of the PUE tower.

The advantage of using PUE standard towers is that there is no need for structural design of towers nor testing of tower prototypes.

The design of a new family of towers shall be in accordance with current EN 50341-1:2012 standard. The newly designed family of towers would provide better allocation of angle (tension) towers, lighter design adjusted to current climatic loadings and better usage of material (limit states design, probabilistic determination of climatic loadings). The new design of towers comprises of structural design, detailing and includes testing of towers.

If the new transmission line (220 kV) is designed in conformance with PUE, the following climatic zones shall be applied:

Wind Zone: 4 (wind speed 36 m/sec, 2 sec gust, once in 15 years) Ice Zone: 2 (ice thickness of 5 mm, once in 5 years)

In accordance with PUE, conductors, earth-wires, insulator strings, fittings, towers and their foundations were standardized for each nominal voltage level. The rated voltage of 220 kV shall be observed for the project.

If the Bidder offers newly designed towers, the European Standard EN 50341-1:2012 “Overhead electrical lines exceeding AC 45kV” with the approach of Part 1 “ General requirements – Common specifications” shall be applied for the design of all main components of the 220 kV transmission lines.

The design method to be applied for the design of towers, foundations and line equipment is based on the limit state approach.

The advantage of new towers design shall be an economical design optimized for deviation angles, altitude, average height of conductors and statistically adjusted climatic loading based on meteorological record.

The Contractor’s own investigation, calculations and studies for an optimized line design as per actual project conditions and these technical specifications are required.

4.2.2.1 Particular Design Parameters

The following special site conditions shall be considered for the design.

4.2.2.1.1 Electrical System Data

Nominal voltage U_n		**220 kV**
Maximum operating voltage U_s		245 kV
Power frequency		50 Hz
Basic insulation level design BIL (lightning impulse)		1050 kV_{peak}
Switching impulse withstand voltage phase - earth		460 $kV_{r.m.s.}$

Ratio of switching over-voltage phase- to-phase and phase to ground		1.5
System highest 1-phase short-circuit current level (1s)		25 kA
Short circuit current for thermal stability check of the OPGW (1s)		6 kA
Conductor type		ACSR 400sqmm ("Zebra")
Number of conductors per phase		1
Transmission Capacity of the Line (thermal)		300 MVA
Number and type of ground-wires		1 OPGW Steel 70mm^2
Design creepage distance for medium pollution as per IEC 60815		31mm/kV (U_S)
Altitude above sea level		900 – 2.000 m

Particular wind and ice data derived from the climatic records is presented in further schedules.

4.2.2.1.2 Climatic Conditions

General Description

The northern area of Tajikistan in which the transmission line is located is characterized by dry climate. The precipitation from November to March is not more than 100-200 mm in most of the area (in plains) and can reach 400 mm and more in more hilly areas. The precipitation consists mainly of rain and wet snow.

Due to mild winter climate in the plains, rarely solid snow cover builds up. The biggest average height of snow cover is less than 10 cm and melts down quickly. The period from June to October is the driest.

Snowfall occurs mostly between mid of December and to mid of February, rainfall from March to mid of May. The annual accumulated duration of sunshine is between 2,800 to 3,000 hours.[6]

4.2.2.1.3 Site Conditions

[6] See Initial Environmental Investigation, ADB, February 2010

	Unit	
Maximum ambient air temperature SS Ayni SS Rudaki	°C	 +40 +40
Minimum ambient air temperature SS Ayni SS Rudaki	°C	 -26 -15
Average yearly ambient air temperature SS Ayni SS Rudaki	°C	 11.4 12.4
Humidity, max SS Ayni SS Rudaki	%	 50 60
Altitude of site above sea level SS Ayni SS Rudaki	m	 1400 940
Wind, maximum SS Ayni SS Rudaki	m/s	29
No. of days with lightning per year	days	20
Earth quake design: Vertical acceleration Horizontal acceleration	 g g	 0.20 0.25

4.2.2.1.4 Geological Conditions

Soil profiles encountered in the project area are typically sierozem (grey desert soil) and light sierozem, loamy sands, conglomerates and loess with gypsum inclusions, gravels. The humus layer is insignificant and is not present below the root system. The soil quality is low in organic matters. The right of way for the transmission line is mainly represented by sandstone, conglomerates, gypsum, and clay rocks. Consequently the geological and seismic features within and around the right of way are completely suitable for the construction of the TL.

Ground water levels in the northern area are at depths ranging from 5-100 m. As the transmission line mostly is running on elevated ground of about 100 – 200 m higher than the Kayrakkum Reservoir and due to the high layers of very permeable soils, the groundwater table can be assume to be deeper than 10 m.

A normative map of seismic zoning was compiled in 1978 by A.M. Babayev, T.A. Kinyapina, K.M. Mirzoev, R.S. Mikhailova and G.V. Koshlakov under the guidance of S.Kh. Negmatullaev. The map shows three major seismic zones in Tajikistan with 7, 8 and 9 points seismic intensity of MSK-64. In each of these zones earthquake at mentioned level are possible. The northern transmission line and substations are located in one of the rather less-dangerous seismic areas where earthquake intensity likely will not exceed 8 points.[7]

4.2.3 Preliminary Line Routing

In determination of the preliminary route we have used the following documents:

- Geo-referenced satellite images, commercially available;
- Field survey reports and photographs.

The proposed line routes are presented in the annexes. This map is originated through digitalization of geo-referenced topographic maps, and can be presented in a different scale or in other projection system, if necessary.

WGS 84 coordinates (World Geodetic System 1984) is used for the horizontal datum (X and Y) and Mean Sea Level of the Baltic Sea for the elevations (vertical datum Z). The projection is Universal Transversal Mercator (UTM).

The lists of angle point coordinates in the UTM/WG84 system, along with section lengths and line deviation angles are presented in the annexes.

The detailed geodetic survey of the proposed route corridor will be required, in order to finalize the line design.

The accuracy of the measurements and the precision of representation can be estimated at +/-2.5 m. This precision is sufficient to locate the proposed angle points on the spot and to follow the line route between such points.

4.2.4 Line Routing and Survey

Following the proposed line route and in order to finalize the line design the Contractor at a later stage of the project shall carry out his own detailed line survey,

The Contractor may also propose his own route optimization, and submit it for approval by the Client/Engineer.

During the survey the Contractor shall also verify the location of the existing services like water mains, gas pipelines, telecommunication equipment or electricity distribution lines in the vicinity of the line.

The Contractor shall ensure that no induced voltages or any other interferences or hazards affect the proposed line. In the event of complications within the proposed line route corridor, the Contractor shall propose a technical solution and submit it for approval by the Client/Engineer

In conducting the detailed line design, the following guiding principles need to be observed:

[7] See Initial Environmental Investigation, ADB, February 2010

- Avoid or minimize crossings over other high voltage lines, main roads and railways. The crossing angles need to be as close to perpendicularity as possible;
- River/ channel crossings to be located at suitable positions;
- Access to tower locations, and in particular to angle towers need to enable supply and installation of conductor drums and stringing equipment;
- The construction access plan should also provide for future maintenance and operation access;
- Diligent and considerate approach to main environmental aspects is required;
- Minimize the eventual impact (physical and financial) of construction activities to properties;
- Avoid zones prone to erosion - flash flood areas, intermittent water courses, river banks etc.

Final detail drawings of the line route shall be submitted to the Client/Engineer for approval.

Line Profiles

Unless specified otherwise, the scale of the line profile shall be:

1:2000 horizontally
1:500 vertically.

4.2.5 Line Route Approval

The Contractor shall submit to Client/Engineer, for review and approval the following:

- Route maps and profile plans;
- Tower lists and the proposed tower locations precisely presented in order to facilitate identification of the concerned landowners;
- Clearance reports demonstrating that clearance requirements are met for all the crossings;
- A map showing all access roads, work areas and storage yards necessary for the construction works.

The negotiations with the landowners and authorities concerning the tower locations, the right of way, the access to the line for the construction works and the compensation for land acquisition, for crops, temporary damages etc. shall be in the responsibility of the Employer.

During the approval procedure by the authorities and negotiations with landowners, tower locations may be shifted again or the line route may need to be realigned. The Contractor shall consider such changes after surveying the modified line route in order to accommodate them into revised line design.

No extra cost for survey and preparation of revised drawings of such route alterations will be paid to the Contractor.

4.2.6 Towers

4.2.6.1 General Instructions

These technical requirements cover:

- PUE towers: Manufacture, pre-assembly, inspection and packing; copies of type test certificates shall be attached to the Offer.
- New towers design: Design, work shop detail drawings, manufacture, pre-assembly, type testing, inspection and packing.

All materials, design, details, fabrication and tests shall be in compliance with the requirements described hereafter, details shown on the drawings and in accordance with design parameters specified in Technical Data Sheets.

Eventual alterations and deviations (during project implementation) shall be approved by Client/Engineer, in accordance with Approval Procedures.

The electrical and mechanical design and details shall conform to the requirements of PUE and EN 50341-1.

If the existing tower designs (PUE) are proposed, the Contractor shall demonstrate that the structures meet the minimum electrical and mechanical requirements.

Suitable design adjustments will be considered upon submission of relevant design calculations, detailing and other supporting documentation.

4.2.6.2 Materials

All materials shall be brand-new and of the best quality for use in the conditions and the vareations in temperature and pressure that will be encountered in service without undue distortion or deterioration or the setting up of undue strains in any part that might affect the efficiency and reliability of the transmission line.

Any steel member with traces of hole filling shall not be used. Special attention shall be paid to eliminating the possibility of corrosion resulting from galvanic effects.

Materials used for the design and construction of the steelwork shall comply with the codes and standards listed below. In case of deviations, the
proposed material shall be subject to Client's/Engineer's approval.

The materials for steel tower structure shall be as follows:

a) Rolled shapes and plates

PUE towers

- All materials shall be hot-rolled of mild steel and /or high-tensile steel and shall conform to the standards GOST (ГОСТ) 380-71, TU (ТУ) 14-1-3023-80, GOST (ГОСТ) 19281-73
- The chemical composition and mechanical properties of the grades of steel used shall be suitable for working in the project area, without zinc or paint protection.

Newly designed towers

- Shall conform to the following acceptable steel grades and qualities, in accordance with EN 10025:

  - S235J2G3
  - S235J2G4
  - S275J2G3
  - S275J2G4
  - S355J2G3
  - S355J2G4

- the chemical composition and mechanical properties of the grades of steel used shall be suitable for application in the project area;
- • the towers will be protected by zinc coating.
- the chemical composition and mechanical properties of the grades of steel used shall be suitable for application in the project area;
- the towers will be protected by zinc coating.

Unless agreed to the contrary the following maximum Carbon Equivalent Values (CEV) for steel supplied in accordance with BS EN 10025 and BS EN 10210 shall not be exceeded:

Grade	
S235	0.35
S355	0.45

b) Connection bolts, nuts and washers:
c) All tower steel connection bolts, nuts and washers shall conform to ISO 898-1 and –2 or equivalent. Only the bolt classes 5.6 and/or 8.8 shall be used.
d) Locking devices
e) All tower bolt connections shall be provided with one flat washer and one spring washer.
f) Tower signs
g) Signs, consisting of aerial patrol signs, phasing signs, circuit name signs, danger signs and tower number signs shall be made of mild steel covered with enamel on both sides, or of aluminum. The thickness shall not be less than 2 mm.

Writings on signs shall be in Tajik and Russian language.

4.2.6.3 Design

4.2.6.3.1 Design Method

The design philosophy for verification of an existing design (PUE towers) and for newly designed towers shall be based on the limit state concept applied in conjunction with the partial factor method.

The probabilistic (limit states) approach to tower design loads and the concept of differentiated partial material factors, shall be applied as recommended by EN 50341-1:2012.

According to this concept the weighted resistances (Rd) of the observed OHL components shall be greater than the ultimate (factored) actions (Ed) applied to the OHL components:

$$E_d \leq R_d$$
$$E_d \rightarrow \Sigma(\gamma_F \cdot F_K) \leq R_d = R_K / \gamma_M$$

The directly calculated physical loads are increased by partial safety factors (γ_F), whereas the resistance capacities are divided by material factors (γ_M), in order to compensate for material strength uncertainties.

4.2.6.4 Tower Types

Self-supporting lattice steel towers designed for one circuit (three phases) and one OPGW (earth wire) shall be applied.

PUE Towers
In case of using the standardized PUE towers, the type of towers shall be as per Ministry of Energy and Electrification of SSSR Catalogue of unified and standardized towers (1984), and as per Technical Schedules :

220 kV:
Suspension tower: P (П) 220 (one EW peak) Tension tower: U (Y) 220

New Design as per EN50341

The functional tower types of the tower family are selected based on the line angles of the line route. For fabrication, tower testing and erection but also for spare parts keeping, three (3) tower types are specified:

- NST normal suspension tower, capable to be utilized in straight line;
- LA light angle tower for line angles of up to 30°;
- HA/ DE heavy angle tower for line angles of 30° to 60° and dead-end tower for 0 to 10° angle in line direction and 0° to 45° angle of the slack span to the gantry.

For the DE tower the indicated angles refer to one side of the tower while for angle towers the angles given are actual line angles (i.e. line deviation angle at both sides).
Tower Outlines

The outlines of the suspension and angle towers shall comply with the general requirements as specified and shown in the annexes. They shall meet the required minimum clearances between conductors, live parts, tower steelwork and the ground and obstacles.

PUE Towers
As per above referenced catalogue

New EN50341 Towers

220 kV - single circuit towers are of the “Triangle” type, with phases arranged in two levels. Two phases in one level and one phase above. The tower outline is shown in the annexes.

4.2.6.5 Design Spans

PUE Towers

The table below shows the Catalogue spans tabulated for wind region 4 (Raion IV) and ice region 2:

Voltage: 220 kV SC Tower type		Line angle [°]	Nom. span [m]	Wind span [m]	Weight span (max/min) [m]
Suspension	P (П)220	0	440	470	550/-150
Tension	U (Y)220	0 - 60	440	470	550/-150

New EN50341 Towers

The following 220 kV single circuit tower types are specified:

Tower type	Line Angle [°]	Nominal Span [m]	Wind Span [m]	Weight Span (max/min) [m]	Max. Span [m]
Normal suspension (NST)	0	400	520	545/150	600
Light angle (LAT)	0-30	400	520	750/-250	640
Medium angle (HAT) and Terminal (DET)	30-60 (0-90)[1]	400 360	520 360	750/-250	640

1) angle between incoming span and slack span to S/S gantry

Special towers have also to be designed for 90 degree angle having all three cross-arms at one side in vertical configuration.

4.2.6.6 Tower body and leg extensions

PUE Towers

220 kV
Suspension Towers P220
Body extensions as per catalogue: +5m, +10m,

Angle Towers U220
Body extensions as per catalogue: +5m, +9m, +14m

The towers are connected to foundations via base plates and four anchor bolts embedded

in foundations.
New EN50341 Towers
(220 kV)

Suspension Towers (NST):
Body Extensions: -3 m; ±0 m
standard tower height, +3 m; +6m; +9m; +12m

Angle Towers (LA, HA, DE):
Body extensions : -3 m, ±0 m
standard tower height, +3 m; +6m; +9m

Leg Extensions:
±0 m (standard leg), -2m; -1m; +1m; +2m

Tower stub angle connection to foundations shall be applied. The stub angles shall be quoted at foundation part.

4.2.6.7 Spacing and clearances

Generally, minimum air clearances shall be determined in accordance with
Section 5 of EN50341-1:2012 - Electrical requirements.

Internal Clearances

The positioning of the conductors and of the OPGW on the tower shall be determined considering the following minimum clearance conditions

a) in-span between phases and between phase and earth wire (OPGW), in still air;
b) between live parts (jumpers, conductors, earth wire) and the earthed parts of the support;
c) the earth wire shielding angle (as tower top geometry parameter);

The following formulas and distances shall be applied for the most unfavorable conditions. Load cases for calculation of clearances shall be as per Section 5.6 of EN 50341-1:2012

a)In-span clearance between phases and between phase and earth wire / OPGW (maximum conductor temperature, still air)

The phase to phase distance:
a) In-span clearance between phases and between phase and earth wire / OPGW (maximum conductor temperature, still air)

The phase to phase distance:

horizontal phase disposition is in [m]

The phase to phase distance:

horizontal phase disposition is in [m]

$$c = k\sqrt{fmax + li + 0{,}75Dpp} + 0{,}40$$

vertical phase disposition

$$c = k\sqrt{fmax + li + 0{,}75Dpp}$$

Phase to OPGW distance

$$c = k\sqrt{fmax + li + 0{,}75Del}$$

where:
k: factor according to EN 50341-3-4, Table 5.4.3/DE.2:
k=0.75 for vertical distance k=0.62 for horizontal distance)
li length of swinging suspension insulator set [m]
fmax maximum sag of the longest span [m]

Dpp min. phase-phase clearance; for 220kV lines = 2.00m
Del min. phase-earth clearance; for 220kV lines = 1.70m

The maximum and minimum conductor sag shall be calculated for maximum and minimum conductor temperatures, in still air.

The sag calculations shall be based on the assumption that the conductor elongation due to long time creep (10 years) shall be compensated through increase of initial tension and subsequent conductor tension adjustments.

The dimensions of the cross-arms of the tension towers shall be such to ensure that horizontal spacing between conductors in a plain perpendicular to the conductors are not less than that at normal suspension towers.

The earth wire support positions have to ensure the corresponding spacing between earth wires as well as the assumed shielding angle.

The phase-to-phase and phase-to-earth wire in-span clearances determine the maximum span of the respective tower.

The maximum span limited by two different tower types is the average of the maximum spans of the two towers.

b) Clearance between live parts and earthed tower steelwork

The clearances between live and earthed parts have to be considered separately for different clearance cases and swing angles corresponding to the three voltage stress types (lightning, switching and power frequency), as per the table below:

		Minimum

Clearance in still air*		1.70
Clearance under moderate wind** (3 year return period)		1.28
Clearance under maximum wind (50 year return period)***		0.43

* between live parts of lateral phases, to cross-arms and tower body, determined by lightning over-voltages, for:

- "I" suspension sets, under 10° swing
- jumper loops, under 10° swing

**between live parts and any tower steelwork or earth wires, under swing due to moderate (3-year) wind (58% of the pressure of the maximum mean wind),:
- "I"-jumper suspension sets under 20° swing
- Jumper loops under 0-20°swing

*** between live parts and any tower steelwork or earth wire, insulator swing due to maximum (maximum 10 minutes average wind) design wind, determined by power frequency voltages, for:
- "I"-jumper suspension sets under 35° swing
- jumper loops under 35° swing.

Conductors down drop, calculated for a conductor drop angle of 20o, shall be considered in all Clearance Cases defined above.

For the "I"-type suspension insulator set, the ratio of weight to wind span is to be considered with 0.65 for swing under moderate and full design wind.

The angle of deflection of the insulator string shall be calculated with:

$$\alpha = \text{atan}\ (0.58\ (Qwc + 0.5Qwi) / r\ (Wc + 0.5Wi))$$

where:

0.58 reduced wind pressure coefficient (3-year return) according to EN50341-1
QWc Force acting on insulator, due to maximum mean (10 min average) wind acting on conductor, developed in accordance with EN 50341-1
r ratio weight to wind span wind force on insulator set
Wc weight of the conductor, over nominal wind span
Wi weight of the insulator set
c) Earthwire protection angle

A protection angle of the OPGW of 30° shall be considered.
The sag of the OPGW under every day temperature (+15°C) shall be 10% less than the sag of conductor for the basic span of 400m.

External Clearances:

External clearances are generally determined in accordance with Section 5.9 of EN 50341-

1, and they impose minimum allowable distances to ground, vegetation, roads, other power lines and telecommunication lines and recreational areas.

Loading cases to be observed are:

- Maximum conductor temperature;
- Nominal wind load.

Clearance Case		Minimum clearance 220 kV [m]
To ground in unobstructed countryside normal ground profile rockface or steep slope		6.7 3.7
Vegetation under the line (vertical) Vegetation beside the line (horizontal) Trees under the line (vertical) Trees beside the line (horizontal)		1.7 1.7 3.2 3.2
Residential and other buildings Line above buildings (vertical dist) Line adjacent to buildings (horiz. dist.)		 7.0 5.0
Antennas, street lamps, flag poles, signs, other urban obstacles		3.7
Roads Crossings (vertical) to road surface Adjacent to roads (horizontal)		8.0 4.0
Power lines or telecommunication lines Crossing of lines (vertical dist.) Adjacent to lines (horizontal		 2.0 1.7
Playgrounds, sports areas		10.5

Loading Cases

The loading cases to be considered for the design of the line supports and of their foundations are normal working cases and exceptional cases, as follows:

a) Normal working cases (N):
- transverse wind, no ice (N1)
- oblique (at 45°) wind, no ice (N2)
- longitudinal wind, no ice (N3) – suspension towers only
- ice load with reduced transverse wind (N4)
- ice load with reduced oblique (at 45°) wind (N5)
- ice load with reduced longitudinal wind (N6) – suspension towers only
- ice load, no wind, unbalanced conductor tensions (N7)

b) Exceptional loading cases (E):

- broken wire cases (E1)
- cascading (E2)
- erection and maintenance (E3).

Table Overview of Tower Load Cases:

Structure Type	**Normal Working Load Cases**			**Exceptional Loading Cases**		
				Broken Wires	**Cascading**	**Erection, Stringing and Maintenance**
	N1, N2, N3	**N4, N5, N6**	**N7**	**E1**	**E2**	**E3**
	Design factors for steel sections, profiles and plates			Safety factors for steel sections, profiles and plates		
	overal design factor = 1.65, (i.e. load factor of 1.5 x material factor of 1.1)			overall design factor = 1.21, (i.e. load factor of 1.1 x material factor of 1.1)		1.5 for vareable loads 2.0 for dynamic loads
Suspension Towers	• Deadweights • Wind on tower, accessories and conductors (longitudinal wind on conductor shall be assumed to be 10% of transverse wind on conductor)	• Deadweights • Ice loads • Reduced wind on tower, accessories and iced conductors (longitudinal wind on conductor shall be assumed to be 10% of transverse wind on conductor)		• Deadweights • Ice loads • one sided alleviation of conductor or earthwire tension (both under wind and ice load condition) by 33% for phase conductor and 50% for OPGW / EW acting at any one attachment point	• Deadweights • Ice loads • one sided reduction of conductor or earthwire tensions (both under wind and ice load condition) by 15% for phase conductors and 40% for OPGW / EW acting at all attachment points simultaneously	• Deadweights • Erection and maintenance loads • a) No wind, conductor tension for min. temperature b) 50% of max. wind on tower, accessories and conductors, conductor tensions accordingly, without man-load • All structural members supporting a lineman (horizontal angle up to 30°), able to support 1.0 kN applied vertically at their midpoint • 3 kN additional load on any one crossarm bottom chord member
Angle Tension Towers	(N1 and N2 only) • Deadweights • Wind on tower, accessories and conductors • Conductor tensions under wind load condition	(N4 and N5 only) • Deadweights • Ice loads • Reduced wind on tower, accessories and iced conductors • Conductor tensions under wind and ice load condition	• Deadweights • Ice loads • 2/3 of conductor tensions under wind and ice load condition acting at all attachment points simultaneously at one side only	• Deadweights • Ice loads • one sided reduction of conductor or OPGW / EW tension (both under wind and ice load condition) by 100% acting at any one attachment point		
Dead End Towers	• Deadweights • Wind on tower, accessories and conductors • Conductor tensions under wind load condition acting on one side	• Deadweights • Ice loads • Reduced wind on tower, accessories and conductors • Conductor tensions under wind and ice load condition acting on one side		• Deadweights • Ice loads • reduction of conductor or OPGW / EW tension (both under wind and ice load condition) by 100% acting at any one attachment point		

Normal Working Load Cases (N1 to N6)
The load assumptions as specified above shall take into consideration the maximum transverse wind hypothesis and the maximum oblique (45°) wind hypothesis without and with iced conductors. The maximum longitudinal wind hypothesis shall be considered for suspension towers only. Then 10% of the value of wind transverse on conductor shall be applied for wind longitudinal on conductor.

Normal Working Load Case (N7)
This load case is a combined load hypothesis for making the towers stronger in longitudinal direction (to resist cascading) and is applied to the angle towers only.

Broken Wire Loads (E1)
Design spans for the broken phase conductor or the broken OPGW as well as for the other intact conductors apply the design spans specified.

The one sided reduced conductor tension refers to the complete conductor.

Cascading (E2)
Suspension tower capability is controlled by exceptional load cases E2 in order to prevent extended cascading in case of tower failures. Such unequal conductor tensions may result from unequal ice loading or from unequal spans in the line sections.

Erection, Stringing and Maintenance Loads (E3)
All stages during conductor installation shall be described. The configuration of the back stays has to be taken into account. The Contractor has to define the load cases for stringing work based on his stringing methodology and anticipated locations of stringing equipment. Ambient conditions: erection under minimum temperatures, interrupted erection under 50% of maximum wind conditions.

Partial Safety Factors
The following partial factors for actions shall be applied to the different loads within the respective load cases (see Technical Data Schedules):

Effect	Safety factor	Load cases (N1 ... N7)	Load cases (E1 ... E2)	Load case (E3)
Deadweight*	γ_G	1.0	1.0	1.0
Wind	γ_W	1.5	1.1	1.1
Ice	γ_I	1.5	1.1	1.1
Conductor tension	γ_C	1.5	1.1	1.1
Construction/ maintenance, vareable loads	γ_P			1.5
C&M Loads, stringing, dynamic loads	γ_s			2.0

For compression loading cases, the partial safety factor for the tower dead weight is to be considered 1.1. In case of uplift loads for cross-arms and foundations, this factor shall be taken as 1.0.

Minimum thickness and size of steel members
The minimum thickness (t) and size of steel members of towers shall be as follows:

All other members having computed stresses	5 mm
Redundant members without computed stresses	4 mm
Gusset plates	5 mm
Minimum flange width of an angle	45 mm

Minimum and maximum spacing of bolts, end and edge distances shall be in accordance with Section 3.5 of EN 1993-1-8:2005.

Tower structures
The tower model shall be a fully triangulated system and the tower body slope (taper) shall not exceed 300 mm / m.

Stubs suitable for the foundation types and for legs of the tower types are part of the scope.

In order to facilitate transportation and handling, the length of any structural member shall not exceed 9 meters.

For the towers having line deviation angles of 60°, rectangular cross-arms may be used so that live metal clearances are maintained with or without the use of jumper suspension insulator strings.

The cross-arms of suspension towers shall be designed to allow the attachment of double insulator strings. Additionally for the Employer's use during maintenance, each suspension cross-arm tip shall incorporate two attachment points of equal strength at approved positions: one for the suspension insulator set and the other for maintenance equipment.

Bolt spacing and edge distance, in mm, for new EN50341 towers, shall be:

Nominal Bolt Diameter	**Bolt Spacing**		**Minimum Edge Distance**	
	Min.	Max.	Rolled Edge	Sheared Edge
16	40	160	22	25
20	50	200	27	30
24	60	240	32	40

Step bolts
Each tower shall be provided with step bolts of an approved type on two diagonally opposite legs spaced alternately on the angle flanges at not more than 380 mm between centers, starting immediately above the foundation cap and continue to the earth wire. The minimum diameter of the step bolts shall be 16 mm. Step bolts shall not be used as connection bolts.

The step bolts up to 3,00m height shall be removed and only installed during erection and maintenance.

Attachment devices
Attachment devices shall be suitably furnished on all cross-arms to suspend and to terminate insulator strings or earth wire assemblies. The attachment points shall be designed in accordance with the requirements of this technical requirements and the calculation shall be submitted together with the structural analysis of the tower.

Tower signs

The Contractor shall furnish all materials for tower signs including all bolts, nuts, washers, brass eyelets fitted with the holes and supporting structures, if required, for attaching signs to the structure as per the structure list.

The design of sign plates (colors of figures and background) shall be as described below or as will be indicated later by the Employer and shall be of corrosion resistant aluminium or enameled mild steel, with painted, embossed letters.

Circuit designation plates
Circuit designation plates shall show the circuit abbreviation and number in black letters, on a white background. The figures height shall be 150mm.

Circuit designation plates shall be installed under each circuit, about three meters from ground level and above anti-climbing guards and shall be provided at every tower.

Phase plates (A, B and C)
Phase plates shall show the letters “R”, “S” and “T”, in black color, on red, yellow and blue background, respectively. One set of three phase plates shall be installed under each circuit, about three meters from the ground level and above the anti-climbing guards and shall be provided at angle and dead end towers.

Danger plates
Danger plates (2 Nos.) shall feature red symbols on a white background.
The warning symbol shall be provided by the Client, or alternatively proposed by the Contractor

The text “DANGER” shall be boldly written in the Tajik and in Russian language. The voltage shall be shown, as well. Danger plates shall be attached about three meters from ground level and above the anti-climbing guards, at every tower.

Number plate
The tower number plate (1 No.) shall show the tower number in black letters, on a white background. The figures height shall be 150mm. The number plate shall be attached about three meters from ground level and above anti-climbing guards and be provided at every tower.

4.2.6.8 Corrosion protection

General

All steel structures shall be protected against corrosion by hot dip galvanizing as per EN ISO 1461.

Galvanizing

All defects of the steel surface including cracks, surface laminations, laps and folds shall be removed. All drilling, cutting, welding, forming and final fabrication of unit members and assemblies shall be completed before the structures are galvanized.

All steelwork shall be hot dip galvanized in accordance with internationally recognized standards such as EN ISO 1461, or equivalent, providing a smooth, clean and uniform zinc coating of min 85 micrometers thickness for bars and plates and 55 micrometers for bolts and nuts. The ingot zinc used for galvanizing shall comply with the requirements of BS EN 1179.

4.2.6.9 Tower load test

General

Standard PUE towers shall not be load tested.

If the Bidder proposes other existing tower designs, type test reports of these towers shall be submitted with the Bid.

In case of a new designed tower family the following towers shall be load tested:

- The suspension tower shall be tested to destruction as described below.
- One tension tower shall be tested to ultimate design loads as described below.

Load Test

The test shall be performed in the Client's/Engineer's presence and in accordance to IEC 60652 "Loading tests on overhead towers".

The Contractor shall give the Client/Engineer notification in writing, not less than 30 days in advance, of the date when towers will be ready for test. Test program shall be subject to approval by the Client/Engineer prior to testing.

In addition to the approach of IEC 60652, the following requirements shall be observed:

- The test loads shall be the design loads multiplied by the corresponding partial safety factors and by the material factor for steel member sections.
- The Contractor shall submit for approval diagrams showing the proposed methods of applying loads and deflection measuring.
- The Contractor shall program the tests for the decisive load cases in order to most favorably demonstrate that the towers will carry all design loads and conditions specified in the loading diagrams.
- Each load increment shall be maintained for not less than two minutes except that under full design load, the period of five minutes shall be maintained and during this time there shall be no slacking off or adjustment of the loads. Should it become necessary to adjust the loading, the two or five minutes period shall start after the loading is stabilized and constant.
- Load Cell Calibration shall be carried out before and after each test or series of tests in the presence of the Client/Engineer.
- After the successful completion of the load tests, the tower shall be further tested to destruction by increasing the horizontal loads only for a given loading case, as specified/approved by the Client/Engineer. The load increment shall not exceed 5% of the full design loads. Each load increment shall be held at least five minutes while deflec-

tions are being recorded.

- • The expenses associated with re-design and re-test due to a defect in the
- Contractor's work shall be borne by the Contractor.

4.2.6.10 Foundations

4.2.6.10.1 General

The Contractor shall select and propose up-to-date methods and equipment to ensure that the design and construction of foundations will be in accordance with relevant internationally recognized standards.

The construction work referred hereto shall be performed in such a manner that the high quality standards and required function as detailed below are achieved. Special attention shall also be paid to the aspects which are specific to the route of the overhead line, its local climate and specific geology.

The works shall be designed and executed with due regard to the need for inspection, cleaning and repair works, and service for prolonged periods of operation requiring minimum of inspection, adjustment and repair works.

All materials shall be new and of the best quality, suitable for working under the climatic conditions without undue distortion or deterioration or the occurrence of undue stresses in any part, such as to affect stability, safety as well as the efficiency and reliability of the works.

The Contractor shall take full responsibility for:

- the use of the most suitable materials
- appropriate design
- competent workmanship
- full serviceability in unrestricted continuous operation
- • observation of the technical requirements.

4.2.6.10.2 Foundations

PUE Towers

Standard PUE foundations (pre-cast or cast in-situ), selected for appropriate soil bearing capacity, are acceptable. Otherwise, the maximum foundation forces for particular tower types shall be developed and foundations designed accordingly.

The legs of towers shall be fabricated in accordance to PUE and equipped with end connection plates, provided with four holes to be fixed and leveled on foundations by anchor bolts cast in foundation.

Depending on compression, tension and horizontal loads, the type of the connection between tower and foundation is:

- a direct connection, tower base-plate-to-concrete
- an intermediate connection, tower base-plate to intermediate steel piece (arrangement).

In case of direct connection, the load from tower leg is transmitted in the foundation column by four anchor bolts. The anchor bolts shall be welded to steel reinforcement bars and embedded into the concrete adequately.
In case of intermediate connection, the load from tower leg is transmitted in the foundation column by four bolts and a metallic structure embedded into foundation concrete and welded to reinforcement bars.

Both solutions are acceptable.

Both "pre-cast" or "concrete in-situ" foundation types are accepted. The proposed foundations type shall be submitted to Client/Engineer for review and approval.
New EN50341 Towers
Tower stubs shall be used for the connection between tower and foundations.

The loads are transmitted into foundation by stub-foundation friction and by cleats. The cleats shall be designed to transfer 50% of full leg loads.

Avalanche Protectors
Where the tower location may be exposed to avalanches, the foundation shall be protected by v-formed avalanche protectors, at least not less than 25 m³ of concrete each.

4.2.6.11 Soil investigations

4.2.6.11.1 General

The Contractor shall ascertain in an early stage of the works at his own cost, that the foundation types to be used are suitable for the soil conditions encountered at each tower location.

The Employer will provide the results of a soil investigation which has already been performed for the proposed line route. The contractor shall verify these results. He shall carry out additional detailed soil investigations along the line route if necessary for planning of the foundations. The extent of the investigations shall be such as to permit the satisfactory determination of all necessary sub-soil characteristics, to exclude any unacceptable settlement and to determine reliable type, size and execution of foundations.

The Contractor shall submit to the Client/Engineer a soil investigation report. This report is to be based on investigations at all line angle point locations and additionally, at sufficient number of locations between the angle points, depending on the terrain configuration.

It shall comprise a soil classification for all tower locations. All soil investigations have to be completed before the start of the design work. The soil investigation report shall also contain data about soil resistivity, required for the proper design of the earthing system, for each tower location.

The acceptable penetration sounding equipment is summarized in the table below:

Main Characteristic Of Equipment	SPT Standard Penetration Test	DPL Dynamic Probing Light	CPT Dutch Cone Penetrometer
Applicable standard	ASTM 1586	DIN 4094	BS 5930
Penetration force	dynamic	dynamic	static
Data reading	blows/30cm	blows/10cm	pressure/20cm
Cone diameter	Ø49-51mm	Ø34-36mm	Ø35-36mm
Sectional area	hollow 20cm²	solid 10cm²	solid 10cm²
Point angle	40°/180°	90°	60°
Drop weight	63-64 kg	9.9-10.1 kg	accuracy ≤ 5 % of reading
Fall height	74-78cm	49-51cm	
Penetration rate	20-40 blows/min.	15-30 blows/min.	1,5-2,5 cm/sec.
Drill rod deviation	bend ≤ 0,1 % and plumb ≤ 2 % of drill rod length		

In-situ testing shall comply with the following requirements:

- Non-cohesive soils (granular, sandy, silty sand):
- SPT
- CPT
- PMT (pressure meter test), in the absence of large gravel particles.
- Cohesive soil: as for non cohesive soils except that use of SPTs is subject to the Client's /Engineer’s approval. Vane shear tests (VSTs) may also be used in fairly uniform, fully saturated soils;
- Weak rock - SPT
- Medium to hard rock - PMT;
- Hard rock - drilling; laboratory examination of samples.

Where it is proposed to determine the soil classification indirectly from the in-situ tests e.g. CPTs, cross correlation shall be undertaken at specified intervals using auger borings.

For all soil investigation locations, the contractor shall give clear information, in addition to results of subsurface investigation (drilled boreholes), about the following local conditions:

- Soil condition at the surface;
- Terrain gradient (slope) estimate, in vicinity of the planned foundations;
- Direction and inclination of cracks and fissures in the rock and their stratification; assessment of the global stability;
- Relevant inclination of the ground surface in the vicinity of the planned tower foundation if sliding or rolling stones may affect the selected locations;
- Flooding or scouring action in the area of foundations;
- Groundwater levels at tower sites. Available data on maximum groundwater levels shall be sought after.

For all soil investigation locations of the transmission line including gantries, the following is to be carried out:

- Boreholes down to minimum 3.0m below the intended base level of the planned block foundation or 3.0m into the bearing soil;
- • For rocky areas, the depth of drillings shall be 6.0m.

The following soil parameters shall be determined by the geotechnical laboratory:

Cohesive soil	Granular soil	Rock
State of consistency	Degree of compactness	Degree of hardness
Atterberg limits	Grain size	Metamorphic grade
Unit weight	Unit weight	Weathering state
Water content	Saturation degree	Rock defects
CPT/DPL resistance	SPT/DPL resistance	RQD core recovery
Subsoil description, texture and stratigraphic sequence		
Ground water and flood water level		
Aggressiveness of ground water and subsoil (SO^{2}_{4}, Mg^{2}, pH)		
Position and depth of pit, borehole, sounding and samples taken		
Electrical ground resistance (conductivity of in-situ soil)		

The Contractor shall name a professional soil mechanics expert and foundation engineering expert. The expert shall supervise the boring works.

Standards

Generally, the design shall be in accordance with Section 8 of EN 50341- 1:2012, and specifically:

General requirements:
EN 1997-1:2004, Sections 1 to 5
EN 1997-2:2007

Geotechnical design:
EN 1997-2:2007, Section 2

Soil investigation:
EN 1997-2:2007, Section 3

Construction:
EN 1997-2:2007, Sections 4 and 5

The tests are to be carried out in conformity with international standards, EN, DIN, BS, GOST or equivalent by an experienced institution to be named by the Contractor and approved by the Client/Engineer. Other standards are subject to the approval prior to the performance of the laboratory tests.

The following standards are important and acceptable but the list is not exhaustive, and the Contractor may propose to utilize other standards they are familiar with.

Standard	Part/Yr	Description
BS 5930		Code of Practice for Site Investigations
DIN 4021	1 (1971)	Subsoil; exploration by trial pits and borings as well as sampling; investigations in soils
	2 (1976	As above, investigations in rock
	3 (1976)	As above; investigations of groundwater
BS 1377		Method of test for soils for civil engineering purposes. Classification tests.
DIN 4022	1 (1969)	Subsoil and groundwater; designation and description

		of soil types and rocky soil; list of soil courses for testing and boring without continuous gaining of core samples
	2 (1977)	As above; list of soil courses for investigations and boring in rocky soil
DIN 4023	1975	Subsoil and water drilling; graphical presentation of results
DIN 4094	1 (1974)	Subsoil; equipment for dynamic and static subsoil soundings; dimensions of apparatus and process
	2 (1980)	Subsoil; dynamic and static penetrometer; application and evaluation of results
DIN 18196	(1970)	Earthworks; soil classification for civil engineering purposes and methods for identification of soil groups
IEEE 691	2001	Guide for Transmission Structure Foundation Design and Testing
ASTM D2488		Standard Practice for Description and Identification of Soils (Visual - Manual Procedure)

In addition, we recommend that the Contractor takes cognizance of the following standards and publications:
EC 61773
Overhead lines – Testing of foundations for structures

BS EN 1537
Execution of special geotechnical work – Ground Anchors

BS EN ISO 1461
Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods

BS EN 12620:
Aggregates for concrete

BS 4449:
Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar, coil and decoiled product. Specification

BS EN ISO 3766
Construction drawings. Simplified representation of concrete reinforcement

BS 4483
Specification for steel fabric for the reinforcement of concrete

BS EN 206-1
Concrete. Specification, performance, production and conformity

BS EN 10025:
Specification for hot rolled products of non-alloyed structural steels and their technical delivery requirements

ASTM C33:
Specification for concrete aggregates

ASTM C227:
Standard Test Method for Potential Alkali Reactivity of

EC 61773
Overhead lines – Testing of foundations for structures cement/aggregate combinations (Mortar bar method)

ASTM C289:
Standard Test Method for Potential Alkali Reactivity of Aggregates (chemical method)

CIGRE:
Special Publication No.81 Foundation Testing

4.2.6.12 Foundation design

4.2.6.12.1 General

The foundations shall be designed by the Contractor on the basis of accepted codes of practice, the relevant standards or methods which have been used with satisfactory practical experience by the Contractor, and agreed by the Client/Engineer. Generally, the design approach shall follow the recommendations of:

- EN 1997-1-1 (Eurocode 7, Geotechnical Design, Part1: General Rules)
- EN 1992-1-1 and EN 1992-3 (Eurocode 2, Design of Concrete
- Structures, Part3: Concrete Foundations)
- ASCE 10-97 Design of Latticed Steel Transmission Structures

The following standards may also be applied:

- EN 50341-3-4 (German National Normative Aspects), clause 8
- BS 8004, Code of Practice for Foundations
- EN BS 8110, Structural Use of Concrete
- EN BS 61773, OHL Testing of Foundations for Structures

The Bidder is encouraged to consult an overview of foundation design practice and common tower foundation types presented in CIGRE Recommendation 2006, August 2002.

All foundations shall be designed to withstand uplift, settlement and overturning (as appropriate) when subjected to the applied system loading. Allowances shall be made in the foundation design for hydrostatic pressure where this may occur and the effects of seasonal rains, drying out or other cyclic loading.

The tower reactions acting on the foundations shall be calculated considering appropriate maximum simultaneous loadings on the towers. Since a limit state method is used, the obtained tower reactions forces shall include the partial safety factors for the loads as indicated in the chapter 4.4

Towers, and the resultant reactions shall be used for foundation design. The partial safety factors for material are given in technical Schedules.

Any information given in this technical specification in relation to the foundation design is for bidding purpose only. For the final foundation design, the Contractor has to perform the required soil investigations and has to base his design calculations on the detailed information obtained

4.2.6.12.2 Soil classification

The geotechnical parameters for bidding purposes are provided below. The Contractor shall however use existing soil investigation results or/and perform the geotechnical investigation at each location as specified in this bidding document in order to justify the below given values. No extra payment will be made if the actual soil condition is found to be worse than the soil parameter given in these technical requirements.

Class 1
Sound rock with a permissible bearing capacity of at least 1000kN/m2.

Class 2
Weathered rock in layers with clefts filled by cohesive materials and with a permissible bearing capacity of 500 - 1000kN/m2.

Class 3
Good soil conditions:
- non-cohesive soils (sand, gravel) at least medium dense to dense (density index more than 0.5)
- well consolidated layers of sand and gravel
- very stiff silt, till or clay (consistency index at least 1.0)
- groundwater level below foundation level
- permissible soil pressure at least 300kN/m2.

Class 4
Normal soil conditions with bearing capacity of at least 200kN/m2:
- Class 4.1 no groundwater, or
- Class 4.2 with groundwater level above foundation level (possibility for submerged conditions).

Class 5
Poor soil conditions with bearing capacity of at least 100 kN/m2:
- Class 5.1 no groundwater, or
- Class 5.2 with groundwater level above foundation level (possibility for submerged conditions).

Further design parameters are provided in Sections 6.4 and 6.5, Technical Data Sheets.

4.2.6.12.3 Foundation types

Corresponding to the defined soil classifications the following foundation types (separate foundation for each tower leg) shall be designed:

a) Rock anchor foundations
Consisting of rock anchors and a reinforced concrete block directly cast against rock for soil class 1. The length of the anchor bolts or anchor profiles shall be calculated with the consideration of the following mechanical characteristics:

- the bearing capacity of the anchoring bolts or profiles
- the rupture of the adhesive power between the steel anchor and grouting material
- the rupture of the adhesive power between the grout and rock
- the failure-rupture of the rock due to shear forces.

b) Shaft foundations
An undercut reinforced concrete shaft, square or circular, deeper than 1.5 m, diameter larger than 800 mm, cast directly against firm sub-base (soils class 1, 2 and 3).

c) Pad and chimney (or pyramid) foundations
Reinforced concrete base with square, round or pyramid chimney more than 2 m deep; applicable for soil classes 3, 4 and 5.

d) Heavy pad and chimney (or pyramid) foundations
For soil class 5.2, not expected.
Schematic drawings of typical foundations are presented in the annexes. Standard PUE precast foundations are accepted for PUE towers only. The types of foundations specified herewith are suggested, but not obligatory. The Contractor is encouraged to propose alternative foundation solutions, should he assess them to be more economical and adequate for the actual soil and topographical conditions on site.

As a result of the soil investigation undertaken by the Contractor at the tower locations, other types of foundations may be required. The appropriate foundations design is within Contractor's responsibility, therefore no claims will be accepted if other types of foundations become necessary.

Any alternative foundation type proposed by the Bidder shall meet the following requirements:

- Identical or higher safety in all aspects;
- The record of previous application of the similar type of foundations, for the similar type of projects (220 kV);
- Practical feasibility of implementation of proposed construction works;
- Testing methods for the alternative proposal.

The Contractor shall submit to the Client/Engineer the calculation of each typical foundation type with the following design data:
- Maximum compression and uplift as well as horizontal loads without safety factors
- The stability of the foundations with respect to uplift, compression and horizontal loading, calculated according to the safety factors.
- The effective pressure of the soil shall not exceed the limits calculated by the Contractor on the basis of the data of the soil investigation report.

All relevant calculations and verifications thereof are to be established with the following as minimum:

- Permissible soil pressure;
- Effective foundation capacity and loading;
- Settlements (compatibility with superstructure above);
- Safety against horizontal movement (sliding);
- Stability of frustum plane against shear failure (including slope stability if applicable);
- Safety against uplift;
- Verification that actual stresses in concrete and steel are less than permissible stresses;

All foundations on slopes greater than 1:4 shall be checked for stability against rotation where appropriate. Due consideration shall be given to the increased up-slope lateral loading of the soil and the decrease in downhill resistance provided by the soil, when compared to foundations installed on level ground.

Due consideration shall also be taken of any decrease in the uplift resistance of the foundation. Where appropriate, decrease in soil bearing resistance shall also be considered.

The calculations are subject to the approval of the Client/Engineer.

4.2.7 Conductor and Optical Groundwire (OPGW)

4.2.7.1 Phase Conductor

4.2.7.1.1 Design

The principal conductor configuration shall be:
one ACSR 400sqmm (Zebra) conductors per phase, for 220 kV.

The Contractor shall carry out all works in skilled manner in compliance with modern methods of engineering, in conformance to all applicable regulations regarding the manufacture and delivery of the goods, following all instructions issued by the Client/ Engineer

The preferred conductor types (aluminum conductor steel reinforced):

220 kV:
ACSR “Zebra”, as per EN 50182 or approved similar Standard.

The steel part of conductors shall be greased. The minimum drop point of grease shall be 120°C.

Basic Conductor Characteristics:

Description “Zebra”		**220 kV**
Cross section		
Aluminium [mm^2]		428,90
Steel [mm^2]		55,60

Total [mm^2]		484,50
Stranding and wire diameter		
Aluminium [mm]		54/3,18
Steel [mm]		7 / 3,18
Overall diameter [mm]		28.62
Weight [*kg/km*]		1.621

Basic Standards

Complete conductors:

- EN 50182
- DIN VDE 48204
- BS 215 Part 2, Aluminum Conductor Steel Reinforced
- IEC 61089
- ASTM B232
- GOST 839
- GOST 5800

Components:

- aluminum wires EN 60889, IEC 889, BS 2627, ASTM B233-77
- steel wires EN 50189
- grease EN 50326
- conductor creep IEC 61395

Alternative standards or codes are subject to approval by the Client/Engineer

The conductors shall be suitable for service in the specific climate with the main characteristics as specified in technical Schedules.

The Contractor shall submit certificates of analysis giving the percentage and nature of aluminum impurities. The copper content shall not exceed 0.04%.

The outermost aluminum layer shall be stranded with a right hand lay and there shall be no joints in its individual wires.

The conductors shall be of design and construction as to ensure long service with high economy and low maintenance costs. They shall be suitable in every respect for continuous operation at nominal parameters as well as in transient operating conditions, under the climatic conditions peculiar to the Site.

Special attention shall be paid to the conductor stranding process to ensure the necessary tightness between different layers in order to avoid slippage or relative movement of strands or cage formation during stringing.

In the event of any machinery used for conductor manufacture being used for materials, other than aluminum, galvanized or aluminum clad steel, the manufacturers shall furnish the Employer with a certificate stating that the machinery has been thoroughly cleaned before use on aluminum, aluminum alloy, galvanized or aluminum clad steel wire and that the conductor is free from contamination.

Joints of the individual aluminum wires of the conductor are not permitted in the respective outermost layers and as specified in the standards. In the inner aluminum wire layer of the phase conductor, joints are permitted before final drawing. Such joints (welds) shall be made by cold-pressure butt-welding. Joints made in individual aluminum wires by resistance butt- welding shall not be permitted.

When it becomes necessary to weld the aluminum, the welding shall be done in the aluminum wire rod before it is drawn so that the welds shall be indistinguishable in the finished wire.

Welds shall not be made in the aluminum wires during stranding.

The particulars and guarantees specified in technical Schedules shall be guaranteed within the tolerances permitted by the relevant standards, this data and conditions being part of the Contract. If the guaranteed values are not achieved, the Client/Engineer may reject the said part of the goods at the Contractor's expense.

If the electrical resistance per kilometer of conductor on any drum exceeds the guaranteed resistance, the Client/Engineer may then reject any drum found faulty in this respect.

4.2.7.1.2 Sag and tension requirements

The conductor shall be strung with consideration of the following maximum tension/stress criteria:

Every day tension criteria:
At the yearly average temperature (15°C), with no wind, the final horizontal tension/stress shall not exceed 20% of the rated breaking strength (RBS) of the conductor, as indicated by the manufacturer and confirmed by testing.

Maximum load criteria:
For the maximum load conditions, which should be:

- maximum design wind at 15°C or
- wind simultaneous with ice load, at -5°C or
- minimum temperature of -15°C, no wind.

Related to whole conductor, the maximum load stress σmax, in daN/mm2,will be calculated with following formula:

$$\sigma_{\max,i} = \sigma_{adAl} \frac{E_c}{E_{Al}} - (\alpha_{Al} - \alpha_c)(t_i - t_f) E_c$$

where:
σad, Al = σmax, Al / γM,Al daN/mm2
EC = modulus of elasticity of Conductor daN/mm2
EAl = modulus of elasticity of Aluminum daN/mm2
αc = coefficient of linear expansion of conductor 1/degree
αAl = coefficient of linear expansion of Al 1/degree

ti = load condition temperature °C
tf = conductor fabrication temperature °C
$\gamma M,Al$ = partial material safety factor of Aluminum 2
The maximum load stress σmax, obtained from the formula above, shall be used for the strength verification of the overall conductor. The overall conductor shall have a partial material safety factor, applied to the maximum load stress σmax, of $\gamma M,C$ = 2.5.

This is equivalent to a limitation to approximately 40% of the rated breaking strength within the standard global safety factor method.

The Bidder shall supply sag-tension charts for the conductor stringing data (initial and final), calculated for various line spans in a chart or tabular form, for the temperatures between -15°- 50°C, in increments of 5°C.

4.2.7.1.3 Tests

Conductor
Sample tests shall be undertaken in accordance with the requirements of EN 50182, namely:

Tensile strength	Section 6.4.8. of EN 50182
Stress strain curves	Section 6.4.7. of EN 50182
Stringing test	Section 6.4.9. of EN 50182
Routine / sample tests	Table 5 of EN 50182

The tensile strength can also be tested according to EN 10002.

The mechanical tests shall be taken on straightened samples of individual wires taken after conductor stranding. In the event of the sample from any length not passing the mechanical or resistance tests, a second and third sample shall be undertaken from the same length, and if one of these also fails under test, the length of conductor (i.e. drum) from which it has been taken shall be rejected. For the ductility tests, should any vareation occur in the results between the torsion and elongation methods of testing the results of the torsion test shall prevail.

Wrapping test shall be undertaken in accordance with ISO 7802.

Tests for galvanized steel wire shall be carried out at the works to ensure compliance with the requirements of IEC 60888.

The galvanizing thickness shall be randomly tested. The zinc coatings must comply with the thickness requirements of ISO 1461.

Details of the test results shall be made available to the Client/Engineer upon request for approval.

Grease
The manufacturer's type test proposals for proving compliance with this technical requirements with regard to the following grease properties shall be submitted to the Client/Engineer for approval:

- dropping point tests
- thermal history test
- reversibility
- oxidation
- corrosive substances in grease
- anti-corrosion properties
- complete conductor test to ensure that the grease does not appear through the outer wires at less than the specified temperature.

Sample tests on grease shall be undertaken at the same time as sample tests on the conductor. The mass and length of the conductor sample shall be measured and recorded. The sample shall be inspected to ascertain that no grease is visible on the exterior. The wires shall then be separated progressively layer by layer whilst being inspected to verify the coating requirements are met.

Grease for the dropping test shall be removed without heating, the remaining grease may then be removed by a convenient method. The mass of the cleaned conductor sample shall be determined and recorded. The mass of grease shall be determined from the difference in masses and shall be recorded.

4.2.7.1.4 Packing, shipping, transport

The conductors shall be delivered and shipped on stoutly constructed timber or steel drums as specified and lapped with protective covering across the whole width of the drum. The packing for the corresponding spare parts shall comply with the requirements specified for long time storing.

All drums with conductors shall have a layer of waterproof wax paper or plastic sheet which must be safe against chemical reactions laid around the barrel under the conductors and another one laid over them and under the lapping. Drums shall be securely fastened around the perimeter and shall be suitable for rolling on the flanges without causing damage to the conductor. The disposal of all empty drums shall be the responsibility of the Contractor.

4.2.7.2 Optical Groundwire

4.2.7.2.1 Design

Electrical and Mechanical Requirements
The Contractor shall carry out all works in a skilled manner in compliance with modern methods of engineering. In addition, the Contractor shall conform to all applicable regulations regarding the manufacture and delivery of the goods and shall follow all instructions issued by the Client/Engineer.

The towers are to be equipped with one OPGW (ground-wire) of cross section area of at least 70mm2

The OPGW shall be based on an ACS (aluminum clad steel) wire construction in order to fulfill the requirements regarding mechanical strength, conductivity for lightning discharge and short circuit current resistance, corrosion resistance and protection of the optical fibers. The OPGW construction shall be suitable for incorporation of a number of 24 optical fibers.

The OPGW shall possess:

- Electrical conductivity allowing to support the single phase short circuit currents
- Electrical conductivity for an effective screening and reduction of induced voltages into nearby telecommunication lines and other conductive objects (pipes, fences, etc.),
- Mechanical performance allowing proper sag co-relation with the phase conductor,
- Corrosion resistance
- Efficient protection of the optical fibers

An aluminum clad steel (ACS) conductor with an approximate diameter and mechanical characteristics like ACS 70 standard earth-wire shall be supplied for the OPGW.

The main characteristics of ACS 70 standard earth-wire are:

- Conductor diameter: 10.5 mm
- Sectional area: 65.81 mm^2
- Design tensile strength: 85.65 kN
- Mass: 437 kg/km

The Bidder shall propose the type of armoring they intend to apply taking into account state of the art practice.

The Bidder shall demonstrate suitable operation experience and have type test records for the type of OPGW proposed.

Ordering of OPGW lengths on drums is recommended to be done considering the line lengths between designated and approved joint box positions for minimizing OPGW waste.

Governing Standards:

Optical fibers IEC 60793
ITU-T Recommendation G. 652**D**
ITU-T Recommendation G. 655

Optical ground-wire construction
IEEE Std 1138
GOST 5800
EN 50182
IEC 61089
IEC 61232

Tests and test requirements :
IEC 60794, IEC 61395, IEC 61089, IEEE Std 1138, EIA/TIA-455-81A, EIA/TIA-455-

82B, IEC 60811, EIA-455-113;122;124
IEC 61280-4-2, IEC 60793-1-40, ITU-T G.650.1 (3.1) and (4.5) or IEC 60793-1-42, IEC 61744, ITU-T G.957 (5.5), G.691 (5.4) or G.692 (8.3), IEC 60793-1-44 … -47, IEC 60793-1-51 and -52, IEC 61280-4-2, IEC 61746

Alternative standards or codes are subject to approval by the Client/Engineer.

The OPGW shall be suitable for service in the specific climate with the main characteristics as specified.

The main design data and performances of the OPGW are to be entered by the bidders in the Technical Schedules. All these data shall be proven by means of calculations and tests as specified.

Optical Fibers

The OPGW shall have 24 (twenty four) single mode optical fibers with characteristics as specified. The optical fibers shall be single mode type.

In Technical Schedules are specified two qualities of fibers:

- Single Mode type, in accordance with ITU-T G652D standard and
- Non Zero Dispersion Single Mode type, in accordance with ITU-T G655 standard.

Before tendering, the Client/Engineer will make a decision which kind of fibers are to be used. The Contractor is required to supply a graph of attenuation versus wavelength over the range of 1500 nm to 1600 nm.
No joints shall be allowed in any fiber in any drum length. Discontinuities will be acceptable if ODTR traces from both ends of the cable at 1550 nm wavelength show a difference of less than 0.05dB/km for every fiber in every drum.

The Bidder shall state the refractive index of the optical fibers at 1550 nm and all basic parameters of the proposed fiber.

4.2.7.2.2 Sag and tension requirements

The OPGW shall be strung with consideration of the following maximum tension/ stress criteria:

Everyday tension condition:
At the yearly average temperature (+ 15°C), with no wind, the everyday stress (EDS) shall not exceed 20% of the rated breaking load/ stress or respective of the guaranteed breaking load minimum indicated by the manufacturer.

Maximum load condition:
For the maximum load condition, which can be:

- maximum design wind or
- reduced wind and ice load or
- minimum temperature.

The OPGW shall have, within the adopted limit state design method, the following partial safety factors

- partial safety factor for actions: 1.00
- partial material safety factor: 2.50

This is equivalent to a limitation to 40 % of the breaking load within the classical global safety factor method.

The OPGW shall be suitable for stringing on spans up to 900 meters in length, with sags coordinated to those of the conductor. For the nominal span under every day condition the final OPGW sag shall not exceed 90% of the phase conductor sag.

The Contractor shall supply for the OPGW stringing data (initial and final) calculated for different line spans in a chart or tabular form, sag and tensions for the temperatures between -15° - 50°C.

Before starting the delivery of the goods, the Contractor shall submit the detailed OPGW length calculation for the line, according to the actual sections, spans and dislevelments.

The Bidder is required to state the maximum tension to which the OPGW may be strung without affecting the optical properties of the fibers and to retain efficient operation of the communication link

4.2.7.2.3 Splicing and joint boxes

On the Substation gantries and at every 3 … 5 km on tension towers, connections between OPGW’s and between the OPGW and the OPUG (optical fiber underground cable) shall be realized by means of joints in Joint Boxes.

At the tension towers not provided with Joint Boxes, the Contractor shall provide suitable attachment fittings to by-pass the tower without any additional joint. At all angle points the prescribed minimum bending radius shall be observed. If necessary, special tandem or multiple stringing blocks have to be used for stringing the OPGW at angle points.

The joint boxes shall be of the 'hood' type with encapsulated cable entry and they shall be mounted within the framework of the transmission towers above the anti-climbing device. The OPGW access to the casing should be via entry ports in the base, properly sealed to prevent moisture ingress.
Same joint casing shall be suitable for jointing OPGW with OPUG by substitution of appropriate glands in entry ports.

Weatherproof units shall be provided for the joint boxes (casings). The joint boxes shall include all necessary hardware to terminate, protect and fix the spliced fibers. Optical losses shall be no more than 0.08 dB at average per splice and no single splice loss shall exceed 0.10 dB. Each splice shall have a spare length of fiber of approximately 1m or more. A finished splice shall be supported within the joint box by suitable clips or restraints. It shall be possible to remove and replace the splice in the support device without risk of damage to the splice or fiber

4.2.7.3 Insulators and Fittings

4.2.7.3.1 General

Generally, the insulators shall conform to Section 10 of EN50341-1:2012. Complete insulator sets consisting of solid rod composite insulator unit and assembling fittings as well as fittings for phase conductors and OPGW are required as described below
Insulator sets shall generally be in compliance with the typical assembly as per existing standard design or as per typical drawings shown in the annexes.

Alternative designs will be acceptable provided that they are functionally similar and meet the performance specifications.

The Contractor shall provide detailed assembly drawings for each type of assembly required.

4.2.7.3.2 Insulators and insulator sets

The single “I” composite insulator, long rod type, of sufficient mechanical capacity shall generally be used.

For the 220 kV voltage, the minimum creepage distance is related to the highest phase-to-phase voltage (245 kV)

The unit creepage distance for 220kV voltages is 31mm / kV.

The insulator string shall be of sufficient length to provide the required electrical performance in regard to specific leakage path and minimum required withstand voltages. This has to be determined as per catalogue data, but has to be finally confirmed by tests on complete sets, as the insulator set fittings contribute to overall performance.

The electrical and mechanical performance requirements for insulator sets are shown in Technical Schedules.

All insulator sets including their clamps and fittings shall be in fair weather free from visible corona discharges. In particular, the live part of all insulator sets shall be conceived and shielded in a way to avoid visible corona under fair weather condition.

All insulator sets shall be provided with the necessary arcing devices in order to keep their radio and television noise as low as possible. A noise level less than 50 dB above 1 microvolt shall be ensured under standard laboratory conditions. This is to be proven by tests as per the mentioned standards.

All insulator sets will have to be provided with arcing fittings for assuring the necessary corona radiation level and to protect the insulators from the effects of the electric arc.

All insulator sets shall be designed to withstand the single-phase fault currents. This performance shall be proven by design tests in the workshop or laboratories in accordance with the tests described below. The upper and lower horns shall be installed on the insulator assemblies as recommended by the fittings manufacturer and confirmed by electrical tests.

Locking devices for the insulator units themselves and for associated ball and socket fittings shall be of stainless steel and shall comply with IEC 60372. The design shall be such as to allow easy removal for replacing of insulator units or fittings without the necessity to remove the insulator set from the cross-arms. Locking devices shall be incapable of rotating when in position.

For the dimensioning of the insulator sets from the mechanical point of view, the loads and loading conditions shown below, along with partial safety factors for loads, as well as the material safety factor given below and in the Data Sheets have to be considered:

- Weight of the conductors and of the insulator set as well as the weight of the ice loads,
- Wind loading on conductors and on ice covered conductors, or on the OPGW respectively,
- Maximum working tension of the conductor and of the OPGW.

The partial safety factors to be considered for the insulator and insulator string design calculation are:

- for actions (loads), normal conditions $\gamma_F = 1.50$
- for actions (loads), exceptional conditions $\gamma_F = 1.10$
- for material, insulators and fittings, normal conditions $\gamma_M = 1.60$
- for material, insulators and fittings, exceptional conditions $\gamma_M = 1.30$

The electromechanical failing load for the insulator units and the nominal loading capacity for the insulator string fittings shall be referred to respectively.

The insulator string shall be of sufficient length to provide the required electrical performance in regard to the specific leakage path and minimum required withstand voltages. This has to be determined as per catalogue data, but has to be finally proven by tests on complete sets, due to impact of insulator set fittings on the overall performance.

The suspension towers will be equipped with suspension insulator sets. The tension towers (angle-tension and dead-end towers) and gantries will be equipped with tension insulator sets. The insulator sets shall be designed for conductor types stated in Section 4.6, and as per EN 50182.

Spacing between double strings shall be sufficient to assure good behavior of insulators and good performance of arcing horns.

The single “I” type suspension insulator set shall be used as standard set on suspension towers and as jumper suspension set on the tension and terminal towers, where clearance requirements so demand.

The double suspension insulator set shall be used for crossings of main roads and other overhead transmission lines. Double suspension insulator sets shall have two sub-strings in a plane parallel to the line and be fixed to the cross-arm at two attachment points. Single tension sets shall be used as standard sets on tension towers. Double tension sets will be installed for crossings of main roads and overhead transmission lines and on all tension and terminal towers. The insulator set attachments to the tower cross-arms are of special importance for the safety required. Therefore, two independent attachment points to the tower are specified for double insulator sets.

Suitable adjustment, in case of tension sets, has to be done for the different line angles in order to assure equal distribution of the loads to the two insulator strings of the set.

Special attention has to be paid to ensure that by breakage of an insulator string of a double set, the remaining string shall withstand the resulting static and dynamic stress by applying the specified partial safety factors shown above.

In general, attachments to the tower are to be secure connection such as with swivels. Hooks are not acceptable.

Between the terminal towers and gantries (in the slack span), upright and inverted low duty tension sets will be installed.

4.2.7.3.3 Composite Insulator Units

The insulator units shall consist of composite long-rod type insulator featuring a glass-fiber reinforcing epoxy rod core with high temperature vulcanized silicone rubber housing and clevis caps. The design shall be in accordance with IEC 61466-2.

Standards

The composite insulator shall be designed, manufactured and tested according to the following standards:

- IEC 61109 (1992) and amendment no. 1 (1995);
  Composite insulators for AC overhead lines with a nominal voltage greater than 1000V, Definitions, test methods and acceptance criteria.
- IEC 61466-1 (1997);
  Composite string insulator units for overhead lines with a nominal voltage greater than 1000 V . Part 1 : Standard strength classes and end fittings.
- IEC 61466-2 (1998);
  Composite string insulator units for overhead lines with a nominal voltage greater than 1000 V, Part 2 : Dimensional and electrical characteristics.
- IEC Standard 60471, Dimensions of clevis and tongue couplings of string insulator units
- IEC Standard 60120, Ball and socket coupling of string insulator units.

Design

The insulators shall be of sufficient length to provide the required electrical performance in one single unit. In-line coupling of two or more units is not acceptable.

The core shall be an epoxy resin rod with axial glass fiber reinforcement of high strength (fiber reinforced plastic rod). The interface formed between rod and housing shall be of a quality to prevent brittle fracture phenomena, i.e. high electrical strength and equivalent acid resistance are required. Therefore, E-CR-glass fibers shall be used for the core.

The core of the composite insulator shall be protected against environmental influences by silicone rubber housing. The thickness of the silicone rubber covering the rod shall be at least 3 mm. The housing shall be perfectly (chemically) bonded to the core. The chemical bond between the core and the housing must be stronger than the tear strength of the housing material.

The manufacturer shall have a proven record of using non destructive technique (N.D.T.) to check the quality of the core to housing interface.

The silicon rubber can be directly molded onto the core. In order to achieve an excellent pollution performance and tracking performance (minimum class 1A 3.5 according to IEC 60587), the application of high temperature vulcanizing (HTV) silicon rubber filled with an appropriate amount of aluminum tri hydrate (ATH) shall be applied. The material shall be of blue/gray color and be resistant against the ultra-violet radiation being present in the solar spectrum at ground level. For the design of shed profiles, IEC 60815 shall be applied.

The metal end fittings should be made of forged steel and hot dip galvanized according to ISO 1461.

The fittings shall be attached onto the rod by a compression method process which does not damage the individual fibers of the rod in any way. Fittings configuration shall be defined by the actual need (e.g. ball and socket or clevis and tongue connection) and shall comply with the standard requirements.

The gap between fitting and core housing shall be sealed permanently against the ingress of moisture. Sealing by compression only is not regarded to be permanently waterproof. Covering the cap, even partly, with housing material is unacceptable due to electrical reasons. Sealing of the interface by application of an elastomer with permanent elasticity is considered an acceptable solution. The material shall adhere to the surface of the metal cap, as well as to the housing.

4.2.7.4 Clamps and fittings for conductors

4.2.7.4.1 General

Clamps and fittings for conductors may be supplied as per GOST standards and catalogues but an alternative design complying within the international standards specified will also be accepted. However, all clamps and fittings shall comply with the requirements. They shall be suitable for conductor configurations described.

4.2.7.4.2 Suspension clamps

The conductor suspension clamps shall be of high-tensile corrosion-resistant aluminum alloy, suitable for a working temperature of 80°C. The clamping components shall be forged or cast. In case of casting additional reinforcing strap is foreseen.

The suspension clamps shall be as light as possible and of a vibration proof cover type. They shall be such as to form a fully articulated support for the conductors. The clamp bodies shall be centrally pivoted and the rotational axis of the clamp shall be preferably at same level as the conductor center line or below but not above. The clamp body shall be able to pivot at least 45° above and below the horizontal line. Special attention shall be paid to the mass moment of inertia of the clamp in order to avoid resonance of the clamp plus conductor system by wind induced vibrations. The Contractor shall ensure by appropriate calculations and design a suitable suspension clamp for the specified conditions also from this point of view.

As per existing experience and as per standard design of suspension insulator strings, the phase conductors are not protected within the suspension clamps by means of armor rods.

The conductor supporting groove shall be curved at its ends in the vertical plan to an appropriate radius to permit the conductor to leave the clamp at the maximum angle of inclination (20°).

The mouth of the supporting groove shall be slightly flared in plan. The grooves in the clamping piece shall be bell-mouthed at each end and all conductor grooves and bell-mouths shall be smooth and free from waves, ridges or other irregularities.

The bolts used in the suspension clamps shall be hexagonal hot-dip galvanized or stainless steel bolts. The washers underneath the bolt head shall be made from stainless steel only.

Subsequent to tightening of bolts to the torque as recommended by the manufacturer, the clamp shall be capable of withstanding the maximum working tension of the conductor without any conductor slippage. They shall permit the conductor to slip at a load lower than the conductor breaking load.

The clamp bolts and the clamping force shall be chosen to satisfy also the electrical requirements. The phase conductor clamps must be capable of withstanding the three-phase and the single-phase fault currents shown in Technical Schedules without any damage.

Attention must be paid to the elimination of fair weather corona emission from all parts of conductor suspension clamps under the specific site conditions

4.2.7.4.3 Tension clamps, joints and repair sleeves

Tension clamps and joints
Conductor tension clamps and joints shall be of the compression type, suitable to withstand a working temperature of 85°C.

The conductor tension clamps:

- shall be ended with a jumper terminal, or
- shall be supplied with a jumper terminal which may be bolted at 0° or 30°.

The coupling element of the tension clamps to the string shall be eye-type or clevis-type, hot dip galvanized.

The electrical conductivity and current carrying capacity of the tension clamps, joints and jumper terminals shall be not less than those of the equivalent length of conductor.

The tension clamps and joints of the phase conductors must be capable to withstand also the three phase short-circuit current shown in Technical Schedules without damage.

Attention must be paid to avoid fair weather corona emission from the conductor tension clamps and joints.

Compression-type clamps and joints shall be tested by the Contractor to ensure that they will stand up to at least 95% of the rated ultimate strength of the conductor.

Joints and tension clamps shall be made of aluminum alloy-steel.

Joints and tension clamps shall be supplied with filler compounds, to protect the assembly clamp-conductor against corrosion.

The split pins used shall be of stainless steel.

The design of the joints and tension clamps shall be such that only one pair of dies is necessary for the compression of the conductor.

Mid-span joints shall not be less than 30m from the nearest conductor clamp.

Unless the Client/Engineer agrees mid-span joints shall not be used under the following circumstances:

- in spans crossing power lines, buildings and main roads.
- in single span sections.

Joint and repair sleeves
Conductor repair sleeves shall not be used without the permission of the Client/Engineer which will be granted only in exceptional circumstances.

Joint sleeves and repair sleeves for the conductors shall be of compression type. The joint sleeves shall consist of steel compression sleeve for the steel core of conductor, and aluminum compression sleeve for the complete of conductor.

The aluminum compression sleeves shall be of aluminum alloy conforming to the specification in IEC 60889 standard or equivalent, and the steel compression sleeves shall be of carbon steel conforming to the
specification in BS 970 part 1 respectively EN 10084, 10085, 10087, 10095, 10250-4 and BS PD 970.

After compressed, the electrical resistance of the joint sleeve must be less than that of the jointed conductor with the same length as the sleeve, and the ultimate tensile strength of the joint sleeve must not less than 95% of the ultimate tensile strength of the conductor.

4.2.7.4.4 Armor rods

In case of an alternative design, preformed armor rods shall be used to protect the phase conductors in suspension assemblies.

The direction of the armor rod lay shall be equal to the direction of the outermost wire lay of the conductor.

The suspension clamps offered for the phase conductors shall accommodate the increased diameter resulting from armor rods.

The ends of the armor rod wires shall be well rounded, without sharp edges, to avoid an increase in corona level.

4.2.7.5 Clamps and fittings for OPGW

4.2.7.5.1 General

All clamps and fittings shall comply with the requirements of this Design Report and must be approved by the Client/Engineer. They shall be suitable for the OPGW type proposed by the Contractor. The Contractor shall ensure close and continuous liaison between the manufacturers of OPGW, clamps and fittings so that the equipment will be perfectly adapted. The detailed design of OPGW suspension and tension hardware shall be coordinated with the manufacturer of the OPGW. The installation techniques and procedures shall be submitted to the OPGW manufacturer and his written approval for the complete design and materials intended to be used with the approved OPGW type will be presented to the Client/Engineer before the final approval for the hardware and OPGW will be granted.

All clamps and fittings except for vibration dampers shall be supplied by the same manufacturer. Splitting up of the supply of clamps and fittings will not be permitted.

Besides, the Contractor shall assure perfect fitting of the OPGW set attachment armatures (connecting hardware) to the tower steel construction. The design of adjacent metal parts and mating surfaces shall be such as to prevent corrosion of the contact surfaces and to maintain good electrical contact under service conditions.

At all suspension, tension towers and substation gantries, the OPGW shall be electrically connected to the steelwork by means of jumpers of the same size and material as the OPGW as well as by means of suitable fittings.

The OPGW connections to the towers (connecting hardware, earthing connections) shall withstand the single-phase fault current shown in chapter Technical Schedules, without suffering damage and this performance must be checked in accordance with the requirements.

All ferrous parts of the assemblies component elements and of the accessories for conductors and OPGW shall be hot dip galvanized according to ISO 1461.

The split pins of all clamps and fittings shall be of stainless steel.

The suspension towers will be equipped with suspension sets and the tension towers with tension sets. All sets shall be designed for the OPGW selected type and for the mechanical loads and loading conditions shown below as well as the safety factors given in Technical Schedules:

- OPGW dead weight
- design spans as specified
- maximum wind speed
- maximum ice load
- ice load with reduced wind
- maximum working stress in the OPGW.

The partial safety factors to be considered for the OPGW fitting design calculation are

- for actions (loads), normal conditions $\gamma_F = 1.50$
- for actions (loads), exceptional conditions $\gamma_F = 1.10$
- for fitting material, normal conditions $\gamma_M = 1.6$
- for fitting material, exceptional conditions $\gamma_M = 1.3$

Particular care shall be taken during manufacture of clamps and fittings and during subsequent handling to ensure smooth surfaces free from burrs and sharp edges.

4.2.7.5.2 Suspension assemblies

Armor grip suspension clamps shall be used for OPGW. The clamp body shall be of high-tensile strength corrosion-resistant aluminum alloy and shall be preferably forged or cast. In the case of cast ones an additional reinforcement shall be foreseen. The spiral rods shall also be of aluminum alloy and shall not have diameters less than 4mm.

The material of the clamps should satisfy the norms EN 1559 for aluminum alloy castings and EN 1562 for malleable cast iron.

The neoprene or other non-metallic material shall have good resistance to aging and be capable of withstanding temperatures between –20°C and +50°C without changing of essential properties. The material shall have adequate resistance to the effects of ultra-violet radiation, ozone or pollution factors.

The rotational axis of the clamp shall be in the longitudinal axis of the OPGW to avoid unacceptable distortion of the OPGW due to unbalanced longitudinal loads. The Contractor shall ensure by appropriate design a suitable performance of the clamp-conductor assembly by wind induced vibration.

In addition to the suspension clamp, connecting hardware is required for a suitable mechanical and electrical connection to the tower, and the Contractor is responsible to supply the complete set of the suspension assembly.

4.2.7.5.3 Tension assemblies

The OPGW attachments to tower shall be of helical grip type consisting of two helical parts (fittings), one for OPGW protection and the other one as actual dead-end fitting. Preformed helical dead-ends shall have "cabled loop" eyes. The material of the spiral rods shall be high-tensile strength aluminum clad steel.

The protection part is defined to protect the OPGW against radial forces produced by the high longitudinal tensions during operation. The protection part must be laid in the opposite direction of the outer layer of the OPGW and the dead-end part must be laid in opposite direction to the protection part. The grip strength shall be at least 95 % of the ultimate tensile strength of the OPGW.

The tension attachment devices must correspond to the OPGW type and dimensions. The protection part must be longer than the tension (dead-end) part and the length must be sufficient to install vibration dampers. The number and diameter of the spiral rods of the two parts are generally different but must be coordinated to meet the operational requirements.

4.2.7.5.4 Fittings for insulator strings

General
The insulator units shall be assembled to insulator sets with appropriate fittings.

The connection to tower fittings will be in accordance with the existing standardized design (see annexes).

The design of adjacent metal parts and mating surfaces shall be such as to prevent corrosion of the contact surfaces and to maintain good electrical contact under service conditions.

All parts shall be designed to withstand the mechanical loads during the lifetime as calculated for the insulator string sets and to avoid loosening in service due to vibrations or due to other reasons.

Each insulator set and OPGW set connection-to-tower shall withstand such a short-circuit without exceeding a temperature of 400°C in the fittings and without welding between the component parts.

All ferrous parts of the assemblies component elements and of the accessories for conductors and OPGW shall be hot dip galvanized with a minimum zinc weight of 700 g/m2, except bolts, nuts and washers where a minimum zinc weight of 500 g/m2, will be accepted. The split pins of all clamps and fittings shall be of stainless steel.

Arcing rings
The arcing rings of the insulator sets must fulfill simultaneously the functions of arcing

rings, corona shield and potential distribution devices.

As arcing device, the guard rings shall be designed to protect insulators and conductors when flashover occurs. The arcing fittings shall be made of hot dip galvanized steel and must have the capability to withstand a short circuit current of 40kA for 1s. The arcing fittings must be designed so that in case of flashover the arc will be led to the end burning spot.

They may reach a final temperature not exceeding 600°C during the short- circuit. The function of arcing protection must not be greatly altered by the power arc.

As corona shield devices, the guard rings shall be designed to ensure under fair weather and under the specific site conditions a corona-free insulator set line end as well as the specified insulator set radio noise performance

As potential distribution devices, the guard rings must be designed to insure a uniform distribution of the potential along the insulator string.

The design of the guard rings shall consider and optimize simultaneously all the functions required.

The rings shall be strong enough to support a weight of 90kg without permanent deformation. The ring attachment shall be via bolted connections to the hardware assembly.

4.2.8 Vibration Damping System and Dampers

4.2.8.1 Requirements

Conductors are excited to vibration by laminar wind flows which may lead to damage by failures of individual strands and, eventually, of the whole conductor.

In this respect, to protect the conductors, vibration systems and Stockbridge Dampers are specified

The OPGW’s shall be protected by Stockbridge Dampers only.

Vibration dampers of Stockbridge type shall be installed at OPGW suspension and tension points.

On OPGW the dampers shall be mounted on armor rods.

Minimum two dampers per span shall be provided; one damper per span is not permitted.

The exact number of dampers shall be determined by a Damping Study which is deemed to be included in the scope of work.

The Contractor shall submit all data and calculations regarding the characteristics, number and placement of the vibration dampers to be used for the various ranges of spans. The calculations shall cover the range of 1 to 7 m/s wind velocity and typical conductor and

OPGW tensions (EDS) and the range of span lengths, as appropriate

4.2.8.2 Vibration dampers for conductors and OPGW

Vibration dampers of Stockbridge type or of an approved equivalent shall be fitted:

- at OPGW Suspension and tension points.
- at conductor suspension and tension points

The number of dampers at each end of OPGW shall not be less than:

1 damper for span lengths up to 400 m;
2 dampers for span lengths greater than 400 m

Regarding the damping characteristics of the vibration damper, the Contractor shall guarantee that the amplitudes of the wind and wake- induced vibrations are kept within acceptable limits over the entire range of possible frequencies.

The damper clamps shall be forged Aluminum alloy.

For OPGW the damper clamps shall be designed to fit it on suitable amour rods to ensure that dampers shall not damage the OPGW with which they are used.

The clamping bolts shall be of steel having a minimum tensile strength of 800 N/mm2 and shall be designed to facilitate an easy damper mounting. The screws shall be locked in an approved manner. The washers shall be made of stainless steel.
All ferrous parts of the damper component elements shall be hot dip galvanized.

4.2.9 Aircraft Warning System (if necessary)

4.2.9.1 Warning spheres

Aircraft warning spheres for denoting obstacles, conforming to the Convention on International Civil Aviation shall be installed on the line in case of:

- areas close to airports
- on Employer / Local Authorities selected line sections.

Aircraft warning system is proposed in vicinity of Penjikent airport.

Warning spheres shall be fitted to the OPGW of the OHL. The warning spheres shall be 600 mm diameter and manufactured from fiber-glass or aluminum. The spheres shall be colored International Orange which will not fade when subjected to the direct rays of the sun.

They shall be manufactured in two halves and designed such that assembly and attachment to the OPGW is simple. Provision for drainage shall be included. Suitable clamping devices shall be provided to fit the warning spheres on OPGW locally protected by armor rods, which will not damage the OPGW but will prevent the sphere from twisting or slipping on the OPGW. All metal parts used for holding the spheres in position shall be of mild steel and galvanized.

The position of the spheres shall meet the following requirements:

- The spheres on the OPGW for any span shall be fixed so that the maximum distance between any two spheres is not greater than 30 m or according to international or local regulations.
- The type and details of the spheres shall be closely coordinated with the OPGW manufacturer in order to avoid any excessive stress on the OPGW.

4.2.10 Earthing

4.2.10.1 General

The line route passes through infertile, fertile, deserted areas, predominantly of loamy sands.. The soil conditions should be normal for the tower earthing. Therefore, a standard earthing of the foundation steel is specified and completed by an extension of the standard earthing for such locations where a standard earthing cannot meet the specified requirements regarding resistance.

Each tower shall be connected to ground by means of an earthing system, as shown in the annexes.

The design and tests shall generally follow EN 50341 and IEEE 80-1986. The tower earthing system will be composed of:

- The basic earthing system of foundation reinforcing steel;
- An additional earthing system;
- Extension of the additional earthing system.

Connection of the earthing devices to the tower steel shall be made upper- ground, by means of short intermediate earthing connection wires or alternatively by earthing connection straps.

The individual tower earthing resistance measured without the OPGW connected, in dry season is specified depending on the soil resistivity as per the following table:

Table 4-3 Tower earthing resistance

Soil resistivity [Ω m]	<100	100-500	500-1000	1000-2000	>2000
Earthing resistance [Ω]	10	15	20	25	30

4.2.10.2 Basic earthing

In order to include the foundation steel into the tower earthing system, the vertical reinforcing bars will be connected electrically to the stub angle inside the concrete by a steel wire/ tape which connection shall be welded or bolted.

Further earthing connections shall be provided between vertical and horizontal bars in order to include also the horizontal reinforcing mesh net at the bottom of the foundation.

4.2.10.3 Additional earthing

If the tower earthing resistance as per table above cannot be met, the tower basic earthing system has to be extended by additional measures.

Additional Earthing – Step 1

The type of additional earthing devices will be specified as grounding wire/ tape system. One loop shall be installed in a depth of 0.6m from ground level surrounding the tower location, being connected to each tower leg and equipped with earthing rods.

After installation of the additional earthing system, the Contractor shall measure the earth resistance at each tower structure.

Additional Earthing – Step 2

If the tower earthing resistance as per table above cannot be met although the basic system as well as a grounding wire/ tape loop have been installed, the tower earthing system has again to be extended by additional measures.

The loop shall be extended by additional grounding wires/ tapes of 10m length or more, running in radial direction from the tower center. Earthing rods shall be used at each end of the tapes.

After application of additional earthing, the Contractor shall repeat the resistance measurement in all concerned locations and submit the results to the Client/Engineer for approval.

Grading Rings

At tower locations subject to special requirements of safety of public, a closed earthing ring has to be buried around the tower leg, to a depth of 0.6 m at a distance of 1m to the tower steelworks. The ring is to be connected to the tower legs.

If found necessary, a second grading ring shall be installed at a depth of 0.8m in a distance of 1m to the first grading ring.

For tower locations where the Contractor is advised by the Client/Engineer to install earthing rings for public safety, he shall perform calculations proving the safety limits of step and touch voltages. These calculations shall be carried out in accordance with approved standards.

4.2.10.4 Material

Earthing conductor

The tower grounding wire or the grounding tape (earthing strap) shall be at least

- 11.5mm diameter galvanized steel wire
- 40x6mm galvanized steel band.

The earthing conductor shall be connected to the tower steel structure (stub) by using connectors and/ or bolts.

Connectors

The connection of the basic and additional earthing system to the tower stubs inside the concrete or above the foundation shall be made by means of a flat connector compressed on the steel wire and bolted to the stub. In case of using an earthing tape, the tape may be connected directly to the stub by two bolts. The bolts shall be of sufficient length to suit the steel connecting angle/ plate thickness and provide for the nut and washer.

A compression type connector may be used for the grounding connection of steel wire to steel wire/ to reinforcement bars. The connector shall be made of steel. The current carrying capacity of the connector shall not be less than that of ground wire. The effective length of the clamp shall be sufficient to grip the connecting wires firmly under normal service conditions.

Alternatively bolted clamp connectors can be proposed.

Grounding Rods

The ground rods shall be of galvanized steel type, delivered in modules and provided with connectors. The minimum length may not be smaller than 2.0 m and the diameter not smaller than 12 mm.

The earth electrode shall be connected to the tower steel by using ground wires/ tapes and connectors.

4.2.11 Access roads

General

Access roads/routes shall be identified by the Contractor themselves as and where necessary, and shall be constructed by them at their own expense. A map showing all access roads (existing ones and ones to be constructed) has to be prepared and submitted to the

Client/Engineer for approval.

4.3 Impact of 220 OHL on grid operation, protection and communication systems;

The proposed new transmission line between SS Ayni-220 kV and SS Rudaki is very useful and necessary for the electrical network in this part of Tajikistan.

The new 220 kV OHL shall be the new backbone for the energy supply of Penjikent area. With the new line the energy supply to Penjikent area will be stabilized and the operation of grid will be improved.

For integration of the 220 kV SS Rudaki into the 220 kV Network of Tajikistan the coordination of protection system and extension of communication and SCADA system is necessary. These activities have been considered in the related sections.

In future a parallel operation of the grid on certain voltage levels in Uzbekistan and in Tajikistan will be possible. Over and above the synchro check relays no further protection equipment has been considered for this operational mode..

4.4 Condition of 220kV Rudaki and Alyni substations, required reconstruction and rerouting of existing lines

4.4.1 General

4.4.1.1 Input for Basic Design for 220 kV SS Rudaki and 220 kV SS Ayni

The basic design features presented below have been prepared for the following measures:

- Ayni Substation

extension of 220 kV substation Ayni

- Rudaki Substation

rehabilitation of 220 kV Rudaki substation

- OHL

220 kV transmission line Ayni – Rudaki

4.4.1.2 Standards and regulations

For designing, calculation, manufacturing, packing and transporting, storing, installa-tion and testing of the substation and trans-mission line works, the following standards, regulations, and rules shall apply:

- IEC standards and recommendations
- EU standards
- VDE regulations and DIN standards
- Tajikistan standards, regulations and rules (where available)

As far as practicable and applicable indica-tions of the different standards, regulations and recommendations are given in the text

4.4.1.3 Basic Technical Data of Equipment for 220 kV at SS Rudaki and 220 kV SS Ayni

The basic technical values have been select-ed in accordance with the existing system in Tajikistan and under consideration of the recommendations of IEC.

220 kV System

The following basic technical values shall be considered:

nominal system voltage:	220 kV
highest voltage for equip-ment:	245 kV
rated frequency:	50 Hz
standard lightning impulse withstand voltage:	1050 kV (peak value)
standard switching impulse withstand voltage:	460 kV (peak value)
creepage distance:	6,125 mm

4.4.2 220 kV SS Rudaki

The first part of 220/110/35/10 kV substation Rudaki was built 50 years ago and ex-tended by 220 kV part more than 30 years ago. All installed equipment is old and at the end of the service life.

The Rehabilitation of the complete substation is necessary but in this project only sched-uled for the 220 kV part.

The next figure indicates the existing layout and the adjusting area.

Figure 4-3 Layout of existing SS Rudaki

Any extension of 220 kV switchyard in the direction of 110 kV switchyard is only possible in south western direction. In the other direction is not enough space available (existing oil separator and river).

The land required for the double bus bar extension does not belong anymore to Barqi Tojik.

The 220 kV switchyard includes:

- 2 (two) OHL bays for the 220 kV OHL Sogdiana (Uzbekistan) and 220 kV OHL Sary Bazar (Uzbekistan).
- 2 (two) transformer bays 220/110/10 kV, 63 MVA each
- 2 (two) measuring bays

The 110 kV switchyard includes:

- 4 (four) OHL bays
- 2 (two) transformer bays 220/110/10 kV
- 1 (one) transformer bay 110/35/10 kV
- 1 (one) coupling bay
- 1 (one) bypass bay
- 3 (three) measuring bays

The documentation has been made available for the following topics:

- Single line diagram of existing 220/110/35/10 kV Rudaki substation
- A layout drawing for civil work.
- Equipment data sheet

4.4.2.1 Rehabilitation of 220 kV switchyard at SS Rudaki

The following equipment and measures are necessary for rehabilitation of 220 kV switchyard and connection of new OHL from Ayni at SS Rudaki:

General Rehabilitation works:

- Removal of all existing busbars and HV conductors including HV equipment connection and hand over to the client
- Removal of all old HV equipment including steel structure, foundation and hand over to the client
- Removal of all old power and control cable including cable channels and hand over to the client
- Supply and installation of new busbars and HV equipment connection
- Supply and installation of new power and control cable including cable channels
- Barqi Tojik requested to replace 2 (two) 220/110/10 kV 63 MVA transformers by 2 (two) new 220/110/10 kV 125 MVA transformers including foundation and connection to the existing oil collector.

Rehabilitation of OHL one (1) overhead transmission line bay to SS Ayni 220 kV (former OHL Line to Sogdiana, Uzbekistan) equipped with:

- 1 (one) circuit breaker
- 2 (two) disconnecting switches with earting switches on both sites
- 3 (three) current transformers
- 3 (three) voltage transformers
- 3 (three) lightning arresters
- Control and protection equipment for OHL bay Ayni
- Communication equipment for the OHL
- Foundation and steel structure for the new equipment
- Clamps, Conductors etc.
- Cabling including cable canals
- Leveling and gravelling of area

Rehabilitation of OHL one (1) overhead transmission line bay to Sari Bazar (Uzbekistan) equipped with:

- 1 (one) circuit breaker
- 2 (two) disconnecting switches with earthing switches on both sites
- 3 (three) current transformers
- 3 (three) voltage transformers
- 3 (three) lightning arresters
- Control and protection equipment for OHL bay

- Communication equipment for the OHL
- Foundation and steel structure for the new equipment
- Clamps, Conductors etc.
- Cabling including cable channels
- Leveling and gravelling of area

Rehabilitation of one (1) transformer bay and replacement of one (1) autotransformer AT1 equipped with:

- 1 (one) circuit breaker
- 3 (three) disconnecting switch with earthing switches on both sites
- 6 (six) current transformers
- 3 (three) lightning arresters
- 1 (one) 220/110/10 kV 125 MVA auto-transformer
- Control and protection equipment for autotransformer and transformer bay
- Foundation and steel structure for the new equipment
- Foundation and rail system for new auto-transformer
- Clamps, Conductors etc.
- Cabling including cable channels
- Leveling and gravelling of area

Rehabilitation of one (1) transformer bay and replacement of one (1) autotransformer AT2 equipped with:

- 1 (one) circuit breaker
- 3 (three) disconnecting switch with earthing switches on both sites
- 3 (three) current transformers
- 3 (three) lightning arresters
- 1 (one) 220/110/10 kV 125 MVA auto-transformer
- Control and protection equipment for autotransformer and transformer bay
- Foundation and steel structure for the new equipment
- Foundation and rail system for new auto-transformer
- Clamps, Conductors etc.
- Cabling including cable channels
- Leveling and gravelling of area

Ring Bus bar system (option 1)

The like for like replacement of the existing 220 kV switchyard at the SS Rudaki in a ring bus bar configuration has been proposed. In this solution one of the existing 220 kV OHL to Uzbekistan will be replaced by the line routed to the SS Ayni 220 kV. The other remains connected.

The replacement of the equipment will be possible at the given space at the substation, which forms a major advantage.

The single line and a sketch indicating the space requirements for the modification included in option 1 are attached in the annexes.

Double Bus Bar system (option 2)

Barqi Tojik requested also to define the possibility of modification of the existing ring busbar system by double busbar system.

In case of installing the requested double bus bar system the extension of 220 kV switchyard in the direction of 110 kV switchyard is only possible in south western direction (please refer to Figure 4-3 Layout of existing SS Rudaki). In the other direction is not enough space available (existing oil separator and river).

In this case it is necessary to rearrange the existing 110 kV switchyard and to buy additional territory of existing Greenhouse and the territory above them up to the fences of the 10 kV switchyard.

A drawing indicating a draft for the layout and the required additional land for option 2 including a single line for the modified 220 kV part in a double bus bar configuration is attached in the annexes.

Advantages and disadvantages

Option 1 and option 2 are having the following advantages and disadvantages, which are outlined in the tables below:

Ring Bus Bar System (option 1)	
Advantage	**Disadvantage**
Flexible System	Extension of ring busbar system is difficult, large space required
One switching bay can switched off for maintenance etc. but the 220 kV switchyard is fully in operation	Long switch off time for extension necessary

Double Bus Bar System without Transfer Bus (option 2)	
Advantage	**Disadvantage**
Extension of double busbar system is simple.	Not so flexible system.
No switch off time of 220 kV switchyard for extension necessary.	Maintenance is only possible when the switching bay is off.
	Additional land to be purchased for the extension.

The options will require the following investments:

Option 1: Rehabilitation of existing ring busbar system	**Option 2: New double busbar system without transfer bus**
• Rehabilitation of ring busbar system USD 2,860,000.- • Replacement of 2 (two) 63 MVA transformers by 2 (two) new 125 MVA transformers USD 6,000,000.-	• New double busbar system without transfer bus USD 4,000,000.- • Replacement of 2 (two) 63 MVA transformers by 2 (two) new 125 MVA transformers USD 6,000,000.-

	• Rearrangement of 110 kV switchyard USD 2,500,000.-
Total Costs **USD 8,860,000.-**	Total Costs **USD 12,500,000.-**

During the presentation of the Draft project Design Barqi Tojik confirmed that option 1 shall be considered in the design.

The main 220kV equipment should be of similar type and rating as close as possible to the existing one, but taking into account the calculated values of loading and short circuit and currents.

The proposed equipment design and ratings are given in the chapters below.

4.4.2.2 Circuit breakers

For the 220 kV circuit breakers the consult-ant proposes that SF6 type shall be used. The SF6 breakers will be of the outdoor type, single pole, constructed according to IEC 60056 and other relevant IEC standards / recommendations as well as VDE regulations and DIN standards.

The circuit breakers for the line feeders shall be suitable for single and 3-phase multiple rapid auto-reclosing. Pumping shall be pre-vented. Operation and fault operation counters will be provided.

The principle data of the 220 kV circuit breakers shall be as follows:

Rated voltage	220 kV
Number of poles	3
Rated normal current (feeder)	4000 A
Rated short-circuit breaking current	50 kA
Rated short-circuit making current	100 kA
Breaking time	max. 60 ms
Switching cycle	O - 0.3s – CO - 1 min. - CO

The circuit breaker operating mechanism shall be preferably of the motor-wound spring operated type.

4.4.2.3 Isolators and earthing switches

All insulators shall be equipped with motor drives, however, manual operation must also be possible. The isolators will be combined with manually operated interlocked earthing switches.

The isolators are of the 2 column rotary type. Three single-phase isolators will be mounted on their common frame onto a support and operated three-phase by the re-spective operat-ing mechanism.

The isolators and earthing switches will be constructed according to IEC 60129 and will have the following principal values:

Rated voltage	220 kV
Number of poles	3
Rated normal current (feeder)	4000 A
Rated short time withstand current	50 kA
Rated peak short circuit current	100 kA

4.4.2.4 Voltage transformers

Voltage transformers shall be installed in all line feeders. The voltage transformers will be of the capacitive type, single phase, with one end of the primary winding directly earthed and will be in-stalled on separate supports.

The voltage transformers shall be con-structed in accordance with IEC 60186 and will have the following principal technical data:

Rated primary voltage	220/√3 kV
Rated secondary voltages	2x 100/√3 V
(two independent secondary windings)	
Rated output	2 x 100 VA
Accuracy class	0.2

4.4.2.5 Current transformers

Current transformers shall be installed in all line and transformer feeders.

The current transformers shall be single-phase and directly installed on separate supports. For measuring and protection the same current transformers with multiple secondary cores will be used.

The current transformers will be designed according to IEC 60185 and will have the following principal technical data:

Rated voltage	220 kV
Rated primary current	
Line bays	300-600-1200A
Transformer bays depending on size of transformer	
Rated secondary current for measuring	1A
Rated secondary current for protection	1/1/1A
Rated short time withstand current	50 kA
Rated peak short circuit current	100 kA

Accuracy class for measuring	0.5 M 5
Accuracy class for protection	10 P 10

4.4.2.6 Lightning arresters

In the present high voltage system lightning arresters are installed only at the primary and secondary side of the transformers. There are no arresters at the entrance of the line feeder bays into the substations.

However, most of the utilities in western countries have installed lightning arresters in line bays. The arresters provide an additional overvoltage protection for the switchyard equipment.

The risks of damage of equipment by overvoltages are reduced and therefore reliability of the electrical system is improved.
It is therefore recommended to install lightning arresters in the line bays.

The lightning arresters will be fitted with individual surge counters. They shall be of gapless, zinc-oxide, heavy duty type.

The lightning arresters will have the follow-ing technical characteristics:

Maximum system voltage	126 kV
Continuous operating voltage	94 kV
Nominal discharge current	20 kA

4.4.2.7 Telecommunication equipment

On the new transmission lines OPGW shall be installed for the new 220 kV line, as well as for the connection to the existing substations. The refurbished PLC connection on the 110 kV OHL shall be used as a backup connection only.

The OPGW shall consist of 24 fibers, depending of the choice of the Client/Engineer, optical fibers shall be according ITU recommendation G.652**D** or G.655.

4.4.2.8 Control & Protection equipment

The basic design parameters/ schemes for the OHL protection are the following as minimum requirements:

Numerical distance protection with polygon loop characteristics including minimum three distance zones acting on trip coil 1of circuit breaker (Main 1).

Numerical distance protection with polygon loop characteristic and minimum three distance zones (from another manufacturer) acting on trip coil 2
(Main 2).

Alternatively differential protection shall be foreseen for Main 2 protection for OHL with OPGW

Each of the above protection should include a communication logic to the remote end, autoreclosing function, switch onto fault logic, power swing detection, overcurrent protection, synchrocheck and energizing check, overvoltage protection, fuse failure supervision, loss of system voltage, fault locator, breaker failure current unbalance for parallel lines and power flow control.

Regarding the parallel operation of the power grids in the Republic of Tajikistan and the Republic of Uzbekistan a central coordination will be required. In the scope of the project only a synchrocheck relay is included.

Bussbar protection shall be foreseen for the new substations.

Transformer protection should include as a minimum, transformer differential protection (Main 1), restricted earth fault protection (Main 2), impedance/distance protection (back-up), overcurrent and earth fault protection, breaker failure protection, synchrockeck function, tertiary winding protection, phase unbalance protection.

4.4.2.9 Substations control and monitoring equipment

The substation control and monitoring system (SCMS) for the rehabilitated substations should be a digital control and monitoring system to supervise and operate the 220 kV switchyards completely in every respect for monitoring and control also the existing switchyards via existing distribution frame and existing control cubicles.

The SCMS shall be designed for easy modification of hardware and software and for easy extension of the substations. Maintenance, modification or extension of components may not force a shut-off of the whole SCMS.

Self monitoring of single components, modules and data transfer channels shall in-crease the availability and the reliability of the equipment and minimizes maintenance. Failure of any component of the system may not force a total system failure.

The new substations shall be controlled and supervised from the digital Substation Control and Monitoring System (SCMS) and from the National Dispatching Center while individual bays are supervised and con-trolled from the new bay units or existing local control cubicles. It shall not be possible to control at the same time from different control levels.

The substation control system shall consist of the following main parts:

Substation Control Computer (SCC) System

- Man Machine Interface (MMI)
- Data Communication Interface (DCI)

- Protection & Fault processing unit (PFP)
- Operator Control Station (with two displays and one event printer)
- Service and Analysis System Station (with one display and one hardcopy)
- Serial high speed bus (process interface) for data transmission between the different system components via fiber optical links.
- Bay Units (BU) for local control

The main process information (binary and analog inputs and out-puts and pulse inputs) of the substation shall be stored in distributed data bases. The system shall include a concept of bay oriented "Distributed Intelligences" for safety reasons. Whenever possible, functions shall be decentralized and bay orientated.

The MMI-system shall only contain information which is related to presentation, control and analysis of the substation.

Control for the new bays should be done in the following way:

- from new circuit breakers and disconnectors in the bays
- from bay unit computers
- from the redundant station computer located in control room

from the NDC

4.4.3 SS Ayni 220 kV

The Ayni 220 kV substation is a 220/110/10 kV substation and was commissioned in 2012.

The technical condition is good.

During the design and construction of the SS prearrangements for the connection of the 220 kV OHL to Rudaki for example with a space reserve for the additional bay has been made.

The substation was designed and constructed by the company TBEA Co. Ltd.

In the annexes a layout of the substation and a single line diagram (SLD) is attached.

The 220 kV switchyard includes:

1(one) OHL bay to substation Shahristan
2 (two) transformer bays 220/110/10 kV
1 (one) coupling bay
2 (two) measuring bays

The 110 kV switchyard includes:

4 (four) OHL bays
2 (two) transformer bays 220/110/10 kV
1 (one) coupling bay
2 (two) measuring bays

Documentation

Layout and single line diagram of existing 220/110 kV Ayni substation was handed over by the client.

4.4.3.1 Extension of 220 kV switchyard at Substation Ayni

For the connection of the new 220 kV OHL from the SS Ayni 220 kV to the SS Rudaki in the City of Penjikent the following modification work will be required in the SS Ayni:

- Installation of one (1) overhead transmission line bay equipped with:
  - 1 (one) circuit breaker
  - 1 (one) disconnecting switch with earthing switch on one site
  - 3 (three) current transformer
  - 3 (three) voltage transformer
  - 3 (three) lightning arrester
  - Control and protection equipment for the new OHL bay
  - Communication equipment for the new OHL
  - Foundation and steel structure for the new equipment
  - Cabling including cable canals
  - Leveling and gravelling of area

- Installation of one (1) coupling between the existing OHL and the new OHL equipped with:
  - 2 (two) disconnecting switch with earthing switch on one site
  - Foundation and steel structure for the new equipment
  - Cabling including cable canals
  - Leveling and gravelling of area

- Modification of the control and protection system. The existing SCMS need to extended with respect to the additional equipment.
- Modification of the communication system with respect to the extension of the OPGW respectively of the SDH network to the SS Rudaki. A multiplexer will be required.

Barqi Tojik requested to modify the existing Transformer bays at SS Ayni 220 kV as follow:

- Modification of two (2) 220/110 kV transformer bay equipped with:
  - Installation of 1 (one) circuit breaker in each bay
  - 1 (one) disconnecting switch with earthing switch on one site in each bay
  - 3 (three) current transformers in each bay
  - Foundation and steel structure for the new equipment
  - Cabling including cable canals
  - Leveling and gravelling of area

- Installation of Busbar Protection for 220 kV switchyard and modification of Control System

This modification with conventional HV open air equipment and also with compact open air SF 6 equipment is not possible due to the lack of space between existing bus-bar, transportation road and transformers (< 5 m).

This issue can be solved only by rearrangement of the complete 220 kV switchyard. As a consequence the substations needs to be switched off for the whole time of rearrangement approximately for 8 months.

As a consequence the power supply for the Penjikent Electrical Network (city of Ayni and the Penjikent Region) will be interrupted for this period.

For the reasons outlined above this modification has not been considered.

This decision was confirmed by Barqi Tojik during the presentation of the draft project design.

4.5 Recommendation for Task 2

The new 220 kV OHL will be the new backbone for the energy supply of the Penjikent Electrical Network.

With the new line the energy supply to the area, where in total 261,000 habitants are living, will be stabilized and improved up to an acceptable level with respect to availability and reliability.
The investment into the new 220 kV OHL from the SS Ayni 220 kV to the SS Rudaki together with the replacement of the outdated 220 kV equipment and the installation of the 125 MVA transformers is justified by:

- The reduction of the duration of the load shedding and by improving the quality and availability of the electrical power supply in the region. The existing and future additional demand of 416,000 MWh will be supplied to residential, commercial, industrial, agriculture, and other customers in the region (City of Penjikent, Zeravshan, Eri, Kolkhozchien etc.). The additional power will be available in the electrical network of the county in 8 months of the year (66%).
- As an additional opportunity for the future the OHL may allow in the future the export of power to the Republic of Uzbekistan especially in summer time. In the month between April and October an excess of hydro power generation capacity does exist.

4.6 Draft Initial Environmental Examination (IEE) report

The draft Final Initial Environmental Examination report is attached in the annex.

4.7 Draft Land Acquisition and Resettlement Plan

The draft Final Land Acquisition and Resettlement Plan is attached in the annex.

5. Task 3: Other items

5.1 Procurement

The procurement and contracting strategy is designed to expedite project implementation, reduce the number of tender processes required for the project while using the most adequate tender process and contract form for each of the project components.

The procurement of the scope required for the Wholesale Metering and Transmission System Reinforcement Project is foreseen as follows.
Lot 1: The wholesale metering component.
Lot 2: The transmission component including the related modifications in the substations Ayni 220 kV and Rudaki

The split into two contracts is caused by the content of the contracts which requires a different qualification and portfolio of potential bidders.

Accordingly all tenders will be organized as open tenders for international competitive bidding (ICB) in full compliance with the respective Procurement Guidelines published by ADB.

The preferred method of procurement for both lots will be turnkey contracts under which the design, engineering, customizing, the supply and installation of equipment, and the construction of the complete facilities are provided by the respective Contractor.

In the technical sections of the bidding documents the scope of supply and services in both lots can be described with sufficient accuracy for a bidder to calculate his bid.

Accordingly for both lots a one stage bidding, two envelop procedure with different envelops for the technical and the commercial proposal will be considered. The templates provided by ADB for bidding documents for “plants” will be used.

The price basis in the bids shall be a lump sum price. For adjustment to possible changes during the implementation a set of fixed unit prices will be defined. Further details will be included in the bidding documents.

Due to time saving and the structure of the standard bidding document template provided by ADB a post qualification process is recommended. The post qualification process will enable ADB and Barqi Tojik to select potential contractors/suppliers who meet contract specific qualification criteria and deemed capable of performing the contract satisfactory.

Post qualification criteria will cover the following areas:
i. General Experience,
ii. Specific Experience,
iii. Personnel Capabilities,
iv. Manufacturing Capacity,
v. Financial Position,

vi. Non-performance History,
vii. Current Obligations and Pending Awards,
viii. Specific Requirement to Joint Ventures/Consortium, etc

In order to reduce the risk of project delay and lack of quality post qualification criteria will also be stipulated for domestic suppliers who will be typically involved in Tajikistan in certain design, construction, and commissioning activities.

The qualification criteria will be further detailed in the bidding documents and the bidder will be requested to provide information using the templates provided by ADB with the bidding documents.

5.2 Project Implementation Schedule

The project implementation schedule consists of the following activities and milestones:

- Grant and ADB internal approval process: from 09/2014 up to 05/2015,
- Recruitment and appointment of Consultant: from 03/2015 up to 12/2015,
- Procurement Wholesale Metering Component: from 01/2016 up to 02/2017,
- Wholesale Metering Component execution: from 03/2017 up to 09/2019,
- Procurement 220 kV OHL construction and Substation Modifications: from 01/2016 up to 02/2017,
- 220 kV OHL construction and SS Modification execution: from 03/2017 up to 09/2019,

A project implementation plan is attached in the annexes.

5.3 Project cost estimate;

The summary of the technical cost estimate is as follows:

Base cost	Amount in Thousand USD
Task 1 Wholesale Metering System	12,200.-
Task 2 OHL and Substation Modification	
2.1 220 kV OHL between SS Ayni 220 kV and SS Rudaki	19,000.-
2.2 Equipment, materials and installation of OHL Bay in Ayni	510.-
2.3 Equipment, materials and installation of Coupling Bay in Ayni	90.-
1.6 Equipment, materials and installation of Switchgear rehabilitation Rudaki	520.-
1.7 Equipment, materials and installation of AT-1 Transformer Bay in Rudaki	3,900.-
1.8 Equipment, materials and installation of AT-2 Transformer Bay in Rudaki	3,900.-
1.9 Equipment, materials and installation of Line Bay to Saktiana in Rudaki	540.-

2	Project Implementation Consultant	5,000.-
3	Project Administration Cost	0.-
4	Environmental and Safeguard	300.-
5	Taxes and Duties	0.-
	Subtotal	**$45,960.-**

The detailed project cost estimate prepared by the Consultant is attached in the annex.

5.4 Financial analysis

Fichtner has prepared the financial analysis including the financial management assessment for the Wholesale Metering and Transmission Reinforcement Project in accordance with ADB's "Financial Management and Analysis of Projects" (2005 and 2006) and "Financial Due Diligence - A Methodology Note'' (January 2009).

The project has two distinct investment components:
1. Installation of approximately 2,700 wholesale meters and billing system; and
2. Construction of approximately 90 kilometers (km) of 220 kilovolt (kV) overhead transmission line between Ayni Substation (Ayni region) Rudaki Substation (Penjikent region) including construction of additional bays and rerouting of existing connections in both substations.

In order to evaluate the financial viability of the project, each component will be assessed individual.

5.4.1 Methodology

The with and without project analysis was performed by using a cash flow analysis projecting future revenue and cost streams for each project component based on certain assumptions. The costs and revenues are assessed over the lifetime of the project. The study period covers the construction time as well as 22 years of operations.

The basic technique for comparing costs and revenues occurring at different times during the study period is to express them in a common value at one point in them. They are set up as the cash flows and then discounted to their present values. In this way the time value of money is taken into consideration.

Since these are new projects, all cash flows are incremental for each component. The future stream of net incremental cash flow is discounted to its present value and the financial internal rate of return (FIRR) as well as the financial net present value (FNPV) are calculated in real terms. The real weighted average cost of capital (WACC) is determined based on the source and cost of financing which is then used as a benchmark to compare with the FIRR. Each project component is considered viable if the FIRR exceeds the project cost of funds as measured by the WACC. A sensitivity analysis has been conducted to establish the robustness of the project's component FIRR to changes in various parameters. A summary is shown in chapter 5.4.4 of this section.

As starting point for the financial analysis data is sourced from project investment, financing and operating plans. Fichtner has prepared a preliminary financing plan, which is subject to negotiations between lending and borrowing entities. Terms and conditions of future loan agreements might be adjusted so that the financing plan also will undergo revisions.

Details of the project investment plan and financing plan are shown in the following two tables.

Table 5-1 Project investment plan

Table 1: Project Investment Plan

($ million)

Item		**Amount** [a]
A.	**Base Costs** [b]	
	1. Wholesale Metering	17.2
	2. Transmission Lines	36.9
	Subtotal (A)	**54.1**
B.	**Contingencies** [c]	**8.1**
C.	**Financing Charges During Implementation** [d]	**4.8**
	Total (A+B+C)	**67.0**

a Includes taxes and duties of [amount] to be exempted by the government.
b In mid-2014 prices.
c Physical contingencies computed at 10% of the base costs excluding taxes and duties. Price contingencies computed at 1.5% on foreign exchange costs and 7.0% on local currency costs; includes provision for potential exchange rate fluctuation under the assumption of a purchasing power parity exchange rate.
d Includes interest for sub-loan to Barki Tojik calculated at 5%, to be financed from Barki Tojik resources.
Source: Asian Development Bank and TA consultant estimates.

Table 5-2 Financing plan

Table 2: Financing Plan

Source	**Amount** ($ million)	**Share of Total** (%)
Asian Development Bank	54.0	80.6
Government	13.0	19.4
	67.0	**100.0**

Source: Asian Development Bank estimates.

The project cost estimates include information from the technical analysis of expected annual capital expenditure during implementation including environmental and social impact mitigation, consultation services, safeguard measures and price and physical contingencies.

5.4.2 Assumptions

The following assumptions were used in carrying out the financial analysis:

Capital costs

The total base capital cost of the project (excluding contingencies and financing charges during implementation) is estimated with US$ 54.1 million. The total project volume is US$ 67.0 including price and physical contingencies as well as financing charges during implementation. US$ 54.0 million of the project cost is supported by ADB and US$ 13.0 million covered by Barki Tojik.

The total base capital cost for the wholesale metering component is estimated with US$ 17.2 million. The total costs amount to US$ 22.0 million which includes price and physical contingencies as well as financing charges during implementation.
The total base capital cost for the transmission lines component is estimated with US$ 36.9 million. The total costs amount to US$ 45.0 million which price and physical contingencies as well as financing charges during implementation.

The following four tables show the cost estimates by expenditure category, by financier, by component and by year.

Table 5-3 Cost estimate by expenditure category

A: Cost Estimates by Expenditure Category

Item		Foreign Exchange	($ million) Local Currency	Total Cost	% of Total Base Cost
A.	**Investment Costs [a]**				
	1 Wholesale Metering	10.1	2.0	12.1	22.4%
	2 Transmission Lines	21.7	6.7	28.4	52.5%
	3 Consulting Services	3.8	1.3	5.1	9.4%
	4 Land Acquisition and Resettlement	-	0.3	0.3	0.6%
	Subtotal (A)	**35.6**	**10.3**	**45.9**	**84.8%**
B.	**Taxes and Duties [b]**	**6.4**	**1.8**	**8.2**	**15.2%**
	Total Base Cost	**42.0**	**12.1**	**54.1**	**100.0%**
C.	**Contingencies [c]**				
	1 Physical	4.6	1.0	5.6	10.4%
	2 Price	1.9	0.6	2.5	4.6%
	Subtotal (C)	**6.5**	**1.6**	**8.1**	**15.0%**
D.	**Financing Charges During Implementation [d]**		**4.8**	**4.8**	**8.9%**
Total	**(A+B+C+D)**	**48.5**	**18.5**	**67.0**	**123.8%**

a In mid-2014 prices; includes environmental and social mitigation costs.
b Covered by the government resources.
c Physical contingencies computed at 10% of the base cost. Price contingencies computed at 1.5% on foreign exchange and 7.0% on local currency; includes provision for potential exchange rate fluctuation under the assumption of a purchasing power parity exchange rate.
d Includes interest for sub-loan to Barki Tojik calculated at 5%, to be financed from Barki Tojik resources.
Source: Asian Development Bank and TA consultant estimates.

Table 5-4 Expenditure by financier

C. Expenditure Accounts by Financier

($ million)

	Item	ADB Amount	ADB % of Cost Category	Government / Barki Tojik Amount	Government / Barki Tojik % of Cost Category	Total Cost
A.	**Investment Costs**					
	1 Wholesale Metering	12.1	100.0%	-	0.0%	12.1
	2 Transmission Lines	28.4	100.0%	-	0.0%	28.4
	3 Consulting Services	5.1	100.0%	-	0.0%	5.1
	4 Land Acquisition and Resettlement	0.3	100.0%	-	0.0%	0.3
	Subtotal (A)	**45.9**	100.0%	**-**	0.0%	**45.9**
B.	**Taxes and Duties**	**-**	0.0%	**8.2**	100.0%	**8.2**
C.	**Contingencies**	**8.1**	100.0%	**-**	0.0%	**8.1**
D.	**Financing Charges During Implementation**	**-**	0.0%	**4.8**	100.0%	**4.8**
	Total (A+B+C+D)	**54.0**	80.6%	**13.0**	19.4%	**67.0**
	% of Total Project Cost	**80.6%**		**19.4%**		

ADB = Asian Development Bank.

Source: Asian Development Bank and TA consultant estimates.

Table 5-5 Expenditure by component

D. Expenditure Accounts by Outputs/Components

($ million)

	Item	Total Cost	Wholesale Metering Component 1 Amount	Wholesale Metering Component 1 % of Cost Category	Transmission Lines Component 2 Amount	Transmission Lines Component 2 % of Cost Category
A.	**Investment Costs** [a]					
	1 Wholesale Metering	12.1	12.1	100.0%	-	0.0%
	2 Transmission Lines	28.4	-	0.0%	28.4	100.0%
	3 Consulting Services	5.1	2.5	49.0%	2.6	51.0%
	4 Land Acquisition and Resettlement	0.3	-	0.0%	0.3	100.0%
	Subtotal (A)	**45.9**	**14.6**	**31.8%**	**31.3**	**68.2%**
B.	**Taxes and Duties** [b]	**8.2**	**2.6**	**31.7%**	**5.6**	**68.3%**
	Total Base Cost	**54.1**	**17.2**	**31.8%**	**36.9**	**68.2%**
C.	**Contingencies** [c]					
	1 Physical	5.6	2.5	44.6%	3.1	55.4%
	2 Price	2.5	0.8	32.0%	1.7	68.0%
	Subtotal (C)	**8.1**	**3.3**	**40.7%**	**4.8**	**59.3%**
D.	**Financing Charges During Implementation** [d]	**4.8**	**1.5**	**31.3%**	**3.3**	**68.8%**
Total (A+B+C+D)		**67.0**	**22.0**	**32.8%**	**45.0**	**67.2%**

a In mid-2014 prices; includes environmental and social mitigation costs.

b Covered by the government resources.

c Physical contingencies computed at 10% of the base cost. Price contingencies computed at 1.5% on foreign exchange and 7.0% on local currency; includes provision for potential exchange rate fluctuation under the assumption of a purchasing power parity exchange rate.

d Includes interest for sub-loan to Barki Tojik calculated at 5%, to be financed from Barki Tojik resources.

Source: Asian Development Bank and TA consultant estimates.

Table 5-6 Expenditure by year

E. Expenditure Accounts by Year

($ million)

	Item	Total Cost	Year 1 2015	Year 2 2016	Year 3 2017	Year 4 2018	Year 5 2019	Year 6 2020	Year 7 2021
A.	**Investment Costs**								
	1 Wholesale Metering	12.1	-	-	1.8	3.6	4.8	1.8	-
	2 Transmission Lines	28.4	-	-	4.3	8.5	11.4	4.3	-
	3 Consulting Services	5.1	-	1.0	1.0	1.0	1.0	1.0	-
	4 Land Acquisition and Resettlement	0.3	0.3	-	-	-	-	-	-
	Subtotal (A)	45.9	0.3	1.0	7.1	13.2	17.2	7.1	-
B.	**Taxes and Duties**	**8.2**	-	0.2	1.3	2.4	3.1	1.3	-
	Total Base Cost	**54.1**	**0.3**	**1.2**	**8.4**	**15.5**	**20.3**	**8.4**	**-**
C.	**Contingencies**	**8.1**	**-**	**-**	**1.3**	**2.3**	**3.3**	**1.1**	**-**
D.	**Financing Charges During Implementation**	**4.8**	**-**	**-**	**0.2**	**0.8**	**1.5**	**2.3**	
	Total (A+B+C+D)	**67.0**	**0.3**	**1.2**	**10.0**	**18.6**	**25.2**	**11.8**	**-**
	% of Total Project Cost	**100%**	**0.4%**	**1.8%**	**14.9%**	**27.7%**	**37.5%**	**17.6%**	**0.0%**

Source: Asian Development Bank and TA consultant estimates.

Implementation period

The implementation of the project will commence in 2014 and will be completed after 3 years in 2016. A three year construction period will commence in 2016 and will be completed by 2019. The disbursement period starts in 2015 and is assumed to be 6 years (2015 to 2020).

Economic useful life

The operating life of the project is assumed to be 22 years and revenues from sale of energy and reduced losses are estimated to flow from January 2020 to December 2042.

Exchange rate and inflation

An average exchange rate of 4.9404 per US$ has been assumed for the base year 2014. For the later years, the exchange rate has been calculated on the basis of purchasing power parity (PPP), which assumed that the annual change in exchange rates is proportional to the ratio of local and foreign inflation indexes.

Tax

A corporate income tax in Tajikistan of 18% is assumed throughout the life of the project.

Depreciation

The assets are depreciated over 25 years on a straight line basis for the purpose of tax calculations.

Weighted Average Cost of Capital

The WACC is normally calculated as the weighted average cost of equity and debt used to fund the project. The cost of equity can be calculated on the basis of the Capital Asset Pricing Model (CAPM), which provides a methodology for estimating the required equity return as a function of the relative risk of the investment. According to CAPM, the cost of equity is the rate of return of a risk free investment such as government bonds, plus a risk premium appropriate for the project. Therefore, the cost of equity for a higher risk project is higher than that having a lower level of risk.

The cost of equity is expressed formulaically below:

$$\mathbf{Re = rf + (rm - rf) * \beta}$$

where:

Re = the required rate of return on equity

rf = the risk free rate
rm – rf = the market risk premium
β = beta coefficient

There is no one specific way to calculate the cost of equity in developing countries where benchmarks are not readily available. But given the assumptions here, using the CAPM does not make sense. Another method is to look at cost of equities of power companies in other developing countries, adjusting for Tajikistan's country risk. Taking previous projects into consideration, the cost of equity was selected at 8.31%.

Based on these assumptions, the overall weighted cost of capital has been calculated. The summary is shown in Table 5-7 WACC calculation.

Table 5-7 WACC calculation

WACC		ADB Sub Loan	BT	TOTAL
A	Amount (US$ million)	52.70	8.30	61.00
B	Weighting	86.39%	13.61%	100%
C	Nominal cost	5.00%	8.15%	
D	Tax rate	18.00%	0.00%	
E	Tax-adjusted nominal cost [C x (1-D)]	4.10%	8.15%	
F	Inflation rate	1.50%	7.50%	
G	Real cost [(1+E)/(1+F)-1]	2.56%	0.60%	
H	Weighted component of WACC [G x B]	2.21%	0.08%	
	Weighted average cost of capital			**2.30%**

Revenues Wholesale Meters component

The financial benefits to BT will accrue from additional incremental energy billed. Based on the projections in the income statement (retails sales revenue) and projected energy sold, Fichtner has estimated the additional energy billed by increasing the billed energy by 1.5% in 2020 compared with 2019. This additional energy billed has been further assumed to be constant for all years of the operating period considered. Incremental energy billed has been weighted with an increasing collection rate.

Replacement cost Wholesale Meters component

Replacement cost for the wholesale meters over the project period was considered with 1% of the investment cost every 5 years starting in 2025.

Revenues Transmission Lines component

The reduction of load shedding in the region is the major financial benefit for BT and is included in the assessment as revenues from incremental energy transmitted by excluding the cost of power supply.

O & M cost Transmission Lines component

The operating and maintenance cost are calculated as annual percentage of 2.5% of the investment cost. In addition, major overhauls every five years starting in 2025 with US$ 0.5 million are included

5.4.3 Results of the financial analysis

Incremental cost and benefits in constant 2014 prices were estimated over the life of the project and used as the basis of calculating the FIRR for each project component. The project cost and project net cash flows were based on constant 2014 prices for the evaluation period 2014 to 2042.

For both components, the FNPV of the projected cash flow discounted at WACC of 2.3% is positive. The real FIRR of both project components is higher than the WACC, confirming that each project component is financially viable.

Table 5-8 Summary of financial evaluation of Wholesale Meters project component and

Table 5-9 Summary of financial evaluation of Transmission Lines project component provide summaries of the financial evaluation of the project outlining the FNPV and FIRR for each project component

Table 5-8 Summary of financial evaluation of Wholesale Meters project component

Year	Period	Costs Investment costs	Replacement costs	Total Cost	Benefits	Net Cash Flow
2014	-4					
2015	-3	0.00		0.00		0.00
2016	-2	0.56		0.56		-0.56
2017	-1	3.34		3.34		-3.34
2018	1	6.05		6.05	0.00	-6.05
2019	2	8.15		8.15	0.00	-8.15
2020	3	3.90		3.90	4.65	0.75
2021	4			0.00	4.76	4.76
2022	5			0.00	4.88	4.88
2023	6			0.00	5.00	5.00
2024	7			0.00	5.12	5.12
2025	8		0.18	0.18	5.24	5.06
2026	9			0.00	5.37	5.37
2027	10			0.00	5.50	5.50
2028	11			0.00	5.63	5.63
2029	12			0.00	5.77	5.77
2030	13		0.18	0.18	5.91	5.73
2031	14			0.00	6.05	6.05
2032	15			0.00	6.19	6.19
2033	16			0.00	6.34	6.34
2034	17			0.00	6.49	6.49
2035	18		0.18	0.18	6.65	6.47
2036	19			0.00	6.81	6.81
2037	20			0.00	6.97	6.97
2038	21			0.00	7.14	7.14
2039	22			0.00	7.31	7.31
2040	23		0.18	0.18	7.48	7.30
2041	24			0.00	7.66	7.66
2042	25			0.00	7.84	7.84
FNPV		**19.41**	**0.47**		**92.26**	**72.39**
FIIR		**20.86%**				
WACC		**2.30%**				

Table 5-9 Summary of financial evaluation of Transmission Lines project component

Year	Period	Costs Investment costs	O&M costs	Major Overhaul	Total Costs	Benefits	Net Cash Flow
2014	-4						
2015	-3	0.30			0.30		-0.30
2016	-2	0.65			0.65		-0.65
2017	-1	6.62			6.62		-6.62
2018	1	12.54			12.54	0.00	-12.54
2019	2	17.00	0.00		17.00	0.00	-17.00
2020	3	7.90	0.93		8.82	7.26	-1.56
2021	4		0.93		0.93	7.39	6.46
2022	5		0.93		0.93	7.52	6.60
2023	6		0.93		0.93	7.66	6.73
2024	7		0.93		0.93	7.80	6.87
2025	**8**		0.93	0.50	1.43	7.94	6.51
2026	9		0.93		0.93	8.08	7.15
2027	**10**		0.93		0.93	8.23	7.30
2028	**11**		0.93		0.93	8.37	7.45
2029	12		0.93		0.93	8.53	7.60
2030	13		0.93	0.50	1.43	8.68	7.25
2031	14		0.93		0.93	8.83	7.91
2032	15		0.93		0.93	8.99	8.07
2033	16		0.93		0.93	9.16	8.23
2034	17		0.93		0.93	9.32	8.39
2035	18		0.93	0.50	1.43	9.49	8.06
2036	19		0.93		0.93	9.66	8.73
2037	20		0.93		0.93	9.83	8.91
2038	21		0.93		0.93	10.01	9.08
2039	22		0.93		0.93	10.19	9.26
2040	23		0.93	0.50	1.43	10.37	8.95
2041	24		0.93		0.93	10.56	9.63
2042	25		0.93		0.93	10.75	28.37
FNPV		**39.68**	**14.32**	**1.29**	**55.30**	**134.93**	**89.22**
FIIR		**14.28%**					
WACC		**2.30%**					

As the two components of the project are treated as a whole in the financing package, Fichtner has prepared an overall financial analysis which is shown in the table below

Table 5-10 Consolidated financial evaluation of the project

Year	Period	Costs			Total Costs	Benefits	Net Cash Flow
		Investment costs	O&M costs	Replacment and Major Overhaul			
2014	-4						
2015	-3	0.30			0.30		-0.30
2016	-2	1.20			1.20		-1.20
2017	-1	9.96			9.96		-9.96
2018	1	18.59			18.59		-18.59
2019	2	25.15			25.15		-25.15
2020	3	11.79	0.93		12.72	11.91	-0.81
2021	4		0.93		0.93	12.15	11.22
2022	5		0.93		0.93	12.40	11.47
2023	6		0.93		0.93	12.66	11.73
2024	7		0.93		0.93	12.91	11.99
2025	8		0.93	0.68	1.61	13.18	11.57
2026	9		0.93		0.93	13.45	12.52
2027	10		0.93		0.93	13.72	12.80
2028	11		0.93		0.93	14.01	13.08
2029	12		0.93		0.93	14.29	13.36
2030	13		0.93	0.68	1.61	14.58	12.98
2031	14		0.93		0.93	14.88	13.96
2032	15		0.93		0.93	15.19	14.26
2033	16		0.93		0.93	15.50	14.57
2034	17		0.93		0.93	15.81	14.89
2035	18		0.93	0.68	1.61	16.14	14.53
2036	19		0.93		0.93	16.47	15.54
2037	20		0.93		0.93	16.80	15.88
2038	21		0.93		0.93	17.15	16.22
2039	22		0.93		0.93	17.50	16.57
2040	23		0.93	0.68	1.61	17.85	16.24
2041	24		0.93		0.93	18.22	17.29
2042	25		0.93		0.93	37.14	36.21
FNPV		**59.09**	**14.32**	**1.76**	**75.17**	**236.78**	**161.61**
FIIR		**16.54%**					
WACC		**2.30%**					

5.4.4 Sensitivity analysis

In order to demonstrate the robustness of the cash flows of the components of the project, a sensitivity analysis has been carried out.

The objective of the sensitivity analysis was to check the results obtained in the main scenario of the financial analysis against possible vareations of major vareables. Based on these calculations, the major risks for the project can be identified. The vareables to be investigated in the sensitivity analysis are those ones which likeliness of a change in the future is highest and those that would have the greatest impact on project performance, if they would undergo a change. The vareables to be tested in the sensitivity analysis are the following:

- Capital cost increase
- Revenue decrease
- Combination of the two

The results of the sensitivity analysis are summarized in the tables below.

Table 5-11 Sensitivity analysis metering component

Summary of sensitivites		FIRR	FNPV
Base cas		20.86%	72.39
Increase Capital cost	10%	19.20%	70.44
Decrease revenue	10%	19.02%	63.16
Combined sensitivities		17.53%	0.00

Table 5-12 Sensitivity analysis transmission component

Summary of sensitivites		FIRR	FNPV
Base cas		14.28%	89.22
Increase Capital cost	10%	13.01%	85.25
Decrease revenue	10%	12.72%	75.73
Combined sensitivities		11.55%	71.76

5.4.5 Conclusion of financial analysis

The analysis of both components of the project as well as the consolidated project demonstrates that the overall project is financially viable by generating sufficient returns and positive net present values. A sensitivity analysis has confirmed this judgment.

5.5 Economic Analysis of the Project

The economic analysis of the project is carried out in accordance with the Asian Development Bank's Guidelines for Economic Analysis of Projects 1997 and based on the Terms of Reference.

The economic analysis covers the two project components:

1. Installation of approximately 2,700 wholesale meters and billing system; and
2. Construction of approximately 90 kilometers (km) of 220 kilovolt (kV) overhead transmission line between Ayni Substation (Ayni region) Rudaki Substation (Penjikent region) including construction of additional bays and rerouting of existing connections in both substations.

In line with the financial assessment, the economic viability of the project is evaluated by assessing each component separately.

5.5.2 Methodology

The economic analysis has the objective to evaluate the overall impacts of the project on the welfare of the people of Tajikistan, and to confirm the economic viability of the project. The consultant looks at the project from a societal perspective and whether the project utilizes scarce resources in an optimal manner for society.

The methodology used for the economic analysis is similar to the financial analysis. The evaluation of the project is carried out in a four step approach. Cost and benefits of the project are:

- identified
- quantified
- express in monetary terms, and
- compared to each other to derive the net benefit of the project.

The costs and benefits are assessed over the lifetime of the project covering in the study period of 22 years of operation plus a 5 year construction time. The operation is estimated to begin in 2019. The basic technique for comparing costs and benefits occurring at different times is to express them in a common value at one point in time using a discounted cash flow. That is costs and benefits are discounted to their present value applying a discount rate of 12%, recommended by ADB.

The costs and benefits are expressed in real terms in constant 2014 prices, i.e. general inflation is not considered in the projection of costs which however include O&M costs. Price contingencies and taxes and duties are not considered in the economic analysis, however physical contingencies are included.

The financial investment costs are converted in economic costs by applying shadow price approach. In an economic analysis, market prices can only be applied if they reflect the true marginal social costs to the economy. In most countries this is not the case, because of government interventions into the competitive market process through price controls, indirect taxes, duties, subsidies etc., or markets are distort due to monopolistic practices. It is therefore necessary to convert the monetary value of project investment costs and benefits into shadow prices using standard conversion factors.

Non-incremental and incremental benefits will be considered in the economic evaluation in order to assess only those effects (costs and benefits) which are attributed to the project. For the wholesale meters component, the additional energy billed multiplied by the Willingness to Pay (WTP) are measured as incremental benefits. For the transmission lines the benefits are generated through the reduction of load shedding multiplied by the WTP. These benefits are quantified in terms of energy (kWh). In order to make them comparable to the project costs, the need to be expressed in monetary terms.

In the economic analysis the economic costs of the project are compared with the benefits and the project is economically viable when the benefits exceed the costs.

5.5.3 Assumptions

Incremental economic costs

The total base capital costs of each project component have been converted into economic costs. In calculating those economic costs, transfer payments (taxes and duties) and price contingencies are excluded. The foreign price component of the investment costs is adjusted upward by a shadow exchange rate factor of 1.11, and a standard conversion factor of 0.9 is applied to the non-traded local cost components. The costs of the local labor is adjusted downward by a shadow wage rate factor of 0.8 applied to the unskilled labor portion of the local cost component (assumed to be 10% of local investment cost and physical contingencies).

Benefits

The main economic benefits for the wholesale meters component are the incremental energy billed. The economic benefits for the transmission lines component are the incremental energy transmitted generated through the reduction of load shedding and improving the efficiency of the network.

An economic value is assigned using the Willingness to Pay approach minus the cost of unserved energy.

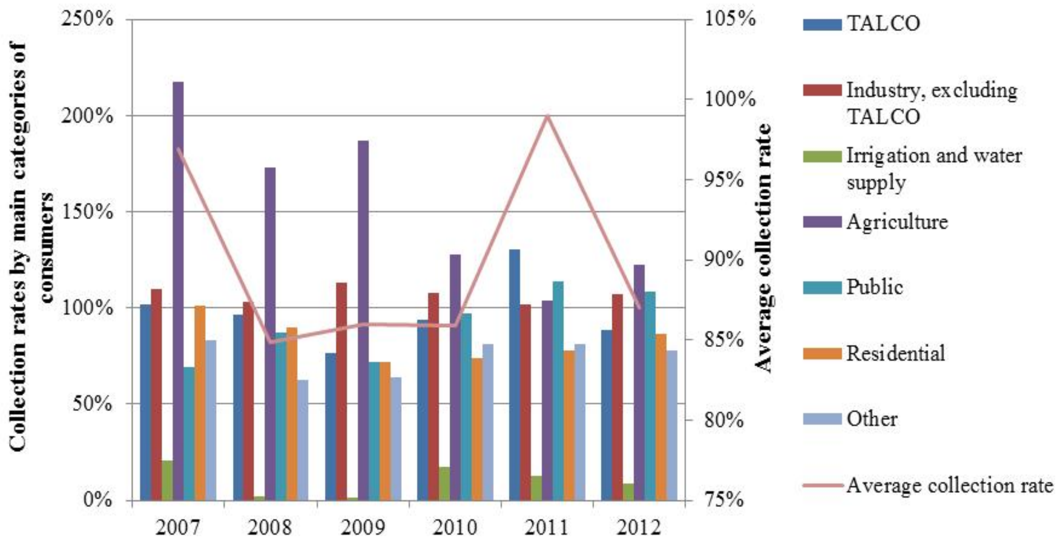
Least Cost

The Least Cost assessment serves to show that the proposed project components are the most efficient and effective solution for the reliable supply of power in the western region and in order to support the restructuring process of the energy sector the Republic of Tajikistan. The identified two components of the project represent the least cost solution to attain the overall objectives of the project. Other reasonable alternatives of the project do not exist.

Currently, wholesale meters are not installed countrywide which is a major impediment to measuring energy flows from generation to distribution. Installing countrywide wholesale metering becomes part of a number of tasks which are currently undertaken to improve BT performance. The new wholesale meters will assist to create a more reliable system of measuring, assessing and minimizing technical and commercial losses improving the collection efficiency of the network.

It was assumed that BT's collection efficiency will increase to 92% by 2018. However, data received from BT does not support this progress. BT states it collection rate for 2012 of 87.1% and fall to 83.9%. in 2013. In order to improve the collection rate, they recognise the importance of installing Automated Metering System (AMR) and SCADA. In addition, at present, as so called FinClient Program is operating in Dushanbe and Sughd Oblast that will connected to the Billing System in the near future. Figure 5-1 shows the ups and downs of the collection rates over the last years.

Figure 5-1 Collection rates 2007 to 2012[8]



Barki Tojik is solely depended on its income from selling electricity to the customers at cost recovering tariffs. Its weak financial performance resulted in higher stemmed from high supply costs and debt on the one side, and poor collection rate and tariffs that are not cost based, on the other side.

One of the key finding of the WB report is that the 2012 average weighted tariff was 27% lower than the estimated cost of supply. Besides operational inefficiencies, the collection rate of 87% contributes to the cash generation shortage. Significant tariff increases are required to overcome this situation.

The average collection rate was around 85% in 2008 to 2010, increased to 99% in 2011 due to the recovery of previous arrears and significant advance payments, and then reduced to 86% in 2012. There are large vareation in collection rates among consumer groups and an unstable payment discipline. Figure 5-1 shows collection rates by main categories of consumers from 2007 to 2012.

The Penjikent region where the new transmission line is to be build, still suffers from the disconnection from the Central Asian Power System in November 2009 when the region was supplied from two 220 kV lines from Uzbekistan. Currently, an old 110 kV line is used to supply the region with electricity. However, demand is much higher than the capacity of the line and households and industry suffer from load shedding even in summer month, when Tajikistan generally has an energy surplus.

With and without project solution

The economic assessment – as well as the financial analysis - will use incremental costs and benefits, meaning that the with and without project situations is indirectly considered. Currently the Penjikent region is under-served and any additional energy through the new transmission lines will be utilized. Wholesale meters are not installed countrywide, therefore, any additional meters will improve the measuring efficiency of BT. An incremental as-

[8] Source: World Bank estimates in World Bank (2013) Tajikistan: Financial Assessment of Barki Tojik, October 2013.

sessment is therefore reasonable.

Table 5-13 summarizes the key assumptions of the economic analysis:

Table 5-13 Key assumptions of the economic analysis

Item	Parameter
Discount rate	12%
Evaluation Period	22 years of operation plus a 5 year construction time
Start of operation	01/01/2020
Price basis	2014
Exchange rate (US$ to TJS)	4.976
Conversion factors (shadow pricing):	
- non tradable goods (local material)	0.90
- unskilled labor	0.80
Share of unskilled work	10%
Transmission lines - Annual O&M cost in % of construction cost - major overhaul every 10 yeas	 2.5% US$ 0.50 million
Wholesale meters - Overhaul costs	 1% every 5 years
WTP	US$ 0.21/kWh
Cost of unserved energy	US$ 0.25/Kwh

5.5.4 Assessment of Economic Costs

The economic costs of the project comprise all costs incurred during implementation and subsequent operation of the project, i.e. investment costs and operation and maintenance (O&M) costs of the wholesale meters and transmission lines. Environment mitigation costs are also considered. The financial investment costs are converted into economic cost, which is summarized in Table 5-14 and Table 5-15.

Table 5-14 Economic investment costs: Wholesale Meters

		Foreign US$m	Local US$m	Total US$m		Unskilled la % of local	Foreign cost US$m	Economic prices US$m	Local Labor cost Economic prices $m	Total Cost US$m
Wholesale Metering					SCF		1.11	0.9	0.8	
A.	Investment Costs									
	1 Wholesale Metering	10.10	2.00	12.10		10%	11.21	1.62	0.16	**12.99**
	3 Consulting Services	1.86	0.64	2.50		10%	2.07	0.52	0.05	**2.63**
	Subtotal (A)			**14.60**						
B.	Taxes and Duties									
	Total Base Cost			**14.60**						
C.	Contingencies									
	1 Physical	2.05	0.45	2.50		10%	2.28	0.36	0.04	**2.68**
	2 Price									
	Subtotal (C)			**2.50**						
D.	Financing Charges During Implementation		1.50	1.50		0%	0.00	1.35	0.00	**1.35**
	Total (A+B+C+D)			**18.60**						**19.65**

Table 5-15 Economic investment costs: Transmission Lines

		Foreign US$m	Local US$m	Total US$m	Unskilled la % of local	Foreign cost US$m	Local cost Economic prices US$m	Local Labor cost Economic prices $m	Total Cost US$m
Transmission Lines					SCF	1.11	0.9	0.8	
A.	Investment Costs								
	2 Transmission Lines	21.70	7.00	28.70	10%	24.09	5.67	0.56	**30.32**
	3 Consulting Services	1.94	0.66	2.60	10%	2.15	0.54	0.05	**2.74**
	Subtotal (A)			**31.30**					
B.	Taxes and Duties								
	Total Base Cost			**31.30**					
C.	Contingencies								
	1 Physical	2.55	0.55	3.10	10%	2.83	0.45	0.04	**3.32**
	2 Price								
	Subtotal (C)			**3.10**					
D.	Financing Charges During Implementation	0.00	3.30	3.30	0%	0.00	2.97	0.00	**2.97**
	Total (A+B+C+D)			**37.70**					**39.35**

The project implementation period of both components is equal to the timeframes outlined in the financial analysis.

Wholesale Meters

In addition to the economic investment costs, cost for overhaul of the wholesale meters in the amount of 1% every 5 years is included.

Transmission Lines

In additional to the economic investment costs, annual cost for operation and maintenance (O&M) are estimated as a percentage of the base cost in the amount of 2.5%, in addition, the cost of major overhauls every 10 years is included with US$ 500,000.

It is assumed that the economic lifetime of the equipment is 50 years, and a residual value has been considered using straight line depreciation at the end of the study period of 25 years.

5.5.5 Assessment of Economic Benefits

Wholesale Meters

Fichtner has identified the following benefits:

- The economic benefits for the wholesale meters component are the incremental energy billed. By installing wholesale meters countrywide the measuring process becomes more effective and efficiency increases throughout the network. BT will have an incremental revenue resulting from additional energy billed.
- From the standpoint of the entire economy of Tajikistan, it is worth to consider that consumers once they are obliged to pay for electricity consumed, there will be increasing efforts of the same to save electricity by using low consumption equipment such as bulbs with low voltage and to avoid any wasting of electricity.
- Furthermore, the installment of such meters will indirectly avoid outages and reduce losses when BT will be able to measure it technical losses more precisely.
- When the process of energy saving is initiated by the installment of the concerned metering equipment, consequently other consumers will benefit from this process because their demand of electricity can be satisfied in a more reliable way. This is an important overall economic benefit for the Tajik society, which has a lot of consequential benefits such as extension of various business areas.
- Finally, the utility BT will have a better understanding and a more clear picture on the real demand of electricity in Tajikistan which facilitates the optimization of the whole electricity system.

- In the base case, it has been assumed that in 2020 an increase of energy billed of 1.5% has been assumed which reflects the aggregate of the economic benefits of the project.

Transmission Lines

The economic benefits for the transmission lines component are the incremental energy transmitted generated through the reduction of load shedding and improving the efficiency of the network. Any additional energy generated through the new transmission line will be used by the people in the Penjikent region because currently load shedding is significant during all periods.

Willingness to pay

Willingness to pay (WTP) is defined as the maximum amount electricity consumers are prepared to pay for electricity or alternative energy sources. Some consumers are able and willing to pay more than others, and in the absence of electricity from the grid will, for example, buy a diesel generator or use kerosene for lighting. This amount depends on the uses of electricity and is different for particular groups of consumers.

To estimate WTP, one of the most likely alternate energy sources considered is self-generation. The 2013 diesel price in Tajikistan were about TJS 6.50 per liter (l) multiplied with the inflation rate to calculate the 2014 price of TJS 6.96/l of US$ 1.40/l. The most efficient diesel units generally have specific consumption of about 0.25 l/kWh, meaning that the lowest possible cost of generation from these sources is about US$ 0.35/kWh (from diesel generation). Generation from smaller generators, running on either diesel fuel or gasoline, will be more expensive, and can reasonably assumed to be 25% higher, or US$ 0.44/kWh. In calculation, the mid-point (US$0.21/kWh) between the WTP and the average tariff of $0.02/kWh was used.

Hence, the economic value is set to be US$/kWh 0.04.

5.5.6 Results of the Economic Evaluation

The incremental and non-incremental costs and benefits were set up as cash flows over the study period and discounted to their net present values. The main indicators for the economic viability of the project are:

- The economic internal rate of return (EIRR), defined as the discount rate which equalizes the net present value of benefits and the net present value of costs.
- The net benefit, defined as the difference between the net present value (NPV) of benefits and the net present value of costs.
- The benefit/cost ratio, defined as the quotient of the net present value of benefits and the net present value of costs.

A project is considered economically viable when the net benefit is positive, the benefit cost ratio is greater than 1, and the EIRR is greater than the discount rate.

The results of the economic evaluation of the Wholesale Meters project component is summarized as follows:

- The economic internal rate of return (EIRR) is 32.31%. This value is appropriate considering the character of the project and. The result confirms that all project components are essential from the viewpoint of increasing efficiency in the network by enhancing the measuring capability.
- At a discount rate of 12%, the project has a net benefit of US$ 19.84 million. This is derived from the net present value (NPV) of costs of US$ 10.69 and a NPV of benefits of US$ 30.53.
- The benefit/cost ratio is 9.09, meaning that the benefits are 9.09 times higher than the costs.

The economic costs and benefits stream for the Wholesale Meters project component is provided in Table 5-16.

Table 5-16 Wholesale Meters component: Economic costs and benefits stream and Economic Internal Rate of Return

Year	Period	Costs		Total Costs	Benefits	Net Benefits
		Economic Investment costs	Replacement costs			
2014	-4				0	
2015	-3	0.00		0.00		0.00
2016	-2	0.53		0.53		-0.53
2017	-1	3.08		3.08		-3.08
2018	1	5.44		5.44		-5.44
2019	2	7.22		7.22	0.00	-7.22
2020	3	3.39		3.39	7.50	4.11
2021	4				7.55	7.55
2022	5				7.60	7.60
2023	6				7.64	7.64
2024	7				7.69	7.69
2025	8		0.16	0.16	7.74	7.57
2026	9				7.78	7.78
2027	10				7.83	7.83
2028	11				7.88	7.88
2029	12				7.93	7.93
2030	13		0.16	0.16	7.97	7.81
2031	14				8.02	8.02
2032	15				8.07	8.07
2033	16				8.12	8.12
2034	17				8.16	8.16
2035	18		0.16	0.16	8.21	8.05
2036	19				8.26	8.26
2037	20				8.31	8.31
2038	21				8.35	8.35
2039	22				8.40	8.40
2040	23		0.16	0.16	8.45	8.29
2041	24				8.50	8.50
2042	25				8.54	8.54
NPV		**10.61**	**0.09**	**10.69**	**30.53**	**19.84**
EIIR		**32.31%**				
Discount rate		**12%**				
B/C ratio:		**9.09**				

The results of the economic evaluation of the Transmission Lines project component is summarized as follows:

- The economic internal rate of return (EIRR) is 14.93%. This value is appropriate considering the character of the project and. The result confirms that the new transmission line is essential from the viewpoint of Tajikistan's economy
- At a discount rate of 12%, the project has a net benefit of US$ 6.86 million. This is derived from the net present value (NPV) of costs of US$ 39.58 million and a NPV of benefits of US$ 46.43 million.
- The benefit/cost ratio is 2.73 and the levelized energy cost (LEC) is 1.87 US$ cents / kWh.

The economic costs and benefits stream for the Transmission Lines project component is provided in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Table 5-17 Transmission Lines component: Economic costs and benefits stream and Economic Internal Rate of Return

Year	Period	Costs			Total Costs	Benefits	Net Benefits
		Economic Investment costs	O&M costs	Major Overhaul			
2014	-4						
2015	-3	0.00			0.00		0.00
2016	-2	0.85			0.85		-0.85
2017	-1	5.91			5.91		-5.91
2018	1	11.10			11.10	0.00	-11.10
2019	2	14.94	0.00		14.94	0.00	-14.94
2020	3	32	1.63		34.13	11.72	-22.41
2021	4		1.63		1.63	11.72	10.09
2022	5		1.63		1.63	11.72	10.09
2023	6		1.63		1.63	11.72	10.09
2024	7		1.63		1.63	11.72	10.09
2025	8		1.63	0.5	2.13	11.72	9.59
2026	9		1.63		1.63	11.72	10.09
2027	10		1.63		1.63	11.72	10.09
2028	11		1.63		1.63	11.72	10.09
2029	12		1.63		1.63	11.72	10.09
2030	13		1.63	0.5	2.13	11.72	9.59
2031	14		1.63		1.63	11.72	10.09
2032	15		1.63		1.63	11.72	10.09
2033	16		1.63		1.63	11.72	10.09
2034	17		1.63		1.63	11.72	10.09
2035	18		1.63	0.5	2.13	11.72	9.59
2036	19		1.63		1.63	11.72	10.09
2037	20		1.63		1.63	11.72	10.09
2038	21		1.63		1.63	11.72	10.09
2039	22		1.63		1.63	11.72	10.09
2040	23		1.63	0.5	2.13	11.72	9.59
2041	24		1.63		1.63	11.72	10.09
2042	25		1.63		1.63	28.12	26.48
NPV		**32.93**	**6.38**	**0.27**	**39.58**	**46.43**	**6.86**
EIIR		**14.93%**					
Discount rate		**12%**					
B/C ratio:		**2.73**					
LEC:		**1.87**	**US$ cents/kWh**				

5.5.7 Sensitivity Analysis

In order to demonstrate the robustness of the cash flows of the components of the project, a sensitivity analysis has been carried out.

The objective of the sensitivity analysis was to check the results obtained in the main scenario of the financial analysis against possible vareations of major vareables. Based on these calculations, the major risks for the project can be identified. The vareables to be investigated in the sensitivity analysis are those ones which likeliness of a change in the future is highest and those that would have the greatest impact on project performance, if they would undergo a change. The vareables to be tested in the sensitivity analysis are the following:

- Capital cost increase
- Revenue decrease
- Combination of the two

The results of the sensitivity analysis are summarized in the tables below. As far as the metering component is concerned, an additional analysis has been performed, showing the impact of the increase and decrease respectively of the viability of the project resulting from increase and decrease of the combined aggregate of the economic benefits (energy billed, plus 1.5% in 2020 as base case).

Table 5-18 Results Economic Sensitivity Analysis Metering Component

Summary of sensitivities

		EIRR	ENPV
Base case		32.31%	19.84
Increase Capital cost	10%	29.83%	18.78
Decrease revenue	10%	29.57%	16.79
Combined sensitivities		27.32%	15.81
Increase of combined benefits	1,6%	34.08%	21.88
Decrease of combined benefits	1.4%	30.50%	17.80

Table 5-19 Results Economic Sensitivity Analysis Transmission Line Component

Summary of sensitivities

		EIRR	ENPV
Base cas		14.93%	6.86
Increase Capital cost	10%	13.40%	3.56
Decrease revenue	10%	12.98%	2.27
Combined sensitivities		14.20%	5.63

5.5.8 Conclusion

From the economic point of view, considering the overall expectations of the Tajik economy, the project is in a good shape and supports the economic goals of Tajikistan. It will contribute to reasonable progress in electricity supply and optimize the distribution of electricity in a efficient way.

The sensitivity analysis performed demonstrates that even in case sensitive parameters change in an adverse direction, the project still provides benefits to the economy.

5.6 Financial Management Assessment of Barqi Tojik

The Financial Management Assessment is included in the annex.

5.7 Project risks assessment

The currently identified risks for the project are attached in the annex.

5.8 Poverty and social analysis.

The poverty and social analysis is included in the LARP Report attached in the annex. Please refer to chapter 4 following.

6. Annex

Annex 1 Map of existing and planned Transmission Network_ENG_RUS.pdf
Annex 2.1 meter data base _20140806.pdf
Annex 2.1.1 Summary meter numbers 20140806.pdf
Annex 2.2 Planned Communication Network.pdf
Annex 2.3 GSM and GPRS coverage.pdf
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Annex 3.9.1 Comment Reply to draft IEE
Annex 3.10 Draft Final LARP report
Annex 4.1 Project Cost Estimate
Annex 4.2 Project Risk Register
Annex 4.3 Project Implementation Schedule