الشركة السعودية للكهرباء
Saudi Electricity Company

TRANSMISSION ASSET DEVELOPMENT DEPARTMENT

SEC TRANSMISSION PLANNING CRITERIA

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1. Introduction

This document presents the Planning Criteria upon which the need for reinforcement and enhancements to SEC transmission system are determined.

The objective of the Planning Criteria is to provide basis for safe , reliable and low cost expansion of the transmission system and to ensure that adequate facilities are available for the benefits of transmission users. The transmission system should be capable of meeting consumer demand while surviving reasonably anticipated contingency conditions without violating specified thermal , voltage and stability limits or experiencing uncontrolled cascading outages.

The transmission system development process includes the application of the Planning Criteria , economic evaluation of alternatives , consideration of transmission operations , maintenance and protection , co-ordination with generation and distribution functions and environmental aspects.

Transmission system in this document refers to voltage levels that include 110 , 115 , 132 , 230 and 380 KV which are applicable to SEC system.

2. Normal and Contingency Conditions

To achieve the Planning Criteria objective it is essential that system simulations be performed in advance to identify the facilities necessary to assure a reliable transmission system in future years.

Table 2.1. specifies the outage events which are used to determine if any thermal or voltage violations exist during peak and minimum demand conditions. The table outlines the acceptable system performance under normal and specific outage conditions.

The tests covered in Table 2.1. do not prelude performing further detailed analysis that would enhance planning for specific components of the transmission system. Additional detailed tests may include substation reliability evaluation , voltage collapse simulations , PSS tuning , switching , etc.

2.1 Normal Condition

The normal condition (base case) represents the system with all elements in service. This is often referred to as N - 0 condition. The system must be able to supply all firm demand and firm transfers to other areas. All equipment must operate within applicable ratings , voltages must be within applicable limits and the system must be stable.

2.2 Single Contingency

Single contingency involves the loss of a generator or single transmission element (transformer , cable , OHL circuit , reactor). This is often referred to as (N-1) event. The acceptable system impact is summarized as follows:

- The system should perform within emergency loading and voltage limits following the outage and within normal limits after system adjustments. System adjustments include transformer tap changing , switching of shunts and generation re-dispatch.
- No loss of load allowed.
- The system should be transiently and dynamically stable under normally cleared SLG faults.

2.3 Double Contingency

Double Contingency involves the loss of a double circuit overhead line. This is often referred to as (N-2) event. The acceptable system impact under N -2 event is similar to N – 1 event except that loss of load is allowed under outage conditions other than the following:

- Tie lines supplying firm power between regions.
- Out-of-power plant 230 and 380 KV lines.
- Out-of-power plant lines (110 / 115 / 132 KV) where resulting overloads can be relieved via generation re-dispatch.

2.4 Single -Maintenance Contingency

This is often referred to as (N-M-1) event. It involves forced outage of a single transmission element while another is out of service for maintenance e.g two OHL circuits, OHL circuit & transformer , OHL circuit & reactor , etc. Acceptable system performance for Single - Maintenance contingencies is similar to that of N -1 contingencies.

2.5 Non – Simultaneous Contingencies

This is often referred to as (N-1-1) event. It includes an outage condition involving single contingency followed by system adjustments and another single contingency. The acceptable system impact under (N-1-1) is as follows :

- The system should perform within emergency limits following either outage and within normal limits after system adjustments. System adjustments include tap changing , switching of shunts and generation re-dispatch.
- Loss of load allowed.
- To cater for extended outage of one of two cables supplying a discrete group , the system should be tested to have enough transfer links to meet 2/3 of the group peak demand.
- The system should be transiently and dynamically stable.

2.6 Less Probable Contingencies

Less probable contingencies involve bus section faults leading to the loss of two or more elements. The acceptable system impact is as follows:

- Loss of load allowed
- The system should be transiently and dynamically stable.
- No voltage collapse , cascading or overloads exceeding the half hour emergency rating of the transmission equipment.

2.7 Extreme Contingencies

Extreme contingencies may result in instability followed by widespread loss of demand and generation. Extreme contingency tests should be run to evaluate risks and consequences and to verify that system integrity can be maintained and that it would be possible to attain a new stable state via coordinated load shedding and islanding. Extreme Contingencies could include:

- Loss of all tie lines between regions.

- Loss of all transmission lines on a common Right-of –Way.
- Loss of a power plant or a transmission substation.
- Loss of a major load center.
- Other severe events involving delayed fault clearance.

Table 2.1 The Contingency Criteria for SEC Transmission System

Test Conditions	Elements out of Service	Analysis	Acceptable System conditions
Base Case	All Elements in Service	Steady State Load Flow	System within normal loading and voltage limits
Single Contingencies (N-1)	- Generator - Transformer - OHL Circuit - Reactor - Cable	Study State Load Flow	- System within emergency loading and voltage limits immediately after outage and within normal limits after systems adjustments - No loss of load allowed
		Dynamic Analysis	- Transiently and dynamically stable
Double Contingencies (N-2)	- Double circuit line	Steady State Load Flow	- System within emergency loading and voltage limits immediately after outage and within normal limits after system adjustments. - Loss of load allowed except under the following conditions: i.) Tie lines supplying firm power between regions ii.) Out of power plant 230 and 380kV lines iii.) Out of power plant lines (110/115/132kV) where resulting overloads can be relieved via generation re-dispatch
		Dynamic Analysis	- Transiently and dynamically stable
Single Maintenance Contingencies (N-M-1)	Single contingency while another element, including bus section, is out of services for maintenance	Steady State Load Flow	- System within emergency loading and voltage limits immediately after outage and within normal limits after system adjustments. - No loss of load allowed
		Dynamic Analysis	- Transiently and dynamically stable
Non-Simultaneous Contingencies (N-1-1)	Single contingency followed by system adjustment and another single contingency	Steady State Load Flow	- System within emergency loading and voltage limits following either contingency and within normal limits after system adjustments - Loss of load allowed
		Dynamic Analysis	- Transiently and dynamically stable
Less Probable Contingencies	- Bus section	Steady State Load Flow	- Loss of load allowed - No voltage collapse, cascading or overloads exceeding half hour emergency ratings
		Dynamic Analysis	- Transiently and dynamically stable
Extreme Contingencies	Severe (less probable contingencies)	Dynamic Analysis	- Avoidance of wide spread loss of load, uncontrolled cascading and system blackouts.

3. Performance Standards

Performance standards relate to how the system responds to normal or contingency events and are measured in voltage , voltage change , thermal loading , frequency changes and stability.

3.1 Voltage Limits

All SEC operating areas apply same steady state voltage limits which vary within ± 5% under normal operating conditions and ± 10% under emergency conditions as shown in Table 3.1.

Table 3.1 Acceptable Range of Steady State Voltages (KV)

Operating Area	Nominal Voltage	Normal Range	Post-Contingency Range
WOA	110	104.5 -115.5	99 -121
EOA	115	109.25-120.75	103.5 -126.5
COA,EOA,WOA, SOA	132	125.4 -138.6	118.8 -145.2
EOA	230	218.5 -241.5	207 -253
COA , EOA, WOA, SOA	380	361 -399	342 -418

3.2 Voltage Stability Criteria

Acceptable transient voltage recovery following fault clearance is critical to prevent motor stalling and other harmful effects on loads.

The Voltage Stability Criteria require that the voltage should exceed: 0.7 p.u soon after fault clearance and 0.8 p.u by the end of a 10 second simulation time.

3.3 Damping Criteria

Adequate damping of power system oscillations is required to ensure proper system operation and to guard against inappropriate operation of power system controls or protection.

The criteria for adequate damping require that the Successive Peak Ratio (peak to peak magnitude of immediate oscillation) is about 70% such that a significant decay of the oscillations is achieved in three to four cycles of oscillations.

3.4 Frequency Variation Criteria

The acceptable transmission system frequency variations , under normal and contingency conditions , are specified in the Grid Code (Item 2.4.2 , Chapter 2 : Connection Code)

3.5 Thermal Loading

The applicable emergency overloads used to determine reinforcement requirements are as follows :

Transformers : 115 %

Overhead Lines : 110 %

Cables : 120 %

3.6 Short Circuit Levels

The maximum short circuit levels of equipment should be calculated for three phase and single phase to earth faults based on the following assumptions :

- 1.05 p.u pre-fault voltage
- Calculated figures not to exceed 90 % of switchgear rating
- All generating units and transmission elements are in service during peak conditions

4. System Studies

4.1 Study Horizon

study horizon considered in the preparation of the transmission system development plans extends from 1 to 10 years.

4.2 Basic Types of Studies

The basic types of studies conducted to assess compliance with the Planning Criteria include but not limited to :

- Power Flow
- Short circuit.
- Transient Stability

4.3 Dynamic Testing Conditions

System stability analyses performed to determine transfer limits and reactive compensation requirements are based on normally cleared SLG faults. For simulations used to evaluate the system performance under less probable and severe contingencies , stability analyses are based on normally cleared single and three phase faults , as well as single and three phase faults with delayed clearance.

4.4 Fault clearing Times (FCT)

The normal fault clearing times applied in dynamic simulations are as follows :

- 380kV : 5 cycles
- 230kV : 6 cycles
- 110 / 115 / 132kV : 7 cycles

Delayed fault clearing times are up to 300 ms. A normal clearing time of 4 cycles or less can be tested for 380 KV system faults. These tests should be performed under special circumstances where using lower figures would result in noticeable reduction in investment requirements without degrading system reliability. The reduced clearing times should be compatible with actual recorded fault data.

5. Definitions

Adequacy : The ability of the system to supply aggregate electrical demand and energy requirements of customers at all times taking into account scheduled and reasonably expected unscheduled outages of system elements**.**

Bus section : The common connection point , in a substation , of two or more Circuits.

Contingency : The unexpected failure or outage of a system element. A contingency may also include the loss of multiple elements.

Cascading: Uncontrolled successive loss of system elements by an incident at any location. Cascading could result in widespread service interruption.

COA : Central Operating Area

Demand : The demand of MW and MVAR of electricity

Delayed Fault Clearing : Fault clearance consistent with correct operation of a breaker failure protection group and its associated breakers.

Emergency : Occurrence of an unplanned loss of facilities , or another situation beyond control , that impair the system ability to supply demand

EOA : Eastern Operating Area

Frequency : The of cycles occurring in each second. The term Hertz (Hz)corresponds to cycles per second.

FCT : Fault Clearing Time is the time within which the protection system is designed , operated and maintained to clear a fault within its protection zone.

Generation Dispatch : The configuration of outputs from the connected generating units

Grid code: The Saudi Arabian Grid Code

Load Flow : Study carried out to simulate the flow of power on the transmission system with a specific generation dispatch and loads

Minimum demand : The lowest amount of electrical power, or forecast, to be delivered at a specific period of time.

Normal Fault Clearing Fault clearance consistent with correct operation of the protection system and with correct operation of all circuit breakers intended to operate in conjunction with that protection system.

Outage event : An event which leads to the loss of one or more transmission system elements

Per Unit (P.U) : Ratio of the actual electrical quantity to the selected base quantity. The base quantity used for calculating per unit impedances is 100 MVA

Peak Demand : The highest amount of electrical power, or forecast , to be delivered at a specific period of time.

Reactive Compensation : The process of supplying reactive power to the network.

Reliability : The degree of performance of the system that results in electricity being delivered to customers within acceptable standards and in the amount desired. Reliability can be addressed considering two basic and functional aspects of the system : Adequacy and Security.

SLG : Single Line to Ground Fault

SOA : Southern Operating Area

Stability : The ability of the system to return to normal stable operating condition after being subjected to some form of change or disturbance.

Substation : A site at which switching and / or transformation equipment are Installed.

SEC : Saudi Electricity Company

Transmission system : The Transmission System consists of all lines and Substation equipment where the nominal voltage is 110 KV and above.

Tie lines : Facilities and equipment that connect the transmission system of one area to that of another.

User : A person or entity that uses the Transmission System and its related facilities. Also a person or entity to which the Grid Code applies.

WOA : Western Operating Area