IEEE Houston Section Continuing Education on Demand

**INTERTIE SUBSTATION DESIGN**

CenterPoint Energy expectations for intertie substations and the required operation / maintenance practices

Don Sevcik and Brian Clowe
CenterPoint Energy

March 3\textsuperscript{rd} and 4\textsuperscript{th} 2015
CenterPoint Energy expectations for intertie substations and the required operation / maintenance practices

OUTLINE:

1. Basic system overview
2. How transmission service is extended
3. Load request and interconnection study
4. Customer substation configurations and switching
5. Customer Substation specification
6. Outage Clearance and Coordination Procedure
7. System faults and automatic reclosing
COMPANY OVERVIEW

CenterPoint Energy operates in five primary businesses: electric transmission and distribution, natural gas distribution, and competitive natural gas sales and services:

- **Electric Transmission & Distribution (T&D)** – We maintain the wires, poles and electric infrastructure serving our 5,000-square-mile electric service territory in the Houston metropolitan area. While CenterPoint Energy employees ensure the reliable delivery of power from power plants to homes and businesses, we neither generate power nor sell it to customers.

- **Natural Gas Distribution** – We sell and deliver natural gas to 3.2 million homes and businesses in Arkansas, Louisiana, Minnesota, Mississippi, Oklahoma and Texas, including the high-growth areas of Houston and Minneapolis.

- **Competitive Natural Gas Sales and Services** – Our natural gas marketing business, CenterPoint Energy Services (CES), sells non rate-regulated natural gas and related services to approximately 25,000 commercial, industrial and wholesale customers located primarily in the eastern half of the United States.
# Electric Transmission and Distribution Fast Facts

*Data as of December 31, 2013*

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<thead>
<tr>
<th>Metered Customers by Classification</th>
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<tbody>
<tr>
<td>Residential</td>
<td>1,965,002</td>
<td>87.5%</td>
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<tr>
<td>Commercial</td>
<td>276,101</td>
<td>12.3%</td>
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<tr>
<td>Industrial</td>
<td>2,033</td>
<td>0.1%</td>
</tr>
<tr>
<td>Municipal / Public Utilities</td>
<td>772</td>
<td>&lt; 0.1%</td>
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</table>

<table>
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<tr>
<th>Megawatt Hours Delivered in 2013</th>
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<tbody>
<tr>
<td>Residential</td>
<td>27,279,007</td>
<td>34.3%</td>
</tr>
<tr>
<td>Commercial</td>
<td>24,136,285</td>
<td>30.4%</td>
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<tr>
<td>Industrial</td>
<td>27,935,132</td>
<td>35.1%</td>
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<tr>
<td>Municipal / Public Utilities</td>
<td>167,352</td>
<td>&lt; 0.2%</td>
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<thead>
<tr>
<th>Transmission and Distribution</th>
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<tr>
<td>Overhead Distribution Lines</td>
<td>28,112 miles</td>
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</tr>
<tr>
<td>Overhead Transmission Lines</td>
<td>3,703 miles</td>
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<tr>
<td>Underground Distribution Lines</td>
<td>21,763 miles</td>
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<tr>
<td>Underground Transmission Lines</td>
<td>26 miles</td>
<td></td>
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<tr>
<td>Substations</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>Service Centers</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>
Tariff applicable to customer that takes transmission service

http://www.centerpointelectric.com/cehe/about/tariffs/

‘Current tariff for retail delivery service’

(Rev. No. 7th, Effective: 1/15/15)

Section 5.5.5 Power Factor

95% lagging

Customer installs corrective equipment
Or demand associated with customer’s use of delivery service is increased by formula
Or CenterPoint Energy may installs corrective equipment and charge customer
Basic Power System Overview
And
CenterPoint Energy
Transmission System
Electric Reliability Council Of Texas (ERCOT)
RED = 345 kV
BLUE = 138 kV
GREEN = 69 kV
CLASSIFICATION OF POWER LINES

DISTRIBUTION (2.4 - 34.5 KV)
Typically radial in configuration and utilized to transmit power to final retail customer.

SUBTRANSMISSION (13.8 - 138 KV)
Radial or network configuration and utilized to transmit power to distribution substations or to transmit power to bulk retail users.

TRANSMISSION (69 - 765 KV and above)
Almost always network in configuration and utilized to transmit power between major substations & interconnecting systems, to wholesale outlets and to large bulk retail users.

TRANSMISSION IS FURTHER DIVIDED INTO:

High Voltage (HV) 115 - 230 kV

Extra High Voltage (EHV) 345 - 765 kV

Ultra High Voltage (UHV) greater than 765 kV
SOME COMMON TRANSMISSION/DISTRIBUTION SYSTEM VOLTAGES (KV) AND CNP VOLTAGES

765
500
345 ^ EHV
230
138 ^ Transmission
115
69 ^ Subtransmission
34.5
13.8
12.47
7.2
4.16
2.3 ^ Distribution
Basic Electric Power System

Generator
4-25 kV

Generator Step-up Transformer

Transmission lines
50-765 kV

Home wiring
120/240 V

Pole-mounted transformer

Distribution lines below 50 kV

Substation transformer
CenterPoint Energy Transmission System

Transmission System

- Phase A
- Phase B
- Neutral
- Phase C

Step-Up (GSU) Transformer

- Wye-grounded
- Delta

Generator

- Two-pole machine magnetic field rotates once per cycle
- 60 times per sec.
- 3600 rpm

Three-Phase Alternating Current

- Three voltages or currents at 120° add up to zero
- One cycle is 360 electrical degrees
- Balanced 3-phase circuit; neutral not required.
CenterPoint Energy (CNP) transmission and distribution systems use the C-B-A counter-clockwise phase rotation designation. This can also be called A-C-B, or even B-A-C rotation designation (any of these is correct as long as the letters are in the same sequence). The phasor rotation diagram is just a way to symbolize the sequence in which the phases reach a peak. Each phase vector is 120 degrees apart from the others which corresponds to each phase sinewave which is 120 electrical degrees apart from the others (this is optimum spacing, the peaking at different times allows the even distribution of 3-phase power to supply large loads).

CenterPoint Energy does not use the A-B-C (also called C-A-B, or B-C-A) phase rotation designations, but some other utilities do. So, it is easy to see where problems would arise if connecting CNP C-B-A phases to another utility’s C-A-B phases or other designation used by industrial customers.
**PHASE DESIGNATION AND INTERCONNECTION COMPARISON CHART**

<table>
<thead>
<tr>
<th>US Industry Standard</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
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<tr>
<td>CNP Transmission/Distribution System</td>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>CNP substation drawings 67V1-n</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>CNP substation drawings 115V1-n</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td><em><em>CNP High Voltage Metering department (inside the metering cabinet</em>)</em>*</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>CPS Energy, STP</td>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>AEP, LCRA, ONCOR, STEC, TMPA, BEC, LST</td>
<td>B</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>TNMP</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>AE</td>
<td>B</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>Typical relay manufacturer connection diagrams</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>European Standard</td>
<td>R</td>
<td>S</td>
<td>T</td>
</tr>
</tbody>
</table>

* CNP High Voltage Metering refers to this as A-B-C clockwise

**Interconnected Phasing Notes (and designations shown on older drawings):**

All designation are referred to as counter-clockwise rotation except as noted.

- **TNMP** = Texas-New Mexico Power (also TNP, formerly Community Public Service, CPS)
- **TMPA** = Texas Municipal Power Agency
- **AEP** = American Electric Power (formerly Central Power & Light, CP&L)
- **LCRA** = Lower Colorado River Authority
- **BEC** = Brazos Electric Cooperative
- **CNP** = CenterPoint Energy (formerly Reliant Energy, HL&P, Houston Lighting & Power)
- **CPS Energy** = City Public Service Energy San Antonio (formerly City Public Service Board, CPSB)
- **AE** = Austin Energy (City of Austin, COA)
- **STP** = South Texas 345 kV Substation
- **STEC** = South Texas Electric Cooperative
- **ONCOR** = Oncor (Texas Utilities, TXU)
- **LST** = Lone Star Transmission
RELATIONSHIP BETWEEN TRANSMISSION VOLTAGE LEVELS

Transmission System Utilization

10,930 MW Total System Load

<table>
<thead>
<tr>
<th>396 MW 345 kV Net Tie</th>
</tr>
</thead>
<tbody>
<tr>
<td>618 MW in 1,014 MW out</td>
</tr>
<tr>
<td>618 345 kV Flow Through</td>
</tr>
<tr>
<td>1,349 345 kV Losses/Mismatch</td>
</tr>
</tbody>
</table>

345 kV Transmission System

<table>
<thead>
<tr>
<th>345 kV Net Gen 6,001 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>345 kV Net Load 56 MW</td>
</tr>
<tr>
<td>345/138 kV Auto Net Flow 4,201 MW</td>
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</table>

138 kV Transmission System

<table>
<thead>
<tr>
<th>138 kV Net Gen 5,850 MW</th>
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</thead>
<tbody>
<tr>
<td>138 kV Net Load 9,347 MW</td>
</tr>
<tr>
<td>138/69 kV Auto Net Flow 606 MW</td>
</tr>
</tbody>
</table>

69 kV Transmission System

<table>
<thead>
<tr>
<th>69 kV Net Gen 0 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>69 kV Net Load 606 MW</td>
</tr>
</tbody>
</table>

Autotransformers which are effectively wye-grounded/wye-grounded transformers (i.e. no phase shift and connected in the zero sequence network)

42 Percent of 138 & 69 kV load served through the 345/138 kV Autos

INTERTIE SUBSTATION DESIGN
IEEE Houston Section CED Seminar March 3/4 2015
THE ROLE OF SUBSTATIONS

Generating station electric power system - An area or group of equipment containing switches, circuit breakers, buses, and transformers for switching power circuits and to transform power from one voltage to another or from one system to another.

Transmission and distribution - An assemblage of equipment for purposes other than generation or utilization, through which electric energy in bulk is passed for the purpose of switching or modifying its characteristics. A substation is of such size or complexity that it incorporates one or more buses, a multiplicity of circuit breakers, and usually is either the sole receiving point of commonly more than one supply circuit, or it sectionalizes the transmission circuits passing through it by means of circuit breakers.
HOW TRANSMISSION SERVICE IS EXTENDED
HOW THE TRANSMISSION SYSTEM IS TYPICALLY EXTENDED TO A CUSTOMER OWNED SUBSTATION

‘MAJOR SUBSTATION’
THREE OR MORE TRANSMISSION CIRCUITS, RING BUS OR BREAKER-AND-A-HALF, WITH TRANSMISSION LINE RELAYING & LOCAL BREAKER FAILURE RELAYING
HOW THE TRANSMISSION SYSTEM IS TYPICALLY EXTENDED TO A CUSTOMER OWNED SUBSTATION

NEW CUSTOMER OWNED “LOOP TAP” SUBSTATION
NO LINE RELAYING

NEW CENTERPOINT ENERGY OWNED “LOOP TAP” OR “SECTIONALIZING” SUBSTATION
NO LINE RELAYING

No change to transmission line relaying

Substation power transformer
- Circuit breaker
- Circuit switcher
- Motor operated switch
- Disconnect switch
Changes to transmission line relaying required

NEW CUSTOMER OWNED “FULL LOOP” LINE RELAYING SUBSTATION
To the extent that it is reasonably and economically practical, CenterPoint Energy seeks to limit the number of “full loop” substations on a transmission line segment between major substations (3 or more line terminals) to three or less.
LOAD REQUEST AND INTERCONNECTION STUDY
Data Needed for Technical Evaluation of Interconnection Requests for New/Existing Transmission Customers

1. Type of interconnection study requested:
   (a) new load customer _____ (b) existing customer adding load _____

2. General location of customer’s new load (provide sketch of the site).

3. Planned in-service date for new load ________________________________

4. Amount of load increase or new load __________ MVA, pf.

5. Total amount of transmission or distribution load transferred from existing___________ sub to the new location, if any, __________ MVA, pf.

6. Current peak load at the existing site, if any, __________ MVA, pf.
Projected load growth over next five years (MVA, pf):

<table>
<thead>
<tr>
<th>Year</th>
<th>MVA</th>
<th>pf</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
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<td>3</td>
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</table>

Load profile (annual load variation, summer/winter peaking, day/night peaking).

Load characteristics (i.e., large motor, lighting, etc.).

Note: If large motor(s), need data for motor(s) starting study, see Attachment ‘A’.

Type of interconnection substation customer intends to build.
CNP utilizes standard electrical transmission system simulations (power flow, short circuit, stability, etc.) and, when applicable, standard discounted cash flow analyses, to develop and compare system improvement options. The following technical parameters are also considered in the design of CNP’s transmission system:

1. To the extent that it is reasonably and economically practical, CNP seeks to limit the number of two-line, loop breaker substations on a transmission line segment between major (3 or more line terminals) substations to three or less. This is due to relay considerations and to limit the exposure of multiple two-line, loop-breaker substations to separation from the CNP transmission system.

2. To the extent that it is reasonably and economically practical, CNP strives to limit the amount of generation that would be tripped by the loss of a double circuit transmission line (Category C) to at most 1250 MW in the design of generator interconnections.

3. CNP takes into account protective relay system dependability, security, and simplicity when determining transmission circuit configurations (i.e. a long radial tap of a transmission line section, etc.)
4. CNP designs its transmission system such that switching of its transmission capacitor banks or inductive reactors limits momentary voltage change at a transmission bus to less than 2% with one transmission line segment out-of-service.

5. CNP also requires that the starting of customer equipment (motors, arc furnaces, etc.) does not result in a momentary voltage change greater than 2% at the customer’s high-side bus with one transmission line segment out-of-service.

6. CNP seeks to limit the number of in-series sectionalizing devices (MOD's, circuit switchers, etc.) on a transmission line segment between breaker substations to three or fewer. This is necessary in order to limit the number of automatic reclose attempts required to isolate the faulted line section to a reasonable quantity and also due to the increased complexity of under voltage sectionalizing relay coordination necessary between breaker substations as more sectionalizing devices are added.
CUSTOMER SUBSTATION CONFIGURATIONS AND SWITCHING
“LOOP-TAP” ALTERNATIVE ‘a’

All disconnect switches only have ‘arching horns’. ‘Circuit Switchers’ are required to be installed in this configuration. The ‘Circuit Switchers’ are used for manual switching of the transmission line sections.

“Loop-Tap” alternative ‘a’ Customer 138 kV Substation
2 Circuit Switchers with 1 or 2 Transformers/Circuit Breakers

CS = circuit switcher
CB = circuit breaker
DS = disconnect switch

Must have a continuous current rating of 4000 A minimum
Can be less than 4000 A
“LOOP-TAP” ALTERNATIVE ‘b’

All disconnect switches only have ‘arcing horns’. ‘Circuit Switchers’ are not used in this configuration. The circuit breakers are used for manual switching of the transmission line sections.

* If two transformers are installed then this ‘DS’ is installed and is ‘normally open’.

CB = circuit breaker
DS = disconnect switch

Must have a continuous current rating of 4000 A minimum
Can be less than 4000 A

“Loop-Tap” alternative ‘b’ Customer 138 kV Substation
2 Circuit Breakers with 1 or 2 Transformers
“LOOP-TAP” ALTERNATIVE ‘b’ SWITCHING – STEP 1

STEP 1 – Close the ‘normally open’ disconnect switch
STEP 2 – **Open the ‘normally closed’ disconnect switch.**

This is referred to as ‘closed-loop switching’ within a substation. No current is interrupted. The current is diverted to the other path within the substation. A disconnect switch with arcing horns is capable of performing this type of switching.
STEP 3 — Open the remote substation circuit breaker(s) or remote substation transmission line switching device.
STEP 4 – Open the customer substation circuit breaker
All disconnect switches only have ‘arching horns’. ‘Circuit Switcher’ are not used in this configuration. The circuit breakers are used for manual switching of the transmission line sections.

* If two transformers are installed then this DS is ‘normally open’ or ‘normally closed’ depending on customer operating preference.

“Full-Loop” alternative ‘a’ Customer 138 kV Substation
3 Circuit Breakers with 1 or 2 Transformers

CB = circuit breaker
DS = disconnect switch

Must have a continuous current rating of 4000 A minimum
Can be less than 4000 A
“FULL-LOOP” ALTERNATIVE ‘b’

All disconnect switches only have ‘arcing horns’. ‘Circuit Switchers’ are not used in this configuration. The circuit breakers are used for manual switching of the transmission line sections.

“Full-Loop” alternative ‘b’ Customer 138 kV Substation
4 Circuit Breakers with 2 Transformers

CB = circuit breaker
DS = disconnect switch

Must have a continuous current rating of 4000 A minimum
Can be less than 4000 A
All disconnect switches only have ‘arcing horns’. ‘Circuit Switchers’ are not used in this configuration. The circuit breakers are used for manual switching of the transmission line sections.
Any customer connection from the “Full-Loop” substation or “Loop-Tap” substation to the customer’s transformers, customer buses, or customer lines (i.e. customer plant internal “loop lines”, etc.) are not required to be 4000 A minimum. However, operational scenarios may exist after scheduled outages for which the transmission line load flow may circulate beyond the “Full-Loop” or “Loop-Tap” portion of the substation and potentially overload the customer’s equipment if rated less than the 4000 A minimum. Therefore, CenterPoint Energy suggests that any customer “loop line” and customer bus/bay equipment (except customer ‘radial’ line or customer transformer bus connection) be 4000 A minimum.
CENTERPOINT ENERGY
SPECIFICATION FOR CUSTOMER 138 kV SUBSTATION DESIGN
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<td>STRUCTURAL AND MECHANICAL DESIGN CRITERIA ....................</td>
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<td>17.</td>
<td>RECOMMENDED TESTS AND INSPECTIONS ................................</td>
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<td></td>
<td>REFERENCE DRAWINGS ..................................................</td>
<td>30</td>
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</tbody>
</table>
Because the customer’s substation becomes an integral part of the CenterPoint Energy transmission system network, CenterPoint Energy requires access to the substation and CenterPoint Energy right-of-ways 7 days-a-week, 24 hours-a-day, 365 days-a-year. Plant site access and access to plant roads to the substation by CenterPoint Energy personnel should be considered when determining the substation location and plant operating procedures.
CENTERPOINT ENERGY SYSTEM CHARACTERISTICS

CenterPoint Energy’s phase rotation is designated C-B-A counterclockwise and the customer shall phase equipment accordingly. Connection of the customer’s H1-H2-H3 power transformer leads to CenterPoint Energy’s C-B-A, B-A-C or A-C-B, respectively, is recommended.

The CenterPoint Energy 138 kV transmission system is wye, effectively grounded. The nominal system voltage is 138L-L/79.7L-G kV +/- 5%. Actual steady-state operational voltage varies around the power system but facilities with a means to regulate the 138 kV transmission system are typically used to control the voltage to be no more than approximately 142 kV to provide a margin from the maximum + 5% (145 kV). Transient conditions exceeding this range may be encountered. See Sub-Articles 3.4, 3.5, 4.7 and 7.1.4 of this specification for additional relevant information. Only instrument transformers, surge arresters, station service voltage transformers, generator step up transformers and auto transformers are allowed to be connected phase-to-ground.

Frequency, which the Electric Reliability Council of Texas Independent System Operator (“ERCOT ISO”) is responsible for maintaining, is nominally 60 Hz. Refer to ERCOT (www.ercot.com) Nodal Operating Guides and Protocols for information regarding frequency regulation.
The minimum acceptable electrical design characteristics are listed below:

<table>
<thead>
<tr>
<th>Description</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer Winding Impulse Level</td>
<td>550 kV BIL</td>
</tr>
<tr>
<td>Bus and Switch Insulator, Apparatus Bushing Impulse Level</td>
<td>650 kV BIL</td>
</tr>
<tr>
<td>(circuit breaker bushings, transformer bushings, CVT, CT, PT, surge arresters etc.)</td>
<td></td>
</tr>
<tr>
<td>Bus and Switch Insulator Leakage Distance</td>
<td>132 in. creep (equivalent to extra creep 650 kV BIL or 750 kV BIL. May require coating in extra heavy contamination areas)</td>
</tr>
<tr>
<td>Apparatus Bushing Leakage Distance</td>
<td>92 in. creep (equivalent to 650 kV BIL – light contamination levels. May require coating in some areas)</td>
</tr>
<tr>
<td>(circuit breaker bushings, transformer bushings, CVT, CT, PT, surge arresters etc.)</td>
<td></td>
</tr>
<tr>
<td>Phase to Ground Clearance</td>
<td>52 in. (Metal to Metal)</td>
</tr>
<tr>
<td>Phase to Phase Bus Spacing (including vertical spacing at crossover point of high and low bus)</td>
<td>63 in. (Metal to Metal)</td>
</tr>
<tr>
<td>Phase to Phase Horizontal Spacing Center Line to Center Line, at Incoming Line Dead-End Structure</td>
<td>144 in. (regardless of the line angle)</td>
</tr>
</tbody>
</table>
The 138 kV substation shall be designed for a short circuit current of 63 kA rms symmetrical, with X/R ratio of 15, unless otherwise specified by CenterPoint Energy.

The application of key interlock systems are not permitted on customer substation 138 kV equipment.

The customer’s connected load and equipment shall be designed and operated to adhere to the recommended harmonic limits of IEEE Std. 519 and limits of voltage fluctuations and associated light flicker of IEEE Std. 1453.

The operation of customer’s equipment (starting of motors, operating furnaces, energizing capacitor bank, etc.) shall not produce a step voltage change greater than 2.0% at the customer’s high side bus with any one transmission line segment directly associated with the electrical supply to the customer substation out-of-service.

The substation ground mat shall be designed for a short circuit current of 63 kA rms symmetrical with X/R ratio of 15 and duration of 0.25 seconds and comply with IEEE Std. 80 and IEEE C2 (NESC). Ground mat connections shall comply with IEEE Std. 837, unless otherwise specified by CenterPoint Energy.

The substation direct lightning stroke shielding design shall comply with IEEE Std. 998
New requirement for 2-hr emergency current rating:

The 2-hr emergency current rating of all equipment in the transmission line loop or ring portion of the substation shall be 4,400A minimum (110% of 4000A continuous rating). This includes line disconnect switches, conductors, circuit breakers, line traps, etc. which are in the transmission line loop or ring portion of the substation.
The customer will design a mounting stand and foundation for the hurricane wind speeds and overloads from section 5.4.2. If the AISC ASD design method is used, the 1/3 increase in allowable stress will not be permitted. If the AISC LRFD method is used, the structure must have a second order elastic analysis (also called a Geometric Nonlinear Analysis). The Customer shall limit the horizontal deflection of the PT/CT at the instrument mounting height to the mounting height divided by 100. The wind load used for the deflection limit shall be the 5 year mean recurrence interval wind. A conversion factor of 0.78 applied to the hurricane wind pressure will yield the 5 year MRI.
This diagram represents the maximum dimensions, and maximum weight of possible 138 kV CT's or PT's that CenterPoint Energy will provide for the 138 kV billing metering.

This diagram provides the necessary structural and mechanical design parameters to be used for the instrument transformer foundations and stands that will support 138 kV CT's or PT's that CenterPoint Energy will provide.

This diagram must also be used, in conjunction with substation bus profile dimensions, to determine the height of the stands that will support the instrument transformers that CNP would provide for the 138 kV billing metering.

After the instrument transformer stand height has been determined based on the above information, the manufacturer’s outline drawing for the actual 138 kV CT’s and PT’s that CenterPoint Energy will provide must be used to determine the details of the primary connection(s) and secondary terminal box conduit connection.
The instrument transformer stand mounting surface for the 138 kV CT & PT that CenterPoint Energy will provide for the 138 kV billing metering must be adjustable or use grating to accommodate diverse instrument transformer mounting bolt patterns.
Additional design documentation:

The customer shall provide a complete structural and foundation design package for the dead-end structures (supporting the CenterPoint Energy transmission lines connected to the customer’s 138 kV substation) and the instrument transformer stands in accordance with Article 15.0. The design package shall be signed and sealed by a professional engineer registered in Texas (including the firm name and firm registration number) and shall include design references/codes, computer analysis, member design, connection design, foundation design, soil report, structural and foundation drawings, and all other information that documents the design of the structure(s).
CIRCUIT BREAKERS

Change to accommodate interface with any existing circuit breakers with 2000:5 multi-ratio CT’s in an existing substation while maintaining the design capability for 4000 ampere operation in the future and in a new substation:

Each 138 kV circuit breaker shall be equipped with two 3,000:5 A multi-ratio CT’s per 138 kV bushing. Each CT shall have an accuracy of C800 on the 2,000:5 A tap in accordance with IEEE C57.13. The secondary resistance of circuit breaker bushing CT’s shall not exceed 0.0025 ohms per turn. CT secondary rated continuous current shall be 10 A minimum. Rating Factor (R.F.) shall equal 2.0.
CIRCUIT BREAKERS

Additional information required:

The customer shall indicate on the relay and metering one-line diagram whether the low SF6 gas pressure wiring to set to ‘BLOCK TRIP’ or to ‘AUTOMATICALLY TRIP’ the circuit breaker.
New requirement for three secondary windings required by transmission line protective relaying schemes:

The 138 kV Metering PT’s will have three secondary windings (i.e. “X”, “Y”, and “Z”). The “X” and “Z” windings will be used for relaying, SCADA and the customer’s equipment. The “Y” winding will be used exclusively for CenterPoint Energy metering.
CNP calculates and implements all settings for the Customer’s relays installed for the protection and automatic reclosing of CNP transmission lines and for the Customer’s relays installed to prevent back-energizing CNP’s system from generation installed on the low side of the Customer’s power transformers. On a case-by-case basis, CNP may issue settings for other relays owned by the Customer. The relay settings implemented by CNP for the Customer’s relays will be provided to the Customer upon request.
11.10. An electronic device that can directly or indirectly trip a circuit breaker connected to a CenterPoint Energy transmission circuit (i.e. transmission line protective relay, transformer bus protective that includes breaker failure relaying, etc.) is not allowed to be monitored via routable protocol communication (i.e. Ethernet), serial or dial-up communication. Data can be provided from the CenterPoint Energy RTU (refer to CenterPoint Energy specification 007-400-02 for details) or customer may install separate monitoring devices.
The line turner requires separate mounting at the base of the coupling capacitor stand. A single conductor must be run as directly as possible between this line turner and the coupling capacitor base housing. The single conductor must be 4 AWG stranded, 5 kV, non-shielded, XLP insulation. The single conductor must be mounted on insulators and fed through bushings at each end. The single conductor insulation should be unbroken between its ends to maintain low leakage. The single conductor must not be directly up against or touching the coupling capacitor support column or other metal components.
Added method to help identify underground fiber optic cable:

CenterPoint Energy will also pull a single conductor #10 stranded copper wire (supplied by CenterPoint Energy) along with the fiber optic cable in below grade PVC conduit to make fiber optic cable route identifiable in the future when locating underground objects.
With outdoor circuit breakers and indoor relay panels a routing method herein called "radial", shall be used since the dc circuitry to the circuit breakers radiates outward from the control cubicle. Routing of the conductors is from the dc supply to the relay panels or switchboards and then on to the circuit breakers. Positive and negative conductors are carefully routed together so that sudden changes in current, such as those from tripping a circuit breaker, do not result in large magnetic coupling to other control and measuring conductors. (The effects of external magnetic fields tend to cancel when the "go" and "return" conductors are in close proximity.) All wires of a circuit should be contained in the same cable so that all are affected similarly by any inductive coupling.
When terminal blocks and other connections permit, ring tongue lugs should be used instead of spade or stab-on lugs which can become loose and fall off.
This specification is not intended to be totally comprehensive. To ensure the efficient coordination between CenterPoint Energy and the customer during the design and construction of the customer’s substation, CenterPoint Energy requires that engineering documents be submitted to CenterPoint Energy for review before certain equipment is ordered or construction begins. All items requiring CenterPoint Energy review are listed in Article 14.0 of this specification and shall be submitted in writing to the designated CenterPoint Energy representative.
Added details of needed information on ‘site plot’ including substation site elevation:

Site plot plan drawings shall be submitted to CenterPoint Energy for comment. Facilities that must be shown on this drawing include dimensions of the substation site, dead-end structure location, access roadways to substation, space around the outside of the substation (roadways, railroad tracks, walks, pipe racks, culverts, ditches etc.). Additionally, the elevation of the substation site should be indicated on the drawing.
DIVISION OF OWNERSHIP AT LINE TERMINATION

NOTES:
1. DRAWING INDICATES TERMINATION OF CENTERPOINT ENERGY LINE & SERVICE TO CUSTOMER SUBSTATION.
2. THIS DRAWING NOT INTENDED TO SHOW THE LOCATION OR TYPE OF CUSTOMER EQUIPMENT.
3. NUMBER & TYPE OF INSULATORS TO BE DETERMINED BY STATION VOLTAGE.

CUSTOMER OWNED SUBSTATION LINE TERMINATION STANDARD

CENTERPOINT ENERGY, INC.
HOUSTON, TEXAS

DRAWN: B. CHATMAN
CHECKED: LIE
DRAWING NUMBER: KD-2467

REVISED DRAWING NUMBER: KD-24574

DATE: 4-24-63
JOB NO.: ----
REVISION: ---
BY: CH
COR: ----
APP: ---

SHEET 1 OF 2 SHEETS
SCALE: ----
NTS: ----

APPROVED: 4-8-2012
D. SEVICK

4-5-2012
REDAWN & CONVERTED TO CAD
BC
BC
BC

4-24-63
ADDED 3RD LINE NOTE & SHEET 2
LIE
---
---

3-6-63
REVISED DRAWING NUMBER FROM KD-24574
LIE
---
---

004 241 04
OUTAGE CLEARANCE AND COORDINATION PROCEDURES
CONTENTS

CENTERPOINT ENERGY TELEPHONE NUMBERS
1. INTRODUCTION
2. CNP ACCESS TO THE CUSTOMER’S FACILITIES
3. COMMUNICATIONS WITH CNP
4. SWITCHING, CLEARANCES, GROUNDING
5. OUTAGE SCHEDULING CHECK LIST
6. UNPLANNED OUTAGES
7. GENERATION OPERATION
8. PROTECTIVE RELAYING AND CONTROL
9. EQUIPMENT ADDITIONS, REPLACEMENT, UPGRADES AND REMOVAL
10. EQUIPMENT MAINTENANCE
11. PLANT DESIGN CONSIDERATIONS
This procedure applies to entities ("the Customers") who own high voltage transmission and/or generation facilities interconnected to CenterPoint Energy Houston Electric, LLC’s ("CNP") 69 kV, 138 kV, or 345 kV transmission system. Customer, as used in this document, includes the Customer’s authorized contractors or agents. The Customer shall ensure that the provisions in this document are applied to facilities that may be owned by others and that are interconnected to the Customer’s facility at the same voltage at which the Customer’s facility is interconnected to CNP’s transmission system.

The purpose of this document is to facilitate the coordinated operation, outage coordination, maintenance, design, and modification of the Customer’s high voltage transmission or generation facilities with CNP facilities.
RTO operates CNP’s transmission system and coordinates the operation of interconnected high voltage facilities. RTO provides routine and emergency switching instructions, issues clearances, and dispatches CNP personnel in response to electrical outages and problems. The Customer shall schedule planned outages with RTO and obtain from RTO switching instructions for any equipment at the Customer’s substation that is directly interconnected with CNP’s transmission system. Switching in the Customer’s facilities that are remote to the Customer’s substation directly interconnected with CNP’s transmission system does not need to be scheduled. CNP will notify the Customer one or more days in advance if switching is required in the Customer’s substation for planned transmission line outages or if the Customer’s substation will be placed in a single-ended condition.
## PLANNED OUTAGE SCHEDULING

<table>
<thead>
<tr>
<th>Equipment Being Requested</th>
<th>Minimum Advance Notice</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>69 kV and 138 kV lines, single load transformers, individual breakers and bus outages of no more than one day in duration.</td>
<td>No later than 1200 hours Wednesday two weeks before the Planned Outage is to take place.</td>
<td>Outage Scheduler @ 713-207-2196 or 713-207-2714</td>
</tr>
<tr>
<td>All transmission line outages and equipment outages, including busses, of up to four contiguous days duration (daily or continuous outages).</td>
<td>35 Calendar Days</td>
<td>Outage Scheduler @ 713-207-2196 or 713-207-2714</td>
</tr>
<tr>
<td>Any transmission line outages and/or equipment outages, including busses, of 5 days or longer duration (daily or continuous)</td>
<td>90 Calendar Days</td>
<td>Outage Scheduler @ 713-207-2196 or 713-207-2714</td>
</tr>
</tbody>
</table>
CUSTOMER SUBSTATION EQUIPMENT ADDITIONS, RELOCATIONS, UPGRADES AND/OR REMOVALS

When installing, relocating, or upgrading transmission system equipment, Customers must contact their appropriate CNP Transmission Accounts representative with sufficient notice to meet the timelines and data requirements shown below. ERCOT Nodal Protocols Section 3.10.1 requires that all changes to transmission equipment energized at 60 kV and above be communicated by CNP to ERCOT using the Network Operations Model Change Request ("NOMCR") process as summarized below:

Table 2

<table>
<thead>
<tr>
<th>Target Physical Equipment In-Service Month</th>
<th>Deadline to Submit to RTO</th>
<th>Timeline to Submit initial information to Transmission Accounts Rep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month of January</td>
<td>Sept. 1</td>
<td>June 1 (prior year)</td>
</tr>
<tr>
<td>Month of February</td>
<td>Oct. 1</td>
<td>July 1 (prior year)</td>
</tr>
<tr>
<td>Month of March</td>
<td>Nov. 1</td>
<td>August 1 (prior year)</td>
</tr>
<tr>
<td>Month of April</td>
<td>Dec. 1</td>
<td>September 1 (prior year)</td>
</tr>
<tr>
<td>Month of May</td>
<td>Jan. 1</td>
<td>October 1 (prior year)</td>
</tr>
<tr>
<td>Month of June</td>
<td>Feb. 1</td>
<td>November 1 (prior year)</td>
</tr>
<tr>
<td>Month of July</td>
<td>Mar. 1</td>
<td>December 1 (prior year)</td>
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<td>Month of October</td>
<td>June 1</td>
<td>March 1</td>
</tr>
<tr>
<td>Month of November</td>
<td>July 1</td>
<td>April 1</td>
</tr>
<tr>
<td>Month of December</td>
<td>Aug. 1</td>
<td>May 1</td>
</tr>
</tbody>
</table>
11.1 Emergency Systems
11.1.1 Continuous electric service from utility power systems cannot be guaranteed even for facilities that are connected to a large number of transmission lines. The possibility exists that a total power outage or separation from the utility system may occur. It is important to consider this when plant emergency systems are designed.

11.2 Automatic Reclosing
11.2.1 CNP utilizes automatic reclosing of high voltage circuit breakers following unplanned tripping of CNP transmission lines. CNP endeavors to intentionally delay the initial reclose attempt by at least one second. The Customer is responsible for the separation of necessary motors or other equipment within one second of the tripping.

11.3 System Voltage
11.3.1 Electric service from a utility power system cannot be guaranteed against fluctuations. Voltage sag is a common fluctuation that occurs during the time of a fault. The large majority of faults on a utility transmission system are single line-to-ground faults. With automatic reclosing of circuit breakers, several voltage sags can occur within a one-minute period. Most voltage sags from faults on transmission systems have a very short duration of less than ten cycles with high-speed fault clearing. Another common fluctuation is a transient voltage oscillation that occurs each time a capacitor bank is energized. Equipment, such as motor contractors, adjustable speed drives, programmable logic controllers, and high intensity discharge lamps, can be sensitive to these short duration voltage sag and transient voltage oscillation.
11.3.2 It is important to consider voltage sag “ride-through” for equipment applied to critical processes where nuisance tripping can cause a whole process to shut down. Plant power systems and equipment control systems can be designed or modified to ride-through the most common voltage sags and transient voltage oscillations on utility power systems. CNP will provide additional information upon request.

11.4 Electrical Protection Coordination Studies
11.4.1 If the Customer performs plant electrical protection coordination studies, the Customer may contact a Transmission Accounts representative to request the available CNP system fault current and system impedance at the Customer’s facility.
## NUMBER OF SUBSTATION SITES CONNECTED TO THE CNP TRANSMISSION SYSTEM

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>6</td>
<td>1</td>
<td>20</td>
<td>31</td>
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<tr>
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<td>0</td>
<td>8</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>52</td>
<td>73</td>
<td>19</td>
<td>153</td>
<td>113</td>
</tr>
</tbody>
</table>
SYSTEM FAULTS AND AUTOMATIC RECLOSING
Digital Fault Recording C-phase-to-ground fault of 3 cycles duration

91 % Dip
Digital Fault Recording of B-phase-to-ground fault of 4 cycle duration

42% Dip
Digital Fault Recorder of C-phase-to-B-phase-to-ground fault of 3.5 cycle duration

5 % Dip

55 % Dip

53 % Dip
Digital Fault Recorder of C-phase-to-B-phase-to-ground fault of 3 cycle duration

12 % Dip

26 % Dip

27 % Dip
Because the transmission system is connected in a network, a fault at a substation or along a transmission circuit will result in a voltage sag at numerous substations remote from the location of the fault.
Calculated Sensitivity Area for Trans. Customer Based on 2003 SC Model

Substation Location vs Voltage dip at LS caused by SLG fault at 138kV Sub
Calculated Sensitivity Area for Trans. Customer Based on 2003 SC Model

Substation Location vs Voltage dip at LS caused by 3-Phase fault at 138kV Sub
Calculated Sensitivity Area for Trans. Customer Based on 2003 SC Model
Calculated Sensitivity Area for Trans. Customer Based on 2003 SC Model

Substation Location vs Voltage dip at LS caused by 3-Phase fault at 345kV Sub
Calculated Sensitivity Area for Trans. Customer Based on 2003 SC Model
Calculated Sensitivity Area for Trans. Customer Based on 2003 SC Model

Substation Location vs Voltage dip at LS caused by 3-Phase fault at 138kV and 345kV Sub
Translation of Phase-to-Neutral Voltage on Highside To Phase-to-Neutral and Phase-to-Phase Voltage on Lowside

Standard transformer highside leads the lowside by 30 degrees

50% A-N on highside translates to:

76.4% X3-N, 100% X2-N, 76.4% X1-N and
66.7% X1-X3, 92.8% X2-X1, 92.8% X3-X2
The customer’s equipment “voltage dip ride through” design criteria, that CenterPoint Energy suggests the customer utilize when designing and selecting plant equipment is illustrated in figure 3.1.

“V” represents the phase-to-neutral voltage at the customer’s “load side” of a delta-wye transformer for a phase-to-ground fault at the “high side” of the transformer.

Figure 3.1
Typical portion of transmission system

- Customer "Loop-Tap" Substation
- Customer "Ring Bus" Substation
- CenterPoint Energy "Ring Bus" Substation
- CenterPoint Energy "Breaker-and-a-half" Substation
Transmission line relaying

L1 Relays

L2 Relays

L2 Relays

IEEE Houston Section CED Seminar March 3/4 2015
Transformer high side bus and transformer differential & overcurrent
Transformer high side bus and transformer differential & overcurrent
Transformer high side bus and transformer differential & overcurrent

Transmission line relaying
Example of Typical Protective Relaying Operation Sequence
FAULT OCCURS

T = 0

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TRANSMISSION LINE PROTECTIVE RELAYS AND CIRCUIT BREAKERS BEGIN TO OPERATE

T = 5 to 8 cycles
TRANSMISSION LINE PROTECTIVE RELAYS AND CIRCUIT BREAKERS HAVE OPERATED

Motor coasting down

OPEN

T = 5 to 25(+) cycles
CUSTOMER MOTOR PROTECTIVE RELAYS AND CIRCUIT BREAKERS BEGIN TO OPERATE

T < 1 second
CIRCUIT BREAKER AUTOMATICALLY RECLOSES

CLOSE

T = 1 second
T = 1(+) second
TRANSMISSION LINE PROTECTIVE RELAYS AND CIRCUIT BREAKER HAVE OPERATED

\[ T = 1(+) \text{ second} + 5 \text{ to } 8 \text{ cycles} \]
CIRCUIT BREAKER AUTOMATICALLY RECLOSES

T = 7(+) seconds
FAULT REOCCURS

T = 7(+) seconds

IEEE Houston Section CED Seminar March 3/4 2015
TRANSMISSION LINE PROTECTIVE RELAYS AND CIRCUIT BREAKER HAVE OPERATED

\[ T = 7(+) \text{ seconds} + 5 \text{ to } 20(+) \text{ cycles} \]
CIRCUIT BREAKER AUTOMATICALLY RECLOSES

T = 15(+) seconds
CIRCUIT BREAKER AUTOMATICALLY RECLOSES

FAULT DOES NOT REOCUR!

T = 21(+) seconds

CLOSES ONLY IF LINE IS ALREADY ENERGIZED

T = 21(+) seconds
REMAINING CIRCUIT BREAKERS AUTOMATICALLY CLOSE

Closes only if other breakers are already closed.

T = 35 to 55 seconds

Customer begins steps to restart motor.
BUT WHAT IF THE FAULT WAS PERMANENT?
TRANSMISSION LINE PROTECTIVE RELAYS AND CIRCUIT BREAKER HAVE OPERATED

T = 7(+) seconds + 5 to 20(+) cycles
FAULT REOCCURS

PERMANENT FAULT

T = 15(+) seconds

CLOSE
TRANSMISSION LINE PROTECTIVE RELAYS AND CIRCUIT BREAKER HAVE OPERATED

\[ T = 15(+) \text{ seconds} + 5 \text{ to } 8 \text{ cycles} \]
NO MORE CIRCUIT BREAKER AUTOMATIC OPERATIONS OCCUR

T = 1(+) MINUTE

CenterPoint Energy SYSTEM DISPATCHER DIRECTED RESTORATION PROCESS BEGINS
FAULTED LINE SECTION IS ISOLATED.

SERVICE IS RESTORED TO "LOOP-TAP" CUSTOMER.

TRANSMISSION EQUIPMENT IS REPAIRED/REPLACED.
TRANSMISSION SYSTEM BACK TO NORMAL
END