

Central Maine Power Company

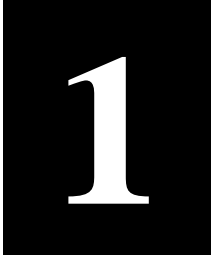
Transmission Planning Criteria

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BACKGROUND

1.1 Introduction

This document establishes general criteria and guidelines to maintain an acceptable transmission network that meets the needs of Central Maine Power’s customers in a safe, reliable and economical manner. The reader should use the procedures outlined here with those established by the New England Power Pool (NEPOOL) and ISO New England, Inc. and the Northeast Power Coordinating Council (NPCC). If conflicts exist between criteria in this document and the requirements of NEPOOL and ISO New England and/or NPCC, follow the more restrictive procedures.

1.2 Transmission System Design and CMP’s Supply Obligations

Both internal and external parties define Central Maine Power’s transmission system design. CMP and Transmission Planning “Mission Statements” specify the system’s design and performance characteristics. The Maine Public Utilities Commission’s Service Standards for Electric Utilities (Chapter 32, MPUC Rules and Regulations) further define CMP’s supply obligations.

“Our role may change, but whatever we may undertake, CMP customers must continue to see us as a credible organization efficiently delivering a dependable supply of energy essential to the well being of Maine.”

Comments on CMP’s vision and values, October 1992 (edited)

- 1. Design/plan a transmission system which serves our customers’ needs economically, reliably and safely.**
- 2. Contribute to the efficient utilization of our resources by integrating our plans and coordinating our efforts with the other areas of CMP, with the operating departments at CMP, neighboring utilities, and with NEPOOL, ISO New England, Inc. and the Northeast Power Coordinating Council (NPCC).**

Transmission Planning Mission Statement, August 1991 (updated)

The Maine Public Utilities Commission's Service Standards for Electric Utilities (Chapter 32, MPUC Rules and Regulations) require CMP to meet certain reliability, voltage and frequency constraints in supplying its customers' electricity. These constraints are as follows:

- Continuity of Service** Every utility shall maintain its entire plant and system in such condition as will enable it to furnish safe, adequate and as far as practicable continuous service.
- Frequency** Alternating current service under normal conditions shall be supplied at 60 cycles per second and under normal conditions shall not have a deviation in excess of two (2) percent.
- Voltage Variation**
- a. For service rendered principally for residential or commercial purposes the normal voltage variation shall not exceed plus or minus five percent ($\pm 5\%$) from the standard voltage for any period longer than one (1) minute.
 - b. For service rendered principally for power purposes the normal voltage variation shall not exceed plus or minus ten percent ($\pm 10\%$) from the standard voltage for any period longer than one (1) minute.
 - c. A greater variation of voltage than specified above may be allowed when service is supplied directly from a transmission line, in the case of emergency service, or in a limited or extended area where customers are widely scattered and the service supplied does not justify close voltage regulation. In such cases the best practicable voltage regulation shall be provided.

1.3 Definition of the Transmission System

The CMP transmission system consists of transmission lines and substations within CMP's service territory which interconnect generating stations in CMP's system and other utility systems with CMP's distribution system and large retail customers and wholesale customers. CMP's present transmission system operating voltages are 345 kV, 115 kV and 34.5 kV (with some of the 34.5 kV system designed to 69 kV standards). Some distribution circuits are also operated at 34.5 kV, but they are not considered part of the transmission system.

1.4 Transmission Network Operating Conditions

The ultimate goal of the transmission planning engineer is to design a transmission network that works predictably and effectively to meet customer needs in the future. Since the network is susceptible to outside influences such as equipment failure, weather and accidents, engineers must design the system to perform under many conditions and operating scenarios. While engineers cannot build the system to withstand every possible combination of events, due to financial constraints, they design it to operate under three *probable* conditions: normal, single outage and scheduled maintenance outage.

Normal	Normal conditions are present during “all lines & equipment in” periods. Normal conditions include extremes of customer loads, and generator forced and scheduled outage conditions. While this condition may not be the most common in terms of operating time, it serves as a benchmark against which to measure other conditions.
Single Outage	This document defines single outage conditions as loss of a single transmission network element such as a power transformer, capacitor, circuit breaker or transmission line. Most of Transmission Planning analysis involves studying single outage conditions.
Scheduled Maintenance Outage	Frequently, system dispatchers and CMP maintenance crews must remove a transmission network element from service to perform maintenance. Effectively, this causes a “single outage” condition. The Company should design the system to withstand an <i>additional</i> single outage during scheduled maintenance periods. However, designs need only provide this capability for system loads of 85 percent of system peak and less. Based on recent system load data, system load exceeds 85 percent of peak only 5 percent of the time throughout the year (about 440 hours). Nearly all of those times are from December through March. That leaves system operators over 8300 hours per year during which to schedule maintenance.

Transmission Planning performs most analyses using a computer loadflow program, modeling existing and future system configurations. Engineers analyze simulations for winter and summer peak, as well as off-peak conditions. This ensures that the transmission network will perform adequately under normal and “worst case” conditions.



DESIGN CRITERIA

2.1 Power Frequency Criteria

Since CMP's transmission network is well interconnected with the transmission network in the northeastern United States and Canada, power frequency deviation is not a significant concern. The interconnected transmission systems of eastern North America typically have a frequency variation of a fraction of 1 percent. CMP also designs its system to comply with NPCC Criteria for under-frequency load shedding and generator frequency or speed protection. These criteria are designed to help survive "islanding" and stabilize system frequency at 60 Hz.

2.2 Voltage Criteria

Voltage is one of the most critical parameters planning engineers consider when analyzing the power system. Low voltage can be responsible for damaging company and customer equipment, and decreasing the reactive power supply capability of system capacitors. CMP designs its transmission network so that voltages remain between 95 percent and 105 percent of nominal (up to 110 percent for 34.5 kV subtransmission).

CMP plans its distribution system based on a fixed voltage of up to 1.05 per-unit at the substation low-side (distribution substation voltage) bus. To maintain this voltage, high-side (transmission or subtransmission) bus voltage must remain above 95 percent, assuming a maximum +10 percent voltage boost and unity nominal high-side tap in the step-down transformer. Maximum voltage criteria are based upon equipment operating limit specifications.

2.3 Line & Transformer Loading Criteria

Since transmission lines and power transformers carry high current, they can also experience high temperatures due to resistive heating losses. Power transformers can suffer damage from excessive heat, decreasing their reliability and life expectancy. Overhead conductors can stretch as their temperature increases, decreasing the clearance from the conductor to ground. Extremely high temperatures can cause physical damage to the wire.

The transmission network should be designed so that line and transformer loadings do not exceed their ratings. However, under certain extreme conditions, equipment loading may exceed ratings to maintain customer service. Section 3 discusses ratings specifically, and in more detail.

2.4 Reliability Criteria

Reliability criteria help to maintain high quality electric service to CMP customers. The criteria include five major reliability indicators: Event Frequency (EF), Event Duration (ED), Loss of Load magnitude (LOL), Expected Unserved Energy (EUE), and the Number of Customers affected (NC). These indicators provide engineers with quantitative methods for revealing system weaknesses. While no single indicator can entirely measure acceptable customer service, the effective combination of all can provide important insights into system problems and their solutions.

The following page describes each indicator and its significance for identifying and prioritizing projects.

Indicator	Description
Event	Outage (contingency); it may be a maintenance outage intended to minimize interruptions, a temporary or permanent fault (short circuit), or equipment failure.
Event Frequency (EF)	EF specifies the number of outages per unit time that a system element experiences. EF for transmission elements should not exceed industry averages.
Event Duration (ED)	The elapsed time between outage/interruption and repair or restoration is complete. ED for transmission elements should not exceed industry averages.
Loss of Load (LOL)	<p>LOL indicates how much <i>peak</i> customer load is lost if a certain transmission element fails. LOL is a very important measure of the transmission system dependence on specific system elements. LOL provides no information about customer service levels. For example, in a well-networked transmission system such as in Greater Portland, a transformer failure might have a 0 MW LOL. However, a Detroit 115/34.5 kV transformer outage has winter peak LOL of 34 MW since it serves radial transmission lines.</p> <p>CMP should design its transmission system so LOL is less than 25 MW for single outages, and less than 60 MW for maintenance outages.</p>
Expected Unserved Energy (EUE)	<p>EUE is a statistical indicator aimed at quantifying reliability in terms of unserved megawatt hours per year (MWh/yr).</p> $EUE (MWh/yr) = EF (outages/yr) \times ED (hrs/outage) \times LOL (avg. MW)$ <p>EUE provides another way to evaluate and prioritize projects. In cases where single contingency EUE exceeds 70 MWh per year, engineers should investigate ways to improve service reliability. This threshold was first specified in an area study. It will be updated as Transmission Planning obtains more EUE data.</p>
Number of Customers Affected (NC)	NC is a measure of how many customers an outage affects. Sometimes LOL may be relatively low even though an outage affects a large number of customers. For these cases it is important to recognize the severity of an outage based on the number of CMP customers it affects. At this time NC is a qualitative measure only. Engineers should consider the NC when evaluating contingencies.

2.5 Contingency List

Contingency	Design Requirements
<i>Transformer outage</i>	Outages caused by transformer failures can range from hours to months depending on the failure's cause and the size of the transformer. CMP must design the system to withstand the loss of one transformer.
<i>Transmission line outage</i>	Transmission line outages have a number of causes from lightning strokes to tree contact. The transmission system must be able to withstand the loss of a single transmission line.
<i>Generator outage</i>	The typical availability of a generator is 80 percent. Therefore, the unavailability of generators is more likely than an outage of transmission lines or transformers. An outage of these generators is considered an operating condition, rather than a contingency. Planning engineers should design the transmission system to withstand the loss of a generator and one additional system element.
<i>Bus Fault (Extreme Contingency)</i>	These contingencies, caused either by direct faults or incorrect relay or circuit breaker operation, should be studied to determine their effect on the surrounding system. Historical effects of bus faults are a Greater Portland outage in 1986, and more recently, a Camden-Rockland area outage in 1993.

3

EQUIPMENT RATINGS

To maintain a reliable and enduring transmission system, equipment must be sized and operated according to manufacturers' specifications, industry and national standards, and Company guidelines. These guidelines specify everything from maximum operating temperatures, to energy dissipation, to mechanical operation times.

Transformer and transmission lines carry specific ratings according to normal and emergency conditions. For transformers, in particular, "normal" ratings are intended to protect the equipment from premature aging caused by excessive heating. The "long-term emergency" (LTE) rating specifies the amount of load the transformer can carry while suffering 1 percent "loss of life." The "short-term emergency" (STE) rating allows two-times the transformer nameplate rating for 15 minutes. Overhead transmission lines also have normal, LTE and STE ratings, and in some cases a "drastic action limit" (DAL) under extreme conditions to prevent catastrophic system failure. The duration specified for each rating is based on typical system load shapes. For example, peak loads typically last only a few hours within each load cycle. The emergency rating durations below are consistent with NEPOOL criteria.

Ratings for Transformers & Transmission Lines

Rating	Duration	Comments
Normal	indefinite	no loss of life (transformers)
LTE (summer)	12 hours	1% loss of life tolerated (transformers)
LTE (winter)	4 hours	1% loss of life tolerated (transformers)
STE	15 minutes	rating is 2 times nameplate (transformers)
DAL	5 minutes	only transmission lines have a DAL rating

The following sections provide the basis for the ratings applied to CMP's equipment.

3.1 Power Transformers

Power transformer ratings are specified according to ANSI Standard No. C57.92 ("ANSI Guide for Loading Oil Immersed Distribution and Power Transformers").

Loss of life refers to equipment deterioration resulting from conditions other than normal aging processes. The major cause of loss of life is excessive temperature within the transformer. During routine operation, "hot spots" in the windings develop which stress insulating material. If hot spot temperatures are severe enough for extended periods of time, winding insulation can fail resulting in an internal fault. In emergency situations, system operators tolerate some loss of life to maintain system integrity.

3.2 Overhead Conductors

CMP's overhead conductor ratings are based predominantly upon maintaining adequate clearances between wires and the ground (earth). Transmission and distribution line structures are designed to maintain these clearances while accounting for conductor sag. Sag can increase due to high conductor temperature or physical loads on the wire such as ice. As the current increases, conductor temperatures rise causing wires to stretch and sag. Ambient air temperature, wind speed, and even the solar absorptivity of the conductor itself directly affect transmission line

ratings because of their effects upon conductor temperature. Sag can be reduced by increasing wire tension, or by placing support structures closer together.

To maintain proper transmission line clearances, conductor temperatures should not exceed 120°F for older lines, or 212°F for lines built or rebuilt since about 1980. Ratings are calculated based on these conductor temperature operating limits, and on 50°F and 95°F ambient air temperatures for the winter and summer months, respectively. Engineering should investigate specific ratings for lines whose clearances are in question.

3.3 Cables

Underground and submarine cables are rated according to IEEE Standard No. 135, “Power Cable Ampacities.”

3.4 Circuit Breakers

Power circuit breakers are rated according to ANSI standard No. C37.010/IEEE Standard No. 320, “ANSI Application guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.”

3.5 Air Switches

Air switches are rated according to ANSI Standard No. C37.37, “Loading Guide for AC High Voltage Air Switches, Part I — Allowable Continuous Current.”

3.6 Buswork

Aluminum substation buswork is rated according to the [Alcoa Conductor Engineering Handbook](#); allow no excessive expansion or sag and maximum bus temperature 10°C less than connected equipment temperature.

3.7 Miscellaneous Equipment

Electrical equipment such as metering transformers, relays, reactive compensation devices, and communication equipment should be used according to the manufacturer’s voltage and thermal limit specifications.

4

SPECIAL CRITERIA & GUIDELINES

4.1 Capacitor Switching & Motor Starting Standards

Switching large reactive loads can cause special problems in some locations of the power system. For example, switching capacitors can cause serious voltage impulses in the short term, and result in changes in steady-state system voltages. Electric motors can cause voltage sags due to the large amounts of starting current that is largely reactive. When such equipment is switched, the steady-state bus voltage must not change by more than 3 percent.

4.2 Sectionalizing Application

Automatic sectionalizers are an acceptable design alternative at tap points or substations with only two line terminals. Automatic sectionalizing, when appropriately applied, offers a relatively inexpensive means to increase service reliability for our customers by isolating faults to only a portion of a line, rather than the entire line.

Sectionalizing accomplishes two purposes:

1. Typically, it limits the length of some customer outages to less than a minute (rather than nearly an hour or more). Sectionalizing schemes can isolate faults to portions of transmission lines, while restoring service to customers on unfaulted portions.
2. Automatic sectionalizing enables line crews to locate the cause of the fault and fix a problem faster, by reducing the amount of line that they must patrol to locate the problem. This also speeds service restoration to customers served by the faulted portion of the line.

4.3 Special Protection System (SPS) Application

Special Protection Systems are relaying systems that are used other than to protect and isolate system elements from faults. Engineers typically use SPSs to cross-trip other lines, or transfer trip load or generation in response to a system condition such as a line outage, overload or low voltage.

SPSs are an acceptable design alternative if they do not interrupt customer load unless a specific customer requests an SPS designed to trip their load as an alternative to paying for transmission or distribution facilities for more reliable service under CMP's line extension policy.

Although SPSs are not an acceptable design alternative if they interrupt customer load, they are acceptable as a temporary measure to avoid customer equipment damage or CMP facility damage until the Company can implement a permanent solution. NEPOOL and ISO New England and NPCC must review and approve any new or changed SPS on the 115 kV or 345 kV system.