MANUAL ON TRANSMISSION PLANNING CRITERIA

GOVERNMENT OF INDIA
MINISTRY OF POWER
CENTRAL ELECTRICITY AUTHORITY

NEW DELHI
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सत्यमेव जयते

सदस्य
तथा पदेन अतिरिक्त सचिव भारत सरकार
केन्द्रीय विद्युत प्राधिकरण

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नई दिल्ली-110066 22nd June 1994

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The power transmission network of the country owned by the State Electricity Boards and Central Sector Organisations fully integrated with each other presently stands unique in terms of its vastness. We have today over 29,000 ckt kms of EHV lines at 400 kV and above including 1634 ckt kms of HVDC besides 1,90,000 ckt kms of lines at 220 kV and below. The grid system is rapidly expanding and transmission lines in the 800 kV class are in the process of being introduced. A centrally owned and operated National Power Grid is also getting established. The need for defining Transmission System Planning Criteria keeping in view the specific needs of the country and the international developments in this field has assumed added significance in this context.

A modest effort was made by CEA in 1985, when a ' Manual on Transmission Planning Criteria' was brought out incorporating the views and suggestions received from the different Power Utilities in the country. It was also envisaged then that in course of time this manual should be reviewed and revised, if necessary, on the basis of experience and advancements in the transmission technology. Accordingly a committee was constituted in June 1992 under the chairmanship of Member (Power System), CEA to review the existing manual and bring out a new document incorporating the feed back and experience gained on EHV transmission system till date. The present document is the result of efforts put in by this committee. CEA have also had the benefit of consultations with Sh. Mata Prasad, Advisor NTPC, Dr. M. Ramamurthy, Director General CPRI, Dr K. Parthasarathy, Professor Electrical Engineering, Indian Institute of Science and Mr Giancarlo Manzoni, Chairman SC37 CIGRE.

The criteria and guidelines described in the document are to be used in the planning and design of interconnected power system in such a way that the objectives of efficient transmission system are achieved to provide a good service while operating the power system in an integrated mode. It will be the responsibility of individual beneficiaries, utilities in the state and central sector to ensure that it is planning and designing the system conforming to these criteria. Any deviation will have to be formally documented and its ramification adequately highlighted..

It is hoped that the power utilities in the country will find this manual useful in developing a strong and reliable power transmission network for the country.

H. C. Mital

(H.C. MITAL)
MEMBER (POWER SYSTEMS)

CONTENTS

PREAMBLE

The objective of system planning is to evolve a power system with a level of performance characterised by an acceptable degree of adequacy and security based on a trade-off between costs and risks involved. Insofar as power transmission systems are concerned, there are no widely adopted uniform guidelines which determine the criteria for transmission planning vis-a-vis acceptable degree of adequacy and security. The criteria generally depends on the factors such as availability of generation vis-a-vis demand, voltage levels, size and configuration of the system, control and communication facilities, and resource constraints. Practices in this regard vary from country to country. The common theme in the various approaches is the "acceptable system performance". Even though the factors affecting system performance are probabilistic in nature, deterministic approach has been used most commonly, being rather easy to apply. For adopting probabilistic approach, long operating experience and availability of reliable statistical data regarding performance of system components, namely equipment failure rate, outage duration, etc. are essential. Such data are presently being compiled by a few utilities; but these are still inadequate to go in for a totally probabilistic approach. Hence it is considered prudent to adopt a deterministic approach for the present with a committed thrust towards progressive adoption of probabilistic approach (An Action Plan for adoption of probabilistic approach has been initiated). Keeping in line with the above broad approach, this manual covers the planning criteria proposed to be used in evolving power transmission system on regional basis (EHV AC - 132 kV & above and HVDC), ultimately leading to an All India Power Grid.

A brief write-up on Operational Standards and Data preparation for transmission planning studies is also annexed to the manual.

1. SCOPE

The Planning Criteria detailed herein are primarily meant for Long Term Perspective (10 years and above) and Medium Term (5-10 years) Transmission Planning Studies of large inter-connected power systems.

1.2 The manual covers in detail the planning philosophy, load demands and generation despatches to be considered and security standards. It also indicates the broad scope of system studies and gives guide-lines for provision of reactive compensation and for planning of substations as are relevant to perspective transmission system planning. A list of definitions of terms used in the manual is also appended.

2. PLANNING PHILOSOPHY & GENERAL GUIDELINES

2.1 The transmission system shall be planned on the basis of regional self-sufficiency with an ultimate objective of evolving a National Power Grid. The regional self-sufficiency criteria based on load generation balance may still dictate to have inter-regional exchanges with adequate inter-connection capacity at appropriate points taking into account the topology of the two networks, the plant mix consideration, generation shortages due to forced outages, diversity in weather pattern and load forecasting errors in either regions. Such inter-regional power exchanges shall also be considered in these studies.

2.2 The system shall be evolved based on detailed power system studies which shall include

i) Power Flow Studies

ii) Short Circuit Studies

iii) Stability Studies (including transient stability, voltage stability and steady state oscillatory stability studies)

iv) EMTP Studies to determine switching / temporary overvoltages

***Note:** 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.*

2.3 The adequacy of the transmission system should be tested for different feasible load generation scenarios as detailed in para 3.

2.4 The following options may be considered for stengthening of the transmission network.

- Addition of new Transmission lines to avoid overloading of existing system. (Whenever three or more circuits of the same voltage class are envisaged between two sub stations, the next transmission voltage should also be considered.)

- Application of Series Capacitors in existing transmission line to increase power transfer capability.

- Upgradation of the existing AC transmission lines

- Reconductoring of the existing AC transmission line with higher size conductors or with AAAC.

- Adoption of multi-voltage level and multi-circuit transmission lines.

The choice shall be based on cost, reliability, right-of-way requirements, energy losses, down time (in case of upgradation and reconductoring options) etc. The adoption of existing or emerging semi conductor based technology (e.g. FACTS) in transmission upgradation may also be kept in view.

2.5 In case of generating station close to a major load centre, sensitivity of its complete closure with loads to be met (to the extent possible) from other generating stations (refer para 3.3.3) shall also be studied.

2.6 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.

2.7 The evacuation system for sensitive power stations viz., Nuclear Power Stations, shall generally be planned so as to terminate it at large load centres to facilitate islanding of the power station in case of contingency.

2.8 Where only two circuits are planned for evacuation of power from a generating station, these should be (as far as possible) two single circuit lines instead of a double circuit line.

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.

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.

2.11 Inter-regional links shall, in the present context, be planned as asynchronous ties unless otherwise permitted from operational consideration.

3. LOAD-GENERATION SCENARIOS

3.1 The load-generation scenarios shall be worked out so as to reflect in a pragmatic manner the daily and seasonal variations in load demand and generation availability.

3.2 LOAD DEMANDS

3.2.1 The profile of annual and daily demands will be determined from past data. These data will usually give the demand at grid supply points and for the whole system identifying the annual and daily peak demand.

3.2.2 Active Power (MW)

The system peak demands shall be based on the latest reports of Electric Power Survey (EPS) Committee. In case these peak load figures are more than the peaking availability, the loads will be suitably adjusted substation-wise to match with the availability. The load demands at other periods (seasonal variations and minimum loads) shall be derived based on the annual peak demand and past pattern of load variations.

From practical considerations the load variations over the year shall be considered as under:

- Annual Peak Load

- Seasonal variation in Peak loads (corresponding to high thermal and high hydro generation)

- Minimum load.

- Off -Peak Load relevant where Pumped Storage Plants are involved or inter-regional exchanges are envisaged.

3.2.3 Reactive power (MVAR)

Reactive power plays an important role in EHV transmission system planning and hence forecast of reactive power demand on an area-wise or substation-wise basis is as important as active power forecast. This forecast would obviously require adequate data on the reactive power demands at the different substations as well as the projected plans for reactive power compensation.

For developing an optimal power system, the utilities must clearly spell out the substation-wise maximum and minimum demand in MWs and MVARs on seasonal basis. This will require compilation of past data in order to arrive at reasonably accurate load forecast. Recognising 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.

3.3 GENERATION DESPATCHES

3.3.1 Generation despatch of Hydro and Thermal/Nuclear units would be determined judiciously on the basis of hydrology as well as scheduled maintenance program of the Generating Stations. The norms for working out the peaking availability of different types of generating units is given at Annex I. In case of nuclear units the minimum level of output shall be taken as not less than 70% of the rated capacity.

3.3.2 Generation despatches corresponding to the following operating conditions shall be considered depending on the nature and characteristics of the system

- Annual Peak Load
- Maximum thermal generation
- Maximum hydro generation
- Annual Minimum Load
- Special area despatches
- Special despatches corresponding to high agricultural load with low power factor, wherever applicable

- Off peak conditions with maximum pumping load where Pumped Storage stations exist and also with the inter-regional exchanges, if envisaged

- Complete closure of a generating station close to a major load centre.

3.3.3 The generation despatch for purpose of carrying out sensitivity studies corresponding to complete closure of a generating station close to a major load centre shall be worked out by increasing generation at other stations to the extent possible keeping in view the maximum likely availability at these stations, ownership pattern, shares, etc.

4. PERMISSIBLE LINE LOADING LIMITS

4.1 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 30^0 between the two ends of the line. In case of shunt compensated lines, the SIL will get reduced by a factor k, where

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

For lines whose permissible line loading as determined from the curve is higher than the thermal loading limit, permissible loading limit shall be restricted to thermal loading limit.

4.2 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 75 ° C. However, for some of the existing lines which have been designed for a conductor temperature of 65 ° C the loading shall be correspondingly reduced. In the case of AAAC conductors, maximum conductor temperature limit will be taken as 85 ° C. 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.

5. STEADY STATE VOLTAGE LIMITS

The steady state voltage shall be maintained within the limits given below

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

Note : The step change in voltage may exceed the above limits where simultaneous double circuit outages of 400 kV lines are considered. In such cases it may be necessary to supplement dynamic VAR resources at sensitive nodes.

TEMPORARY OVERVOLTAGES due to sudden load rejection .
420 kV system 1.5 p.u. peak phase to neutral (343 kV = 1 p.u.)
800 kV system 1.4 p.u. peak phase to neutral (653 kV = 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.)

6. SECURITY STANDARDS:

6.1 The security standards are dictated by the operational requirements. A brief write-up on the same is given at Annex -IV.

For the purpose of transmission planning the following security standards shall be followed:

6.2 STEADY STATE OPERATION

i) As a general rule, the EHV grid system shall be capable of withstanding without necessitating load shedding or rescheduling of generation , the following contingencies:

- Outage of a 132 kV D/C line or,
- Outage of a 220 kV D/C line or,
- Outage of 400 kV single circuit line or,
- Outage of 765 kV single circuit line or
- Outage of one pole of HVDC Bipolar line or
- Outage of an Interconnecting Transformer

The above contingencies shall be considered assuming a pre-contingency system depletion (planned outage) of another 220 kV double circuit line or 400 kV single circuit line in another corridor and not emanating from the same substation. All the generating plants shall operate within their reactive capability curves and the network voltage profile shall also be maintained within voltage limits specified in para 5.

ii) The power evacuation system from major generating station/ complex shall be adequate to withstand outage of a 400 kV Double Circuit line if the terrain indicates such a possibility.

iii) In case of large load complexes with demands exceeding 1000 MW the need for load shedding in the event of outage of a 400 kV Double circuit line shall be assessed and kept minimum. System strengthening required, if any, on account of this shall be planned on an individual case-to-case basis.

iv) The maximum angular separation between any two adjacent buses shall not normally exceed 30 degrees.

6.3 STABILITY CONSIDERATIONS

A. Transient Stability

i) The system shall remain stable under the contingency of outage of single largest unit.

ii) 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 s/ in 100 msec (5 cycles) and successful reclosure (dead time 1 sec).

iii) The system shall be able to survive a single phase-to-ground fault on a 400 kV line close to the bus as per following criteria:

<u>A. 400 kV S/C line :</u> System shall be capable of withstanding a permanent fault. Accordingly, single pole opening (100 msec) of the faulted phase and unsuccessful reclosure (dead time 1 sec.) followed by 3-pole opening (100 msec) of the faulted line shall be considered.

<u>B. 400 kV D/C line :</u> System shall 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. Accordingly, 3 pole opening (100 msec) of the faulted circuit shall be considered when both circuits are assumed in operation (single pole opening and unsuccessful auto-reclosure is not considered generally in long 400 kV D/C lines since the reclosure facility is bypassed when both circuits are in operation, due to difficulties in sizing of neutral grounding reactors) and single pole opening (100 msec) of the faulted phase with successful reclosure (dead time 1 sec) when only one circuit is in service.

iv) In case of 220/132 kV networks, the system shall be able to survive a three-phase fault with a fault clearing time of 160 msec (8 cycles) assuming 3-pole opening.

v) The system shall be able to survive a fault in HVDC converter station resulting in permanent outage of one of the poles of HVDC Bipoles

Besides the above the system may also be subjected to rare contingencies like outage of HVDC bipole, delayed fault clearance due to stuck breaker conditions etc. The impact of these on system stability may also be studied while working out the defence mechanisms required in system operation such as load shedding, generation rescheduling, islanding, etc.

B. Voltage stability

Each bus shall operate above knee point of Q-V curve under normal as well as the contingency conditions as discussed above in para 6.2.

C. Steady State Oscillatory Stability

The steady state oscillatory stability may be evaluated through Eigen-value analysis. In case all the real parts of Eigen-values of linearized system matrix are negative, the system may be considered to have steady state oscillatory stability.

7. REACTIVE POWER COMPENSATION

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.

7.2 Shunt Reactors

7.2.1 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

7.2.2 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.

7.2.3 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.

7.3 Static VAR Compensation (SVC)

7.3.1 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.

8. SUB-STATION PLANNING CRITERIA

8.1 The requirements in respect of EHV sub-stations in a system such as the total load to be catered by the sub-station of a particular voltage level, its MVA capacity, number of feeders permissible etc. are important to the planners so as to provide an idea to them about the time for going in for the adoption of next higher voltage level sub-station and also the number of substations required for meeting a particular quantum of load. Keeping these in view the following criteria have been laid down for planning an EHV substation:

8.2 The maximum fault level on any new substation bus should not exceed 80 % of the rated rupturing capacity of the circuit breaker. The 20% margin is intended to take care of the increase in short-circuit levels as the system grows. The rated breaking current capability of switchgear at different voltage levels may be taken as -

132 kV	-	25/31kA
220 kV	-	31.5/40 kA
400 kV	-	40kA
765 kV	-	40kA

8.3 Higher breaking current capability would require major design change in the terminal equipment and shall be avoided as far as possible.

8.4 The capacity of any single sub-station at different voltage levels shall not normally exceed :

765 kV	2500 MVA
400 kV	1000 MVA
220 kV	320 MVA
132 kV	150 MVA

8.5 Size and number of interconnecting transformers (ICTs) shall be planned in such a way that the outage of any single unit would not over load the remaining ICT(s) or the underlying system.

8.6 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.

DEFINITIONS

1. **System Elements** : All switchable components of a transmission system such as Transmission lines, transformers, reactors etc.

2. **Contingency :** Temporary removal of one or more system elements from service. The cause or reason for such removal may be a fault, planned maintenance/repair etc.

   i) **Single Contingency :** The contingency arising out of removal of one system element from service .

   ii) **Double Contingency :** The contingency arising out of removal of two system elements from service. It includes a D/C line, two S/C lines in same corridor or different corridors, a S/C line and a transformer etc.

   iii) **Rare contingency** : Temporary removal of complete generating station or complete sub-station (including all the incoming & outgoing feeders and transformers) from service, HVDC bipole and stuck breaker condition.

3. **Annual Peak Load :** It is the simultaneous maximum demand of the system being studied. It is based on latest Electric Power Survey (EPS) or total peaking power availability, whichever is less.

4. **Minimum Load :** It is the expected minimum system demand and is determined from average ratio of annual peak load and minimum load observed in the system for the last 5 years .

5. **Maximum Hydro Generation :** It is the condition when hydro power availability is maximum during the year. It is also known as High Hydro condition.

6. **Maximum Thermal Generation** : It is the condition when hydro generation is low (not necessarily minimum) and thermal generation is kept maximum to meet seasonal peak loads (not necessarily annual peak load). In other words it is the condition when the gap between monthly peak demand and hydro power availability is maximum.

7. **Special Area Despatch** : It is the condition when power output form all the generating stations located in a area (in close proximity) is kept at the maximum feasible level.

   Maximum Feasible Level of a generating station is the maximum power output when all the units in a power station are in service assuming no planned or forced outages. However, in case of power station/complex where six or more units exist, for every six units one unit - second largest - is assumed to be under annual planned maintenance.

   Illustration: *While preparing special area despatch for Vindhyachal (6X210 MW + 2X500 MW) & Korba (3X200 MW + 2X500 MW) complex, one unit of 210 MW is assumed as under maintenance at Vindhyachal and one unit of 200 MW at Korba.*

8. **System Stability :** A stable power system is one in which synchronous machines, when perturbed, will either return to their original state if there is no change in exchange of power or will acquire new state asymptotically without losing synchronism. Usually the perturbation causes a transient that is oscillatory in nature, but if the system is stable the oscillations will be damped.

9. **Damping :** A system is said to be adequately damped when halving time of the least damped electro-mechanical mode of oscillation is not more than 5 seconds.

10. **Oscillatory Stability:** When voltage or rotor angle oscillations are positively damped following a grid disturbance, the system is said to have oscillatory stability.

11. **Voltage Stability :** It is the ability of a system to maintain voltage so that when load admittance is increased, load power will also increase so that both power and voltage are controllable.

12. **Transient Stability** : This refers to the stability following a major disturbance (faults, opening of a major line, tripping of a generator) and relates to the first few swings following disturbance.

13. **Temporary overvoltages** : These are power frequency overvoltages produced in a power system due to sudden load rejection, single-phase-to -ground faults, etc.

14. **Switching overvoltages :** These overvoltages generated during switching of lines, transformers and reactors etc. having wave fronts 250/2500 micro sec.

15. **Surge Impedance Loading** : It is the unit power factor load over a resistance line such that series reactive loss (I^2X) along the line is equal to shunt capacitive gain (V^2Y). Under these conditions the sending end and receiving end voltages and current are equal in magnitude but different in phase position.

16. **Thermal capacity of line:** It is the amount of current that can be carried by a line conductor without exceeding its design operating temperature .

ANNEX-I

(refer para 3.3.1)

PEAKING CAPABILITY OF GENERATING STATIONS.

The peaking availability of generating units would be taken on the basis of the latest norms laid down by CEA. The spinning reserve of 5% for Thermal, Nuclear, Hydro generation and Backing down allowance of 5% for Gas based generation as laid in the present norms of Generation Planning Criteria of CEA may not be taken into consideration for Transmission Planning due to continuing peaking shortage of power in all the regions during eighth plan period and beyond.

Norms for peaking Capability of Thermal Stations :

The peaking capability of generating units would be computed as given below.

Unit Capacity (MW)	Outage rates			Aux. consu-mption (AC) %	Capacity availabilit factor (CAF) %	Peaking capabili factor (PCF) %
	Planned (PMR) %	Forced (FOR) %	Partial (POR) %			
200 MW & Above	10.0	14.0	9.0	10.0	67.0	60.3
Below 200 MW	10.0	16.0	14.0	10.5	60.0	53.7

Note: i) CAF=100-(PMR+FOR+POR)

PCF=CAF-CAF x AC

ii) In case of Eastern and North-Eastern Regions forced outage rate will be increased by 5%.

Norms for peaking capability of Hydro stations

Capital Maintenance (CM)	=	3 %
Forced Outage rate (FOR)	=	4.5 %
Auxiliary Consumption (AC)	=	1.0 %
Capacity availability factor (CAF)	=	100 - (CM + FOR) = 92.5 %
Peaking Capability Factor (PCF)	=	CAF - CAF x AC = 91.5 %

Norms for peaking Capability of Gas based Stations:

The gas based power stations are grouped into two categories namely base load stations and peak load stations. The base load stations are normally Combined cycle power plant which have Gas Turbine units and Steam Turbine units. The peak load stations are open cycle Gas Turbines which are generally used for meeting peak load for about 8 Hours in a day at 80 % of their rated capacity. For combined cycle gas based power station, the peaking capability would be as given below :

Unit Capacity (MW)	Outage rates			Aux. consumption (AC) %	Capacity availabilty factor (CAF) %	Peaking capability factor (PCF) %
	Planned (PMR) %	Forced (FOR) %	Partial (POR) %			
Gas turbine units	15.0	10.0	10.0	1.0	65.0	64.4
Steam Turbine units	15.0	10.0	10.0	4.0	65.0	62.4

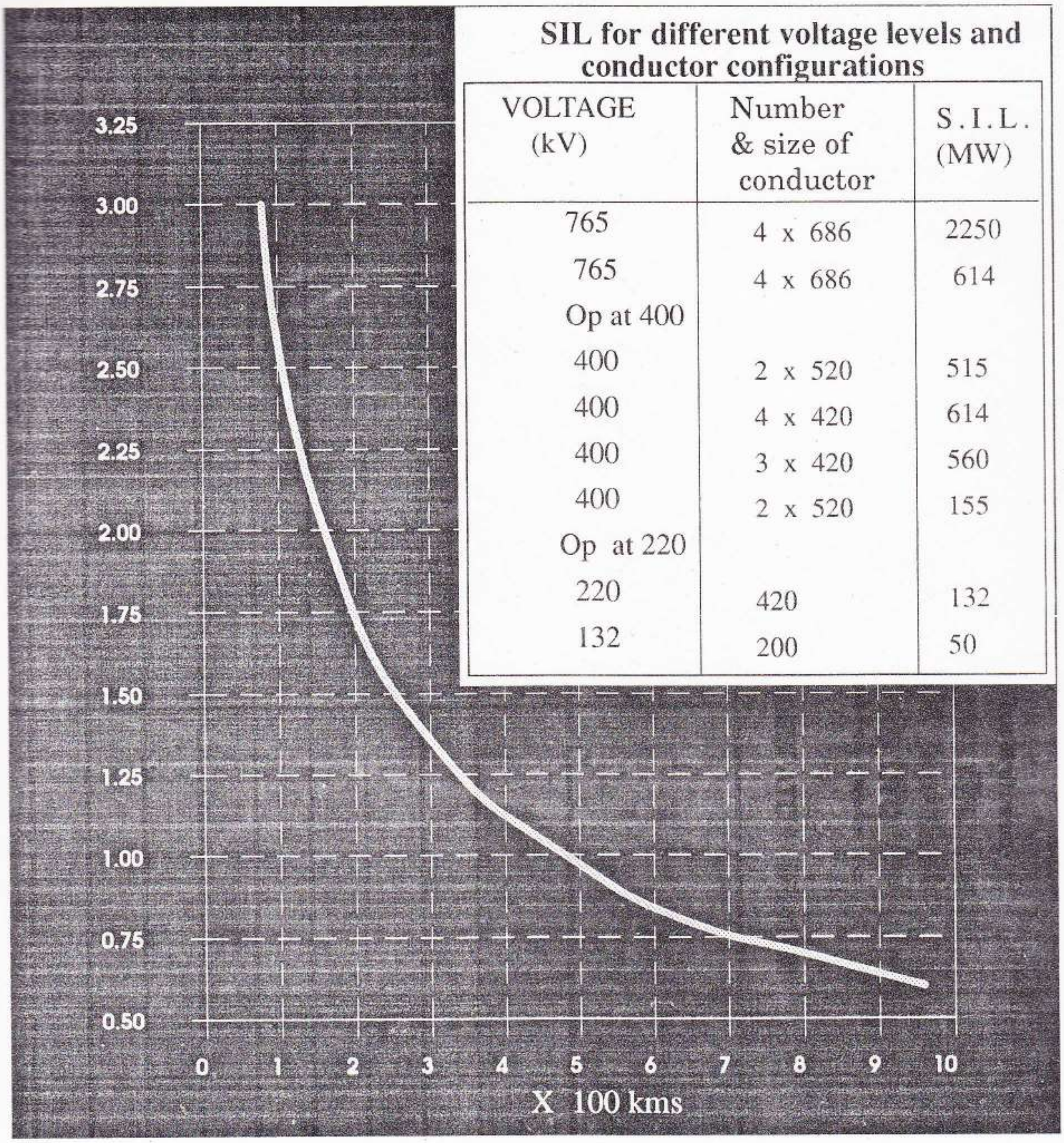
Note: CAF=100-(PMR+FOR+POR)

PCF=CAF-CAF x AC

ANNEX-II

(refer para 4.1)

LINE LOADING AS FUNCTION OF LENGTH



SIL for different voltage levels and conductor configurations

VOLTAGE (kV)	Number & size of conductor	S.I.L. (MW)
765	4 x 686	2250
765 Op at 400	4 x 686	614
400	2 x 520	515
400	4 x 420	614
400	3 x 420	560
400 Op at 220	2 x 520	155
220	420	132
132	200	50

ANNEX-III

(refer para 4.2)

THERMAL LOADING LIMITS

Conductor type and dimension	Ambient temperature (°C)	AMPACITY FOR Maximum Conductor Temperature (°C)		
		65	75	85
ACSR PANTHER 210 sq mm	40	312	413	
	45	244	366	
	48	199	334	
	50		311	
ACSR ZEBRA 420 Sq. mm	40	454	622	
	45	339	546	
	48	240	493	
	50		454	
ACSR MOOSE 520 Sq mm	40	487	684	
	45	345	595	
	48	214	532	
	50		487	
ACSR BERSIMIS 680 Sq. mm	40	565	804	
	45	388	697	
	48	220	621	
	50		565	
AAAC 420 Sq mm	40			762
	45			701
	48			661
	50			632
AAAC 520 Sq. mm	40			843
	45			773
	48			726
	50			694
AAAC 560 sq mm	40			882
	45			808
	48			759
	50			725

Assumptions : solar radiations = 1045W/sq.mt., Wind velocity = 2kM/hour

Absorption coeff. = 0.8, Emissivity coeff = 0.45 Age > 1 year

OPERATIONAL STANDARDS

The operational standards normally define the expected level of power system performance under different conditions of system operations and thus provide the guiding objectives for the planning and design of transmission systems. In the absence of any detailed document on operational standards, the following objectives are considered in the context of formulating the manual:

1. The system parameters (voltage and frequency) shall be as close to the nominal values as possible and there shall be no overloading of any system element under normal conditions and different feasible load-generation conditions.

2. The system parameters and loading of system elements shall remain within prescribed limits and not necessitate load shedding or generation re-scheduling in the event of outage of any single system element over and above a pre-contingency system depletion of another element in another corridor. In the case of 220 kV and 132 kV systems this shall hold good for outage of Double Circuit lines. In case of power evacuation from major generating station/complex (when the terrain indicates possibilities of tower failure) the system shall withstand the outage of two 400 kV circuits if these are on the same tower. Also in the case of large load complexes with demands exceeding 1000 MW the impact of outage of two incoming 400 kV circuits (if these are on the same towers) shall be minimum.

3. The system shall remain in synchronism without necessitating load shedding or islanding in the event of Single-phase-to-ground fault (three- phase fault in the case of 220 kV and 132 kV systems) assuming successful clearing of fault by isolating/opening of the faulted system element.

4. The system shall have adequate margins in terms of voltage and steady state oscillatory stability.

5. No more than four 220 kV feeders/ two 400 kV feeders/ one 765 kV feeder shall be disrupted in the event of a stuck breaker situation.

DATA PREPARATION FOR TRANSMISSION PLANNING STUDIES

Actual system data wherever available should be used. In cases where data is not available standard data given below can be assumed.

Load flow & Short circuit studies

i) Load power factor shall be taken as per para 3.2.3 of the manual

ii) Reactive power limits for generator buses can be taken as

Qmax = Fifty percent of active generation

Qmin = (-) Fifty percent of Qmax

iii) Desired voltage of generator (PV) buses may be taken between 1.03 and 1.05 for peak load conditions and between 0.98 to 1.0 for light load conditions .

iv) Line parameters (p.u. / km / ckt at 100 MVA base)

Line voltage (kV)	conductor configuration	Positive Sequence			Zero Sequence		
		R	X	B	R	X	B
765	Quad Bersimis	1.9513E-6	4.475E-5	2.4E-2	4.5E-5	1.8E-4	1.406E-2
400	Twin Moose	1.862E-5	2.075E-4	5.55E-3	1.012E-4	7.75E-4	3.584E-3
400	Twin AAAC	1.934E-5	2.065E-4	5.67E-3	1.051E-4	7.73E-4	3.66E-3
400	Quad Zebra	1.05E-5	1.59E-4	6.65E-3	5.708E-3	5.94E-4	4.294E-3
400	Quad AAAC	0.979E-5	1.676E-4	6.99E-3	5.32E-3	6.26E-4	4.51E-3
400	Triple Zebra	1.401E-5	1.87E-4	5.86E-3	7.616E-3	6.949E-4	3.783E-3
220	Zebra	1.547E-4	8.249E-4	1.42E-3	4.545E-4	2.767E-3	8.906E-4
132	Panther	9.31E-4	2.216E-3	5.1E-4	2.328E-3	9.31E-3	

		Generating Unit	Inter-connecting
v)	Transformer reactance (At its own base MVA)	14-15 %	12.5 %

In planning studies all the transformers should be kept at nominal taps and On Load Tap Changer (OLTC) should not be considered. The effect of the taps should be kept as operational margin.

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 .

Transient Stability Studies

Transient stability studies shall be carried out on regional basis. Export/Import to/from neighbouring region shall be represented as passive loads.

Voltage Dependency of the system loads

Active loads (P) shall be taken as $P = P_0 (V/V_0)$
Reactive loads (Q) shall be taken as $Q = Q_0 (V/V_0)^2$

Frequency Dependency of the system loads

Active loads (P) shall be taken as $P = P_0 (f/f_0)$
Reactive loads (Q) shall be taken as independent of frequency.
where P_0, Q_0, V_0 and f_0 are values at the initial system operating conditions.

Synchronous machines may be represented as given below
(for all regions except North-eastern region)

Machine Size	**To be represented as**	
less than 30 MW	may be represented as passive loads.	
30 to 100 MW	**Classical model**	**(IEEE type 1)**
100 to 190 MW	Transient model	(IEEE type 2 for Hydro) (IEEE type 3 for Thermal)
200 and above	Sub-transient model	(IEEE type 4 for Hydro) (IEEE type 5 for Thermal)

TYPICAL PARAMETERS FOR THERMAL & HYDRO MACHINES

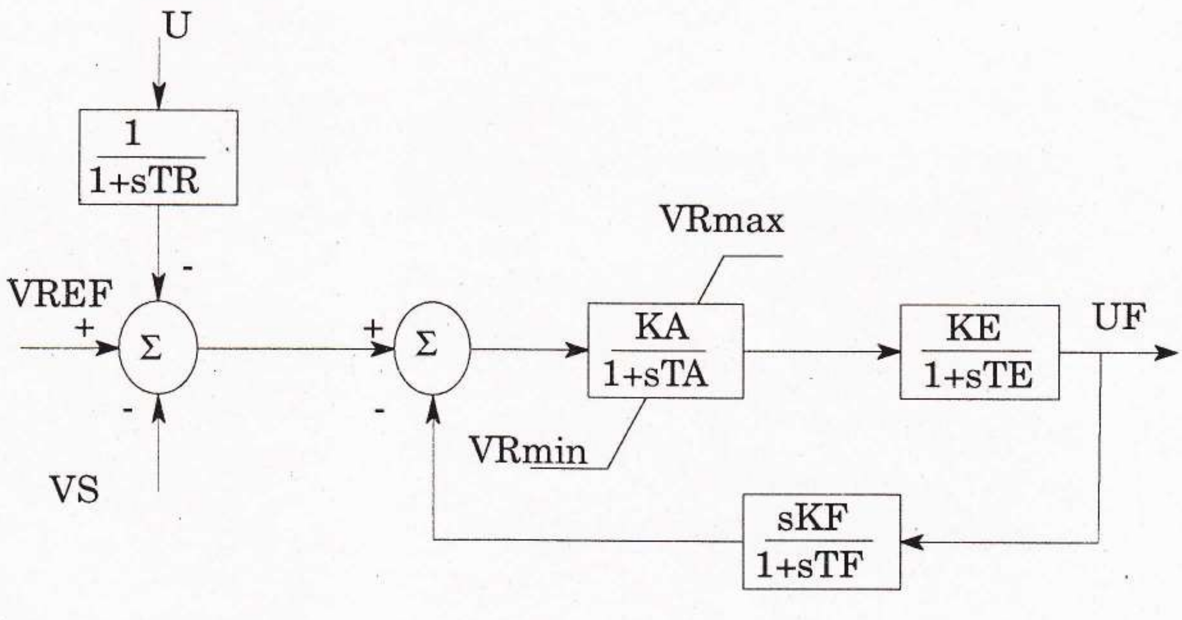
MACHINE DATA - THERMAL / HYDRO

MACHINE PARAMETERS	MACHINE RATING (MW)		
	THERMAL		HYDRO
	500	210	200
Rated Voltage (kV)	21.00	15.75	13.80
Rated MVA	588.00	247.00	225.00
Inertia Constant (H)	3.07	2.73	3.5
Reactance			
Leackage (Xl)	0.14	0.18	0.16
Direct axis (Xd)	2.31	2.23	0.96
Quadrature axis (Xq)	2.19	2.11	0.65
Transient reactance			
Direct axis (X'd)	0.27	0.27	0.27
Quadrature axis (X'q)	0.70	0.53	0.65
Sub-transient reactance			
Direct axis (X"d)	0.212	0.214	0.18
Quadrature axis (X"q)	0.233	0.245	0.23
Open Circuit Time Cont			
Transient			
Direct axis (T'do)	9.0	7.0	9.7
Quadrature axis (T'qo)	2.5	2.5	0.5
Sub-transient			
Direct axis (T"do)	0.04	0.04	0.05
Quadrature axis (T"qo)	0.2	0.2	0.10

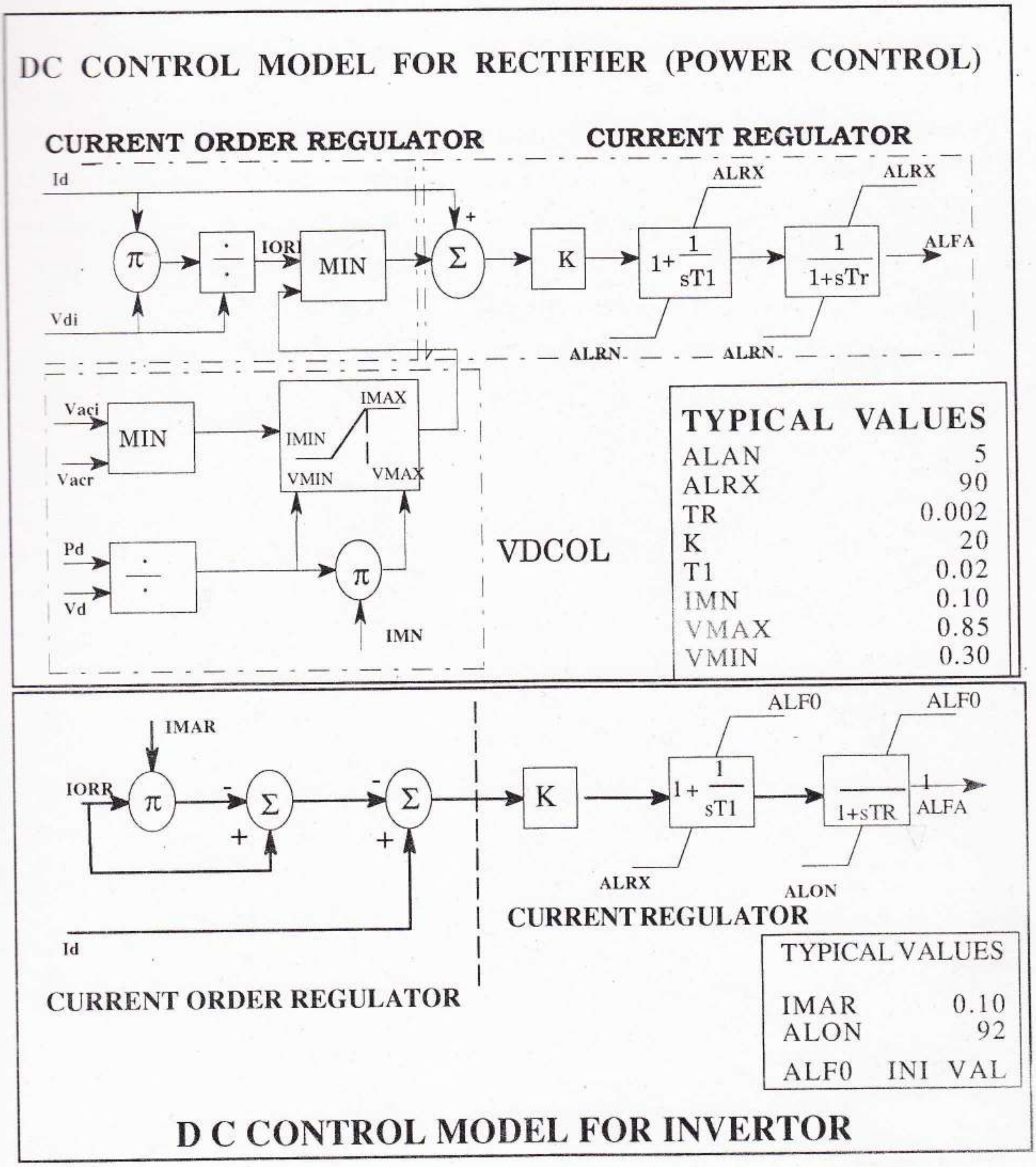
Source : M/S Bharat Heavy Electricals Ltd.

TYPICAL PARAMETERS FOR EXCITERS

Typical parameters	Hydro	Thermal	
		<210 MW	>210 MW
Transdu. Time Cons.(TR)	0.040	0.040	0.015
Amplifier gain (KA)	25 - 50	25 - 50	50-200
Amplif. Time Cons.(TA)	.04-.05	.04-.05	.03-.05
Regulator limiting voltage			
Maximum (VRmax)	4.0	6.0	5.0
Minimum (VRmin)	-4.0	-5.0	-5.0
Feed back signal			
Gain (KF)	0.01	0.01	.01
Time Constant (TF)	1.00	1.00	1.00
Exciter			
Gain (KE)	1.0	1.00	1.00
Time Constant (TE)	0.7	0.3	0.001



H.V.D.C. data : No standardised DC control model has been developed so far as this model is usually built to the loacl requirements of the DC terminals. Based on the past experience in carrying out stability studies, the following models have been suggested for rectifier and invertor terminals.



E.M.T.P. Studies: System shall be, to the extent possible, represented in detail. Parallel circuits/ alternate paths shall also be considered. At least one source shall be represented as type 59 (detail representation). Saturation characteristics of transformers and reactors shall also be considered.

Voltage Stability Studies : These studies are carried out using loadflow analysis program by creating a fictitous synchronous condenser at most voltage sensitive bus i.e. bus is converted into PV bus. By reducing desired voltage of this bus MVAR generation/ absorption is monitored. When voltage is reduced to some level it may be observed that MVAR absorption does not increase by reducing voltage further instead it also gets reduced. The voltage where MVAR absorption does not increase any further is known as Knee Point of Q-V curve. The knee point of Q-V curve represents the point of voltage instability. The horizontal 'distance' of the knee point to the zero-MVAR vertical axis measured in MVARs , is therefore an indicator of the proximity to the voltage collapse.