

Issues for discussion on transmission planning criteria

1. Reliability criteria for contingencies:

In the present planning manual, generally the n-1 reliability criteria is prescribed. In the National Electricity Plan (NEP 2007), the criteria of n-1 to withstand without load shading or re-scheduling of generation during study state operation is mentioned whereas the 'n-2' is prescribed with re-scheduling of generation.

There is need to review this criteria considering options like n-1, n-2, n-g-1, n-1-1 etc separately for inter-regional / regional/ intra-state/ or system that feeding major load centres like metro cities/ industrial complexes.

2. Consideration of various types of line/conductor configurations:

In the present manual, only ACSR Moose/Bersimis or AAAC conductors for 400kV and 765kV voltage level are listed. With the need and advent of (i) new conductors like AL-59, HTLS, INVAR, (ii) line configurations like Hexa Zebra, triple snowbird etc, or (iii) maximum conductor temperature up to 95 degree centigrade for ACSR/AAAC, there is now need to revise the planning manual considering various types of available conductors, line configuration or tower configurations and possible maximum conductor temperatures.

3. Assumptions for calculating thermal ampacity of lines :

Assumptions for calculating thermal ampacity in the present manual is given as below:

- a. Solar Radiations = 1045W/Sq.mt
- b. Wind Velocity = 2 km/hour
- c. Absorption Coeff=0.8
- d. Emissive Coeff=0.45
- e. Ambient Temperature= Varying from 40 to 50 °C.

The above assumptions are to be reviewed for future planning requirements.

4. Criteria of assumption of fault level:

Under Annex-V of the manual it is mentioned that –

“For Short circuit studies transient reactance (X'_d) of the synchronous machines shall be used. [Although sub-transient reactance (X''_d) is generally lower than transient reactance and therefore short circuit levels computed using X''_d shall be higher than those computed using X'_d . but since circuit breaker would operate only after 100 msec from fault initiation, the effect of sub-transient reactance would not be present.] For short circuit studies for asymmetrical faults vector group of transformers shall be considered. Inter-winding reactances in case of three winding transformers shall also be considered. For evaluating short circuit levels at generating bus (11 kV, 13.8 kV etc.) that unit along with its unit transformer shall be represented separately.”

The above criteria may be reviewed. In addition to the assessment of maximum fault level, there is also a requirement to assess fault level under various load-generation scenarios.

5. (a) Voltage limits:

The present manual prescribe steady state voltage limits, temporary over-voltage and switching over-voltages, as given below:

VOLTAGE (kV rms)		
Nominal	Maximum	Minimum
765	800	728
400	420	380
220	245	198
132	145	122

TEMPORARY OVERVOLTAGES due to sudden load rejection.

420 kV system 1.5 p.u. peak phase to neutral (343kV=1 p.u.)

800 kV system 1.4p.u. peak phase to neutral (653kV=1 p.u.)

SWITCHING OVERVOLTAGES

420 kV system 2.5 p.u. peak phase to neutral (343 kV= 1 p.u.)

800 kV system 1.9 p.u. peak phase to neutral (653 kV= 1 p.u.)

The above voltage limits may be reviewed.

(b) Voltage stability assumption criteria:-

The present manual prescribes that (section 2.2) Voltage stability, oscillatory stability and EMTP studies may not form part of perspective planning studies. These are however required to be done before any scheme report is finalised. Further it says that (section 6.3) - each bus shall operate above knee point of Q-V curve under normal as well as the contingency conditions.

The above position/approach is required to be reviewed and there should be specific criteria for carrying out voltage stability studies and margins.

6. Criteria for providing VAr compensation:

The present manual, regarding MVar/power factor provides some guidance for reactive power management/compensation, as given below:

Section 3.2.3 – *“Recognizing the fact that this data is presently not available it is suggested that pending availability of such data, the load power factor at 220/132KV voltage levels shall be taken as 0.85 lag during peak load condition and 0.9 lag during light load condition excepting areas feeding predominantly agricultural loads where power factor can be taken as 0.75 and 0.85 for peak load and light load conditions respectively. In areas where power factor is less than the limit specified above, it shall be the responsibility of the respective utility to bring the load power factor to these limits by providing shunt capacitors at appropriate places in the system.”*

Section 2.9 – *“Reactive power flow through ICTs shall be minimal. Normally it shall not exceed 10% of the rating of the ICTs. Wherever voltage on HV side of ICT is less than 0.975 pu no reactive power shall flow through ICT.”*

Section 7.1 – *“Shunt Capacitors: Reactive Compensation should be provided as far as possible in the low voltage systems with a view to meeting the reactive power requirements of load close to the load points thereby avoiding the need for VAR transfer from high voltage system to the low voltage system. In the cases where network below 132/220 kV Voltage level is not represented in the system planning studies, the shunt capacitors required for meeting the reactive power requirements of loads shall be provided at the 132/220 kV buses.”*

Section 2.10 – *“Thermal/Nuclear Generating units shall normally not run at leading power factor. However, for the purpose of charging generating unit may be allowed to operate at leading power factor as per the respective capability curve.”*

Section 7.2 – *“Shunt Reactors : Switchable reactors shall be provided at EHV substations for controlling voltages within the limits defined in the Para 5 without resorting to switching-off of lines. The size of reactors should be*

such that under steady state condition, switching on and off of the reactors shall not cause a voltage change exceeding 5%. The standard sizes (MVAR) of reactors are

400 kV (3-ph units)	50, 63 & 80 at 420 kV
765 kV (1-ph units)	50, 63 & 110 at 800 kV

Fixed line reactors may be provided to control Temporary Power Frequency overvoltage [after all voltage regulation action has taken place] within the limits as defined in para 5 under all probable operating conditions. Line reactors (switchable/controlled fixed) may be provided if it is not possible to charge EHV line without exceeding the voltage limits defined in para 5. The possibility of reducing pre-charging voltage of the charging end shall also be considered in the context of establishing the need for reactors.”

Section 7.3 – “Static VAR Compensation (SVC): *Static Var Compensation shall be provided where found necessary to damp the power swings and provide the system stability under conditions defined in the para 6 on "security Standards ". The dynamic range of static compensators shall not be utilized under steady state operating condition as far as possible.”*

The above provisions in the existing planning manual though scattered under various sections, provide useful guidance for planning of reactive power management. Nevertheless, these criteria may be reviewed.

7. Load Generation Scenario assumption for planning states:-

The planning criteria recommends for carrying out system studies correspondence to the scenarios of - Annual Peak Load, Maximum Thermal Generation, Maximum Hydro, Annual Minimum Load, Special Area Dispatch, Dispatch for high agricultural load, Off Peak condition with pumps storage conditions and complete closer of generating states close to major load centers. In the NEP 2007, it is recommended to carry out systems studies for this scenario that is Summer Peak, Summer Off Peak, Winter Peak, Winter Off Peak, Monsoon Peak, Monsoon Off Peak.

There is a need to discuss more scenarios in the light of synchronous operation of all India Grid and large scale integration of renewable energy sources.

8. Sub-station planning criteria and bus-fault considerations:

The present Planning Manual prescribes that capacity of any single sub-station at 220 kV shall not exceed 320 MVA, 1000 MVA for 400 kV and 2500 MVA for 765 kV. It also recommends that the rated breaking capacity of switchgear at both 400 kV and 765 kV may be taken as 40 kA. The manual also provided that a

stuck breaker condition shall not cause disruption of more than four feeders for 220 kV system and two feeders for 400 kV system and one feeder for 765 kV system. These figures need review.

There has also been a suggestion to consider bus fault as contingency criteria while planning the transmission system. Though, this suggestion has economic considerations yet it should be debated at the time of review of planning criteria.

9. Considerations for voltage and frequency dependency of load

The load incident on 220 kV or 132 kV is a composite load consisting of lighting, agricultural, industrial, railway, etc loads. The load has dependence on voltage and frequency. Presently, this dependence is not considered for study state studies. While carrying out transient stability studies, some factors are assumed. There is a need to specify the factors/functions relating both active and reactive loads (MW and MVAR) with voltage and frequency for steady state as well as for transient studies.

10. Assumptions for load power factor:-

The present manual prescribes as follows:

“For developing an optimal power system, the utilities must clearly spell out the substation-wise maximum and minimum demand in MW and MVAR on seasonal basis. This will require compilation of past data in order to arrive at reasonably accurate load forecast. Recognizing the fact that this data is presently not available it is suggested that pending availability of such data, the load power factor at 220/132KV voltage levels shall be taken as 0.85 lag during peak load condition and 0.9 lag during light load condition excepting areas feeding predominantly agricultural loads where power factor can be taken as 0.75 and 0.85 for peak load and light load conditions respectively. In areas where power factor is less than the limit specified above, it shall be the responsibility of the respective utility to bring the load power factor to these limits by providing shunt capacitors at appropriate places in the system.”

There is a need to review the above provisions both for long –term planning and medium term studies.

11. Peaking capability of generating stations:

Annexe-1 in the planning manual lists availability norms for thermal nuclear hydro and gas stations to arrive at peaking availability of generating units for working

out load generation balance to be used in power system studies. The norms and the approach as given in the present manual (3.3.1 of manual) require a review.

12. Transient stability criteria:

The manual provides to carry out transient stability studies considering that-

- The system shall remain stable under the contingency of a temporary single-phase-to-ground fault on a 765 S/C kV line close to the bus assuming single pole opening of the faulted phase from both ends .in 100 ms (5 cycles) and successful reclosure (dead time 1 sec).
- For 400kV S/C line, the system should be capable of withstanding a permanent fault, with single pole opening (100 ms) followed by unsuccessful reclosure (dead time 1 sec) followed by 3 pole opening.
- For 400 kV D/C line, the system should be capable of withstanding a permanent fault on one of the circuits when both circuits are in service and a transient fault when the system is already depleted with one circuit under maintenance/outage.

These provision require a review as it not generally not being followed and also as recommended by PTI in 1995.

13. Considerations for nuclear plan:

The present manual prescribes that (Section 2.6 and 2.7) in case of transmission system associated with Nuclear Power Stations there shall be two independent sources of power supply for the purpose of providing start-up power facilities. Further the angle between start-up power source and the NPP switchyard should be, as far as possible, maintained within 10 degrees. The evacuation system for sensitive power stations viz., Nuclear Power Stations, shall generally be planned so as to terminate it at large load centers to facilitate islanding of the power station in case of contingency.

The NEP provides that for requirement of reliability, the transient system for Nuclear power station is planned considering outage of one circuit assuming pre-contingency depletion of another circuit from the same station. This is effectively N-2 without rescheduling but with no other pre-contingency.

These aspects require discussion and review.

14. Considerations for wind and solar plans:

Special criteria for planning transmission system for wind and solar generations considering their special nature i.e. intermittency and induction generator/inverter

and their impact on grid operation required to be introduced in the planning criteria.

15. Assessment of Margins:

The planning criteria needs to mention the margins for line loadings, fault levels, voltage stability margins etc both for long term medium term and short term time frames. It requires deliberation.

16. TTC calculation procedure and assumptions:

Presently TTC is calculated for medium and short term time frames for region to region transfers. There is need to assess TTC for planning time frame as well, and also for State to State transfers. The planning manual may mention criteria for base case preparation, procedure and assumptions for calculating TTC for these time frames.

17. Permissible line loading limit:

The present planning criteria mentions the following for assessing permissible line loading limits:

“Permissible line loading limit depend on many factors such as voltage regulation, stability and current carrying capacity (thermal capacity) etc. While Surge Impedance Loading (SIL) gives a general idea of the loading capability of the line, it is usual to load the short lines above SIL and long lines lower than SIL (because of the stability limitations). SIL at different voltage levels is given at Annex -II. Annex-II also shows line loading (in terms of surge impedance loading of uncompensated line) as a function of line length assuming a voltage regulation of 5% and phase angular difference of 30⁰ between the two ends of the line. In case of shunt compensated lines, the SIL will get reduced by a factor k, where

$$k = \sqrt{(1-\text{degree of compensation})}$$

For lines whose permissible line loading as determined from the curve higher than the thermal loading limit, permissible loading limit shall restricted to thermal loading limit. Thermal loading limits are generally decided by design practice on the basis of ambient temperature, maximum permissible conductor temperature. Wind velocity, etc. In India the ambient temperatures obtaining in the various parts of the country are different and vary considerably during the various seasons of the year. Designs of transmission line with ACSR conductors in EHV systems will normally be based on a conductor temperature limit of 75⁰C. However, for some of the existing lines which have been designed for a conductor temperature of 65⁰C the loading shall be correspondingly reduced. In the case of AAAC conductors, maximum conductor

temperature limit will be taken as 85⁰C. The maximum permissible line loadings in respect of standard sizes of ACSR and AAAC conductors employed in EHV transmission lines for different ambient temperatures and different maximum conductor temperatures are given in Annex-III and the same can be followed if permitted by stability and voltage regulation consideration.”

The above methodology needs to be reviewed so as to incorporate assessment of line loadabilities through simulation studies instead of using thumb-rule based assessment using St. Clair curve (Annex-II of the Manual). As fast system study/analysis software is available to planners and dispatcher (in comparison to the time when St. Clair curve was proposed in 1953), the appropriate simulation studies and analysis (load flow/ voltage stability/ transient stability etc) can be used to allow line loadings up to thermal ampacity limit if permitted by stability and voltage regulation considerations. Therefore, it is proposed to drop the St. Clair curve as guiding criteria, and instead use the studies to check violation of thermal, voltage and stability criteria.

18. Integrated planning for State transmission system:

As per section 39 of the Electricity Act, STUs need to carry out their planning function related to intra-state transmission in coordination with the CEA and CTU. There have been a few instances in the past where, the STU has planned important transmission system or allowed connectivity to large generation capacities without involving CEA and CTU and this may result in congestion/operational difficulties for the ISTS/national grid. To start with, it is proposed that STU should evolve following of their systems involving CEA and CTU, which would subsequently be firmed up through the Standing Committee forum:-

- (a) 400 kV and above system
- (b) Large scale harnessing of renewable generation
- (c) System for evacuation of power from a complex having generation capacity of 500 MW above.

19. Any other issues that may have to be reflected in the planning criteria.
