FUNCTIONAL SPECIFICATIONS OF HVAC TRANSMISSION LINE
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F. FUNCTIONAL SPECIFICATIONS OF HVAC TRANSMISSION LINE

F.1 Scope

The Governments of Afghanistan, the Kyrgyz Republic, Pakistan and Tajikistan plan to implement the CASA 1000 Transmission Project under the Central and South Asian Regional Electricity Market (CASAREM) initiative. The aim of the Project is to supply surplus power to Pakistan and to Afghanistan.

As an important component of the CASA-1000 project, it was felt necessary to develop the HVAC transmission interconnection between the Kyrgyz Republic and Tajikistan in order to transfer the surplus energy from the Kyrgyz Republic to Tajikistan for onward transmission to Pakistan and Afghanistan.

This document describes the functional specifications governing Design and Materials for the proposed 500kV AC transmission line between Tajikistan and The Kyrgyz Republic. The functional specifications for the converter stations and substations are included in Appendix G of the report.

It is to be noted that these are functional specifications only to define the general parameters of the line. The specifications will be reviewed and further detailed prior to issuance for bid purposes. The substation works at Datka and Khoudjand are not included in this consultancy mandate. The necessary additional work inside the substations required to terminate the line shall be specified and furnished by others.

F.2 Introduction

The proposed transmission line will be 500kV HVAC, installed on self-supporting lattice steel towers, and wherever required M-type guyed structures will also be utilized. The line will originate from the proposed 500 kV substation Datka near Jalalabad in The Kyrgyz Republic and terminate at the 500kV substation at Khoudjand in Tajikistan.

The approximate total length of the line is 450km. The approximate lengths in each of the two countries i.e. The Kyrgyz Republic and Tajikistan are given in the table below.

<table>
<thead>
<tr>
<th>Country</th>
<th>Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Kyrgyz Republic</td>
<td>430</td>
</tr>
<tr>
<td>Tajikistan</td>
<td>20</td>
</tr>
<tr>
<td>Total Length</td>
<td>450</td>
</tr>
</tbody>
</table>

In the Kyrgyz Republic, about 40% of the route runs within 2000 meters above sea level (masl) altitude. The remaining line route ranges between 2000-2300masl. In Tajikistan, the line route runs at an altitude ranging from 500 masl to about 900 masl.

About one fourth of the route generally follows close and parallel to the existing roads. There are a number of asphalt road crossings along the route as well as secondary motor-able roads/tracks from the main roads which cross the route. The terrain is mostly mountainous reaching an altitude of 2300 masl, with the exception of some sections near Jalalabad, few other small sections of the line in the Kyrgyz Republic, and the segment in Tajikistan are in relatively flat land. The soil varies from sierozem to fractured rock to dried river bed sandy like and in some places at high altitudes, hard rock. The right-of-way width is 100m. This
description is provided as an introduction only. The prospective contractors are expected to make their own evaluation based upon site visit.

F.3 Project Area Weather Conditions

**Khoujand (Tajikistan)**

Main parameters of weather conditions are provided below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum air temperature of the year</td>
<td>46°C</td>
</tr>
<tr>
<td>Minimum air temperature of the year</td>
<td>-26°C</td>
</tr>
<tr>
<td>Average air temperature of the year</td>
<td>14.4°C</td>
</tr>
<tr>
<td>Maximum air pressure of the year</td>
<td>992 hpa</td>
</tr>
<tr>
<td>Minimum air pressure of the year</td>
<td>943.8 hpa</td>
</tr>
<tr>
<td>Average air pressure of the year</td>
<td>967 hpa</td>
</tr>
<tr>
<td>Annual maximum precipitation in the form of rain</td>
<td>338.8 mm</td>
</tr>
<tr>
<td>Annual average precipitation in the form of rain</td>
<td>167 mm</td>
</tr>
<tr>
<td>Annual relative humidity</td>
<td>55%</td>
</tr>
<tr>
<td>Annual average thickness of drift</td>
<td>5 cm</td>
</tr>
<tr>
<td>Annual maximum thickness of drift</td>
<td>47 cm</td>
</tr>
<tr>
<td>Annual maximum thickness of frozen earth</td>
<td>0.6 m</td>
</tr>
<tr>
<td>Average number of days of thunderstorm/year</td>
<td>12 days</td>
</tr>
<tr>
<td>Average number of days of simoom/year</td>
<td>7 days</td>
</tr>
<tr>
<td>Annual average wind speed</td>
<td>4.7 m/sec</td>
</tr>
<tr>
<td>Annual duration of frost-free period</td>
<td>234 days</td>
</tr>
<tr>
<td>Thickness of cables icing</td>
<td>10 mm</td>
</tr>
<tr>
<td>Direction of annual prevailing wind</td>
<td>SW</td>
</tr>
</tbody>
</table>

According to data of Tajik weather station the following data was obtained by making use of the two methods. Maximum average wind speed at altitude 10m during 10 minutes in case by using data of 50 years is 23.56m/s. (USSR District Wind Zone III). Following the Tajik’s data the maximum wind speed during 50 years is 37 m/sec. According to the field reconnaissance by the Tajik team maximum wind speed was 32 m/sec during 20 days. Taking into account above mentioned it is recommended to use average maximum speed during 50 years at 10masl for 10 minutes as 30 m/sec.

**Jalalabad, near Datka substation (the Kyrgyz Republic)**

Monthly meteorological data from the Meteorological Centre of the Jalalabad oblast is provided in the following table.
<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature, C</th>
<th>Relative humidity</th>
<th>Maximum wind speed, m/s</th>
<th>Precipitation, mm</th>
<th>Maximum snow thickness, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Maximum</td>
<td>Minimum</td>
<td>Average %</td>
<td>Minimum %</td>
</tr>
<tr>
<td>January</td>
<td>4.4</td>
<td>5.2</td>
<td>-15.0</td>
<td>83</td>
<td>47</td>
</tr>
<tr>
<td>February</td>
<td>3.7</td>
<td>15.2</td>
<td>-7.8</td>
<td>78</td>
<td>43</td>
</tr>
<tr>
<td>March</td>
<td>10.5</td>
<td>23.5</td>
<td>3.0</td>
<td>63</td>
<td>24</td>
</tr>
<tr>
<td>April</td>
<td>15.8</td>
<td>33.5</td>
<td>1.6</td>
<td>56</td>
<td>19</td>
</tr>
<tr>
<td>May</td>
<td>21.8</td>
<td>34.0</td>
<td>10.4</td>
<td>49</td>
<td>19</td>
</tr>
<tr>
<td>June</td>
<td>24.7</td>
<td>37.0</td>
<td>13.5</td>
<td>41</td>
<td>15</td>
</tr>
<tr>
<td>July</td>
<td>26.4</td>
<td>38.0</td>
<td>15.4</td>
<td>39</td>
<td>14</td>
</tr>
<tr>
<td>August</td>
<td>26.7</td>
<td>38.0</td>
<td>16.8</td>
<td>38</td>
<td>19</td>
</tr>
<tr>
<td>September</td>
<td>20.3</td>
<td>32.6</td>
<td>9.2</td>
<td>47</td>
<td>15</td>
</tr>
<tr>
<td>October</td>
<td>16.9</td>
<td>31.5</td>
<td>9.4</td>
<td>59</td>
<td>17</td>
</tr>
<tr>
<td>November</td>
<td>8.5</td>
<td>17.6</td>
<td>-5.9</td>
<td>69</td>
<td>20</td>
</tr>
</tbody>
</table>

The maximum wind speed in the Shamaldy-Say rayon of the Jalalabad oblast is 25 m/s. But there is no date of information in the table, so using these meteorological data for projecting is limited.

The Kyrgyz Republic follows the project standards PUE- Electrical Installation Code. On the basis of these standards ice- and wind-loading projections for overhead lines shall follow the requirements of Zones II and III for 500kV lines as per PUE 2.5.

### F.4 Codes and Standards

Design, Material and Construction shall meet or exceed the requirements as stated in these specifications according to the codes and standards mentioned here below. The latest revisions of the applicable standards and codes shall be referred.

- **PUE 2.5** Electric Installation Code-Overhead lines for voltages over 1 kV
- **ANSI C29.2** Insulator, Wet-Process Porcelain and Toughened Glass, Suspension Type
- **ASCE 10-97** ASCE Standard “Design of Latticed Steel Transmission Structures”
- **ASTM A36M** Standard Specification for Carbon Structural Steel
- **ASTM A123M** Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
- **ASTM A153M** Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- **ASTM B 232** Specification for Concentric-Lay-Stranded Aluminum Conductors, Coated-Steel Reinforced (ACSR)
- ASTM A363 Standard Specification for Zinc-Coated (Galvanized) Steel Overhead Ground Wire Strand
- ASTM A394 Standard Specification for Steel Transmission Tower Bolts, Zinc-coated and Bare
- ASTM A572M Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
- ASTM B910 Standard Specification for Annealed Copper-clad Steel Wire
- AWS D1.1M Structural Welding Code, Steel
- EIA 440A Fiber Optic Terminology
- EIA/TIA-455 Standard Test Procedures for Fiber Optic Fibers, Cables, Transducers, Sensors, Connecting and Terminating Devices and Other Fiber Optic Components
- EIA 472A Sectional Specification for Fiber Optic Communication Cables for Outside Aerial Use
- EIA 492A General Specification for Optical Waveguide Fibers
- IEC 60208 Aluminum Conductors for Overhead Transmission Purposes
- IEC 60209 Aluminum Conductors, Steel-Reinforced
- IEC 1089 Round Wire Concentric Lay Overhead Electrical Stranded Conductors
- IEC 120 Dimensions of Ball and Socket Couplings of String Insulator Units
- IEC 60372 Locking Devices for Ball and Socket Couplings of Insulator Units – Dimensions and Tests
- IEC 60305 Insulators for Overhead Lines with a Nominal Voltage above 1000V—Ceramic or Glass Insulator Units for AC Systems. Characteristic of insulator units of cap & pin type
- IEC 60383 Insulators for Overhead Lines with a Nominal Voltage above 1000V—Ceramic or Glass Insulator Units for AC Systems. Parts 1&2
- IEC 61467 Insulators for Overhead Lines-Insulator Strings and sets for lines with a Nominal Voltage above 1000V-AC power arc tests
- IEC 60652 Loading Tests on Overhead Line Towers
- IEC 60826 Design criteria of overhead transmission lines
- IEC 60793-1 General Specification, Optical Fibers
- IEC 60794-1 General Specification, Optical Fiber Cables
- IEC 61089 Round Wire Concentric Lay Overhead Electrical Standard Conductors
- IEC 61232 Aluminum Clad Steel wire for Electrical Purposes
- IEC 61854 Overhead Lines – Requirements and Tests for Spacers
• IEC 61897 Overhead Lines – Requirements and Tests for Stockbridge type Aeolian Vibration Dampers
• IEEE 1138 Standard Construction of Composite Fiber Optic Overhead Ground Wire (OPGW) for use on Electric Utility Power Lines
• ITU-T G.652 Characteristics of a Single Mode Optical Fiber Cable

F.5 System Conditions

Unless otherwise specified in the specifications, the following are the Power system and ambient conditions governing the line:

- Rated voltage: 500kV HVAC +/-10%
- Altitude above sea: Up to 2300m
- Average annual ambient temperature: 15 deg C
- Maximum ambient temperature: 46 deg C
- Minimum ambient temperature: -26 deg C
- Maximum conductor temperature: 75 deg C

F.6 Drawings

The following outline sketches of towers and USSR Zoning maps are included with these Functional Specifications:

- Suspension Tower outline sketch;
- M-type (guayed) 0°;
- M-type (guayed) upto 5° line angle;
- Angle Type (Light and Heavy Angle);
- Dead-End, Angle, three post, self supporting, Angle 0° -60°;
- USSR Zoning Map for ice wall thickness (sheets 1 &2); and
- USSR Zoning Map for wind pressure (sheets 1 & 2).

F.7 Design and Material

Engineering and design shall be carried out as per applicable codes and prudent engineering practices. The following are general guidelines for the line design. More detailed guidelines shall be established prior to issuance of bid documents.
F.8 Survey Guidelines

The proposed transmission line corridor has been established, based on a site reconnaissance and preliminary Environmental and Social Impact Studies and is shown on 1:35,000 scale maps included with these specifications (Refer to Appendix C for maps). The centre line of the indicated route is considered as the centre line of a corridor 500m wide within which the final transmission centre line is to be located. The line contractor(s) will be responsible for carrying out the detailed Environmental and Social Impact Studies and for selecting the final centre line within the 500m wide corridor such that environmental and social impacts are minimized. In certain sections, subject to the Owner's approval, it may be advantageous to locate the line outside of the indicated corridor to minimize impacts and/or improve access. The contractor shall submit the detailed Environmental and Social Impact Studies together with his finally selected centre line to the Owner for approval.

After approval of the final centre line, the contractor shall carry out the detailed line survey and prepare plan and profile drawings at a suitable scale. The survey shall include:

- Location points of line deflections (angle points) on site and staking them with permanent markers.
- All points shall be identified in terms of latitude, longitude and elevation above sea level as well as the grid system applicable to the country.
- Appropriate feature codes shall be identified by contractor, and each point shall be identifiable by the feature code. The survey data should be in a format to be imported in the line design program PLS-CADD.
- The contractor will be responsible to survey sufficient points for proper line design and all features that may affect line design.
- The profiles shall be measured along centre line and below the lowest conductor attachment points.
- The points will be measured at maximum intervals of 10m and wherever there is a change in slope.
- Survey and details of obstacles including but not limited to houses, water channels, power lines, telephone lines, vegetation, trees, ground surface, fences, etc. The survey data for line crossings shall include information regarding voltage, structure number, wire quantities, material of support, structure sketch, elevation of conductor supports and sags, and ambient temperature.
- Separate sketches showing plan, profile and all important horizontal and vertical clearances, shall be prepared for all important crossings.

F.9 Line design and layout

The latest version of PLS-CADD will be used for line design purposes. Contractor will be responsible to prepare detailed design criteria, importation of survey data into PLS-CADD, structure modeling, and spotting and optimization.

The following minimum vertical clearances to ground shall be maintained during line design. Vertical clearances will be measured with conductor at final sag at maximum conductor temperature, 75 deg C.
Contractor will ensure that electrical clearances and insulator swing requirements are maintained during structure spotting. The requirements of the Electric Installation Code, PUE 2.5 are to be adhered for vertical and horizontal clearances in various terrains and different circumstances. Also, the maximum distance between any two anti-cascading towers shall not exceed approximately 10km.

As part of line design and layout, the contractor will submit as a minimum the following documents for review:

- Detailed design criteria;
- Route plan drawing;
- Plan & Profile drawings with structures spotted;
- Structure list;
- PLS-CADD back-up; and
- Drawings for crossings.

### F.10 Towers

#### F.10.1 General

The towers shall be self-supporting; broad based galvanized lattice steel towers with two overhead shield wires (one OPGW and one aluminum clad steel) or M-type Guyed structures depending on the terrain, accessibility and locations of structures. The proposed line configuration is horizontal single circuit.

#### F.10.2 Tower Types

The following tower configurations are proposed for this line. All leg extensions for a specific tower type shall also fit the respective body extensions. Unequal leg extensions shall be designed for use at locations with sloping sites.

<table>
<thead>
<tr>
<th>Tower Type – Suspension</th>
<th>Application</th>
<th>Line angle</th>
<th>Body extensions</th>
<th>Leg extensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tangent/small angle structure, suspension strings</td>
<td>0 to 2 deg.</td>
<td>+3m, +6m</td>
<td>0m, 1m, 2m, 3m, 4m</td>
</tr>
</tbody>
</table>
M-Type Guyed structures  Suspension Strings
  Line angle  0 deg
  Line angle  up to 5 deg

Tower Type – Angle
  Application  Medium angle tower with tension strings
  Line angle  0 to 30 deg.
  Body extensions +3m
  Leg extensions 0m, 1m, 2m, 3m, 4m

Tower Type – Angle
  Application  Heavy angle/terminal tower with tension strings
  Line angle  0 to 60 deg.
  Body extensions  None
  Leg extensions 0m, 1m, 2m, 3m, 4m

Dead-end, Angle, three post, self supporting with Tension Strings
  Line angle up to 60 deg.

- Additionally, anti-cascade and transposition structures shall be designed and provided as required.

The families of towers will be required, for use at elevations up to 1000m, at elevations between 1000 and 2000m and at elevations above 2000m.

The types of towers mentioned above are illustrated in the drawings at the end of this appendix.

**F.10.3 Material**

The tower members shall be of structural steel conforming to the latest provisions of the following standards:

- ASTM A36M  250 MPa minimum yield strength
- ASTM A572M (Grade 345)  345 MPa minimum yield strength

The minimum thickness of structure members shall be as follows:

- Leg members, Ground-wire peak members, 6mm
- Main cross-arm members 5mm
- Other stress carrying members 4mm
Bolts, nuts and washers shall conform to ASTM A394, ASTM A563M and ASTM F436 respectively or equivalent. Only two bolt diameters shall be used 16mm and 20mm. All bolts of the same diameter shall be of the same grade. Each tower type shall use only one diameter of bolts.

F.10.4 Galvanizing

All structural steel members shall be hot-dip galvanized in accordance with the requirements of ASTM A123M. The minimum coating thickness shall be 86microns, equivalent to 610g/m2.

The stub angles need not be fully galvanized. These can be galvanized for exposed sections only.

F.10.5 Tower loads

All Tower Types shall be designed for the following design spans, loadings and load cases:

Design spans

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Span</td>
<td>450m</td>
</tr>
<tr>
<td>Max. Wind Span</td>
<td>525m</td>
</tr>
<tr>
<td>Max. Weight Span</td>
<td>650m (Suspension Towers)</td>
</tr>
<tr>
<td></td>
<td>900m (Angle Towers)</td>
</tr>
<tr>
<td>Min. Weight Span</td>
<td>-300m (Angle Towers)</td>
</tr>
</tbody>
</table>

M-Type (Guyed)- 0°

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Span</td>
<td>450m</td>
</tr>
<tr>
<td>Max. Wind Span</td>
<td>450m</td>
</tr>
<tr>
<td>Max. Weight Span</td>
<td>575m</td>
</tr>
</tbody>
</table>

M-Type (Guyed)- upto 5°

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Span</td>
<td>420m</td>
</tr>
<tr>
<td>Max. Wind Span</td>
<td>420m</td>
</tr>
<tr>
<td>Max. Weight Span</td>
<td>525m</td>
</tr>
</tbody>
</table>

M-Type (Guyed)- 0°

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Span</td>
<td>450m</td>
</tr>
<tr>
<td>Max. Wind Span</td>
<td>450m</td>
</tr>
<tr>
<td>Max. Weight Span</td>
<td>575m</td>
</tr>
</tbody>
</table>
Dead-end, Angle up to 60°, three post, self supporting
Max. Wind Span  420m
Max. Weight Span  650m

Design Loadings
In formulating the design loads the USSR Zoning Maps for the wind pressure and ice wall thickness, attached to this specification , shall be used.

The standard wind pressure (N/m²) and radial thickness of glazed ice(mm) for the probable zones in the project area are as follows:

- Zone II area: wind pressure 500 N/m², radial ice thickness of 15mm
- Zone III area: wind pressure 650 N/m², radial ice thickness of 20mm
- Zone IV area: wind pressure 800 N/m², radial ice thickness of 25mm

The loads shall be adjusted to cater for the correction factor for rise of wind pressure with height for relevant type of terrain. The loads as well as the wind direction on conductors, towers and insulators are to be further multiplied with appropriate Safety factors and applied in accordance with the Electric Installation Code, PUE 2.5.

Load Case 1, Normal Cases
All structures shall be designed to withstand loadings due to the Maximum Wind, Maximum Ice, and Ice and Wind loads as defined above. Transverse, longitudinal and vertical loads shall be applied concurrently, and comprise the followings:

- Transversal loadings due to wind pressure on bare or ice coated wires
- Transversal loadings due to wire tensions at line angle
- Longitudinal loadings due to wire tension
- Vertical loadings due to bare or ice coated wires and insulators
- Wind loading on tower surfaces
- Self weight of tower

The wind loadings shall be calculated with all wires intact and wind acting perpendicularly on the conductors for the maximum design wind span. Maximum design line angle for each structure type shall be considered to calculate the transversal loadings due to wire tensions. The weight of insulators and hardware shall be added to wire weights for the maximum weight spans to calculate vertical loadings.

The factor of safety or overload factors for tower designs under Normal Cases shall be as follows:
All vertical loads 1.15
All transverse loads 1.1
Longitudinal loads 1.15

Load Case 2, Construction and Maintenance Loads

All towers shall be designed to withstand the loads applied during construction stages (tower erection and stringing works) and maintenance phase. These loads shall be defined by the contractor, and adequately mentioned on tower drawings and construction manual. The minimum factor of safety shall be 2.0.

Additionally, all structural members that may be required to support a lineman shall, by calculation, be able to support a 1500 N load, applied vertically at their midpoint, conventionally combined with the stresses present during maintenance. These are usually based on still air at the minimum temperature assumed for maintenance operations.

Load Case 3, Unbalance Conditions

Failure containment loads and un-balance loads due to broken conductors on suspension and tension towers.

F.10.6 Insulator swing

The following minimum clearances shall be maintained between energized part and closest tower member (body or cross-arm) after insulator swing vertical. All clearances shall be measured from closest energized part (conductor or suspension clamp or yoke plate).

<table>
<thead>
<tr>
<th>Altitude (masl)</th>
<th>Clearance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1000</td>
<td>3300</td>
</tr>
<tr>
<td>1000 to 2000</td>
<td>3600</td>
</tr>
<tr>
<td>2000 to 4000</td>
<td>5000</td>
</tr>
</tbody>
</table>

The provision of a safe tower climbing clearance of 4.5m as required by PUE 2.5 shall be maintained.

Tower clearances and insulator swings shall be clearly identified in tower outline drawings.

F.10.7 Tower tests

In addition to material tests and inspections identified in the QA/QC sections, Tower Types A and D shall be full scale load tested at a reputable tower testing facility. The testing shall be conducted on the tallest towers of each type. The tests will be witnessed by the Owner/consultant’s representatives.
Prototype assemblies of towers and all their body and leg extensions shall be conducted prior to mass production. Any anomalies observed during prototype assembly shall be rectified prior to mass production.

F.10.8 Drawings
Contractor will provide Tower outline drawings for each type. The outline drawings will indicate all important dimensions and incorporate all body and leg extensions.

A second set of drawings shall be provided indicating the loading conditions.

The third set of drawings will comprise of detailed erection drawings.

F.10.9 PLS-Tower model
The contractor will develop PLS-Tower model (Level-2 and 4) for all structure types. These shall be used for structure spotting purposes.

F.11 Phase Conductor
Each phase configuration is quad-bundle conductor comprising ACSR Pheasant. All associated conductor fittings such as spacers (or spacer-dampers), Stockbridge type dampers, armour rods, mid-span joints, dead-ends etc are to be supplied. The sub-conductor spacing of 400mm to 460mm (or 18 inches) shall be employed.

The maximum allowable tension (final tension with no wind) under Everyday Stress (EDS) shall not exceed 20% of the conductor ultimate tensile strength (UTS).

F.12 Optical Ground-wire (OPGW)
The line shall be equipped with an Optical Ground Wire (OPGW) cable installed on one of its peaks.

OPGW design shall have mechanical and electrical characteristics similar to Aluminum clad steel conventional ground wire. The OPGW shall be able to withstand a short circuit current capacity of 20 kA for 0.3 sec.

The OPGW cable shall incorporate 24 optical Single Mode Fibres (SMF) housed loose inside one (or multiple) optical unit(s) with adequate excess fibre length to avoid any fibre strain at maximum allowable tension.

The minimum optical requirements for the fibres are:

- Number of fibres: 24 SMF
- Type of fibre: Compliant to ITU-T G.652, latest edition
- Maximum attenuation of the fibre: 0.18 dB/km @ 1550 nm

The OPGW shall be of proven design. The bidder will be responsible to provide a list of transmission lines where OPGW of similar design / make has been used.

The optical unit shall be of stainless steel tube sealed with seamless welding totally free from any leaks or pinholes. Alternate optical units (metallic or non-metallic) can also be proposed. The inside of the tubes must be filled with gel to prevent moisture ingress. The buffer tube-filling compound must be non-toxic and safe. It must be free from foreign matter, chemically and mechanically compatible with all cable components, non-nutritive to fungus, non-hygroscopic, and electrically non-conductive.
Armour shall consist of Aluminium Clad Steel wires having minimum of 20% conductivity or a mixture of Aluminium Clad Steel wires and Aluminium Alloy wires to achieve required electrical and mechanical characteristics. Sag tension coefficients compatible with PLS-CADD software will be submitted with the bid.

OPGW design must provide protection from damage for the optical fibres when subjected to installation, environmental and operational conditions.

The OPGW fittings and accessories, including but not limited to joints, suspension units, tension units, dampers, cleats etc shall be approved by the OPGW manufacturer, without voiding the warranties.

A complete set of installation instructions shall also be provided by the OPGW manufacturer, which shall be strictly followed during the course of project execution.

The maximum allowable initial and final tensions at the same temperatures and loadings as specified for the conductor shall not exceed the OPGW manufacturer’s recommendations.

F.13 Overhead Shield-wire (OHSW)

The line shall be equipped with an aluminum clad steel overhead shield wire mounted on the other peak. The shield wire shall have the following characteristics:

- Overall diam. 9.78mm
- No strands/diam. 7/3.26mm
- Rated tensile strength 71kN
- Weight 0.39kg/m

All OHSW fittings such as dampers, mid-span joints, dead-ends, etc. are to be supplied.

The maximum allowable final unloaded “everyday” tension at the same temperatures as used for the phase conductor shall not exceed 15% RTS.

F.14 Insulators, Hardware and Accessories

Only insulator units, hardware and accessories specifically designed for HVAC application and manufactured by companies with a minimum of twenty years of manufacturing experience and of satisfactory in-service performance of such insulators will be accepted.

The insulator discs shall be manufactured from high resistivity porcelain or toughened glass specifically formulated for HVAC application and designed to produce uniform mechanical and electrical stress distribution. The cap shall be of malleable cast iron or forged steel. The pin shall be of forged steel. All insulator units shall be provided with two pure zinc sleeves—one bonded to the cap and one to the pin—to minimize corrosion of the metal parts. All parts of the insulator unit shall be assembled using stable and inert Portland or Alumina cement. Split pins shall be of copper alloy or stainless steel. All HVAC insulator units shall be manufactured and tested in accordance with applicable IEC Standards

All suspension strings shall be double I strings or V strings (where required) and all tension strings shall be quad strings. Jumper strings shall be single strings. The characteristics of the insulator units shall be as follows:
Suspension Units | Tension Units
--- | ---
E.M. Rating (kN) | 160 | 210
Shed Diam., Nominal (mm) | 320 | 320
Unit Spacing, Nominal (mm) | 170 | 170
Creepage Distance/Unit, Nominal (mm) | 550 | 550
Wet Power Frequency Withstand (kV) | 50 | 50
Dry Lightning Impulse Withstand (kV) | 140 | 140
No. of Units/string | 2x34 | 4x36

All hardware associated with both suspension and tension insulator strings is to be supplied.
The insulator strings and armours shall meet the below mentioned minimum safety factors as required by Electric Installation Code, PUE 2.5

1. Normal Conditions
   - Under maximum loads: 2.5
   - Under Every Day loads (EDS):
     - Double Suspension strings: 5.0
     - Quad Tension String: 6.0

2. Emergency Conditions: 2.0

3. Normal & Emergency Conditions
   - For hooks & pins: 1.1

F.15 Tower Foundations

All ultimate foundation loads resulting from the tower designs shall have a further factor of safety of 1.1 for Suspension structures and 1.2 for Tension structures applied for foundation design. Appropriate Seismic loads shall also be included.

A soil investigation has not been carried out. The contractor is required to carry out a comprehensive soil investigation to determine the foundation design parameters. However, based on visual investigations in Tajikistan and the Kyrgyz Republic, it is envisaged that the following foundation types will be required:
### F.16 Tower Grounding

All towers shall be provided with standard grounding on two diagonally opposite legs. Standard grounding shall consist of one 3m long 20mm diameter copper-clad steel grounding rod connected to the tower leg by means of copper-clad steel wire. The tower grounding resistance required is less than 15ohms. Supplementary grounding, consisting of standard grounding on the other two tower legs as a first stage and counterpoise cable as a second stage, shall be installed to achieve the required ground resistance. In hard rock ground other suitable methods of grounding shall be employed. Additionally, the guidelines provided in Electric Installation Code, PUE 2.5 for the grounding and measurements of tower footing resistances shall be complied.

### F.17 Security and Restoration Requirements

#### F.17.1 Security Requirements during construction

The Contractor(s) shall be required to exercise round the clock watch and ward for the material storage yards, site offices and the worker’s camps. Similarly, the material/equipment distributed to tower sites for construction/installation shall also have to be protected from any possible pilferage or vandalism until the construction/installation has been completed.

#### F.17.2 Security and Restoration Requirements during Operation and Maintenance

The proposed O&M organization for the lines shall be equipped with an Emergency Restoration System to deal with line failure due to natural catastrophe or uncontrollable human acts. The Contractor shall supply a pre-designed system of 10 number Chanettes for

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<th>Soft Rock</th>
<th>Good Soil</th>
<th>Poor Soil</th>
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<td>1600</td>
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<td>Angle of frustum resisting uplift (deg.)</td>
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<td>30</td>
<td>30</td>
<td>20</td>
<td>15</td>
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<tr>
<td>Mass of concrete resisting uplift (kg/m3)</td>
<td>2300</td>
<td>2300</td>
<td>2300</td>
<td>1850</td>
<td>1350</td>
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<tr>
<td>Ultimate earth bearing pressure (kN/m2)</td>
<td>2000</td>
<td>1100</td>
<td>370</td>
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500 KV single circuit Quad bundle AC Line designed and tested in accordance with IEEE 1070 Guidelines.

The Emergency Restoration System shall be supplied complete with all insulators, hardware, foundation plates/joints, anchors, tools and tackles and gin poles etc. and stored in a "ready to transport" container at one of the Converter sites or at a spare material store yard.

The O&M staff shall be trained by the Contractor for the field engineering and field installation of the Emergency Restoration System to ensure that field staff acquire proficiency in restoring failed structures in different scenarios of emergency.
500 kV Tower
Dead-end, angle, three-post, self-supporting
Angle 0° to 60°
Pic. 2.5.1  USSR Zoning map for wind pressure. Sheet 1

Pic. 2.5.2  USSR Zoning map for wind pressure. Sheet 2
Pic. 2.5.3  USSR Zoning map for ice wall thickness. Sheet 1

Pic. 2.5.4  USSR Zoning map for ice wall thickness. Sheet 2
PART I

SCOPE DEFINITION
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G-1  PROJECT DEFINITION

The proposed HVDC transmission system shall be a 3-terminal system operating on a +/-500kV bipolar overhead line, 750km long, the system linking the hydro generation in Tajikistan to the load centres in Afghanistan and Pakistan.

The capacity of the three converter stations shall be 1300 MW in SANGTUDA 1, Tajikistan, 1300 MW in Peshawar, Pakistan and 300MW in Kabul, Afghanistan. All converters shall be capable of operating as either rectifiers or inverters, so as to import or export power as needed.

The connecting AC systems shall be 500kV, 50Hz in Tajikistan and Pakistan, and 230kV, 50Hz in Afghanistan.

This document provides the functional specifications governing the design and material for the proposed converter stations and their integration into the respective 500kV or 230 kV AC systems. This document also assumes that suitable sites can be found in the vicinity of each converter station for the installation of an electrode. This can only be confirmed at the time of detailed studies when site outlines and preliminary layouts are prepared.

It is to be noted that these functional specifications only define the general parameters of the converter stations. The specifications will be reviewed and further detailed prior to the issuance for bid purposes.

The functional specifications for the HVDC transmission line are not covered in this specification. These are covered in Appendix E.

G-2  SCOPE OF WORK

G-2.1  Work Included

The scope of work of the contractor shall include a turnkey, lump sum supply of three (3) completely operational converter stations and ground electrodes, including:

- Overall project management;
- Studies, design and detailed engineering;
- Manufacturing, supply and delivery, installation, testing and commissioning;
- Design and construction of all civil works;
- Transfer of technology including training of operation and maintenance personnel;
- Assistance in operation and maintenance during the guarantee periods;
- Supply of tools and spare parts;
- Supply of complete documentation; and
- Provision of guarantees.
G-2.2 System Engineering and Studies

The Contractor shall be responsible for performing all necessary system and design studies to ensure that the equipment to be supplied will be in conformance with the Specification.

The Contractor shall perform studies to investigate the effect of the HVDC converters on the ac networks to which they are connected and vice-versa to determine all constraints on design necessary to ensure that the converters perform in accordance with the Specification when connected to the ac networks throughout the life of the equipment. The System Studies shall provide data needed for the Design Studies and for the equipment design.

The system studies shall include, but shall not be limited to:

- Assessment of Short Circuit Levels;
- Definition of Response Requirement (Operation Mode);
- Reactive Power Management;
- Definition of Harmonic Impedance.

The design studies shall include, but shall not be limited to:

- Main Circuit Design (including steady state and short time rating requirements of all main power circuit equipment such as high voltage cables, step down transformers if used, circuit breakers and disconnects, converter valves, transformers, harmonic, PLC, and other filters);
- Harmonic Filter Design;
- RI, TVI, and PLC Filter Design;
- Audible Noise;
- Auxiliary Power Supply Requirements;
- Losses;
- Over voltages;
- Insulation Coordination; and
- Availability and Reliability.

The Contractor shall perform studies and field investigations to determine the locations of the required ground electrodes and define the parameters of the electrodes and connecting lines to the converter stations.

G-2.3 Engineering and Detailed Design

The Contractor shall be responsible for the engineering and detailed design of the HVDC converter stations and electrodes. The Contractor shall design all equipment to meet the requirements of this specification and to be suitable for the application in the environment described. The detail design shall include, but not be limited to, the following main items in accordance with requirements of the Specification:
• Design and specification of all equipment, systems and subsystems in the converter stations and associated electrodes;
• Station design including all electrical, mechanical and civil engineering, and construction and installation specifications;
• Detail design of all interfaces with the Employer supplied equipment, services and facilities; and
• Design of all temporary construction facilities.

A design basis memorandum shall be prepared for each item of equipment, which shall detail the functional specification for the equipment and the parameters, which will be demonstrated by test.

The Contractor shall be responsible for all subsurface investigations required to establish foundation criteria and parameters for all Site buildings and structures.

G-2.4 Manufacture and/or Supply of Equipment

G-2.4.1 HVDC Converter Equipment

The HVDC converter equipment to be designed, manufactured, tested, supplied, installed and commissioned by the Contractor in accordance with the Specification shall include, but not be limited to, the following major items:

a) Converters and associated auxiliaries, including monitoring, reporting and display systems;

b) Converter/station controls and protection and all associated measuring devices including interfaces with supervisory control and high speed signalling and recording of transient disturbances on the system;

c) Valve cooling systems, including apparatus, control, monitoring and associated piping.

d) Valve hall ventilation systems, including apparatus, control, monitoring and display systems;

e) HV & LV pole equipment and all associated bus-work, insulators, switchgear, controls, protection and measuring devices;

   i. Pole/valve-group/station start, stop etc.; automatic sequences and interlocking systems;

   ii. Master controls of the interconnections;

g) Converter transformers complete with on-load tap-changers, insulating oil and associated control and protection; and

h) DC smoothing reactors complete with associated controls and protection.
G-2.4.2 HVAC Equipment

The HVAC equipment to be designed, manufactured, tested, supplied, installed and commissioned, in accordance with the Specification, by the Contractor shall include, but not be limited to, the following major items:

a) High voltage circuit breakers;
b) High voltage disconnect switches (isolators) and earth (ground) switches;
c) Current transformers for protective relaying, metering and control;
d) Surge arresters;
e) PLC filters;
f) Bus-work, high voltage cable, insulators and hardware including connections to the 500 kV or 230kV switching stations;
g) Protective relaying, control, instrumentation, metering, monitoring, recording and annunciation for all equipment within the scope of the Specification; and
h) All interlocking logic required for the AC equipment.

G-2.4.3 Reactive Compensation Equipment

The reactive compensation equipment to be designed, manufactured, tested, supplied, installed and commissioned by the Contractor, in accordance with the Specification, shall include all the AC harmonic filters, shunt capacitors and reactors and other types of compensation as determined by the studies referred to elsewhere in the Specification. The facilities shall include all control, protection, monitoring and switching equipment.

G-2.4.4 Station Electrical and Mechanical Systems and other Services

The Contractor shall design, manufacture, test, supply, install and commission all the station auxiliary systems and services in accordance with the Specification including, but not limited to:

a) AC and DC insulators and bus-work;
b) Station service transformers;
c) Station service metalclad switchgear, instrument transformers, power centers, motor control centers and AC and DC distribution systems;
d) Uninterruptible power supplies, batteries, battery chargers and associated controls and protection;
e) Diesel generators with all protection, control and auxiliaries;
f) Operator control board/desks;
g) Alarm, monitoring, annunciation and reporting systems;
h) Converter station operation, metering and recording facilities;
i) PAX system and all other devices including telephones, associated cables, conduits and accessories;
j) Lighting systems, including indoor, outdoor and emergency lighting;
k) Complete grounding grid (including interconnection with the Employer’s and existing grids and extension to 2 m outside fence) including connection to apparatus, cubicles, structures, cable trays, perimeter fence etc. and lightning protection system;
l) All cabling systems (including those for power distribution, lighting systems, control and protection systems and other auxiliary systems) and all associated cable trenches and cable trays;
m) Water distribution, treatment and storage systems for equipment cooling, fire protection, domestic and other uses within the station;
n) Air conditioning and ventilation systems;
o) Fire detection, protection and fighting systems;
p) Site maintenance, handling, testing and re-commissioning facilities/equipment; and
q) Control, protection, monitoring, metering for all auxiliary services, as required.

G-2.4.5 Electrodes

The required ground electrodes to be designed, supplied, installed and commissioned, in accordance with the Specification, by the Contractor shall include, but not be limited to, the following major items:

a) Determination of locations;
b) Investigations of deep resistivity;
c) Studies of interference with buried metallic installations, such as pipelines;
d) Studies of interference with adjacent electrical networks, transformers and transmission towers, etc.;
e) Thermal studies of proposed electrodes and suitability of soils;
f) Detail designs of the electrodes and their interfaces with the respective converter station;
g) Testing of the thermal capacity of the electrodes; and
h) Testing of the interference with adjacent installations.

G-2.4.6 System Control Centre

The Contractor shall provide, as part of the installation in the SANGTUDA 1 converter station, the facilities for the management, dispatch and remote control of the HVDC transmission system including the communication facilities to the respective country’s dispatch centers.

The general functional parameters for the system control center are given in Appendix 1.
G-2.5 Civil Works

The Contractor shall provide the civil works within the area allocated to the converter facility. The Contractor shall determine and shall state in his tender the space required for each converter station and for the total converter facility. An area 200m x 200m for each converter station has been assumed. The Contractor shall supply and install a secure fence around the perimeter of each converter station. An access way of at least 10m in width shall be allowed between adjacent converter stations. Access from one converter station to another shall be through the main gates to the converter station areas.

The scope of supply shall include, but shall not be limited to, the major items given in the following sub-sections.

G-2.5.1 Site and General Services

a) Site domestic sewage collection system including connection to the Employer’s raw sewage system immediately outside the fence;

b) Site drainage systems inside the fenced area with capacity including the area of the future equipment inside the fenced area and connected to the external drainage system of the fenced area;

c) Gravel filling and site preparation beyond levelling;

d) The external perimeter fence;

e) Site roads and/or rail tracks complete with drainage ditches;

f) Site landscaping and surface treatment to ensure safety and proper operation of all equipment in the switchyard;

g) Cable trenches, and subsurface duct systems under service roads, road and rail track crossings, sump pits and sump pumps for cable trenches;

h) Oil containment and recuperation systems around all transformers and oil-filled reactors including a central oil sump pit connected to the local soak oil pits of the transformers and reactors so as to ensure the containment of any oil spills from transformer and reactors; and

i) Water storage tanks for fire fighting, cooling, etc.

G-2.5.2 Buildings

a) Converter buildings comprising valve halls, control and relay rooms, electrical and mechanical rooms, maintenance, testing, storage and general services facilities;

b) System control building; and

c) Other buildings or enclosures found necessary as a result of detail design of the converter stations and electrodes.

In addition to the above, proper facilities shall be provided to accommodate the operational and maintenance personnel.
G-2.5.3 Switchyard Foundations and Structures

a) Foundations for all HVAC switchyard equipment and structures including converter transformers, smoothing reactors, etc.

b) All HVAC switchyard structures including strain bus structures, filter support structures, rigid bus support structures and equipment structures; and

c) Internal rail track system, if required, including foundations.

G-2.6 Installation, Testing and Commissioning

The Contractor shall construct and install all equipment, systems and services to be provided for the Works and shall be responsible for the provision of all construction labour, material and supervisory staff in accordance with the Specification.

The Contractor shall furnish all slings, special hoisting equipment, small tools, jacks, braces and all materials, articles, supplies and construction equipment necessary for the proper installation and/or erection of the Equipment.

The Contractor shall erect and install the Equipment under ordinary job conditions and not necessarily those which he considers the most desirable. Inclement weather, the necessity of moving materials within the Works areas and all other circumstances characteristic of construction operations are to be expected and shall not be considered to be a basis for claims for extension in time or for extra payment by the Employer.

The Contractor shall be responsible for testing, commissioning and putting into commercial operation all material, equipment and any other Equipment incorporated in the Scope of Work. The testing, commissioning and putting into commercial operation of said material, equipment and any other system shall be carried out in accordance with the requirements of the Specification. The Employer reserves the right to assign Employer personnel to the Contractor's commissioning team to participate in and witness the commissioning and testing operations at the sites. Employer staff will particularly participate in the commissioning and testing of the HVDC conversion equipment, the HVAC equipment and the HVAC and HVDC switching systems. The Contractor's obligations and responsibilities under the Specification shall not in any way be diminished, reduced, relieved or otherwise altered due to Employer assignment of Employer staff to the commissioning team.

Depending on the regulations in the respective countries, State Acceptance Committees may also be involved in the acceptance of the tests on equipment.

G-2.7 Training of Employer Personnel

Training of employer personnel is subject to negotiations with the concession company. The contractor is not responsible for the training of the employer’s staff in operating and maintenance of the equipment.
G-2.8 Operation and Maintenance Assistance

As with the employer training, the concession company is responsible for maintenance and operation and will decide on the assistance required.

G-2.9 Transportation

- The Contractor shall be responsible for transportation of all the equipment to the sites including overseas and inland transportation, as well as for unloading, handling and storage of the equipment at the sites. The Contractor shall also be responsible for the custom clearance.

- The Contractor shall be responsible for making a careful examination of access roadways to the sites in order to confirm the practical maximum weight and dimensions, as well as to make a careful examination of the ports of disembarkation, in order to confirm the capacity of the hoist cranes installed there and of the access roads to those ports.

G-3 SPARE PARTS

G-3.1 General

The spare parts and maintenance accessories shall be classified into the following:

a) Spare parts and maintenance accessories required by the Contractor to meet the guaranteed availability and reliability over the guarantee period as specified;

b) Optional spare parts recommended by the Contractor or specified in the relevant Specifications, in addition to (a);

c) Spares required by the Contractor during installation, testing and commissioning of the system; and

d) The operation and maintenance accessories and tools as recommended by the Contractor.

All spares shall be of the same materials and workmanship as the corresponding parts of the equipment furnished and shall be fully interchangeable with those.

A spare part intended for use as a replacement for any one of several similar parts, for example a capacitor unit, shall be a replacement to any one of those parts without resulting in deterioration in the performance of the equipment.

All spares meant for outdoor use, such as buildings, transformers, reactors, resistors, capacitors, arrestors, etc. shall be suitable for prolonged outdoor storage without being energized. The spare equipment shall be supplied complete with bushings, coolers, conservator tanks, oil, etc. as applicable.
G-3.2 Availability Spares

The Contractor shall supply the spare parts required to meet the specified guaranteed availability and shall include such spare parts in the scope of supply. The spare parts list shall be categorized in two parts:

i) Major components including test equipment, special tools and fixtures; and
ii) Minimum parts required for scheduled inspections and overhaul.

The detailed lists of spare parts to meet the guaranteed reliability and availability requirements shall be part of the contract documents. However, if it is found during detailed engineering or reliability and availability prediction calculation that additional spares are required to meet target values, the Contractor shall make the same available without any additional cost to the Employer.

G-3.3 Optional Spares

The Contractor shall supply, at the request of the Employer at any time prior to the expiry of the guarantee period, the spare parts listed in the list or any part thereof at unit prices not greater than those quoted by the Contractor in his Tender.

The Contractor shall recommend any additional optional spare parts he considers that the Employer would be advised to purchase and shall have listed and provided prices for these additional parts in his Tender.

G-3.4 Site Spares

The Contractor shall supply additional spares, which he expects to consume during installation, testing and commissioning of the systems.

G-3.5 Tools and Tackles

The Contractor shall also supply one set of all special tools and tackles, testing equipment, handling equipment, etc. which are required by the Employer’s maintenance staff to maintain the stations successfully.

G-4 WORK EXCLUDED

The following materials and services are excluded:

a) At each location, the high voltage AC switching station, comprising air insulated breaker and a half switching bays, will be supplied by others. The contractor will be required to provide the switching equipment required in the switching bays for the converter transformers and associated harmonic filters;
b) For each station, two (2) independent 13.8 kV, 50 Hz power sources for the station’s auxiliary distribution. The Contractor will be required to supply and connect his feeder cables to the assigned circuit breakers, which are provided.

c) The Employer will allocate to the Contractor rough-levelled areas for locating the converter stations;

G-5 APPLICABLE CODES AND STANDARDS

The work, equipment and materials shall conform to the applicable IEC Codes and Standards and Utility Codes and Standards, as well as the General Standard Specifications to be given in the finalized tender documents. The latest revisions of the standards, in force at the time of signing of the contract for this project shall apply.

Where one or more Standards and/or this Specification specify different requirements, the most onerous requirement shall apply unless otherwise agreed to by the Employer/Engineer on a case-by-case basis.
PART II

PARTICULAR TECHNICAL REQUIREMENTS
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</table>
### G-1 SYSTEM TECHNICAL PARAMETERS – DESCRIPTION OF CONNECTED SYSTEMS

HVAC System characteristics for the HVDC Converter Stations shall be as summarized below for the two AC systems:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SANGTUDA-1</th>
<th>KABUL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal system operating voltage</td>
<td>500 kV</td>
<td>500 kV</td>
</tr>
<tr>
<td>Normal (continuous) system voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency (30 minute) system voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightning Impulse Withstand Level (LIWL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switching Impulse Withstand Level (SIWL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated 1 min. dry power frequency withstand voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System frequency</td>
<td>continuous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 minutes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 seconds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5 second</td>
<td></td>
</tr>
<tr>
<td>Number of phases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System earthing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Short Circuit MVA (3-phase symmetrical)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X/R Ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Short Circuit MVA (3-phase symmetrical)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X/R Ratio</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* To be confirmed by studies to be performed by the Contractor.
G-2 CLIMATIC AND ENVIRONMENTAL CONDITIONS

G-2.1 Climatic Data

The climate is characterized by extreme variations of temperatures both seasonally and daily.

The temperatures in the project areas are:

G-2.1.1 Sangtuda 1, Tajikistan

<table>
<thead>
<tr>
<th>Ambient Temperature (Outdoors)</th>
<th>Minimum:</th>
<th>2 5°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum:</td>
<td>+4 5°C</td>
</tr>
<tr>
<td></td>
<td>Daily Average:</td>
<td>+3 5°C</td>
</tr>
<tr>
<td></td>
<td>Mean Ambient Temperature (6 hour period):</td>
<td>+1 7°C</td>
</tr>
</tbody>
</table>

Indoor Temperature

1) No Air-Conditioning and Well Ventilated Building: Rated: 4 5°C

2) Air-Conditioned: For comfort: 2 5°C

For Equipment: 3 0°C
G-2.1.2 Kabul, Afghanistan

| Ambient Temperature (Outdoors) | Minimum:       | -15 C |
|                               | Maximum:      | 50 C  |
|                               | Daily Average:| 25 C  |
|                               | Mean Ambient Temperature (6 hour period): |      |
|                               | Annual mean:  | 20 C  |

**Temperature of Exposed Surfaces.**

<table>
<thead>
<tr>
<th>Indoor Temperature</th>
<th>Rated:</th>
<th>45 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>3) No Air-Conditioning and Well Ventilated Building:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4) Air-Conditioned:</td>
<td>For comfort:</td>
<td>25 °C</td>
</tr>
<tr>
<td></td>
<td>For Equipment:</td>
<td>30 °C</td>
</tr>
</tbody>
</table>

G-2.1.3 Peshawar, Pakistan

| Ambient Temperature (Outdoors) | Minimum:       | -10 C |
|                               | Maximum:      | +50 C |
|                               | Daily Average:|       |
|                               | Max. Mean Av. Temperature (over 24 hour period): | +45 C |
|                               | Annual mean:  | +30 C |

**Temperature of Exposed Surfaces.**

<table>
<thead>
<tr>
<th>Indoor Temperature</th>
<th>Rated:</th>
<th>45 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>5) No Air-Conditioning and Well Ventilated Building:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6) Air-Conditioned:</td>
<td>For comfort:</td>
<td>25 °C</td>
</tr>
<tr>
<td></td>
<td>For Equipment:</td>
<td>30 °C</td>
</tr>
</tbody>
</table>

G-2.2 Atmospheric Conditions

### G-2.2.1 Sangtuda 1, Tajikistan

The atmospheric conditions in the project area are provided in the following tables. This is based on the data and information available from each of the countries. Where the information is missing, it will be provided in the detailed specifications.

<table>
<thead>
<tr>
<th>Relative Humidity:</th>
<th>Jan: 80%, July: 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Rainfall:</td>
<td>400 mm</td>
</tr>
<tr>
<td>Number of days with rain/mist:</td>
<td>100</td>
</tr>
<tr>
<td>Maximum solar radiation:</td>
<td>From 2800 to 3000 hours</td>
</tr>
<tr>
<td>Isokeraunic level:</td>
<td></td>
</tr>
<tr>
<td>Atmosphere – General:</td>
<td></td>
</tr>
<tr>
<td>Atmospheric pollution:</td>
<td></td>
</tr>
<tr>
<td>Maximum soil temperature:</td>
<td>&gt; 36 C</td>
</tr>
<tr>
<td>Surface:</td>
<td>From 32 C to 36 C</td>
</tr>
<tr>
<td>1 m and below:</td>
<td>20 C</td>
</tr>
</tbody>
</table>
### Soil condition:
Sandy loams, loamy soil and loess of light grey and pale color. The humic layer is insignificant and is not present below the root system.

### Ground water table level:
Average 20 – 25 m. In some place < 1 m

### Soil pH:

### Salt concentrations:

### Sulphates, by weight:

### Chlorides, by weight:

### Seismic level: Horizontal acceleration (g):
Third category, 7

### Elevation (masl):
600 m

### Wind speed:
2.1 m/sec

---

#### G-2.2.2 Kabul, Afghanistan

### Relative Humidity:
Min. 23%, Max. 77%

### Average Rainfall:
50 to 230 mm

### Number of days with rain/mist:

### Maximum solar radiation:

### Isokeraunic level:

### Atmosphere – General:

### Atmospheric pollution:

### Maximum soil temperature:

### Surface:

### 1 m and below:

### Soil condition:

### Ground water table level:

### Soil pH:

### Salt concentrations:

### Sulphates, by weight:

### Chlorides, by weight:

### Seismic level: Horizontal acceleration (g):
1791

### Elevation (masl):
4 – 10 knots, average = 7 knots

### Wind speed:
### G-2.2.3 Peshawar, Pakistan

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Relative Humidity:</strong></td>
<td>Min: 20%, Max: 75% (may reach 100% during monsoon season)</td>
</tr>
<tr>
<td><strong>Average Rainfall (mean monthly):</strong></td>
<td>Min: 40 mm, Max: 170</td>
</tr>
<tr>
<td><strong>Number of days with rain/mist:</strong></td>
<td>Min: 10, Max: 40</td>
</tr>
<tr>
<td><strong>Maximum solar radiation:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Isokeraunic level:</strong></td>
<td>Thunderstorm day/year: 20</td>
</tr>
<tr>
<td><strong>Atmosphere – General:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Atmospheric pollution:</strong></td>
<td>Salt deposit density: 0.5 mg/sq.cm</td>
</tr>
<tr>
<td><strong>Maximum soil temperature:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Surface:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>1 m and below:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Soil condition:</strong></td>
<td>Very stiff clayey silt/silty clay with little concretion. SPT blow range 17 to 36 for 10 m deep borehole.</td>
</tr>
<tr>
<td><strong>Ground water table level:</strong></td>
<td>Not encountered up to 10 m</td>
</tr>
<tr>
<td><strong>Soil pH:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Salt concentrations:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Sulphates, by weight:</strong></td>
<td>0.0048 to 0.0080%</td>
</tr>
<tr>
<td><strong>Chlorides, by weight:</strong></td>
<td>0.0045 to 0.0068%</td>
</tr>
<tr>
<td><strong>Seismic level:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Horizontal acceleration (g):</strong></td>
<td>0.16 to 0.24 g</td>
</tr>
<tr>
<td><strong>Elevation (masl):</strong></td>
<td>370 m</td>
</tr>
<tr>
<td><strong>Wind speed</strong>:</td>
<td>45 m/ sec above 10 m from ground level</td>
</tr>
</tbody>
</table>
G-3 PERFORMANCE REQUIREMENTS

G-3.1 Ratings

The specified continuous nominal ratings of the converters, as given in Part I shall be achieved under the full ranges of specified AC network voltages, frequencies and ambient conditions.

The converter stations will be interconnected via a bipolar transmission line, approximately 750 km long, and through ground electrodes when in mono-polar operation mode.

A fibre optic network will be provided over the transmission line for communications between the converter stations.

Simultaneous first contingency outages in the following auxiliary systems shall not reduce the delivered power by the converter stations.

- Converter transformer cooling system;
- Converter transformer tap changer power supply or control system;
- Valve cooling system (including de-ionizing system if applicable);
- AC harmonic or PLC filter capacitor bank;
- Any part of the auxiliary supply system;
- Any part of the control system (including measurement signals);
- Any part of the protection system (including measurement signals); and
- Any component in a switchable AC harmonic filter or shunt reactive compensation bank provided that a replacement bank is available in another converter Station or that another Station is operating and both Stations can be operated with one switchable bank out of service.

The individual converter stations shall be capable of operating continuously at a delivered active power of 10% of their nominal ratings over the full ranges of AC network voltage, frequency, and ambient conditions and for the outage conditions specified.

The HVDC converter system shall be designed and rated to:

a) Have the ability to control reactive power interchange between the converter facility and each AC network independently within the ranges specified;

b) Have the ability to automatically adjust active power flow to control the frequency of one or other AC network; and

c) To operate in mono-polar mode for at least three (3) months.

G-3.1.1 Point of Measurement

Active and reactive power interchanges with the networks shall be defined at the points of connection of the converter transformers to the respective 500 kV or 230kV substation as applicable. Metering accuracy current and potential transformers installed in the AC switchyards shall be used for measuring the real and reactive powers.
Active power delivery shall be defined as the power delivered to the receiving network net of auxiliary power taken from the receiving network.

G-3.1.2 Assessment of Performance

Active and reactive power demand and delivery capability shall be determined by calculation. The Contractor shall state limits for all applicable quantities. Measurable physical quantities shall be established by test, and any equipment, system, or other facility, which has any quantity outside the range specified by the Contractor shall be rejected. The Employer shall be permitted to assume the most unfavorable tolerance or combination of tolerances when calculating equipment rating requirement, active and reactive power interchanges, and any other performance parameters.

G-3.1.3 Continuous Over-load Capability

The continuous overload capability with all cooling systems available and maximum ambient temperature and the overload capability at reduced dry bulb ambient temperature (expressed as a function of overload against temperature) shall not be lower than the values stated by the Contractor in his tender.

G-3.1.4 Short Time Overload Capability

The permissible overloads for 5, 15, and 30 minute durations when at maximum ambient temperature and with cooling system and other outages as specified, shall not be lower than the values stated by the Contractor in his tender.

G-3.2 Dynamic Performance

The Contractor shall carry out studies to demonstrate that the control and protection systems as well as the equipment of the converter stations and of the facility as a whole operate in a stable and correct manner.

The demonstration shall be performed prior to shipment on a suitable simulator using the actual control and protection cubicles to be delivered for the converter stations. The interconnected systems shall be represented in sufficient detail to accurately model the dynamic behaviour of the converter facility.

The objective is that, for major system disturbances as characterized by a loss of generation within any of the interconnected systems, the converter facility shall be required to react and with sufficient speed to stabilize the frequency of the disturbed system.

After any phase to ground or phase-to-phase fault within any the converter stations or the interconnected networks, the converters shall recover once the fault is cleared in a stable and controlled manner and without commutation failure. The recovery shall be within the times stated by the Contractor in his tender or within the times shown necessary by the system studies, whichever is the more onerous.

The control systems of the converters shall be designed to also receive external signals to effect the appropriate change in the current order of the converters.

The design and studies of the converters shall ensure that any thermal generators are neither subject to sub-synchronous resonance nor harmonic current overloading.
G-3.3 Reactive Compensation

The requirements given in this clause shall be met simultaneously on the three connected AC systems. The reactive interchange between the converters and the respective AC network shall be the instantaneous sum of the interchanges between each of the converters and the respective network at the point of measurement.

The reactive power interchange limits shall be respected in any operating condition and with any one switchable reactive power element out of service.

The connected AC systems at the three converter stations shall be assumed to have a 0.95 power factor, in either direction, on the respective 500kV AC bus at nominal voltage.

G-3.4 Harmonic Filtering

AC and DC harmonic filtering shall be provided at each of the converter stations.

The AC harmonic filters shall limit the harmonic voltages and currents for all specified operating conditions. The design shall be fully compatible with the reactive power management requirements.

The DC harmonic filters shall limit the harmonic interference with open-wire telephone lines (if any) for all specified operating conditions.

G-3.4.1 General

The performance of the AC harmonic filters shall be determined by calculation but shall be based on as-tested values of components, reactances, firing angles and any other measurable physical quantities relevant to the calculation of harmonic currents and voltages. If the components as manufactured or the actual generated harmonic currents fall outside the design limits then the Contractor shall, without extra charge, take all steps necessary to fully comply with these specifications, or, at the discretion of the Employer, shall demonstrate that the as-built filter will still meet these specifications.

G-3.4.2 General Design Requirements

The Contractor shall propose in his tender the configuration of the AC filters within the main circuit diagrams of the converter groups, including their voltage class, arrangement, switching, installation and performance.

G-3.4.3 Performance Requirements

The limits of performance parameters, which are given below shall not be exceeded for any period exceeding one minute with any active power exchange between 0 and full load.
1. The individual harmonic distortion $D_n$ shall not exceed the values given in the following Table:

<table>
<thead>
<tr>
<th>Harmonic Range</th>
<th>Maximum $D_n$ %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Even order harmonics</strong></td>
<td></td>
</tr>
<tr>
<td>2$^{nd}$ through 10$^{th}$</td>
<td>0.5</td>
</tr>
<tr>
<td>12$^{th}$ and higher</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Odd order triplen harmonics</strong></td>
<td></td>
</tr>
<tr>
<td>3$^{rd}$ and 9$^{th}$</td>
<td>1.0</td>
</tr>
<tr>
<td>15$^{th}$ and higher</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Odd order non-triplen harmonics</strong></td>
<td></td>
</tr>
<tr>
<td>5$^{th}$ through 25$^{th}$</td>
<td>1.0</td>
</tr>
<tr>
<td>29$^{th}$ and higher</td>
<td>0.5</td>
</tr>
</tbody>
</table>

2. The total harmonic distortion, $D$, shall not exceed 4.0%

3. The total effective distortion, $D_{eff}$, shall not exceed 2.0%

4. The telephone influence factor, $TIF$, shall not exceed 30

5. The balanced IT factor shall not exceed 10,000

Where:

$$ D_n = \frac{E_n \times 100}{E_{ph}} \% $$

$$ D = \sum_{n=2}^{50} (E_n \times 100/E_{ph}) \% $$

$$ D_{eff} = \left[ \sum_{n=2}^{50} (E_n \times 100/E_{ph})^2 \right]^{\frac{1}{2}} \% $$

$$ TIF = \left[ \sum_{n=1}^{50} (E_n \times F_n/E_{ph})^2 \right]^{\frac{1}{2}} $$

$$ IT = \left[ \sum_{n=2}^{50} (I_n \times F_n)^2 \right]^{\frac{1}{2}} $$

$E_n$ = phase to ground RMS voltage at harmonic “$n$”

$E_{ph}$ = nominal phase to ground RMS fundamental frequency voltage

$n$ = harmonic order

$I_n$ = phase current in Amps at harmonic “$n$” in any transmission line leaving the AC bus to which the converter station is connected.

$F_n$ = weighting factor for harmonic “$n$” according to EEI Publication 60-68 (1960) corrected where necessary to 50 Hz operation by graphical interpolation.
G-3.4.4 Method of Calculation of Performance

The extreme value of harmonic current generated by the converter valves at the active power level and in the mode of operation being considered shall be calculated for each harmonic individually taking into account the range of values of firing and extinction angles, dc side current, commutating reactance, dc side current ripple, AC system negative phase sequence voltage, difference in reactance and firing angles between phases and between converter bridges, and all other factors which can influence the harmonic current generation. The conditions giving rise to the most onerous harmonic current at that harmonic alone shall be assumed when calculating $D_n$. For the other performance factors the most onerous consistent set of harmonic currents shall be assumed where all harmonics are calculated at the same values of firing and extinction angles, commutating reactance, and dc side current; but other variables shall be assumed to lie anywhere within the possible range so as to maximize the current at each individual harmonic.

The impedances of the filters, including any shunt capacitors or reactors provided for reactive power management, shall be calculated at the extreme values of mistuning due to component tolerance, element failure not resulting in disconnection of the filter bank within 2 hours, temperature and temperature rise due to load and solar radiation, and frequency within the 30 minute range given in Clause 1 of this Part so as to result in the highest value of performance parameter being considered.

For calculation of $D_n$, the harmonic impedance of the AC system shall be the most onerous value within the line/circle, sector, or other impedance diagram determined by the Contractor in the harmonic impedance study at each harmonic individually. For the calculation of $D$ and TIF, the harmonic impedances within the impedance diagram giving the highest values of 11th and 13th harmonic voltage as well as those two (2) other harmonics giving the highest D or TIF shall be assumed, with the impedance being defined as an open circuit at all other harmonics. For the calculation of IT, the harmonic impedances within the impedance diagram giving the highest values of 11th and 13th harmonic current as well as at those two (2) other harmonics resulting in the highest value of IT shall be assumed, with the impedance being defined as an inductance equivalent to the maximum short circuit level at all other harmonics. If the system impedance defined by an open circuit or equivalent inductance results in a higher value of $D$, TIF, or IT at a particular harmonic than the most onerous value of system impedance from within the impedance diagram determined by the Contractor at that harmonic then the contribution to the performance index of that harmonic may be calculated with the most onerous value of impedance from within the impedance diagram. This shall not, however, be counted as one of the two “other” harmonics resulting in the highest total.

G-3.4.5 System and Ambient Conditions

The limits of the performance parameters specified shall not be exceeded, for the converter facility as a whole, for any period in excess of one minute provided that:

1. The AC bus voltages are 500 kV ± 5%
2. The AC system frequencies are between 49.5 Hz and 50.5 Hz. The AC voltage unbalance at fundamental frequency is less than or equal to a negative phase sequence component of 1.5%.
3. The ambient temperature is between –5°C and 55°C.
4. The transmitted power is between zero and full load (or any reduced ambient rating, if greater).

5. Reactive power interchange between the converter facility and the interconnected AC networks anywhere within the greater of the ranges specified and those determined by the Contractor studies.

G-3.4.6 Component Ratings

The Contractor shall be responsible for the adequate rating of all AC harmonic filter components so that, within the AC system voltage, frequency and ambient temperature conditions and for the modes of operation and transmitted power ranges specified the transmitted power shall not have to be restricted under outage and other conditions of filter branches.

In addition, the filter components shall be rated to withstand a negative phase sequence component of 3% continuously as well as the following short-term frequency excursions on either of the HV buses:

- For 10 minutes: \( \pm 2.5 \% \)
- For 1 minute: \( \pm 5.0 \% \)
- For 5 seconds: \( \pm 10.0 \% \)

G-3.5 Insulation Coordination

G-3.5.1 General

The Contractor shall provide surge arresters, surge capacitors, and other devices as required to protect all equipment within the Contractor's supply from dc, fundamental frequency, harmonic, ferro-resonant, switching surge, lightning impulse, and front of wave over voltages under all steady state, dynamic, transient, and fault conditions.

The Contractor shall perform an insulation coordination study including all necessary TNA and/or HVDC simulator and/or digital studies. The Contractor shall submit a detailed report, which shall include the magnitudes and wave shapes of applied voltages, the characteristics of the surge arresters, all insulation and equipment clearances and leakage distances and justification for the selected values.

The report shall detail the limits of all equipment parameters, which could affect the insulation coordination. If, at any time, any relevant parameter of equipment supplied by the Contractor is altered, the Contractor shall resubmit the report. The Contractor shall not finalize the design of any equipment, which might be affected by changes in protective levels until the Employer/Engineer has approved the report.

The voltage across any equipment or insulation, which is not directly protected by a lightning arrester shall be determined by arithmetic addition of the protective voltage(s) of the closest lightning arrester or arresters and the highest voltage, which can appear between the arrester(s) and the equipment.

Arcing horns etc. shall not be used for the protection of equipment from over voltages. The insulation shall be coordinated so that the lowest air clearances occur across post insulators.
G-3.5.2 Definitions

The **Protective Level** is the highest voltage, which can appear across any insulation.

The **Withstand Level** is the voltage, which any insulation will withstand with at least $3\sigma$ probability. Standard waveforms are assumed for Front of Wave, Lightning Impulse, and Switching Impulse withstand definitions.

The **DC Voltage** is the crest value of any unidirectional voltage ignoring commutation overshoot or transient spikes of less than 1 ms duration. Valve winding to ground voltages are to be considered as dc voltages.

The **Fundamental Frequency Voltage** is the 50 Hz or 60 Hz voltage excluding harmonic and other effects, which can cause distortion of the fundamental frequency waveform.

**Steady State** voltages are voltages, which can exist for a period in excess of 5 seconds.

**Temporary** voltages are voltages, which can exist for a period in excess of 10 cycles.

**Transient** voltages are voltages, which can exist for a period up to 10 cycles

**Switching Impulse Voltages** are transient voltages which may be superimposed on dc or fundamental frequency voltages and which, for the purpose of defining which waveforms occurring in practice shall be tested for or treated as switching impulses, have a rise time to crest in excess of 8 microseconds.

**Lightning Impulse Voltages** are transient voltages which may be superimposed on dc or fundamental frequency voltages and which, for the purpose of defining which waveforms occurring in practice shall be tested for or treated as lightning impulses, have a rise time to crest between 1.2 and 8.0 microseconds.

**Front of Wave Voltages** are transient voltages with a rise time to crest of less than 1.2 microseconds.

At an arrester, the Front of Wave, Lightning Impulse and Switching Impulse Protective Levels shall be defined as the maximum voltage across the arrester when tested with applied waves of 0.6/1.5$\mu$s, 8/20$\mu$s, or 45/90$\mu$s duration respectively and crest current appropriate to the event being considered.

G-3.5.3 Coordination with AC Substation Arresters

The Converter Station insulation and arresters shall be coordinated with the arresters of the 500 kV AC substations so that faults or other events within the Converter Station shall not cause damage to any equipment within the substations to which the Converter Stations are connected.

The Converter Station equipment shall be rated to withstand over voltages appearing within the substations to which the Converter Stations are connected.

G-3.5.4 Calculation of Over voltages

In the calculation of temporary over voltages the Contractor shall allow for blocking of the Converter Station(s) from any power level up to the full transmission capability
corresponding to the relevant system conditions and for the maximum load rejection which could occur and leave any Converter Station or valve group de-blocked. The connected AC harmonic filter shall be assumed to be that with the highest MVAr applicable to the mode of operation.

In the calculation of transient over voltages the Contractor shall consider at least:

- Lightning surges due to direct strikes within the converter station in the event of shielding failure;
- Steep fronted waves resulting from flashovers or faults, including those within the valve hall and to ground from the valve windings of the converter transformers;
- Over voltages due to switching of converter transformers, ac filters and shunt capacitors, shunt reactors, or other equipment;
- Over voltages due to fault initiation and clearing of single phase and three phase to ground faults which may be cleared by circuit breakers;
- Over voltages due to blocking of valve groups;
- Faults within converter equipment, including control and telecommunication malfunctions;
- Uneven distribution of over voltages, particularly within the converter valves;
- Commutation overshoot, particularly when operating at higher than normal firing or extinction angles; and
- Arrester location relative to protected equipment and arrester characteristics.

G-3.5.5 Calculation of Protective Levels

The front of wave, lightning impulse, and switching impulse protective levels of the arresters shall be based upon the highest voltages which can appear across the arrester, or combination of arresters where appropriate, when the highest practical discharge currents are flowing in the arresters.

The discharge current (coordinating current) shall be determined by the Contractor appropriate to the arrester location and line and equipment parameters.

The arrester protective levels shall allow for the possibility of flashovers which could cause high discharge currents in lower rated arresters and, particularly within the valve groups, unequal sharing of voltage between arresters connected in series. Where multi-column arresters are used or arresters are connected in parallel, unequal sharing of the discharge current shall be taken into account.

G-3.5.6 Withstand Levels

The withstand level shall be greater than the protective level with the minimum margins specified below:

G-3.5.6.1 AC Equipment

All equipment connected to the ac bus, including insulators and air clearances shall have a:

- SIWL which is an IEC standard level and is at least 1.15 times the switching
impulse protective level;

- LIWL which is an IEC standard level corresponding to the SIWL and is at least 1.20 times the lightning impulse protective level; and
- FWWL, which is at least 1.25 times the front of wave protective level.

The ac filter capacitors (and shunt capacitors if used) shall have switching and lightning impulse margins 5% higher than specified above, i.e. not less than 1.20 times for SIWL, 1.25 times for LIWL, but retaining 1.25 times FWWL.

The ac filter reactors and resistors (if air insulated) and any VTs or PTs within the filter shall have margins of not less than 1.30 times protective level for LIWL and FWWL, and of not less than 1.20 times protective level for SIWL.

G-3.5.6.2 Oil Insulated Equipment

For all equipment with oil insulation and with arresters connected close to the terminals, for example converter transformers, dc reactors, oil insulated filter reactors (if used); the LIWL shall be an IEC standard value. This value shall not, for internal insulation, be less than:

- 1.40 times the switching impulse protective level;
- 1.20 times the lightning impulse protective level;
- The SIWL shall not be less than 0.83 times the LIWL; and
- The FWWL shall not be less than 1.20 times the front of wave protective level.

G-3.5.6.3 Converter Valves

The Tenderer shall describe in his tender the basic parameters for the insulation of the valves and their coordination.

G-3.5.6.4 DC Side Equipment

The dc side air clearances, insulators, equipment, etc. shall have:

- A SIWL at least 1.20 times the switching impulse protective level;
- A LIWL at least 1.25 times the lightning impulse protective level;
- A FWWL at least 1.25 times the front of wave protective level.

G-3.5.7 Air Clearances

The air clearances shall be determined by the Contractor based on the required withstand levels for all waveforms from dc to front of wave in order to limit the probability of a flashover within the converter station to a target value of one flashover in 10 years on the AC side or one flashover in 20 years on the DC side per converter station.

For equipment or insulation on the AC side, the minimum air clearances shall not be less than those given in IEC publication 60071-2, Tables A.1, A.2 and A.3.

For equipment or insulation on the DC side the minimum air clearances shall not be less than the values given in the CIGRE application guide 33.83(SC) 03.21 WD, appropriate to the electrode configuration and withstand level required. Outdoor bushings shall have a flash
distance of not less than 10 mm per kV of applied steady state dc voltage where the flash
distance is the shortest distance between the bushing cap and the nearest ground plane.

G-3.5.8 Leakage (Creepage) Distances

The leakage distance across insulation shall be determined by the Contractor and shall be ade-
quate to ensure that, under the conditions applicable to the site(s) of the Converter
Stations the probability of a flashover due to failure to withstand the applied voltage does not exceed one flashover in 10 years on the AC side or one flashover in 20 years on the DC side per converter station.

The leakage distance for all outdoor AC side insulators shall not be less than 50 mm per kV of the maximum normal operating voltage across the insulation. The maximum normal operating voltage is defined as the rms value of the phase to phase voltage, including voltage distortion effects,.

For all insulators and bushings which are subject to direct voltage stress, including converter transformer valve winding bushings and valve winding insulators and wall bushings the crest value of the voltage shall be used to define the minimum leakage distance. Based on the above crest voltage the minimum leakage distance shall not be less than:

- 15 mm/ kV for indoor insulation in clean surroundings;
- 30 mm/ kV for outdoor insulators mounted vertically;
- 35 mm/ kV for outdoor insulators mounted horizontally;
- 35 mm/ kV for outdoor bushings mounted vertically; and
- 40 mm/ kV for outdoor bushings mounted other than vertically.

G-3.6 Converter Station Controls, Metering, Protection and Operation Systems

G-3.6.1 General Specifications

The controls, metering, protection and operation systems specified herein shall be in accordance with the applicable sections of the following reference specifications, to be finalized in the tender documents.

1. Control, Metering, and Protection; and
2. SDH Fibre Optic.

These Specifications will cover the following applicable components of Controls, Metering, Protection and Operation Systems including, but not limited to:

- SDH Multiplexer
- Teleprotection Signaling Equipment
- General
- Codes and Standards
- Control, Metering and Protection General Configuration
- Control Panels
- Metering Panels
• Protective Relay Panels
• General Requirements for Control, Metering and Protection Panels
• Programming of Electronic Devices
• Factory Testing
• DCS Control System
• Distributed Controllers
• Human-Machine Interface/SCADA
• Communication Links and Interfaces
• Engineering/Programming Tools
• Programming Language
• Acceptance Tests

G-3.6.2 Converter Station Controls

The Contractor shall provide the control and protection system necessary for the converter system and its proper integration with the connected 500 kV and 230kV AC systems. The control and protection system shall be based on the most modern and proven microprocessor technology available in the market. Control of the converter system shall be organized in a hierarchical fashion both in terms of its function and location in a logical manner. Additional control and protection requirements as specified elsewhere in this Specification shall also be met.

The Contractor shall be responsible for complete coordination of controls, protections, interlocking and switching sequences within the stations as well as for the system as a whole.

The general concepts of the control systems shall be based on the following:

a) Wherever feasible, the controls are to be broken down to control the smallest unit or block of power. Thus, the hierarchy of controls shall be organized from valve group controls to pole controls to bipole controls as applicable with maximum independence.

b) A master control facility shall be provided for the system.

c) The converter controls shall maintain the power flow over the converter stations at the value ordered by the operator.

d) The controls shall ensure that power transmission is maintained at the last ordered value, prior to failure, upon a tele-control or telecommunication system(s) failure causing loss of further tele-control signal updating.

Even during a telecom failure, it shall be possible to change power both in response to manual power order changes and power modulation signals without any risk of current margin loss.

e) All the converter controls shall also be designed to accept signals provided to control the power flow due to:

   i) Sudden changes in power order in response to system load input signals;
ii) Changes in AC system frequency; and
iii) Six additional unspecified inputs.

f) The controls shall have a facility to allow the operator to raise the nominal alpha or gamma up to the maximum economic steady state value in order to consume as many VARs as possible. The nominal alpha or gamma allowable may be a load dependent function, but shall not be less than the levels quoted by the Contractor in his tender.

g) The controls shall ensure smooth transition without any AC system disturbance when transferring from any one operating mode to another operating mode.

h) The power setting shall be adjustable in operator-selected steps, from the minimum operating limit to the maximum overload rating of the converter station. Such changes shall be effected at a linear rate adjustable between 1 and 300 Megawatts per minute. The minimum step size shall be 1 MW.

The control shall provide the facility to utilize the available and possible continuous and short time overload capacity, on an integral basis based on prevailing ambient conditions and available coolers and heat exchangers. Information to this effect shall also be made available (displayed) to the operator.

i) Power shall be allowed to be transmitted under conditions of loss of part of the AC filters and/or of abnormal frequency (within specified limits), resulting in higher than normal distortion. All measures necessary to prevent instability, caused by distortion in the AC waveform or by magnification of harmonics in the AC voltage waveform, shall be provided.

j) The controls shall provide a high speed of response and accurate, stable and drift free operation over the complete operating range.

k) The controls shall be capable of minimizing reactive power requirements under steady state operating conditions consistent with the requirement to permit proper firing of converter valves and maintain successful commutation.

l) The controls shall minimize generation of non-characteristic and characteristic harmonics.

m) The controls shall maintain power transmission under conditions of reduced sending end AC voltages with smooth transition between different converter control modes. Should power transmission capability be reduced by an amount equivalent to the margin value, then such power reduction shall be compensated for by the controls in order to restore full transmission capability.

n) The controls shall be provided with redundancy in the critical control elements (e.g. current order control loop, etc.) and in the protection systems to ensure continuous operation or safe and orderly shutdown of equipment, as appropriate to the fault condition. Backup protection shall also be provided for the event of failure of the main protection.

o) The controls provided shall be so arranged that testing and maintenance can be carried out on any converter station without affecting the operation of the other stations.
p) The controls shall incorporate any other special features based on the Contractor's research and development work and experience that may be of significant benefit to the overall control and protection of the converter facility and converter equipment.

Additional controls shall also be provided for the system. The concepts of the additional control systems shall be based on the following:

a) Transient and dynamic damping controls shall be provided on a converter station basis.

b) The converter controls shall utilize fast control action to suitably stabilize the AC system by rapidly increasing or decreasing the power flow transiently above or below the ordered value in response to AC system stabilizing control signals. Such signals shall have no steady state effect, i.e. the stabilizing signal shall decrease to zero in the steady state. Full use shall be made of the available short-time overload capability in the converters for the purpose of AC system stabilization.

c) Provisions shall be made to accept Load Frequency Control (LFC) power order signals into the DC control equipment on a converter station basis. These signals will be provided by the Interconnection Control Center.

d) Additional controls required by the Contractor to meet the objectives of frequency stabilization, if any, or to meet any other control related objectives specified in this Specification shall be provided.

G-3.6.3 Protection Systems

The Contractor shall provide the protection systems of the equipment and subsystems including:

- Converters
- Converter transformers
- AC filters
- DC filters
- DC bus
- DC line
- Electrode line
- Electrodes

The requirements specified herein are the minimum. The Contractor shall be responsible for defining the actual protection requirements and schemes for the complete converter system.

All the protective devices shall be capable of responding correctly to all types of internal or external faults even in the presence of the harmonic currents produced by the converters and during system frequency excursions.

The Contractor shall provide adequate protection to ensure that all converter equipment is fully protected, and shall ensure that all protections are properly coordinated.
Main protection (including redundancy for critical circuits) shall be provided to ensure safe shutdown of equipment. Back-up protection shall also be provided to protect equipment in the event of main protection failure. Maximum electrical and physical separation shall be kept between main and back-up systems and between the protection systems and control systems.

The protection equipment shall be designed to be fail-safe and shall ensure high security, so as to prevent unnecessary shutdowns due to protection equipment failures. Generally, the main and back-up protections shall utilize different principles. Where utilization of different principles is not possible, redundant protections shall be employed. Back-up and redundant protections shall always be fed by independent separate CT secondaries. All protection trips due to equipment failure shall result in a lockout trip, requiring manual reset. All protection trips shall be separately alarmed.

The Contractor shall also provide any additional protection, which he deems necessary or desirable to improve the performance of the converter equipment.

Converter commutation failure protection shall, in addition to normal protection, include fast-acting circuits to take precautionary control action to minimize the occurrence of commutation failures. Adjustments shall be provided for on-site optimization of commutation failure recovery circuits. Such adjustments shall be achievable by means of simply calibrated devices, each fitted with a physical locking arrangement, mounted in the cubicles. These devices (if used) shall be disconnected after achieving the necessary on-site optimization and replaced by hardwired components mounted on standoffs. For microprocessor based control and protection systems, on-site changes shall be easily achievable through software changes.

Group faults (including auxiliary power supply failures), which also require rapid removal of AC voltage from valves, shall be cleared by initiating immediate blocking of the converters followed by tripping of AC circuit breakers feeding the valve groups. Such tripping of breakers shall be initiated only when essential for protection of converter equipment. Both the main and back-up protective features shall be arranged to operate into each trip coil circuit via electrically separate contacts from the respective main and back-up lock-out tripping relay or self-reset tripping relay, as applicable. Separate contacts from each tripping relay will be used in both the main trip coil circuit and in the back-up trip coil circuit of each circuit breaker. All signals from the main and back-up/redundant protective features shall be carried over separate cables. Similarly, the main and back-up trip coil circuits of each breaker shall be activated by signals carried over physically separate cables from the respective protection cubicles.

The tripping of AC circuit breakers for permanent group faults, as well as for any other protection(s) for which the Contractor deems it necessary to trip the AC supply breakers, shall be via lockout relays.

In the event of a fault on the AC system requiring tripping of a circuit breaker that feeds the valves, the protection shall order the affected valve group to block immediately and then trip the AC circuit breaker. The Contractor shall ensure the adequacy of this method from the viewpoint of ensuring safe opening of these AC circuit breakers under all reasonable conditions. Particular attention shall be given to the problem of delayed arc extinction due to the presence of direct current components.
G-3.6.4 Operator's Control, Monitoring and Support Systems

The Contractor shall provide a fully equipped control room at each converter station. The control room of one of the converter stations, called the master station, will normally be manned continuously.

The operator at the master station shall be able to fully monitor and control all stations. Facilities shall be provided to allow transfer of the operator’s control point at all stations. Three modes shall be selectable:

1. Operator control of each converter station by the operator at that station (from the SCADA/HMI station);
2. Operator control of all converter stations from any one of the three station SCADA/HMI stations;
3. It shall also be possible to take over control of the converter system from a remote Control Center as described below.

All necessary interlocking and signal matching necessary to achieve an orderly change over among the system control modes shall be provided.

The converter control system shall interface with the EMS/SCADA system installed at the Control Center for remote supervision and operation of the converter system. The interface shall be done directly on a redundant Ethernet multimode fiber optic local area network (100 Mbps Fast Ethernet LAN conforming to IEEE 802.3 standard). The quantities and types of data to be transferred between the converter control system and the EMS/SCADA system shall be adequate to allow complete remote control and monitoring of the converter stations.

The interface protocol shall conform to the UCA international Utility Communication architecture, which incorporates TASE.2 IEC60870-6 (Inter-Control Center Communication Protocol, ICCP), CIM IEC 61970 and IEC 61850.

The Contractor shall provide and install this redundant Fast Ethernet network and F.O. distribution panel to be located in the protection panel room of the connecting Switching Station. The Contractor shall be responsible for the communication link and interfacing up to this F.O. distribution panel, including the communication compatibility with the ICC EMS/SCADA system.

The Contractor shall provide the equipment necessary for the purpose of control, status indication and metering of all equipment within his supply and for AC equipment at the AC switchyards as further detailed below:

- At each converter station, an active status display of the Employer’s AC yards, including status of circuit breakers and isolators feeding the converter station, shall be provided in the converter station control room. For the various other feeders from the 500 kV buses, the Contractor shall use a simplified representation, which shall indicate whether the particular feeder is connected.
- The Contractor shall carry out the entire coordination of interfaces between the Employer’s AC yards and the converter stations’ control buildings. The Contractor shall provide an "interface marshalling cubicle/panel" in the Employer’s relay & control buildings of these AC yards which will act as the interfacing cubicle/panel
for termination of cabling required for the control and status indication of AC switchgear under the Employer's responsibility. This panel will also be the interface point for current transformer cables required for converter station bus protection.

- All cables between interface Marshalling cubicle(s)/panel(s) and converter stations shall be provided and installed by the Contractor.

The control rooms shall generally house the following equipment:

- Converter station control system.
- Station service controls and monitoring of all station auxiliaries like:
  - Station electrical auxiliary power system;
  - Valve cooling system; and
  - Station air-conditioning and ventilation systems.
- U.P.S system and batteries for 8 hours backup.
- Station control, protection and monitoring system.
- Transient fault recorders (this function could be integrated in the control protection and monitoring system)
- Telephone system including a PBX with interfaces (E1, E&M, CO, FXS and Public address system interface), 10 outdoor telephones and 30 indoor telephones.
- Public address system including 10 outdoor loudspeakers and 30 indoor loudspeakers.
- Station fire alarm, control and monitoring panel.

G-3.7 Reliability and Availability of the Converter Stations

G-3.7.1 General

The converter stations shall be designed to meet "design target" values of availability and reliability, as specified herein. The Contractor shall also guarantee the availability and reliability. The period over which the guarantees are to be in effect shall be thirty-six (36) months (i.e. three years), or any valid extension thereof, commencing not later than six months after successful completion of trial operation of the converter facility. The operation of the stations will be monitored during the guarantee period to determine whether they meet the guarantees. The reliability and availability guarantees shall be in the form specified in the Conditions of Contract

The facilities shall be assumed to be utilized 100% of the time at 100% load, regardless of the actual power and energy transmitted by the system. Hence the reliability and availability assessment will be based on the capability of the facility to transmit power and energy and provide service, regardless of whether it is actually in service or not. The circuit elements, which are not used at 100% load, shall be assumed to be used continuously.
G-3.7.2 Design Principles

The objective for the design of the converter stations shall be to achieve high levels of availability and reliability, which are an advance in the state of the art. Special attention shall be given to the design of the converter stations to avoid multiple group forced outages.

The Contractor shall conduct a thorough design review and submit a report explaining the measures taken to minimize the risk of such outages. The Contractor shall give careful attention to related factors affecting converter station system performance such as subsystem and system testing, protective relay coordination and proper setting of relays, spare parts and redundancy of design.

The converter stations system shall be designed to prevent unscheduled power reversals due to equipment failure or malfunction.

The design of the auxiliary system and associated controls & protection shall be such that a single contingency shall not cause a reduction in converter station capability. Thus, for example, in the event of failure of a cooling unit, the increased temperature rise shall not be injurious to the power equipment. All cooling pumps, cooling fans and heat exchangers etc. shall have sufficient reserve capacity to cover the loss of one unit. If necessary, cooling pumps, cooling fans and heat exchangers etc. shall be duplicated to meet this requirement.

In general, the following principles shall be followed in the design of the control circuits wherever possible:

a) Use of the least complex design capable of performing the desired function.

b) Use of components/circuit boards similar to those whose reliability has already been proven in use. The Contractor shall provide material specifications and evidence of component reliability upon request by the Employer/Engineer.

c) Use of pre-aged components. A burn-in period shall be applied to all electronic components including within the valves and control and protection equipment.

d) Use circuits capable of operating with a wide range of component tolerances to reduce the necessity for matching replacement items to a specific application.

e) Use of good design practices, surge protection, filtering, and interface buffers to assure immunity of sensitive components and circuits against damage and interference by induced voltages and currents in external cabling and cubicle wiring.

f) Use of fail-safe and self-checking design features.

g) Use of component and equipment redundancy, by means of either duplication or triplication with automatic transfer facilities wherever necessary to meet the requirements of these specifications, but only in addition to the above principles (a) to (f) inclusive.

h) Designs, which, in the event of component failures, provide for transfer to a less complex operating mode.
i) Use of non-lockout features so that equipment may be restarted remotely where permitted and considered prudent.

j) Provision of alarm, fault indication, monitoring and test facilities.

k) Provision of clear, easily read drawings and manuals with sufficient details and cross-references to facilitate repair, servicing and maintenance.

l) Use of equipment not requiring special operating and maintenance environments, test equipment, special tools, or complex operating sequences, wherever possible.

m) Use of modular construction to permit rapid replacement of modules having failed components or sub-assemblies.

n) Physical separation of redundant control cables and circuits to reduce the effect of hazards such as fire and flood. Ensure separate cable routes to an extent that is practically and technically reasonable.

Only components of high quality shall be used in the equipment. In no case shall any control component (excluding digital and micro-electronic logic circuits) be operated at over 70% of the manufacturer's continuous duty rating for power, current or voltage.

G-3.7.3 Availability and Reliability Calculations

G-3.7.3.1 General

The terms availability and reliability, as used in these Specifications exclude the effect of certain outages and curtailment events described below which are, in general, beyond the Contractor's control. Hence these effects will be excluded from the analysis demonstrating that the system meets the guaranteed/design target for availability and reliability, and will be excluded from the Employer/Engineer's evaluation of availability and reliability attained in service.

The outage and curtailment of converter system capacity events to be excluded are as follows:

a) Misuse, operator error or other human cause, which contravenes the Contractor's operating and maintenance instructions.

b) Environmental conditions or ac system conditions outside the design criteria given in these Specifications or as modified during detailed engineering.

c) External causes beyond the control of the Contractor i.e. land slides and subsidence; earthquake shock beyond the seismic criteria of these Specifications, and fire arising from causes outside the Contractor's equipment and Scope of Work.

d) HVDC line failure.

Circumstances causing curtailment of converter system capacity that will be included in the availability and reliability assessment and which can lead to a forced outage include, but are not limited to:

a) Failures of equipment;
b) Mis-operation of control and protection system due to electrical interference, incorrect settings or inadequate interlocks & provisions;

c) Failure to, or delay in, start of a converter station; and

d) Reduction of dc power transmission capability.

**G-3.7.3.2 Definitions**

*Availability* is defined as the percentage of time within the evaluation period during which the converter facility had a continuous power transfer capability equal to or greater than the threshold level. The nominal capability of the converter station or available part thereof shall be used (i.e. overload capacity shall not be assumed). Scheduled outages shall be included in the calculation of availability. The minimum power transfer capability during any hour shall be taken as the power transfer capability throughout the entire hour.

*Reliability* is indicated by the *Reliability Index*, which is the number of forced outages per converter facility per year within the evaluation period resulting in reduction of the power transfer capability of the converter facility greater than the threshold amount. An outage shall be defined as an inability to transfer power for a period in excess of 100ms.

*Transient Disturbance Frequency* is defined as the number of transient disturbances within the evaluation period. A transient disturbance is defined as a reduction in the power transfer capability of 15% or more lasting between 20ms and 100ms.

Any restriction in power transfer capability required to enable a converter station to meet reactive power interchange or other requirements shall be taken as a forced outage.

The period basis for availability and reliability calculations shall be 12 consecutive months (one year).

**G-3.7.3.3 Design Calculations**

The Tenderer shall state the design target and guarantee levels of availability, reliability, and transient disturbance frequency, which he will meet in the form these parameters are specified herein. He shall supply data on availability and reliability for all dc converter terminals, which have been placed in commercial operation by him. Data shall be supplied for each calendar year of commercial operation including the first (partial) year. Details of individual major outages, which may be helpful in interpreting data, shall be given.

The Contractor shall submit a detailed report to the Employer/Engineer for approval within six months of award of Contract and prior to the commencement of manufacture of the equipment demonstrating that the design will meet the design target and guaranteed values of availability, reliability, and transient disturbance frequency specified or offered by the Contractor in his tender, whichever is the more onerous.

The Contractor shall submit his calculations in readily assimilated formats suitable for engineering use in verifying applications in the design. The report shall document the Contractor’s reliability and availability calculation procedures and state his data on component failure rates along with their sources/basis. The data shall include both Contractors’ preliminary design calculations and the final calculations based on the finalized equipment design. Revisions shall be submitted to the Employer/Engineer prior to the acceptance of the equipment and system whenever modifications that may affect the calculations have been introduced.
The calculations shall show the expected availability and reliability of the installation based on the Contractor’s recommended provision of mandatory spare parts/equipment. The Contractor shall also provide calculations showing the effect on availability that would result if spare converter transformers, smoothing reactors, and other major components were omitted from the list of spare components while all other items in the Contractor’s availability (mandatory) spares list are retained.

Outage times for repair, maintenance and replacement of components, shall be based on the premise that all items in the Contractor’s lists of recommended spare parts are on hand, that all Contractor’s schedules of recommended maintenance are adhered to and that maintenance personnel (the number and availability of such personnel shall be as specified by the Contractor in his tender) will be on hand to effect repairs immediately on a normal 6 day, 48 hour week basis. It shall be assumed that outside of normal working hours the maintenance personnel will be available within 2 hours at any converter station. The effect of already consumed spares shall also be considered assuming reasonable spare reorder and delivery time.

For simultaneous events where either of which would result in a loss of capacity, the longer outage time shall be assumed.

G-3.7.3.4 Scheduled Maintenance

Scheduled preventative maintenance by the Employer will be:

a) Performed sequentially on complete converter stations and with a maintenance interval prescribed in Contractor’s tender. The Contractor shall submit a comprehensive maintenance plan, listing the activities to be carried out by the Employer's maintenance staff.

b) Executed according to the Contractor's instructions and following a schedule to be mutually agreed upon. The Contractor shall have the right to witness and advise, during each scheduled maintenance, during the availability and reliability guarantee period and will be informed at least 10 days in advance. The Contractor shall bear the costs for any such witnessing.

c) Executed with a qualified working crew of the size prescribed, properly trained according to the Contractor's prescribed training program. The maintenance will be executed during consecutive days with a shift time per day of 8 hours (plus a maximum of 4 hours overtime) to complete the maintenance program.

G-3.7.3.5 Determination of Actual Curtailment Time

The Employer shall keep and make available to the Contractor, during the availability and reliability guarantee period, operation records so as to make a determination of the cause of any curtailment or outage as well as the sub-division of the total outage time into specified time elements. The basic data and general format of the above operation records are to be mutually agreed upon prior to commencement of the guarantee period or commercial operation of the facility.

When determining the duration of an outage or curtailment covered by the availability guarantee the following time elements will be excluded:
a) Unreasonable lengths of time required to obtain access to a piece of equipment for repair or maintenance including time for permits to de-energize or disconnect equipment, time to get physical access to equipment location, delivery, transport and erection of ladders or lifting facilities (however for calculation purposes, 1 hour for obtaining access shall be assumed). Reasonable times will be established during the Contractor's operator and maintenance training program and during initial operation. These times shall be deemed included in the availability calculations;

b) Time of unavailability of specified tools/repair equipment/repair facilities. Delay caused by the unavailability of a crane exceeding 12 hours;

c) Unreasonable waiting time to locate spares in Employer's stock; and

d) Waiting time caused by delayed (relative to the time specified by the Contractor\(^1\)) ordering by the Employer of replacements for used spares.

The following will be included in outage duration:

a) Time required to determine the cause of an outage and to determine which equipment/unit must be repaired/replaced;

b) Time required for disconnection, grounding of equipment, preparation of repair and reconnection after repair;

c) Time required for movement of spare;

d) Time required for repair; and

e) Time required to acquire spare parts, tools or test equipment whose acquisition was not recommended by the Contractor in his tender.

If scheduled maintenance is not performed using the prescribed size of qualified crew the outage time to be used in the guarantee evaluation will be adjusted based on times established during the maintenance training program.

G-3.7.4 Availability

**G-3.7.4.1 Requirement**

The calculated energy availability of the converter facility assuming availability of spare parts/equipment recommended by the Contractor shall be equal to or shall exceed the following target values. Also, the actual availability averaged during the 36 month availability guarantee period, considering both forced and scheduled maintenance outages, shall be equal to or exceed the following guaranteed values.

\(^1\) The times when replacements have to be ordered during the guaranteed period will be specified, for each type of spare, by the Contractor to ensure that sufficient spares are on hand when required. It shall be assumed that it takes 6 months for the Employer to order spares available indigenously and 9 months to order spares involving international suppliers. Reasonable delivery time shall be assumed/established by the Contractor when determining the order times.
### G-3.7.4.2 Fulfillment of Availability Guarantee

The availability of the complete converter facility will be monitored during the availability and reliability guarantee period. A preventative maintenance check will be carried out immediately before the start of the said period.

The Employer will maintain records of the number and duration of forced and scheduled outages, and the amount of converter station capacity available on an hourly basis.

The availability of dc power transfer capability will be calculated annually. If availability levels achieved are below the target/guaranteed levels, the Contractor shall make a thorough analysis of the cause and take appropriate remedial action to improve the performance. Implementation of corrective actions shall be subject to the approval of the Employer/Engineer. All costs towards such implementation of corrective actions shall be borne by the Contractor. All scheduled outages thereby required will be included in the calculation of the scheduled outage times.

For fulfillment of the guaranteed energy availability, the following shall apply:

a) If the energy availability, averaged over the 36 months (three year) guarantee period, proves to be below the guaranteed value, the guarantee period shall be extended by one year. If at the end of this fourth year, the three-year average energy availability, disregarding the year (any twelve consecutive months) with the lowest availability is equal to or higher than the guaranteed value, then the availability guarantee will be considered fulfilled.

b) If the energy availability is below the guaranteed value at the end of the extended (48 month) guarantee period then the Contractor shall, at his own expense, carry out a complete sequential refurbishment of the converter facility and shall replace any equipment or system having a history of failure with an entirely new equipment or system which has, to the satisfaction of the Employer, a significantly reduced likelihood of failure. In addition the Contractor shall replace, at no cost to the Employer, all spare parts, which have been consumed for whatever reason during the guarantee period to date. Following this refurbishment the guarantee period shall be extended by a further 24 months (2 years) and if, during this 2 year period, the energy availability is equal to or higher than the guaranteed value, then the availability guarantee will be considered fulfilled.

<table>
<thead>
<tr>
<th>Transfer Capability</th>
<th>Design Target %</th>
<th>Guaranteed %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bipole</td>
<td>97.5</td>
<td>95.0</td>
</tr>
<tr>
<td>Pole</td>
<td>99.0</td>
<td>98.0</td>
</tr>
<tr>
<td>Valve Group (if any)</td>
<td>100.0</td>
<td>99.9</td>
</tr>
</tbody>
</table>
c) The average availability shall be calculated after this further 24-month period for both the further 24-month period and for the best 4 years (4 non-overlapping periods of 12 consecutive months) during the total availability guarantee period (72 months). The higher value shall be taken for each capability level; however the same 4 periods shall be used for each level. If, after this further 24-month period, the average availability is still below the guaranteed value then the Employer shall be entitled to recover from the Contractor 5% (five percent) of the total Contract price for the whole facility:

(i) For each 0.05% or part thereof that the valve group availability experienced in this further 24 month period or that the average valve group availability over the best 4 years (4 non-overlapping periods of 12 consecutive months) during the total availability guarantee period (72 months) is below the guarantee value; or

(ii) For each 0.20% or part thereof that the pole availability experienced in this further 24 month period or that the average pole availability over the best 4 years (4 non-overlapping periods of 12 consecutive months) during the total availability guarantee period (72 months) is below the guarantee value; or

(iii) For each 0.50% or part thereof that the bipole availability experienced in this further 24 month period or that the average bipole availability over the best 4 years (4 non-overlapping periods of 12 consecutive months) during the total availability guarantee period (72 months) is below the guarantee value;

Whichever is the greatest penalty up to a maximum penalty of 50%

d) If the best 4-year average of the pole availability is below 96.0% or the bipole availability is below 90.0%, the Employer reserves the right to reject the plant and recover all moneys paid to the Contractor under the Contract.

G-3.7.5 Reliability Requirement

G-3.7.5.1 Requirement

A forced outage is any outage, which was not scheduled at least 7 calendar days in advance. A forced outage during a scheduled outage resulting in a cumulative loss of transfer capability greater than the stated threshold level shall be considered as a forced outage curtailing capacity by the cumulative amount. A forced outage during a previous forced outage (or outages) shall not be considered as a new event but shall increase the curtailment of the existing outage (or outages) to the cumulative loss of transfer capacity.

The calculated reliability index of the converter facility shall be equal to or less than the following design target values. Also, the actual average reliability index per year (12 months) over the availability and reliability guarantee period shall be equal to or less than the following guaranteed values.
### G-3.7.5.2 Fulfillment of Reliability Guarantee

As stated above, the Employer will maintain records and monitor the operation of the converter facility during the guarantee period and a preventative maintenance check will be carried out immediately before the start of the said period.

The reliability of converter facility will be calculated annually. The Employer and the Contractor shall jointly make an annual appraisal of reliability performance. If reliability indices achieved are above the target/guaranteed levels, the Contractor shall make a thorough analysis of the cause and take appropriate remedial action to improve the performance. Implementation of corrective actions shall be subject to the approval of the Employer/Engineer. All costs towards such implementation of corrective actions shall be borne by the Contractor.

For fulfillment of the guaranteed reliability, the following shall apply:

- **a)** If the reliability index, averaged over the 36 months (three year) guarantee period, proves to be above the guaranteed value, the guarantee period shall be extended by one year. If at the end of this fourth year, the three year average reliability index, disregarding the year (any twelve consecutive months) with the poorest reliability is less than or equal to the guaranteed value, then the reliability guarantee will be considered fulfilled.

- **b)** If the reliability index is above the guaranteed value at the end of the extended (48 month) guarantee period then the Contractor shall, at his own expense, carry out a complete sequential refurbishment of the converter facility and shall replace any equipment or system having a history of failure with an entirely new equipment or system which has, to the satisfaction of the Employer, a significantly reduced likelihood of failure. In addition the Contractor shall replace, at no cost to the Employer, all spare parts, which have been consumed for whatever reason during the guarantee period to date. Following this refurbishment the guarantee period shall be extended by a further 24 months (2 years) and if, during this 2 year period, the reliability index is less than or equal to the guaranteed value, then the reliability guarantee will be considered fulfilled.

- **c)** The average number of occurrences of unavailability shall be calculated after this further 24-month period for both the further 24-month period and for the best 4 years (4 non-overlapping periods of 12 consecutive months) during the total availability guarantee period (72 months). The lower value shall be taken for each curtailment level; however the same 4 periods shall be used for each level. If, after this further 24 month period, the reliability index is still above the guaranteed value then the Employer shall be entitled to recover from the Contractor 5% (five percent) of the total Contract price for the whole facility for each:

<table>
<thead>
<tr>
<th>Curtailment in Converter System Capacity</th>
<th>Design Target Value</th>
<th>Max. Acceptable Guaranteed Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than one pole</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>More than one pole</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>One bipole</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>
(i) 0.4 occurrences per year or part thereof above the guarantee value that less than one pole is unavailable (viz. more than one pole is available); or

(ii) 0.04 occurrences per year or part thereof above the guarantee value that more than one pole is unavailable, or

(iii) 0.01 occurrences per year or part thereof above the guarantee value that bipole is unavailable...

Whichever is the greatest penalty up to a maximum penalty of 50%

d) If the lower of the average occurrences of unavailability during the further 24 month or best 4-year periods are greater than (i) 5 events of loss of less than one pole, or (ii) 1.0 event of loss of more than one pole, or (iii) 0.2 events of loss of the bipole, then the Employer reserves the right to reject the plant and recover all moneys paid to the Contractor under the Contract.

G-3.7.6 Transient Disturbance Frequency

The Contractor shall design the control and protection equipment to cause no more than 5 transient disturbances (with a duration exceeding 20 ms) per station per year. Transient disturbances in connection with events resulting in forced outages shall be excluded from the above. When more than one transient disturbance occurs within a time period of up to 10 seconds in connection with the same failure or mis-operation, this shall be counted as single transient disturbance.

In addition, the Contractor shall guarantee there shall not be more than 10 (ten) transient disturbances per converter station per year.

The average transient disturbance frequency per converter station per year over the 3-year availability and reliability guarantee period shall be calculated. If the frequency exceeds the guaranteed level the Contractor shall, at his own expense, carry out a complete sequential refurbishment of the converter controls and shall replace any part having a history of failure with an entirely new part or system which has, to the satisfaction of the Employer, a significantly reduced likelihood of failure. Following this refurbishment the guarantee period shall be extended by a further 24 months (2 years) and if, during this 24 month period, the disturbance frequency is less than or equal to the guaranteed value, then the guarantee will be considered fulfilled.

If the average transient disturbance frequency per converter station per year during this additional 24-month period and the average frequency over 4 years (excluding that 12 month period during the 60 months which had the highest disturbance frequency) are both above the guaranteed level the Employer shall have the right to require the Contractor to redesign the control system and replace or add redundancy to the control system at the Contractor’s cost.
**G-3.8 Losses**

**G-3.8.1 General**

The Contractor shall design the converter stations to have the lowest losses and lowest requirement for auxiliary power commensurate with achieving high reliability and availability and stable, secure operation as required by these Specifications.

The losses of the individual converter station and of the bipole facility as a whole shall not exceed the levels stated by the Contractor in his tender. The losses shall be determined by measurement and by calculation as defined in Clause 3.8.2 below.

The Contractor shall guarantee the maximum losses and, if the actual losses are higher than the guaranteed levels, the Contractor shall pay to the Employer liquidated damages as specified in the tender documents.

**G-3.8.2 Loss Determination**

The losses of each converter station shall be determined by summation of the losses in each of the components plus the auxiliary power requirement. The losses shall be determined as a function of delivered active power over the range between 0 MW and maximum continuous overload appropriate to the ambient temperature with all cooling systems available. Loss curves shall be prepared for at least the following dry bulb ambient temperatures:

- Minimum
- Average annual (30°C)
- Highest 24 hour average (40°C)
- Maximum 6 hour average (50°C)

Harmonic losses shall be included in total losses.

The losses of the following components shall be calculated as defined below:

- **a)** DC smoothing reactor losses shall be calculated using values of DC resistance from routine tests and of AC and harmonic resistance from type tests using the Q factors found in the type test. The direct current shall be the highest value corresponding to the active power transmission level (viz. assuming lowest dc voltage possible with tap changer control tolerance and maximum measurement errors taken into account). The ripple shall be assumed to be made up of fundamental and harmonic components of both 50 Hz and 60 Hz where the highest value of current at each frequency is assumed, whether or not the currents could occur simultaneously. The Contractor shall state the maximum currents based on theoretical calculation and shall demonstrate by on-site measurement that the assumed values are not exceeded in practice.
b) Valve losses shall be obtained by summation of losses in the various components and shall include, but shall not be limited to, forward conduction, grading circuit, damping circuit, thyristor firing, and bus-work losses. Forward conduction loss shall be based on the forward volt drop of a representative sample of thyristors. The direct current shall be the highest value as defined in a) above. The valve winding voltage shall be taken as the highest possible at the active power transmission level being considered taking into account firing angle, tap changer, and measurement range and control tolerances. Maximum current and voltage values shall be assumed even if they cannot occur at the same time in practice.

c) Converter transformer losses shall be based on factory routine and type tests. The load and magnetizing losses shall be calculated independently and maximized individually. For the guarantee, nominal voltage and frequency are assumed; however, for the loss curves, the most onerous voltage and frequency within the steady state ranges given in Section 1 of this Part shall be assumed. The tap position resulting in the highest loss in the transformer shall be assumed for the determination of the transformer losses.

d) AC harmonic filter losses shall be based on measured values of component resistance or loss factors as applicable. For capacitors the loss angle Vs. frequency curves from type tests and the routine power frequency loss angle test results shall be used. For reactors the Q factor Vs. frequency curves from type test and the routine inductance measurement shall be used. At fundamental frequency the most onerous voltage and frequency within the steady state ranges given in Section 1 of this Part shall be taken for calculating the loss curves. Harmonic losses shall be calculated with the spectrum of harmonic currents resulting in the highest loss in each component at maximum detuning but with the harmonic impedance of the AC system assumed to be infinite (open circuit).

e) The harmonic filter and any other reactive compensation components as well as the valve firing angles shall be as required to result in zero reactive interchange with the AC networks to which the converter stations are connected. For the loss curves, the highest AC system voltage shall be assumed when determining the firing angle. At any load below that at which a single converter station can operate at zero reactive interchange; the losses shall be half the total losses of two converter stations operating in opposition giving the desired total active power transmission.

f) Auxiliary power requirements shall be calculated using, where possible, measured values of individual loads. All motors necessary to provide the required cooling or air or water or oil circulation for individual items of equipment, valve hall, other enclosed areas, etc; air conditioning loads; anti-condensation heaters; and all other loads needed for continued operation of the converter station shall be included.

The following loads shall be excluded from the loss calculation:

- Redundant cooling and circulation motors;
- De-ionizing equipment;
- Lighting; and
- Loads (such as potable water, fire fighting, and sewage pumps) expected to operate less than 10% of the time.
G-3.8.3 Minimum Efficiency

The efficiency of each converter station shall be not less than 97% at the rated load delivered at each converter station at a dry bulb ambient air temperature of 30°C and under conditions of nominal AC bus frequency and voltage and zero reactive power interchange with the AC networks.

G-3.8.4 Loss Guarantees

The converter facility losses shall not exceed the guaranteed levels.

In all cases, the dry bulb ambient air temperature shall be taken, as 30°C; the AC bus voltage and frequency shall be nominal; and the reactive power interchange with both AC networks shall be zero.

Losses will be guaranteed and subject to assessment of liquidated damages under the operating conditions with three (3) converter stations available and in the full load mode.

The liquidated damages at the corresponding operating condition specified above shall be:

- $US per kW for no load (fixed) losses; and
- $US per kW for load (variable) losses.

(Note: The liquidated damage values will be specified in final bid documents).

G-3.9 Radio Interference (RI) and Audible Noise (AN)

G-3.9.1 General

The Contractor shall take all precautions necessary to ensure that there will be no mal-operation, damage or danger to any equipment, system or personnel within the converter stations due to electromagnetic or electrostatic interference effects. In particular all control and protection equipment shall be designed to be immune from interference from electronic devices including, for example, cell phones and computer peripherals and shall not require that cubicle doors are shut to prevent mal-operation. Any sensitive electronic equipment, which requires screening, shall be placed in a specially screened enclosure, which cannot be opened when the converter station is in operation or in stand-by.

The Contractor shall carry out studies to demonstrate that the converter stations are designed to meet the RI and AN requirements stated herein. The Contractor shall perform measurements during commissioning to demonstrate that the requirements are met.

G-3.9.2 Radio Interference

The Contractor shall take the necessary precautions in the form of valve hall and building shielding to meet his own requirements plus the following:

a) With the converter station operating at any load up to rated value and within the design range of firing angles, the radio interference level (RIL) from electromagnetic or electrostatic radiation generated by the station shall not exceed 100 microvolt/m under fair weather conditions at locations given in IEEE Standard 430-1986 (R1991).
This RIL criterion shall be achieved at all frequencies within the range of 0.15 MHz to 1000 MHz, and with the converter station operating at any active power transfer level up to and including the rated value.

The design shall provide for adding correcting measures should the specified performance not be realized in the final installation. The Contractor shall be responsible for the entire cost of adding the corrective measures.

b) The valve hall design shall incorporate the screening requirements as defined by the Contractor who shall submit an RI screening specification.

c) The radio interference levels shall be calculated assuming an earth resistivity of 1000 ohmmeters.

d) Measurements of actual RI at the station shall be made by the Contractor, at all critical points. Measurements shall be made at a quasi-peak setting and shall include at least three complete frequency scannings at each selected location. The RIL at a particular frequency and location will be considered to be the average value of all measurements taken at that frequency and location.

Measuring instruments shall comply with the American National Standard Institute Specifications for Electromagnetic Noise and Field Strength Instrumentation 10 kHz to 1 GHz, ANSI C63.2.

e) The Contractor shall inspect the shielding material and installation at significant stages of construction.

G-3.9.3 Radio Influence Voltage

For all AC connected equipment, the radio influence voltage (RIV) measured at a phase to ground voltage of 433 kV rms and at a frequency of 1 MHz, according to NEMA Standard 107, shall be less than 500 microvolt.

G-3.9.4 Audible Noise

The Contractor shall provide equipment with low sound power levels and shall limit the audible noise under the most onerous conditions of active and reactive power, supply system voltage and frequency, and ambient to the following levels:

- Valve hall (in places where access is permitted during normal operation): 90 dBA
- Mechanical equipment areas indoor (measured at 2 meter distance): 75 dBA
- Mechanical equipment areas outdoor (measured at 15 meter distance): 75 dBA
- Office space: 45 dBA
- Control rooms: 45 dBA
- Relay rooms: 45 dBA
- Diesel generator (measured at 2 meter distance): 90 dBA
- Compressor areas (measured at 2 meter distance): 90 dBA
- At the closest point of the perimeter fence: 70 dBA
G-3.10 PLC Filtering

G-3.10.1 General

The Contractor shall take all necessary precautions in the form of noise suppression techniques and filtering devices to prevent harmful interference from the converter station to power-line carrier communication (PLCC) systems operating on the connected AC transmission networks.

The frequency spectra to be protected are from 30 kHz to 500 kHz.

The Contractor shall provide information on the noise spectrum at the termination of the converter station in the frequency range from 5 kHz to 500 kHz.

Information on existing and planned power-line carrier systems and frequencies will be given to the Contractor by the Employer.

G-3.10.2 PLC Filters

The Contractor shall design and supply PLC filters and shall coordinate the design of the PLC filters with the requirements of the designers of the power line carrier systems to reduce conducted noise due to the converter facility at the incoming 500 kV terminal bus to acceptable agreed levels.

The Contractor shall state what restriction (if any) the design will place on PLC carrier frequency allocations at and in the vicinity of the converter facility.

The conducted noise power present on the AC system due to the converter facility shall not exceed the power levels due to corona noise effects under fine weather conditions. The levels shall be taken as the fine weather corona noise levels given in Fig. 9 of IEC 60663 suitably corrected for the effect of AC system voltage gradients, numbers of lines entering the substation and the length of those lines. The noise power shall be measured at the point(s) of connection of the PLC systems to the AC lines and shall take into account the effects (if any) of line traps, coupling capacitors and PLC coupling filters on the power levels.

The filters shall meet the above requirements in the PLC frequency range 30 kHz to 500 kHz.

G-3.10.3 Interference Study

The Contractor shall perform a detailed RI, TVI, and PLC interference study. The study is to be based on data to be provided at that time by the Employer/Engineer and shall determine the extent and severity of possible PLCC and open-wire carrier interference from the converter stations and the mitigating measures necessary to avoid harmful interference. The interference study calculations shall be submitted to the Employer/Engineer and shall include, but not be limited to, the following:

a) Probable normal carrier frequency noise levels, plus prediction of the frequency of occurrence and duration of guaranteed maximum carrier frequency noise levels.

b) Sensitivity to interference from the converter facility of PLCC systems operating on the AC lines.
c) Predicted dB decreases in normal and worst case signal to noise ratios for each PLCC system according to (b) above due to interference from the converter facility.

d) Limit values for carrier frequency noise on the AC busbars that are necessary to avoid harmful interference to the carrier systems studied.

e) Detailed designs and noise reduction performance calculations for carrier frequency (PLC) filtering required to meet the limits derived in (d) above.

f) Test methods, procedures and a test program to verify PLCC frequency interference performance.

G-4 STUDIES

G-4.1 General

The Contractor shall perform all studies necessary to design the equipment to fully meet the requirements of the Specification when connected to the AC systems and in the environmental conditions described therein. Considerable latitude is allowed to the Contractor to optimise the design to obtain the best possible reliability and availability while meeting the specified performance requirements.

The Contractor shall develop specifications or design memoranda as well as technical data sheets for each major piece of equipment in which the detailed design requirements of the equipment are specified as well as the technically acceptable limits for all critical parameters and the detailed test specification.

The Contractor shall detail each system study and shall obtain the approval of the Employer prior to commencing the study. The Contractor shall produce a study report for each system and each design study and shall not commence manufacture of any piece of equipment, which could be affected by the results of a study prior to the approval by the Employer of the study report.

G-4.2 System Studies

Following system studies and design will be undertaken by the Contractor:

- Load Flow, Short Circuit, and Stability Study
- Short Circuit Level
- Dynamic Performance
- Reactive Power Management Study
- Normal Configuration
- Degraded Operation
- Harmonic Impedance Study
- Additional System Studies.
- Design Studies
- Main Power Circuit Design
- Harmonic Filter Design
- RI, TVI and PLC Filter Design
- Audible Noise
- Over voltage Study
- Insulation Coordination
- Losses
- Auxiliary Power Supply
- Reliability and Availability
- Step and Touch Potential
- Equipment Design Studies
- Grounding
- Shielding
- Buswork mechanical strength
- Sag calculations
- Foundation design criteria
- Fire protection and Detection
- Lighting
- Any other study required for the complete design of the converter stations and electrodes
PART III

CONTROL SYSTEM CONCEPTS
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G-1 INTRODUCTION

In the HVDC interconnection proposal the electrical output of a group of generators, initially in the range of 1000 – 1300 MW total will be available for transmission to loads in the vicinity of Kabul in Afghanistan and Peshawar in Pakistan. The dc system will be unidirectional towards the two loads and will consist of bipolar converters -/+500 kV fed though connections to the local 500kV or 230kV AC systems. The power input a Tajikistan will be ac 500kV and the power output will feed in to the NTDC system, Pakistan 500 kV grid at Peshawar. The power output near Kabul will provide up to 300 MW into a local 230kV AC grid with the remaining power available for use in Pakistan.

The provisional circuit lengths from Tajikistan terminal are 500 km to the vicinity of Kabul, and a further 250 km to the Peshawar Terminal.

G-2 DIRECT CURRENT CONTROL SYSTEM

The primary control of the HVDC links will be the Master Controllers at the main sending and receiving stations and a sub-master at the Kabul terminal. These main controllers will interface with the main pole controls at each end, which, together with the dc protection systems, will control all aspects of the ac/dc rectification at the sending end and the dc/ac inversion at the receiving ends. Although the uni-directional link could function correctly without communication, more efficient operation, plus the ability to remotely monitor the functionality of all three ends, will require good digital communications links between all three converter sites.

To provide such communication dual OPGW fibre-optic cables should be provided, one carried on each peak of the transmission line towers with drop points at Kabul and at one repeater station on the link to Tajikistan. Whether additional repeaters are required will depend on the final fibre cable and splice loss design calculation and the final routing of the line.

G-3 BUSINESS OFFICE AND CONTROL CENTRE

G-3.1 Overall Network Control

The HVDC system will be operated as a trader network and will require a separate Business Office and control centre to schedule the power transmission for the various segments of each operational day and transmitting the power order to one of the two master controllers and when the power transfer is to be changed. The centre will also require to have data links into the main national or regional control centres of each of the three interconnecting grids to be able to exchange power availability and pricing, and to offer and confirm transmission power schedules both in forward and real time (gate closure) scales. It will also exchange with those centres suitable subsets of network data to visualize the AC network connections and display these on the various centre’s HMI screens. The centre will also require data links to the 500 kV and 230 kV AC link local switchyards to monitor and remotely switch all the various EHV circuits (filters, transformers etc.) and auxiliary station service power, back up generators, battery systems etc. to ensure the reliable operation of the overall interconnection. It will also be able to download fault records from various control, protection and communication systems to be able to analyse any faults or failures and dispatch and monitor emergency maintenance and repair. The centre would also schedule, switch for and control routine maintenance, and manage the line and terminal station inspection and maintenance teams.
In addition to the transmission network control, the adjacent Business office will manage
day-to-day commercial operation, staffing and other routine activities involved with the
operation of the trade network. An office LAN with interconnections to the three terminal
sites and Sub-LAN's at those sites will be used for staff control and maintenance record
keeping, drawings and manual storage. Firewall feeds will also be provided into and out
from the control centre main control network, to provide access to the network operating
data required for management functions.

G-3.2 Network control area

The network control area will be in a separate secure building, a secured section of a
combined Business Centre building designed for high reliability 24 hours continuous (24/7)
operation staffed by a full shift of operators (at least 2), and shift supervisors. The control
room for this operational team would be provided with three (3) (minimum) work-stations,
double/triple screen Wintel machines, plus a large screen display, "video wall" for the
overview of system operations. Surrounding the control room will be the kitchen, lunchroom,
operator’s toilets etc. and the various equipment rooms for the data servers and
communication systems plus the station service and secure duplicate air conditioning
system, and the required UPS backup supplies to provide autonomous operation for at least
24 hours. At least one standby diesel and extended water storage will be provided to
ensure fully autonomous operation for 7 days without any external service.

Office accommodation will also be provided for the operation manager and other day staff,
telecom maintenance, computer maintenance etc., directly involved with the operation of the
control centre. This staff will interact with the main business centre management team
either within the secure control room area or by passing from the security control area to the
normal business area. Provision for internal and external access security and facilities for
security staff accommodation will also be provided.

G-3.3 Business and Management

The main management and business area will be located, either within separate building
section or in a separate building. This will be provided with normal commercial security for
the management and business office. Equipment areas will be provided for the office LAN
server, telephone/internet systems and firewall links to the Internet as a whole and to the
control centre. The office networks will share the main fibre optic cables for the links to the
network and, from each terminal, over utility communication links to the utility control
centres. However, these management systems will use separate fibre pairs and separate
multiplexed SDH networks from the control room operational communications network.

G-3.4 Site location

The business centre and control centre could be located close to either main terminal but
outside the electrical operation area of these switchyards and HVDC systems. This will
allow the required physical security to be applied without requiring access to EHV system
and the electrical safety requirement of such access. It will also minimise electrical noise
injection to the computer systems.

The final location could be in Tajikistan or Pakistan and the physical security onto, fencing,
guard house, lighting, security camera and access security (pass cards etc) plus security
guard accommodation would need to be adjusted, dependant on the final location and the
local risk rating.
The level of security required for operation when power system security could become involved could also be mandated by local regulations.

G-4 COMMUNICATIONS

The main transmission interconnection will carry two OPGW protected fibre optic cables between all three terminals with each cable carrying between 24 and 48 fibre pairs each. Two pairs in each cable will be used for the dc link control main and backup control links, and two pairs will provide the links for an SDH operational communication ring. A further two pairs, per cable; will carry the Business SDH ring and the business LAN links. Spare fibre will be kept to allow services to be switched between cables and/or pairs should a fibre break or splice failure occur but some "dark fibre" capacity will remain that could be used to provide international fibre communications traffic between the network terminals. This could be a separate business opportunity to be managed by the business office with suitable interface connections at each network terminal.

The use of 2 pairs in each cable for the dc link control main and backup control links will ensure redundancy of the control link. The presence of two (2) OPGW fibre optic cables will ensure an optimal level of redundancy because each OPGW is an individual cable and each side of the tower will support one cable. If there is physical damage to one of the OPGW fibre optic cable, the second OPGW will be able to carry all communications. The only common point of failure between the 2 OPGW fibre optic cables is the tower. Therefore the only event susceptible to disrupt the communication is a tower collapse.

The availability of spare fibre optic pairs in each OPGW means that if there is a failure of a fibre optic, the lost channel can be rapidly and easily re-established over a spare fibre optic pair. Therefore, as long as the failure is properly alarmed, the redundancy can always be maintained. The design of the control system must take this reality into account and the status of the telecom system must be reported at the Control Centre level to allow action to be taken in case of a component failure.

Two pairs will provide the links for an SDH operational communication ring. The concept of a ring is recommended because a ring provides a redundant path. If the ring is broken by the failure of a component, the communication can be maintained because all components will still be connected. Modern telecommunication equipments automatically detect a broken ring and automatically reconfigure themselves and re-establish communication. Many modern networks use an SDH ring to carry protection and inter-tripping signals, which require very fast and reliable channels. The communication between control centres can also be carried on this type of network. Again, it is recommended to monitor the equipment and alarm any failure at the control centre, and to maintain a safe level of spare parts to be able to re-establish redundancy quickly in the event of a failure of a component.

A further two pairs per cable will carry the Business SDH ring and the business LAN links. This way the administrative communication will not interfere with the more crucial control communication. Given the availability of a high number of pairs in modern fibre optic cable, this is a practical solution and can easily be implemented. SDH technology is very flexible and if the traffic increases, the multiplexer can be easily upgraded to provide more bandwidth.

The distance of 750 km will most likely require the use of a repeater station because the equipment currently available on the market will probably not be able to send the signal over such a long distance. An attenuation study will have to be conducted to confirm the need of
this repeater station. If required this repeater station will have to be fed by a redundant power supply and will also require a battery sized to provide sufficient independence in case of outage to the power grid.

It should also be mentioned that the fibre optic technology uses light as the transmission medium. This means that the communication is immune to electromagnetic fields, which are inherently produced by high-voltage equipment. The communication will therefore be maintained even in the presence of strong electromagnetic fields.
DETAILS OF OPERATION AND MAINTENANCE (O&M) PLAN
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H-1 INTRODUCTION

This Operation and Maintenance Plan describes the routine and emergency maintenance tasks and inventory management for operating and maintaining the CASA 1000 Interconnection Facility, namely the HVDC transmission line linking Tajikistan, Afghanistan and Pakistan, the Converter Stations and the System Control Centre, as described below in the Project Definition.

H-2 PROJECT DEFINITION

The proposed HVDC transmission system shall be a 3-terminal system operating on +/- 500kV bipolar overhead line, which is 750km long. The transmission interconnection links the Sangtuda hydro power station in Tajikistan to the 500 kV substation in Peshawar (Pakistan) via Kabul city in Afghanistan.

The initial capacity of the three converter stations shall be 1300 MW in Sangtuda, Tajikistan, 1000MW in Peshawar, Pakistan and 300MW in Kabul, Afghanistan.

Provision of upgrading the ultimate capacity of converter station at Sangtuda to 2000 MW, and at Peshawar to 1700 MW at a future stage has been considered in the design of the transmission interconnection. However, the converter station at Kabul shall be kept at the same initial capacity of 300 MW.

The connecting AC systems shall be 500kV, 50Hz in Tajikistan and Pakistan, and 230kV, 50Hz in Afghanistan.

The multi-terminal system shall be unidirectional in order to transmit the hydropower generation from Tajikistan to the load centres in Afghanistan and Pakistan respectively.

The configurations and ratings of the converter stations, as well as possible staging of installations, are shown in Figure H-1 at the end of this Appendix.

The System Control Centre for HVDC line and Converter Stations to be located either in Tajikistan or Pakistan also forms part of the facilities.

H-3 MAINTENANCE PROGRAMS

The high level of facility reliability and availability, which will allow for reliable power transfers with minimum losses, will be achieved through effective maintenance programs.

The maintenance programs can be broadly divided into “Preventive Maintenance Program” and Emergency Maintenance Program (Plan).

Preventive Maintenance is done during the low load periods of the year. This type of maintenance is always pre-planned and scheduled. Several concurrent maintenance activities can be carried out on multiple equipment/ installations during the same outage.

Emergency Maintenance is done during a forced outage after a breakdown of a part or component of the installation. The need for this type of maintenance can be minimized with sound Design/Engineering of the components and a good Preventive Maintenance Program.

Manuals for O&M should be available to ensure efficient and trouble free operation of the system/equipment. These manuals should contain the following information:
Factory and site test certificates for each item of the system with reference to relevant design calculation and quality assurance standards;

Maintenance instructions for all plants and other preventive and corrective maintenance procedures;

Maintenance and inspection schedules for all items/equipment giving type of work required on a weekly, monthly, and annual basis; and

Performa of the required maintenance record sheets for all the component/equipment.

The modern approach to operation and maintenance of power systems consists of renovation and modernization programs, which are described in the following sections.

H-3.1 Renovation and Modernization

Basically, the deterioration of electrical components in the HVDC system is related to electric, thermal, mechanical, chemical, environmental and combined stresses. Hence, failure of equipment could be due to insulation failure, thermal failure, mechanical failure or any combinations thereof.

Renovation, modernization and life extension of existing power transmission systems and substations and field equipment is one of the cost-effective options for maintaining continuity and reliability of the power supply to the consumers. Renovation and modernization (R&M) is primarily needed to arrest the poor performance of the substation equipment (mainly transformers and switchgears), which are under severe stress due to poor grid conditions, poor and inadequate maintenance and polluting environment. In this changed paradigm, efforts today are being directed to explore new approaches/techniques of monitoring, diagnosis, life assessment and condition evaluation, and possibility of extending the life of existing assets, i.e., converter stations, circuit breaker, surge arrester, oil filled equipment like transformers, load tap changer, etc., which constitute a significant portion of assets for the transmission system.

Assessing the condition of the equipment is the key to improving reliability. The knowledge of equipment condition helps to target the maintenance efforts to reduce equipment failures. Reduction of failures of equipment improves reliability and effectively extends the life of equipment. Hence, utilities are continuously in search of ways and means other than conventional methods/techniques to assess the condition of equipment in service. Thus, remedial measures can be taken in advance to avoid disastrous consequences thereby saving valuable resources.

For assessing normal operation, maintenance planning and scheduling, three major tasks need to be identified:

- Incipient failure detection and prevention through supervisory function, monitoring;
- Identification of malfunction or fault state offered by diagnostic techniques; and
- Planning for repair, replacement and upgrading via life assessment and condition evaluation techniques.

Manufactures and maintenance service providers have come out with various condition assessment, diagnostic monitoring, preventive maintenance, predictive maintenance (PDM) techniques for the equipment to reduce the risk of failure and extend their effective life and thereby help utilities overcome the challenges they face. Various condition assessment tools
are used to establish the health of equipment using latest on-line and off-line diagnostic testing techniques/technologies.

H-3.2 Predictive Maintenance

Predictive maintenance is gaining popularity as it helps eliminate unscheduled downtime of equipment and reduces the overall cost of maintenance. This approach is sometimes called condition-based maintenance. There are no established guidelines for the time interval during which R&M and life extension studies must be carried out. The R&M and life extension studies must be done when the performance of the equipment is noticed as deteriorating but not later than two years from the previous such study.

The predictive maintenance relies on planned inspections, testing, analysing and trending of the relevant equipment parameters. In most cases, these parameters can determine the equipment's health and must be followed up by proactive actions that change the way the equipment is operated to reach the goals set out. In other words, the performance of the equipment is analysed to determine its condition and predict when it will need attention. The techniques so developed are grouped under Residual Life Assessment (RLA) techniques. The potential of such techniques is tremendous and their benefits are so many that utilities cannot ignore their importance in the present scenario.

The main objective of RLA is to determine the condition of a set of equipment (e.g., transformers) in order to identify the most vulnerable component/equipment. Based on the evaluation, a strategic replacement plan for a particular equipment can be developed. The aim should be to maximize the availability and utilization by avoiding unexpected failures and at the same time minimizing risk. Techniques for life assessment are quite complex and involve many aspects (both user-oriented and manufacturer-oriented).

H-3.3 Transmission Line Inspection and Timing of Inspections

Standard line patrolling method is to use teams of two or more linemen who "walk" through a section of line, observing everything about the line, using binoculars and making out a line inspection report.

The inspection plan includes:

- tower inspection;
- conductor, insulator, and ground wire inspection; and
- foundation inspection

For each tower inspection needs to be done for signs of corrosion, loose bolts/fittings, any unusual cracks, etc. For inspecting the towers, each lineman starts either from the top of the tower (using binoculars) or from the base and looks for any unusual conditions.

For the inspection of foundations, any soil settlement around the foundation, or any erosion around the foundation needs to be checked. The towers located in active hill torrent zone will require inspection on a continued and periodic basis.

In areas where the line crosses hills/lowest slopes, very careful checking of ground clearance should be done. It is anticipated that during different times of the year soil may either be drifted up on the tower legs. These should be noted and immediate corrective
measures taken to ensure uplift capability by replacing backfill or re-establishing minimum ground clearance.

The line is to be visually inspected every 3 months that the inspectors fill out a simple inspection report indicating any faults, if any and at what tower or span. This report is to be kept as a permanent record of the routing inspection trips.

After the line has been in service for approximately one year and if it is possible to take the line out of service during day light hours, it is recommended that a thorough and complete climbing inspection be made of every tower. It is anticipated that after this climbing inspection, a climbing inspection would only be necessary every 3 years.

H-3.4 Security and Restoration Requirements during Operation and Maintenance

The O&M organization shall be required to exercise appropriate watch and ward for the material storage yards, converter stations and control centre installations. The security personnel can be directly employed or these services can be outsourced. For the transmission lines this function can be transferred to the linesmen who shall regularly petrol the lines. The proposed O&M organization for the lines shall be equipped with an Emergency Restoration System to deal with line failure due to natural catastrophe or uncontrollable human acts. The Contractor shall supply a pre-designed system for 500 KV single circuit Quad bundle DC Line. The Emergency Restoration System shall be supplied complete with all insulators, hardware, foundation plates/joints, anchors, tools and tackles and gin poles etc. and stored in a “ready to transport” container at one of the Converter sites or at a spare material store yard.

H-3.5 The Contractor's Obligations for the Operation and Maintenance

The various Contractors/Suppliers for the implementation of the project would be obliged to provide the following Operation/Maintenance related Supplies and Services:

- Transfer of technology;
- Assistance in operation and maintenance during the guarantee periods;
- Supply of tools and spare parts;
- Supply of complete documentation (As Built and O&M manuals etc.); and
- Provision of guarantees.

The Employer would reserve the right to assign Employer personnel to the Contractor's commissioning team to participate in and witness the commissioning and testing operations at the sites. Employer staff may particularly participate in the commissioning and testing of the HVDC conversion equipment, the HVAC equipment and the HVAC and HVDC switching systems.
H-3.6 Training of Employer Personnel

Training of employer personnel is subject to negotiations with the concession company. The contractor is not responsible for the training of the employer’s staff in operating and maintenance of the equipment.

H-3.7 Operation and Maintenance Assistance

As with the employer training, the concession company is responsible for maintenance and operation and will decide on the assistance required.

H-4 SPARE PARTS

The following provisions shall be specified for the supply of spare parts/materials in various implementation contracts.

A further list of the required spares/materials for the operation/maintenance of the facilities for a foreseeable period should be prepared and the same shall be ordered taking advantage of the provisions of the supply of Optional Spares as mentioned below.

Consumables and spares should be purchased on a periodic basis.

The spare parts and maintenance accessories shall be classified into the following:

a) Spare parts and maintenance accessories required by the Contractor to meet the guaranteed availability and reliability over the guarantee period as specified;

b) Optional spare parts recommended by the Contractor or specified in the relevant Specifications, in addition to (a);

c) Spares required by the Contractor during installation, testing and commissioning of the system; and

d) The operation and maintenance accessories and tools as recommended by the Contractor.

All spares shall be of the same materials and workmanship as the corresponding parts of the equipment furnished and shall be fully interchangeable with those.

A spare part intended for use as a replacement for any one of several similar parts, for example a capacitor unit, shall be a replacement to any one of those parts without resulting in deterioration in the performance of the equipment.

All spares meant for outdoor use, such as buildings, transformers, reactors, resistors, capacitors, arrestors, etc. shall be suitable for prolonged outdoor storage without being energized. The spare equipment shall be supplied complete with bushings, coolers, conservator tanks, oil, etc. as applicable.
H-4.1 Availability of Spares

The Contractors shall supply the spare parts required to meet the specified guaranteed availability and shall include such spare parts in the scope of supply. The spare parts list shall be categorized in two parts:

i) Major components including test equipment, special tools and fixtures; and
ii) Minimum parts required for scheduled inspections and overhaul.

The detailed lists of spare parts to meet the guaranteed reliability and availability requirements shall be part of the contract documents. However, if it is found during detailed engineering or reliability and availability prediction calculation that additional spares are required to meet target values, the Contractor shall make the same available without any additional cost to the Employer.

H-4.2 Optional Spares

The Contractors shall supply, at the request of the Employer at any time prior to the expiry of the guarantee period, the spare parts listed in the list or any part thereof at unit prices not greater than those quoted by the Contractor in his Tender.

The Contractors shall recommend any additional optional spare parts he considers that the Employer would be advised to purchase and shall have listed and provided prices for these additional parts in his Tender.

H-4.3 Site Spares

The Contractors shall supply additional spares, which he expects to consume during installation, testing and commissioning of the systems.

H-4.4 Tools and Tackles

The Contractors shall also supply one set of all special tools and tackles, testing equipment, handling equipment, etc. which are required by the Employer's maintenance staff to maintain the stations successfully.

The proposed O&M organization for the lines shall also be equipped with an Emergency Restoration System to deal with line failure due to natural catastrophe or uncontrollable human acts. The Contractor shall supply a pre-designed system of 10 number Chanettes for 500 KV single circuit Quad bundle DC Line designed and tested in accordance with IEEE 1070 Guidelines.

The Emergency Restoration System shall be supplied complete with all insulators, hardware, foundation plates/joints, anchors, tools and tackles and gin poles etc. and stored in a “ready to transport” container at one of the Converter sites or at a spare material store yard.

The O&M staff shall be trained by the Contractor for the field engineering and field installation of the Emergency Restoration System to ensure that field staff acquires proficiency in restoring failed structures in different scenarios of emergency.
H-4.5 Transport of Spares and Tools

The Contractors shall transport all spare parts/materials to the designated storage areas. The packing etc. shall be suitable for long-term storage.

H-4.6 Offices / Spare parts and material storage Infrastructure

The office facilities for the Converter Station, System Control Centre and line maintenance staff with secured parking, workshops and material storage area are to be provided at suitable locations preferably besides the HVDC converter station areas wherever possible. Similarly, reliable facilities for communication within the various groups and with the head(s) of the operations maintenance organization shall also be required. Depending on the locations of the offices some residential quarters for the staff may also be required close to the offices/converter stations.
Figure H-1  Single Line Diagram of HVDC Interconnection
(Tajikistan-Afghanistan-Pakistan)
I.1 DRY SEASON SENSITIVITY
I Note I.1 Driest and Wettest Years Sensitivity

Dry Years Sensitivity

An analysis is done of the impact on the summer exports of the driest 5 years on record. The Montecarlo simulations of SDDP use as input the historical sequence of inflows for 23 years from 1987 to 2009. Figures I-1 and I-2 below show the average inflows for Nurek and Toktogul respectively from May to August.

Figure I-1 Nurek: Average Inflows May-Aug

![Nurek: Average Inflows May-Aug](image-url)
An analysis is done to simulate the summer surplus of the combined Tajik/Kyrgyz system for the 5 ‘driest years’, meaning the years that produce the lowest surplus (1989, 1995, 2008, 1991, and 2000). The results are shown in Table I-1 and Figure I-3 hereafter.

### Table I-1 Combined Summer Surplus for Tajikistan and Kyrgyz Republic
For 2016 Simulated as One of the Five Driest Years in Historical Sequence

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<td>0</td>
<td>0</td>
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<tr>
<td>May</td>
<td>22</td>
<td>13</td>
<td>5</td>
<td>22</td>
<td>22</td>
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<tr>
<td>June</td>
<td>22</td>
<td>897</td>
<td>334</td>
<td>0</td>
<td>873</td>
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<tr>
<td>July</td>
<td>669</td>
<td>1,127</td>
<td>1,506</td>
<td>1,658</td>
<td>1,498</td>
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<tr>
<td>August</td>
<td>382</td>
<td>929</td>
<td>670</td>
<td>1,595</td>
<td>549</td>
</tr>
<tr>
<td>September</td>
<td>0</td>
<td>0</td>
<td>738</td>
<td>66</td>
<td>679</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,094</td>
<td>2,965</td>
<td>3,253</td>
<td>3,342</td>
<td>3,621</td>
</tr>
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</table>
Wet Year Sensitivity

The results for the five years that produce the highest surplus for the combined Tajik/Kyrgyz system are also shown, in Table I-2 and Figure I-4.
Table I-2  Combined Summer Surplus for Tajikistan and Kyrgyz Republic
For 2016 Simulated as One of the Five Most Wet Years in Historical Sequence

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<tr>
<td>May</td>
<td>1,752</td>
<td>1,553</td>
<td>801</td>
<td>864</td>
<td>22</td>
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<tr>
<td>June</td>
<td>2,027</td>
<td>2,171</td>
<td>2,469</td>
<td>2,226</td>
<td>2,246</td>
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<tr>
<td>July</td>
<td>2,343</td>
<td>2,247</td>
<td>2,303</td>
<td>2,305</td>
<td>2,317</td>
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<tr>
<td>August</td>
<td>2,760</td>
<td>1,786</td>
<td>2,810</td>
<td>2,330</td>
<td>2,319</td>
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<tr>
<td>September</td>
<td>1,089</td>
<td>1,319</td>
<td>1,089</td>
<td>917</td>
<td>1,392</td>
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<tr>
<td>Total</td>
<td>9,971</td>
<td>9,617</td>
<td>9,472</td>
<td>8,643</td>
<td>8,296</td>
</tr>
</tbody>
</table>

Figure I-4  Combined Summer Surplus for Tajikistan and Kyrgyz Republic
For 2016 Simulated as One of the Five Most Wet Years in Historical Sequence

[Graph showing combined summer surplus for Tajikistan and Kyrgyz Republic for 2016 simulated as one of the five most wet years in historical sequence]
Figure I-5 illustrates the variance between the yearly surplus of a given year and the average of yearly surplus over the study period. There is great variation around the average yearly surplus from one year to the next.

One commercial consequence of the above results is that the design of the PPA for sale to Pakistan/Afghanistan needs to be such that most of the energy available is non-firm. The problem of the monthly distribution of exports is less important than the lack of firmness of the summer export volumes.

In conclusion, when a dry year occurs, the region might have a little over 1,000 GWh of surplus to export but when a wet year occurs, there may be close to 10,000 GWh of exports. This volatility makes the export mostly non-firm, with an average around 5,900 GWh.
1.2 DEMAND VS SURPLUS SENSITIVITY
I. Note I.2  Demand Vs. Surplus Sensitivity

Following the sensitivity analysis done on the demand forecast, another sensitivity analysis was conducted to assess the effect of the demand change on the available surplus. For each of the 8 scenarios of demand forecast by country, a modified SDDP simulation generated a new available surplus for each country.

Effect of demand forecast sensitivities on Tajik available surplus:

![Bar chart showing TAJ Surplus Vs. Tariff Increase](image)
Effect of demand forecast sensitivities on Kyrgyz available surplus:

**TAJ Surplus Vs. Loss Reduction (No Tariff increase)**

- S6: -1.35% p.a. up to 2020
- BC: -0.9% p.a. up to 2020
- S7: No Loss Reduction
- S8: -0.45% p.a. up to 2020

**KYR Surplus Vs. Tariff Increase**

- S1: No increase
- BC: 4% p.a. up to 2015
- S2: 6% p.a. up to 2015
The main conclusions are:

1. Tariff increase drives demand forecast down hence it increases surplus
2. Higher elasticity increases demand and reduces surplus
3. Loss reduction makes the system requires less generation to supply the same load hence more generation is available for export. The surplus increases.

In the case of Tajikistan the changes are minimal. But in the case of the Kyrgyz Republic, there are some major differences in between the scenarios. This is a mirror of the operation of the Kyrgyz Republic's system which is governed by a very volatile historical hydrology.
I.3 COORDINATION OF RESERVOIR OPERATION
I. Note I.3  Coordination of Reservoir Storage

When running the two systems in a coordinated operation mode, the software optimizes the use of the water from both reservoirs to minimize operational costs of the system, taking into consideration the export capacity to minimize spillage as well.

Without coordination, both reservoirs are optimized individually by targeting maximum generation in July and August. However with small export capacities (i.e. 1300 MW) this creates a big amount of spillage in these months and a very low export in the months of May, June and September.

With coordination, Toktogul which is the larger of the two reservoirs can shift its production to these other 3 months, letting Nurek handle July and August. There is increased flexibility in taking advantage of Toktogul’s larger size without significantly changing Nurek’s operation. This mode of operation does not violate riparian issues and it firms up the power available particularly during shoulder months, increasing the benefits overall.

In the graphs below the difference in the monthly profile can be observed as well as the annual evolution of the exports, given for the 1300 MW converter size which was deemed the optimal in the report. The blue bars representing the exports under maximum reservoir coordination in the summer are higher than the green ones representing the exports under minimum summer reservoir coordination, with the biggest differences coming in the non-peak months of May, June and September. Included also are the contribution of Kyrgyzstan in both the minimum coordination (purple) and maximum coordination (red) cases.
1300 MW CASA Line Export (Monthly - First 4 Years)

Maximum Coordination - Export
Minimum Coordination - Export
KG→TJ - Maximum Coordination
KG→TJ - Minimum Coordination
The graphs show that the Kyrgyz Republic is focusing on optimizing the exports in the off-peak months letting Tajikistan handle the peak months. This contribution of the storages of Nurek and Toktogul increases the total benefits from the exports with a better distribution for the summer exports and a shift of the “spilled energy” to months where there is unused export capacity.

The operation of both reservoirs can be seen below:
In conclusion, the coordination of reservoir operation in summer shows an improvement in terms of total energy and monthly profile. Hence it is the preferable way to operate the system.

Other benefits that may be considered include reduction of deficits by allowing flow through the interconnector in both directions and throughout the whole year as right now the flow direction is only South and only in the summer, for the sole purpose of optimizing the exportable surplus.
1.4 COSTS
I. NOTE I.4  COST DETAILS FOR SIZE OPTIMIZATION AND PROJECT ALTERNATIVES

I.1. DETAILS OF COST INPUTS FOR SIZE OPTIMIZATION ANALYSIS

The details of cost inputs for the size optimization analysis in section 6 are presented in the tables below. The cost inputs include:

- The HVDC interconnection between Sangtuda, Kabul and Peshawar. The costs of relocating the existing 220 kV line closer to the mountain on steel tubular poles with insulated arms and shorter spans to limit the conductor swing; and route the proposed HVDC line on steel tubular poles (option 1 of the three options proposed in section 7.2) are included in the HVDC interconnection link costs below.

- The HVAC interconnection between Datka and Khoudjand. Based on the analysis presented in section 8.6, the Datka-Khoudjand line is taken as the most viable alternative for interconnection of the Kyrgyz Republic and Tajikistan.

- The internal reinforcements in the countries

- The environmental and social costs.

Estimates provided are inclusive of EPC costs, owner’s engineer fees and contingencies. The O&M cost was estimated as 3% of the investment cost following the experience of the consultant for this type of project. This takes into account additional cost due to rugged terrain and other local conditions.

<table>
<thead>
<tr>
<th>HVDC Size Option (MW)</th>
<th>HVDC Taj-Afg-Pak Line</th>
<th>HVAC Kyr-Taj Line</th>
<th>HVDC + HVAC Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Converters</td>
<td>Transm. Line</td>
<td>Electrodes</td>
</tr>
<tr>
<td>1,300</td>
<td>366</td>
<td>242</td>
<td>18</td>
</tr>
<tr>
<td>1,800</td>
<td>415</td>
<td>283</td>
<td>18</td>
</tr>
<tr>
<td>2,300</td>
<td>457</td>
<td>283</td>
<td>18</td>
</tr>
<tr>
<td>2,800</td>
<td>499</td>
<td>364</td>
<td>18</td>
</tr>
<tr>
<td>3,300</td>
<td>527</td>
<td>364</td>
<td>18</td>
</tr>
</tbody>
</table>

Notes: Project Costs include EPC, Owner’s Engineer and Contingency estimates. The O&M was calculated as 3% of investment cost. An allowance of 3% was made for the losses on the HVDC interconnection itself.
Table 2  Network Reinforcement Costs (million USD)

<table>
<thead>
<tr>
<th>HVDC Size Option (MW)</th>
<th>Tajikistan</th>
<th>Afghanistan</th>
<th>Pakistan</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,300</td>
<td>24.1</td>
<td>4.3</td>
<td>5.9</td>
<td>34.3</td>
</tr>
<tr>
<td>1,800</td>
<td>49.7</td>
<td>4.3</td>
<td>5.9</td>
<td>59.9</td>
</tr>
<tr>
<td>2,300</td>
<td>87.5</td>
<td>4.3</td>
<td>5.9</td>
<td>97.7</td>
</tr>
<tr>
<td>2,800</td>
<td>87.5</td>
<td>4.3</td>
<td>5.9</td>
<td>97.7</td>
</tr>
<tr>
<td>3,300</td>
<td>87.5</td>
<td>4.3</td>
<td>5.9</td>
<td>97.7</td>
</tr>
</tbody>
</table>

Project Costs include EPC, Owner's Engineer and Contingency estimates.

Table 3  Environmental and Social Costs (million USD)

<table>
<thead>
<tr>
<th>HVDC Size Option (MW)</th>
<th>Pakistan</th>
<th>Afghanistan</th>
<th>Tajikistan</th>
<th>Tajikistan-Kyrgyz Line</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,300</td>
<td>2.6</td>
<td>10.9</td>
<td>2.2</td>
<td>0.4</td>
<td>16.1</td>
</tr>
<tr>
<td>1,800</td>
<td>2.6</td>
<td>10.9</td>
<td>2.2</td>
<td>0.4</td>
<td>16.1</td>
</tr>
<tr>
<td>2,300</td>
<td>2.6</td>
<td>10.9</td>
<td>2.2</td>
<td>0.4</td>
<td>16.1</td>
</tr>
<tr>
<td>2,800</td>
<td>2.6</td>
<td>10.9</td>
<td>2.2</td>
<td>0.4</td>
<td>16.1</td>
</tr>
<tr>
<td>3,300</td>
<td>2.6</td>
<td>10.9</td>
<td>2.2</td>
<td>0.4</td>
<td>16.1</td>
</tr>
</tbody>
</table>

*: A 15% increase of the environment and social costs for CASA Phase II Study has been assumed for inflation for the past 3 years.

I.2. DETAILS OF COSTS FOR DIFFERENT PROJECT SCENARIOS

Table 4 summarizes a comparison of the recommended project with alternate project configurations. Table 5 provides the detailed breakdown of the HVDC and HVAC components of the alternate configurations. The network reinforcements environmental and social are respectively 34.3 million USD and 16.1 million USD for all alternate configurations.
Table  Project Configurations Analysed for 1,300 MW Taj-Afg-Pak HVDC Interconnection

<table>
<thead>
<tr>
<th>#</th>
<th>Option</th>
<th>Total Cost (MUSD)</th>
<th>Analysis Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Recommended option: 3 terminal 1,300-300-1,300</td>
<td>873</td>
<td>Offers flexibility for Pakistan to absorb any of Afghanistan’s share that the latter does not need, up to 1,300 MW, which is desirable given the import potential assessments presented in sections 3 and 4.</td>
</tr>
<tr>
<td>B</td>
<td>3 terminal 1,300-300-1,000</td>
<td>858</td>
<td>Most cost effective option, though does not offer flexibility of option A.</td>
</tr>
<tr>
<td>C</td>
<td>3 terminal 1,300-300-1,300 with 2,300 MW line</td>
<td>913</td>
<td>Offers the flexibility to accommodate additional generation capacity though not recommended as the project is based on using existing low cost energy in the exporting countries to supply the importing countries, and that this energy decreased over the study period.</td>
</tr>
<tr>
<td>D</td>
<td>2 terminal with back-feed</td>
<td>870</td>
<td>Offers the benefit of providing electrification to towns between Kabul and Jalalabad. However it would render permanent the segregation of Kabul North and South power systems, which is not recommended, or would require a back to back HVDC converter which would increase the costs.</td>
</tr>
<tr>
<td>E</td>
<td>4 terminal interconnection</td>
<td>n/a</td>
<td>Implies limitations on operations and power transfers and significant costs as a 4 terminal HVDC scheme has never been implemented.</td>
</tr>
</tbody>
</table>

Project costs include EPC, owner’s engineer, contingency estimates, internal country reinforcements and environmental and social costs.

Table 5  Project Costs for HVDC and HVAC Project Components for Alternate Project Scenarios (million USD)

<table>
<thead>
<tr>
<th>Option</th>
<th>HVDC Component</th>
<th>HVAC Component</th>
<th>HVAC Pak – Afg Feedback</th>
<th>HVDC + HVAC Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Converter Stations + Substations</td>
<td>Transmission Line</td>
<td>Electrodes</td>
<td>197</td>
</tr>
<tr>
<td>A</td>
<td>366</td>
<td>242</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>351</td>
<td>242</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>366</td>
<td>283</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>291</td>
<td>242</td>
<td>12</td>
<td>197</td>
</tr>
</tbody>
</table>

Project Costs include EPC, Owner’s Engineer and Contingency estimates. Internal reinforcements and environmental are not included and are estimates at 50 million USD for all scenarios.
1.5 ADDITION OF A FOURTH TERMINAL
Note I.5  Addition of a Fourth Terminal to the CASA Interconnection
Summary of Impacts of the Project

I.1  Introduction

The currently envisaged scheme for the CASA HVDC Interconnection includes three converter stations in Tajikistan, Afghanistan and Pakistan. These three terminals are linked by a 750 km DC line operated at a nominal voltage of +/-500kV.

The implications of eventually adding a fourth terminal to the overall scheme are examined in this note. This may be related to exporting any surplus power from Uzbekistan down to Pakistan or Afghanistan.

The purpose of this document is (i) to outline the various implications of a fourth terminal, (ii) clarify any limits on technical operations, and (iii) recommend the best way forward to keep cost at a minimum while allowing for provisions of a fourth terminal.

I.2  Implications of adding fourth terminal to the CASA Project

HVDC transmission is normally used to achieve efficient power transfers from a single point to another, using an AC/DC converter at each end. DC transmission is preferred over long distances as it does not require any intermediate substations or compensation as AC transmission does. In this case, DC transmission is also preferred as it allows the networks of Pakistan, Tajikistan and Afghanistan to exchange power while remaining asynchronous and shielded from faults or disasters occurring on the other side of the line.

The level of complexity of an HVDC scheme however increases quickly with the number of terminals, hence if there is a possibility to add a fourth terminal to the CASA interconnection, provisions may have to be taken as early as the initial design stage. The following impacts need to be taken into account.

a)  Impact on the Control System

In traditional AC transmission, the power transferred through a line depends on the voltage magnitude and angle difference between the two ends of the line. In DC transmission however, the power transferred is “ordered” at each terminal. Converter stations are given orders to transfer exactly a given amount of power in a given direction and at a given time. Converter stations will then inject power into a network or absorb power from an AC network irrespective of the state of network.

The master control system is then required to (i) synchronize all power orders to ensure that the power injected into the DC line from the exporting countries is equal to the power being sent into the importing countries, (ii) execute any switching or polarity reversal on the line as may be required to allow for an exporting country to import power, (iii) manage and execute all the control strategies required to clear a fault on the DC line, block the valves, ramp-up/down power levels, etc.

Adding a fourth terminal impacts the control system both in terms of hardware and software. In terms of hardware, the fourth terminal will need a telecommunication link to the other terminals and to the master controller (wherever it may be physically located). The master controller itself may require a hardware upgrade to support the processing of the additional signals it received from the fourth terminal. In terms of software, the control system software will need to be upgraded to account for the new set of combinations triggered by the addition of a fourth terminal.
b) Limitations on technical Operations

Given that power is ordered at the receiving end of the line (the “inverter” station), it is the voltage at the receiving end, along with the power ordered that will determine the DC current flowing into the line. The DC current, along with the line resistance, will in turn determine the voltage at the sending end (the “rectifier” station). The design of the three terminal scheme will take into account given differences in voltage between the inverter and rectifier. This dictates basic features such as the AC side transformer tap changer range and needs to stay fixed following the addition of a fourth terminal.

Certain limitations may then depend upon the location of the addition of the fourth terminal. Two possibilities exist: (i) the fourth terminal may consist in a new “tap”, located along the DC line, anywhere between Pakistan and Tajikistan, or (ii) the new terminal may be located outside the DC line and would require an extension of the DC line to the north or to the south.

In the first case, the power injected in the DC line at the fourth terminal will be limited by the current rating of the DC line itself. If the line is rated, for say, 2000 MW at +/- 500kV, this corresponds to a nominal current rating of 2000 A. If Tajikistan is exporting 2000 MW to Pakistan, then there is no capacity left on the DC line for a fourth terminal to inject any power, irrespective of the size of the converter station at the Pakistan terminal. This implies that if the addition of a fourth terminal is foreseen as an intermediate “tap” along the line, then the DC line will have to be rated accordingly in the initial design stage.

In the second case, the DC line would need to be extended on either side of the interconnection. The same limitations apply regarding the existing DC line rating. Furthermore, if the fourth terminal acts as a rectifier (i.e. the country is exporting power), then the converter will be designed according to the voltage dictated by the voltage at the inverter end(s) of the line. If however, the fourth terminal acts as an inverter (i.e. the country is importing power), then it will try to dictate what the voltage should be at the rectifier end(s), which may not be compatible with the exiting converter station design.

These limitations on technical operations can be avoided if (i) the DC line is rated accordingly, (ii) the location of the potential fourth terminal is known, (iii) the “role” of each terminal is fixed (rectifier vs. inverter or importer vs. exporter) and (iv) corresponding provisions are taken in the design of the three terminals in Tajikistan, Afghanistan and Pakistan.

c) Impact on Cost

The impact on the project cost can be approached in two different ways:

1) If the future implementation of the 4th terminal is not confirmed, then the three terminal project could be executed as planned. If the plans for a fourth terminal later materialize, then upgrade requirements and/or operational limitations will have to be studied and evaluated at the appropriate time. If however the plans for the fourth terminal do not materialize, then there will have been no impact on cost whatsoever.

2) If the future implementation of the 4th terminal is confirmed, then appropriate provisions can be taken at the initial design stage of the three terminal project. These provisions include detailed studies to (i) over-rate the DC line, (ii) determine how the first three converter stations need to be specified, and (iii) specify the appropriate provisions within the DC control system. Item (i) is likely to have the greatest impact on project cost.
Another potentially significant impact on the project cost comes from the strength of the AC network that will be interconnected through the fourth terminal. Cost of AC network reinforcements, in the form of lines, SVCs, synchronous condensers, or shunt equipment, may have to be added to the overall project cost. This will especially be the case if (i) the fault level is low on the point of interconnection of the fourth terminal\(^1\), (ii) the AC network is not able to evacuate the power imported from the converter bus (or not able to supply power to the bus for exports), and (iii) the network becomes unstable if a fault appears anywhere close to the converter and triggers loss of the power import/export. This component of the cost has to be determined by detailed studies at the appropriate time.

d) International Experience on Four Terminal and Multi Terminal Projects

Only one fully multi-terminal scheme currently exists for commercial operation. The objective was to upgrade the Hydro-Quebec-New England HVDC link (commissioned in 1986) into a five terminal scheme with the addition of three further terminals. However, the original two terminal link (between Des Cantons and Comerford) was never integrated into the multi-terminal DC network because of anticipated performance problems. No other (higher than three) multi-terminal scheme has ever been implemented since then\(^2\).

The implementation of a four-terminal scheme for the CASA project would then constitute a milestone in the application of HVDC transmission.

Recommendation

Unlike AC transmission, DC technology is not “off the shelf”, and implies a more complex approach where each converter needs to be tailored to the AC network that it interconnects to. Furthermore, the addition of a fourth terminal along the DC line would be equivalent to reducing the transmission distance, which makes the DC solution less competitive to start with.

Finally, the additional import/export combinations that are made available by adding a fourth terminal would need to be extensively studied to ensure the overall scheme works as planned. As mentioned above, the only planned multi-terminal system in operation (Quebec-New England) was finally restricted to three terminals because of performance concerns (and is being operated most of the time as a two terminal), and there has been no experience world-wide in planning and executing multi-terminal HVDC schemes since.

Based on the above, it is recommended that future exchanges of power with neighboring countries should be studied at the appropriate time, at which point other solutions can be evaluated, such as AC transmission, back-to-back converters, etc.

For the purpose of the CASA project, it is SNC-Lavalin’s recommendation that the number of terminals be limited to either two or three.

\(^1\) “low” implies that the fault level is less than 2.5 times the MW rating of the converter

\(^2\) USE OF HVDC MULTI TERMINAL OPTIONS FOR FUTURE UPGRADE OF THE NATIONAL GRID, JOS ARRILLAGA, June 2006
I.6 BENEFIT ALLOCATION
I. NOTE I.6 COUNTRY-WISE BENEFIT ALLOCATION

I.1. Approaches

The allocation of benefits to the countries for regional projects covering many countries is a complex exercise. The approaches are generally used for benefit allocation for regional interconnection projects are briefly described below.

(i) Approach 1 - Allocation of benefits proportional to total costs including the capital costs and O&M costs: In this method a general principle is adopted to distribute the benefits to each of the participant country in proportion to the costs incurred by them. However, this approach ignores the risk allocation to the participants of the project. According to the allocation of project costs to the respective countries as presented in previous sections, Afghanistan would incur the highest cost, and therefore maximum benefits would be allocated to it by adopting this approach.

(ii) Approach 2 - Allocation of benefits based on even distribution: This approach estimates the total project benefits and distributes equally to all the participant countries. Giving the contentious nature of the issue of allocation of benefits and in situations where disagreement of what constitutes an appropriate benefit allocation mechanism, this approach can be adopted by mutual agreement of all the participating countries.

(iii) Approach 3 - Allocation of benefits based on energy: According to this approach, the benefits are allocated in proportion to the quantum of energy being supplied or received by each of the participant countries. This approach estimates the benefits by taking the difference of the selling or purchasing price and multiplying it by the energy to estimate the benefits. For example, the benefits for the country exporting the energy would be: \( 0.5 \times (\text{purchasing price for the importing country} - \text{selling price for the export energy}) \times \text{energy exported} \). Similarly for the importing country, the benefits would be: \( 0.5 \times (\text{purchasing price for the importing country} - \text{selling price for the export energy}) \times \text{imported energy} \). Generally speaking, by adopting this method, the countries that are supplying or importing higher quantum of energy gets the higher benefits. However, the difference in the selling or purchasing price also plays a significant role in the estimation of benefits.

All the three approaches described above were utilized to estimate the benefits for each of the countries for the interconnection option assessed for the economic viability in the above sub-sections - the CASA HVDC transmission line with a capacity of 1,300 MW converters and 1,300 MW transmission line.

I.1.1. Summary of Project Costs incurred by Countries

The capital costs incurred by each of the countries, presented in the table below, were used for the benefit allocation calculation. All costs are based on the premise that this project will be bid internationally and will adhere to international standards. The total investment costs quoted below include contingencies and owner's engineering costs as well as the environmental and social costs. The O&M costs are estimated to be 3% of the capital costs.
Project Costs incurred by Countries (million US$)

<table>
<thead>
<tr>
<th>Countries</th>
<th>HVDC Component</th>
<th>HVAC Component</th>
<th>Reinforcements</th>
<th>Environmental &amp; Social costs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tajikistan</td>
<td>186</td>
<td>17</td>
<td>24</td>
<td>2</td>
<td>230</td>
</tr>
<tr>
<td>Afghanistan</td>
<td>268</td>
<td>-</td>
<td>4</td>
<td>11</td>
<td>283</td>
</tr>
<tr>
<td>Pakistan</td>
<td>172</td>
<td>-</td>
<td>6</td>
<td>3</td>
<td>181</td>
</tr>
<tr>
<td>Kyrgyz</td>
<td>-</td>
<td>180</td>
<td>-</td>
<td>0.2</td>
<td>180</td>
</tr>
<tr>
<td>Sub-total</td>
<td>626</td>
<td>197</td>
<td>34</td>
<td>16</td>
<td>873</td>
</tr>
</tbody>
</table>

The above table illustrates that the investment of HVDC components, HVAC components and the reinforcements as well as the environmental and social costs in Tajikistan, Afghanistan and Pakistan are estimated to be US $ 230 million, US $ 283 million and US $ 181 million, respectively, giving the total Project investment costs of US $ 874 million. As the Kyrgyz Republic is not part of the HVDC transmission interconnection, the cost of the HVDC component is not allocated to it. The HVAC components for the Kyrgyz Republic are estimated to be US $ 180. Similarly, costs for the HVAC component are not allocated to Afghanistan and Pakistan due to the reason that HVAC interconnection link will be only between the Kyrgyz Republic and Tajikistan.

I.1.2. Summary of Benefit Allocation and B/C Ratio

As discussed in Section 10.4, the present value of benefits (year 2016) for each of the countries was calculated based on the discount rate of 10% and for the study period of 30 years. The present worth of the benefits and the total costs including the capital costs and O&M costs for the overall project are estimated to be US$ 1,724 million and US$ 1,281 million, respectively, discounted to the beginning of 2016 at 10%.

The present value of the total benefits (million US$) for each of the countries for each of the approaches described above are presented in the table below.

Present Value of Benefits for the Countries (million US$)

<table>
<thead>
<tr>
<th>Country</th>
<th>Approach 1</th>
<th>Approach 2</th>
<th>Approach 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tajikistan</td>
<td>454</td>
<td>431</td>
<td>656</td>
</tr>
<tr>
<td>Afghanistan</td>
<td>558</td>
<td>431</td>
<td>199</td>
</tr>
<tr>
<td>Pakistan</td>
<td>356</td>
<td>431</td>
<td>663</td>
</tr>
<tr>
<td>The Kyrgyz Republic</td>
<td>355</td>
<td>431</td>
<td>206</td>
</tr>
<tr>
<td>Total</td>
<td>1,724</td>
<td>1,724</td>
<td>1,724</td>
</tr>
</tbody>
</table>
The present value of the capital costs and O&M costs for each of the countries was obtained at a discount rate of 10%. The PV of costs (year 2016) of Tajikistan, Afghanistan, Pakistan and the Kyrgyz Republic, are US $ 336 million, US $ 414 million, US $ 265 million US $ and 265 million, respectively.
J TERMS OF REFERENCE

CENTRAL ASIA - SOUTH ASIA ELECTRICITY TRANSMISSION AND TRADE (CASA-1000) PROJECT

TERMS OF REFERENCE FOR REVISED FEASIBILITY STUDY
Revised January 2009

I. BACKGROUND

Afghanistan, the Kyrgyz Republic, Pakistan and Tajikistan have been pursuing the development of electricity trading arrangements and the establishment of a Central Asia - South Asia Regional Electricity Market (CASAREM). These four countries have intensified their cooperation since 2005 among themselves and with the International Financial Institutions (IFIs) comprising the Asian Development Bank (ADB), the European Bank for Reconstruction and Development (EBRD), the International Finance Corporation (IFC), the Islamic Development Bank (IsDB) and the World Bank (WB).

The initiative to develop the regional market is based on the following considerations:

- expectations that sufficient quantities of surplus electricity are available in the Central Asian countries (the Kyrgyz Republic and Tajikistan);
- significant need for electricity imports in South Asia to meet existing and projected demand;
- differences in the cost of electricity between the importing and exporting countries that potentially provide a justifiable rationale to make transmission investments in order to support the electricity trade; and,
- The expectation that the establishment of the transmission interconnection and the trading mechanisms would attract future private sector investment to enhance the electricity trade in the entire region.

One of the key components of this initiative is the development of the cross-border transmission interconnection linking the four countries to facilitate the transfer of surplus power that would be made available in the Kyrgyz Republic and Tajikistan to Pakistan and Afghanistan.

In order to examine the possibility of regional electricity trade, the four countries together with the experts from the Asian Development Bank and World Bank first met in Islamabad in May 2006. Subsequent meetings to further explore the potential of regional cooperation in electricity trade were held in Istanbul and Dushanbe in June 2006 and October 2006 respectively. A Memorandum of Understanding (MOU) was signed in Dushanbe that commits the countries to pursue the feasibility of the transmission interconnection and trading of electricity with the concomitant institutional and legal framework.

As a result of various meetings, it was established that the proposed transmission line project would be a dedicated link essentially aimed at supplying surplus power from the Kyrgyz Republic and Tajikistan to Pakistan and Afghanistan. The development of the first phase of CASAREM, which is to establish the necessary transmission and trading infrastructure and systems to enable a trade of 1000 to 1300 MW of electricity between Central Asia and South Asia, is referred to as “CASA-1000”. It is envisaged that the major
share of the export will be used by Pakistan, while a relatively smaller quantity of power (up to 300 MW) will be imported by Afghanistan. Pakistan also expressed interest in increasing imports over the medium to long term.

Based on the above broad guidelines, it was decided to undertake a feasibility study of the transmission interconnection project. Terms of Reference (TOR) were prepared for the feasibility study and for the commercial assessment of the Project, which were later on endorsed by the countries through a Memorandum of Understanding (MOU).

The feasibility study was financed by the Asian Development Bank and was awarded to SNC Lavalin of Canada. The study was to be carried out in two phases, with Phase 1 covering a pre-feasibility assessment of the technical and economic viability of the transmission interconnection, and Phase 2 providing the detailed feasibility analysis of the project.

Phase 1 of the study commenced in April 2007 and the inception report was submitted in May 2007. The initial draft of the Phase 1 pre-feasibility report was submitted in July 2007 and a review meeting involving all the participating countries, IFIs and consultants took place in Montreal in August 2007. Based on the decisions taken during the Montreal meeting, a revised draft of the Phase 1 report was submitted in September 2007.

A meeting to review the findings of the Phase 1 pre-feasibility report took place in Kabul in November 2007. During this meeting, a decision was taken by the countries to proceed with the project, and a Memorandum of Understanding (MOU) was signed by the countries, providing a commitment to cooperate and facilitate the implementation of the project. Subsequent to the Kabul meeting, the Phase 1 report was completed in December 2007 and the Phase 2 component was initiated.

The Draft Phase 2 report was initially prepared in July 2008 and was discussed during a meeting in Islamabad in August 2008. Based on the outcome of the discussions in the Islamabad meeting, SNC-Lavalin was asked to carry out additional work. Subsequently, a revised Draft Final Phase 2 report was prepared and submitted in October 2008, and the Final Phase 2 Report was submitted in January 2009. However, ADB’s decision to suspend its involvement in the project in early 2009 resulted in residual reservations about the report not being addressed. The purpose of these Terms of Reference is to address these reservations so that project implementation can proceed on the basis of an acceptable and accepted feasibility study for the project.

II. OBJECTIVES OF THE CONSULTING ASSIGNMENT

The Objective of the consulting assignment is to finalize the feasibility study for the CASA-1000 Project, and present the conclusions and recommendations of the study to the four participating countries, as well as the participating International Financial Institutions, so that these are confirmed and accepted.

III. SCOPE OF SERVICES

The scope of the services to be provided by the Consultants covers updating of the following aspects:
1. **Assessments of the availability of surplus power in Tajikistan and in the Kyrgyz Republic.** These updated assessments will cover a base case and appropriate sensitivities. Relevant recent work carried out by other Consultants will be reviewed and any significant variations in the results of surplus analyses will be documented and analyzed.

**Base Case**

The analysis for the base case will take into consideration the following:

- **Generation from Existing Plants.** This will be based on an updated analysis of existing hydrological data as well as the potential impact of factors such as climate change. Available reservoir capacities and limitations imposed by the need to meet commitments for irrigation releases will be appropriately considered. Reported summer spillages at the Nurek and Kairakum reservoirs due to lack of summer demand will be investigated and taken into account. Latest data on the efficiency and availability of generating plants will be considered, as well as any likely future plant outages.

- **Generation from New Projects.** Generation from those new projects will be included that are already under construction, have committed financing, and can be reasonably accepted to be commissioned in the next few years. Potentially controversial projects or projects that could trigger complex safeguard issues will be excluded.

- **Current Demand.** Assessment of the current demand, on a month by month basis, will be based on a detailed review of the net actual billed sales to the various classes of consumers as well as an estimate of unmet demand.

- **Demand Projections.** Projections of future demand will take into account all relevant factors, including:
  - **Reduction in Transmission and Distribution Losses.** The transmission and distribution losses are currently quite high: about 19% for Tajikistan and 33% for Kyrgyzstan. Given that the losses associated with the sizeable consumption of Talco in Tajikistan would be very low, the loss percentage for the non-Talco consumers is not too different from the Kyrgyz level. A reasonable rate of reduction in these losses will be assumed keeping in view both the Governments’ programs as well as relevant experience from other countries with similar level of losses. If the loss reduction is expected to result primarily from a reduction in commercial losses, part of the reduction in losses will be assumed to be converted to demand as a result of consumers now being compelled to pay for this part.
  - **Tariff Increases.** For each country, a reasonable estimate of future tariff increases will be assumed and the impact on future demand evaluated using an appropriate price elasticity factor.
  - **GDP Growth.** For each country, the impact of GDP growth on electricity demand will be evaluated based on the latest growth estimates and appropriate income elasticity factors.
Existing Import-Export Commitments. The assessments of the availability of surplus power in Tajikistan and in the Kyrgyz Republic will take into account all applicable existing agreements for the export and import of electricity.

Sensitivity Analysis

The sensitivity analyses will include:

- An analysis to assess the impact of considering only generation from existing plants, i.e. excluding generation from new plants.
- An analysis to assess the impact of a reduction in hydropower generation.
- An analysis to assess the impact of an increase in hydropower generation.
- An analysis to assess the impact of no tariff increases.
- An analysis to assess the impact of greater tariff increases than that assumed in the base case.
- Analyses to assess the impact of variations in the income elasticity factor.
- Analyses to assess the impact of a slower/faster rate of loss reduction than that assumed in the base case.

Analysis will also be carried out to assess the impact on the available surplus of a typical dry year (or, if more appropriate, a dry cycle) and the implications for the project will be assessed.

2. Assessment of the Import Potential of Pakistan. This update will take into account recent developments in the energy sector in Pakistan, including the contracts recently awarded for rental plants, updated demand projections and the latest generation expansion plans.

3. Assessment of the Import and Export Potential of Afghanistan. This assessment will take into account recent developments in the energy sector in Afghanistan, including updated demand projections, latest generation expansion plans, recent electricity import agreements, and an assessment of the capacity of the distribution network to supply the potential CASA-1000 imports to consumers. The potential for using the CASA-1000 transmission link for winter exports (night time) from Afghanistan and for possible swap of power with Pakistan will also be assessed.

4. Assessment of the Cost of Supply of the Available Surplus from Tajikistan and the Kyrgyz Republic and of the Cost of Supply from Alternate Sources for Afghanistan and Pakistan. This update will separately consider both economic costs and financial costs for the different periods of the year in which the surplus exports are foreseen, as these will be inputs into the assessment of the economic and financial viability of the project.
5. Assessment of the Optimum Size of the Project and the Exportable Surplus. On the basis of the assessments of (i) the available surplus from Tajikistan and the Kyrgyz Republic, and (ii) the import potentials of Afghanistan and Pakistan, the optimum capacities of the DC transmission interconnection required and of the DC-AC conversion stations at Sangtuda, Kabul and Peshawar will be determined. The optimization will consider economic and financial aspects, as well as flexibility of operation and adaptability to future capacity enhancements.

Based on the upper limits imposed by this optimum configuration, the exportable electricity surplus for each month of each year will be evaluated. In assessing the exportable surplus, the Consultants will analyze the impact of the use of average hydrology to calculate the export surplus to take into account the fact that the impact of a transmission capacity constraint on the higher output during wet years is not fully reflected when average hydrology is used. This analysis will include the mitigating effect of using available storage capacity of the reservoirs (particularly at Toktogul).

For periods when available surpluses exceed transmission capacity, the Consultants will identify options to apportion the exportable surplus between the two exporting countries, keeping in view the possibility that the terms of the Power Purchase Agreements could be different for the two exporting countries.

6. Recommended Route for the DC Transmission Line. In view of recent security-related developments, the route recommended in previous studies for the Kabul-Peshawar portion of the DC transmission line will be reviewed. The Consultants will determine the need for considering any alternative routing and, if considered necessary, identify such routing and make appropriate recommendations.

7. Identification of the Transmission Needs of the Existing Networks of the Four Countries. Based on the preceding analyses, the augmentation required for the existing transmission networks of each of the four countries will be identified by review and, if required, updating of available load flow studies. This will cover:

- Assessment of the transmission augmentation required in Tajikistan and the Kyrgyz Republic to transmit the electricity surpluses to the Sangtuda AC-DC conversion station.

- Assessment of the transmission augmentation required in Afghanistan from the Kabul DC-AC conversion station and in Pakistan from the Peshawar DC-AC conversion station to transmit the electricity imports to the distribution networks.

For transmission of the exportable surplus from the Kyrgyz Republic, the following two options will be investigated:

- A direct transmission line from the Datka substation in the Kyrgyz Republic to the Sangtuda AC-DC conversion station for onward export through the CASA project.

- A swap arrangement whereby the exportable surplus from the Kyrgyz Republic is transmitted to an appropriate substation in Tajikistan for consumption in the northern part of the country, with equivalent electricity from Tajik generation in the south being transmitted to Sangtuda for onward export through the CASA project.

The assessment of these options will take into consideration appropriate factors, including costs, transmission losses, and contractual issues.
8. **Defining the Control Scheme to Manage the Operation of the Transmission Interconnection.** Based on the review and updating of the load flow studies carried out for the previous activity, and any other analysis required, the Consultants will assess the control philosophy and additional equipment required to ensure that the available surplus power from the Kyrgyz Republic and Tajikistan reaches the Sangtuda AC-DC conversion station and is transmitted through the CASA transmission line. Requirements relating to the monitoring and control centres will also be analyzed to assess whether a new control centre is needed or one of the existing control centres could be upgraded to monitor the power flows across the relevant borders and to communicate with other existing control/dispatch centres.

9. **Assessment of the Project Cost and Its Country-wise Allocation.** The project cost estimate will be updated taking into account the results of the above analyses and the specific project conditions (altitude, terrain, seismicity, impact of security concerns, etc.). Appropriate contingency provisions will be included. The country-wise allocation of the costs will be based on each country bearing the cost of the facilities to be located within its borders.

10. **Developing the Implementation Plan for the Project.** An updated and detailed project preparation and implementation schedule will be developed. Adequate time will be provided for preparation, review and approval of bidding documents and evaluation of bids. Requirements for environmental assessment and mitigation will be appropriately reflected. An assessment of potential bidder interest in the project will be provided, together with recommendations for maximizing participation in the bidding.

11. **Undertaking the Economic Analysis.** The updated project economic analysis will reflect changes in project scope and size, updated assessment of the electricity to be exported, revised cost estimates, economic costs of supply of the electricity exported from the Kyrgyz Republic and from Tajikistan, economic benefit of the electricity imported into Afghanistan and Pakistan, updated implementation schedule, etc. Appropriate sensitivity analyses will also be carried out. Country-wise distribution of benefits will be estimated.

12. **Defining the Major Risks Associated with the Implementation and Operation of the Project.** The Consultants will identify and classify the major risks associated with the implementation and operation of the project, and will make appropriate recommendations for mitigating these risks.

13. **Functional Specifications of the DC Transmission Line and Conversion Stations.** If required as a result of the analyses carried out by the Consultants as part of this assignment, the functional specifications of the DC transmission line and the conversion stations will be updated.

14. **Operation & Maintenance Plan.** If required as a result of the analyses carried out by the Consultants as part of this assignment, the Operation & Maintenance Plan will be updated.

**IV. Deliverables and Schedule**

The following reports will be submitted by the Consultants to the Inter-Governmental Council (IGC) through the IGC Secretariat:
• **Inception Report.** The Inception Report will present the methodology and work plan proposed by the Consultants to perform the services listed above, including the main assumptions to be adopted for the various analyses. This Report will be submitted by the Consultants within two weeks of the start of the assignment. Submission will be in the form of twenty hard copies, as well as electronically. Comments on the Inception Report will be provided to the Consultants within two weeks of the receipt of the Report.

• **Interim Progress Report.** Six weeks after the start of the assignment, the Consultants will provide a brief Interim Progress Report (two to three pages), outlining the progress made on each activity listed in the Scope of Services and any major constraints being faced by the Consultants in carrying out this study. This Report can be submitted electronically.

• **Draft Revised Feasibility Report.** The Draft Revised Feasibility Report will present the results of the studies and analyses performed by the Consultants in compliance with the scope of services given above. This Report will be submitted by the Consultants within ten weeks of the start of the assignment. Submission will be in the form of twenty hard copies, as well as electronically. Comments on the Report will be provided to the Consultants within three weeks of the receipt of the Report. A review meeting to discuss these comments will be held in Washington with the project stakeholders to clarify any outstanding issues, validate the conclusions and recommendations of the study, and take appropriate decisions relating to the implementation of the project.

• **Final Revised Feasibility Report.** The Final Revised Feasibility Report will incorporate the comments received by the Consultants on the Draft Revised Feasibility Report. This Report will be submitted by the Consultants within four weeks of the receipt of comments on the Draft Revised Feasibility Report. Initial submission will be in the form of twenty hard copies, as well as electronically. Approval of the Report will be provided to the Consultants within two weeks of the receipt of the Report. After intimation of the approval, the Consultant will submit a further eighty hard copies of the Report.
K COMMENTS TO DRAFT FINAL REPORT

Project stakeholders (participating countries and financing agencies) provided comments to the draft final report, which were incorporated in the final report. These comments and the revisions incorporated in the final report are summarized below.
## FEASIBILITY UPDATE BY SNC-LAVALIN - PRELIMINARY DRAFT FINAL REPORT
### RESPONSES TO COMMENTS FROM AFGHANISTAN

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<tr>
<td>1. Pgs. 2-1 to 2-17, Section 2, Assessment of Export Potential:</td>
<td>This will be clarified for the Final Report as part of the review requested in comments from Kyrgyz Republic</td>
<td>The load forecast and energy surplus assessment in section 2 were revised</td>
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<td>The analysis in this Section 2, as noted in the study, is based on rather broad assumptions, particularly with respect to the Kyrgyz Republic. The loss reduction and collection rate assumptions appear somewhat aggressive (e.g., Kyrgyz Republic losses dropping from 29% in 2009 to 15% in 2015 and collections reaching a 98% in 2015).</td>
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<td>2. Pg. 2-11, Section 2.4.1, Modeling Assumptions, Existing Exports subsection:</td>
<td>Reference reports indicated that the transmission line would be operational by 2010. The consultant understands that since the issuance of these reports, certain delays may have been incurred.</td>
<td>Sections 2, 4 and 8 have been revised to indicate that the line is under construction and is expected to be operational by 2016, which is the beginning of the study period.</td>
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<td>As in SNC Lavalin’s Interim Report, it is stated in this Feasibility Study Update that: Tajikistan already exports to Afghanistan through a 220 kV line rated at 300 MW. The annual exports are close to 650 GWh. There is currently only a 110 kV line from Tajikistan to Afghanistan. The only 220 kV line from Tajikistan to Afghanistan is the 220 kV line, rated at 300 MW, under construction, which is being financed by ADB and the Islamic Bank, and is not currently operational. This needs to be clarified with SNC Lavalin, and the modeling corrected, if necessary. Note also that SNC Lavalin later in Section 8 of the study refers to a pre existing 200 MW power export from Tajikistan to Afghanistan through the Sangtuda-Kunduz and Pol-e-Khumri 220 kV, double circuit interconnection. See my comments 10 and 11 below.</td>
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<td>3. Pg. 2-11, Section 2.4.2, Kyrgyz Republic Surplus, 2nd line:</td>
<td>This is noted and will be revised.</td>
<td>Text revised in section 2.4.2</td>
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<td>A minor issue is that the reference to Section 3.1.2 in this line is incorrect. It should be to Section 2.3.1.</td>
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<td>4. Pg. 2-12, Section 2.4.3, Tajikistan Surplus, 2nd line:</td>
<td>This is noted and will be revised.</td>
<td>Text revised in section 2.4.3</td>
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<td>A minor issue is that the reference to Section 3.1.2 in this line is incorrect. It should be to Section 2.3.2.</td>
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<td>5. Pg. 3-1, Section 3.1, Generation Capacity, 1st Paragraph:</td>
<td>This is noted and will be revised.</td>
<td>Text revised in section 3.1</td>
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<td>A minor issue is that the thermal, hydro and nuclear generation numbers in the text do not add up to the total generation capacity in the text. All generation capacity numbers in the text match the numbers in the accompanying Table 3-1, except for the text number for thermal generation capacity. The number in the text for thermal capacity should be 13,370, instead of 13,379. This should be corrected.</td>
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## Responses to Comments from Afghanistan

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<td><strong>6.</strong> Pg. 3-4, Section 3.3, Evaluation of Supply-Demand Balance: According to Table 3-4, Pakistan will have a supply surplus in the period 2015-2016 through 2022-2023. This would begin about the time of the projected commissioning of the CASA 1000 line and continue for eight years. However, the Study is correct in observing that it may be difficult to build all the generation capacity included in Table 3-4, particularly the large coal and hydropower projects, which are subject to financing difficulties and construction delays. Therefore, the CASA 1000 line would likely contribute to alleviating the shortage in generating capacity in Pakistan. This conclusion is underscored by the regulatory, economic and political difficulties that have plagued coal development in Pakistan, and the recent World Bank determination in May of this year not to finance the large proposed Thar coal-fired power plant. While some maintain that the Thar project can still be completed by the 2015-2016 period, this is a very optimistic schedule.</td>
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**Response:** Comment acknowledged. The CASA imports are included in the supply projections from 2016 onwards. The Final Report will explicitly state level of imports assumed. Added in section 3.1 |

| **7.** Pg. 4-2, Section 4.2, Power Demand Situation in Kabul Region and Country: A Forecast of Afghanistan Demand by Province was prepared by a working group of the Afghanistan Inter-ministerial Commission for Energy in 2008, and updated by the Ministry of Energy and Water in 2010. This demand forecast projects much higher demand than is reflected in the feasibility study update. The Demand Forecast accompanies these comments. Accordingly, the power demand situation in the Kabul Region and the whole of the country discussed in the feasibility study update should be re-evaluated and the relevant input values adjusted. |

**Response:** The demand forecast shows a 10% yearly increase for the study period, which does not take into account projected economic growth such as GDP. Added in section 4.2.
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<td>8. Pg. 6-8, Section 6.4.3, Potential Addition of a Fourth Terminal to the CASA Interconnection: The study notes that there have been discussions concerning the addition of a fourth terminal to the interconnection scheme, presumably related to the possibility of exports of power from Uzbekistan to Afghanistan or Pakistan. SNC-Lavalin recommends that the CASA project be limited to two or three terminals. As stated in the study, the “only planned multi-terminal system in operation (Quebec-New England) was finally restricted to three terminals...and there has been no experience world-wide in planning and executing multi-terminal HVDC schemes since.” In light of that fact, the recommendation of SNC-Lavalin should be heeded, and such a sophisticated scheme should be avoided.</td>
<td>Comment noted.</td>
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<td>9. Pgs. 7-1 and 7-2, Section 7.2, Transmission Line Route: In this section various options and their costs for HVDC line use of the constrained Salang Pass route are discussed. However, an alternate route to by-pass the Salang Pass should be considered and evaluated, which the study appears to indicate will be done in the final feasibility update report.</td>
<td>An alternate route to by-pass the Salang Pass is being evaluated and will be presented.</td>
<td>The alternate route is provided in section 7.</td>
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<td>10. <strong>Pg. 8-2, Section 8.2, Transmission Needs of the Existing Network in Tajikistan, subsection Results, 1st bullet on the page:</strong> SNC-Lavalin again states that “There is a pre-existing 200 MW power export from Tajikistan to Afghanistan through the Sangtuda-Kunduz and Pol-e-Khumri 220 kV, double circuit interconnection.” Again, no such 220 kV line exists at this time, although there is a 300 MW 220kV line under construction. It may be that SNC-Lavalin is referring to the line under construction, although in Section 2.4.1 they speak of a 300 MW line and here they speak of a 200 MW line, and in both cases indicate it is in existence. However, by “pre-existing” they may mean that it will be in existence in 2016, because in the discussion of Afghan power imports in Section 4.1, SNC-Lavalin recognizes the 300 MW of power from Tajikistan to be imported from the ADB financed interconnection under construction. If in this Section 8.2 they are referring to the 300 MW line that is under construction and are treating it as pre-existing for purposes of the study, there may be no modeling problems, but, at a minimum, the language in this Section 8.2 and in Sections 4.2.1 and 8.7 should be clarified and they should be conformed to one another as to the size of the line. See my comments 2 and 11.</td>
<td>Reference reports indicated that the transmission line would be operational by 2010. The consultant understands that since the issuance of these reports, certain delays may have been incurred.</td>
<td>Sections 2, 4 and 8 have been revised to indicate that the line is under construction and is expected to be operational by 2016, which is the beginning of the study period.</td>
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<td>11. <strong>Pg. 8-5, Section 8.7, Backfeed Option between Peshawar and Kabul, 2nd full Paragraph following bullets:</strong> Once again there is a reference to a northern 220kV link to Tajikistan rated at 200 MW. See my comments 2 and 10 above. Additionally, in analyzing the operational difficulties of the back-feed option, SNC-Lavalin observed that “Supplying a total of 300 MW to Kabul would require 100 MW to be supplied from Peshawar,” since the northern 220 kV Tajikistan connection is “rated at 200 MW” It appears from the statement that SNC-Lavalin considers the 300 MW importation of power from Tajikistan through the ADB/Islamic Bank financed interconnection to be tied to Afghanistan’s 300 MW entitlement to power under CASA 1000, implicitly limiting Afghanistan to a total of 300 MW under the two projects. The 300 MW in imports through the ADB/Islamic Bank financed interconnection, and the 300 MW entitlement of Afghanistan under CASA 1000 are two separate projects providing a total of 600 MW of power to Afghanistan. This issue</td>
<td>This will be clarified and addressed in the Final Report.</td>
<td>Sections 2, 4 and 8 have been revised to indicate that the line is under construction and is expected to be operational by 2016, which is the beginning of the study period.</td>
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<td>must be clarified.</td>
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<td><strong>12. Pgs. 8-4 to 8-6, Section 8.7, Backfeed Option between Peshawar and Kabul:</strong> As an alternative to the three terminal scheme, a two terminal interconnection between Sangtuda and Peshawar with a backfeed from Peshawar to Kabul over a 220 kV line is evaluated. The bottom line savings of the two terminal option is $10 million if equivalent service is provided, and those savings may well evaporate if the line losses through the 220 kV line from Peshawar to Kabul are considered. However, severe operational problems would be encountered by Afghanistan, as outlined in the study, if the backfeed option is adopted. The disadvantages posed by these operational problems are not justified, according to the study, by the cost savings that may result. The study observes that the operational problems could be overcome if the backfeed from Peshawar was taken into Kabul by a back-To-back HVDC converter at a cost of $25-30 million, but this would render the backfeed option more expensive than the three terminal scheme. The study also considers some potential advantages that the backfeed option could offer, but observes that those potential advantages could be accomplished by other means possibly at less cost. Therefore, Afghanistan opposes the backfeed option for the reasons related in the study.</td>
<td>Comment noted.</td>
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<td>13. <strong>Pgs. 9-1 to 9-4, Section 9, Assessment of Project Cost and Country Wise Allocation:</strong> The project cost estimates are for the HVDC interconnection link with 1300 MW conversion capacity and 2300 line capacity, assuming the Salang Pass route option of moving the existing 220 kV line closer to the mountain, with the cost of electrodes and the cost of network reinforcements excluded. Under the current allocation of costs using best estimates for the engineering, procurement and construction (EPC) costs for both the HVDC interconnection (Tajikistan-Afghanistan-Pakistan) and for the overall project, including the HVAC interconnection (the Kyrgyz Republic-Tajikistan), Afghanistan is to bear the highest percentage of EPC costs among the participating countries. The EPC costs for the HVDC interconnection total $565 million of which Afghanistan is to bear 46% of the EPC costs, Tajikistan 29%, and Pakistan 25%. The EPC costs for the overall project total $741 million of which Afghanistan is to bear 35% of the EPC costs, Tajikistan 24%, the Kyrgyz Republic 22%, and Pakistan 19%. When the costs of Owner’s Engineer, Contingency, and Interest During Construction (IDC) are added they increase the overall project cost by $253 million making the total project cost $994. The benefit allocation for each country was requested during the initial study to provide some indication of how benefits can be allocated to each country. However, for deciding the viability of the project, the overall economic project benefit / cost ratio should be the determining economic criteria rather than individual country benefit / cost ratios. Commercial agreements should ensure that each country receives appropriate allocation of the financial benefits to ensure adequate return to fund financial commitments.</td>
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<td>The economic analysis in Section 10 (see table 10-4) considers the overall project costs to be comprised of EPC costs for the HVDC interconnection and the HVAC interconnection, the costs of the Owner’s Engineer, Contingency, and System Reinforcement Costs (but excluding IDC). With such a composition of costs, the overall project total is $866 million, of which Afghanistan is to bear $296 million or 34% of the costs, Tajikistan 26%, Kyrgyz Republic 21%, and Pakistan 19%.</td>
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<td>14. Pgs. 10-1 to 10-9, Section 10, Economic Analysis: For purposes of the economic analysis, the economic benefits of the project are considered to be the avoided costs in Afghanistan and Pakistan as a result of the import of energy from Tajikistan and the Kyrgyz Republic. The benefits were assessed by comparing the cost of generation in the exporting countries plus the cost of the transmission interconnection with the cost of generation in the importing countries. The present value of the benefits and the present value of the project costs were calculated based on a discount rate of 10% for the study period of 30 years (2016 through 2045). With those parameters, SNC-Lavalin calculates the present value of the benefits of the project at the beginning of 2016 to be $1,366 million, and the present value of the project costs to be $1,274 million, yielding a project benefit to cost (B/C) ratio of 1.07 and an EIRR of 11.4%. If environmental and social costs are included in project costs, the B/C ratio would be 1.05 and the EIRR would be 11.0%. The study then outlines three approaches to the allocation of benefits to the individual countries. The first approach is based on the proportion of the project cost borne by each country. As noted in comment 13 above, Afghanistan is to bear $296 million of the project costs estimated, for purposes of the economic analysis, to be $866 million, or 34% of those costs. The second approach to allocation of benefits is based on an equal allocation of benefits to all participating countries, and the third approach is based on the amount of energy supplied or received by each country. As shown in Table 10-4, the use of any approach other than the first (benefits allocated proportional to capital costs) makes the project a disaster for Afghanistan, and Afghanistan opposes any approach other than Approach 1.</td>
<td>See comments above in Item 13.</td>
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# Feasibility Update By SNC-Lavalin - Preliminary Draft Final Report

## Responses To Comments From Pakistan

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<tr>
<td><strong>1. Annual Export Potential</strong>&lt;br&gt;The average export potential for the Central Asian States tables provided on page 6.2 and 6.3 of above report indicate that the export potential is decreasing each year, both in terms of firm and non-firm energy / power over the term of the years (2016-2035). This necessitates that the economic analysis should carried out based on the yearly export potential (of course considering transmission capability) and not the initial years energy / power which is taken as constant for the rest of the period of analysis. Such an analysis will reflect a true picture of the economic viability of the project.</td>
<td>The scenario selected (no new power plants in the exporting countries) is a conservative scenario and was selected after extensive discussion. The economic analysis is based on the yearly exportable surplus, and not on the initial years’ energy assumed to be constant for the period of analysis – the latter is a sensitivity.</td>
<td>Addressed in section 5. The costs were reviewed to consider the cost of purchasing power from the Sangtuda I &amp; II projects as well as the O&amp;M fixed costs of Nurek and other existing hydro power plants.</td>
</tr>
<tr>
<td><strong>2. Price of Export Energy</strong>&lt;br&gt;On page 10.3 the price of export of energy has been taken as US$ 0.015 / kWh for Tajikistan and US$ 0.xxx / kWh for Kyrgyz Republic as a proxy to cost of export. In the previous study, this has been taken as 4.4 cent/kWh. This issue needs to be probed further reasonably. In this context a copy of table produced by US Embassy Bishkek is attached which indicates that the Kyrgyz average export price for 2008 and 2009 was US Cent 4.55 and 4.03 respectively. The report further states that Kyrgyzstan plan to export 3.29 billion kWh of electricity in 2010, most of which will go to Kazakhstan at a price of 2.8 cent / kWh. Another attached report/news item states that Tajikistan is losing millions of dollars at a cost-price of two (2) cent/kWh.</td>
<td>The numbers used in the report were based on information provided by each of the countries and adjusted (as required) to ensure information used in the modeling was on a consistent basis. There are many news items and reports that provide different numbers but as the sources and the method of calculation could not be determined, the numbers that we provided officially were used. Should the official source data received from the countries change, then the inputs to the models could be changed subject to complete review.</td>
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<tr>
<td><strong>3. Pakistan Generation Cost</strong>&lt;br&gt;For the purpose of assessment of generation cost in Pakistan (page 5-1), the price that the state owned utility (NTDC) is paying for the recent long term PPAs with the IPPs has been used as a proxy of LRMC. The blended rate for firm and not firm energy has been taken as US$ 0.09 / kWh. However, the detail working has not been provided in the study.</td>
<td>The details of how this numbers will be provided. In the absence of official numbers, assumptions based on available information were made.</td>
<td>The prices of firm and non-firm energy are provided in sections 5 and 10.</td>
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# Feasibility Update by SNC-Lavalin - Preliminary Draft Final Report Responses to Comments from Pakistan

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<tr>
<td><strong>4. Long Run Marginal Cost</strong>&lt;br&gt;Further, this rate of LRMC is somewhat less than US 10.8 cents / kWh as determined in the previous feasibility of January 2009 (page 2-7). It may be pertinent to add here that this rate, being a proxy to IPPs tariffs, does not reflect a real LRMC which should have been based on proper Least Cost Generation Plan. In fact the Least Cost Generation Plan is under preparation for which the consultants have been hired and the work is expected to be completed within few months. So the present proxy LRMC of US$ 0.09 / kWh is not the realistic LRMC.&lt;br&gt;The Least Cost Generation Plan for Pakistan that is currently under way will not be ready before May 2011. The numbers used in the previous report have been updated to reflect new information obtained in September 2010. The models that will be provided can be used to update the costs. It is the Consultants opinion that 9 cents/kWh is very likely an underestimation of the LRMC. Any additional information that the Government of Pakistan could provide on the latest assessment of the LRMC would be appreciated.</td>
<td>The opportunity cost for Pakistan was revised in Section 5. The updated economic analysis is in section 10.</td>
<td></td>
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<tr>
<td><strong>5. Benefit Cost Ratio</strong>&lt;br&gt;The estimated benefit/cost ratio of 1.1 is too low. For an international project of this size, with so many risk factors, a benefit/cost of at least 1.5 should be considered. A low benefit/cost ratio means a slight change in any of the assumptions could turn this project into a money loser.&lt;br&gt;The results of the analysis are based on conservative assumptions agreed to by all concerned. The results of the analysis will be the basis for each participating country to make decisions based on their particular comfort level.</td>
<td>The economic analysis has been revised in section 10.</td>
<td></td>
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<tr>
<td><strong>6. Portfolio of Projects</strong>&lt;br&gt;At an executive level in the sector, projects should be evaluated for availability of investment capital and by IRR (Interest Rate of Return) which accommodates variations in the cost and benefit streams. NTDC should be evaluating its portfolio of projects using the IRR method. The TRG suggests that NTDC may have many projects with a higher IRR, and that there is not enough capital or borrowing capacity to fund the all the higher return projects. By this logic, the CASA project would most likely fall below a cutoff line.</td>
<td>The consultant is not in a position to comment on this decision criteria as this decision is for each country to make. The recommended approach would be to perform a least cost generation study to see up to what price CASA-1000 is picked up as the least cost option. For example, a 1000 MW during the peak season for a capital investment of under $300 million could be a major factor in a resource-constrained environment.</td>
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**CASA-1000 Update**

K-10

020913-4SRP-0300-01
### Feasibility Update by SNC-Lavalin - Preliminary Draft Final Report

#### Responses to Comments from Pakistan

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| **7. Secondary Benefits**  
There is some upside in the project that is not reflected in the benefit/cost ratio (socio-economic development of the concerned countries, potential shift toward environmentally preferred generation sources, potential to decrease the incentives for civil unrest). Any cross-border transmission and energy transactions logically stand to strengthen regional cooperation. However, these upside factors are intangible, outside the scope of the TRG review. | This is outside the scope of the current Consultant’s Mandate | |
| **8. Availability of Power / Risk**  
It is clear from the demand/supply analysis of the supplying countries that the availability of power in the supplying countries for export is very low. This is seasonal power to start with, but the actual availability depends on a lot of factors including completion of some projects, planned programs to reduce of losses, security in involved countries, and good weather and hydrology conditions. These risk factors make the availability of power too risky to consider at this time given the very large capital cost. | The consultant’s mandate is restricted to the analysis.  
As commented before the base case scenario assumptions are all very conservative, e.g., only existing generation projects and projects that are being built before 2016 with committed funding have been considered. No assumptions of “good weather and hydrological conditions” have been made and risks related to security have been embedded in the cost estimates for the project (see comment #13 below). Appropriate commercial agreements will apportion risks. | |
| **9. Availability of Power**  
The availability of power from Tajikistan and Kyrgyzstan counts on some ambitious goals in loss reduction, tariff escalation, collection rates, load growth, new hydro, and renovation of some old Soviet-era hydro plants. We should verify these are actually on track, or there may not be any power to export, or the tariff differential AND availability of power may disappear. | The consultant has based the analysis on information provided for the load forecast by the respective countries as this update was essentially limited to a desktop study. As mentioned before, only new generation projects before 2016 with committed funding have been considered. Some new generation projects that were suggested were however not selected as they didn’t fulfilled | |
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<tr>
<td>10. <strong>Regional Availability of Power</strong>&lt;br&gt;The regional availability of power depends not only on Kyrgyzstan and Tajikistan, but on interconnections with Uzbekistan and Turkmenistan and safe/reliable transport across Afghanistan.</td>
<td>The consultant has considered but not assessed regional power availability. There is an ADB funded study just started looking at the Regional Master Plan for the CAREC region.</td>
<td>this criterion.</td>
</tr>
<tr>
<td>11. <strong>Power from Turkmenistan</strong>&lt;br&gt; Afghanistan has another option to receive power directly from Turkmenistan by an other route, and this alternative option should be evaluated before committing $850 million.</td>
<td>This is out of the scope of the current mandate. Given the rapidly changing power generation scenarios in the region, the option of Afghanistan receiving additional power from other sources underscores the importance of providing flexibility for Afghanistan to be able to transmit surplus power to Pakistan.</td>
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<tr>
<td>12. <strong>Cost of Supply</strong>&lt;br&gt;The suggested cost of supply from the sending countries is in the range of 1-2 cents/kwh. That is too low to be realistic, especially considering that these countries are developing themselves and their demand is also rising sharply. That price will not recover investment in new facilities. It may not even be enough to cover O&amp;M costs on existing facilities. As these countries develop new resources, the marginal cost will be higher. It will not be economical and reasonable for them to sell the power at such a deep discount. There may be political and economical repercussions of such a discounted power deal. If the financial logic of the deal becomes stressed in this way, there will be incentive for some participants to break their contracts or to demand renegotiation.</td>
<td>See related comment #2 above.</td>
<td>Addressed in section 5. The costs were reviewed to consider the cost of purchasing power from the Sangtuda I &amp; II projects as well as the O&amp;M fixed costs of Nurek and other existing hydro power plants.</td>
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<tr>
<td>13. <strong>Security of Supply</strong>&lt;br&gt;The security situation across the transmission line route has been adverse for decades. Even if the fighting stops, there will likely be a loose, centrally controlled security</td>
<td>The consultant has used 3% O&amp;M which is higher than the normal amounts used. This takes into account the fact that the security situation is not</td>
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### Feasibility Update by SNC-Lavalin - Preliminary Draft Final Report

**Responses to Comments from Pakistan**

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<td>It will be hard to guarantee security in outlying areas. The additional cost of 1% added for O&amp;M will likely not be enough to pay the cost of secure supply.</td>
<td>the same in every area where the converter stations and the lines will pass. Furthermore, the reliability of the existing lines is highly encouraging.</td>
<td>This is address in the conclusion, section 15.</td>
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<td><strong>14. Risk Payment</strong></td>
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<td>Whatever the project economics and risks, these are dominated by the risk of payment by Afghanistan, which does not have a functional economy and which must rely on foreign assistance to meet its contractual commitments. The situation could easily arise in which the power supplying countries refuse to make further delivery until paid, leaving Pakistan with a non-performing capital asset.</td>
<td>There are many examples (South Africa Power Pool) which have shown that contractual and operational agreements can overcome this problem. Based on previous discussions, the supply of power to Pakistan is independent of Afghanistan's ability to meet its financial contractual commitments.</td>
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<tr>
<td><strong>15. Project Framework</strong></td>
<td>Comment noted.</td>
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<td>The project is based on a good conceptual framework. It evacuates potentially excess power from the countries in the north to the severely power deficient countries in the south. It provides diversity to the supply mix in the receiving countries and the proposed delivered price is below the long-run marginal cost in these countries.</td>
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<td><strong>16. New Type of Aluminum Conductor</strong></td>
<td>The costs were based on existing technologies known to withstand the rugged terrain through which the line will follow. The functional specifications allow for a wide variety of designed to be proposed by the contractors provided that they meet the technical criteria.</td>
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<td>The capital cost of the line may be reduced with a new annealed aluminum conductor design which has lower line losses, carries three times the load, and actually costs slightly less.</td>
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<td><strong>17. Financial Structure</strong></td>
<td>This is outside the scope of the consultant’s mandate. However, it should be noted that only the cost of assets in Pakistan’s territory is charged to the project.</td>
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<td>The financial structure of the project may be reorganized so that only the marginal cost of the link from Kabul to Peshawar is charged to the capital costs to Pakistan. That will increase the capital cost to the Afghanistan portions of the line, which may be subsidized in consideration of its military and socio-economic development value.</td>
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### General Assessment
The overall conclusion is that the CASA 1000 project on the whole is too risky for the nominal returns.

**Comment**
Comment Noted

### 18. Favourable Comment
There is one very favorable positive comment.

The CASA 1000 project would deliver 1,000 MW to Pakistan during peak demand periods and Pakistan's share of the cost would be only $261 million because the other parties would bear their geographic shares of the project. That is much cheaper peaking power than other options, the power would cost less than the average tariff, and the power would offset more expensive imported fuel costs. Provided the following conditions are met:

- **a)** Power purchase price plus the amortized cost of the transmission investment is lower than the marginal cost of producing power in Pakistan
- **b)** Physical security of the line can be guaranteed by Afghanistan with penalties for any downtime

The option of bringing the DC line direct to Pakistan and then 220kV AC line to Kabul is pursued. The added advantage of this option will be that Pakistan can export non summer power to Afghanistan if and when available.

**Comment**
Comment Noted

### 19.
The uncertainty about cost of energy prevails. In the preliminary study the price of energy was stated as 4.4 cents/kWh whereas in the current updated study, it has been in the range of 1.5 to 2.5 cents/kWh. These figures stated to have been taken from some website revealing information about such contracts. These contracts may be for the old or existing arrangements. Since the CASA-1000 project will be coming in few years from now, so for future, it will be appropriate that some official version of the maximum export price (negligible downward later) is taken from the supplier countries and incorporated in the economic analysis.

The mandate required the use of prices based on publicly available information or information supplied by the countries. The study is based on the sale of surplus power (energy that would not be used under normal operation, i.e. spilled energy). Establishing future prices was not part of the consultant’s mandate, however, this will have to be discussed at the time of commercial negotiations.
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<td><strong>20.</strong> The study terms of reference did not include provision for transit charges. In addition, this information is not available at the time that the study was undertaken. However, this has been identified as a topic that needs to be addressed along with other contractual issues.</td>
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<td><strong>21.</strong> The LRMC numbers are not available at the issuance of this report. However the numbers can be updated once the information becomes available.</td>
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### FEASIBILITY UPDATE BY SNC-LAVALIN - PRELIMINARY DRAFT FINAL REPORT
### RESPONSES TO COMMENTS FROM THE KYRGYZ REPUBLIC

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| **1. Discrepancy in Load Growth**  
We think that demand growth projections of 3.2% for 2015-2030 are unreasonably high in the base case scenario and need to be further elaborated. | In the demand projections received from the Kyrgyz Republic, a flat rate of increase of 2% from 2015 onwards was projected. The differences between these projections and those appearing in the report are due in large part to the GDP growth rates. The consultant assumed a GDP growth of 4% for the entire projection period (as was assumed in CASA-I). This will be compared to World Bank / IMF rates and the impacts of any such adjustments will be assessed. | The load forecast in section 2 was revised. |
| **2. Load Growth Clarification**  
We want to inform that GDP growth rate in 2010 was negative. According to Ministry for Economic Regulation of Kyrgyz Republic the GDP growth rate in 2010 (11months) was -1.6%. Please, make sure to include this data in your input values.  
The demand forecast growth rates for 2011-2014 presented in the Draft Final report are similar to those furnished by the Kyrgyz Republic. | The load forecast in section 2 was revised. |
| **3. Use of Thermal Plants**  
We do not agree with the assumption that Thermal plants will not be considered as a source for exports to CASA. Thermal plants generate power year-round and power generated by them is supplied to the whole system. Any generation added to the system contributes to the surplus available for CASA. But more importantly, they may have to be used to supply “firm power” in dry years.  
Thermal plants are rather old and their cost of generation is very high to be considered as an export source. The use of old thermal generation plants to increase the level of firm power to be delivered is a contractual issue to be determined when contracts are negotiated. Since the value of firm energy is higher than non-firm energy, the use of older plants to guarantee a higher level of firm power could be considered in the development of contractual commitments. This analysis is outside the scope of this current study. | Addressed in section 2. |
### Feasibility Update by SNC-Lavalin - Preliminary Draft Final Report

**Responses to Comments from the Kyrgyz Republic**

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<td><strong>4. Import Considerations</strong>&lt;br&gt;We would like to receive clarifications about the impact of assumed surplus power on winter deficit in Tajikistan? (p. 2-9) Does the availability of imports from Turkmenistan to meet the winter demand effect the amount of summer surplus by decreasing water level at Nurek? If yes, why is that not included in the base case scenario?</td>
<td>Given the current situation in Tajikistan regarding winter demand and available supply, the Turkmenistan’s potential exports (if available) would serve only to attenuate (but not eliminate) the deficits. We have assumed for the base case that the imports from Turkmenistan will not be available (perhaps too conservative an assumption). Under this deficit conditions Nurek’s levels would be expected to reach minimum levels before the start of the summer period.</td>
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<tr>
<td><strong>5. Name Clarification</strong>&lt;br&gt;Please correct the name of the generation company in Kyrgyzstan from “JSC” to “JSC Power Plants” since JSC stands for Joint-Stock Company only.</td>
<td>Noted, this will be corrected.</td>
<td>Text revised in Section 5.</td>
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<tr>
<td><strong>6. Pakistan Avoided Cost</strong>&lt;br&gt;You have calculated the benefits of the project as current prices multiplied by the energy surplus. Could you provide reasons for not including Pakistan’s potentially avoided cost of building new generation?</td>
<td>The prices used include the cost of capacity and have been based on an average of the IPP portfolio. The Pakistan Power System Master Plan is currently under preparation and results will not be available until June 2011. Since there is a large portfolio of candidate Hydro and Thermal projects, it is not possible to assess the avoided cost of building new generation at this time.</td>
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<td><strong>7. Financing for New Generation</strong>&lt;br&gt;As for Generation Capacity Development program provided by NTDC, have they indicated if the financing for the planned new generation plants were secured and at what stage of development they are? Given your conclusions about Afghanistan we think it is important to accurately estimate the electricity deficit in Pakistan.</td>
<td>Pakistan is facing severe shortages of power and is addressing. While candidate generation plants, both Hydro and Thermal have been identified, there has not been any least cost optimization completed at this stage. Initial</td>
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<td>8. Load Swap</td>
<td>estimates indicate that all of the power provided by CASA-1000 can be easily absorbed by the Pakistan system.</td>
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<td>We would like to emphasize that the Kyrgyz-Tajik load swap analysis needs to be done thoroughly, and should address such issues as who will be administering the metering, safeguards to ensuring transparency of dispatch and calculation of losses and throughput, and dispute resolution mechanisms.</td>
<td>This analysis needs to be done, however it is outside the focus of the current study and would be part of a subsequent study. This will be included in a list of follow-up actions required for an subsequent study.</td>
<td>This issue has been identified in section 15 as an issue that needs to be analysed as part of subsequent studies.</td>
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<td>9. Request for Documents</td>
<td>It is suggested the request be made to the IGC.</td>
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<td>We would like to request if it is possible for the Kyrgyz party to receive documents referred to in p. 4-3 with regards to Tajikistan’s electricity system. (Power Rehabilitation Phase II and Jacobs Report)</td>
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<td>10. 2010 Tariff Structure</td>
<td>Comment noted. However, given that the Final Report will be issued in January 2011, it is not possible to have all the complete 2010 data.</td>
<td>Addressed in section 2.</td>
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<tr>
<td>Table 2-1.p.2-2. We think it is necessary to take into account the 2010 tariff of the State Regulatory Department for Fuel and Energy Sector under the KR Ministry of Energy and to adjust it according to the midterm tariff policy (revised).</td>
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<td>As for the whole document further we consider it necessary to give data for 2010 as the document is updated by current year.</td>
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<td>11. Kambarata</td>
<td>The basis for considering new generation is that plants should have financing in place. The Consultant needs written confirmation that financing is in place for commissioning in 2012 if it is to be considered as part of the base case. The data used in this report is based on information received in September 2010 and no confirmation of status has been received.</td>
<td>Addressed in section 2.</td>
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<td>p. 2-8. For your information, we would like to let you know that commissioning of the first unit of Kambarata HPP2 took place on august 30, 2010. And the commissioning of the second unit with 120 MW capacity is planned for 2012. Please, introduce these changes into the relevant tables for calculation of final estimates of generation in 2016.</td>
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<td><strong>12. Control Centre</strong>&lt;br&gt; The Parties should make a decision on allocation of central control unit before preparation of final report. In any of the options the central control unit should have the functional connection with dispatch control units of all energy systems of the participating countries.</td>
<td>The interconnection control centre could be located in any one dispatch centre of any of the countries involved, or could be a separate control centre. This depends on the agreements reached between the countries. The scheme could also be set up so that all countries have the possibility of taking control of the scheme, however only one country could have control at any given time. The cost implications of the various options are not significant.</td>
<td>A clarification was added in section 12.</td>
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<tr>
<td><strong>13. Towers in Mountain Regions</strong>&lt;br&gt; The towers in straitened mountainous conditions – to consider possibility of using multisided tubular metalic towers.</td>
<td>The functional specifications are designed so that contractor can propose the least cost solution that meets the specification. Multi sided tubular metalic towers are an option.</td>
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<td><strong>14. Insulation</strong>&lt;br&gt; Isolation – to eliminate the possibility of using glass suspended insulators or polymer insulators, porcelain insulators due to the control problems in hard-to-reach conditions. Strings retraining from tower body must be used on the line anchor towers on the sites with huge wind loading.</td>
<td>Comment noted – see response to Item 13 above.</td>
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<td><strong>15. Tower Grounding</strong>&lt;br&gt; To analyze the grounding of towers (not typical) on the sites with rocky ground.</td>
<td>Comment noted – see response to Item 13 above.</td>
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<td><strong>16. Deicing Wires</strong>&lt;br&gt; In mountainous conditions it is necessary to use deicing wires (AERZ type).</td>
<td>Comment noted – see response to Item 13 above.</td>
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<tr>
<td><strong>17. Datka-Khodgent Line</strong>&lt;br&gt; In contractual relationships during operation of 500kV Datka-Khodgent HVL it is necessary to take into account the variation of daily load curve and identify the buyer of power regulation services and tariff.</td>
<td>This will have to be established at the time of formulating contractual agreements – this is not in the scope of the present study. This would be included in a list of follow up actions.</td>
<td>This issue has been identified in section 15 as an issue that needs to be analysed.</td>
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<tr>
<td>18. Contractual Relationship</td>
<td>Unauthorized power take-off along the line is very unlikely considering this is HVDC. In all cases, the amount of power sent and received at each converter station is strictly controlled by the valves and the control system.</td>
<td>A discussion on this risk has been added in section 11.</td>
</tr>
<tr>
<td>19. Tariff and Transit Fee</td>
<td>This will have to be established at the time of formulating contractual agreements – this is not in the scope of the present study.</td>
<td>This issue has been identified in section 15 as an issue that needs to be analysed as part of subsequent studies.</td>
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<tr>
<td>20. Power Flow Control</td>
<td>See response to comment #12.</td>
<td>A clarification was added in section 12.</td>
</tr>
<tr>
<td>21. Typographical Errors</td>
<td>This is noted and will be corrected.</td>
<td></td>
</tr>
</tbody>
</table>

We ask you to take into consideration the fact that some pages and tables have grammatical mistakes and discrepancies in investment cost indicators in table 6.1, 9.2, 10.4, paragraph 6.2.4 p. 6-6, and paragraph 7.3 p. 7-3. (DC line must be AC line).
22. Starting Demand Figure

We propose to take the domestic demand figure for 2010 as the starting number for load growth estimates. Although there were no electricity use limitations imposed this winter (2010-2011) we observe lower electricity consumption than in respective period of 2007. Therefore, we believe that 2010 figures are more accurate representation of Kyrgyz domestic demand than the 2007 ones. Please, see the table below for comparison.

<table>
<thead>
<tr>
<th></th>
<th>Unit of Measurement</th>
<th>2007</th>
<th>2010</th>
<th>2010 unment demand in Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Generation</td>
<td>million kWh</td>
<td>14 644,76</td>
<td>11 857,25</td>
<td>12 998,2</td>
</tr>
<tr>
<td>Export</td>
<td>million kWh</td>
<td>2 379,23</td>
<td>1 472,0</td>
<td>1 472,0</td>
</tr>
<tr>
<td>Total Domestic Demand</td>
<td>million kWh</td>
<td>12 265,54</td>
<td>10 385,23</td>
<td>11 526,23</td>
</tr>
<tr>
<td>1st Q</td>
<td>million kWh</td>
<td>4616,4</td>
<td>3 475,5</td>
<td>4 616,4</td>
</tr>
<tr>
<td>2nd Q</td>
<td>million kWh</td>
<td>2014,0</td>
<td>1 862,9</td>
<td>1 862,9</td>
</tr>
<tr>
<td>3rd Q</td>
<td>million kWh</td>
<td>1756,3</td>
<td>1 700,4</td>
<td>1 700,4</td>
</tr>
<tr>
<td>4th Q</td>
<td>million kWh</td>
<td>3878,6</td>
<td>3346,4</td>
<td>3346,4</td>
</tr>
</tbody>
</table>

As 2010 data is not available for all countries and as it is necessary to use consistent data for all countries to ensure the reliability of the demand figure, data up until and including 2009 was used.
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<table>
<thead>
<tr>
<th>COMMENT</th>
<th>RESPONSE</th>
<th>ADDRESSED IN REPORT SECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>23. CHP generation</strong></td>
<td>We would like to make it clear that Bishkek and Osh CHPs generate electricity year-round while providing heating and hot water. Although during the winter months electricity generation from CHPs is much higher than during the summer, they help to keep the equivalent amount of water at Toktogul, which then can be released during the summer months to generate electricity for export. Therefore, we hope you agree that the contribution of CHPs cannot be ruled out altogether. Please see table below for details on how much electricity is generated by CHPs.</td>
<td>The objective of the CASA-1000 project was to utilize the surplus hydro power. The availability of additional energy from thermal sources can be considered as part of the negotiations to establish firm energy levels in the commercial agreements.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generation Source</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPP</td>
<td>13 841,3</td>
<td>10 608,42</td>
<td>9 925,39</td>
<td>11 070,0</td>
</tr>
<tr>
<td>CHP</td>
<td>803,5</td>
<td>1 011,95</td>
<td>963,98</td>
<td>787,2</td>
</tr>
</tbody>
</table>

| **24. 2nd unit of Kambarata HPP-2** | In addition, the Ministry of Energy of the Kyrgyz Republic would like to assure you that the 2nd unit of Kambarata HPP-2 will be available for generating additional power by 2016. The respective issue of allocating funds for further construction is being considered at this stage by the Government of the Kyrgyz Republic. | The parameters for this study were to include projects under construction and for which financing was already in place. At the time of undertaking this study, the financing for Kambarata HPP-2 was not in place and therefore this plant was not considered. However, given that there CASA-1000 project is viable without Kambarata-2, its addition will increase the economic viability of the project. |
2.2.2 Tajikistan forecasting needs in electricity
We propose to make the following changes into the Table 2-4
• GDP growth 7.8% in 2007; 7.9% in 2008; 3.4% in 2000 and further
• Loss reduction - 17.6% in 2008 to 13% in 2020
• Consumption by TALCO will make about 7 billion hours per year, in 2016 it will be not more than 25% of total output.

1. In the table 2-4 to change the value of perimeter «Change of tariff for 2070-2010» on «0,68 - 1,76 US cents/kWt.h».

'Table 2-4. Baseline data of Tajikistan for projecting the load
We propose to put the line «Loss reduction» in the following way:
Loss reduction: 17.6% in 2008 up to 13% in 2020

In the table 2-5 average growth of tariffs, as planned by «Barki Tojik», to change the value of average tariff (in dirams), on the basis of attached table

<table>
<thead>
<tr>
<th>Year</th>
<th>Average tariff</th>
<th>Exchange rate of USD to somoni</th>
<th>% of increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010 Expected</td>
<td>7.75</td>
<td>1.76</td>
<td>4.39</td>
</tr>
<tr>
<td>2011 Projections</td>
<td>9.60</td>
<td>2.00</td>
<td>4.80</td>
</tr>
<tr>
<td>2012 Projections</td>
<td>11.30</td>
<td>2.20</td>
<td>5.14</td>
</tr>
<tr>
<td>2013 Projections</td>
<td>13.75</td>
<td>2.50</td>
<td>5.50</td>
</tr>
</tbody>
</table>

Thus it is required to change the percentage ratio of planned increase in the text. In percentage ratio of tariffs increases will be the following:
2010 - 25%     2012 - 18%
2011 - 24%     2013 - 22%
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**RESPONSES TO COMMENTS FROM TAJIKISTAN**

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<th>ADDRESSED IN REPORT SECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3.2 Tajikistan - existing and obligatory output</td>
<td>See response to 2.3.2 above. Comments noted and this will be reflected appropriately in the Final Report. As agreed by all parties at the outset of this study, for future generation only plants that have financial commitments will be considered. In the case of Hydro, only Sangtuda 2 will be considered.</td>
<td>The information on power plants was revised. The power plants that qualify per the TOR were included in the analysis.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Installed capacity (MWT)</th>
<th>Output Annual average (bil. kWt/h)</th>
<th>Commissioned year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DCHP-2</td>
<td>270</td>
<td>1,62</td>
<td>2014</td>
</tr>
<tr>
<td>2. Shurob HPP</td>
<td>600</td>
<td>3,6</td>
<td>2016</td>
</tr>
</tbody>
</table>

As Tajikistan does not plan to import electricity, we propose a comment regarding the import from Turkmenistan and table 2-15 should be deleted from final feasibility study.

Table 2.14 HPP, which are planned to put into operations by 2016

<table>
<thead>
<tr>
<th>Name</th>
<th>Installed capacity (MWT)</th>
<th>Output Annual average (bil. kWt/h)</th>
<th>Commissioned year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sangtuda-2</td>
<td>220</td>
<td>0,955</td>
<td>2011</td>
</tr>
<tr>
<td>2. Rogun (1 line) Planned</td>
<td>800</td>
<td>5,6</td>
<td>2016</td>
</tr>
</tbody>
</table>

We propose Abstract 1 to write in the following way:

Most part of electricity in Tajikistan is generated at Nurek HPP (3200 MWT, 12060 GWT/h/year)

Release of water from Nurek reservoir regulates the inflow of water to the stations, located downstream, which generate about 7242 GWT/h annually.

Kayrakkum HPP has its own reservoir and generates 870 GWT/hour a year
Abstract 2 - to delete, as Sangtuda HPP-1 is fully commissioned and in 2009 generated 670 MWh/year

To make the following changes in the Table 2-13
Table 2.13 Current system of HPPs in Tajikistan

<table>
<thead>
<tr>
<th>Name of stations</th>
<th>Type</th>
<th>Installed capacity (MWh)</th>
<th>Annual Output (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurek</td>
<td>Reservoir</td>
<td>3200</td>
<td>12060</td>
</tr>
<tr>
<td>Baypaza</td>
<td>River-run HPP</td>
<td>600</td>
<td>2693</td>
</tr>
<tr>
<td>Sangtuda-1</td>
<td>River-run HPP</td>
<td>670</td>
<td>3088</td>
</tr>
<tr>
<td>Golovnaya</td>
<td>River-run HPP</td>
<td>240</td>
<td>1231</td>
</tr>
<tr>
<td>Perpeadmaya</td>
<td>River-run HPP</td>
<td>30</td>
<td>180</td>
</tr>
<tr>
<td>Centralnaya</td>
<td>River-run HPP</td>
<td>15</td>
<td>50</td>
</tr>
<tr>
<td>Kayrakkum</td>
<td>Reservoir</td>
<td>126</td>
<td>870</td>
</tr>
<tr>
<td>Varzob</td>
<td>River-run HPP</td>
<td>25</td>
<td>205</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>4,905</td>
<td>20,377</td>
</tr>
</tbody>
</table>

Table 2.16 Energy System in Tajikistan in 2016, installed capacity and annual output

<table>
<thead>
<tr>
<th>Type</th>
<th>Established capacity (MWh)</th>
<th>Annual output of electricity (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPP</td>
<td>5921</td>
<td>23495</td>
</tr>
<tr>
<td>Thermal stations</td>
<td>1188</td>
<td>7128</td>
</tr>
<tr>
<td>Total</td>
<td>7109</td>
<td>30623</td>
</tr>
</tbody>
</table>
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<thead>
<tr>
<th>Comment</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Note: as DHCP and Yavan Thermal Plant are operated on natural gas, they are not considered in calculation of the total domestic output of electricity for the Project CASA-1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excessive electricity of Tajikistan by 2020</td>
<td>Energy available for export potential is limited by a number of factors including transmission constraints due to the capacity of the line.</td>
<td>The available energy surplus was reassessed in light of the changes to the load forecast.</td>
</tr>
<tr>
<td>Name</td>
<td>Capacity (MWT)</td>
<td>Output (bln kWt.h)</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Sangtuda HPP-2</td>
<td>220</td>
<td>1,0</td>
</tr>
<tr>
<td>Rogun HPP (Planned)</td>
<td>800</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>3600</td>
<td>13.4</td>
</tr>
<tr>
<td>Dushanbe CHP-2 (on coil fuel)</td>
<td>270</td>
<td>1,62</td>
</tr>
<tr>
<td>Shurob Thermal Plant (on coil fuel)</td>
<td>600</td>
<td>3,6</td>
</tr>
<tr>
<td>Nurabad HPP-1</td>
<td>350</td>
<td>1,42</td>
</tr>
<tr>
<td>Nurabad HPP-2</td>
<td>200</td>
<td>0,9</td>
</tr>
<tr>
<td>Shurob HPP</td>
<td>850</td>
<td>3,5</td>
</tr>
<tr>
<td>HPP “Ayni”</td>
<td>120</td>
<td>0,54</td>
</tr>
<tr>
<td>HPP “Fondaryo”</td>
<td>150</td>
<td>0,68</td>
</tr>
</tbody>
</table>

- Installed capacity of HPP and thermal stations is 11361 MWt
- Annual average output of electricity – (17+25.66)=42.66 bln.kWt/h

**Export potential:**

- 2016 - (30.6-21.6) = 9 bln.kWt/h
- 2020 - (43-23) = 20 bln.kWt/h per year

---

**Note:**

The available energy surplus was reassessed in light of the changes to the load forecast.
Domestic consumption for 2016-2020 is described on the diagramme 2-7 (base option) (2016-21,6 bln.kWt/h, 2020-23 bln.kWt/h)

Diagramme 2-4. Annual average volume of excessive electricity in Tajikistan (GWT/h)

2.4.4. Total volume of excessive electricity (Tajikistan + Kyrgyzstan)

Energy available for export potential is limited by a number of factors including transmission constraints due to the capacity of the line. Surplus was reassessed in light of the changes to the load forecast.
According to Diagramme 2-4, the total volume of excessive electricity will also change.

With regard of the changes, the company SNC «Lavalin» should make recalculations of:

<table>
<thead>
<tr>
<th>Baseline data:</th>
<th>RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>- total annual volume of export - 5000 000 000 1 kWt/h.</td>
<td>The costs for TL in the territory of Tajikistan are already included in the total investment cost of CASA project. Therefore, the cost of supply in Tajikistan should be the purchasing costs at the power plants, which is USD 0.015/kWh, the same value used in the draft final report.</td>
</tr>
<tr>
<td>- Purchase of electricity from Sangtuda HPP-1 in the volume of 2 730 000 000 1 kWt/h per year by tariff USD 0.0263 per 1 kWt/h;</td>
<td>It should be noted that water that is spilled without CASA has zero value and that this will be considered in any future analysis.</td>
</tr>
</tbody>
</table>
**FEASIBILITY UPDATE BY SNC-LAVALIN - PRELIMINARY DRAFT FINAL REPORT**  
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<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>- Cost of construction of transmission line via territory of Tajikistan is USD 180 000 000;</td>
<td>should not be applied to exports.</td>
<td></td>
</tr>
<tr>
<td>- Costs for maintenance and operations of TL 500 via territory of Tajikistan - 3% of the total amount of investments for TL construction annually;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Costs for engineering design and dispatcher - 2% of total amount of investments for TL construction annually;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Costs for depreciation of TL for 30 years;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Costs for repayment of credit for construction of TL for 30 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Contingency costs - 10% of total costs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

II. Calculations of cost of export of kWt/h of electricity  
1. Total annual amount of purchase of electricity from Sangtuda HPP-1 will make USD 71 799 000 (2 730 000 000 x 0,0263 = 71 799 000).  

2. Total annual amount of purchase of electricity from Sangtuda HPP-2 will make USD 29 800 000 (1 000 000 000 x 0,0298 - 29 800 000).  
3. Total annual amount of purchase of electricity from Rogun HPP will make USD 25 400 000 (1 270 000 000 x 0,02 = 25 400 000).  
4. Total amount of annual costs for maintenance and operations of TL in the territory of Tajikistan will make USD 5 400 000; (180 000 000 x 3 / 100 = 5 400 000).  
5. Total annual amount of costs for engineering design with regard of dispatcher will make USD (180 000 000 x 2 /100 = 3 600 000).  
6. Costs of depreciation of TL for 30 years will make USD 6 000 000 (180000000 / 30 = 6000000).  
7. The sum of credit repayment will make USD 6 000 000 annually (180000000/30=6000000)  
Total costs for export of electricity in the volume of 5 000 000 000 kV will make USD 147 999 000 without payment of VAT  
(71799000+29300000+25400000+54000000+36000000+60000000+6000000)  
0 =1479990000  

The costs for TL in the territory of Tajikistan are already included in the total investment cost of CASA project. Therefore, the cost of supply in Tajikistan should be the purchasing costs at the power plants, which is USD 0.015/kWh, the same value used in the draft final report.  

It should be noted that water that is spilled without CASA has zero value and that this will be considered in any future analysis.  

VAT is an internal tax and subject to revision. It should not be applied to exports.
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</thead>
<tbody>
<tr>
<td>Total costs with contingencies (10% of amount of costs) will make USD 162 798 900 (147999000 x 1,10= 102798900). Thus, the real cost of 1 kWt/h of exported electricity will make USD 0,033 without VAT 18% (162798900 / 500000000 =0,033).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ill. Calculation of tariff for 1 kWt/h of electricity for export with regard of 15% of real cost will make USD 0,038 (0,033 x 1,15 = 0,038) without VAT. With VAT the tariff of 1 kWt/h of electricity for export will make USD 0,045.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6. Assessment of the optimal size of the project</strong></td>
<td>Comment noted.</td>
<td></td>
</tr>
<tr>
<td>For defining the optimal size of project, we find that it is rational to construct transmission lines with power flow 2300 MW with consideration of the opportunity to increase capacity of converters if there will be a need to increase volume of export of electricity to Afghanistan and Pakistan</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6.2.2. Export potential for Afghanistan and Pakistan</strong></td>
<td>The surplus assessment is based on the information that was provided officially by the countries during the inception period. It was agreed to use this data as input for the study.</td>
<td>The surplus assessment was revised in light of changes to the load forecast.</td>
</tr>
<tr>
<td>The values of potential excessive electricity for export should be revised, according to the changes made in sections 2 para 2.,4.2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6.2.3. Costs for modernization of grids</strong></td>
<td>See comments under 8.</td>
<td></td>
</tr>
<tr>
<td>In costs for modernization of grids for CASA-1000 it is required to include construction of TL-500 kV, SS “Regar-500 kV”, SS “Dusti-500 kV” for transmission of Kyrgyz electricity and connect SS “Dusti-500 kV” with Rogun, Nurek, and Baypaza HPP.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6.3. Export of Excessive electricity</strong></td>
<td>The surplus assessment is based on the information that was provided officially by the countries during the inception period. It was agreed to use this data as input for the study.</td>
<td>The surplus assessment was revised in light of changes to the load forecast.</td>
</tr>
<tr>
<td>Make changes in Diagramme 6-4 according to the changes made in Table 2.4.2.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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</thead>
<tbody>
<tr>
<td><strong>6.4.3. Possible addition of the 4th terminal connected to the line CASA-1000</strong></td>
<td>We propose to exclude the issue of addition of the 4th terminal to the Project CASA, it will decrease the reliability of the project, because currently it is impossible to synchronize works of Uzbekistan grids with Tajikistan and Kyrgyzstan grids. Also, as electricity in Uzbekistan is generated at thermal stations, including Uzbekistan to project CASA will hold down (set-off) export price and thus, reduce attractiveness of the project.</td>
<td>Comment noted.</td>
</tr>
<tr>
<td><strong>8. Identification of needs in power transmission in existing Tajikistan grids</strong></td>
<td>Five different options for reinforcing the 500 kV system in Tajikistan are presented, all of which involve relocating the converter station from Sangtuda to a location near the border with Afghanistan. This reinforcement work provides a reinforced supply to the communities in the border area. As such the cost and benefits of this portion should not be included in the economic appraisal of CASA-1000. The cost allocated to the CASA-1000 project is estimated as the minimum reinforcement required to accommodate the project.</td>
<td>Addressed in section 8.</td>
</tr>
<tr>
<td><strong>9. Estimation of the costs of the project and its distribution by countries.</strong></td>
<td>In connection of proposals from Tajikistan, based on the optimal scheme of transmission of power for export under the project CASA-1000, it is required to construct TL-500 kV “SS-500 kV “Regar-SS-500 kV “Sangtuda” (with dividing transformers 220/500 kV), and it is needed to revise the assessment of the project cost.</td>
<td>See comment under no 8.</td>
</tr>
</tbody>
</table>
## Feasibility Update by SNC-Lavalin - Preliminary Draft Final Report

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<thead>
<tr>
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<th>Response</th>
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</tr>
</thead>
</table>
| **10. Economic analysis (part 1)**  
1. Point 10.4 The final results of economic analysis should be added by the following abstract: In this study the economic assessments of additional services of participating countries are not considered. These services are implemented within this project, including transit of power supply via territory of participating country and regulation of power supply. These services will contribute to the increase of economic efficiency of the Project. Terms and price for providing these services will be established in agreements of the parties. | Additional benefits in exporting countries will be added and discussed in the final report. | The additional benefits are discussed in section 10. |
| **10. Economic analysis (part 2)**  
2. Point. 10.6 Distribution of revenues and relations of Д/М by countries. Revenues, generated within Project realization, include exclusively power transit services through the transmission lines, within the framework of Project «CAS A. - 1000». In the proposed Report there are no required technical –economic justification on cost of transit services and actual volume of revenues in this Project. Reviewed in the Report Approach 2 on distribution of revenues we find impossible, because of the disproportion of inputs by participating countries, not only at construction phase of the Project, and costs of output of transmitted power, but also in the use of exciting infrastructure of energy systems. Revenues of exporting countries and importing countries will be defined according to the volumes and cost of actual supply of electricity, and also by the cost of additional services for electricity transit and power regulation, according to the agreements between economic entities. | The benefit allocation for each country was requested during the initial study to provide some indication of how benefits can be allocated to each country. However, for deciding the viability of the project, the overall economic project benefit / cost ratio should be the determining economic criteria rather than individual country benefit / cost ratios. Commercial agreements should ensure that each country receives appropriate allocation of the financial benefits to ensure adequate return to fund financial commitments. | Addressed in section 10. |
| **10. Economic analysis (part 3)**  
3. Agreement and coordination of the regime of operation of TL-500 kV with Joint Energy System of СА (ОЭС ЦА). Within the framework of this report we find necessary to conduct study of the regime of operation of projected TL-500 kV., in parallel work with Joint Energy System of СА (ОЭС ЦА), and also stipulate issues of automation, preventing breaks and collapses. | This needs to be done but is outside the focus of the current report and would be done as part of a subsequent report once there is an agreement on contractual issues. | This is highlighted in the list of issues that need to be addressed as part of a subsequent study in section 15. |
## FEASIBILITY UPDATE BY SNC-LAVALIN - PRELIMINARY DRAFT FINAL REPORT

### RESPONSES TO COMMENTS FROM NON-COUNTRY SOURCES

<table>
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<th>COMMENT</th>
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<tbody>
<tr>
<td>1. <strong>General</strong>&lt;br&gt;An Executive Summary should be provided in the Report. It should be suitable for public disclosure.</td>
<td>An executive summary will be provided in the feasibility update study final report.</td>
<td>An executive summary has been included.</td>
</tr>
<tr>
<td>2. <strong>Demand Projections</strong>&lt;br&gt;The assumptions underlying the demand projections will need to be reviewed jointly with the respective countries, particularly where there is a significant difference in the demand projections.</td>
<td>The differences in load forecasts were reviewed and it was decided to go with the data that was provided officially by the countries during the inception mission. The load forecast provided by Afghanistan is particularly problematic as it does not take into account GDP growth. The consultant will review the impact of changes proposed by the countries..</td>
<td>The demand projections have been reviewed and revised (section 2).</td>
</tr>
<tr>
<td>3. <strong>Supply-Demand Assessment for Pakistan (part 1)</strong>&lt;br&gt;The assessment given in Table 3-16 is overly simplistic. Some of the generation plants are quite old and actual available capacity is significantly less than the installed capacity. Furthermore, there is a significant hydropower component where the actual production can be significantly lower than the installed capacity, particularly in dry years. It would be beneficial to review the available capacity assessment and to include an energy supply-demand assessment (in GWh).</td>
<td>The first paragraph in section 3.3 highlights that the available capacity is less than the installed capacity due to outages and derating of generation units. As specific information regarding the condition of units is scarce, an overall assumption has been made that the installed capacity is derated by 20% to obtain the available capacity.</td>
<td>Addressed in section 3.</td>
</tr>
<tr>
<td>3. <strong>Supply-Demand Assessment for Pakistan (part 2)</strong>&lt;br&gt;It may be useful to present actual monthly demand-supply figures for two or three recent years (both in MW and GWh) to demonstrate the extent of the current shortfall and its seasonal variation.</td>
<td>Graphs will be included in the Final Report.</td>
<td>This is addressed in section 4.</td>
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<tr>
<td><strong>4. Supply-Demand Assessment for Afghanistan (part 1)</strong>&lt;br&gt;The final paragraph of Section 4 undermines the analysis presented earlier. While it is important to state the element of uncertainty associated with the load forecast and capacity development, it would be still worthwhile to add a final sentence reiterating that, even taking into account these uncertainties, Afghanistan may well have a surplus by 2015 or shortly thereafter, particularly in the summer months, and this summer surplus may continue for several years of the project life.</td>
<td>The final paragraph of Section 4 will be reviewed. A concluding sentence will be added.</td>
<td>This is revised in section 4.</td>
</tr>
<tr>
<td><strong>4. Supply-Demand Assessment for Afghanistan (part 2)</strong>&lt;br&gt;Details of the existing import agreements should be provided, if possible. This should include provisions of firm and non-firm percentages, permissible seasonal variations, details of supply-or-pay and take-or-pay provisions, etc.</td>
<td>The extent of details available from the data provided and our research have been provided in the report. The IGC will be requested to provide an updated list of existing import agreements.</td>
<td>This is added in section 4.</td>
</tr>
<tr>
<td><strong>4. Supply-Demand Assessment for Afghanistan (part 3)</strong>&lt;br&gt;Please add a reference for the demand forecast from Global Edison.</td>
<td>A reference will be added for the demand forecast from Global Edison.</td>
<td>A reference has been added in section 4.</td>
</tr>
<tr>
<td><strong>5. Available Surplus (part 1)</strong>&lt;br&gt;The surplus from the Kyrgyz Republic has increased from an earlier assessment of about 1500 GWh (see Interim Report) to a little above 2000 GWh of annual surplus at the beginning of the study horizon (2016) – what is the reason for this?</td>
<td>Additional potential is due to the coordinated reservoir operation between Toktogul and Nurek, the details of which are provided in Note I.3 in appendix I. The Consultant will review the available surplus and make appropriate changes, if required, in the final report.</td>
<td></td>
</tr>
<tr>
<td><strong>5. Available Surplus (part 2)</strong>&lt;br&gt;There is also a relatively minor increase in the Tajikistan surplus shown in the Interim Report and the Draft Final Report; the reason for this may also be explained.</td>
<td>As the model used to obtain the surplus for both countries is sensitive to any input change, the Tajikistan surplus is also affected by the coordinated operation of reservoirs. As noted, this change is minor.</td>
<td></td>
</tr>
<tr>
<td><strong>5. Available Surplus (part 3)</strong>&lt;br&gt;As the available surplus during wet periods will exceed the transmission capacity of the CASA-1000 project, an average value of possible hydrology scenarios will give an</td>
<td>Please note that the analysis for exportable surplus did not use average values for hydrology scenarios. The exportable surplus was calculated</td>
<td>An additional explanation was added in section 2.</td>
</tr>
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</table>
overestimation of the exportable surplus unless this capacity constraint is taken into account in the evaluation of the average. Has this been done?

using SDDP simulations, which use as inputs 23 historical hydrologies (for years 1987-2009). The first simulation assumes that the hydrology of 2016, the first year of the study period, will correspond to the hydrology of 1987 (2017 will correspond to 1988, etc.) and calculates the exportable surplus for each year of the study horizon, taking into account transmission capacity constraints. The simulation is repeated assuming that the hydrology of 2016 will correspond to the hydrology of 1988 (2017 will correspond to 1989, etc.), again taking into account the transmission constraint in obtaining the exportable surplus. This simulation is run 23 times, rotating the year that would correspond to the hydrology for 2016. For each year, the 23 simulated values are averaged to obtain the ‘average’ value for exportable surplus. This method differs from the approach using average hydrology values and addresses. Explanations of the exportable surplus simulation and the SDDP program are provided in the report in section 2.4.1, Average Values over the Simulation Scenarios and in Appendix A.
### FEASIBILITY UPDATE BY SNC-LAVALIN - PRELIMINARY DRAFT FINAL REPORT

**RESPONSES TO COMMENTS FROM TAJIKISTAN**

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<tr>
<td><strong>5. Available Surplus (part 4)</strong></td>
<td>The firm energy in certain years is lower for higher transmission capacities (Fig 6-2); e.g. for 2016, firm energy for the 1300 MW option is the highest. There are other such cases also. This leads to total energy being sometimes less for a higher capacity. These differences are relatively minor but are counter-intuitive and will raise questions about the entire analyses. This could well be linked to the optimization criteria used in the SDDP model. Either an adequate explanation for this apparent inconsistency should be added or some adjustments should be made for presentational reasons. A statement can also be added that the actual operation of the reservoirs can be adjusted to optimize the availability of the surplus on a daily basis to suit the requirements of the importing countries and thereby maximize the benefits.</td>
<td>A clarification or adjustment will be added. A clarification is added in section 2.</td>
</tr>
<tr>
<td><strong>6. Cost of Supply</strong></td>
<td>Given the scarcity of reliable information needed to compute the LRMC, the cost of supply in Tajikistan and the Kyrgyz Republic is stated to have been based on the price of existing exports. This aspect requires further analysis taking into account the actual export price agreed in recent contracts, the transmission costs built into the export price, the firm and non-firm proportions of the exports, etc. The analysis should also take into account the fact that part of the surplus will be generated from water that is spilled currently without generating electricity and part will be from hydropower capacity to be added by 2016.</td>
<td>Additional analyses will be included in the report to address this issue. Price of recent contracts need to be supplied to the Consultant. This analysis may show an increase in the cost of supply. Addressed in section 5. The costs were reviewed to consider the cost of purchasing power from the Sangtuda I &amp; II projects as well as the O&amp;M fixed costs of Nurek and other existing hydro power plants.</td>
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</table>
### Generation Costs in Pakistan

The price that the state-owned utility (NTDC) is paying for the recent long-term PPAs with the IPPs has been used as a proxy of LRMC to estimate the generation cost in Pakistan over the life time of the interconnection project. It may be useful to state that, if electricity shortages continue for the foreseeable future (a not unlikely eventuality), the blended rate for firm and non-firm energy of about US$ 0.09/kWh assumed for the analysis will be a conservative assumption.

A statement will be added. Generation costs in Pakistan will be reviewed. The conservative assumptions used in the economic analysis have been summarized in section 10.3. In addition, the generation costs of Pakistan have been revised in section 5.

### Generation Costs in Afghanistan

It may be useful to also present the costs at which Afghanistan is obtaining imports from Tajikistan and Uzbekistan. There should also be an assessment of whether these rates can or cannot be used to predict future import rates from these and other Central Asian countries.

In the absence of any other credible data, the generation cost in Afghanistan is estimated to be, at least, US$ 0.06/kWh for the study based on the information provided by DABS. It is useful if the costs at which Afghanistan is obtaining imports from Tajikistan and Uzbekistan can be provided to estimate the generation cost in Afghanistan. The Consultant requests that Afghanistan provide the current costs. Considering the new generation options and fuel supply situation, the generation costs in Afghanistan is likely higher than US$ 0.06/kWh. Even if alternative imports are cheaper, the CASA imports will displace the most expensive generation options in Pakistan.

A review of PPAs that were provided to the consultant is provided in section 4.
Recommended Project (part 1)
The recommended project has a greater transmission capacity (2300 MW) in comparison to the convertor capacity (1300 MW) so as to provide flexibility to eventually expand the system to the ‘optimal’ 2300 MW while limiting the initial financing requirements. This adds approximately 7% to the costs but no additional benefits have been taken into account in the economic analysis. This stated benefit of flexibility is debatable and the economic return will be even less than that for the 1300 MW transmission and convertor capacity. It is also worth noting that the major part of this additional cost would have to be borne by Afghanistan.

Planning for a higher line capacity does add 7% to the project however this recommendation for flexibility was given in light of the requirement for adaptability to future capacity enhancements. The Consultant will provide the actual additional cost.

The surplus assessment is built on the conservative assumption that no new generation will be built, the 2300 MW conductor provides flexibility in the scenario that new generation is built. However, other options for flexibility could include that the initial capacity of interconnection be built for 1300 MW and that for a variety of other reasons, new HVDC lines be built for any further generation. This latter option provides flexibility with respect to additional reliability, it would be based on commercial arrangements without having to directly involve IFIs and could have alternative sending and receiving points.

Although a benefit for the initial larger conductor line would be the reduction in losses compared to the smaller conductor line, this is not significant.

Comments and additional information provided as comments to the draft report were reviewed. Their impact on the recommended project is reflected in section 6.
9. **Recommended Project (part 2)**
It may be more advantageous to have a project configuration that has a conductor size appropriate for a capacity of 1300 MW, with 1300 MW HVDC converter capacities at Sangtuda and Peshawar, and 300 MW HVDC converter capacity at Kabul. This will entail additional capital cost for Pakistan, and the possible benefits that would justify this expenditure will need to be identified.

It is possible to include a 1300 MW line rating and two 1300MW converters in Pakistan and Tajikistan, however it should be emphasized that even if additional surplus becomes available in the future, it will not be possible to upgrade the scheme without building a new line provided that additional surplus is available even with increased domestic demand in the exporting countries.

Also it must be remembered that even if the project is built with a smaller conductor for the 1300 MW capacity, the sections of the line at altitudes above 2,000 m will still require the larger conductor to meet technical criteria on noise limitation. The additional cost for the larger conductor has been factored in both the costs for the 1300 MW and the 2300 MW options. 

Addressed in section 6.

9. **Recommended Project (part 3)**
Is the 300 MW convertor station in Kabul just for imports or will it also permit exports? It should be for both, and the cost estimate should reflect this capability.

The converter station in Kabul is set up as bi-directional. This is included within the cost.

This is specified in section 6.

9. **Recommended Project (part 4)**
On Page 6-1, an option to limit the initial project investment by staging the total required converter capacity is mentioned. In such a scheme, the first stage would be to build a 650 MW monopole converter, connected to the bipolar transmission line. It is stated that drastic cost reductions would then arise from the reduced converter capacity and from using the second transmission line conductor as a metallic return, thus avoiding the need for electrodes near each of the converter stations. However, no details are provided of the cost reductions or of the economic analysis of this option. Either this option should be adequately analyzed and presented, or deleted from the Report.

Considering staging in terms of a monopole configuration with the other conductor as an earth return followed by the addition of a second converter some time later is very standard when dealing with HVDC projects. In the case, this scenario was dropped as the bulk of the benefits occurred in the first few years following the implementation of the interconnection. This comment will be deleted.

The introductory paragraph in section 6 has been revised.
### Feasibility Update By SNC-Lavalin - Preliminary Draft Final Report

#### Responses To Comments From Tajikistan

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<tbody>
<tr>
<td>10. Transmission Reinforcement of Existing Networks (part 1)</td>
<td>The comments made from the countries were reviewed and will be addressed in separate documents.</td>
<td></td>
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<tr>
<td>Section 8.5 states that if the import level into Pakistan were increased from 1000 MW to 2000 MW, then some additional 500 kV transmission out of the Peshawar area would be required. It is not clear if some transmission reinforcement would be required for import levels of 1300 MW and 1600 MW; this should be stated.</td>
<td>The need for additional transmission out of Peshawar to absorb any import above 1,000 MW has not been studied in detail and information would need to be provided by NTDC on this point.</td>
<td></td>
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<tr>
<td>11. Salang Pass</td>
<td>A high level cost estimate and assessment of potential risks/issues will be provided in the final report.</td>
<td>See section 7.</td>
</tr>
<tr>
<td>What are the cost implications of an alternative route bypassing the congestion of the Salang Pass? Are there any technical issues associated with this alternative route?</td>
<td>Cost comparisons of the back-feed option are provided in Tables 6-5 and 6-6. An additional comparison can be provided with an option that has a 1300 MW converter station in Peshawar and a 300 MW converter station in Kabul, in addition to an independent 220 kV line from Kabul to the border, and possibly a line also from Peshawar to the border.</td>
<td>Summary tables of the different project alternatives are provided in section 6.</td>
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<tr>
<td>12. Back-feed Option (part 1)</td>
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</table>
### Back-feed Option (part 2)

A realistic comparison for the back-feed option would be with an option that has a 1300 MW converter station in Peshawar and a 300 MW converter station in Kabul, in addition to an independent 220 kV (or 132 kV) line from Kabul to the border, and possibly a line also from Peshawar to the border. This would allow any unutilized part of the Afghanistan share to be absorbed by Pakistan, and electrification of villages in the Kabul-Peshawar corridor. The back-feed option would still offer the advantage of allowing Kabul to export to Pakistan through the 220 kV link in addition to allowing the full 1300 MW DC supply to be taken in Peshawar.

**Response:**
The analysis will be simplified in the Final Report See the write-up on the backfeed option, in section 6.

### Back-feed Option (part 3)

While discussing the issues of synchronous operation, it should be mentioned that splitting of the Kabul system is already being resorted to for existing imports from Central Asia.

**Response:**
If the splitting of the system is already being resorted to for imports from Central Asia, and if it is considered acceptable by the utility keep resorting to this solution, then a back to back is not necessary, as one part of the system will be synchronized to Pakistan and the other to Central Asia. The addition of the back to back would only be required for the exchange of power between these two parts of the system, if required. However, the ideal situation would to have the Afghanistan system synchronized within all of Afghanistan.

**Response:**
See the write-up on the backfeed option, in section 6.

### Back-feed Option (part 4)

The location of an additional Back-to-Back HVDC converter for a possible back-feed from Peshawar to Kabul is given as Kabul on Page 8-6. Would the border not be a more advantageous location so that communities on either side can be supplied from their respective systems?

**Response:**
The location of the back to back could well be at the frontier as proposed in the comment, so that the communities on either side are supplied by their own systems.

**Response:**
See the write-up on the backfeed option, in section 6.
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<tr>
<td><strong>13. Cost Estimate (part 1)</strong>&lt;br&gt;It is difficult to cross-check the consistency of the costs used for different analyses; for example, it is not clear as to how the US$865.7 million is derived from the cost breakdown given in Table 9-4. All cost figures may please be checked again and footnotes added showing the derivation of the figures from the detailed cost estimate.</td>
<td>Additional information on cost estimates will be provided to allow cross-checking of figures.</td>
<td>The tables in section 6, 9, 10 and appendix I, note I.4 were revised.</td>
</tr>
<tr>
<td><strong>13. Cost Estimate (part 2)</strong>&lt;br&gt;The preliminary estimate of the environmental and social mitigation costs should be included in the base cost estimate.</td>
<td>The preliminary estimate of environmental and social mitigation costs will be included in the base cost estimate for the final report.</td>
<td>The placeholder for environmental and social costs was included in the base costs. See sections 9 and 10.</td>
</tr>
<tr>
<td><strong>13. Cost Estimate (part 3)</strong>&lt;br&gt;It is not clear which option for relocating the existing 220 kV line has been included in the base cost estimate. Given the large difference in the estimated cost of the two options (US$ 4.2 million and US$ 28 million), this can make a significant difference in the total cost. The Report should clearly state which cost has been included.</td>
<td>The basis for the cost estimates are listed in section 9. Please refer to the third bullet of the paragraph which starts with “The project cost estimates provided are derived on the following basis” on page 9-1.</td>
<td></td>
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<tr>
<td><strong>13. Cost Estimate (part 4)</strong>&lt;br&gt;The base cost estimate does not include any provision for a ground electrode at each of the three convertor stations. As these ground electrodes would improve the reliability of the line, an appropriate cost provision for the three electrodes should be included. Can the cost of these electrodes vary that widely (US$ 1 million to US$ 9 million per electrode)?</td>
<td>A cost provision will be made for the electrodes in the final report.</td>
<td>A provision has been made for the electrodes. See sections 6, 9 and 10.</td>
</tr>
<tr>
<td><strong>13. Cost Estimate (part 5)</strong>&lt;br&gt;Table 9-5 shows the costs to be incurred in Euros as €222 m; should this not be €158 m?</td>
<td>The presentation of numbers in table 9-5 will be revised.</td>
<td>See revised section 9.</td>
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<tr>
<td>14. Economic Analysis (part 1)</td>
<td>A paragraph will be added to summarize the various conservative assumptions in the final report.</td>
<td>A paragraph was added in section 10.</td>
</tr>
<tr>
<td>When presenting the results of the base case economic analysis, it would be useful to summarize the various conservative assumptions adopted (e.g. no addition in generating capacity, the use of a conservative ‘blended rate for firm and non-firm energy’ of about US$ 0.09/kWh for the exports to Pakistan, certain benefits not being quantified, etc.).</td>
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<tr>
<td>14. Economic Analysis (part 2)</td>
<td>This sensitivity will be added to the report.</td>
<td>This sensitivity is presented in Table 10-4.</td>
</tr>
<tr>
<td>An important sensitivity will be a delay in the completion of the project by one year. This could have a significant adverse impact as the project will lose the benefit of the maximum surplus in 2016. It is important to highlight this so as to stress the importance of accelerated decision making.</td>
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<tr>
<td>14. Economic Analysis (part 3)</td>
<td>A sensitivity on uncoordinated reservoir operation will be added to the report.</td>
<td>This sensitivity is presented in Table 10-4.</td>
</tr>
<tr>
<td>Can we include a sensitivity which does not take into account coordinated operation of the two reservoirs? This will serve to emphasize the benefits that accrue from such coordination. It will also be useful in case riparian issues prevent such coordination.</td>
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<tr>
<td>14. Economic Analysis (part 4)</td>
<td>Information on the projected hourly prices of energy in Pakistan was not made available. If provided, this information could be used to estimate benefits related to on-peak imports.</td>
<td>An analysis of availability of firm energy during peak summer hours has been added to section 6.</td>
</tr>
<tr>
<td>The Draft Report states that, given the regulation capabilities of the reservoirs of Nurek and Toktogul, whenever there is a limited energy condition (e.g. during periods where the exported energy is such that the capacity of the CASA line is not fully utilized), it should be possible for the exports to be scheduled at the peak hours of the receiving systems so as to maximize the value of this energy for the importer. Can this benefit be estimated and included in the economic evaluation?</td>
<td></td>
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</tr>
<tr>
<td>14. Economic Analysis (part 5)</td>
<td>The levelized cost of transmission and the annual transmission costs will be added to the final report.</td>
<td>These are provided in section 10.</td>
</tr>
<tr>
<td>The levelized cost of transmission should be given in the report; it would also be useful to show how the transmission costs vary over the life of the project, as they will increase with reduced levels of the surplus.</td>
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## Feasibility Update by SNC-Lavalin - Preliminary Draft Final Report
### Responses to Comments from Tajikistan

| COMMENT |
|-----------------|-----------------|-----------------|
| **15. Country-wise Benefit Allocation (part 1)**<br>The approach adopted is based on the previous work done but needs to be reconsidered. Factors that also need to be considered include: differentiation between economic and financial benefits; the role and shareholding in the special purpose company; determination, payment and allocation of transmission charges through the special purpose company to the shareholders, etc. | The benefit allocation for each country was requested during the initial study to provide some indication of how benefits can be allocated to each country. However, for deciding the viability of the project, the overall economic project benefit / cost ratio should be the determining economic criteria rather than individual country benefit / cost ratios. Commercial agreements should ensure that each country receives appropriate allocation of the financial benefits to ensure adequate return to fund financial commitments. | Revised in section 10. |
| **16. Risks**<br>This section needs to be strengthened. If the cost of the electrodes is included in the project cost estimate, the discussion of the electrodes can be taken out of the risks section. | The risks section will be revised. | The risks section has been revised. |
| **17. Contractual and Operational Issues (part 1)**<br>The Report contains references to issues for which the related contractual and operational aspects will need to be resolved. It would be useful to add a section where all these issues are summarized, particularly for the recommended project configuration. | A section summarizing contractual and operational issues will be added. | See section 15. |
| **17. Contractual and Operational Issues (part 2)**<br>In the discussion regarding operations and maintenance (and other matters) in the Appendix, the “Contractor” is dealing with the “Employer” who will be trained to operate the facilities, etc. (e.g., sections G-2.7 and 2-8, et seq.). The circumstances envisioned for the CASA project are different from this Contractor-Employer relationship as it is the concession company that will be responsible for operations. These sections need to be edited accordingly. | Appendix G will be reviewed. | Appendices G and H were revised. |
### FEASIBILITY UPDATE BY SNC-LAVALIN - PRELIMINARY DRAFT FINAL REPORT RESPONSES TO COMMENTS FROM TAJIKISTAN

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<td><strong>18. Bidder Participation</strong>&lt;br&gt;On bidder participation, the Draft Report states that an addendum will be issued once there is a clear decision to go to the next phase of the project. There should be at least some discussion of the likely extent of bidder interest in the project included in the Final Report.</td>
<td>An additional discussion on likely extent of bidder interest will be included in the final report.</td>
<td>This is added in section 13.</td>
</tr>
<tr>
<td><strong>19. (1) Chapter 2:</strong>&lt;br&gt;With reference to figure 2.3 (showing rapidly dropping KYR surplus) and figure 2.4 (rapidly dropping TAJ surplus), the feasibility report should give a detailed justification for the construction of 2300 MW HVDC Line (instead of a 1300 MW). Please elaborate further on this aspect in the light of new power generation additions planned by the Kyrgyz Republic and Tajikistan. It is suggested that the generation plan be super-imposed on this graph and the net surplus be graphically shown over the years. Similarly Figure 2.5 may depict the overall combined effect of the net surpluses of the two countries.</td>
<td>The conservative assumption of no new generation plan is made based on TOR requirements. The generation plans for Kyrgyz Republic and Tajikistan are not available at this time.</td>
<td>See revisions in section 2.</td>
</tr>
<tr>
<td><strong>20. (2) Chapter 4</strong>&lt;br&gt;Chapter 4 narrates the demand forecast for Afghanistan. Please show the data and trend in the form of a table as done for the Pakistan case in Chapter 3 showing the new projects and years of commissioning as well as imports (from TAJ, TUR and UZB) versus the demand forecast. Such a comparison table will facilitate the decision-making when deciding whether a converter is needed at Kabul.</td>
<td>The generation planning information for Afghanistan is not available at the same level of detail as for Pakistan.</td>
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<tr>
<td><strong>21. (3) Chapter 6 (part 1)</strong>&lt;br&gt;a) Tables 6-5 and 6-6 can be combined in a single table to demonstrate the comparisons at a glance. Figure 6-2 is rather alarming due to the very low firm export potential under</td>
<td>The economic analysis does take the low firm export potential into account by using different prices for firm and non-firm energy.</td>
<td>A additional discussion on availability of firm</td>
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<td>all scenarios. This figure deserves detailed discussion in the feasibility report as it has implications on the overall viability of the project</td>
<td>The final report will discuss this in greater detail as it has implications on the overall viability of the project.</td>
<td>Energy is added to section 2.</td>
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<td><strong>21. (3) Chapter 6 (part 2)</strong> b) Is it possible to combine all the possible scenarios that have been studied to arrive at the optimum project size? Such a table can be added as an annex and, again, it will facilitate management level decision making.</td>
<td>The scenarios that have been studied will be summarized in a table.</td>
<td>Summary tables are provided in section 6.</td>
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<td><strong>22. (4) In Chapter 10:</strong> In section 10.3.4, the life time of the project is considered to be 30 years, while Figures 2.3 and 2.4 show the power surplus for only 20 year period. Therefore, to verify the viability of the assumption, the time-frame should be extended for the figures 2.3 and 2.4. In section 10.5, the report states that the project has a negative NPV and the B/C ratio less than one in case the capital cost increases by 10% or the power supply decreases by 10%. The consultant needs to elaborate on the probability of the occurrence of these two scenarios to ensure the viability of the project.</td>
<td>The economic analysis has extended the benefits to 30 years to verify the economic viability of the project. A footnote and/or the table extended to 30 years to clearly indicate that a 30 year period is used. The purpose of the sensitivity is to evaluate the robustness of the project and the impacts of variation of certain factors. More information and significant efforts are needed to assess and provide a sound probability of the occurrence.</td>
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<td><strong>23. (5) – Viable Alternatives</strong> The study should also comment on viable alternatives available to Afghanistan and Pakistan to meet their energy deficit and import requirements to help provide a comparison of cost/benefit of various options available to the Energy Importing Countries to justify the long-term investment in the project.</td>
<td>The costs for alternatives are expected to be higher than the proxy used for Pakistan and Afghanistan. This will be discussed in greater detail in the Final Report with indicative costs of generation for different fuel types. It should also be noted that capital requirements are significantly large.</td>
<td>See section 4.</td>
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<td>COMMENT</td>
<td>RESPONSE</td>
<td>ADDRESSED IN REPORT SECTION</td>
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<td>24. Supply Position</td>
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<td>Supply position from Kyrgyzstan &amp; Tajikistan has been explained in your Final Draft report. After studying in detail it has been observed that during 3 months (June, July &amp; August) in Summer, Supply is more than the capacity of Converter Stations at Sangtuda &amp; Peshawar. This supply is available during 3 months Out of 4 MONTHS, leaving 2 Nos. shoulder months where the supply is quite less. This supply position has been calculated on the existing sources and if we consider the resources to be energized up to 2016 in Tajikistan &amp; Kyrgyzstan, when CASA Project shall be completed, this capacity is going to increase more than the capacity as indicated below. Overall if you calculate MW, it shall be increasing more than 1800 MW during these 3 months, but that could be utilized only if the higher capacity Converters are available as the DC Transmission Lines have been designed on the capacity of 2300 MW. Pakistan can utilize completely whatsoever available if the converter stations are rated accordingly, otherwise it shall be restricted to 1000 MW. I shall suggest that the 1800 MW converter stations at both places Peshawar &amp; Sangtuda are designed, so as to utilize the complete capacity available on CASA-1000 System. I agree that in this case PRICE OF THE PROJECT SHALL BE INCREASED BUT AS COMPARED TO ITS UTILIZATION, IT SHALL BE WORTH, as it shall be covered through increased returns. Please take into consideration the above observations and calculate whether it shall be beneficial for the project or otherwise.</td>
<td>Economically the 1,300 MW to 2,300 MW options are about equivalent, with the 2,300 MW and 1,800 MW being slightly better than the 1300 MW. The option for a 2,300 MW conductor with 1,300 MW converters is provided in the event of financial constraints. The final report will contain a review of the economics in light of the all recommended changes from the comments received.</td>
<td>The recommended project option was review in light of changes and feedback to the draft report. Please refer to section 6.</td>
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