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LONG TERM TRANSMISSION EXPANSION PLANNING FOR INDIAN POWER SYSTEM: A REVIEW

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ABSTRACT: Long Term Transmission Expansion Planning plays a vital role in electrical power systems. As electrical load grows unboundedly, it causes electrical generation has to rise accordance with load and than simultaneously it leads to enhance the facilities of transmission system. To enhance the facilities of Transmission system, one must has to asses load forecasting, generation growth, social economic constraints and environmental impacts. In this paper, objectives, tools and methodologies for LTEP are discussed. Present transmission facilities available in India are presented and also suggested different LTEP methodologies for Indian Power System. Transmission growth and expected growth during 11th plan and 12th plan and 13th plan are discussed.

Keywords: Transmission Expansion Planning, Indian Power Systems, Load, Generation, environmental impacts.

I. INTRODUCTION

Due to large number of projects under consideration, regulators and other stakeholders are calling for examination of basic system wide needs. Different plans suggest similar routes which raise questions for decision makers about the optimum use of limited transmission corridors and invested capital, questions such as:

• What must be the long term outline of the transmission system?
• What should be the timing of capacity additions?
• How are projects to be incorporated with each other?
• Will incremental expansion lead to a coherent overall design?
• Should higher capacity lines be built as part of a plan for an extra-high voltage overlay that could avoid unnecessary propagation of lines in the long-run?

II. OBJECTIVES OF PLANNING

To answer questions mentioned above will require assessment of long term needs, i.e. looking out 20 or additional years. The effective long-term planning requires scenario analysis, which generates alternate future based on the variation of major drivers – population growth, technology, regulatory policy, etc. From the transmission planner's perspective, each such scenario produces a possible load and resource trajectory (timing of events and their geographical locations) for which a transmission plan must be developed. By examining scenario probability and the central tendencies of the plans generated for the set of scenarios, transmission planners can make informed recommendations regarding decisions to be made today.

The objective of transmission planning is not to determine the shape of the future transmission network. No long-term transmission plan will ever be able to accurately forecast the facilities that will materialize over a 20 year period. Rather, the goal of transmission planning is to make the best possible recommendation about what to do today. By considering the future options, their costs and likelihood as suggested above, good choices are enabled that tend to minimize future regret about past decisions.

The objectives of a long term transmission plan are:

1. Meets expected future needs for delivery of energy and facilitates energy trade across the region.
2. Considers environmental values to minimization impact of network expansion.

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3. Is adaptable to a broad range of future conditions, to the extent possible.
4. Is not intentionally overbuilt, while recognizing that transmission expansion is lumpy so that additions must usually be grown into.
5. Provides planning guidance for near-term decision making.

Transmission System Assessment Planning includes detailed evaluation of transmission facilities over a 10- year period. As distribution load forecasts are considered, it is possible that projections indicate that one or more reliability criteria would not be met at some date in the future. In such cases, remedial actions are developed and planned to assure the system continues to comply with reliability criteria. There are a number of possible actions that can address transmission system reliability criteria deficiencies:

1. Additional transmission lines on the existing right-of-way (ROW) or new ROW;
2. Increasing the capacity of existing transmission components by:
a. Re-conductor of existing transmission line with higher ampacity conductor or the use of high temperature low sag (HTLS) conductor;
b. Installation of parallel transmission transformer.
3. Upgrade of existing facility to higher voltage;
4. Installation of transmission capacitor banks in various transmission as well as distribution stations and/or,
5. Combinations of the above.

Interconnection of New Generation Resources Reliability criteria can be met in some cases by the interconnection of new generation resources within the system or by interconnections to new or existing generation resources outside the system. New generation resources are not only a source of additional real power but are also a source of reactive power, all of which help bring the system into compliance with reliability criteria. Resources closer to load will provide greater reactive support than those further away. At some point, the interconnection of new generation resources is needed to meet reliability and supply requirements.

III. FORECASTING OF FUTURE NEEDS

To accomplish Transmission planning, it requires the following forecasting needs:

- Must anticipate future demand for electricity, generation capacity and appropriate reserves required to meet the forecast load.
- Must make assumptions about future load growth, the timing and location of future generation additions and other related assumptions.
- Must make an assessment of the transmission facilities required to provide for the efficient and reliable access to jurisdictions outside the country and
- May, if the ISO considers it necessary to do so, make an assessment of the contribution of a proposed transmission facility to any of the following:
    - Improving transmission system reliability.
    - A robust competitive market.
    - Improving transmission system efficiency.
    - Improving operational flexibility.
    - Maintaining options for long term development of the transmission system.

Preparation and maintenance of a transmission system plan for at least the next 20 years shall have the following steps:

i. Forecasting of load on the interconnected electric system, including exports of electricity,
ii. Anticipation of generation capacity.
iii. Identification of timing and location of future generation additions.
iv. Finalization of transmission facilities required to meet the forecast load, imports and exports.
v. Establishment of transmission facilities required to provide for the efficient and reliable access to jurisdictions , and
vi. other matters related to the items described in sub clauses (i) to (v) that the Central Electricity Regulating Authority has to
    - Update the transmission system plan periodically as required.
    - Make the transmission system plan, including the assumptions and supporting data on which the plan is based, and the updates made to the plan, available to the public, and file copies of them with the Commission and the Minister for information.

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IV. FACTORS AFFECTING THE LONG-RANGE TRANSMISSION PLAN

The following are the various factors that will affect the Plan:

i. Changes in reliability requirements.
ii. Changes in econometric load forecasts.
iii. Impact of demand side management programs.
iv. Impacts from the State's Energy regulating programs.
v. Other state and national policy programs such as the Regional Greenhouse Gas Initiative.
vi. New merchant generation and transmission.
vii. Decisions under the ISO's Comprehensive Reliability Planning Process.
viii. Potential of new legislation on the interconnection-wide planning process.

V. ENVIRONMENTAL CONSIDERATIONS IN LONG-TERM PLANNING

To develop, Transmission plans environmental constraints must be considered. To ensure that it's planning studies pay adequate attention to land use, wildlife, water, and other factors. Wildlife, specifically, is particularly sensitive to the impacts of electricity transmission lines. Transmission modeling tools to be proposed that accommodate both qualitative and quantitative environmental data (wildlife, land use, water, etc.). Tools proposed should not preclude use of available wildlife data, whether by applying a pre-processing step to incorporate environmental considerations or by integrating such data in the tools' analytical processes. Proposed tools should incorporate environmental data directly from state agencies, and may include both quantitative and qualitative data, as well as provide mapping and other graphic portrayals of data to assist data users in making siting and routing decisions during study case development. Proposed tools must be flexible to consider new data inputs, such as environmental geographic information system data analysis or changing policy requirements that may impact carbon emissions, multiple resource attributes, location, costs, and other variables important to future use of the long-term planning tools and policy analysis. Incorporating environmental data into transmission planning tools is a relatively new concept and seeks innovative approaches to accommodating this capability.

VI. LIMITATIONS IN THE SCOPE OF THE PLAN

Transmission utilities during its analysis to identify all concerns that may require system upgrades, however, some concerns may not have been identified due to insufficient information, unforeseen events, new requirements or the emergence of new information. From time to time, utilities must make improvements to in its system to replace obsolete equipment, make repairs; relocate a piece of equipment, or otherwise carry out its obligations to maintain a reliable grid. Sometimes these activities require significant projects, such as the current work to replace obsolete equipment and line rebuilds to replace aging equipment or maintain acceptable ground clearances.

All issues relating to planning and development of Transmission System in the country are dealt in the Power System Wing of CEA. This includes evolving long term and short term transmission plans. The network expansion plans are optimized based on network simulation studies and techno economic analysis. This also involves formulation of specific schemes, evolving a phased implementation plan in consultation with the Central and State transmission utilities and assistance in the process of investment approval for the Central sector schemes, issues pertaining to development of National Power Grid in the country and issues relating to trans-country power transfer. Transmission planning studies are being conducted to identify evacuation system from generation projects and to strengthen the transmission system in various regions. The studies for long-term perspective plans are also being carried out on All India basis for establishing inter regional connectivity aimed towards formation of the National Power System. The National Power System is being evolved to facilitate free flow of power across regional boundaries, to meet the short fall of deficit regions from a surplus region as well as for evacuation of power from project(s) located in one region to the beneficiaries located in other region(s).

VII. TOOLS AND METHODOLOGIES REQUIRED FOR PLANNING

The classic tools used in transmission system planning are power flow and dynamic stability analysis. These analytic tools are well developed and broadly applied. They are used to evaluate the performance of proposed additions to the transmission system against reliability criteria for system performance. They result in transmission system ratings that allow system operators to maintain system reliability while serving the energy needs of the system users. Transmission system is assessed using a variety of system modeling and simulation tools to measure the transmission system's

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capabilities against design criteria. This is done for present and planned configurations at present and future load levels, respectively. The simulations are validated using real-time measurements made under normal and contingency conditions whenever possible. Assessments are made in the following areas, using standardized software packages to study the system's performance:

a. Thermal.
b. Voltage.
c. Short Circuit.
d. Under-frequency Load Shedding.
e. Extreme Contingencies.
f. Equipment Replacements Due to Condition.

Thermal: Load flow studies are the primary method used by Transmission Planning to assess the performance of the transmission system under normal and contingency conditions. The software's used for these studies are MATLAB, PSCAD, Mipower and PSS/E. These are the leading software packages for bulk transmission system load flow studies. The load flow levels established by the studies are measured against the thermal ratings of transmission facilities. Transmission equipment including lines and transformer banks are assigned with thermal ratings for normal operation, long-time emergency operation (LTE), and short-time emergency operation (STE). Load flow studies are conducted to simulate normal operation under peak forecast loads. No transmission facilities should exceed their normal ratings at this operating condition. During single contingency conditions, no facilities should exceed their LTE ratings. Also following the various contingency conditions transmission system must exhibit the capability to be returned to operation within normal thermal limits following the worst case single contingency within the time frame specified in the rules.

Voltage: Voltages throughout the transmission system are checked using the same load flow studies that are used to make the thermal assessments described in the section above. The focus, however, shifts from the delivery of real power, measured in MW, to voltage support and control provided by reactive power, measured in MVAR.

Short Circuit: Short circuit studies are conducted to assess the following:
1. The ability of circuit breakers on the transmission system to interrupt fault currents; and
2. The ability of all equipment on the transmission system, including but not limited to circuit breakers, bus work, disconnect switches, and structural supports to withstand the mechanical forces associated with fault currents. Momentary forces generated within the first one-half cycle following the inception of a fault typically present the highest mechanical stresses.

Under-frequency Load Shedding: Under-frequency relays are installed at various locations throughout the system to provide protection against widespread system disturbances.

Extreme Contingencies: As required by the standards, planners measure system performance under three increasingly stressed conditions to determine whether the system will remain within mandatory performance criteria under various operating scenarios. Planners analyze the system with:
1. All facilities in service (no contingencies or N-0).
2. A single element out of service (single contingency or N-1).
3. Multiple elements out of removed from service (multiple, due to a single contingency or a sequence of contingencies, i.e., or N-1-1).

In the N-1-1 scenario, planners assume one element is out of service followed by another event that occurs after a certain period. After the first contingency operators make adjustments to the system in preparation for the next potential event, such as switching in or out certain elements, resetting inter-regional tie flows where that ability exists, and turning on peaking generators. In each scenario, if the software used to simulate the electric grid shows the system cannot maintain acceptable levels of power flow and voltage, a solution is required to resolve the reliability concern.

VIII. TRANSMISSION SYSTEM PERFORMANCE CRITERIA

Assessing the performance of the transmission system may include analyses, such as:

1. Stability assessment, the analysis of system dynamic performance as a result of sudden system changes including those caused by a contingency;
2. Steady state assessment, the analysis of power flows before and after contingencies when the system has returned to synchronism;

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3. Voltage assessment, the analysis of reactive power sources/sinks to control voltage;
4. Fault current assessment, the analysis of the capability of electrical devices to physically withstand and interrupt short-circuit currents; and
5. Power-quality assessment, the analysis of current and voltage waveforms for distortion.

Stability Assessment: Stability of the transmission system shall be maintained during and following the most severe of the contingencies stated below, with due regard to reclosing, and before making any manual system adjustments. For each of the local area systems contingencies listed below that involves a fault, stability shall be maintained when the simulation is based on fault clearing initiated by either protection group on the faulted element without consideration to equipment failures.

a. A permanent three-phase fault on any generator, transmission circuit, transformer or bus section with normal fault clearing.
b. Simultaneous permanent phase-to-ground faults on different phases of each of two adjacent transmission circuits on a multiple circuit transmission tower, with normal fault clearing.
c. A permanent phase-to-ground fault on any transmission circuit, transformer or bus section with delayed fault clearing.
d. Loss of any element without a fault.
e. A permanent phase-to-ground fault in a circuit breaker, with normal fault clearing.
f. The failure of any special protection systems (“SPS”) which is not functionally redundant to operate properly when required following the contingencies listed in "a" through "e" above.
g. The failure of a circuit breaker to operate when initiated by an SPS following: loss of any element without a fault; or a permanent phase-to-ground fault, with normal fault clearing, on any transmission circuit, transformer, or bus section.

Steady State Assessment: Transmission system equipment loadings shall be within normal ratings for pre-contingency conditions and within applicable emergency ratings for the system load and generation conditions that exist following the contingencies specified below and with due regard to electrical system reconfiguration:

a. Contingencies listed in Section Stability Assessment
b. The transmission system shall be designed such that the loss of any single element will not result in the loss of customer load, except in cases where customers are served by a single transmission element. Where alternate transmission or distribution service exists, interruption of customer load for a radial line contingency will occur only for the short time required to transfer the load to the alternate service connection. Absent such transfer capability, the acceptable magnitude of customer load lost under a single element contingency will depend upon the local area system load profile, available resources, the expected duration of an outage caused by equipment failure, and the availability of spare equipment to support restoration efforts.

For contingencies involving multiple elements that interrupt transmission service to local area systems, measures should be taken to reduce the frequency and/or the impact of such contingencies when the amount of customer peak load interrupted exceeds 100 MW. For contingencies involving multiple elements that interrupt transmission service to local area systems with less than 100 MW of peak demand, measures should be evaluated to mitigate the frequency and/or the impact of such contingencies depending on the local area system’s load profile, available resources, the expected duration of an outage caused by equipment failure, and the availability of spare equipment to support restoration efforts.

Voltage Assessment: Design contingencies listed in Section Stability Assessment and Steady State Assessment shall not result in voltage collapse of the bulk power system, local area system or initiate a cascade outside of the local area system. Reactive power capacity with adequate reserves and appropriate controls shall be installed to maintain system voltages within normal limits for pre-contingency conditions, and within limits listed below for the steady-state system conditions that exist following the contingencies specified in Section Stability Assessment and Steady State Assessment.

a. Voltages for transmission system facilities equal to or greater than 230 kV, during normal conditions, shall not exceed plus 5% or minus 2% of nominal. Voltages for facilities equal to or greater than 230 kV, during emergency conditions, shall not exceed plus or minus 5% of nominal.
b. Voltages for transmission system facilities equal to 115 kV and below, during normal or emergency conditions, shall not exceed plus or minus 5% of nominal.

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c. The permissible transmission system minimum voltage at nuclear generating plants may be restricted to a fixed minimum limit less than 5% of nominal.
d. The instantaneous voltage change resulting from equipment switching not associated with fault clearing shall not exceed plus or minus 2.5% of nominal voltage. During emergency conditions, such as having a line out of service, the instantaneous voltage change resulting from equipment switching not associated with fault clearing shall not exceed plus or minus 6% of nominal voltage.
e. Overvoltage's (transient and temporary) must be within the rating capabilities of the electrical equipment as defined by the manufactures.

Fault Current Assessment: In each area, the system design must ensure that equipment (circuit breakers, switches, bus work, wave traps, etc.) capabilities are adequate to withstand fault current levels. The system design must be coordinated with adjacent areas and neighboring electric utilities. Short-circuit studies shall be performed to ensure that all transmission system equipment is capable of withstanding the forces generated under fault conditions and that the fault can be safely interrupted. These studies shall be performed with all generation (excluding retirements) connected to the power system in operation. Equipment shall be considered as over-stressed and either replaced or upgraded, depending on system conditions, when the corrected fault current level (accounting for voltage, X/R, etc.) is in excess of 90% of the manufacturer's nameplate rating and must be replaced or upgraded when the corrected fault current level exceeds 100% of the manufacturer's nameplate rating.

Power Quality Assessment: The transmission system including customer interconnections shall be designed in a manner that avoids, harmonic frequencies exceeding specified limits, voltage flicker exceeding the specified limits, frequency variations, voltage or power factor levels should be within the limits as per IEEE standards.

Generator Output Assessment: Transmission system switching can change the electrical power output (commonly referred to as "delta P") of a generator and introduce mechanical forces on generator equipment. Generator output assessments shall be performed in accordance with IEEE standards.

IX. REVIEW OF ACHIEVEMENTS DURING 11TH PLAN

Programme and achievements during 11th plan: It was decided in 11th Plan for construction of 88,515 ckm transmission lines for evacuation of power from generating stations as well as for strengthening of transmission network corresponding to generation capacity addition programme of 78,700 MW. Afterward, in the mid-term appraisal by the Planning Commission, generating capacity target for the 11th plan was scaled down to 62,374 MW. According to Mid-Term assessment of the Planning Commission, it was expected that 68,673 ckm of transmission lines will be added in the 11th plan and it consists of 2,773 ckm of 765 kV lines, 40,000 ckm of 400 kV lines, 24,300 ckm for 230/220 kV lines and 1600 ckm for HVDC lines. Against this programme, actual addition of transmission lines during first four years of 11th Plan is 49,852 ckm comprising of 1,636 ckm of 765 kV lines, 1580 ckm of HVDC lines, 26,856 ckm of 400 kV lines and 19,780 ckm of 230/220 kV lines .Table 1 and Table 2 gives growth of transmission lines during 11th plan.

Table 1: Transmission Lines- 11th Plan Programme & Achievement (All figures in circuit kms)

Voltage level	11th plan programme	Achievement up to Mar 2011 during 11th plan	Anticipated addition during 2011-12	Anticipated addition in 11th plan
765kv	2773	1636	824	2460
±500kv HVDC	1600	1580	2000	3580
400kv	40000	26856	12401	39257
220kv	24300	19780	6567	26347
Total	68673	49852	21792	71644

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Table 2: Cumulative Growth In Transmission Lines

Cumulative Growth In Transmission Lines					
Transmission lines	**Unit**	**At the end of 8th plan i.e. March 1997**	**At the end of 9th plan i.e. March 2002**	**At the end of 10th plan i.e. March 2007**	**At the end of 11th plan i.e. March 2012**
765kv	Ckm	0	1160	2184	4644
HVDC	Ckm	1634	4738	5872	9452
400kv	Ckm	36142	49378	75722	114979
230/220kv	Ckm	79600	96993	114629	140976
Total	Ckm	117376	152269	198407	270051

Inter-regional capacity addition during 11th Plan: The total inter-regional transmission capacity at the beginning of 11th Plan was 14,050 MW. During Mid Term Review of 11th Plan, additional inter-regional transmission systems of 18,600 MW capacities were anticipated, taking the expected inter-regional capacity to 32,650 MW by end of 11th Plan. Out of the programme for 11th Plan, 2400 MW capacity was added during 2007-08, 3300 MW during 2008-09, 1000 MW during 2009-10 and no addition during 2010-11. Thus a capacity addition of 6700 MW has already been added in 11th Plan up to 31-03-2011. With these additions the total transmission capacity of inter-regional transmission system, as on 31-03-2011 is 20,750 MW.

Fund Requirement and actual utilization during 11th Plan: Total Fund requirement for transmission system development and related schemes as estimated at the beginning of XI plan was Rs 1,40,000 Crore (Central Sector- Rs 75,000 Crore, and State Sector- Rs 65,000 Crore). Against this estimated funds requirement, the total utilization during XI Plan is anticipated to be of the order of Rs. 1,22,800 Crore.

Analysis and Reasons for shortfall in targets: The achievement of transmission line addition in the first four years of the 11th plan has been by and large satisfactory. The shortfall in addition of transformation capacity is mainly on account of substations associated with the generation projects which have now slipped to 12th Plan. It is expected that in the terminal year of 11th plan, the transmission line target would be fully met.

X. OPEN ACCESS IN TRANSMISSION AND TRADING OF ELECTRICITY

Transmission Planning keeping in view open Access: Based on application by a generator for Long Term Open Access, the transmission system is planned for evacuation of power from generating stations. The system planning studies are carried out considering projected demand in accordance with load forecasts. The loads of various States are assumed irrespective of any PPAs. However adequate intra-state transmission system is also required to absorb power injected from ISTS. During the planning process, some design margins get created in the network generally due to long term optimization. These margins, along with operational and reliability margins which are variable in nature and depend upon system conditions and load flow pattern at that time provide sufficient additional capacity in the system for trading and States to buy power more than their long-term PPAs. However, these margins can be utilized only up to a limit and may result into congestion if States start buying Power much in excess of their forecasted requirements.

Long term open access in inter-state transmission: The nodal agency for providing long term open access in inter-state transmission is the CTU. Up till March 2011, CTU has received about 187 Long Term Access(LTA) applications for transfer of power from their generation projects of capacity of about 1,77,000 MW to various target regions. The applications were processed by CTU and progress of each generation project in terms of land acquisition, fuel tie-up, environment and forest clearance, water linkage, EPC award, financial closure etc. was reviewed by CTU and CEA. Based on the progress, LTA has been granted to 135 applicants with capacity of about 1,17,000 MW. Out of this, transmission system is already in place for a capacity of about 43,500 MW and system strengthening identified for a capacity of about 73,500MW. The progress of balance 52 applications with capacity of about 60,000MW was not up to the mark and was proposed to close/review the application based on subsequent progress.

The grant of Long Term Access generally involves evolution or strengthening of the ISTS to accommodate desired transaction of power and is akin to transmission planning. The primary inputs required for transmission planning include (i) generation plant capacity, (ii) its location, (iii) time frame of materialization, (iv) beneficiaries to whom the

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power shall be delivered etc. However, in the present circumstances, none of these inputs are available with certainty. Under such a situation where the basic inputs required for evolving a transmission Plan are not available readily, it is prudent that transmission planners follow some innovative strategies to ensure fulfillment of broad objectives including ensuring that (i) transmission development takes place to cater to the transmission requirement, (ii) bottling up of the power is avoided, (iii) mismatch of generation and transmission system is avoided, (iv) congestion if observed in some part of grid should be removed at the earliest etc. In view of above it is a challenge to evolve optimal transmission system and once the plan is in place it is equally challenging to plan its implementation so as to avoid mismatch between development of generation project and transmission system.

XI. 12TH PLAN TRANSMISSION PROGRAMME

Evolving the Transmission System for 12th Plan: Identification of transmission expansion requirement for a Plan period is done based on power system studies corresponding to the generation expansion programme and forecasted demand scenario expected at the end of that Plan. The implementation programme is worked out keeping in view identification of projects, schemes and transmission elements that should be implemented matching with programme of generation capacity addition and load growth on yearly basis during the Plan. Timely development of transmission network requires firming-up of the specific transmission schemes corresponding to specific generation projects, which, particularly in respect of inter-state transmission system, need to be done 3 to 5 years ahead of the target date of completion. Meeting this requirement, most of the 12th Plan schemes have already been identified, discussed in the Regional Standing Committees on Power System Planning, finalized, scheme formulated and process of implementation initiated. Of the identified schemes, many are under construction, particularly those which are required to be completed during first half of the 12th Plan.

Transmission Schemes Planned for 12th Plan Period: CEA, in coordination with all the stake-holders i.e. Central Transmission Utility, State Transmission Utilities and Central Sector Generation Companies, have planned transmission systems required for evacuation of power from various generation projects which are in the pipeline and likely to yield benefit during 12th Plan period or early 13th Plan period, and also the transmission systems required for strengthening of regional and inter-regional transmission networks. Most of these schemes have been firmed up, however these also include some schemes, which are yet to be firmed up depending upon progress of associated generation project.

A few transmission schemes, particularly those required for generation projects coming up towards the last years of the 12th Plan and having common transmission system, could be altered depending upon progress of generation capacity linking to a common pooling point. Transmission systems for some of the 12th Plan generation capacities under the State sector (or private sector but giving benefit to only home State) have also been tentatively considered for integrated system planning process, however, these transmission schemes are required to be firmed up by the respective State Transmission Utilities.

Assessment of transmission system addition during 12th Plan Period : During 12th Plan period, a total of about 1,09,000 circuit kilometers(ckm) of transmission lines, 2,70,000 MVA of AC transformation capacity and 13,000 MW of HVDC systems are estimated to be added. Highlights of this transmission expansion are addition of three new HVDC Bipole systems of 13,000 MW capacity and quantum jump in 765kV transmission systems. During 12th Plan about 27,000 ckm of 765kV lines and 1,49,000 MVA transformation capacity addition is expected. This huge increase in the 765kV system is due to a number of pooling and de-pooling 765/400kV stations that have been planned to evacuate power from cluster of generation projects mainly in pit-head and coastal areas and transfer their power through long distance transmission lines up to load centers in the country. In addition to above, 400kV lines of 38,000 ckm, 220kV lines of 35,000 ckm and transformation capacity of 45,000 MVA and 76,000 MVA, respectively is estimated to be added during 12th Plan period. Table 3 gives development of the transmission system in India in 11th Plan period and expected to be added during 12th Plan period. These estimates are considering about 76 GW generation capacity additions for 12th Plan over and about 63 GW capacity addition target for 11th Plan:

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Table 3: Expected growth of Transmission Lines during 12th plan

Transmission Lines (both AC and HVDC systems) for 11th Plan and expected in 12th Plan (values in ckm)	As at the end of 10th Plan	Addition during first four years of 11th Plan (2007-11)	Expected at the end of 11th Plan	Expected addition during 12th Plan	Expected by end of 12th Plan
HVDC Bi-pole lines	5872	1580	9452	**9440**	18892
765 kV	1704	1636	4164	**27000**	31164
400 kV	75722	26856	114979	**38000**	152979
220 kV	114629	19780	140976	**35000**	175976
Total Transmission Line, ckm	**197927**	**49852**	**269571**	**109440**	**379011**

Fund Requirement for development of transmission system during 12th Plan Period: Considering 76 GW generation capacity addition for 12th Plan over and about 63 GW target (the Mid-term assessment for 11th plan by Planning commission) for 11th Plan, total fund requirement for development of transmission system is estimated to be of the order of Rs 1,80,000 crore (Rs 1,00,000 Crore in Central Sector, Rs. 55,000 Crore in State Sector and Rs.5,000 Crore in Private Sector). In the Central Sector, there is no problem of capital resources for setting up transmission facilities. However, in the State Sector some of the STUs require financial support, especially for building transmission system for renewable energy sources such as wind, solar and small hydro. In case of conventional hydro and renewable generation, the plant load factor is low and as a result the cost of transmission per kWh becomes high. Therefore, it is proposed that viability gap funding may be provided on case to case basis for building intra-State transmission system for renewable generation and conventional hydro stations.

Investment through Private Sector participation in development of transmission system during 12th Plan Period: It may be noted that transmission schemes for the projects identified for 12th Plan have been mostly planned, firmed up in the Standing Committees for Power System Planning and the transmission agreements (BPTA) have been signed with the CTU as the nodal agency for Long Term Transmission Access to ISTS prior to the cut-off date of 5th January 2011. As such most of the ISTS schemes would be implemented by POWERGRID as central sector schemes. In addition Dedicated Transmission Lines from the inter-State Generating Stations would mostly be built by the generation developers as private sector lines. Some schemes, under the direction of the Empowered Committee for developing ISTS through competitive bidding have been identified and are in the various stages of implementation. These would materialize during 12th Plan period. Further, barring a few exceptions, new transmission schemes required for system strengthening, drawl of power by the states and for power evacuation to be identified in future would be implemented through competitive bidding process as far as possible. POWERGRID would also participate in the competitive bidding. Similarly in the State sector also it is likely that majority of the schemes during 12th Plan period would be implemented by the STUs.

XII. TRANSMISSION EXPANSION ASSESSMENT FOR 13TH PLAN

As explained above, transmission system for a number of generation projects have been planned under the LTA process, majority of which are expected to materialize during 12th Plan and the rest would be implemented during 13th Plan depending upon actual progress of the generation project. Based on progress and development of generation projects and transmission system during 12th Plan, some of the already planned transmission systems would have to be reviewed. This review would be carried out along with planning for new transmission requirements for specific generation projects coming in 13th Plan. Under such scenario, only a broad assessment of transmission capacity addition for 13th Plan can be made considering probable load growth and indicative generation capacity addition scenarios or 13th Plan. Accordingly, following assessment has been made for transmission capacity addition during 13th Plan period:

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Table 4: Transmission Capacity Expansion in 13th Plan

Transmission capacity addition for 13th Plan (220kV and above system)		
S.No	**Item**	**Expansion / requirement**
1	Transmission lines	130 Thousand ckm
2	Substation (Transformation) Capacity	300 Thousand MVA
3	Fund requirement	Rs 200,000 Crore

XIII. MEETING CHALLENGES IN TRANSMISSION SECTOR

In order to meet the growing power demand of various regions, power transfer capacity of the grid is being enhanced continuously. This expansion poses few challenges that need to be met through planning and adoption of new technologies. Following are some of the challenges:

- Right Of Way (ROW)
- Flexibility in Line Loading and Regulation of Power
- Improvement of Operational Efficiency

Following measures are being implemented to meet above challenges:

Increase in transmission voltage: Power density of transmission corridors (MW per meter ROW) is being enhanced by increasing the voltage level. It is 3 MW/m for 132kV and 45 MW/m for 765kV. Transmission voltage upto 765kV level are already in operation. A ±800 kV, 6000 MW HVDC system as a part of evacuation of bulk power from North Eastern Region (NER) to Northern Region (NR) over a distance of around 2000 km is under implementation. In addition, increasing the AC voltage level at 1200kV level has been planned. Research work for 1000kV HVDC system has also been commenced.

Upgradation of transmission line: Upgradation of 220kV D/C Kishenpur- Kishtwar line in J&K to 400 kV S/c, which was first time in India, has resulted in increase of power transfer capacity of the exist transmission corridor with marginal increase in ROW (from 35m to 37m).

Upgradation of HVDC Terminal: Upgradation of Talcher(ER) – Kolar(SR) 500kV HVDC terminal from 2000MW to 2500MW has been achieved seamlessly without changing of any equipment. That has been achieved with enhanced cooling of transformer and smoothing reactor with meager cost.

High capacity 400kV multi-circuit/bundle conductor lines: POWERGRID has designed & developed multi circuit towers (4 Circuits on one tower with twin conductors) in-house and the same are implemented in many transmission systems, which are passing through forest and RoW congested areas e.g. Kudankulam and RAPP-C transmission system.

High Surge Impedance Loading (HSIL) Line: In order to increase the loadability of lines, development of HSIL technology is gaining momentum. POWERGRID is building up one HSIL line viz. 400kV Meerut – Kaithal D/c where SIL is about 750 MW as against nominal 650MW for a normal quad bundle conductor line.

Compact towers: Compact towers like delta configuration, narrow based tower etc. reduce the space occupied by the tower base are being used. First 765kV Sipat – Seoni 2xS/c line with delta configuration tower is under operation. Further, 400kV Pole structure is also being used in high population density areas. Pole type structures with about 1.85 m base width as against 12-15m base width of a conventional tower were used in transmission line approaching Maharani Bagh, Delhi substation to address Right-of-way problem in densely populated urban area.

Increase in current: High Temperature Low Sag (HTLS) conductor line: High temperature endurance conductor to increase the current rating are in use for select transmission corridors and urban/metro areas. POWERGRID has already implemented twin INVAR conductor line for LILO portion (15kms stretch) of 400kV Dadri-Ballabgarh quad conductor line at Maharanibagh substation. Further, the Siliguri – Purnea, twin Moose conductor line is being re-conductored with high temperature low sag (HTLS) conductor.

Reduction in land for substation: With scarce land availability there is a growing need for reduction of land use for setting up of transmission systems, particularly in Metros, hilly and other urban areas. Gas Insulated Substations (GIS), requires less space (about 70% reduction) i.e. 8-10 acres as compared to conventional substation which generally requires 30-40 acres area.

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Regulation in Power Flow/ FACTS devices: With electricity market opening up further, more and more need has been felt to utilize the existing assets to the fullest extent as well as regulate the power. This could be possible through use of power electronics in electricity network.

Improvement of operational efficiency by Condition Based Monitoring: POWERGRID has adopted many state of the art condition monitoring & diagnostic techniques such as DGA, FRA, PDC, RVM etc. for transformers, DCRM for CBs, Third Harmonic Resistive current measurement for Surge Arrestors etc. to improve Reliability, Availability & Life Extension. Further, on-line monitoring systems for transformers have been implemented to detect faults at incipient stage and provide alarms in advance in case of fault in the transformers.

Preventive Maintenance: Preventive State-of-the-art maintenance techniques for various equipment applied in our system include on line monitoring of various components of transformers and reactors, Circuit Breakers, Instrument transformers, lightening arrester etc.

1200kV Test Station: In order to increase the power density of the corridor, development of 1200kV AC system as next higher AC voltage level has been decided. However, 1200kV AC technology is relatively a new one in the world. Therefore, to develop this technology indigenously, a unique effort has been made by POWERGRID through a collaborative research between POWERGRID and Indian manufacturers to establish a 1200kV UHVAC Test Station.

XIV. CONCLUSION

In this paper objectives and need of Long Term Transmission Expansion Planning are discussed. Assessment of load forecasting, generation growth, social economic constraints and environmental impacts required for Transmission Expansion Planning are explained. Tools and methodologies required for transmission planning and transmission system performance criteria are elucidated. Existing transmission facilities available in India are presented and also suggested different LTEP methodologies for Indian Power System. Transmission growth and expected growth during 11th plan and 12th plan and 13th plan are discussed.

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