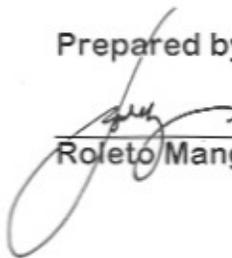




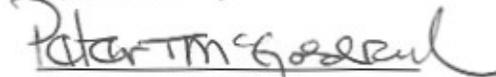
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# TRANSMISSION PLANNING GUIDELINES (Revision 1)

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# TRANSMISSION PLANNING GUIDELINES

## I. TRANSMISSION SYSTEM

### A. DEFINITION

The Transmission System consists of all electric facilities, which are used to connect the Bulk Power System (BPS), i.e. 345 kV system and the generation system, to the Distribution System. The Transmission System includes all facilities operated at voltages between 34.5 kV and 138 kV and their supply transformers. However, facilities operating at 34.5 kV in the Central and Western Divisions are considered part of the distribution system, with the exception of the Harriman-West Point area system.

The basic functions of the transmission system are:

- (1) To deliver generation from remote sites to load centers while operating within the electrical limitations of existing transmission facilities, and supplying service at the desired time and amounts in a reliable manner;
- (2) To accommodate system emergencies including outages of generation or transmission facilities without disruption of service; and,
- (3) To dispatch generation from the most economical resources available while maintaining system reliability.

### B. RELIABILITY

#### **No Loss of Load**

The Transmission System will be designed and operated to a level where no loss of load will be allowed during reasonably foreseeable contingencies. Loss of small portions of a system, such as radial portions, will be tolerated provided these do not jeopardize the integrity of the overall transmission system.

### **Maintenance Outages**

The Transmission System will be designed to allow for maintenance outages. In cases where a substation or customers are supplied from two sources, loss of load will be accepted for reasonably foreseeable contingencies with one supply out for maintenance.

### **Sufficient Capability**

The Transmission System will be designed with sufficient capability as can be economically justified. Losses will be reduced where possible, optimum economic generation will be provided for and the ability to purchase or sell capacity and energy through various interconnections with other utilities will be maintained.

### **New Facilities**

New facilities will be designed to provide physical separation so that a single occurrence will not cause simultaneous loss of two supplies to the same distribution substation or load center.

### **Restoration of Service**

The transfer of load by rearrangement of lines and busses via supervisory control and field switching and readjustment of generator outputs following outages are acceptable means to restore service.

## **C. CONTINGENCIES**

The Transmission System shall be designed to sustain the following contingencies during all load levels while meeting applicable voltage criteria and limiting equipment loadings to within applicable design ratings:

### 1. Reasonably Foreseeable Single Contingencies

The System will be planned to sustain the following more probable single contingencies without loss of load, except for loss of those customers and substations which solely depend on the outage circuit:

- a. Outage of a Single Circuit;
- b. Outage of a Transformer;
- c. Outage of a Bus Section; and,
- d. Outage of a Generator.

During any of the above contingencies, **no facility will be loaded above its long-time emergency (LTE) limits.**

### 2. Double Contingencies

The occurrences of the following specific double contingencies are to be examined for the consequences and possible solutions. However, in no case should they result in a system outage affecting more than 10% of total system peak for a duration greater than four (4) hours.

- a. Transmission circuit and transformer within same substation or load area;
- b. Generator and either a transformer or a transmission circuit within the same substation or load area;
- c. Two transmission circuits on the same structure
- d. Two transformers within same substation
- e. Two adjacent bus sections.

### 3. Extreme Contingencies

Extreme contingencies are the occurrence of multiple contingency events especially in the BPS that will subject the whole Transmission system to severe conditions. The occurrences of the following extreme contingencies, per NPCC criteria, are to be examined for possible consequences and solutions:

- a. Loss of the entire capability of a generating station;
- b. Loss of all lines emanating from a generating station, switching station or substation;
- c. Loss of a Right of Way (ROW);
- d. Permanent three-phase fault on any generator, transmission circuit, transformer, or bus section, which delayed fault clearing and with due regard to reclosing;
- e. The sudden dropping of a large load or major load center;
- f. The effect of severe power swings arising from disturbances outside the NPCC's interconnected system; and,
- g. Failure of a special protection system, to operate when required following the normal contingencies.

#### **D. VOLTAGE**

The Transmission System shall have supervisory or automatic controls capable of maintaining voltages at levels, which will not exceed limits of the connected equipment during both normal and contingency conditions and will allow for meeting the criteria for customer voltage as defined in the Distribution Planning Criteria.

##### **Normal Operating Conditions**

The voltages on the Transmission System will be maintained within  $\pm 5\%$  of nominal voltage under normal conditions.

##### **Single Contingency Operating Conditions**

The maximum acceptable voltage deviation during single contingency conditions after LTC transformers have operated is 10%, but not less than 90% or greater than 105% of nominal voltage.

## **E. GENERATING UNIT STABILITY**

With all transmission facilities in service, generator unit stability shall be maintained on those facilities not directly involved in clearing the fault for:

1. A permanent three-phase fault or phase-to-ground fault on any generator transmission circuit, transformer or bus section cleared in normal time;
2. A permanent phase-to-ground fault on any generator transmission circuit, transformer or bus section with delayed clearing.

## **F. THERMAL RATINGS**

The methodology and criteria used by the Company in rating its transmission line facilities are in accordance with the latest report of the NYPP Task Force on Tie Line Ratings. The Valley Group's Rate Kit Program was utilized to calculate of the thermal ratings for the overhead conductors. For underground cables, EPRI's Underground Transmission Design Tools (UTDT) with ACE Program was used in the computation.

The transformer thermal ratings are derived from the latest version of EPRI's Power Transformer Loading Program (PT LOAD), which is based on the latest version of IEEE's "Guide for Loading Oil-Immersed Distribution and Power Transformer "(IEEE C57.91-1995).

The detailed explanation and additional information of these methods can be found in **Part III - Thermal Transmission Circuit and Substation Equipment Methodology**.

## II. SYSTEM FREQUENCY

### A. STANDARD FREQUENCY

The standard frequency on the O & R system is nominally 60 hertz. A sustained frequency excursion of  $\pm 0.2$  hertz is an indication of a major load-generation unbalance and possible formation of an island. A load shedding program has been developed in order to provide selectivity and flexibility. Most generators are incapable of sustained operation below a specified minimum frequency, typically less than 58.5 hertz.

### B. AUTOMATIC UNDERFREQUENCY LOAD SHEDDING

Underfrequency relays are installed at various locations throughout the system to provide protection against widespread system disturbances. The Underfrequency Load Shedding Program (UFLS) is updated each year for the NYISO and PJM.

#### 1. Circuit Weight

A circuit weight is calculated annually for each circuit based on the priority of the customers that are located on the circuit. For example,

- (a) A circuit contains a hospital (150), a nursing home (25) and a prison (2) would have a circuit weight of 177.
- (b) An artificial weight is given for the two circuits that feed the O & R SVOC building.

The available circuits with underfrequency relays are then prioritized by circuit weight. Excluding circuits with high priority customers, such as hospitals and malls, the UF relays are then turned on for the higher-weighted circuits until the cumulative load for these circuits reaches the requirement for each level. The Underfrequency relays for the remaining circuits are turned off.

## **2. Underfrequency (U/F) relays:**

2.1. The **Northeast Power Coordinating Council (NPCC)** requirements are for two frequency settings based on the previous year's peak. The first setting requires 10% of the previous year's peak plus 25% of the curtailables and co-generation used during the previous year's peak to be shed at 59.3 hertz. The second setting requires 15% of the previous year's peak to be shed at 58.8 hertz.

2.1. The **Reliability-First Corporation (RFC)** requirements are for three frequency settings based on forecasted peak. The first setting requires 10% of the year's forecasted peak to be shed at 59.3 hertz. The second setting requires 10% of the year's forecasted peak to be shed at 58.9 hertz. The third setting requires 10% of the year's forecasted peak to be shed at 58.5 hertz.

## **3. Manual Load Shedding:**

The Manual Load Shed Program is updated every year based on the new circuit weights and the circuits selected for the underfrequency program. Excluding the high priority customers, such as hospitals and malls (public place for heat and air), the circuits that do not have underfrequency relays and the circuits in which the UF relays are turned off are grouped together and prioritized by circuit weight in ascending order. When these circuits are completed, the circuits with underfrequency relays turned on are prioritized by circuit weight in ascending order. Finally, after these circuits are completed, the remaining circuits (high-prioritized circuits) are prioritized by circuit weight in ascending order as well.

### **III. THERMAL TRANSMISSION CIRCUIT AND SUBSTATION EQUIPMENT METHODOLOGY**

#### **A. OVERVIEW**

It is the responsibility of the Transmission and Substation Engineering Department (“T & S Engineering”) to calculate and issue the thermal ratings of O & R’s overhead and underground transmission facilities. T & S Engineering shall issue ratings for all O & R transmission facilities operated at nominal voltages of 69 kV or greater; and certain facilities operated below 69 kV including the 34.5 kV system in the Eastern Division operated as distribution system as well as the Harriman-West Point 34.5 kV loop in Central Division.

The purpose of this section is to describe the methodologies used to rate all equipment which may in any way impose loading constraints on transmission circuits, and thus, the ratings are referred to as “thermal ratings.” Three thermal ratings will be computed, namely, Normal rating, Long-term Emergency (LTE) rating and Short-time Emergency (STE) rating. However, non-thermal restrictions, such as those imposed by relay settings or design sag limitations, are also recognized and included where appropriate.

The focus of this section is on the capabilities of the transmission circuits, therefore, station equipment not associated with specific transmission circuits will not be included. However, all transmission circuit ratings include the ratings of substation equipment where the equipment terminates and/or limits the specific circuit.

## **B. TRANSMISSION CIRCUIT METHODOLOGY AND DERIVATION OF RATINGS**

The methodology and criteria used by O & R in rating its transmission facilities are largely derived from latest version of the “Final Report NYPP task Force on Tie Line Ratings (1995).” From the report, the conductor ratings are thermal and the prime consideration in thermal rating determination is that the conductor should not sustain more than ten percent (10%) loss of strength due to annealing over its useful life.

### **1. Definition of Terms**

The operating conditions for which each circuit is rated are defined in the following manner:

#### **1.1 Normal Rating**

This refers to the maximum loading that the conductor can carry continuously.

#### **1.2. Long Term Emergency (LTE) Rating**

This refers to the maximum loading, which may be carried by a conductor up to four (4) hours following a contingency, totaling not more than 300 hours for the life of the line.

#### **1.3. Short-Time Emergency (STE) Rating**

This refers to the maximum loading, which may be carried by a conductor up to fifteen (15) minutes following a contingency totaling not more than twelve and a half (12-1/2) hours for the life of the line.

**2. Calculation Assumptions For Overhead Conductors**

The Valley Group’s Rate Kit 4.1 Program was used in the calculation of the overhead conductors’ thermal ratings with the following assumptions:

**2.1. Maximum Overhead Conductor Temperature**

Conductor Type	SUMMER			WINTER		
	Normal	LTE	STE	Normal	LTE	STE
ACSR	95°C	115°C	125°C	95°C	115°C	125°C
Copper	75°C	100°C	125°C	75°C	100°C	125°C
HTLS*	180°C	200°C	220°C	180°C	200°C	220°C

*\*High Temperature Low Sag conductors*

**Table 1: Maximum Allowable Overhead Conductor Temperature**

**2.2. Weather Conditions**

The weather provides cooling by means of convective heat loss to the surrounding air. The degree of cooling mainly depends on air temperature, wind speed and wind direction.

*a. Ambient Air Temperature*

The ambient air temperatures for summer and winter operating conditions are 35 °C (95°F) and 10°C (50°F), respectively.

*b. Wind Speed*

The wind speed used is **3 feet per second**.

*c. Wind Direction*

For given wind speed, winds blowing parallel to the conductor result in a 60% lower convective heat loss than winds blowing perpendicular to the conductor. Thermal ratings for bare conductors are traditionally calculated for perpendicular

wind even though this is not a conservative assumption. (Perpendicular wind is adopted for the calculations).

### **2.3. Solar Heating**

Five data are used solely in calculating the solar heat input to the conductor, namely, Altitude/Latitude, Date, Solar Time, Conductor Orientation and Atmosphere. The conductor's solar absorptivity and emissivity are also used. Elevation above sea level affects both solar heat input and convection heat loss since air density also depends on elevation.

#### ***a. Elevation above Sea Level***

The solar heat intensity increases with altitude being about 15% higher at 1500 m (5000 ft) than at sea level. (Assumed elevation above sea level is 0 ft).

#### ***b. Latitude (deg)***

Latitude of the line determines both the solar azimuth and solar altitude angles. (Assumed 45 degree Latitude).

#### ***c. Date***

Summer months are June through September while winter months are December through February.

#### ***d. Solar Time***

Solar heating is at its maximum between noon and 3 pm.

#### ***e. Atmosphere***

The solar heating in a heavily polluted air is reduced from 20% to 50% depending on the solar altitude. (Assumed most conductors are in industrial area).

*f. Absorptivity and Emissivity*

Absorptivity and Emissivity factors range from 0.3 to 0.9 depending on the conductor's years of service. For this calculation, a factor of 0.5 was used for both absorptivity and emissivity.

### 3. Calculation Assumptions for Underground Cables

For derivation of the underground cables thermal ratings, EPRI's Underground Transmission Design Tools (UTDT) with ACE Program was used. The ACE program was developed by EPRI to permit users to perform integrated technical and economic analysis of pipe-type, self-contained and extruded dielectric cable systems. The ACE ampacity calculations are based upon the IEC 289 calculation procedures for steady-state calculations, and the IEC-853 approach for transient/emergency calculations. The Neher-McGrath procedure is used to calculate the thermal resistance of the cable to earth ambient temperature.

#### 3.1 ACE Program Parameters

The following parameters are utilized in the calculation of the thermal ratings depending on the insulation material used in the cable:

##### *a. Allowable Conductor Temperature for Different Insulation Materials*

INSULATION MATERIAL	MAXIMUM TEMPERATURE	
	NORMAL	EMERGENCY
Impregnated Paper AEIC CS2-90 for HPFF and HPGF AEIC CS4-79 for SCLF	85°C 75°C	105°C for 100 hr 100°C for 300 hr
Laminated Paper-Polypropylene AEIC CS2-90	85°C 75°C	105°C for 100 hr 100°C for 300 hr
Cross-linked polyethylene AEIC CS7-87	90°C 80°C	130°C Cumulative to 1500 Hrs
Ethylene-propylene rubber AEIC CS6-87	90°C 80°C	130°C Cumulative to 1500 Hrs
Electronegative gas/spacer	Consult manufacturer to specific designs	

**Table 2: Allowable Conductor Temperature for Various Insulation Materials**

*b. Dissipation Factors for Insulation Materials*

INSULATION MATERIAL	DISSIPATION FACTOR	
	RANGE	TYPICAL
Impregnated Paper	0.002 - 0.0025	0.0023
Laminated Paper-Polypropylene	0.0007 - 0.0008	0.0007
Cross-linked polyethylene	0.0001 - 0.0003	0.0001
Ethylene-propylene rubber	0.002 - 0.08	0.0035
Electronegative gas/spacer	0+	0+

**Table 3: Dissipation Factors**

*c. Dielectric Constants for Insulation Materials*

INSULATION MATERIAL	DIELECTRIC CONSTANT	
	RANGE	TYPICAL
Impregnated Paper	3.3 - 3.7	3.5
Laminated Paper-Polypropylene	2.7 - 2.9	2.7
Cross-linked polyethylene	2.1 - 2.3	2.3
Ethylene-propylene rubber	2.5 - 4.0	2.8
Electronegative gas/spacer	1+	1+

**Table 4: Dielectric Constants**

*d. Thermal Resistivities of Cable Materials in C° - cm/watt*

INSULATION MATERIAL	RANGE	TYPICAL
Impregnated Paper	500 - 600	600
Laminated Paper-Polypropylene	500 - 600	600
Crosslinked polyethylene	350 - 400	350
Ethylene-propylene rubber	450 - 500	450
Somastic	100	100
Transite	200	200
PVC	400 - 450	400
Neoprene	380 - 580	400
Epoxy	70 - 445	100
Thermoplastic Pipe Coating	350 - 450	400

**Table 5: Thermal Resistivities of Cable Materials**

**4. Bus and Other Substation Terminal Equipment**

The following are the rating factors for other substation terminal equipment:

**4.1. Substation Rigid and Strain Bus (Maximum Conductor Temperature)**

Bus Type	SUMMER			WINTER		
Aluminum	85°C	95°C	105°C	85°C	95°C	105°C
ACSR	95°C	115°C	125°C	95°C	115°C	125°C
Copper	75°C	100°C	125°C	75°C	100°C	125°C
Connections	85°C	95°C	105°C	85°C	95°C	105°C

*Table 6: Substation Bus (Maximum Conductor Temperature)*

**4.2. Other Substation Terminal Equipment including Circuit Breakers, Line Traps, Current Transformer and Disconnect Switches (As a percentage of nameplate ratings):**

Equipment Type	SUMMER			WINTER		
	Normal	LTE	STE	Normal	LTE	STE
Circuit Breakers	104%	116%	133%	122%	134%	149%
Line Traps	101%	111%	141%	107%	118%	150%
Current Transformer	100%	128%	150%	122%	148%	150%
Switches						
30°C Rise	108%	153%	200%	141%	178%	200%
53°C Rise	105%	127%	160%	125%	144%	174%

*Table 7: Other Substation Terminal Equipment (Percentage of Nameplate Rating)*

## **C. TRANSFORMER RATINGS METHODOLOGY**

### **1. Overview**

The methodology and criteria used by O & R in rating its power transformers and distribution substation transformers are derived from EPRI's PT LOAD 6 Program, which was based on the latest version of the IEEE "Guide for Loading Oil - Immersed Distribution and Power Transformers" (IEEE Standard C57.91-1995). Like its earlier versions, the recommendations developed in the IEEE C57.91-1995 used the thermal aging of the winding insulation as the basis for its criteria. The aging of the transformer winding insulation is a major factor in the life expectancy of a transformer, commonly referred to as the "Loss of life" of a transformer.

Transformer life and loading are primarily dependent upon the thermal characteristics of a transformer. Life curves of insulation systems have been established which relate loss of life with the absolute temperature of the insulation (hot spot) and time. The effects of temperature and time are cumulative. The rating factors have been selected so that the total loss of life for the insulation system will be approximately 10% over a 40-year life.

Ambient temperatures have a significant effect on loadability. IEEE Standard C57.91-1995 recommends that the average ambient temperature be used when determining normal ratings and average maximum ambient temperature be used in determining ratings with some loss of life.

PT Load 6 Program utilizes the "Top Oil" Model with various specific test data and physical characteristics as input, and then computes the summer and winter loading capability as a function of loss of life and preloading conditions. Typical input data are enumerated in the succeeding pages.

## 2. EPRI'S Power Transformer Loading (PTLOAD 6) Program

This program implements calculations from IEEE Standard C57.91-1995, "Guide for Loading Mineral-Oil Immersed Transformers," as well as the IEC Standard 354, "Loading Guide for Oil-Immersed Power Transformers." The guide covers general recommendations for loading 65° C rise mineral-oil-immersed power transformers as well as recommendations for the 55° C rise transformers still in the system. PTLOAD 6 calculates transformer temperatures, ratings, loss of insulation life, and gas bubble formation based on user-specified physical parameters for the transformer and user-specified load and air temperature data. Although PTLOAD 6 offers a choice between the conventional "top oil" rating algorithm, based on IEEE Standard C57.91-1995, and the new "bottom oil" rating algorithm also from the same standard, the calculations here were only based on the "top-oil" concept.

### Top Oil

The "Top Oil" model assumes a linear temperature distribution from the bottom bulk oil to the top bulk oil and a parallel rise in the winding temperatures. These temperatures are assumed to vary as a function of the losses.

### Bottom Oil

The "Bottom Oil" model is more complex than the top oil model. This model takes into account the faster-rising duct oil-temperatures, as well as a more complex calculation of bottom and top oil temperatures as a function of loss.

### 2.1. Input Data

PTLOAD 6 utilizes operating conditions, specific test data and physical characteristics as input to determine the loading capability of the transformer:

- Coincident load for each distribution substation bank for 24-hour period during the summer peak days.
- Ambient Temperature Cycle over a 24-hour period on the corresponding peak day.
- Assumed 90% preloading.

Typical transformer data consists of the following information from the nameplate or final test reports.

- Top-oil temperature rise over ambient temperature at rated load.
- Average conductor temperature rise over ambient temperature at rated load.
- Winding hot-spot temperature rise over ambient temperature at rated load.
- Load loss at rated load.
- No load (core loss).
- Total loss at rated load.
- Confirmation of oil flow design (that is, directed or non-directed).
- Weight of core and coil assembly.
- Volume of oil in the tank and cooling equipment (excluding LTC compartments, oil expansion tanks, etc.).

## **2.2. Transformer Loading**

Applications of loads in excess of nameplate rating involve some degree of risk. While aging and long time mechanical deterioration of winding insulation have been the basis for the loading of transformers, it is now recognized that there are additional factors that may involve greater risk for transformers of higher mega-volt-ampere (MVA) and voltage ratings.

Power transformer life expectancy at various operating temperatures is not accurately known, but the information given regarding loss of insulation life at elevated temperatures is the best that can be produced from present knowledge of the subject. Loads in excess of nameplate rating may subject insulation to temperatures higher than the basis of rating definition. To provide risk associated with higher operating temperature, three (3) basic loadings have been included in this report.

**2.2.1. Normal Loading**

The basic loading of a power transformer for normal life expectancy is continuous loading at rated output when operated under usual conditions. It is assumed that the operation under these conditions is equivalent to operation in an average ambient temperature of 30°C for a cooling air or 25°C for cooling water.

Normal life expectancy will result from operating with continuous hottest-spot temperature of 110°C (or equivalent variable temperature with 120°C maximum in any 24-hour period). The 110°C hottest-spot temperature is based on the hottest-spot rise of 80°C plus the standard average ambient temperature of 30°C (105°C for an average ambient of 25°C).

This loading should entail normal winding insulation loss of life for a 24-hour period with a load cycle of 90% preloading or about **0.0133%**. For a 55°C Rise and 65°C Rise transformers, the top oil temperature and hottest-spot temperatures are:

<b>Temperatures</b>	<b>55°C Rise</b>	<b>65°C Rise</b>
Top Oil	95°C	105°C
Hottest-spot	105°C	120°C

**Table 8: Normal Loading Top Oil & Hottest Spot Temperatures**

**2.2.2. Long Term Emergency (LTE) Loading**

Long term emergency loading results from the prolonged outage of some system element and causes either the conductor hottest-spot or the top-oil temperature to exceed those suggested for normal loading beyond nameplate rating. This is not normal operating condition, but may persist for some time. It is expected that such occurrences will be rare. This loading assumes a **0.25%** loss of insulation life per occurrence not to exceed 4 hours, also with a 90% preloading. This is equivalent to approximately 19 days loss-of life for the one day in which the emergency occurs.

The LTE top oil temperature and hottest-spot temperatures used in the calculations for 55°C rise and 65°C rise transformers are:

Temperatures	55°C Rise	65°C Rise
Top Oil	100°C	110°C
Hottest-spot	140°C	140°C

*Table 9: LTE Loading Top Oil & Hottest Spot Temperatures*

**2.2.3. Short Time Emergency (STE) Loading**

Short time emergency (STE) loading is unusually heavy loading brought about by the occurrence of one or more unlikely events that seriously disturb normal system loading and cause either the conductor hottest-spot or top-oil temperature to exceed the temperature limits suggested for normal loading beyond nameplate rating. Unlike during long-term emergency, the 0.25% loss of insulation life per occurrence **will not be reached** for this

type of loading given the short 15 minutes time period and other limiting criteria.

The top oil temperature and hottest-spot temperatures used in the calculations for 55°C rise and 65°C rise transformers are:

<b>Temperatures</b>	<b>55°C Rise</b>	<b>65°C Rise</b>
Top Oil	100°C	110°C
Hottest-spot	150°C	150°C

**Table 10: STE Loading Top Oil & Hottest Spot Temperatures**

PT LOAD 6's provision for Bubble Avoidance as suggested by the IEEE Standard was not applied in the calculations.

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