
ESB National Grid

Transmission Planning Criteria

1 General Principles

The specific function of transmission planning is to ensure the co-ordinated development of a reliable, efficient, and economical system for the transmission of electricity for the long-term benefit of transmission users. The planning process involves the application of technical reliability criteria, economics, consideration of transmission operations, maintenance and protection, co-ordination with generation and distribution functions, information technology, strategic considerations and environmental aspects.

The Transmission Planning Criteria set out the standards that are applied in the planning time frame. The standards for day-to-day operation of the system are set out in the Grid Protocol.

1.1 Objective

The primary aim of transmission planning is the maintenance of the integrity of the bulk transmission system for any eventuality. The adequacy and security of supply to any particular load or area is secondary to this primary aim. The technical considerations are continually mitigated by economic considerations and all other factors that various stakeholders in the transmission system would consider significant.

1.2 Reliability Criteria

Reliability criteria are defined and measured in terms of performance of a system under various contingencies. Prediction of performance is based on simulation, rather than actual tests. These criteria are based on the fundamental assumption that system integrity will be maintained for the more probable and less probable contingencies and that there is no loss of load for the common more probable contingencies.

1.3 Overall Assessment

Any transmission plan proposed for adoption under these criteria must ultimately be justifiable taking account of economic, financial, strategic and environmental considerations.

1.4 Planning Horizons

These criteria and performance tests are applied to medium-term planning horizons (of the order of ten years) upon which Transmission Development Reports are to be based. Planning time frames in the near term (one year ahead) and long-term (15-20 years ahead) are subject to a limited set of performance tests which at the least includes tests for more probable contingencies.

2 ESB Transmission Planning Criteria

The system shall be designed to operate within normal operating ranges for credible load and generation patterns for **base case** operation. The system shall be designed to withstand the more probable contingencies without widespread system failure and instability, maintaining power quality within specified voltage and frequency fluctuation ranges and maintaining voltage and thermal loadings within operating limits. The more probable contingencies are comprised of **single contingency** (N-1), **overlapping single contingency and generator outage** (N-G-1) and **trip - maintenance** (N-1-1) disturbances.

In the immediate aftermath of a disturbance, the system should reach a steady state that is within emergency limits. Then, by use of remedial actions specified in the criteria, the system should be capable of being returned to normal limits

The criteria for transmission system contingency performance are established in terms of the results of simulation tests. These are summarised in Table 1. These tests do not preclude further, detailed tests that would enhance planning for specific components of the transmission systems. Additional detailed tests may include, substation reliability evaluation, voltage collapse simulation, subsynchronous resonance calculations, dynamic stability, switching simulations etc.

2.1 Contingencies

2.1.1 More Probable Contingencies

Base Case

For base case operation, i.e. with all items of transmission plant available, the system shall operate within normal limits. This test is performed using steady-state power flows. Transformer tap changing, switched shunts and busbar sectionalising may be utilised as required to provide acceptable base case loadings and voltages. Several base cases may be required to model the necessary range of load levels and generation patterns.

The **base cases** are used as the starting point for contingency studies.

Single Contingency

The single contingency test **N-1** covers the loss of any single item of generation or transmission equipment at any time. Since it is plausible that at any time, one of the generators could be off line, for any number of reasons, an overlapping single contingency and generator outage **N-G-1** is also investigated.

Where transformer tap changing, switched shunts and busbar sectionalising can be used in the base case to minimise the impact of potential single contingencies, this shall be done. The **N-G-1** case may be modified in preparation for the second outage (i.e. following the generator outage but before the second outage) as follows: tap changing, switched shunts, generation redispatch and busbar sectionalising.

The various aspects of the test are:

1. For the transient period, the planned transmission system should be transiently stable with voltage and frequency fluctuations within acceptable limits. This test is performed with dynamic simulation of fast-acting automatic controls such as generator voltage regulators and power system stabilisers, and static var systems. Relay-based remedial actions, except for those that shed load such as underfrequency and undervoltage relays, are also represented in this simulation.

2. Immediately following an outage, when responses from automatic controls have reached a steady state, the transmission system should not be in voltage collapse or experience cascading outages, voltages should be within post contingency limits and thermal loadings should be within emergency limits. This test is performed using steady-state power flows. The power flow shall include automatic response for voltage regulators, static var systems, speed governors and automatic transfer of disconnected load where appropriate.
3. Within the time for which emergency limits are valid, the system should be able to return to normal limits. This test is performed using steady-state power flows, allowing for control actions such as operator-actuated or automatic tap-changing, capacitor and reactor switching, and generation redispatch. Phase-shifting transformers may be included here if and when ESB NG acquires this type of equipment. Off line generation units (with the exception of fast response hydro and combustion turbine plant) may not be considered for generation redispatch.

Trip – Maintenance N-1-1

The trip - maintenance **N-1-1** tests include disturbances in which the forced outage of a transmission or generating element occurs while another element is out on maintenance. The **N-1-1** tests also include the overlapping forced outage of two elements at a time, where there is sufficient period between the first and second outage to allow for adjustment back to normal operation.

The maintenance case may be modified in preparation for trip-maintenance outages (i.e. following the first *maintenance* outage but before the second *trip* outage) as follows: tap changing, phase angle regulators, switched shunts, generation redispatch and busbar sectionalising.

Although single contingency and trip - maintenance are both considered probable disturbances, the criteria for trip - maintenance events are slightly different, recognising that exposure to these events is much less than single contingency events. In particular, some loss of load is allowed for trip - maintenance events.

2.1.2 Less Probable Contingencies

For system integrity, the system should be able to withstand more severe but less probable contingencies without going into voltage collapse or uncontrolled cascading outages. Examples of this class of contingencies are busbar faults, busbar coupler faults, breaker failures, relay misoperation, loss of double circuit, etc.

Table 1: Contingency Performance Tests

Disturbance	Analysis	Criteria	Allowable Remedial Actions
Base Case			
None	Steady-state load flow	Normal limits Capacitor switching voltage step	Tap-changing, Phase angle regulators, Switched shunts, Busbar Sectionalising
	Short-circuit analysis	Allowable short circuit levels	None
More Probable Contingencies			
Single Contingency (N-1)			
<ul style="list-style-type: none"> - line - transformer - generator - SVC, reactor or capacitor 	Dynamic simulation	Transient stability, voltage and frequency fluctuation range	None
	Steady-state load flow	No voltage collapse, cascading outages; voltage step; emergency limits	None
	Steady-state load flow	Normal limits	Tap-changing, Phase angle regulators, Generation redispatch, Switched shunts, Network Switching
Overlapping Single Contingency and Generator Outage (N-G-1)			
<ul style="list-style-type: none"> - generator + line - generator + transformer - two generators - generator + (SVC, reactor or capacitor) 	Dynamic simulation	Transient stability, voltage and frequency fluctuation range	None
	Steady-state load flow	No voltage collapse, cascading outages; voltage step; emergency limits	None
	Steady-state load flow	Normal limits	Tap-changing, Phase angle regulators, Generation redispatch, Switched shunts, Network Switching
Trip – Maintenance (N-1-1)			
<ul style="list-style-type: none"> - two lines - line + transformer - line + power conditioning unit - two transformers - transformer + (SVC, reactor or capacitor) - (SVC, reactor or capacitor) + (SVC, reactor or capacitor) 	Dynamic simulation	Transient stability, voltage and frequency fluctuation range	None
	Steady-state load flow	No voltage collapse, cascading outages	None
		Emergency limits	Load Shed 15MW
Steady-state load flow	Normal limits	Tap-changing, Phase angle regulators, Generation redispatch, Switched shunts, Network Switching, Load Shed 15MW	
Less Probable Contingencies			
Busbar fault, busbar coupler fault, breaker failure, protection failure, loss of double circuit	Steady-state load flow	No voltage collapse, cascading outages	None

2.2 Performance Requirements

2.2.1 Short Circuit Levels

Planned maximum subtransient short circuit fault levels shall not be greater than 90% of equipment ratings. In most cases, this corresponds to saying that, for three-phase or single-phase-to-earth faults, planned maximum subtransient short circuit fault levels shall not be greater than:

400kV: 45kA, 220kV: 36kA, 110kV: 23.4kA

System Earthing

The 400kV, 220kV and 110kV transmission networks are effectively earthed systems. The line to earth voltage during single line to earth faults should not rise above 80% of the rated line to line voltage.

2.2.2 Dynamic Testing

The strength of the system shall be such as to maintain stability following a three-phase zero impedance line-end fault. It shall be assumed that the fault is correctly cleared by primary protection and that line reclosing is in operation where appropriate. This test may be relaxed and instead apply a single phase fault test where the situation is a stage of ongoing development and has a short duration

Pole slipping, even for a short time, is unacceptable.

2.2.3 Cascading outages

A contingency shall not result in the islanding of major portions or in the shutdown of the system due to the cascade tripping of transmission circuits and generators. Cognisance shall be taken in planning the transmission system of the protection equipment and relay settings in use on the main system.

2.2.4 Voltage collapse

A safe margin should be provided between the transmission loading in an area and the voltage collapse point determined by parametric studies as the transmission loading is increased.

2.2.5 Thermal Limits (Normal and Emergency)

Table 2: Thermal Limits

Equipment	Emergency Rating	Minutes
Overload		
Overhead line	110% Normal Rating	30
Cable and Transformer	within half hour limit	30
	within two hour limit	120

Normal and emergency thermal limits on equipment shall be as determined by the assumed seasonal ambient conditions. Normal and overload ratings must take account of the ratings

of auxiliary and ancillary equipment such as switchgear, bushings, instrument transformers, tap-changers, etc..

No overloading on equipment shall be acceptable in planning either for normal or emergency operation except in the immediate aftermath of a disturbance (while corrective action, either automatic or manual, is being taken).

2.2.6 Voltage Ranges

The system shall be so planned that voltage shall remain within the following limits. It is acceptable for the voltage to fall within the post contingency limits for the duration of an outage or contingency.

Table 3: Voltage Ranges

Nominal Voltage	Base Case limits (meshed network)	Post Contingency limits (all buses)
400kV	370 – 410kV	350 – 410kV
220kV	210 – 240kV	200 – 240kV
110kV	105 – 120kV	99 – 120kV

2.2.7 Voltage step

For base case operation, i.e. with all lines in service, the voltage step resulting from capacitor switching shall not exceed 3.0%.

For single contingencies (N-1), the maximum step change between pre- and post-contingency steady-state voltages shall be no more than 10%.

2.3 Remedial Actions

Pre-Contingency

Four actions are available for the preparation of a **base case**:

1. transformer tap changing,
2. Phase angle regulators,
3. switched shunts and
4. busbar sectionalising.

Preparation of a base case involves eliminating overloads and voltage deviations as well as preparing for potential single contingencies. There is no limit on how many actions of this type may be taken to prepare an acceptable base case. The resulting **base case** is used as the starting point for contingency studies.

For **N-G-1** and **N-1-1** studies, it is assumed that there is sufficient time following the first *maintenance* or *generator* outage but before the second *trip* outage to prepare the system for the second contingency. The same four remedial actions as for the base case plus generation redispatch are available and there is no limit on how many actions may be taken at this point.

Post Contingency

Following **N-1** or **N-G-1** contingencies and provided that emergency operating limits have not been violated, five remedial actions are available to return the system to normal limits:

1. transformer tap changing,
2. Phase angle regulators,
3. switched shunts,
4. generation redispatch and
5. network switching.

The number of types of remedial actions requiring operator intervention that may be assumed post contingency is limited to three. The action types selected should be those with most impact on alleviating emergency violations. These post contingency remedial actions may be used to alleviate 30 minute overloads only where the station is manned or where remote control is available.

In addition, for **N-1-1** events, up to 15MW of load can be shed to remove violations of emergency and / or normal limits. A maximum of five trip – maintenance **N-1-1** combinations where load shed is required shall be allowed in an area.

2.3.1 Generation Redispatch

Generation redispatch is permitted following the first *generator* or *maintenance* outage but before any potential second *trip* outage in **N-G-1** or **N-1-1** contingencies.

As a post-contingency remedial action, it is acceptable to redispatch on line generation to return the system to normal limits. In addition, fast response off line generation such as hydro generation or combustion turbines may be used to help reduce overloads and alleviate voltage problems.

2.3.2 Transformer Tap Changing

Appropriate transformer tap positions are selected in preparation of the **base case** and following the first *generator* or *maintenance* outage but before any potential second *trip* outage in **N-G-1** or **N-1-1** contingencies.

As a post contingency remedial action, it is acceptable to tap the transformers at two transmission stations up to two taps from their base case settings, to return the system to normal limits. The transformer taps adjusted should be those with most impact on alleviating emergency violations.

2.3.3 Phase Angle Regulators

Appropriate phase angle settings are selected for phase angle regulators (if and when ESB National Grid acquires this type of equipment) in preparation of the **base case** and following the first *generator* or *maintenance* outage but before any potential second *trip* outage in **N-G-1** or **N-1-1** contingencies.

As a post contingency remedial action, it is acceptable to utilise phase angle regulators to return the system to normal limits.

2.3.4 Switched Shunts

An appropriate dispatch of switched shunts is permitted in preparation of the **base case** and following the first *generator* or *maintenance* outage but before any potential second *trip* outage in **N-G-1** or **N-1-1** contingencies.

As a post contingency remedial action, it is acceptable to utilise installed switched shunts (capacitors and reactors) to return the system to normal limits.

2.3.5 Busbar Sectionalising and Network Switching

In preparation of the **base case** and following the first *generator* or *maintenance* outage but before any potential second *trip* outage in **N-G-1** or **N-1-1** contingencies, busbar sectionalising is permissible provided that no load becomes tail fed that would not otherwise be tail fed. Busbar sectionalising shall not result in tail feeding any commercial or industrial load for which a contract to provide continuous duplicate supply has been signed.

As a post-contingency remedial action, it is acceptable to utilise a reasonable amount of network switching to return the system to normal limits. This may result in load being tail fed that would not otherwise be tail fed.

2.3.6 Load Shed

Up to 15MW of load may be shed under trip – maintenance **N-1-1** conditions to prevent overloads and / or voltage problems that exceed the emergency limits and / or normal limits.

3 Modelling Assumptions

3.1 Load

All tests shall be carried out on currently valid energy and peak demand forecasts. The performance of the planned system should meet ESB Transmission Planning Criteria at peak and other load levels. Planning of the ESB transmission system shall be carried out on the basis of normal distribution feeding arrangements.

3.2 Generation

All tests shall be based on the best information on generation development.

Large scale wind farms or other large MW-scale distributed generation plants connected to the transmission system are to be modelled in detail like any other large generating plant in the system.

3.3 Dispatch

Because of its low load factor, supply to any part of the transmission system should not depend on wind generation.

Planning of the transmission system shall be carried out on the basis that generation is dispatched according to normal operational methods for a credible range of dispatches.

The strength of the transmission network should be such that:

- i. No limitation shall be put on the output of any generation station to the system under normal conditions, i.e. all lines in service.
- ii. A pre-arranged complete shutdown of a generation station or part of it (required, for example, because of common equipment such as chimneys, cooling water culverts, etc.) during a suitably chosen low-load period may be tolerated when necessary. During such a shutdown, relevant planned maintenance or other scheduled voluntary

outages of generation and/or transmission equipment elsewhere is regarded as being suitably minimised.

3.4 Interconnection

The system shall be capable of transmitting the net flows resulting from the inflows or outflows of an interconnection with any other power system.

4 Design Criteria

4.1 Supply to Transmission Stations

4.1.1 220kV Bulk Supply Points

Two circuits shall be regarded as adequate to connect a 220kV bulk supply point with a load of less than 300 MVA to the rest of the system. This is provided each circuit has a seasonal rating in excess of the seasonal load and supply can be restored to load equivalent to one third of winter peak load within two hours for an outage of both circuits.

4.1.2 110kV stations

The provision of single or duplicate supply to 110/38kV, 110/20kV or 110/10kV stations shall take account of distribution network requirements as well as transmission system requirements.

The load that would be isolated for the loss of two 110kV lines shall not exceed four 110kV stations supplying distribution networks or 80MW of distribution load.

4.1.3 110kV Tees

Tees represent a degradation of reliability by increasing the amount of line subject to outage and providing for additional exposure to protection and equipment failures.

Tees are not allowed on the 400 and 220 kV systems. 110kV overhead lines may be teed provided that the integrity of the main system is not affected. All tees shall be switched and no more than two tees shall be made to a 110kV line.

Normal operation, protection and maintenance equipment and practices on the ESB NG transmission system shall not be affected by the connection of generation capacity to a teed 110kV station or the distribution network fed therefrom, either at 110kV or at a lower voltage. High speed automatic reclosing equipment shall not require to be disabled nor shall embedded generation back-feed into a correctly cleared fault on the teed 110kV line.

A contingency involving a tapped 110kV line (switched Tee) involves loss of all line sections on the tapped line and transfer of the isolated load to alternative 110kV buses.

A maintenance outage of a section of a tapped 110kV line (switched Tee) need only concern the section on which maintenance is being performed. Load is transferred to an alternate 110kV bus only if the tee section is removed for maintenance. A maintenance outage of an existing tapped 110kV line (unswitched Tee) involves loss of all line sections on the tapped line and transfer of the isolated load to alternate 110kV buses.

A trip-maintenance combination involving two tapped 110kV lines is a combination of a contingency and a maintenance outage.

4.2 Generation Station Arrangements

Arrangements concerning generation plant shall be as follows:

- i. Not more than 35% of the generation capacity on the system shall be situated in the one location;
- ii. The generation station arrangement shall be such that the loss of generation capacity arising from a busbar fault shall not exceed the rating of the largest single unit on the system. The loss of generation capacity arising from a fault involving a busbar sectionalising or coupling circuit breaker, shall not exceed twice the rating of the largest single unit on the system.
- iii. While, as a general principle, generation plant shall be connected to the main transmission voltage levels, it is permissible to connect generation plant to lower voltage levels where appropriate. However, this should not occur at the cost of simplicity or ease of operation, nor should it hinder future sectionalising of the 110 kV network.
- iv. A block of generation capacity in excess of the rating of the largest generation unit on the system shall be connected to the rest of the system by at least two circuits. It shall be possible where the station capacity exceeds twice the rating of the largest generation unit on the system, to transmit the full output of the station less the capacity of any one of the units to the system even with a trip - maintenance combination of the connecting circuits.

4.3 Transformer on Prolonged Outage

The system shall be planned to have sufficient transformers such that following the loss of a 400/220kV or 220/110kV transformer on prolonged outage and, if necessary, having moved an existing transformer to replace the damaged one, the transmission system shall be capable of withstanding any further single **N-1** or **N-G-1** contingency.