DETAILED PROJECT REPORT FOR TRANSMISSION SYSTEM FOR SOLAR POWER PARKS AT BHADLA, RAJASTHAN

1.0 CONTEXT / BACKGROUND

Government of India has taken an initiative for development of Solar Power parks (SPP) in various parts of the country. As part of above initiative, an ultra-mega solar Power park is being developed by M/s SauryaUrja Company of Rajasthan Ltd (JVC of Govt. of Rajasthan and IL&FS) for 1000MW capacity, M/s Adani renewable energy park Rajasthan ltd. (JVC of Govt. of Rajasthan and AREPL)for 500MW capacity as well as by M/s EsselSaurya Company of Rajasthan Ltd(JVC of Govt. of Rajasthan and EsselInfraprojects Ltd) for 750 MW in/nearBhadla, Jodhpur distt, Rajasthan. Ministry of Power (MOP) informed that evacuation system for various Solar parks including Solar Power Parks in Bhadla, Rajasthan shall be developed by POWERGRID in compressed time schedule.The interstate transmission scheme for Solar Power Parks in Rajasthan was discussed and agreed in the 36th Standing committee meeting on Power system Planning of Northern region held on 13.07.15 as well as in 37thStanding committee meeting on Power system Planning of Northern region held on 20.01.16.

The present DPR covers scheme of "Transmission system for Solarpower parks at Bhadla, Rajasthan"

2.0 DESCRIPTION OF TRANSMISSION SYSTEM

Based on the requirement of evacuation and transfer of power from Bhadla Solar Power parks', following transmission system is proposed:

- 765kV Bhadla (PG) – Bikaner (PG) D/c
- 400kV Bhadla (PG)- Bhadla (RVPN) D/c (Quad)
- Establishment of 765/400/220kV (765/400kV: 3x1500MVA, 400/220kV : 3x500 MVA) Pooling Station at Bhadla (PG)
- 4 nos. 220kV & 2 nos. 400kV line baysat Bhadla (PG) for interconnection of solar power parks

The schematic of the proposed Transmission system is shown at **Exhibit-1.0.**

3.0 JUSTIFICATION

MNRE has authorized M/s SauryaUrja Company of Rajasthan Ltd (JVC of Govt. of Rajasthan and IL&FS), M/s Adani renewable energy park Rajasthan ltd. (JVC of Govt. of Rajasthan and AREPL) as solar power park developers for 1000 MW & 500 MW capacity atBhadla (Jodhpur). MNRE has also authorized M/s EsselSauryaUrja Company of Rajasthan Ltd (JVC of Govt. of Rajasthan and EsselInfraprojects Ltd) as solar power park developers for 750 MW (Phalodi / Pokran) capacity.

Out of above generation capacity, M/s SauryaUrja Company of Rajasthan Ltd., Adani renewable energy park Rajasthan Ltd has applied for Long Term Access in ISTS for

500 MW and 250 MW respectively. Power from above project is envisaged to be transferred to beneficiaries of northern region.

Further, M/s EsselSauryaUrja Company of Rajasthan Ltd has applied for Long Term Access in ISTS for 750 MW indicating target beneficiary as NR-400 MW and WR-350 MW.

In order to facilitate pooling of power from various Solar power modules in the park as well as evacuate & transfer of power from aboveultra mega solar parks, establishment of 765/400/220kV pooling station at Bhadla is proposed along with its 765kV interconnection to Bikaner (POWERGRID) substation. 765/400kV Bikaner (PG) substation is already being established under Green Energy Corridor-Part-D scheme. Bikaner S/s is also being interconnected to 765kV Moga in Punjab & Ajmer in Rajasthan for further dispersal of power towards Load center in Punjab/Rajasthan under Green energy corridors scheme. Bhadla pooling station is also proposed to be interconnected with nearby Bhadla (RVPN) substation through a 400kV D/c (Quad) line.

Necessary 220kV & 400kV interconnection line from Solar Power Parks upto 220/400/765kV Bhadla Pooling station (ISTS) shall be developed by the respective applicants/SPPD as part of its internal transmission infrastructure. However, provision of 4 nos. 220kV line bays, to interconnect pooling stations of SauryaUrja Solar Power Park (SPP) as well as Adani SPP with the main pooling station i.e. 765/400/220kV Bhadla Pooling station is kept under present scope. Further, 2 nos. 400kV line bays to interconnect pooling station of EsselSaurya Solar Power park to Bhadla Pooling station is also kept under the present scope.

In order to address reactive power management aspects including during low/no solar generation periods, 1x240MVArbus reactor (at 765kV bus)& 1x125MVAr (at 400kV bus) at Bhadla Pooling station is proposed. For 765kV Bhadla (PG) – Bikaner (PG) D/c line also, 1x240 MVAR switchable line reactor is provided at both ends on each circuit. In this way, proposed transmission system shall facilitate transfer of power from solar generation of BhadlaUltra mega solar parkwith reliability.

The above inter-state transmission scheme was discussed and agreed in the 36th standing committee meeting of northern region held on 13.07.15 as well as 37thStanding committee meeting on Power system Planning of Northern region held on 20.01.16.

4.0 SCOPE OF WORK

Transmission Lines

(i) 765kV Bhadla (PG) – Bikaner (PG) D/c line – **175 km**
(ii) 400kV Bhadla (PG)- Bhadla (RVPN) D/c (Quad) – **26 km**

Substation

a) 765/400/220kV Bhadla (PG)

765kV

- Line Bays : 2 nos.
- 1500MVA, 765/400kV transformer : 3 nos.

- 240MVAR Bus reactor : 1 no.
- Transformer bays : 3 nos.
- Bus reactor bay : 1 no.
- 240MVAr switchable line reactors : 2 nos.
- 240MVAr switchable line reactor bays : 2 nos.

400kV

- Line Bays : 4 nos.
- 500MVA, 400/220kV transformer : 3 nos.
- Transformer bays : 6 nos.
- 125MVAR Bus reactor : 1 no.
- Bus reactor bay : 1 no.

220kV

- Line Bays : 4 nos.
- Transformer bays : 3 nos.
- BC + TBC : 1 no.

b) 765/400kV Bikaner (PG) Substation Extn.

765kV

- Line Bays : 2 nos.
- 240MVAr switchable line reactors : 2 nos.
- 240MVAr switchable line reactor bays : 2 nos.

c) 400/220kV Bhadla (RVPN) Substation Extn. *

400kV

- Line Bays : 2 nos.

** Note : Bay Extn. works at Bhadla(RVPN) S/s to be carried out by RVPN as deposit work on behalf of POWERGRID*

Reactive Compensation

- **Bus Reactors**

Bus	**Reactor (MVAR)**
765kV Bhadla (PG) 400 kV Bhadla(PG)	1x240 MVAr (765kV) 1x125 MVAr (400kV)

- **Line Reactors**

Transmission Line		
	From end (each ckt)	**To end (each ckt)**
Bhadla(PG) – Bikaner (PG) 765 kV D/c line	1x240 (**switchable**) (eachckt.)	1x240 (**switchable**) (eachckt.)

4.1 PROJECT HIGHLIGHTS

The objective of the project is to facilitate power transfer from the Jalaun solar power park to various beneficiaries including Uttar Pradesh.

a)	Project	:	Transmission system for Solar Power parks at Bhadla, Rajasthan
b)	Location of the Project	:	Northern Region
c)	Project Cost	:	**Rs.1429.38Crores**at **April 2016**Price Level (including IDC of **Rs.74.24Crores**)
d)	Monthly Fixed Charges	:	**Rs. 2078.42Lakhs** on Base Cost **Rs. 2056.39Lakhs** on Projected Completed Cost
e)	Commissioning schedule	:	Transmission System is proposed to be implemented within **30 months** from the date of investment approval.

5.0 PROJECT APPROVAL BY CONSTITUENTS / SHARING OF TRANSMISISION CHARGES

5.1.1 The Prior approval of the Government of India under Section 68 of the Electricity (Supply) Act, 2003 for the subject project has been obtained vide MoPs letter dated 13.01.2016 (Copy is enclosed at **Annexure -9.0**).

5.1.2 The scheme was discussed and agreed in the 36th Standing committee meeting on Power system Planning of Northern region held on 13.07.15 as well as in 37thStanding committee meeting on Power system Planning of Northern region held on 20.01.16. The scheme has also been agreed in the *36th& 37thmeetings of NRPC held on 24.12.15 & 22.03.16 respectively*(Copies of the minutes of meetingenclosed at **Annexure -8.0**.)

5.1.3 MOP vide letter dated 08.01.15& 04.08.15 intimated PGCIL for taking up of transmission system for evacuation of power from 9 solar generating parks being set up in 7 –states along with pooling stations as ISTS Scheme, including subject Bhadla Solar Park on compressed time schedule basis.(Copy of the above letter is enclosed at **Annexure – 8.0.**)

5.2 SHARING OF TRANSMISSION CHARGES

The transmission charges for this project shall be shared by the beneficiaries in line with the sharing regulations notified by CERC and as per the applicable point of connection (PoC) charges determined by the implementing agency.

6.0 PROJECT STRATEGY

POWERGRID had undertaken and evolved the various elements of this transmission scheme in consultation with CEA keeping in view the present and future load requirement of Northern Region.

7.0 LEGAL FRAMEWORK

It is proposed to execute the above entire transmission scheme as per provisions contained in the Indian Electricity Act, 2003 and the rules made there-under and the Electricity (Supply) Act, 1910 and 1948, in so far as these are applicable.

8.0 ENVIRONMENTAL IMPACT ASSESSMENT

8.1 Environmental Risk

As per the policy and procedures laid down in ESPP, preliminary route selection is done based on environmental screening and scoping procedure with the help of secondary/published data/documents such as Forest Atlas and the Survey of India maps using "bee" line method, followed by field verification through walk over survey. All possible steps are taken to avoid the route alignment through forests. In cases where it becomes unavoidable due to the geography of terrain, the alignment is made in such a way that the route through the forests is the barest minimum. For selection of optimum route, following points are taken into consideration:

(i) The route of the proposed transmission line does not involve any human rehabilitation.
(ii) Any monument of cultural or historical importance is not getting affected.
(iii) The route does not create any threat to the survival of any community.
(iv) It does not affect any Public-Utility Services like Playground, School, Other establishments, etc.
(v) It does not pass through any sanctuaries, National Park, etc.
(vi) It does not infringe with areas of natural resources.

As per the preliminary assessment based on Forest Atlas, toposheet and walk over survey of the area, certain forest stretches are likely to be encountered for this Transmission system comprising of the following line:

NAME OF TRANSMISSION LINE	FOREST INVOLVEMENT (Approx. area in Ha)
➢ 765kV Bhadla (PG) - Bikaner (PG) D/c line	13.40 Ha
➢ 400kV Bhadla (PG)- Bhadla (RVPN) D/c (Quad) line	4.60 Ha

However, exact involvement of forest stretch shall be known only after detailed survey and finalization of route alignment.

8.2 Social Issues/R&R measures

As per the prevailing law, land below transmission line is not required to be acquired andcompensation towards all damages is required to be paid. However, the land owners/farmers are now demanding cost of land for tower base area as well as diminution in land value for transmission line corridor area due to severe restriction imposed on land use. These demands of farmers were considered by a committee specifically constituted to resolve such issue and to develop a uniform policy / rules for such compensation. Based on the MoP guidelines issued on 15.10.15 regarding payment of compensation towards damages in regard to Right of Way for transmission lines, provisions in the DPR has been kept to meet such cost.

POWERGRID has developed its own Environmental and Social Policy & Procedure (ESPP) for its project activities after detailed consultation, within and outside POWERGRID, including National Consultation. **POWERGRID's ESPP envisages a progressive policy on Resettlement & Rehabilitation (R&R).** National policy on R&R is not attracted by the transmission projects, as these do not involve displacement of a large number of families. However, POWERGRID has adopted entitlement benefits listed in the national R&R policy in its **"Social Entitlement Framework"** that is being implemented wherever land acquisition for substations was undertaken by invoking Land Acquisition Act, 1894. However, to make land acquisition process in the country more transparent and participative as well as to ensure Rehabilitation and Resettlement of affected families GOI has enacted a new act viz.**"The Right to Fair compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013"** by repealing the old "Land Acquisition Act, 1894". The new act has become operational from 1st January 2014. Under this the **Social assessment and R&R of affected persons is the responsibility of concerned State govt**. **or its authorized agency instead of utility (POWERGRID).** However, costs of such measures are to be borne by the utility.

In the instant project, new 765/400/220 kV substation is coming up at Bhadla for which **129.70** acres of land is required. To meet the cost of R&R measures, a provision of Rs. **150** lakhs has been kept for the substation.

For extension of 765/400kV Bikaner S/S noadditional land is required .

9.0 EQUIPMENT SELECTION PHILOSOPHY

POWERGRID has in-house developed infrastructure/software capabilities and computer aided facilities for Planning, Design, Operation and Maintenance of transmission system. Before planninga transmission system, various system studies like Load flow, Stability, Short-Circuit, etc. are undertaken keeping in view the existing system, present and future load flow requirements and the most optimal transmission system either associated with generation projects or Grid strengthening projects, is evolved with bare minimum redundancy required. Further, Designstudies are undertaken forselection of major system and equipment parameters for transmission system upto 800KV level.

Transmission system for solar power parks at Bhadla, Rajasthanproject has been designed in the most optimal manner based on the various studies as mentioned above. The system and equipment parameters are chosen keeping in view the present trend in technology. The conductors are selected such that the losses in them due to internal resistance as well as due to external effects are bare minimum. The bus bar materials and the clamps and connectors are chosen meeting the stringent international requirements so that there is least loss of energy in them. The reactors and other switchgears are also suitably selected and evaluated before award itself for most efficient operation from thermal and loss efficiency point of view. The energy thus saved is energy transmitted to the beneficiaries. This is a major step in energy conservation as the energy saved on account of losses is construed as energy generated.

10.0 TECHNOLOGY ISSUES

10.1 Salient features of 765/400/220 KV Substation Equipment and facilities

The design and specification of substation equipment are to be governed by the following factors:

10.1.1 Insulation Coordination

765/400/220 KV System would be designed to limit the Switching overvoltage to 2.5 pu and is expected to decay to 1.5 p.u. in 5 to 6 cycles. Consistent with these values and protective levels provided by lightning arrestors, the following insulation levels are proposed to be adopted for 765&400 kV systems:

		765 KV	420 KV	245 kV
a	Impulse withstand voltage for - Transformer and reactors - for Other Equipment	 1950kVP 2100 kVP	 1300 kVP 1550 kVP	 950 kVP 1050 kVP
b	Switching surge withstand voltage	1550 kVP	1050 kVP	
c	Minimum creepage distance	13020 mm	10500 mm	6125 mm
d	Max. faultcurrent	50kA	63 kA	40 KA
e	Duration of fault	1 Sec	1 Sec	1 Sec
f	Corona extinction voltage	508 kV rms	320kV rms	

To control the steady state, transient and dynamic overvoltage to specified levels, compensation equipment shall be provided.

10.1.2 Steady State Stability

The Steady State Stability is the ability of a system, to return/remain in the state of equilibrium when subjected to small or gradual changes of disturbances. The steady state stability limit is the maximum power that can flow through some lines in the system when the entire or part of the system to which the stability limit refers is subjected to a small disturbance without loss of its stability.

The steady state stability is usually quantified by measuring the relative angular displacement (also called as swing curve) between the two buses (nodes) in a network when a small disturbance is applied somewhere into the system.

In an integrated power system consisting of large number of generator, load and line etc., a maximum relative angular separation of about 30 deg. between the two buses may be assumed to be acceptable (safest) limit for maintaining the steady state stability of the system. Angular separation for different alternatives have been studied and found to be in order.

10.1.3 Switching Schemes

It is essential that the system should remain secured even under conditions of major equipment or bus-bar failure. Sub-stations being the main connection points have large influence on the security of the system as a whole. The selection of the bus switching scheme is governed by the various technical and other related factors. One & Half breaker bus scheme has been considered for 400kV side due to their merits in terms of reliability, security, operational flexibility and ease of maintenance of equipments.

The following switching schemes have been considered in various substations:

Substation	765kV side	400kV side	220kV side
765/400/220kV Bhadla (New) S/S	One & half breaker	One & half breaker	DMT
765/400kV Bikaner S/S Extn.	One & half breaker	-	-
400/220kV Bhadla(RVPN) S/S Extn	-	One & half breaker	-

10.1.4 765/400 KV Substation equipment:

The switchgear shall be designed and specified to withstand operating conditions and duty requirements.Further, switchgear for all voltage levels shall be generally of conventional type air insulated switchgear due to economy, subject to availability of suitable land.

10.1.4.1 Power Transformer

Power transformers shall conform to IEC: 60076 in general. These transformers shall generally have OLTC with a range of $\pm$5.5%, the range and requirement of which shall be finalized based on the system requirement. The air core reactance shall be of the order of 20%. Tertiary windings shall be provided for large auto transformers, which shall be capable of being loaded to one third of transformer loading. Insulation level of tertiary winding shall not be less than maximum transferred surge from HV/MV winding to tertiary winding.

10.1.4.2 Circuit Breakers

Circuit breakers shall in general comply to IEC 62271-100 & IEC-62271-1 and shall be of SF6 Type. The rated break time shall not exceed 60 ms for 220 kV &45 ms for 400 kV circuit breakers. Circuit breakers shall be provided with single phase and three phase auto reclosing. The short line fault capacity shall be same as the rated capacity and this is proposed to be achieved without use of opening resistors.

10.1.4.3 Isolators

The isolators shall comply to IEC 62271-102 in general. Isolators shall be horizontal/knee type/double break/vertical break/ pantograph type keeping in view the bus switching schemes proposed. Isolators shall be motor operated. Earth switches are provided at various locations to facilitate maintenance. Main blades and earth blades shall be interlocked and interlock shall be fail safe type. All earth switches shall be motor operated type.

10.1.4.4 Current Transformers

Current Transformers shall comply with IEC 60044-1 in general. All ratios shall be obtained by secondary taps. They shall have six secondaries for 400 kV& 220 kV. The burden and knee point voltage shall be in accordance with the requirements of the system including possible feeds for telemetry.

10.1.4.5 Capacitor Voltage Transformers

Voltage transformers shall comply with IEC 60044-5 in general. These shall have three secondary out of which two shall be used for protection and one for metering. Accuracy class for protection core shall be 3 P and for metering core shall be 0.2. The voltage transformers on lines shall be suitable for Carrier Coupling. The Capacitance of CVT shall be 4400/6600/8800 pF depending on PLCC requirements.

10.1.4.6 Surge Arresters

Station class current limiting, heavy duty gapless type Surge arresters conforming to IEC 60099-4 in general shall be provided. The rated voltage of Surge arrester and other characteristics are chosen in accordance with system requirements. Surge arresters shall be provided near line entrances, so as to achieve proper insulation coordination. These shall be fitted with pressure relief devices and diverting ports suitable for preventing shattering of insulator housing providing path for the flow of rated currents in the event of arrestors failure.

The switchgear shall be designed and specified to withstand operating conditions and duty requirements.

10.1.4.7Shunt Reactors

Shunt Reactors, wherever provided, shall comply to IEC:289/IS:5553 in general. 765 KV Shunt reactors shall have linear characteristics upto 1.5 p.u. voltage. These should be ONAN Cooled. The neutral of line reactors shall be grounded through adequately rated neutral grounding reactors to facilitate single phase recloser against trapped charges. The neutral of 765 kV and 400kV class shunt reactors shall be insulated to 550 kV peak for lightning impulse and shall be protected by means of 145 KV Class surge arresters.

10.1.5 Substation Support facilities

Certain facilities required for operation & maintenance of substations as described below shall be provided in new substation and in existing substation they have already been provided and would be extended, wherever required.

10.1.5.1AC & DC power supplies

For catering to the requirements of three phase & single phase AC supply and DC supply for various substation equipment the following arrangement is envisaged :-

i) For LT Supply, at new Substation, 2 nos. 800 kVA, 33/0.433 kV LT Transformers shall be supplied.

ii) 2 Nos. batteries of 220 V for control & protection and 2 Nos. 48 V battery for PLCC would be provided at new Substation. Each battery would have a boost and trickle charger.

iii) Suitable AC & DC distribution boards and associated LT Switchgear would be provided at new Substations.

10.1.5.2 Firefighting System

Firefighting system in general conforms to fire insurance regulations of India. The firefighting system is proposed with both AC motor & diesel engine driven pumps. Automatic heat actuated emulsifying system is proposed for transformers & reactors. In addition for alarm system based on heat/smoke detectors are proposed to be installed

at sensitive points in a substation e.g. Cable Vault, Main Control Room, MCC Room etc. Further, adequate water hydrants and portable fire extinguishers shall be provided in the substations.

10.1.5.3 Oil evacuating, filtering, testing & filling apparatus

To monitor the quality of oil for satisfactory performance of transformers, shunt reactors and for periodical maintenance necessary oil evacuating, filtering, testing and filling apparatus would be provided at new substations. Oil tanks of adequate capacities for storage of pure and impure transformer oil would be provided.

10.1.5.4 Lighting & communication

Adequate normal & emergency AC & DC lighting shall be provided in the control room of the substation. The switchyards shall also be provided with adequate lighting. A telephone exchange of 24 lines shall be provided at new substations as means of effective communication between various buildings of the substation.

10.1.5.5 Telemetry and Communication

The communication network under the proposed project shall have the following aspects in order to meet the high reliability, availability and maintainability criteria:

i. The proposed FO based communication links/network shall be used for speech and data communication to SLDC and/or RLDC. The capacity planned has scope for future usages including for Special protection schemes.

ii. The Fiber Optic (FO) terminal equipment to be installed under the project shall be based upon SDH technology with STM-4 and STM-16 bit rate having support for both existing PDH & Ethernet based requirement. The interfaces shall be selected meeting the present requirement for grid management etc. The SDH equipment shall be provided with redundancy to facilitate path protection and against failure of any interface card/power supply.

iii. Suitable interface cards shall be provided for data transmission and interfacing with data equipment such as PMU*. SPS, RTU and/or sub-station automation system.

**The PMUs provide real time phase angle measurement which is utilized for better Visualization & help to increase the situational awareness of Power System Operators to facilitate real-time congestion management, design of an advanced warning system, validation of data, fine tuning of system models and design of an adaptive protection system*

10.1.5.6 Control Room

Substation control room would be provided to house substation for station level control along with its peripheral telemetry equipment and recording equipment, AC & DC distribution boards, DC batteries, etc. Air conditioning will be provided in the building as functional requirements.

10.1.6 Protection & Control

The substations shall be provided with control, relaying & monitoring functions along with substation automation system based on IEC 61850 protocol using fiber optic network. The communication with adjacent connected substations shall be through PLCC & digital protection through OPGW.

The state of art protection system based on numerical technology has been provided to minimize the damage to equipment in the event of fault for Transformers, Reactors, Transmission lines and Bus bars. These protective relays are with self diagnostic feature and conforming to latest IEC 61850 for communication purposes for communicating the detailed list of events recoded by these relays in the event of fault or any abnormal conditions. Normally all these relays are equipped with in built fault recorder which can record the analogue as well as digital information for analysis of fault.

Auto Transformers & Reactors

Auto transformers shall be provided with the following protections:
i) Differential protection
ii) Restricted earth fault protection
iii) Back-up impedance protection

Besides, these transformers & reactors shall also be provided with Bucholz relay, protection against oil and winding temperatures & pressure relief device.

Transmission Lines

400/132kV lines shall have MAIN-I protection and shall also have numerical distance protection scheme carrier as three zone distance type with carrier aided inter-tripping feature. All lines shall also have MAIN-II protection which shall have numerical distance protection scheme like Main-I but from different make that of MAIN-I.

They shall also be provided with two stages over voltage protection. Further, all lines shall be provided with single and three phase auto-reclosing facility to allow reclosing of circuit breakers in case of transient faults.

These lines shall also be provided with distance to fault locators to identify the location of fault on transmission lines.

Protective Relaying System

765kV lines shall have MAIN-I protection and shall also have numerical distance protection scheme carrier as three zone distance type with carrier aided inter-tripping feature. All lines shall also have MAIN-II protection which shall have numerical distance protection scheme like Main-I but from different make that of MAIN-I.

They shall also be provided with two stages over voltage protection. Further, all lines shall be provided with single and three phase auto-reclosing facility to allow reclosing of circuit breakers in case of transient faults.

These lines shall also be provided with distance to fault locators to identify the location of fault on transmission lines.

Further, transmission lines shall be provided with OPGW which shall be used to meet the requirements of Power System Communication. Optical Fibre technology provides

an efficient telecommunication network to support their various applications requiring higher speed & bandwidth. POWERGRID has taken up PMU based WAMS project for the entire Power System network. Installation of PMUs is also envisaged at all the sub-stations under the project. PMU based WAMS applications cannot be implemented without Fiber Optic based communication system.
OPGW installation is easier and cost effective during the construction of the line. The fibres are located within ground wire therefore the cost of earth wire towards supply and installation is reduced.

Bus bar Protection

The high speed bus bar differential protection which is essential to minimize the damage and maintain system stability at the time of bus bar faults shall be provided for 400 kV buses. Bus bar protection scheme shall be such that it operates selectively for each bus and incorporate necessary features required for ensuring security. The scheme shall have the provision for future expansion.

Local Breaker Back up Protection

This shall be provided for each of 765kV and 400 kV breakers and will be connected to de-energize the affected stuck breaker from both sides.

Time synchronization equipment

Time synchronisation equipment complete in all respect including antenna, cable, processing equipment required to receive time signal through GPS or from National Physical Laboratory(NPL) through INSAT shall be provided.

Substation Automation System

For all the new substations, state of art Substation Automation System (SAS) conforming to IEC-61850 has been provided. The distributed architecture has been used for Substation Automation system where the controls are provided through bay control unit and bay control units are provided bay wise for voltage level 400kV and above. All bay control units as well as protection units are normally connected through an optical fiber high speed network. The control and monitoring of substation elements such as circuit breaker, disconnector, resetting of relays etc. are being done from Human Machine Interface(HMI) from the control room. SAS is equipped with the facility of remote operation. By providing remote HMI and suitable communication link, the substation can be controlled from a remote location.The functions of control, annunciation, disturbance recording, event logging and measurement of electrical parameters shall be integrated in Substation Automation System. The Automation System shall be provided with the facility of communication and control for remote end operation.

10.1.7 PLCC

Power line carrier communication (PLCC) equipment complete for speech transmission, line protections, and data channels shall be provided on each 765 KV transmission line. The protections for transmission line and the line compensating equipment shall have hundred percent back up communication channels. The PLCC equipment shall in brief include the following:-

Coupling device, line traps, digital/analog carrier terminals, protection couplers, HF cables, trunk selectors, automatic exchange, and maintenance and testing instruments.

Coupling devices shall be suitable for 4400/6600/8800 pF for 420 kV CVTs for phase to phase coupling. The pass band of coupling devices shall have sufficient margin for adding communication channel in future if required. Necessary protection devices for the safety of personnel and low voltage part against power frequency voltages and transient over voltage shall also be provided. The line traps shall be broad band tuned suitable for blocking the complete range of carrier frequencies.

Line Trap shall have the necessary protective devices such as lightning arresters for the protection of tuning device and shall be equipped with corona rings. Decoupling network consisting of line traps and coupling capacitors may also be required at certain substation in case of extreme frequency congestion.

10.1.8 Control Concept

All the EHV breakers in substation/switching stations shall be controlled and synchronized from the switchyard control room / remote control center. Each breaker would have two sets of trip circuits which would be connected to separately fused DC supplies for greater reliability. All the isolators shall have control from remote/local whereas the earth switches shall have local control only.

10.2 Salient features of Transmission Lines

The salient features of the proposed transmission lines are given here under:

The primary consideration for design and estimation of transmission line is walk over survey, which is based upon topographical map/forest map of India. Type of terrain, forest stretches, crossings etc. to be encountered by the transmission line has been taken into consideration while estimating the quantities.

10.2.1 765KV Double Circuit AC Transmission Lines

10.2.1.1 Wind Zone

The weight of tower will vary in an ascending order from wind zone 1 to wind zone 6 as the transverse load on the tower considered owing to the wind pressure increases in the same pattern. The identification of wind zone is based on the wind zone map given in IS: 875 (part-I) 1987 and the past experience in the region.

The transmission lines fall under wind zone- 4 (47 m/s) as per IS: 875 and shall be designed accordingly.

10.2.1.2 Design Criteria

The design parameters proposed to be adopted for the transmission line are generally based on the report of standardization committee of CEA and stipulations of relevant Indian Standards.

10.2.1.3 Line Configuration

The 765 kVD/C lines shall have vertical configuration of conductor bundles.

10.2.1.4 Towers

Self-supporting latticed bolted steel towers, fabricated from structural steel angle section shall be used. Tower components and bolts & nuts shall be hot dip galvanized.

Normally, the following four types of double circuit tower shall be used in these lines.

i) DA type suspension towers for upto 2 degree angle of deviation.
ii) DB type tension towers for upto 15 degree angle of deviation.
iii) DC type tension towers for upto 30 degree angle of deviation.
iv) DD type tension towers for upto 60 degree angle of deviation and suitable for dead end condition. These may also be used for terminal locations.

The standard extension normally used for various types of towers are as follows:

DA & DD : 3m, 6m, 9m, 18m, 25m
DB & DC : 3m, 6m, 9m

In addition to the above, special towers, for major river crossing, power line crossing and the places where the terrain is particularly different, such as approach to the sub-station, forest stretches etc. shall also be used. All towers shall be designed in accordance with latest edition of IS-802 and considering necessary improvements and reinforcements evolved as per suggestions/recommendations of CEA's expert committee based on the experience of previous tower failures in the country.

Structural steel sections used in towers shall be of High Tensile (HT) steel & Mild Steel (MS) of requisite quality as per IS-2062 or equivalent International Standards.

10.2.1.4.1 Foundations

Tower Foundations are generally pad & chimney type and typically classified as Dry, Wet, Partially submerged(PS), Fully Submerged (FS), Wet Black Cotton (WBC), Sandy, Dry Fissured Rock (DFR), Wet Fissured Rock (WFR), Submerged Fissured Rock (SFR), Hard Rock etc. depending upon type of soil encountered and designed accordingly based on relevant Indian standards and CBIP guidelines. For river crossing locations & soils having poor bearing capacity, wherever required, pile/well type foundations are used.
Typesof soil encountered by the transmission lines are generally mixed dry, wet, wet black cotton type in the plain terrain and dry fissured rock, wet fissured rock & hard rock in the hilly terrain. The requirements of the foundations are considered in accordance with the type of soil.

10.2.1.4.2<u>Revetment and Benching</u>

For hilly and undulating stretch, wherever the line is passing through, revetment and benching shall be provided as per site conditions.

10.2.1.5Conductors

Conventional ACSR type conductors have been considered based on system requirements as these are most common type of conductors with proven technology having low cost & easy availability.

Hexagonal bundle ACSR Zebra Conductor (54/3.18Aluminium and 7/3.18 mm steel)of overall diameter 28.62 mm shall be used per phase for 765 KV D/C line. The sub-conductor spacing will be 457 mm.

10.2.1.6Earthwire

One OPGW and one 7/3.66 mm galvanized steel earthwire shall be used on the lines so that it can withstand two successive lightning stroke of 150 kA. Shielding angles of 20 deg is considered for transmission lines.

10.2.1.7 Grounding

The tower footing resistance shall be kept below 10 ohms. Pipe type or counterpoise earthing shall be used to bring the tower footing resistance down to acceptable level.

10.2.1.8Insulator and Hardware Fittings

Composite long rod insulators shall be used. The following types of insulator strings along with hardware fittings shall be used :

765 KV D/C TRANSMISSION LINE WITH HEXAGONAL ACSR ZEBRA CONDUCTOR

Type of Strings	Size of Composite Insulator (Core dia x Nominal length) (mm)	Minimum Creepage distance (mm)	No. of individual Units per String (Nos.)	Electro mechanical Strength of Individual Unit (KN)	Ultimate Strength of Insulator String with Hardware assembly (KN)
a) Double I suspension (Tower DA)	24 x 2975	12400	2x2	160	320
b) Quad Tension (Tower DB, D C & D D)	24 x 2975	12400	4x2	210	840 (in line strength)
c) Single I suspension Pilot	24 x 2975	12400	1x2	160	160
d) Single tension	24 x 2975	12400	1x2	160	160

Suitable hardware fittings shall be used for attachment of the insulators with the tower at one end and also for supporting the conductors at the other end. Corona control rings or grading rings will be used for improving corona and RIV performance as well as to improve the voltage distribution across the insulators discs.

10.2.1.9Line Accessories

i) **Mid span compression joint for conductor/ earthwire**

Mid span compression joint suitable for conductor/ earthwire shall be used for joining two lengths of conductor / earthwire. The minimum slipping strength of the joint after compression shall not be less than 95 % of the UTS of conductor / earthwire.

ii) **Repair sleeve for conductor**

Repair sleeve shall be used only for repairing not more than two strands broken in the outer layer of conductor. It shall be of compression type in two parts with provision of seat sliding of keeper piece.

iii) **Flexible copper bond for earthwire**

Flexible copper bonds shall be used for good electrical continuity between the earthwire and the tower. One bond per suspension tower & two bonds (two for each earthwire) per tension tower shall be used.

iv) **Vibration damper for earthwire**

Stockbridge vibration dampers shall be used to reduce the maximum dynamic strain caused by aeolian vibrations to a value of 150 micro-strain.

v) **Spacers/SpacerDamper**

Hexabundle spacers shall be used for 765kV D/c lines to reduce vibrations and maintain sub-conductor spacing under all working conditions.Hexabundle Rigid spacer for jumpers shall be used at all tension towers.

vi) **Suspension/Tension clamps for earthwire**

Suitable suspension/tension clamps shall be used for attachment of earthwire at suspension/tension towers.

vii) **T-connectors**

Compression type T-connectors shall be used for conductor jumpering at transposition towers wherever required.

10.2.1.10River Crossings

Special towers shall be used for major river crossings where the span is more than 600 mtrs with anchor towers on either end of river crossing span.

10.2.1.11 Power line, Railway line, Road and P&T line crossing

The transmission lines shall be crossing power lines, railway lines roads and P&T lines for which suitable extensions of towers shall be used.
The standard extension normally used for various types of towers are as follows:

A/DA & D/DD : 3m, 6m, 9m, 18m, 25m
B/DB & C/DC : 3m, 6m,9m

In addition to the above body extension, suitable leg/Chimney extensions shall also be provided in the hilly terrain, wherever required, to reduce the benching.

10.2.2400KV Double Circuit AC Transmission Lines

The salient features of the proposed transmission lines are given here under:

The primary consideration for design and estimation of transmission line is walk over survey conducted for the transmission lines by POWERGRID. Type of terrain, forest stretches, crossings etc. to be encountered by the transmission line has been taken into consideration while estimating the quantities.

10.2.2.1The Wind Zone

The weight of tower will vary in an ascending order from wind zone 1 to wind zone 6 as the transverse load on the tower considered owing to the wind pressure increases in the same pattern. The identification of wind zone is based on the wind zone map given in IS: 875 (part-I) 1987 and the past experience in the region.

The transmission lines fall under wind zone- 4 (47 m/s) as per IS: 875 and shall be designed accordingly.

10.2.2.2Design Criteria

The design parameters proposed to be adopted for the transmission line are generally based on the report of standardization committee of CEA and stipulations of relevant Indian Standards. Quad bundle conductors have been considered for the design of transmission lines as per requirements of the identified system.

10.2.2.3Line Configuration

The 400 kV Double circuit (D/C) lines shall have vertical configuration of conductors.

10.2.2.4Towers & Foundations

Self supporting latticed bolted steel towers, fabricated from structural steel angle section shall be used. Tower components and bolts & nuts shall be hot dip galvanized.

Normally, the following four types of double circuit tower shall be used in these lines.

i) DA type suspension towers for upto 2 degree angle of deviation.
ii) DB type tension towers for upto 15 degree angle of deviation.
iii) DC type tension towers for upto 30 degree angle of deviation.
iv) DD type tension towers for upto 60 degree angle of deviation and suitable for dead end condition. These may also be used for terminal locations.

The standard extension normally used for various types of towers are as follows:

DA & DD : 3m, 6m, 9m, 18m, 25m
DB & DC : 3m, 6m, 9m

In addition to the above, special towers, for major river crossing, power line crossing and the places where the terrain is particularly different, such as approach to the sub-station, forest stretches etc. shall also be used. All towers shall be designed in accordance with latest edition of IS-802 and considering necessary improvements and reinforcements evolved as per suggestions/recommendations of CEA's expert committee based on the experience of previous tower failures in the country.

Structural steel sections used in towers shall be of High Tensile (HT) steel & Mild Steel (MS) of requisite quality as per IS-2062 or equivalent International Standards.

10.2.2.4.1 Foundations

Tower Foundations are generally pad & chimney type and typically classified as Dry, Wet, Partially submerged(PS), Fully Submerged (FS), Wet Black Cotton (WBC), Sandy, Dry Fissured Rock (DFR), Wet Fissured Rock (WFR), Submerged Fissured Rock (SFR), Hard Rock etc. depending upon type of soil encountered and designed accordingly based on relevant Indian standards and CBIP guidelines. For river crossing locations & soils having poor bearing capacity, wherever required, pile/well type foundations are used.

Typesof soil encountered by the transmission lines are generally mixed dry, wet, wet black cotton type in the plain terrain and dry fissured rock, wet fissured rock & hard rock in the hilly terrain. The requirements of the foundations are considered in accordance with the type of soil.

10.2.2.4.2Revetment and Benching

For hilly and undulating stretch, wherever the line is passing through, revetment and benching shall be provided as per site conditions.

10.2.2.5Conductors

Conventional ACSR type conductors have been considered based on system requirements as these are most common type of conductors with proven technology having low cost & easy availability.
For 400 KV Quad lines, Quad 'Moose' ACSR conductors (54/3.53 Aluminium and 7/3.53 mm steel) of overall diameter 31.77 mm shall be used per phase. The sub-conductor spacing will be 457 mm.

10.2.2.6Earthwire/OPGW

One 7/3.66 mm galvanised steel earth wire shall be used on the line so that it can withstand two successive lightning stroke of 150 kA. Shielding angles of 20 deg is considered for transmission line.

In the present scheme 1 No OPGW is proposed to be installed on all the lines to meet the requirements of Power System Communication. Optical Fibre technology provides an efficient telecommunication network to support their various applications requiring higher speed & bandwidth.

10.2.2.7 Grounding

The tower footing resistance shall be kept below 10 ohms. Pipe type or counterpoise earthing shall be used to bring the tower footing resistance down to acceptable level.

10.2.2.8Insulator and Hardware Fittings

High strength composite long rod insulators shall be used. The following types of insulator strings along with hardware fittings shall be used :

400 KV TRANSMISSION LINE WITH QUAD ACSR MOOSE CONDUCTOR WITHCOMPOSITE LONG ROD INSULATOR

Sl. No.	Type of string	Size of Comp. insulators (Core dia x nominal len)(mm)	Minimum creepage distance of each disc (mm)	No. of individual units per string (nos)	Electro-mechnical strength of insulator disc(KN)	Mechanical strength of insulator string along with hardware fittings (KN)
a)	Double 'I' suspension	20x3335	13020	1x1	120	2 x 120
b)	Single suspension Pilot	20x3335	13020	1x1	120	120
c)	Quadruple Tension	24x3910	13020	4x1	160	4 x 160

Items 1(a) and (1c) are mostly used for suspension and tension towers respectively. Item (b) is used in transposition towers. Item 1(b) also shall be used in heavy angle towers DC & DD types) to restrict jumper movement. Suitable hardware fittings shall be used for attachment of the insulators with the tower at one end and also for supporting the conductors at the other end. Corona control rings or grading rings will be used for improving corona and RIV performance as well as to improve the voltage

distribution across the insulators discs. The voltage across any disc shall not exceed 9 % in case of suspension type and 10 % in case of tension type of the line to earth voltage. This will reduce aging and also minimize radio interference.

10.2.2.9Line Accessories

i) **Mid span compression joint for conductor/ earthwire**

Mid span compression joint suitable for conductor/ earthwire shall be used for joining two lengths of conductor / earthwire. The minimum slipping strength of the joint after compression shall not be less than 95 % of the UTS of conductor / earthwire.

ii) **Repair sleeve for conductor**

Repair sleeve shall be used only for repairing not more than two strands broken in the outer layer of conductor. It shall be of compression type in two parts with provision of seat sliding of keeper piece.

iii) **Flexible copper bond for earthwire**

Flexible copper bonds shall be used for good electrical continuity between the earthwire and the tower. One bond per suspension tower & two bonds (two for each earthwire) per tension tower shall be used.

iv) **Vibration damper for earthwire**

Stockbridge vibration dampers shall be used to reduce the maximum dynamic strain caused by aeolian vibrations to a value of 150 micro-strain.

v) **Spacers/SpacerDamper**

Quad bundle spacers shall be used for the Quad bundle lines to reduce vibrations and maintain sub-conductor spacing under all working conditions.

vii) **Suspension/Tension clamps for earthwire**

Suitable suspension/tension clamps shall be used for attachment of earthwire at suspension/tension towers.

vii) **T-connectors**

Compression type T-connectors shall be used for conductor jumpering at transposition towers wherever required.

10.2.2.10River Crossings

Special towers shall be used for major river crossings where the span is more than 600 mtrs with anchor towers on either end of river crossing span

10.2.2.11 Power line, Railway line, Road and P&T line crossing

The transmission lines shall be crossing power lines, railway lines roads and P&T lines for which suitable extensions of towers shall be used.
The standard extension normally used for various types of towers are as follows:

A/DA & D/DD : 3m, 6m, 9m, 18m, 25m
B/DB & C/DC : 3m, 6m,9m

In addition to the above body extension, suitable leg/Chimney extensions shall also be provided in the hilly terrain, wherever required, to reduce the benching.

11.0 MANAGEMENT ARRANGEMENTS

11.1 Organisational set up

In POWERGRID the 'Organizational Concept' has been given due importance and the basic structure of organization has been made with a view to achieve the following objectives:

i) To group related functions together to have clearly defined 'Roles' for the relevant 'functional heads'.
ii) To have well defined 'Responsibility & Authority' centers in the structure.
iii) To have well defined 'communication channels' and optimum 'span of control' in the organization.
iv) To have optimum manpower.
v) To have decentralization of activities as far as possible.

At the first level in the organization, Corporate Centre will be planning, monitoring and controlling the objectives and activities of the organization. At the second level, the Regional HQs will be playing the role of controlling the activities in the regions and will report to Corporate Centre. In POWERGRID, 9 regions have been identified as NR-I, NR-II, SR-I, SR-II, WR-I, WR-II, ER-I, ER-II & NER, and these regions will be headed by GM/ED. At the third level in the structure, the Substation Groups will be controlling the activities of the respective Substation and associated lines under that Group and will report to the Regional HQs. The Groups will consist of basic working units such as substation Construction/maintenance, line construction/maintenance. The Groups will have both service and technical functions, to cater to the basic functional requirements.

11.1.1 Project Management

The project of transmission system will be planned, implemented, monitored and controlled through Integrated Project Management and Control System (IPMCS).

IPMCS uses PERT/CPM technique as the basic management tool. For effective project planning and review, three tier level of planning and review have been adopted.

Level-I :

Planning is done by the Corporate Monitoring Group, a central planning cell, which is in the form of an overall project schedule called the Master Network, for the project which forms the basis for all subsequent planning and monitoring of the activities. This covers broadly all the packages of project and indicates activities of engineering, contracts, manufacturing, erection and commissioning. The Master Network is prepared using computerized techniques which subsequently helps in comparing the actual progress of the project with the scheduled progress. This gives indication of the likely critical areas and helps in preventing the same, thereby resulting in smoother implementation. The Master Network also acts as a source for the planning to be done at Level - II & Level - III.

Level-II :

Planning is done package-wise and is worked out and finalised with the respective contractor/vendor during the pre-award stage. Level II networks are made within the milestones identified in the project Master Network (L-I).

Level-III :

Plans deal with elaborate schedules and weekly/monthly rolling plans which are prepared for activities of engineering, supply (as the case may be) & field activities. These form the basis of monitoring by the various functions.

The system envisages monthly review of the level II programmes with contractors and at field on a weekly basis. A site monthly progress report is sent to the head office having four sections, i.e.

i) Project completion trend
ii) Salient achievements for the month
iii) Programme for next month
iv) Areas needing attention of top management

11.1.2 Project Implementation Review

As on 31st July 2016, POWERGRID operates about 1,31,728ckt. kms. of transmission lines and 213 Substations with a transformation capacity of about 2,65,663 MVA. POWERGRID has a team of dedicated experts in the field of substation and Transmission Line Engg. equipped with state-of-the-art technology, software capabilities and computer aided facilities for Planning, Design, Operation and Maintenance of transmission system. It has a well-established system of continuous feedback from the field and upgrades the system accordingly.

Based on the feedback as well as in pursuit to economize the cost and implementation period, its experts are vigorously pursuing the standardization of Transmission Line designs, substation/switchyard layouts, schemes, technical parameters of equipment, etc.

POWERGRID has developed a project monitoring system matching with the organization structure, complexity / intricacies involved in the project implementation and Management information system. The system calls for increasing details of planning in all facets of functioning such as engineering, contracts, site and corresponding levels of monitoring and control; for generating a management summary report to the top management. This management summary report highlights the project completion trends, actions being taken/to be taken for the attention of the top management on exceptional basis of critical areas.

Further, the monitoring system envisages a regular total project review called project review meeting (PRM). This review meeting is headed by the Regional in-charge with representation from all functions viz. Contracts, Engineering, Field, Personnel, Finance, Corporate Monitoring Group, etc. The participants discuss project critical, project interface problems and project completion trends, etc.

From the discussions held during the PRM emanates a status report and also an exception report put up to the Chief Executive and Directors which highlights extremely critical areas needing immediate attention and assistance required. Once in three

months the PRM is held at Corporate Centre. These discussions help in identifying the critical areas and seeking decisions for speedy project implementation.

12.0 MEANS OF FINANCE AND PROJECT BUDGET

12.1 Project Cost Estimate

The estimated cost of the project based on **April 2016 price level** is as follows:

(Rs. in crores)

		Total cost
1.	Transmission System	1355.14
2.	Interest during Construction	74.24
	TOTAL	**1429.38**

The abstract cost estimate for Transmission Line and Substation portion are given at **ANNEXURE - 1.0**. The break-up of the cost estimate for civil works, Transmission lines and substations are given at **ANNEXUREs - 1.1, 1.2**and **1.3**respectively.

The detailed cost estimates for the civil works for Transmission Lines and Substations have been given at **ANNEXUREs - 1.1.1, 1.1.2** and **1.1.3**.

12.2 Basis of Cost Estimate

The estimated cost of the project as on **April 2016 price level** works out to **Rs. 1429.38crores** including an IDC of **Rs. 74.24crores.** Unit ratesfor 765kV & 400kV transmission lines and 765/400/220kV Substation Works &has been taken from ***Schedule of Rates*** (*which has been prepared based on the average of unit rates of latest LOAs/Bids and/or from Raw material prices*) for **April 2016**Price level.

The cost estimate is exclusive of Excise Duty but inclusive of CST @ 2% for all equipment - (as funding for supply of equipment is proposed to be done through ADB Loan).Also, F&I @ 4% & 6% has been considered in the Estimate for plain & hilly terrains respectively.

12.3 Project Overheads

The following overheads have been charged on to the cost of the transmission system as a percentage of the equipment cost:

	For Tr. Lines & Substations
i) Incidental Expenditure During Construction	5.00% (Excl.Afforestation cost)
ii) Contingencies	3.00%

12.4 Funding arrangement

12.4.1 Phased Fund Requirement

The anticipated year wise fund requirement for the project including interest during construction is given below:

YEAR	TOTAL (Rs in Crores)
2016 – 2017	276.24
2017 – 2018	570.15
2018 – 2019	488.13
2019 – 2020	94.86
Total	**1429.38**

12.4.2 Mode of Financing

The project is proposed to be funded through POWERGRID's Internal Resources (IR) and through ADB Loan &domestic borrowings/bonds/External Commercial borrowings. The equity component **(30%)** is proposed to be met through the Internal Resources (IR) and the loan component **(70%)** through ADB Loan &domestic borrowings/bonds/External Commercial borrowings.

12.5 Interest during Construction

Based on the assumption that the project will be financed from loan and equity in the ratio of **70:30** and the equity component being released simultaneously along with the loan component, the interest during construction works out to **Rs.74.24crores**. The interest rate for the loan amount has been considered @ **10.5%** for domestic loan. The details of calculation are furnished in **ANNEXURE - 4.0**.

The interest during construction would however be based on the actual financial structure of the project and applicable terms of interest on loan(s), etc.

12.6 Monthly Fixed Charges

Considering rate of interest on, ADB Loan @7.0% p.a. & Domestic Loan @ 10.5% p.a., return on equity @ 15.5%, depreciation @ 0% for land, @ 3.34% for building, @ 5.28% for transmission lines & substations and @ 6.33% for PLCC, O&M charges @ Rs.1.21Lakhs per km for D/C line (with four or more conductors)and @ Rs.96.20 Lakhs per 765 KV bay, @ Rs.68.71 Lakhs per 400 KV bay , @ Rs.48.10 Lakhs per 220 KV bay for Substation, Debt:Equity ratio 70:30, interest on working capital @ 12.80%, the tentative monthly fixed charges work out as **Rs.2078.42Lakhs** on Base Cost and**Rs. 2056.39Lakhs** on Projected Completed Cost(**ANNEXURE - 3.0**).

12.7 Completion Cost

The completion cost of the project is expected to be **Rs.1412.34crores**including IDCof **Rs.73.64crores**. The above cost has been worked out based on the average movement of WPI (80% weightage) and CPI (20% weightage) for the preceding 12 month period as per guide lines dated 06.08.1997. Details of calculation are enclosed at **ANNEXURE - 5.0**. The abstract cost estimate for completed cost is enclosed at

ANNEXURE - 1.0a. The phased fund requirement and calculation for IDC for completed cost are enclosed at **ANNEXURES - 2.0a** and **5.0a** respectively.

12.8 IRR Calculation

The Project IRR, Equity IRR and Economic IRR on Projected Completed Cost have been calculated for the project and the same is tabulated below:-

	For Completed Cost
Project IRR	10.56%
Equity IRR	18.84%
Economic IRR	11.09%

The details of calculation are furnished in **ANNEXURE - 7.0**.

As the project is proposed to be funded through ADB loan (@7.0%) and domestic sources, the Weighted Average Cost of Capital (WACC) on Projected Completed Cost works out to **10.00%.** The Project IRR **10.56 %**being higher than the WACC, establishes the viability of the project.

13.0 TIME FRAME

Transmission system for solar power parks at Bhadla, Rajasthanproject is scheduled to be commissioned within **30months** from the date of investment approval. (Implementation schedule is given at **EXHIBIT-3.0**).

14.0 RISK ANALYSIS

Revenue Risk

The capital cost of the transmission system comprises of i) an equity component and ii) a loan component. This is recovered through the annual transmission charges consisting of return required for the equity, an interest for the loan component together with the depreciation charges, the O & M charges and interest on working capital from the beneficiaries as per Notification in proportion to the benefits derived by them. These are recovered in monthly fixed charges from the beneficiaries. In addition to annual charges Income Tax, FERV and incentives, etc. as per notification would also be payable.

The Bulk Power Transmission Agreement (BPTA) which covers the payments for transmission charges for all the existing projects as well as those that may be included in future after approval by CEA already exists.

Regulatory Risk

BPTAs have the provision that the transmission tariff for new / existing transmission assets commissioned as well as the additional tariff payable due to additional capitalization from year0 to year, etc. shall be computed by POWERGRID based on norms / methodology followed in the GOI notification dated 16.12.97 in accordance with

the norms to be specified by the Central Electricity Regulatory Commission (CERC) as amended from time to time.

Environmental Risk

Transmission line projects are environmentally friendly and do not involve any disposal of solid effluents and hazardous substance in land, air and water. Moreover, in forest areas trees are felled below each conductor to facilitate stringing. On completion of construction only one such strip is maintained for O&M purpose. Therefore the actual loss of forest is restricted to some selected area only. However, as per the requirement of Forest (Conservation) Act, 1980 approval of Ministry of Environment & Forests, Govt of India for diversion of forest land shall be taken before construction of line and compensatory afforestation shall be done on double the area of degraded forest land to compensate the loss of vegetation, due to diversion of forest land if there is any after detailed survey.

Legal / Contractual Risks

The procurement practices of POWERGRID are in line with best practices followed internationally. Further, requisite due diligence is carried out prior to award of contracts which inter-alia includes assessment of capacity and capability of bidders to perform the contract, thereby mitigating contractual risks. In the unlikely event of such risk, adequate provisions such as Dispute Resolution, Risk & Cost procurement, etc are in built in the Bidding/Contract Document to deal with the same.

The legal framework governing the contracts in India is well established and finally in place. As such, there is minimal probability of any legal risk.

Project Management Risks

POWERGRID being the Central Transmission Utility of the country holds vast experience in the area of construction of 400kV and 765 KV long Inter-state Transmission lines and associated substations. It has commissioned several 400 KV and 765 KV Transmission Lines and Substation projects successfully which are under operation.

POWERGRID has developed and implemented systems & procedures aligned with Integrated Management System. The Critical projects are monitored even more closely. As such, with a dedicated and experienced pool of manpower and application of IMS in implementation of its projects, POWERGRID makes every endeavor to achieve the target making probability of impact of Project Management Risks to minimal.

15.0 PASTRECORD OF SUCCESSFUL PROJECT IMPLEMENTATION

The above transmission system has been evolved, carrying out detailed studies by using latest available power system analysis software (PSS/E), and the proposed system is considefrred to be adequate to transfer power to the respective beneficiaries with reliability and security. Regarding achieving its objective in the stipulated time frame, it is to mention that POWERGRID has in-house expertise in all specialized areas of transmission with systemsupto 800KV AC, ±500KV HVDC, Gas Insulated Sub-Stations, Static VAR Compensation, Series Capacitors, FACTS (Flexible AC Transmission System), Controlled Shunt reactors etc.

POWERGRID, since its formation has commissioned many large size and difficult transmission projects. Majority of such projects have been completed on or ahead of schedule.

As on 31st July 2016, POWERGRID operates about 1,31,728ckt. kms. of transmission lines and 213 Substations with a transformation capacity of about 2,65,663 MVA.POWERGRID has maintained the transmission system's availability at over **99%**consistently.

In recognition of POWERGRID's excellence in areas of its operations as above, POWERGRID has been rated as "Excellent" many times since 1993-94 in achieving the MoU targets with Ministry of Power. POWERGRID is also a recipient of Prime Minister's MoU Award consecutively for many years for being amongst top ten PSUs.

16.0 SUSTAINABILITY

16.1 System Design Philosophy

The power evacuation system is designed in the most optimum manner such that losses in the system are minimal. The system and equipment parameters are chosen according to the present trends in technology, the conductors available are such that the losses in them due to internal resistance as well as due to external effects such as corona and RIV are bare minimum. The busbar materials and the clamps and connectors are chosen after meeting the stringent international requirements so that there is least loss of energy in them. The transformers, reactors and other switchgear are also similarly selected and evaluated before award itself for most efficient operation from thermal loss and efficiency.

16.2 System Operation Philosophy

The power flow in a particular line varies due to demand variation, failure of equipment, line faults, etc. For the system to be stable and to use optimised resources, it is very important to record the power flow at each and every time. This necessitates the monitoring of operation of the system on a three shift basis.

16.3 System Maintenance Philosophy

The maintenance management system in vogue in POWERGRID aims at keeping the system under stable conditions while ensuring minimum maintenance cost and safety of equipment and personnel. The maintenance management schedule detailed work specification covering all maintenance jobs permit to work system, long term maintenance planning meeting for about 30 minutes for finalizing maintenance schedule for next 24 hours and resolution of interface problems between departments. These meetings are supplemented by meeting of HODs for one hour on alternate days to accelerate the decision making process and to lay down the priorities and guidelines for maintenance work during next 72 hours.

16.3.1 Spare parts Management System

The primary objective of spare part management system will be to ensure timely availability of proper spare parts for efficient maintenance of the substations and lines without excessive build-up on non-moving and slow moving inventory. The spare parts management system for this project will cover the following areas:

a) Proper codification of all spares and consumables
b) Spare parts indenting and procurement policy
c) Ordering of critical mandatory and recommended spares
d) Judicious fixation of inventory levels and ordering levels for spare parts basedon our experience in other projects.
e) Development of more than one source wherever practicable.

16.3.2 Training of personnel

The expertise available with the country is adequate to cover maintenance of Transmission Line and sub station EHV equipments, etc. Also, available technical expertise within POWERGRID is adequate to cover operation and maintenance requirements of equipments. Hence, training in these areas can be arranged by POWERGRID's training facility with the help of training officers, equipment suppliers and consultants, site commissioning personnel as well as POWERGRID's own specialists.

16.3.3 O&M Manuals

a) Adequate O & M manuals will be distributed to all concerned as per the policy of the company.
b) O & M manuals will be available to all concerned prior to commissioning of substations and transmission lines to avoid problems in preparation of commissioning documents as well as proper installation & commissioning of equipment.

16.3.4 Special Maintenance tools and Plants

A set of Special maintenance tools and plants shall be provided for installation, commissioning and proper maintenance of the elements of the transmission system. Suitable provision is kept for the same in the cost estimate @ 1% of the total EquipmentCost .

DETAILED PROJECT REPORT FOR GREEN ENERGY CORRIDORS–ISTS-PART-D

1.0 CONTEXT / BACKGROUND

About 33 GW renewable capacity addition has been envisaged in 12th plan in the eight (8) Renewable rich states viz. Tamil Nadu, Andhra Pradesh, Karnataka, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh and J&K.In order to facilitate integration of such large scale renewable capacity in 12th plan, a comprehensive transmission plan comprising intra state and inter-state transmission system strengthening was identified as a part of "*Green Energy Corridors*". IntraState strengthening (STU) included transmission system within the host state for absorption of power through additional transmission system including transmission lines as well as sub-stations.

In view of the quantum of envisaged Renewable capacity addition, associated challenges like volatility, as well as need to enlarge balancing area through strong grid interconnections, there is a need to strengthen Inter-state transmission system. Considering this, High capacity transmission corridor, as part of Inter-state transmission system, connecting major renewable pockets is being proposed right from the Bhuj Pooling station in Gujarat (WR) to Moga in Punjab (NR) via Chittorgarh/Ajmer/Bikaner in Rajasthan (NR). In addition, establishment of Tirunelveli Substation and its interconnection with already planned high capacity transmission corridors associated with other IPP Projects in SR is also proposed as part of proposed ISTS strengthening of Green Energy Corridors. Above identified ISTS scheme is to be implemented simultaneously. However from funding point of view, scheme is divided in various parts. Part-A of above scheme covers establishment of 765/400kV substation each at Chittorgarh& Ajmer in Rajasthan & 400/230kV substation at Tirunelvelli in Tamil Nadu whereas Part-B cover establishment of 765/400kV Banaskantha S/s interconnected to Chittorgarh& Ajmer through High capacity transmission corridors. Part-C covers establishment of 765/400kV Bhuj Pool S/s interconnected to Banaskantha through High capacity transmission corridors. For further dispersal of power from Ajmer onwards, interconnection are also planned to Moga via Bikaner as part of Green Energy Corridors-ISTS Part-Dscheme.

The present DPR on Green Energy Corridors-ISTS covers Part-Dscheme.

The above inter-state transmission scheme was discussed and agreed in 32nd SCM of NR held on 31.08.13as well as in 36th meeting of the Standing Committee of Power System Planning of Northern Region held on 13th July, 2015. The scheme has also been agreed by the constituents in the 29th meeting of northern regional power committee meeting held on 13.09.13.

2.0 DESCRIPTION OF TRANSMISSION SYSTEM

In order to facilitate power transfer from renewable generation projects, following system is proposed:

1) Ajmer(New) – Bikaner(New) 765 kV D/c Line
2) Bikaner(New) – Moga(PG) 765 kV D/c line
3) LILO of one circuit of 400kV Bhadla (RVPN) –Bikaner (RVPN) D/C line at Bikaner (New)*
4) Establishment of 765/400 kV, 2x1500 MVA S/s at Bikaner (New) S/s

The schematic of the proposed Transmission system is shown at **Exhibit-1.0**.

2.1 PROJECT HIGHLIGHTS

a)	Project	:	Green Energy Corridors – ISTS-Part-D
b)	Location of the Project	:	Northern Region
c)	Project Cost	:	**Rs.3938.34Crores**at **February 2015**Price Level (including IDC of **Rs.234.10Crores**)
d)	Monthly Fixed Charges	:	**Rs. 5326.58Lakhs** on Base Cost **Rs. 5655.73Lakhs** on Projected Completed cost
e)	Commissioning schedule	:	Transmission System is proposed to be implemented within **36 months** from the date of Investment Approval.

3.0 JUSTIFICATION

As mentioned earlier, it is envisaged that about 33,000 MW renewable generation capacity shall be added during 12th plan period in eight (8) RE resource rich states viz. Rajasthan (5700 MW), Gujarat (4700 MW), Tamil Nadu (7400 MW), Maharashtra (4100 MW), Karnataka (4300 MW), AP (4800 MW), HP (1300 MW) and J&K (500 MW) through Wind/Solar & Small Hydro generation.

Considering above quantum of envisaged Renewable capacity, it is expected that some of the Renewable Energy (RE) Resource rich states including Rajasthan shall have more RE capacity than the capacity required for fulfilling their Renewable Purchase Obligations (RPO). Further, such RE rich host state may not absorb full RE energy locally particularly during the other than peak hour conditions when renewable generation is at peak. Intermittency/ variability,inherent characteristics of renewable, also necessitates requirement of strong grid interconnections for grid stability.

In addition, the IEGC stipulates, renewable energy plants to have “MUST RUN” status and not to be subjected to “merit order dispatch” principles. Considering above, there is a need to strengthen Inter-state transmission which shall facilitate transfer of power outside the RE resource rich states with reliability and security as well as enlargement of balancing area to address volatility issues of renewables.

In Gujarat about 4700 MW renewable generation capacity is envisaged through Wind & Solar. Out of above, about 1100 MW Wind and 200 MW Solar generation

capacity addition is envisaged in Kutch areaalone.In Rajasthan about 5700 MW renewable generation capacity is envisaged through Wind & Solar. Out of above, in southern part of Rajasthan (Banswara/Pratapgarh) total about 800 MW Wind generation is envisaged near Chittorgarh. Further, about 1000 MW Wind/Solar generation potential is indicated around Bikaner in western Rajasthan.

Considering immense potential of renewable resources in Kutch/Banaskantha/Chittorgarh/Bikaner area, high capacity 765/400kV substation at above location is proposed.

For dispersal of power, High capacity transmission corridor, as part of Inter-state transmission system, connecting major renewable pockets is being proposed right from the Bhuj Pooling station in Gujarat (WR) to Moga in Punjab (NR) via Chittorgarh/Ajmer/Bikaner in Rajasthan (NR). Identified transmission system shall also be integrated with the grid so as to ensure optimal utilization of transmission system.

For onward dispersal of power beyond Ajmer/Bikaner, 765kV High capacity transmission corridor is proposed towards Moga in Punjab, a major load centre in NR, as part of Green Energy Corridors-Part-D scheme. Moga is well connected to major hydro complexes in J&K/HP(3400 MW) and Uttarakhand (1400MW). In addition, more such hydro capacity (3300 MW) including pumped storage plants is under construction in above complexes, which shall help in addressing intermittency aspect of renewables. Moga is also inter-connected with High capacity HVDC system at Bhiwadi which shall provide flexibility in power transfer requirement to address variability of renewable generation.In this manner, this shall facilitate integration of Renewable with hydro complex, enabling supply side balancing through flexible Hydro resources as well as address intermittency issues of renewables.

4.0 SCOPE OF WORK

The present Detailed Project Report covers the following scope of work:

Transmission Lines

1) Ajmer(New) – Bikaner(New) 765 kV D/c –**272 km**
2) Bikaner(New) – Moga(PG) 765 kV D/c – **350 km**
3) LILO of one circuit of 400kV Bhadla (RVPN) –Bikaner (RVPN) D/C line at Bikaner (New)– 60**km**

Substation

a) 765/400kV Bikaner Substation (New)

765kV

- Line Bays : 4 nos.
- Transformer bays : 2 nos.
- 1500MVA, 765/400kV transformer : 2 nos.
- 330 MVAR Switchable Line reactor bays : 4 nos.
- 330 MVAR Switchable Line reactors : 4 nos.

- Bus reactor bay : 1 no.
- 330 MVAR Bus reactor : 1 no.

400kV

- Transformer bays : 2 nos.
- Line Bays : 2 nos.
- Bus reactor bay : 1 no.
- 125MVAR Bus reactor : 1 no.

b) 765/400kV Ajmer Substation Extn.

765kV

- Line Bays : 2 nos.
- 240 MVAR Switchable Line reactor bays : 2 nos.
- 240 MVAR Switchable Line reactors : 2 nos.

c) 765/400kV Moga (PG) Substation Extn.

765kV

- Line Bays : 2 nos.
- 330 MVAR Switchable Line reactor bays : 2 nos.
- 330 MVAR Switchable Line reactors : 2 nos.

Reactive Compensation

- **Line Reactors**
-

Sl. no.	Transmission Line		
		From end (each ckt)	To end (each ckt)
1	Ajmer(New) – Bikaner(New) 765 kV D/c line	1x240 (**switchable**) (each ckt.)	1x330 (**switchable**) (each ckt.)
2	Bikaner(New) – Moga(PG) 765 kV D/c line	1x330 (**switchable**) (each ckt.)	1x330 (**switchable**) (each ckt.)

- **Bus Reactors**

Sl. No.	Bus	Reactor (MVAR)
1.	765/400 kV Bikaner(New)	1X330 MVAr (765kV) 1x125 MVAr (400kV)

5.0 PROJECT APPROVAL BY CONSTITUENTS / SHARING OF TRANSMISISION CHARGES

5.1 The above inter-state transmission scheme was discussed and agreed in 32nd SCM of NR held on 31.08.13. The scheme has also been agreed by the constituents in the 29th meeting of northern regional power committee meeting held on 13.09.13.Copies of the MINUTES of Meetings are enclosed at **ANNEXURE – 8.0**.

5.2 Subsequently, during 36th meeting of the Standing Committee of Power System Planning in Northern Region held on 13th July, 2015, as per the request of Rajasthan RajyaVidyutPrasaran Nigam Ltd. (RVPN), it was agreed to establish substation near Bikaner (in place of earlier proposed at Suratgarh) due to Solar generation potential near Bikaner. Further, due to space constraint at Bikaner substation of RVPN, in place of earlier proposed Bikaner (New) – Bikaner (RVPN) 400kV D/C (Quad) line, LILO of one circuit of 400kV Bhadla (RVPN) – Bikaner (RVPN) D/C line at Bikaner (New) substation was proposed. (Copy of minutes enclosed at**ANNEXURE – 8.0(b)**..

5.3 The Prior approval of the Government of India under Section 68(1)of Electricity supply) Act, 2003 for the subject project has been received vide letter dated 21.09.15(Copy enclosed at **ANNEXURE – 9.0)**.

5.4 MOP vide its letter dated 03.03.2015 conveyed their approval for implementation of above Inter-state Transmission scheme under Green Energy Corridors by POWERGRID, under compressed time schedule through regulated tariff mechanism route (Copy enclosed as **ANNEXURE – 8.0(a)).**

5.5 SHARING OF TRANSMISSION CHARGES

The transmission charges for this project shall be shared by the beneficiaries in line with the sharing regulations notified by CERC and as per the applicable point of connection (PoC) charges determined by the implementing agency.

6.0 PROJECT STRATEGY

POWERGRID had undertaken and evolved the various elements of this transmission scheme keeping in view the envisaged RE generation and to facilitate transfer of the RE power to load centresof Northern Region.

7.0 LEGAL FRAMEWORK

It is proposed to execute the above entire transmission scheme as per provisions contained in the Indian Electricity Act, 2003 and the rules made there-under and the Electricity (Supply) Act, 1910 and 1948, in so far as these are applicable.

8.0 ENVIRONMENTAL IMPACT ASSESSMENT

8.1 ENVIRONMENTAL SCREENING AND SCOPING OF TRANSMISSION LINES

As per the policy and procedures laid down in ESPP, preliminary route selection is done based on environmental screening and scoping procedure with the help of secondary/published data/documents such as Forest Atlas and the Survey of India maps using "bee" line method, followed by field verification through walk over survey. All possible steps are taken to avoid the route alignment through forests. In cases where it becomes unavoidable due to the geography of terrain, the alignment is made in such a way that the route through the forests is the minimum. The said process has been followed in the instant project to find out most optimum route .

Since the most important and major environmental issue related to transmission line is clearing of vegetation in ecologically sensitive areas like forest, all possible measures are adopted to avoid/minimize involvement of forest with careful route selection as described above. As per preliminary assessment based on environmental screening and scooping procedure the forest involvement in different lines associated with this project is as follows:

Name of Transmission Line	**Line Length (Km.)**	**Forest Stretch (Km.)**	**Forest Area (Ha.)**
Ajmer(New) – Bikaner(New) 765 kV D/c	272	0.30	2.01
Bikaner(New) – Moga(PG) 765 kV D/c	350	2.28	15.30
LILO of one circuit of 400kV Bhadla (RVPN) –Bikaner (RVPN) D/C line at Bikaner (New)	60	0.22	1.0

8.2 Social Issues/R&R measures

As per the prevailing law, land below transmission line is not required to be acquired and only temporary rights for use are availed as per relevant provisions of Electricity Act, 2013 read with applicable provisions (section 10-16) of Indian Telegraph Act, 1885 which only provides for compensation towards all damages incurred while utilizing such right during construction. There is a well laid down procedure for assessment of damages and payment of compensation followed in all cases with built-in provision of grievance redressal (refer flow chart).

However, land for substation is required to be acquired for each substation area of which is dependent on the type and voltage level. These acquisitions of substation land normally do not involve any displacement due to requirement of small size of land and inherent flexibility in locating such substations which are not site specific.

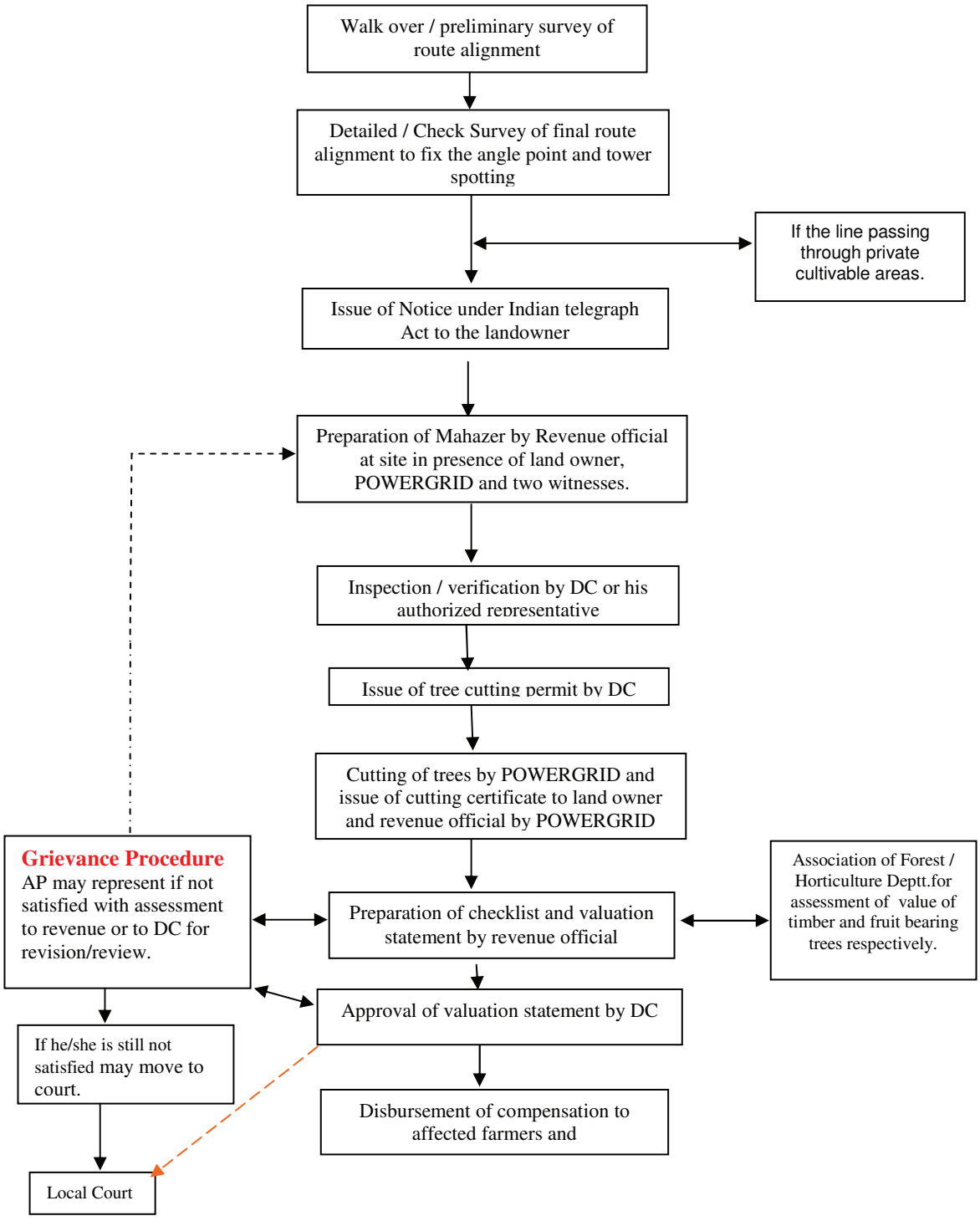
Even for substation land POWERGRID is following the practice of land management to minimize the land requirement to the barest minimum. POWERGRID tries to locate substation on government land as far as possible and only in the absence of government land private land is acquired. In order to minimize/mitigate impact of land acquisition and to provide adequate Rehabilitation/Resettlement measures for people affected/ displaced by our projects, POWERGRID's ESPP envisages a progressive policy on Resettlement & Rehabilitation It provides "people affected by our projects, means to improve or at least restore their former living standards, earning capacity and production levels" through a process in which they participate through their own social and cultural institutions including provision of mandatory social assessment by independent agency and comprehensive grievance redressal mechanism. However, with the introduction of new "Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation & Resettlement Act, 2013" w.e.f. 1.1.14 the Social Assessment and land acquisition including planning, execution and monitoring of R&R shall be in the scope of concerned State instead of Utility. The new act provides for total transparency and participation of peoples/owners in all decision making with robust provisions for compensation at market rate which in rural areas goes up to 4 times with mandatory R&R provisions.

In the instant project, one new 765/400 kV Substation at Bikaner in Rajasthan is proposed. Around 120 acres land is required for setting up of this 765 kV substation. The process for identification of land has already been initiated and all efforts are being made to identify suitable Govt. for proposed substation to avoid/minimize social impact. In case suitable government land is not found private owned land may be considered as last resort and in that case all provision of new land acquisition act including Social Impact Assessment (SIA) as described above shall be followed for acquisition of private land.

To meet the cost of R&R measures, a provision of Rs. 200 lakhs has been kept for the Substation.

For extension of 765/400 KV Moga S/S 52 acres of additional land is required and the estimated cost is Rs.100.83crores. This includescompensation amounting to Rs. 618.93 lakhs for three dwelling houses, one temple and one rice mill. The rate is taken from the decision given by Hon'ble District Judge Faridkot on dt.11.04.13 in the Land Acquisition of last 765kV sub-station construction at Moga (the calculation sheet is enclosed).

TREE / CROP COMPENSATION PROCESS



9.0 EQUIPMENT SELECTION PHILOSOPHY

POWERGRID has in-house developed infrastructure/software capabilities and computer aided facilities for Planning, Design, Operation and Maintenance of transmission system. Before planninga transmission system, various system studies like Load flow, Stability, Short-Circuit, etc. are undertaken keeping in view

the existing system, present and future load flow requirements and the most optimal transmission system either associated with generation projects or Grid strengthening projects, is evolved with bare minimum redundancy required. Further, Designstudies are undertaken forselection of major system and equipment parameters for transmission system upto 800KV level.

Green Energy Corridor-ISTS-Part-Dhas been designed in the most optimal manner based on the various studies as mentioned above. The system and equipment parameters are chosen keeping in view the present trend in technology. The conductors are selected such that the losses in them due to internal resistance as well as due to external effects are bare minimum. The bus bar materials and the clamps and connectors are chosen meeting thestringent international requirements so that there is least loss of energy in them. The reactors and other switchgears are also suitably selected and evaluated before award itself for most efficient operation from thermal and loss efficiency point of view. The energy thus saved is energy transmitted to the beneficiaries. This is a major step in energy conservation as the energy saved on account of losses is construed as energy generated.

10.0 TECHNOLOGY ISSUES

10.1 Salient features of 765/400 KV Substation Equipment and facilities

The design and specification of substation equipment are to be governed by the following factors:

10.1.1 Insulation Coordination

765/400 KV System would be designed to limit the Switching overvoltage to 2.5 pu and is expected to decay to 1.5 p.u. in 5 to 6 cycles. Consistent with these values and protective levels provided by lightning arrestors, the following insulation levels are proposed to be adopted for 765 KV & 420 KV systems:

		765 KV	420 KV
a	Impulse withstand voltage for - Transformer and reactors - for Other Equipment	 1950kVP 2100 kVP	 1300 kVP 1550 kVP
b	Switching surge withstand voltage	1550 kVP	1050 kVP
c	Minimum creepage distance	13020 mm	10500 mm
d	Max. faultcurrent	50kA	63 kA
e	Duration of fault	1 Sec	1 Sec
f	Corona extinction voltage	508 kV rms	320kV rms

To control the steady state, transient and dynamic overvoltage to specified levels, compensation equipment shall be provided.

10.1.2 Steady State Stability

The Steady State Stability is the ability of a system, to return/remain in the state of equilibrium when subjected to small or gradual changes of disturbances. The

steady state stability limit is the maximum power that can flow through some lines in the system when the entire or part of the system to which the stability limit refers is subjected to a small disturbance without loss of its stability.

The steady state stability is usually quantified by measuring the relative angular displacement (also called as swing curve) between the two buses (nodes) in a network when a small disturbance is applied somewhere into the system.

In an integrated power system consisting of large number of generator, load and line etc., a maximum relative angular separation of about 30 deg. between the two buses may be assumed to be acceptable (safest) limit for maintaining the steady state stability of the system. Angular separation for different alternatives have been studied and found to be in order.

10.1.3 Switching Schemes

The following switching schemes have been considered in various substations:

Substation	765kV side	400kV side
765/400kV Bikaner (New) S/S	One & half breaker	One & half breaker
765/400kV Ajmer (New) S/S	One & half breaker	-
765/400kV Moga S/S Extn	One & half breaker	-

10.1.4 765/400KV Substation equipments:

10.1.4.1 Power Transformer

Power transformers shall conform to IEC: 60076 / IS: 2026 in general. These transformers shall generally have OLTC with a range of $\pm$5.5%, the range and requirement of which shall be finalized based on the system requirement. The air core reactance shall be of the order of 20%. Tertiary windings shall be provided for large auto transformers, which shall be capable of being loaded to one third of transformer loading. Insulation level of tertiary winding shall not be less than maximum transferred surge from HV/MV winding to tertiary winding.

Power transformers are installed on foundations with independent oil soak pits of sufficient capacity to avoid possible spillage in case of a technical breakdown.

10.1.4.2 Circuit Breakers

Circuit breakers shall in general comply to IEC 62271-100 & IEC-60694 and shall be of SF6 Type. The rated break time shall not exceed 45ms for 765 kV and 40ms for 400kV circuit breakers. Circuit breakers shall be provided with single phase and three phase auto reclosing. The Circuit breakers controlling 765 kV and 400kV lines wherever required shall be provided with pre insertion closing resistor of about 450 ohms with 9msinsertion timefor 765 kV and 400 ohms with 8 ms insertion time for 400kV. The short line fault capacity shall be same as the rated capacity and this is proposed to be achieved without use of opening resistors.

10.1.4.3 Isolators

The isolators shall comply to IEC 62271-102 in general. Isolators shall be horizontal/ double/ vertical break/ pantograph type keeping in view the bus switching schemes proposed. Isolators shall be motor operated. Earth switches are provided at various locations to facilitate maintenance. Main blades and earth blades shall be interlocked and interlock shall be fail safe type. All earth switches shall be motor operated type.

10.1.4.4 Current Transformers

Current Transformers shall comply with IEC 60044-1 in general. All ratios shall be obtained by secondary taps. They shall have sixsecondaries for 400 KV and 765 kV. The burden and knee point voltage shall be in accordance with the requirements of the system including possible feeds for telemetry.

10.1.4.5 Capacitor Voltage Transformers

Voltage transformers shall comply with IEC 60044-2 in general. These shall have three secondary out of which two shall be used for protection and one for metering. Accuracy class for protection core shall be 3 P and for metering core shall be 0.2. The voltage transformers on lines shall be suitable for Carrier Coupling. The Capacitance of CVT shall be 4400/6600/8800 pF depending on PLCC requirements.

10.1.4.6 Surge Arresters

Station class current limiting, heavy duty gapless type Surge arresters conforming to IEC 60099-4 in general shall be provided. The rated voltage of Surge arrester and other characteristics are chosen in accordance with system requirements. Surge arresters shall be provided near line entrances, so as to achieve proper insulation coordination. These shall be fitted with pressure relief devices and diverting ports suitable for preventing shattering of insulator housing providing path for the flow of rated currents in the event of arrestors failure.
The switchgear shall be designed and specified to withstand operating conditions and duty requirements.

10.1.4.7 Shunt Reactors

Shunt Reactors, wherever provided, shall comply to IEC:289/IS:5553 in general. 765 KV Shunt reactors shall have linear characteristics upto 1.5 p.u. voltage. These should be ONAN Cooled. The neutral of line reactors shall be grounded through adequately rated neutral grounding reactors to facilitate single phase recloser against trapped charges. The neutral of 765 kV and 400kV class shunt reactors shall be insulated to 550 kV peak for lightning impulse and shall be protected by means of 145 KV Class surge arresters.

10.1.5 Substation Support facilities

Certain facilities required for operation & maintenance of substations as described below shall be provided in new substation and in existing substation they have already been provided and would be extended, wherever required.

10.1.5.1 AC & DC power supplies

For catering to the requirements of three phase & single phase AC supply and DC supply for various substation equipment the following arrangement is envisaged :

i) For LT Supply, at each new Substation, 1 no. 800 kVA 33/0.415 kV LT Transformer shall be connected with SEB supply and 1 no. with tertiary of 765/400/33kV transformer.

ii) 2 Nos. batteries of 220 V for control & protection and 2 Nos. 48 V batteries for PLCC would be provided at each new Substation. Each battery would have a boost and trickle charger.

iii) Suitable AC & DC distribution boards and associated LT Switchgear would be provided at new Substation.

10.1.5.2 Firefighting System

Firefighting system in general conforms to fire insurance regulations of India. The firefighting system is proposed with both AC motor & diesel engine driven pumps. Automatic heat actuated emulsifying system is proposed for transformers & reactors. In addition for alarm system based on heat/smoke detectors are proposed to be installed at sensitive points in a substation e.g. Cable Vault, Main Control Room, MCC Room etc. Further, adequate water hydrants and portable fire extinguishers shall be provided in the substations.

10.1.5.3 Oil evacuating, filtering, testing & filling apparatus

To monitor the quality of oil for satisfactory performance of transformers, shunt reactors and for periodical maintenance necessary oil evacuating, filtering, testing and filling apparatus would be provided at new substations. Oil tanks of adequate capacities for storage of pure and impure transformer oil would be provided.

10.1.5.4 Lighting & communication

Adequate normal & emergency AC & DC lighting shall be provided in the control room of the substation. The switchyards shall also be provided with adequate lighting. A telephone exchange of 24 lines shall be provided at new substations as means of effective communication between various buildings of the substation.

10.1.5.5 Telemetry and Communication

The communication network under the proposed project shall have the following aspects in order to meet the high reliability, availability and maintainability criteria:

i. The proposed FO based communication links/network shall be used for speech and data communication to SLDC and/or RLDC. The capacity planned has scope for future usages including for Special protection schemes.

ii. The Fiber Optic (FO) terminal equipment to be installed under the project shall be based upon SDH technology with STM-4 and STM-16 bit rate having support for both existing PDH & Ethernet based requirement. The interfaces

shall be selected meeting the present requirement for grid management etc. The SDH equipment shall be provided with redundancy to facilitate path protection and against failure of any interface card/power supply.

iii. Suitable interface cards shall be provided for data transmission and interfacing with data equipment such as PMU*. SPS, RTU and/or sub-station automation system.

**The PMUs provide real time phase angle measurement which is utilized for better Visualization & help to increase the situational awareness of Power System Operators to facilitate real-time congestion management, design of anadvanced warning system, validation of data, fine tuning of system models and design of an adaptive protection system*

10.1.5.6 Control Room

Substation control room would be provided to house substation for station level control along with its peripheral telemetry equipments and recording equipments, AC & DC distribution boards, DC batteries, etc. Air conditioning will be provided in the building as functional requirements.

10.1.6 <u>Protection & Control</u>

The substations shall be provided with control, relaying & monitoring functions along with substation automation system based on IEC61850 protocol using fiber optic network. The communication with adjacent connected substations shall be through PLCC & digital protection through OPGW.

The state of art protection system based on numerical technology has been provided to minimize the damage to equipment in the event of fault for Transformers, Reactors, Transmission lines and Bus bars. These protective relays are with self diagnostic feature and conforming to latest IEC 61850 for communication purposes for communicating the detailed list of events recoded by these relays in the event of fault or any abnormal conditions. Normally all these relays are equipped with in built fault recorder which can record the analogue as well as digital information for analysis of fault.

Auto Transformers & Reactors

Auto transformers shall be provided with the following protections:

i) Differential protection
ii) Restricted earth fault protection
iii) Back-up impedance protection

Besides, these transformers & reactors shall also be provided with Bucholz relay, protection against oil and winding temperatures & pressure relief device.

Transmission Lines

765kV lines shall have MAIN-I protection and shall also have numerical distance protection scheme carrier as three zone distance type with carrier aided inter-tripping feature. All lines shall also have MAIN-II protection which shall have

numerical distance protection scheme like Main-I but from different make that of MAIN-I.

They shall also be provided with two stages over voltage protection. Further, all lines shall be provided with single and three phase auto-reclosing facility to allow reclosing of circuit breakers in case of transient faults.

These lines shall also be provided with distance to fault locators to identify the location of fault on transmission lines.

Further, transmission lines shall be provided with OPGW which shall be used to meet the requirements of Power System Communication. Optical Fibre technology provides an efficient telecommunication network to support their various applications requiring higher speed & bandwidth. POWERGRID has taken up PMU based WAMS project for the entire Power System network. Installation of PMUs is also envisaged at all the sub-stations under the project. PMU based WAMS applications cannot be implemented without Fiber Optic based communication system.

OPGW installation is easier and cost effective during the construction of the line. The fibres are located within ground wire therefore the cost of earth wire towards supply and installation is reduced.

Bus bar Protection

The high speed bus bar differential protection which is essential to minimize the damage and maintain system stability at the time of bus bar faults shall be provided for 400 kV buses. Bus bar protection scheme shall be such that it operates selectively for each bus and incorporate necessary features required for ensuring security. The scheme shall have the provision for future expansion.

Local Breaker Back up Protection

This shall be provided for each of 765kV &400 kV breakers and will be connected to de-energize the affected stuck breaker from both sides.

Time synchronization equipment

Time synchronisation equipment complete in all respect including antenna, cable, processing equipment required to receive time signal through GPS or from National Physical Laboratory(NPL) through INSAT shall be provided.

Substation Automation System

For all the new substations, state of art Substation Automation System (SAS) conforming to IEC-61850 has been provided. The distributed architecture has been used for Substation Automation system where the controls are provided through bay control unit and bay control units are provided bay wise for voltage level 400kV and above. All bay control units as well as protection units are normally connected through an optical fiber high speed network. The control and monitoring of substation elements such as circuit breaker, disconnector, resetting of relays etc. are being done from Human Machine Interface(HMI) from the control room. SAS is equipped with the facility of remote operation. By providing remote HMI and suitable communication link, the substation can be controlled from a remote

location.The functions of control, annunciation, disturbance recording, event logging and measurement of electrical parameters shall be integrated in Substation Automation System. The Automation System shall be provided with the facility of communication and control for remote end operation.

10.1.7 PLCC

Power line carrier communication (PLCC) equipment complete for speech transmission, line protections, and data channels shall be provided on each 765kV &420 KV transmission line. The protections for transmission line and the line compensating equipment shall have hundred percent back up communication channels. The PLCC equipment shall in brief include the following:-

Coupling device, line traps, digital/analog carrier terminals, protection couplers, HF cables, trunk selectors, automatic exchange, and maintenance and testing instruments.

Coupling devices shall be suitable for 4400/6600/8800 pF for 420 kV CVTs for phase to phase coupling. The pass band of coupling devices shall have sufficient margin for adding communication channel in future if required. Necessary protection devices for the safety of personnel and low voltage part against power frequency voltages and transient over voltage shall also be provided. The line traps shall be broad band tuned suitable for blocking the complete range of carrier frequencies.

Line Trap shall have the necessary protective devices such as lightning arresters for the protection of tuning device and shall be equipped with corona rings. Decoupling network consisting of line traps and coupling capacitors may also be required at certain substation in case of extreme frequency congestion.

10.1.8 Control Concept

All the EHV breakers in substation/switching stations shall be controlled and synchronized from the switchyard control room / remote control center. Each breaker would have two sets of trip circuits which would be connected to separately fused DC supplies for greater reliability. All the isolators shall have control from remote/local whereas the earth switches shall have local control only.

10.2 Salient features of Transmission Lines

The salient features of the proposed transmission lines are given here under:

The primary consideration for design and estimation of transmission line is walk over survey, which is based upon topographical map/forest map of India. Type of terrain, forest stretches, crossings etc. to be encountered by the transmission line has been taken into consideration while estimating the quantities.

The weight of tower will vary in an ascending order from wind zone 1 to wind zone 6 as the transverse load on the tower considered owing to the wind pressure increases in the same pattern. The identification of wind zone is based on the wind zone map given in IS: 875 (part-I) 1987 and the past experience in the region.

10.2.1 765 KV Double Circuit AC Transmission Line

10.2.1.1 Design criteria

The design parameters are generally similar to design parameters of other 765 kV POWERGRID lines. Keeping in view the high power flow, the lines shall be designed for reliability class – 2 (150 years return period). The transmission lines fall under wind zone – 4 (47 m/sec) as per IS-875 and it shall be designed accordingly. The transmission lines would be designed with maximum conductor temperature of 85 Degree C. The details of equipment have been given in subsequent clauses.

10.2.1.2 Line Configuration

The 765 kV D/C lines shall have vertical configuration of conductor bundles.

10.2.1.3 Towers

Self-supporting latticed bolted steel towers, fabricated from structural steel angle section shall be used. Tower components and bolts & nuts shall be hot dip galvanized. Normally the following four types of tower shall be used in these lines.

i) 'DA' type suspension towers for 0 degree angle of deviation with suspension insulator strings.

ii) 'DB' type suspension towers upto 15 degree angle of deviation with suspension insulator strings for S/C line and tension towers upto 15 degree angle of deviation with tension insulator string for D/C line.

iiii) 'DC' type tension towers upto 30 degree angle of deviation with tension insulator strings.

iiv) 'DD' type tension towers upto 60 degree angle of deviation with tension insulator strings.

In addition to the above, special towers, for major river crossing, power line crossing and the places where the terrain is particularly different, such as approach to the sub-station, forest stretches etc. shall also be used. All towers shall be designed in accordance with latest edition of IS-802 and considering necessary improvements and reinforcements evolved as per suggestions/recommendations of CEA's expert committee based on the experience of previous tower failures in the country.

Structural steel sections used in towers shall be of High Tensile (HT) steel & Mild Steel (MS) of requisite quality as per IS-2062 or equivalent International Standards.

10.2.1.3.1 Foundations

Tower Foundations are generally pad & chimney type and typically classified as Dry, Wet, Partially submerged(PS), Fully Submerged (FS), Wet Black Cotton (WBC), Sandy, Dry Fissured Rock (DFR), Wet Fissured Rock (WFR), Submerged Fissured Rock (SFR), Hard Rock etc. depending upon type of soil encountered and designed accordingly based on relevant Indian standards and CBIP guidelines. For

river crossing locations & soils having poor bearing capacity, wherever required, pile/well type foundations are used.

Types of soil encountered by the transmission lines are generally mixed dry, wet, wet black cotton type in the plain terrain and dry fissured rock, wet fissured rock & hard rock in the hilly terrain. The requirements of the foundations are considered in accordance with the type of soil.

10.2.1.3.2 Revetment and Benching

Hilly and undulating stretch, wherever the line is passing through, revetment and benching shall be provided as per site conditions.

10.2.1.4 Conductors

Conventional ACSR type conductors have been considered based on system requirements as these are most common type of conductors with proven technology having low cost & easy availability.

Hexagonal bundle ACSR Zebra Conductor (54/3.18Aluminium and 7/3.18 mm steel)of overall diameter 28.62 mm shall be used per phase for 765 KV D/C line. The sub-conductor spacing will be 457 mm.

10.2.1.5 Earthwire/OPGW

One 7/3.66 mm galvanised steel earth wire shall be used on the line so that it can withstand two successive lightning stroke of 150 kA. Shielding angles of 20 deg is considered for transmission line.

In the present scheme 1 No OPGW is proposed to be installed on all the lines to meet the requirements of Power System Communication. Optical Fibre technology provides an efficient telecommunication network to support their various applications requiring higher speed & bandwidth.

10.2.1.6 Grounding

The tower footing resistance shall be kept below 10 ohms. Normally pipe type grounding shall be used. In case of rocky ground where the ground resistance is high, counterpoise earthing shall be used to bring the tower footing resistance down to acceptable level.

10.2.1.7 Insulator and Hardware Fittings

765 KV D/C TRANSMISSION LINE WITH HEXAGONAL ACSR ZEBRA CONDUCTOR

High strength composite long rod insulators shall be used. The following types of insulator strings along with hardware fittings shall be used :

Type of Strings	Size of Composite Insulator (Core dia x Nominal length) (mm)	Minimum Creepage distance (mm)	No. of individual Units per String (Nos.)	Electro mechanical Strength of Individual Unit (KN)	Ultimate Strength of Insulator String with Hardware assembly (KN)
a) Double I suspension (Tower DA)	24 x 2975	12400	2x2	160	320
b) Quad Tension (Tower DB, D C & D D)	24 x 2975	12400	4x2	210	840 (in line strength)
c) Single I suspension Pilot	24 x 2975	12400	1x2	160	160
d) Single tension	24 x 2975	12400	1x2	160	160

Suitable hardware fittings shall be used for attachment of the insulators with the tower at one end and also for supporting the conductors at the other end. Corona control rings or grading rings will be used for improving corona and RIV performance as well as to improve the voltage distribution across the insulators discs.

10.2.1.8 Line Accessories

i) Mid span compression joint for conductor/ earthwire

Compression joints suitable for conductor /earth wire shall be used for joining two lengths of conductor / earthwire. The minimum slipping strength of the joint after compression shall not be less than 95 % of the UTS of conductor / earthwire.

ii) Repair sleeve for conductor

Repair sleeve shall be used only for repairing not more than two strands broken in the outer layer of aluminium. It shall be of compression type in two parts with provision of seat of sliding of keeper piece.

iii) Flexible copper bond for earthwire.

Flexible copper bonds shall be used for good electrical continuity between the earthwire and the tower. Two bonds per suspension tower and four bonds per tension tower shall be used.

iv) Vibration dampers for earthwire

Stockbridge vibration dampers shall be used to reduce the maximum dynamic strain caused by aeolian vibrations to a value of 150 micro-strain.

v) Spacers/Spacer dampers

Hexagonal spacer dampers shall be used for line conductor bundle and hexagonal rigid spacers shall be used for jumpers. These shall maintain sub-conductor spacing of 457 mm under all working conditions and also help in restoration of the bundle after abnormal electrical conditions.

10.2.1.9 River Crossings

Special towers shall be used for major river crossings where the span is more than 600 mtrs with anchor towers on either end of river crossing span.

10.2.1.10 Power line, Railway line, Road and P&T line crossing

The transmission lines shall be crossing power lines, railway lines roads and P&T lines for which suitable extensions of towers shall be used. The standard extensions normally used for various types of towers are as follows:

DB& DC: 3m, 6m, 9m
DA & DD: 3m, 6m, 9m, 18m & 25m

In addition to the above body extension, suitable leg/Chimney extensions shall also be provided in the hilly terrain, wherever required, to reduce the benching.

10.2.2 400KV Double Circuit AC Transmission Lines

The salient features of the proposed transmission lines are given here under:

The primary consideration for design and estimation of transmission line is walk over survey conducted for the transmission lines by POWERGRID. Type of terrain, forest stretches, crossings etc. to be encountered by the transmission line has been taken into consideration while estimating the quantities.

10.2.2.1 The Wind Zone

The weight of tower will vary in an ascending order from wind zone 1 to wind zone 6 as the transverse load on the tower considered owing to the wind pressure increases in the same pattern. The identification of wind zone is based on the wind zone map given in IS: 875 (part-I) 1987 and the past experience in the region.

The transmission lines fall under wind zone- 4 (47 m/s) as per IS: 875 and shall be designed accordingly.

10.2.2.2 Design Criteria

The design parameters proposed to be adopted for the transmission line are generally based on the report of standardization committee of CEA and stipulations of relevant Indian Standards. Quad bundle conductors have been considered for the design of transmission lines as per requirements of the identified system.

10.2.2.3 Line Configuration

The 400 kV Double circuit (D/C) lines shall have vertical configuration of conductors.

10.2.2.4Towers & Foundations

Self supporting latticed bolted steel towers, fabricated from structural steel angle section shall be used. Tower components and bolts & nuts shall be hot dip galvanized.

Normally, the following four types of double circuit tower shall be used in these lines.

i) DA type suspension towers for upto 2 degree angle of deviation.

ii) DB type tension towers for upto 15 degree angle of deviation.

iii) DC type tension towers for upto 30 degree angle of deviation.

iv) DD type tension towers for upto 60 degree angle of deviation and suitable for dead end condition. These may also be used for terminal locations.

The standard extension normally used for various types of towers are as follows:

DA & DD : 3m, 6m, 9m, 18m, 25m
DB & DC : 3m, 6m, 9m

In addition to the above, special towers, for major river crossing, power line crossing and the places where the terrain is particularly different, such as approach to the sub-station, forest stretches etc. shall also be used. All towers shall be designed in accordance with latest edition of IS-802 and considering necessary improvements and reinforcements evolved as per suggestions/recommendations of CEA's expert committee based on the experience of previous tower failures in the country.

Structural steel sections used in towers shall be of High Tensile (HT) steel & Mild Steel (MS) of requisite quality as per IS-2062 or equivalent International Standards.

10.2.2.4.1 Foundations

Tower Foundations are generally pad & chimney type and typically classified as Dry, Wet, Partially submerged(PS), Fully Submerged (FS), Wet Black Cotton (WBC), Sandy, Dry Fissured Rock (DFR), Wet Fissured Rock (WFR), Submerged Fissured Rock (SFR), Hard Rock etc. depending upon type of soil
encountered and designed accordingly based on relevant Indian standards and CBIP guidelines. For river crossing locations & soils having poor bearing capacity, wherever required, pile/well type foundations are used.

Typesof soil encountered by the transmission lines are generally mixed dry, wet, wet black cotton type in the plain terrain and dry fissured rock, wet fissured rock & hard rock in the hilly terrain. The requirements of the foundations are considered in accordance with the type of soil.

10.2.2.4.2Revetment and Benching

For hilly and undulating stretch, wherever the line is passing through, revetment and benching shall be provided as per site conditions.

10.2.2.5Conductors

Conventional ACSR type conductors have been considered based on system requirements as these are most common type of conductors with proven technology having low cost & easy availability.

For 400 KV Quad lines, Quad 'Moose' ACSR conductors (54/3.53 Aluminium and 7/3.53 mm steel) of overall diameter 31.77 mm shall be used per phase. The sub-conductor spacing will be 457 mm.

10.2.2.6Earthwire/OPGW

One 7/3.66 mm galvanised steel earth wire shall be used on the line so that it can withstand two successive lightning stroke of 150 kA. Shielding angles of 20 deg is considered for transmission line.

In the present scheme 1 No OPGW is proposed to be installed on all the lines to meet the requirements of Power System Communication. Optical Fibre technology provides an efficient telecommunication network to support their various applications requiring higher speed & bandwidth.

10.2.2.7 Grounding

The tower footing resistance shall be kept below 10 ohms. Pipe type or counterpoise earthing shall be used to bring the tower footing resistance down to acceptable level.

10.2.2.8Insulator and Hardware Fittings

High strength composite long rod insulators shall be used. The following types of insulator strings along with hardware fittings shall be used :

1. 400 KV TRANSMISSION LINE WITH QUAD ACSR MOOSE CONDUCTOR WITHCOMPOSITE LONG ROD INSULATOR

Sl. No.	Type of string	Size of Comp. insulators (Core dia x nominal len)(mm)	Minimum creepage distance of each disc (mm)	No. of individual units per string (nos)	Electro-mechnical strength of insulator disc(KN)	Mechanical strength of insulator string along with hardware fittings (KN)
a)	Double 'I' suspension	20x3335	13020	1x1	120	2 x 120
b)	Single suspension Pilot	20x3335	13020	1x1	120	120
c)	Quadruple Tension	24x3910	13020	4x1	160	4 x 160

Items 1(a) and (1c) are mostly used for suspension and tension towers respectively. Item (b) is used in transposition towers. Item 1(b) also shall be used in heavy angle towers DC & DD types) to restrict jumper movement. Suitable hardware fittings shall be used for attachment of the insulators with the tower at one end and also for supporting the conductors at the other end. Corona control rings or grading rings will be used for improving corona and RIV performance as well as to

improve the voltage distribution across the insulators discs. The voltage across any disc shall not exceed 9 % in case of suspension type and 10 % in case of tension type of the line to earth voltage. This will reduce aging and also minimize radio interference.

10.2.2.9Line Accessories

i) **Mid span compression joint for conductor/ earthwire**

Mid span compression joint suitable for conductor/ earthwire shall be used for joining two lengths of conductor / earthwire. The minimum slipping strength of the joint after compression shall not be less than 95 % of the UTS of conductor / earthwire.

ii) **Repair sleeve for conductor**

Repair sleeve shall be used only for repairing not more than two strands broken in the outer layer of conductor. It shall be of compression type in two parts with provision of seat sliding of keeper piece.

iii) **Flexible copper bond for earthwire**

Flexible copper bonds shall be used for good electrical continuity between the earthwire and the tower. Two bonds per suspension tower & four bonds (two for each earthwire) per tension tower shall be used.

iv) **Vibration damper for earthwire**

Stockbridge vibration dampers shall be used to reduce the maximum dynamic strain caused by aeolian vibrations to a value of 150 micro-strain.

v) **Spacers/SpacerDamper**

Quad bundle spacers shall be used for the Quad bundle lines to reduce vibrations and maintain sub-conductor spacing under all working conditions.

vi) **Suspension/Tension clamps for earthwire**

Suitable suspension/tension clamps shall be used for attachment of earthwire at suspension/tension towers.

vii) **T-connectors**

Compression type T-connectors shall be used for conductor jumpering at transposition towers wherever required.

10.2.2.10River Crossings

Special towers shall be used for major river crossings where the span is more than 600 mtrs with anchor towers on either end of river crossing span

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10.2.2.11 Power line, Railway line, Road and P&T line crossing

The transmission lines shall be crossing power lines, railway lines roads and P&T lines for which suitable extensions of towers shall be used.
The standard extension normally used for various types of towers are as follows:

A/DA & D/DD : 3m, 6m, 9m, 18m, 25m
B/DB & C/DC : 3m, 6m,9m

In addition to the above body extension, suitable leg/Chimney extensions shall also be provided in the hilly terrain, wherever required, to reduce the benching.

11.0 MANAGEMENT ARRANGEMENTS

11.1 Organisational set up

In POWERGRID the 'Organizational Concept' has been given due importance and the basic structure of organization has been made with a view to achieve the following objectives:

i) To group related functions together to have clearly defined 'Roles' for the relevant 'functional heads'.
ii) To have well defined 'Responsibility & Authority' centers in the structure.
iii) To have well defined 'communication channels' and optimum 'span of control' in the organization.

iv) To have optimum manpower.
v) To have decentralization of activities as far as possible.

At the first level in the organization, Corporate Centre will be planning, monitoring and controlling the objectives and activities of the organization. At the second level, the Regional HQs will be playing the role of controlling the activities in the regions and will report to Corporate Centre. In POWERGRID, 9 regions have been identified as NR-I, NR-II, SR-I, SR-II, WR-I, WR-II, ER-I, ER-II & NER, and these regions will be headed by GM/ED. At the third level in the structure, the Substation Groups will be controlling the activities of the respective Substation and associated lines under that Group and will report to the Regional HQs. The Groups will consist of basic working units such as substation Construction/maintenance, line construction/maintenance. The Groups will have both service and technical functions, to cater to the basic functional requirements.

11.1.1 Project Management

The project of transmission system will be planned, implemented, monitored and controlled through Integrated Project Management and Control System (IPMCS).

IPMCS uses PERT/CPM technique as the basic management tool. For effective project planning and review, three tier level of planning and review have been adopted.

Level-I :

Planning is done by the Corporate Monitoring Group, a central planning cell, which is in the form of an overall project schedule called the Master Network, for the project which forms the basis for all subsequent planning and monitoring of the activities. This covers broadly all the packages of project and indicates activities of engineering, contracts, manufacturing, erection and commissioning. The Master

Network is prepared using computerized techniques which subsequently helps in comparing the actual progress of the project with the scheduled progress. This gives indication of the likely critical areas and helps in preventing the same, thereby resulting in smoother implementation. The Master Network also acts as a source for the planning to be done at Level - II & Level - III.

Level-II :

Planning is done package-wise and is worked out and finalised with the respective contractor/vendor during the pre-award stage. Level II networks are made within the milestones identified in the project Master Network (L-I).

Level-III :

Plans deal with elaborate schedules and weekly/monthly rolling plans which are prepared for activities of engineering, supply (as the case may be) & field activities. These form the basis of monitoring by the various functions.

The system envisages monthly review of the level II programmes with contractors and at field on a weekly basis. A site monthly progress report is sent to the head office having four sections, i.e.

i) Project completion trend
ii) Salient achievements for the month
iii) Programme for next month
iv) Areas needing attention of top management

11.1.2 Project Implementation Review

As on 31st May 2015, POWERGRID operates about 1,16,625ckt. kms. of transmission lines and 195 Substations with a transformation capacity of about 2,34,709 MVA.POWERGRID has a team of dedicated experts in the field of substation and Transmission Line Engg. equipped with state-of-the-art technology, software capabilities and computer aided facilities for Planning, Design, Operation and Maintenance of transmission system. It has a well-established system of continuous feedback from the field and upgrades the system accordingly.

Based on the feedback as well as in pursuit to economize the cost and implementation period, its experts are vigorously pursuing the standardization of Transmission Line designs, substation/switchyard layouts, schemes, technical parameters of equipment, etc.

POWERGRID has developed a project monitoring system matching with the organization structure, complexity / intricacies involved in the project implementation and Management information system. The system calls for increasing details of planning in all facets of functioning such as engineering, contracts, site and corresponding levels of monitoring and control; for generating a management summary report to the top management. This management summary report highlights the project completion trends, actions being taken/to be taken for the attention of the top management on exceptional basis of critical areas.

Further, the monitoring system envisages a regular total project review called project review meeting (PRM). This review meeting is headed by the Regional in-charge with representation from all functions viz. Contracts, Engineering, Field, Personnel, Finance, Corporate Monitoring Group, etc. The participants discuss project critical, project interface problems and project completion trends, etc.

From the discussions held during the PRM emanates a status report and also an exception report put up to the Chief Executive and Directors which highlights extremely critical areas needing immediate attention and assistance required. Once in three months the PRM is held at Corporate Centre. These discussions help in identifying the critical areas and seeking decisions for speedy project implementation.

12.0 MEANS OF FINANCE AND PROJECT BUDGET

12.1 Project Cost Estimate

The estimated cost of the project based on **February 2015 price level** is as follows:

(Rs. in crores)

		Total cost
1.	Transmission System	3704.24
2.	Interest during Construction	234.10
	TOTAL	**3938.34**

The abstract cost estimate for Transmission Line and Substation portion are given at **ANNEXURE - 1.0**. The break-up of the cost estimate for civil works, Transmission lines and substations are given at **ANNEXUREs - 1.1, 1.2**and **1.3**respectively.

The detailed cost estimates for the civil works for Transmission Lines and Substations have been given at **ANNEXUREs - 1.1.1, 1.1.2** and **1.1.3**.

12.2 Basis of Cost Estimate

The cost estimates for all equipment for 765 kV& 400 KV transmission line and 765/400/220 KV Substationshave been considered from ***Schedule of Rates*** *(which was prepared based on the average of unit rates of latest LOAs/Bids/*Raw material prices*)* for **February 2015**Price level.

The cost estimate is exclusive of Excise Duty and Customs Duty but inclusive of CST @2.0% (as funding for supply of equipment is proposed to be done through ADB Loan and domestic borrowings/bonds/External Commercial borrowings). F&I @ 4%have been considered in the Estimate. Also Entry Tax @ 4.0% for T/L & S/S equipment and @5% for OPGW & Telecom equipment has been considered in the State of Rajasthan.

12.3 Project Overheads

The following overheads have been charged on to the cost of the transmission system as a percentage of the equipment cost:

	For Tr. Lines & Substations
i) Incidental Expenditure During Construction	5.00% (Excl.Afforestation cost)
ii) Contingencies	3.00% (Excl. Afforestation cost)

12.4 Funding arrangement

12.4.1 Phased Fund Requirement

The anticipated year wise fund requirement for the project including interest during construction is given below:

YEAR	TOTAL (Rs in Crores)
2016 – 2017	759.69
2017 – 2018	1368.52
2018– 2019	1439.70
2019– 2020	370.42
Total	**3938.34**

12.4.2 Mode of Financing

The project is proposed to be funded through POWERGRID's Internal Resources (IR) and through ADBLoan&domestic borrowings/bonds/External Commercial borrowings. The equity component **(30%)** is proposed to be met through the Internal Resources (IR) and the loan component **(70%)** through ADBLoan&domestic borrowings/bonds/External Commercial borrowings.

12.5 Interest during Construction

Based on the assumption that the project will be financed from loan and equity in the ratio of **70:30** and the equity component being released simultaneously along with the loan component, the interest during construction works out to **Rs.234.10crores**.The interest rate for the loan amount has been considered **@7.0%** for ADB Loan and **@10.5%** for domestic loan. The details of calculation are furnished in **ANNEXURE - 4.0**.The Schemeis scheduled to be commissioned within **36 months**from the date of Investment Approval.

The interest during construction would however be based on the actual financial structure of the project and applicable terms of interest on loan(s), etc.

12.6 Monthly Fixed Charges

Considering rate of interest onADB Loan @ 7.0%p.a.,Domestic Loan @ 10.5% p.a., return on equity @ 15.5%, depreciation @ 0% for land, @ 3.34% for building, @ 5.28% for transmission lines & substations and @ 6.33% for PLCC, O&M charges @ Rs.1.25Lakhs per km for D/C line (with four or more sub-conductors), @ Rs.99.40 Lakhs per 765 KV bay,@ Rs.70.99 Lakhs per 400 KV bay for Substation, Debt:Equity ratio 70:30, interest on working capital @ 13.50%, the tentative monthly fixed charges work out as **Rs.5326.58Lakhs** on Base Cost and **Rs. 5655.73Lakhs** on Projected Completed Cost(**ANNEXURE - 3.0**).

12.7 Completion Cost

The completion cost of the project is expected to be **Rs4195.78crores**including IDCof **Rs. 244.20crores**. The above cost has been worked out based on the average movement of WPI (80% weightage) and CPI (20% weightage) for the preceding 12 month period as per guide lines dated 06.08.1997. Details of calculation are enclosed at **ANNEXURE - 5.0**. The abstract cost estimate for completed cost is enclosed at **ANNEXURE - 1.0a**. The phased fund requirement and calculation for IDC for completed cost are enclosed at **ANNEXURES – 2.0a** and **5.0a** respectively.

12.8 IRR Calculation

The Project IRR, Equity IRR and Economic IRR on Projected Completed Cost have been calculated for the project and the same is tabulated below:

	For Completed Cost
Project IRR	**10.28%**
Equity IRR	17.67%
Economic IRR	10.71%

As the project is proposed to be funded through ADB loan (@7.0%) and domestic sources, the Weighted Average Cost of Capital (WACC) on Projected Completed Cost works out to**9.94%**. The Project IRR **10.28%**being higher than the WACC,establishes the viability of the project.

a. **Depreciation Periods:** The depreciation rates and life have been considered as per CERC norms which are tabulated below:

Component	Useful Life (years)	Depreciation Rate (%)	Salvage Value (%)
Transmission Line	35	5.28	10
Sub Station	35*	5.28	10
Building (Civil)	35	3.34	10
PLCC	15	6.33	10
Land	NA	NA	100

**25 years as per CERC norms 2009-14*

The depreciation as per the above norms has been considered in the projections which have been added to Profit After Tax (PAT) to get the Gross Cash Accruals for the purpose of estimating cash flows.

b. **Salvage Values**: Salvage value is considered at 10 percent for Transmission Lines, Sub Station, Civil and PLCC and 100 percent for land as per the CERC order.

c. **Outflows in Equity IRR**: The outflows depict repayment of loan required to be deducted from gross cash accruals for assessing the free cash flows to equity.

d. **Desired Debt Service Coverage Rate**: The desired debt service coverage rate shall be greater than one to ensure adequate cash flows for servicing and repayment of debt.

e. **Days of Receivable**: Days of receivable is 60 days as allowed under the CERC norms for recovery of interest on working capital.

f. **Days of Payable**: Days of Payable is 30 days as stipulated in ongoing POWERGRID contracts.

g. **Cash Requirement related to operating expenses**: The operating expenses considered in the projections are O&M and Depreciation. Thus, the cash requirements shall only be for O&M expenditure only.

h. **Corporate Income Tax Rate**: Since POWERGRID income is charged MAT rate for income tax purposes, MAT rate (20.9605%) shall be the Corporate Income Tax Rate.

i. **Expected Return on Equity**: The expected return on equity is 15.5 percent (post tax) as allowed under the CERC norms.

The details of calculation are furnished in **ANNEXURE - 7.0**.

13.0 TIME FRAME

Green Energy Corridor-ISTS-Part-Dis scheduled to be commissioned within **36months**from the date of Investment Approval.(Implementation schedule is given at **EXHIBIT-3.0**).

14.0 RISK ANALYSIS

Revenue Risk

The capital cost of the transmission system comprises of i) an equity component and ii) a loan component. This is recovered through the annual transmission charges consisting of return required for the equity, an interest for the loan component together with the depreciation charges, the O & M charges and interest

on working capital from the beneficiaries as per Notification in proportion to the benefits derived by them. These are recovered in monthly fixed charges from the beneficiaries. In addition to annual charges Income Tax, FERV and incentives, etc. as per notification would also be payable.

The Bulk Power Transmission Agreement (BPTA) / Transmission Service agreement (TSA) which covers the payments for transmission charges for all the existing projects as well as those that may be included in future already exists.

Regulatory Risk

BPTAs/ TSA have the provision that the transmission tariff for new / existing transmission assets commissioned as well as the additional tariff payable due to additional capitalization from year to year, etc. shall be computed by POWERGRID based on norms / methodology followed and specified by the Central Electricity Regulatory Commission (CERC) as amended from time to time.

Environmental Risk

Transmission line projects are environmentally friendly and do not involve any disposal of solid effluents and hazardous substance in land, air and water. Moreover, in forest areas trees are felled below each conductor to facilitate stringing. On completion of construction only one such strip is maintained for O&M purpose. Therefore the actual loss of forest is restricted to some selected area only. However, as per the requirement of Forest (Conservation) Act, 1980 approval of Ministry of Environment & Forests, Govt of India for diversion of forest land shall be taken before construction of line and compensatory afforestation shall be done on double the area of degraded forest land to compensate the loss of vegetation, due to diversion of forest land if there is any after detailed survey.

Legal / Contractual Risks

The procurement practices of POWERGRID are in line with best practices followed internationally. Further, requisite due diligence is carried out prior to award of contracts which inter-alia includes assessment of capacity and capability of bidders to perform the contract, thereby mitigating contractual risks. In the unlikely event of such risk, adequate provisions such as Dispute Resolution, Risk & Cost procurement, etc are in built in the Bidding/Contract Document to deal with the same.

The legal framework governing the contracts in India is well established and finally in place. As such, there is minimal probability of any legal risk.

Project Management Risks

POWERGRID being the Central Transmission Utility of the country, holds vast experience in the area of construction of 400kV and 765 KV long Inter-state Transmission lines and associated substations. It has commissioned several 400 KV and 765 KV Transmission Lines and Substation projects successfully which are under operation.

POWERGRID has developed and implemented systems & procedures aligned with Integrated Management System. The Critical projects are monitored even more closely. As such, with a dedicated and experienced pool of manpower and application of IMS in implementation of its projects, POWERGRID makes every endeavor to achieve the target making probability of impact of Project Management Risks to minimal.

15.0 PASTRECORD OF SUCCESSFUL PROJECT IMPLEMENTATION

The above transmission system has been evolved, carrying out detailed studies by using latest available power system analysis software (PSS/E), and the proposed system is considered to be adequate to transfer power to the respective beneficiaries with reliability and security. Regarding achieving its objective in the stipulated time frame, it is to mention that POWERGRID has in-house expertise in all specialized areas of transmission with systemsupto 800KV AC, ±500KV HVDC, Gas Insulated Sub-Stations, Static VAR Compensation, Series Capacitors, FACTS (Flexible AC Transmission System), Controlled Shunt reactors etc.

POWERGRID, since its formation has commissioned many large size and difficult transmission projects. Majority of such projects have been completed on or ahead of schedule.

As on 31st May 2015, POWERGRID operates about 1,16,625ckt. kms. of transmission lines and 195 Substations with a transformation capacity of about 2,34,709 MVA.POWERGRID has maintained the transmission system's availability at over **99%** consistently.

In recognition of POWERGRID's excellence in areas of its operations as above, POWERGRID has been rated as "Excellent" many times since 1993-94 in achieving the MoU targets with Ministry of Power. POWERGRID is also a recipient of Prime Minister's MoU Award consecutively for many years for being amongst top ten PSUs.

16.0 SUSTAINABILITY

16.1 System Design Philosophy

The power evacuation system is designed in the most optimum manner such that losses in the system are minimal. The system and equipment parameters are chosen according to the present trends in technology, the conductors available are such that the losses in them due to internal resistance as well as due to external effects such as corona and RIV are bare minimum. The busbar materials and the clamps and connectors are chosen after meeting the stringent international requirements so that there is least loss of energy in them. The transformers, reactors and other switchgear are also similarly selected and evaluated before award itself for most efficient operation from thermal loss and efficiency.

16.2 System Operation Philosophy

The power flow in a particular line varies due to demand variation, failure of equipment, line faults, etc. For the system to be stable and to use

optimisedresources, it is very important to record the power flow at each and every time. This necessitates the monitoring of operation of the system on a three shift basis.

16.3 System Maintenance Philosophy

The maintenance management system in vogue in POWERGRID aims at keeping the system under stable conditions while ensuring minimum maintenance cost and safety of equipment and personnel. The maintenance management schedule detailed work specification covering all maintenance jobs permit to work system, long term maintenance planning meeting for about 30 minutes for finalizing maintenance schedule for next 24 hours and resolution of interface problems between departments. These meetings are supplemented by meeting of HODs for one hour on alternate days to accelerate the decision making process and to lay down the priorities and guidelines for maintenance work during next 72 hours.

16.3.1 Spare parts Management System

The primary objective of spare part management system will be to ensure timely availability of proper spare parts for efficient maintenance of the substations and lines without excessive build-up on non-moving and slow moving inventory. The spare parts management system for this project will cover the following areas:

a) Proper codification of all spares and consumables
b) Spare parts indenting and procurement policy
c) Ordering of critical mandatory and recommended spares
d) Judicious fixation of inventory levels and ordering levels for spare parts basedon our experience in other projects.
e) Development of more than one source wherever practicable.

16.3.2 Training of personnel

The expertise available with the country is adequate to cover maintenance of Transmission Line and sub station EHV equipments, etc. Also, available technical expertise within POWERGRID is adequate to cover operation and maintenance requirements of equipments. Hence, training in these areas can be arranged by POWERGRID's training facility with the help of training officers, equipment suppliers and consultants, site commissioning personnel as well as POWERGRID's own specialists.

16.3.3 O&M Manuals

a) Adequate O & M manuals will be distributed to all concerned as per the policy of the company.
b) O & M manuals will be available to all concerned prior to commissioning of substations and transmission lines to avoid problems in preparation of commissioning documents as well as proper installation & commissioning of equipment.

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