Welcome to the Power Quality Seminar

October 2017

CenterPoint® Energy

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Seminar Agenda

- Electric Reliability
- Fundamentals of the Grid
- Break
- Design for Reliability Planning and Implementation
- Case Study- International Airport

Electric System Reliability Update

Customer service through reliability

Martin Narendorf Jr.

Vice President, Power Delivery Solutions

October 24, 2017

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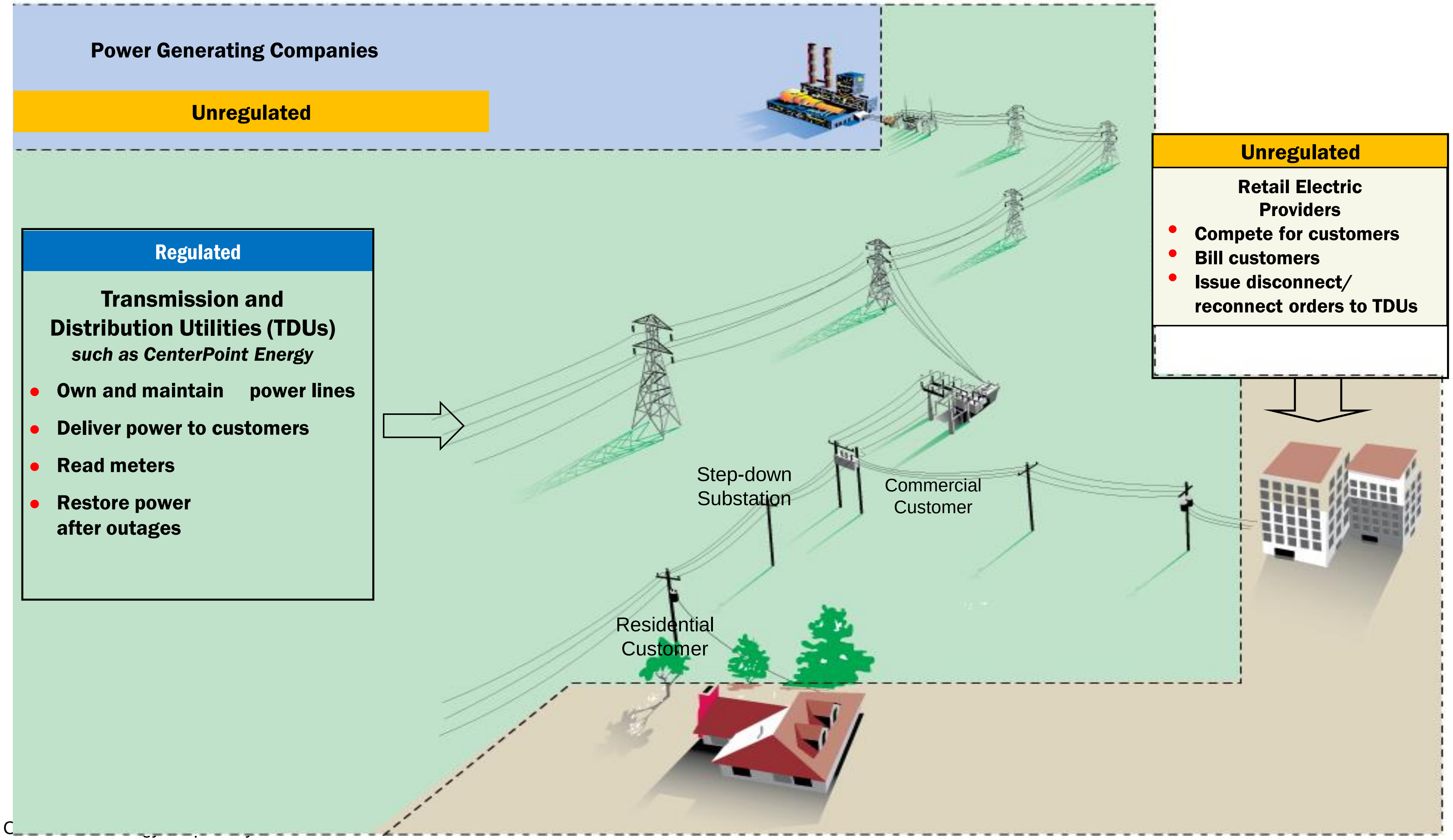
Introduction

- Texas Electric System Overview
- CenterPoint Energy Transmission & Distribution
- System Design Comparison – Overhead vs Underground
- Modernizing and Advancing the Reliability of the Grid
- Disturbance Mitigation Technology Overview
- Hardening the Addicks Operation Center

The Texas Electric System

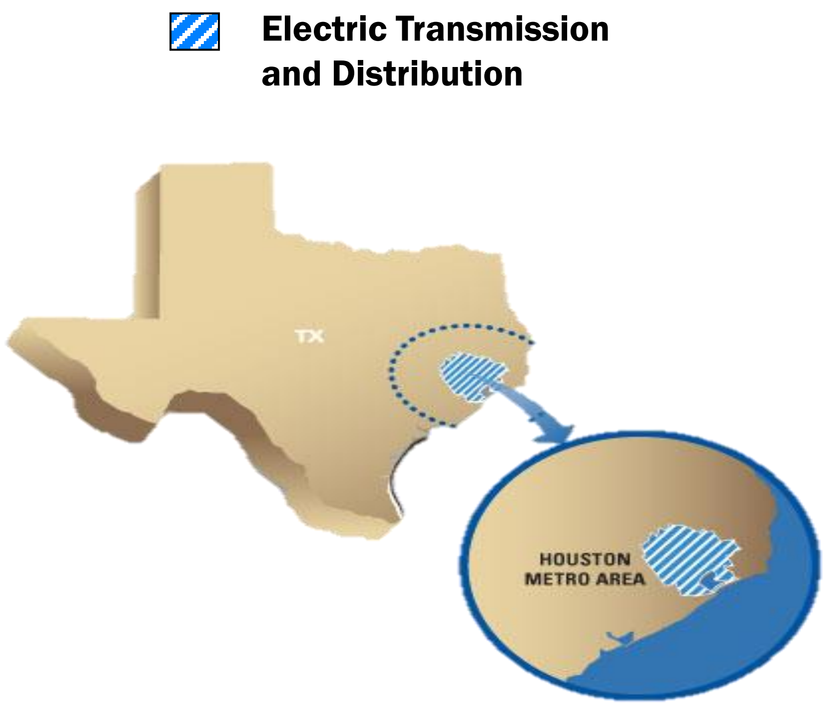


Electric Transmission & Distribution

- Customers consist of about 64 retail electric providers that sell electricity to over 2.4 million metered customers in a 5,000 square-mile area that includes the vast majority of the Houston/Galveston metropolitan area

- Owns and maintains:
  - 52,639 miles of overhead and underground distribution lines
  - 3,718 miles of overhead and underground transmission lines

- Delivered 86.8 million megawatt-hours in 2016
- Experienced 2% customer growth, nearly 55,000 new meters
- Invested $858 million in capital projects
- Expect to invest $4.1 billion over next 5 years



Source: Form 10-K

System Design Comparison

Overhead Construction

- Standard service approved by PUCT
- Lines exposed to weather, vegetation, wildlife, traffic
- More events in recent years with frequent storm activity
- Outage/blink mitigation methods available

Dedicated Underground

- Area approved by the PUCT
- Includes Texas Medical Center, Downtown and Galleria
- Highly dense load centers

Why Isn't Dedicated Underground Used Everywhere?

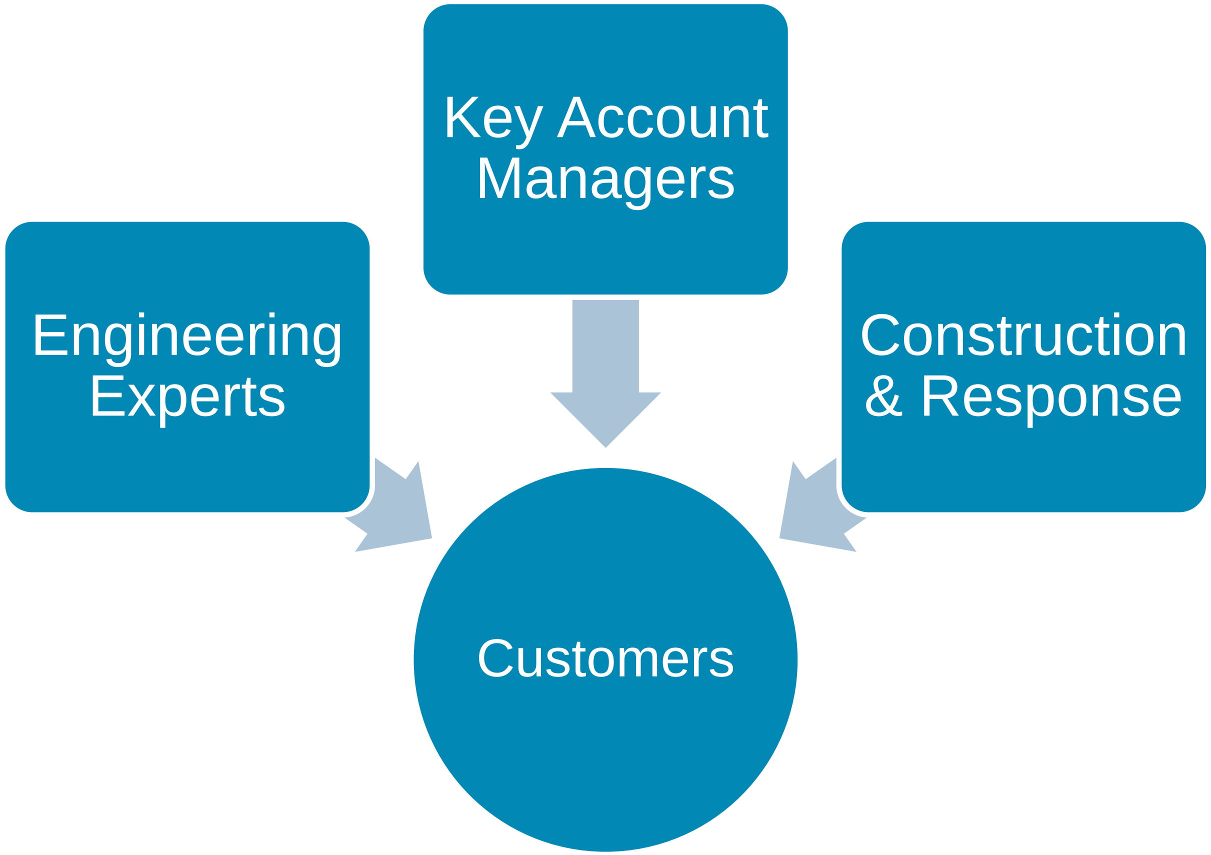
Because of the Cost…

- Nearly 40 times the cost of overhead construction
- $1,000 – $1,200 per foot converted
- $28 Billion to convert distribution grid, plus: *
  - $37,000 additional per commercial customer
  - $2,400 additional per residential customer

*FINAL REPORT Cost-Benefit Analysis of the Deployment of Utility Infrastructure Upgrades and Storm Hardening Programs by Quantum Technology for the Public Utility Commission of Texas, March 4, 2009

Dedicated Team

All facilities are treated equally with specialized resources.



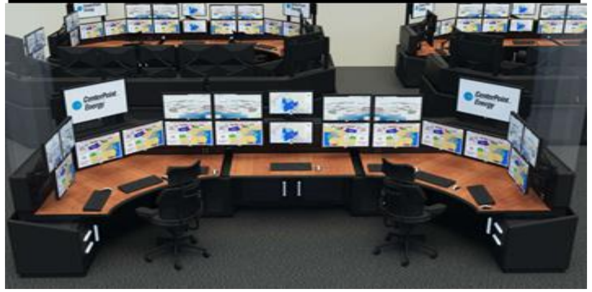
We are modernizing and advancing the reliability of the grid

- Deploying intelligent grid with advanced management system
- Utilizing real-time situational awareness to restore services
- Crews are mobile managed and electronically dispatched
- Trees trimmed on proactive cycles
- Maintenance includes regular scheduled infra-red, wood pole replacements and inspection programs

IG Switching Device

Control Panel

Distribution Control Center



Good news! There are mitigations…

- Possible option for premium two circuit roll-over services
- **On your side of the meter:**

Battery UPS

TVSS

Transformer

Sag Corrector

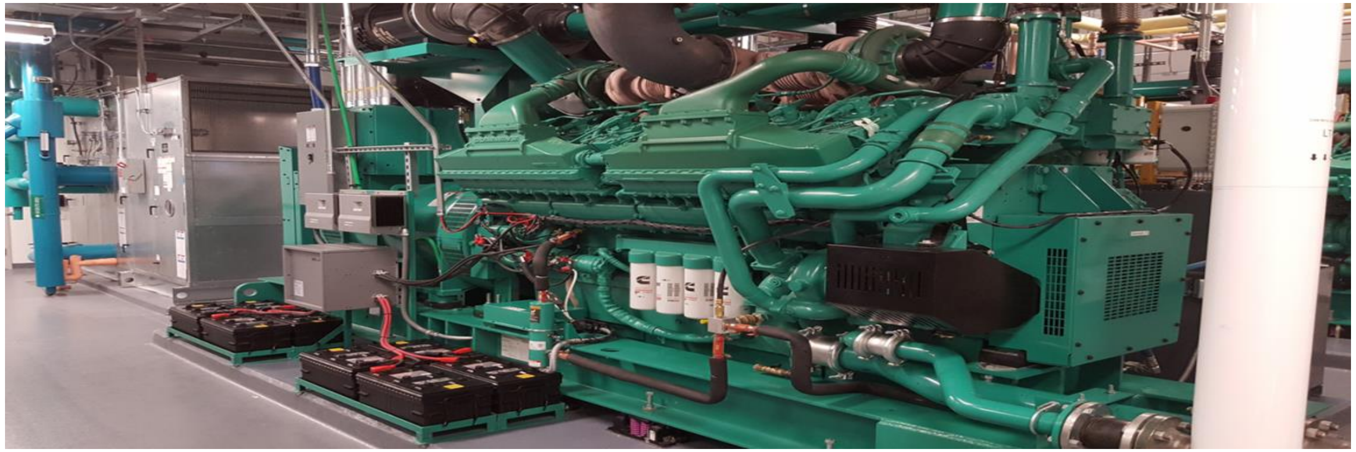
Rotary UPS

Dip proofing inverter

Lightning protection system

Addicks Operation Center

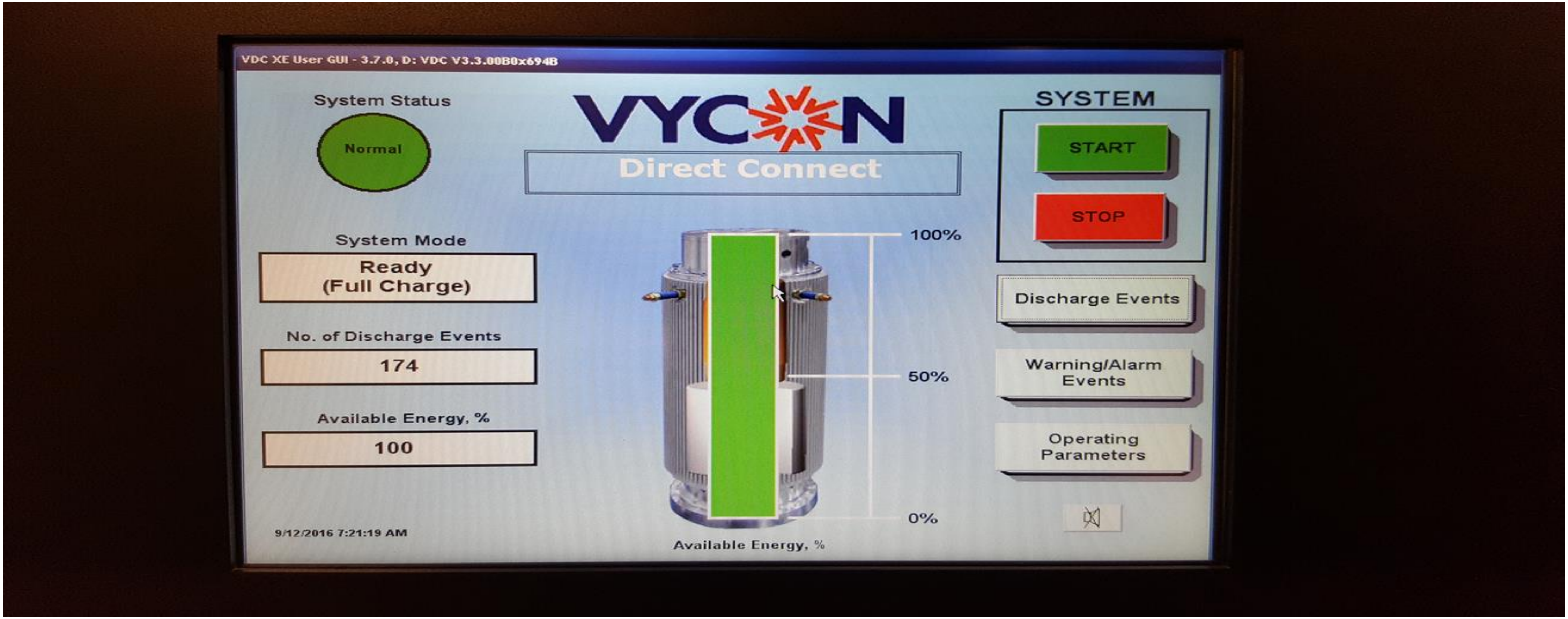
Addicks Operation Center



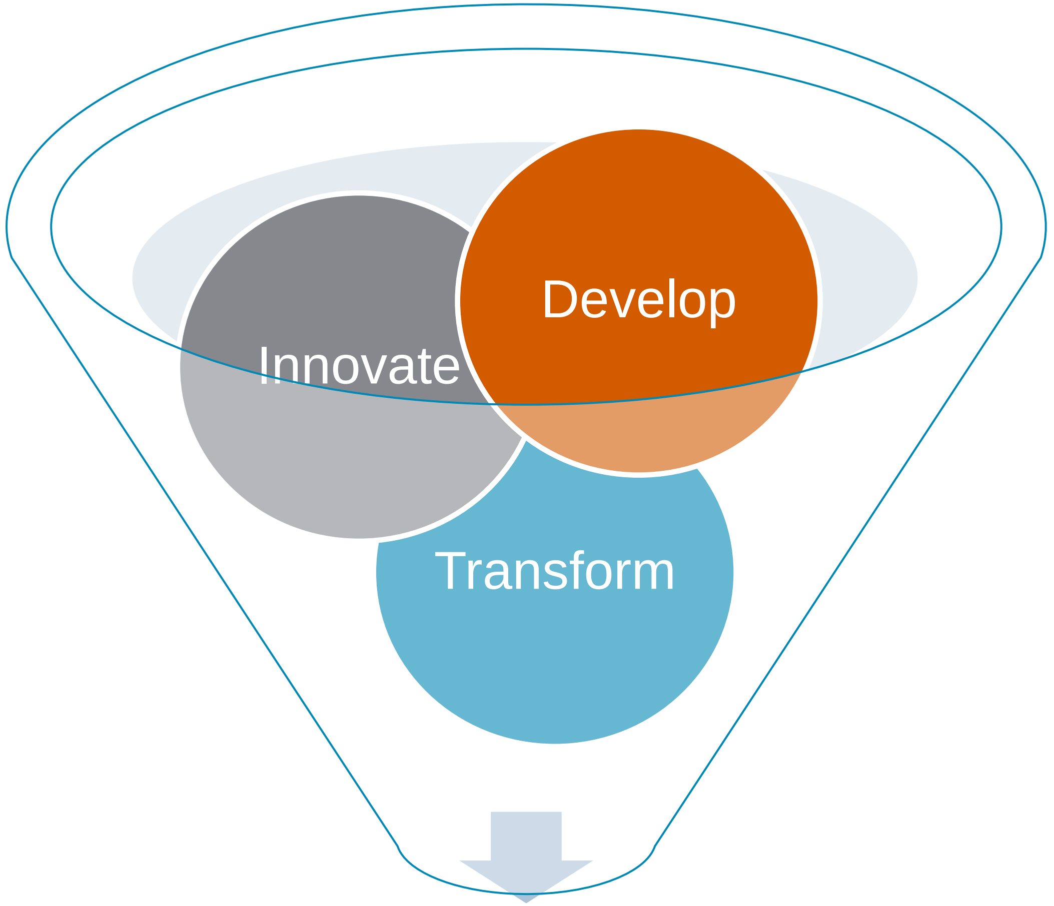
Generator

Battery UPS

Addicks Operations Center



Let’s do this together



Reliability Solutions

Fundamentals of the Grid

John Dodge

Manager, Reliability Reporting

October 24, 2017

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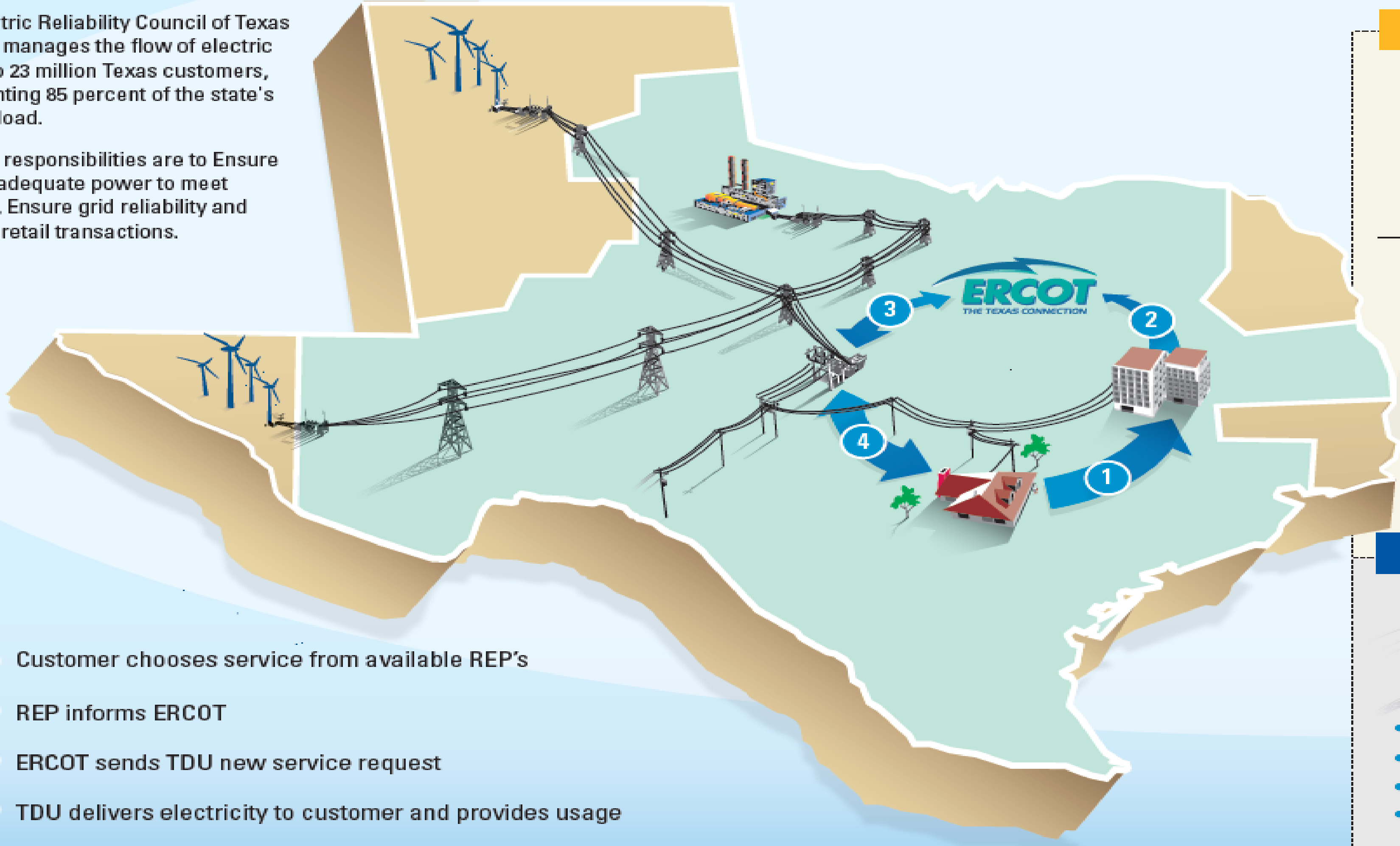
The Texas Electric Market

The Electric Reliability Council of Texas (ERCOT) manages the flow of electric power to 23 million Texas customers, representing 85 percent of the state's electric load.

ERCOT's responsibilities are to Ensure there is adequate power to meet demand, Ensure grid reliability and oversee retail transactions.



1. Customer chooses service from available REP's
2. REP informs ERCOT
3. ERCOT sends TDU new service request
4. TDU delivers electricity to customer and provides usage

Unregulated

Power Generation Sources

Power Plants | Wind Farms

Retail Electric Providers (REPs)

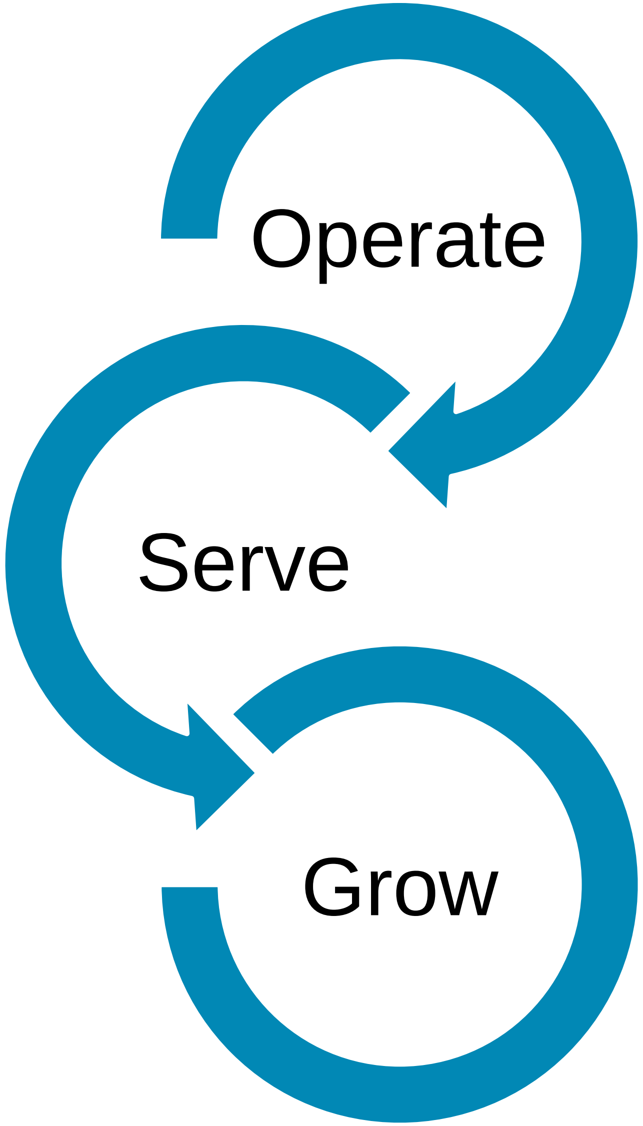
- Compete for customers
- Bill customers
- Issue disconnect/ reconnect orders to TDUs
- Contracts for and schedules bulk power

Regulated

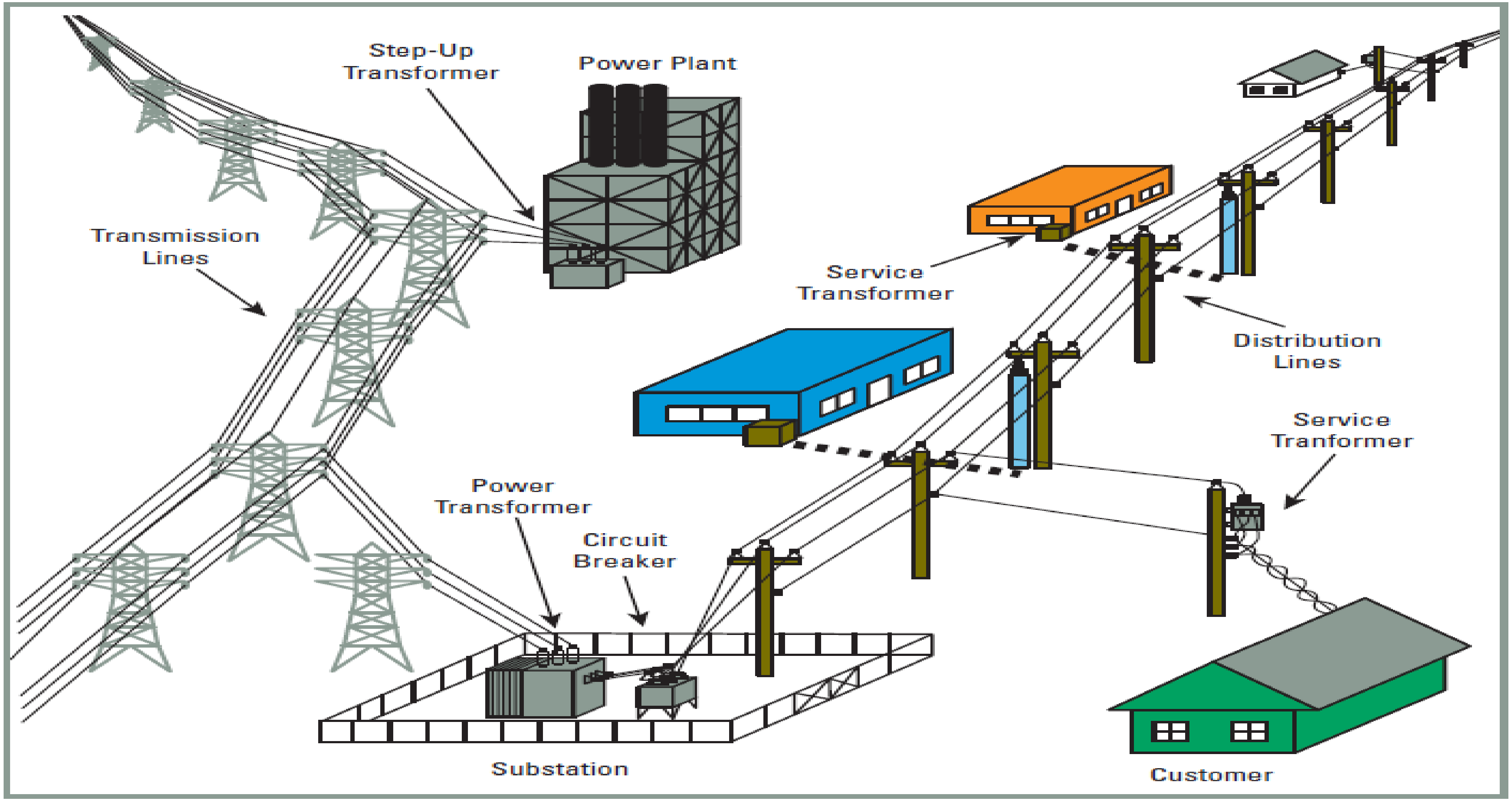
Transmission and Distribution Utilities (TDUs) such as CenterPoint Energy

- Own and maintain power lines
- Deliver power to customers
- Provide usage information to REPs
- Restore power after outages

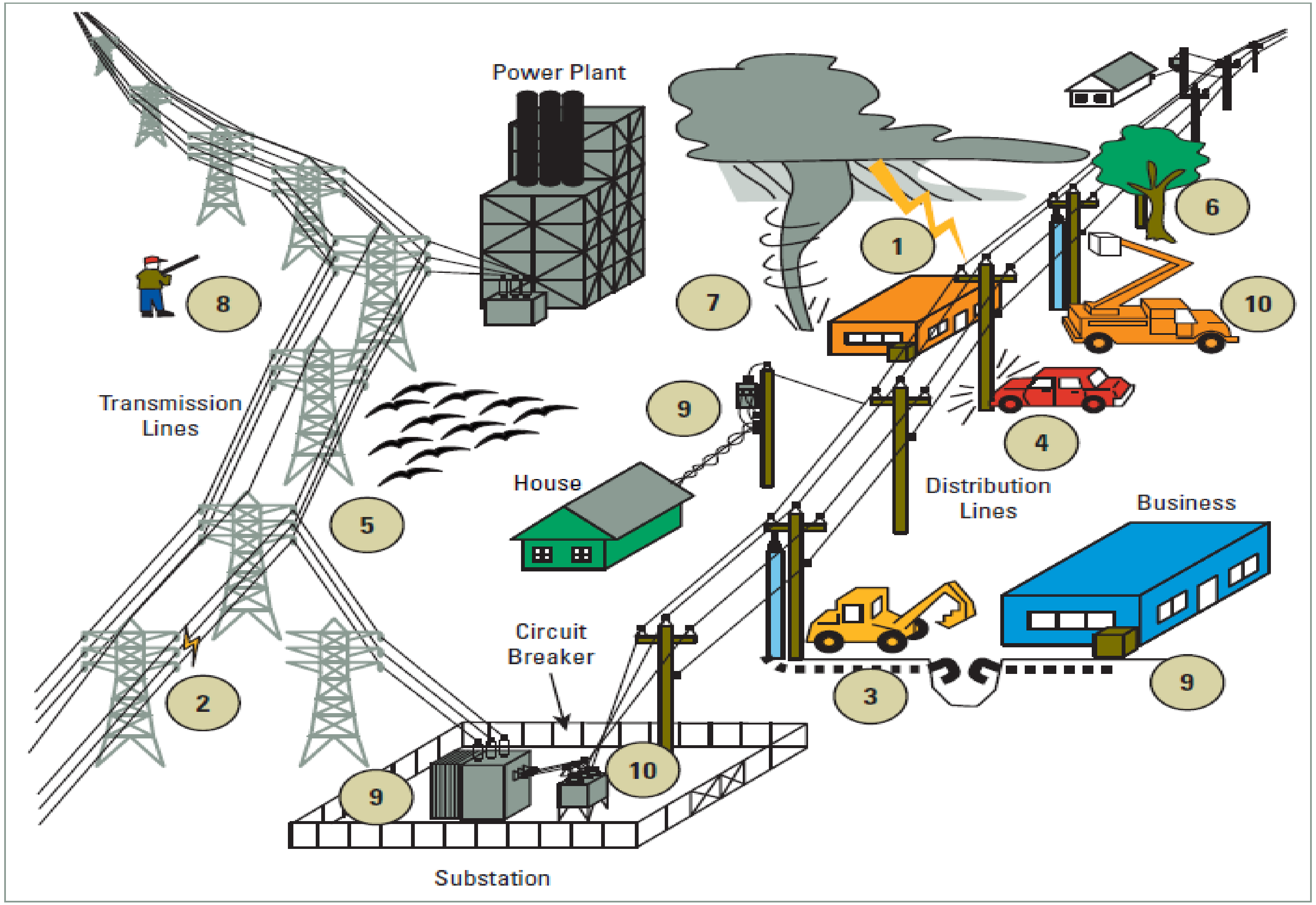
Our Strategy



How Electricity is Delivered



What to expect from an Electric Utility



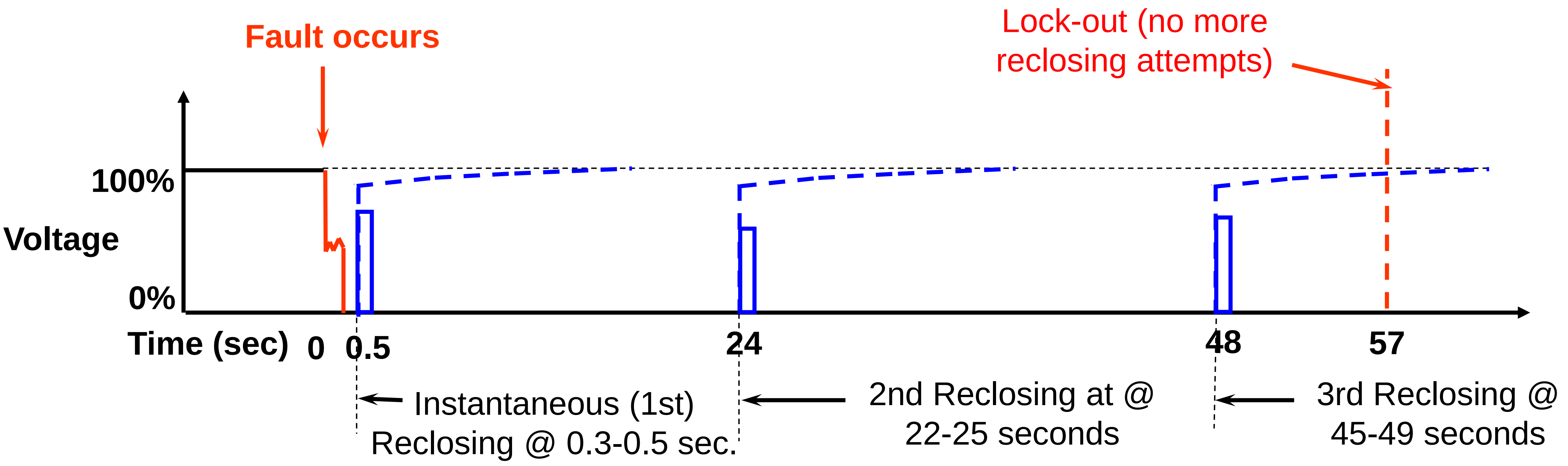
Common Sources of Faults

1. Lightning
2. Insulator Flashovers
3. Dig-ins on Underground Lines
4. Automobile Collisions
5. Birds and Other Wildlife
6. Trees and Vegetation
7. Strong Winds
8. Vandalism
9. Equipment Failures
10. Switching and Maintenance

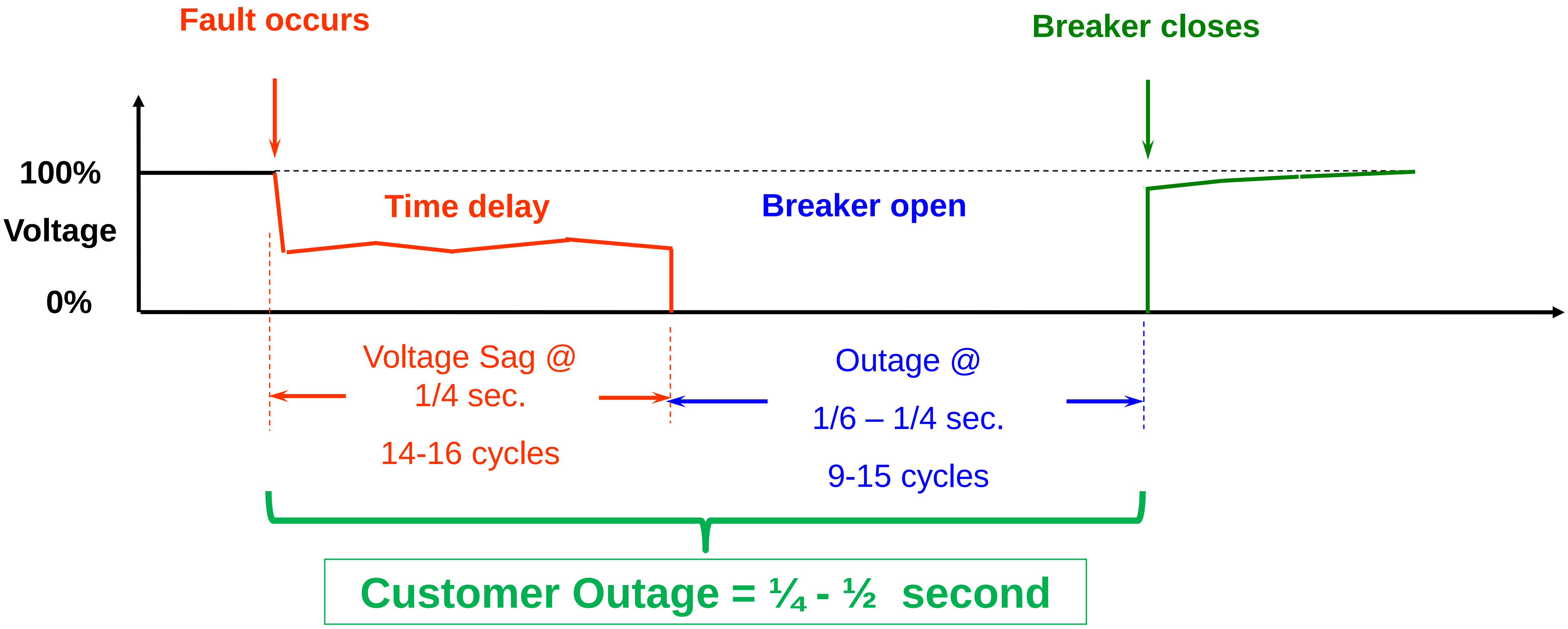
Protection Reclosing Sequence

- Typically there is a 10 cycle (1/6 sec.) time delay on 1st trip for substation feeder breaker.
- Breaker trips and then first (instantaneous) reclose attempt begins:
  - 9-20 cycle (1/5 to 1/3 of a second) outage
- For more permanent faults,
  - 2nd reclosing attempt is at approximately 24 seconds
  - 3rd reclosing attempt is at approximately 48 seconds
- If 3rd reclosing attempt fails, then breaker remains open.
  - This is referred to as a circuit lock-out.

Additional Reclosing Attempts



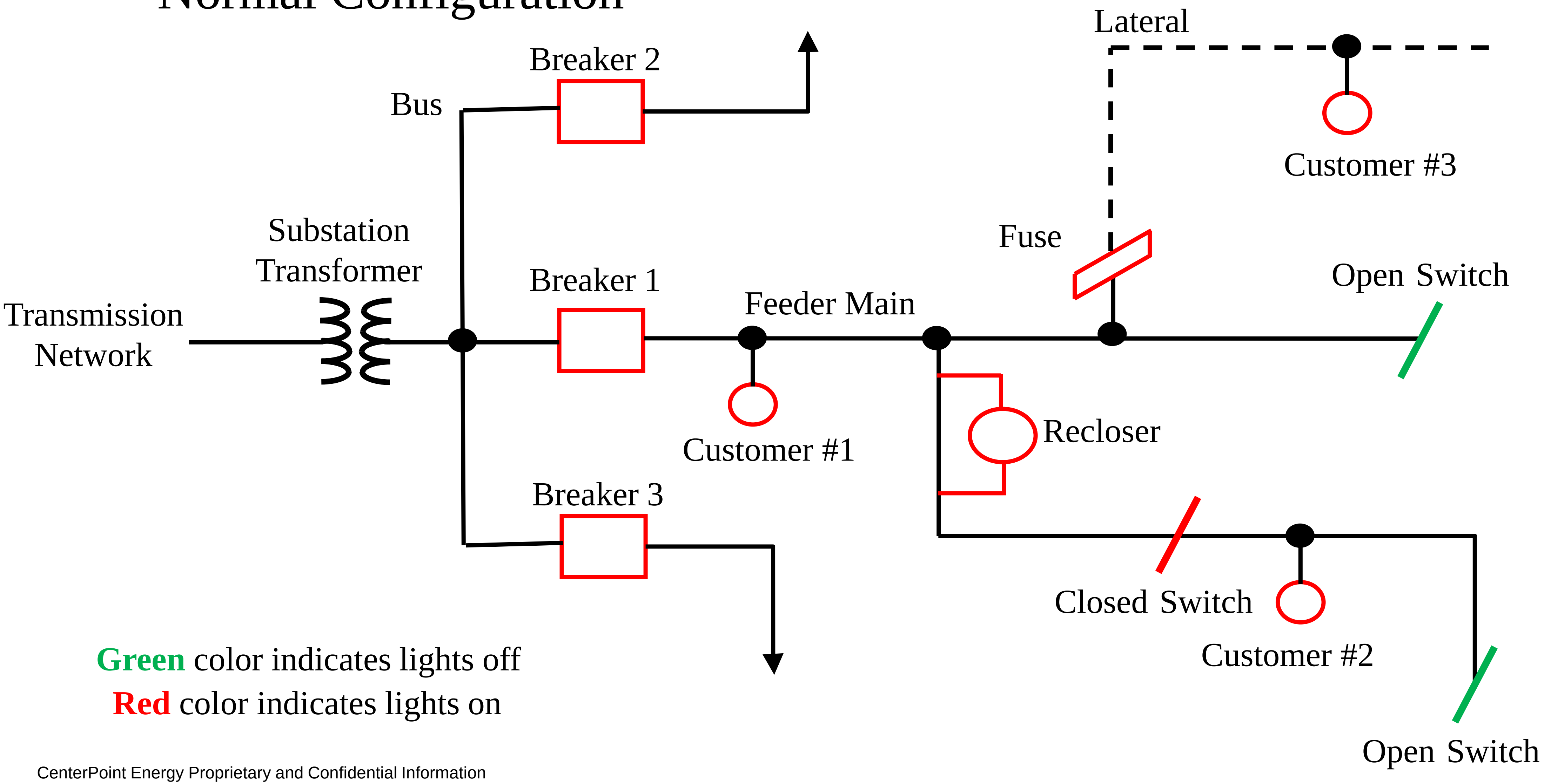
Temporary Fault - Instantaneous Reclosing



RMS Trend Graph

Typical Distribution Circuit Configuration

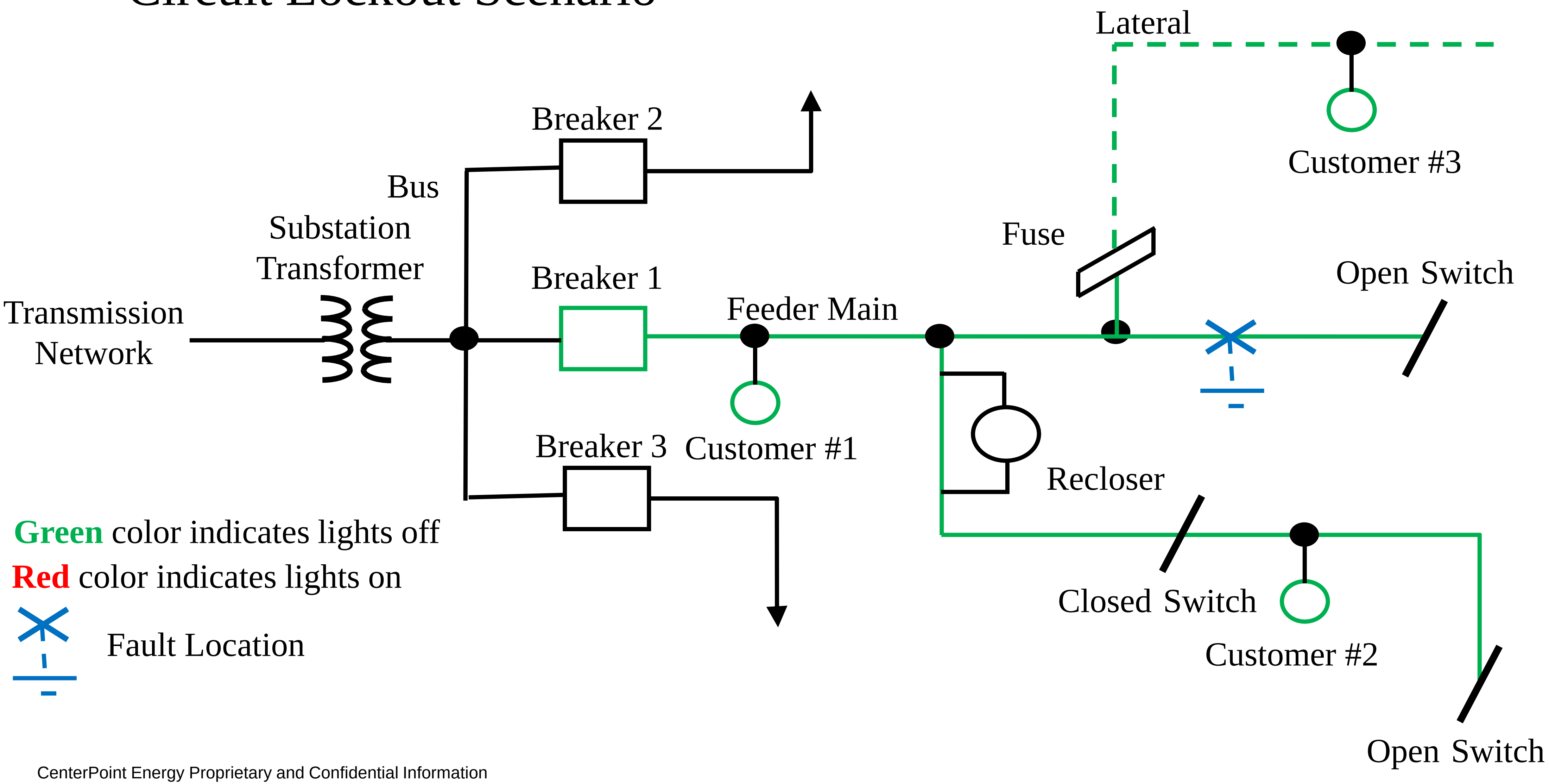
- Normal Configuration



Green color indicates lights off
Red color indicates lights on

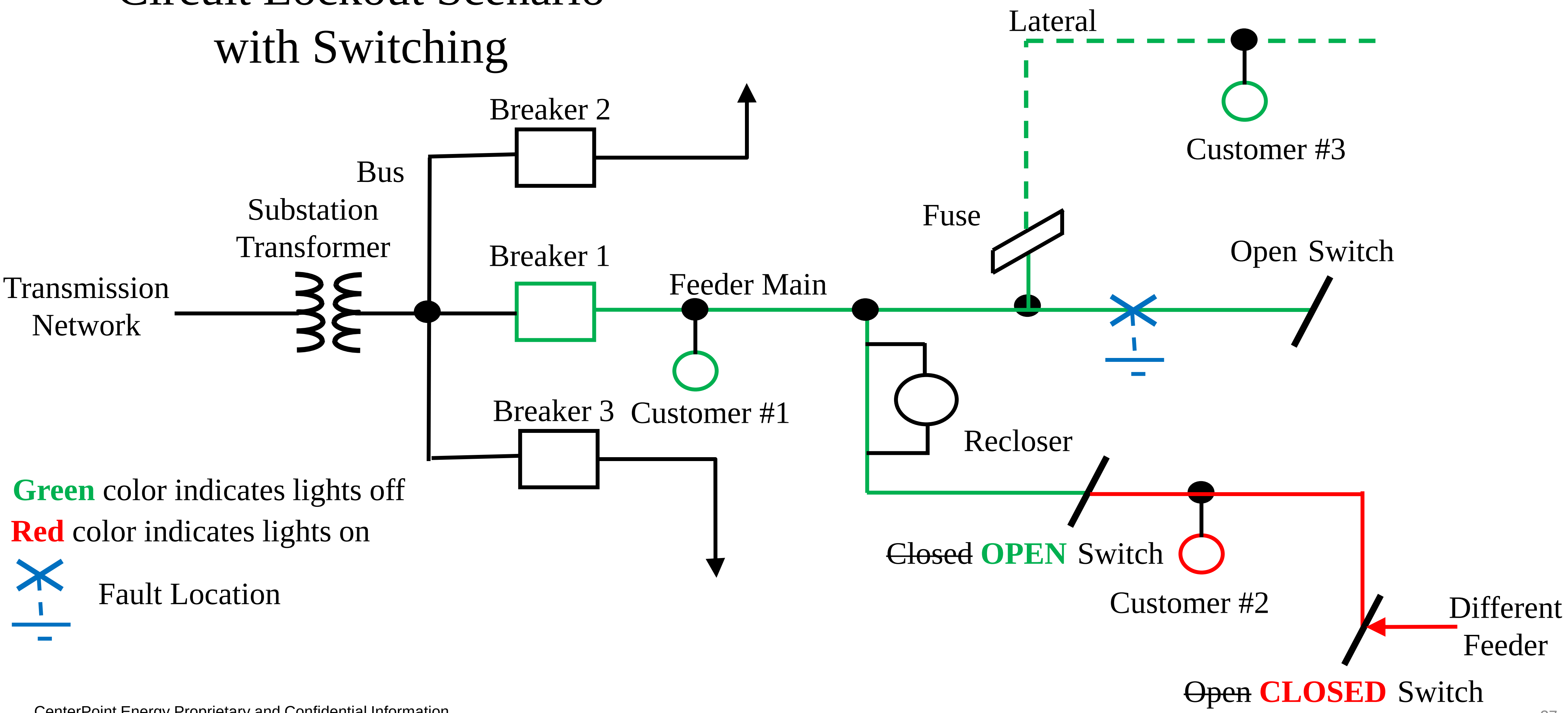
Typical Distribution Circuit Configuration

– Circuit Lockout Scenario



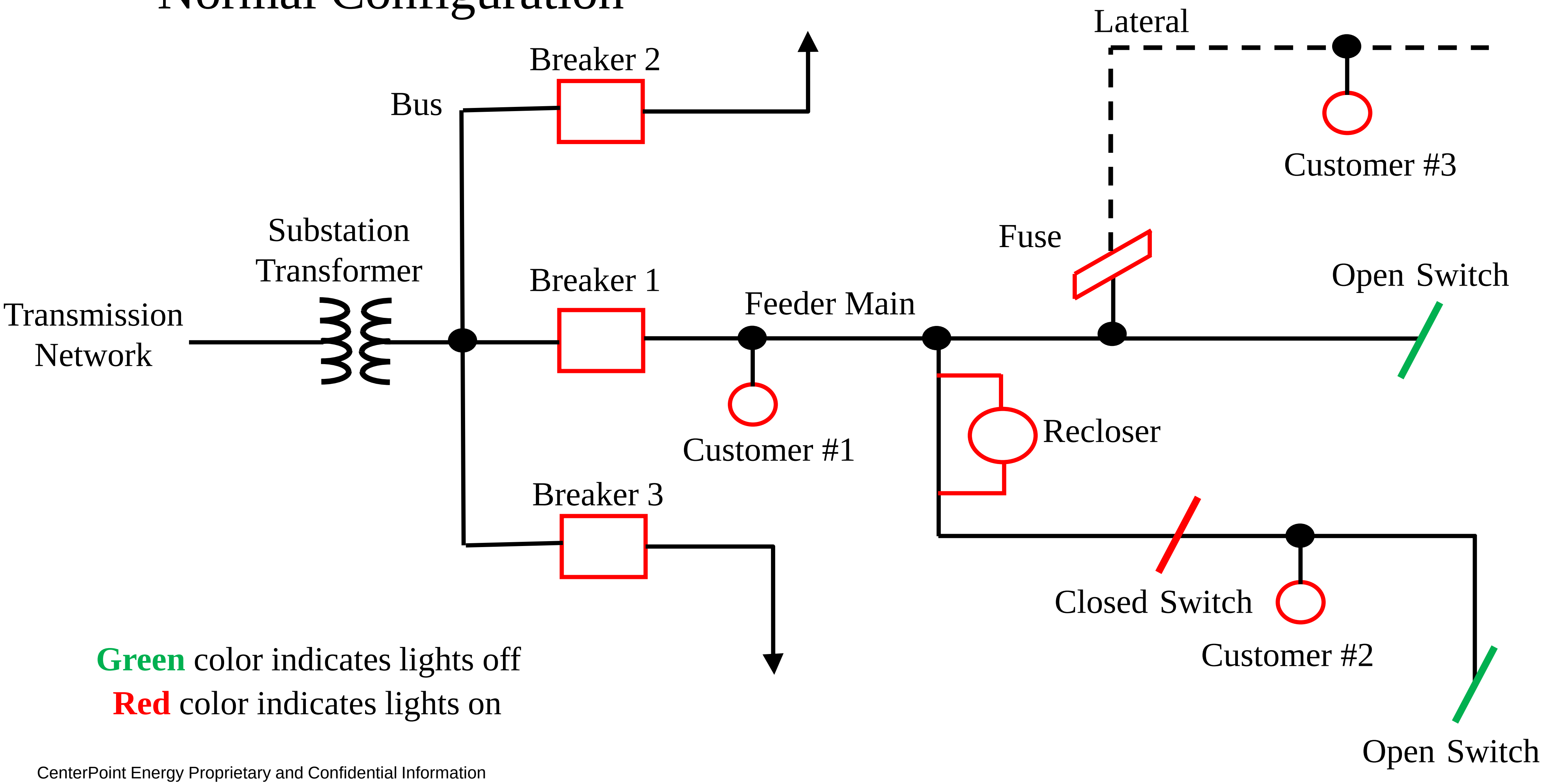
Typical Distribution Circuit Configuration

Circuit Lockout Scenario with Switching



Typical Distribution Circuit Configuration

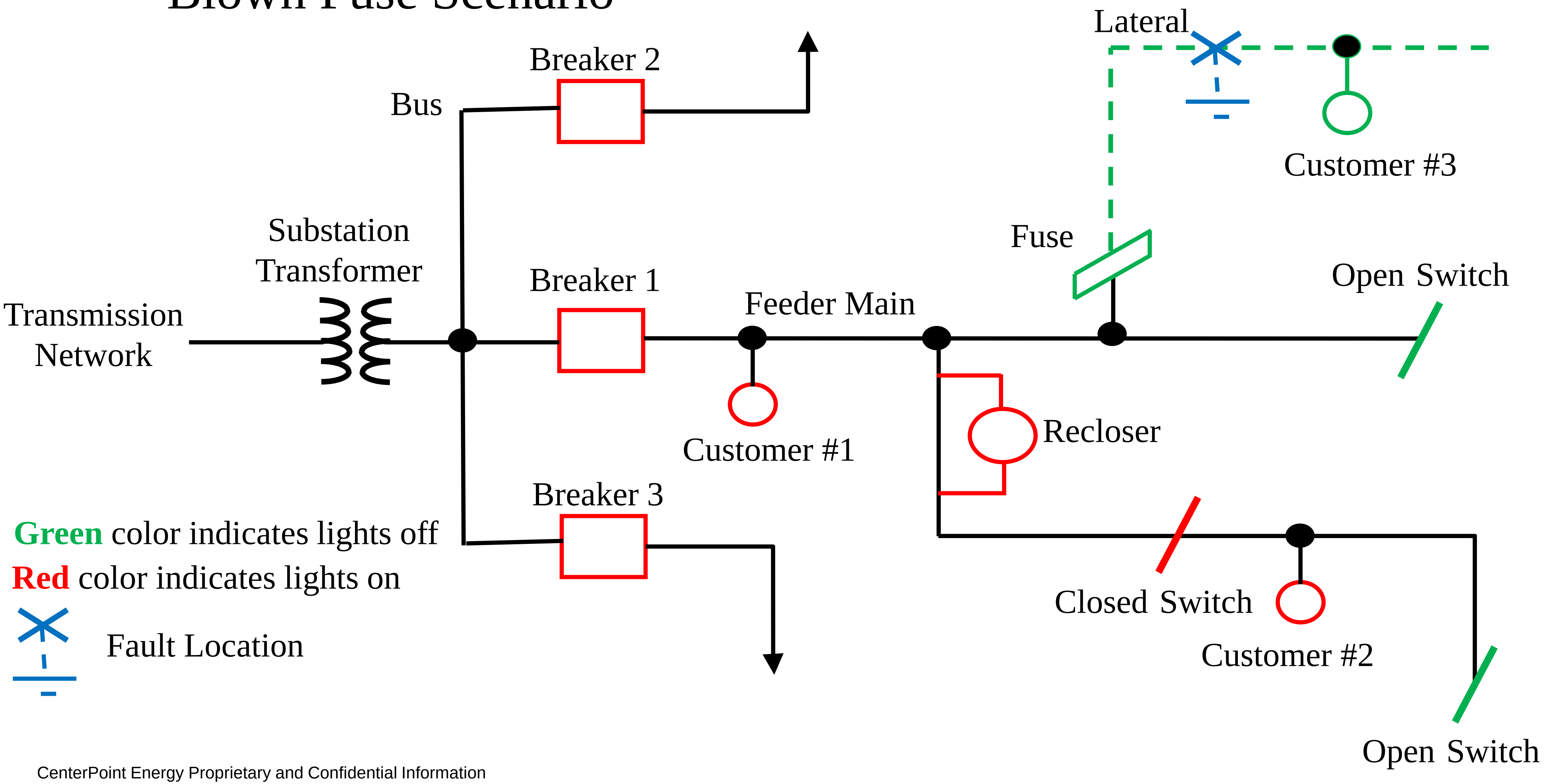
Normal Configuration



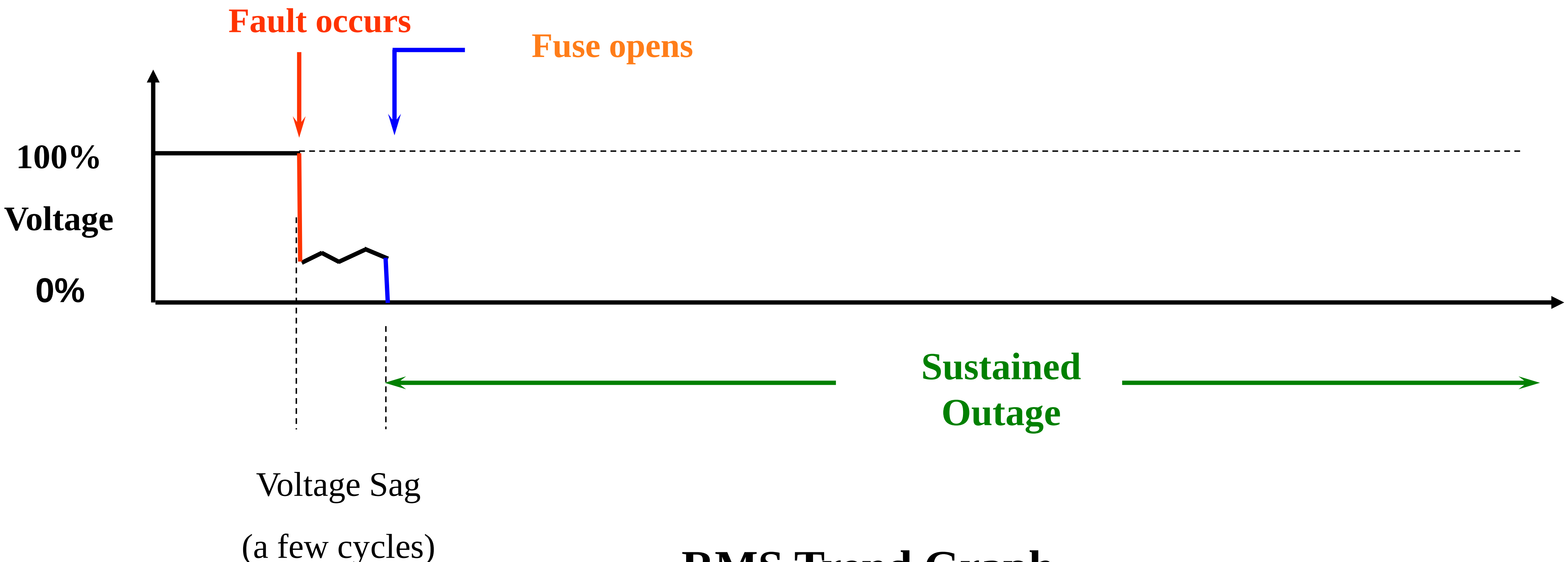
Green color indicates lights off
Red color indicates lights on

Typical Distribution Circuit Configuration

Blown Fuse Scenario

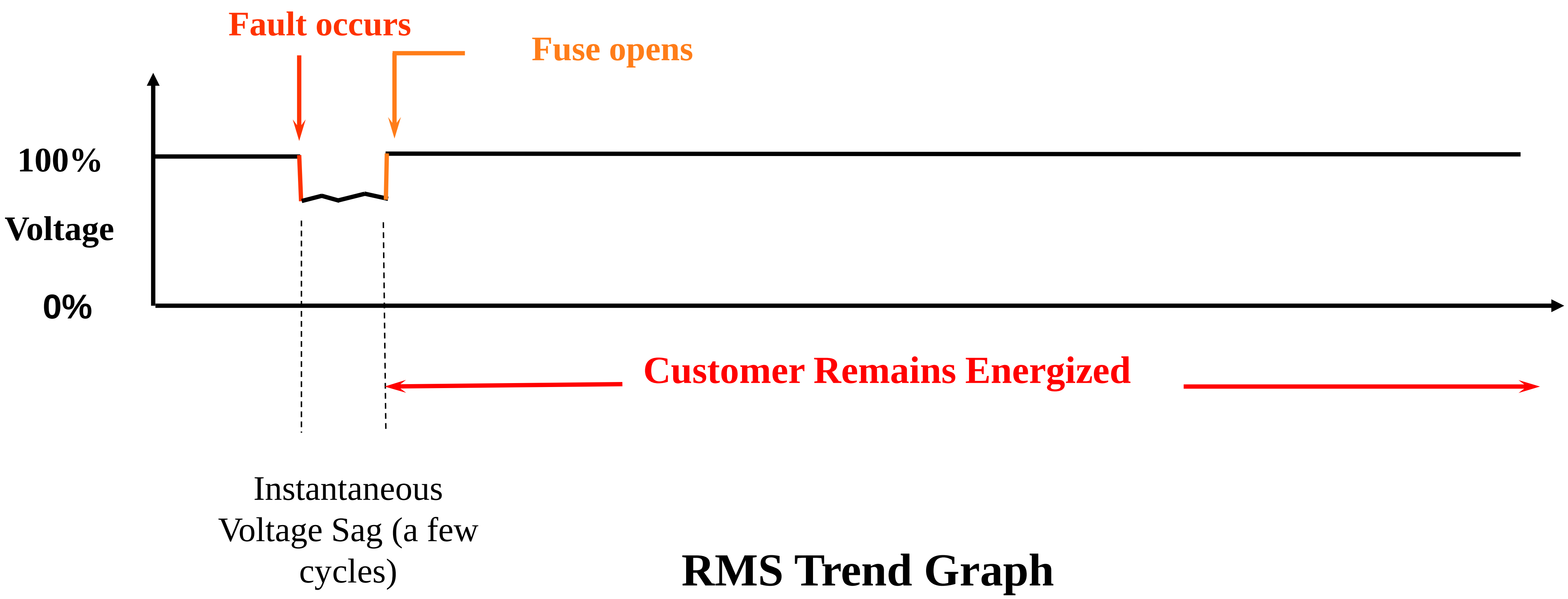


Outage Characteristics for Customers behind Fuse



RMS Trend Graph

Outage Characteristics for Customers Not behind Fuse



Reliability vs Power Quality

- **Reliability:**

  refers to the continuity of electric delivery as described by the number and duration of power outages.

- **Power Quality:**

  describes the characteristics of power fluctuations, such as momentary interruptions, voltage sags or swells, flickering lights, transients, harmonic distortion and electrical noise.

- **For more info:**

  https://standards.ieee.org/findstds/standard/1100-2005.html

Reliability and Continuity of Service

- **Reliability Metrics:**

    SAIDI – System Average Interruption Duration Index

    YTD for CNP is 85 minutes

    SAIFI –System Average Interruption Frequency Index

    YTD for CNP is 0.85

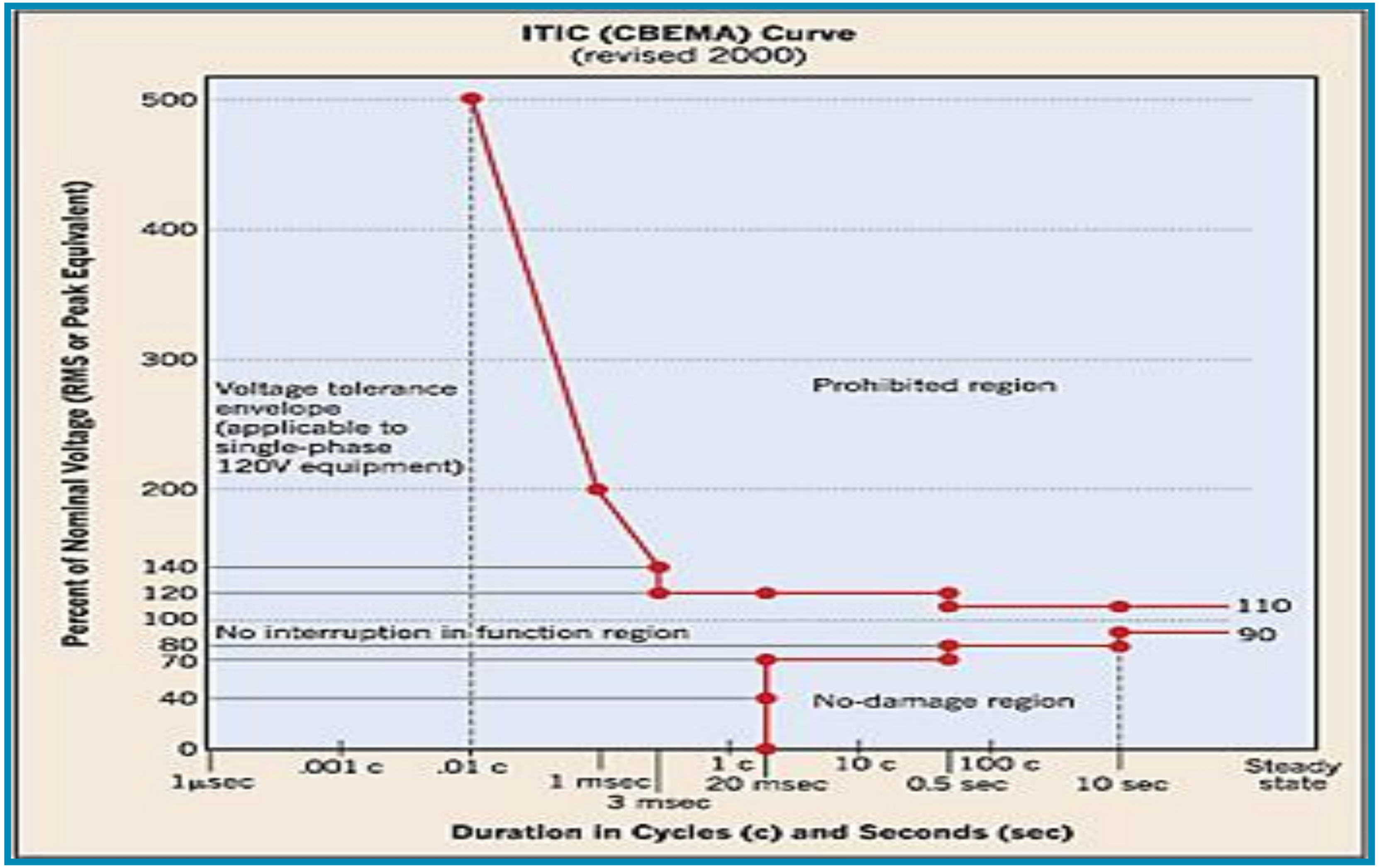
    MAIFI – Momentary Average Interruption Frequency Index

    YTD for CNP is 9

The ITIC (CBEMA) curve

ITIC curve for susceptibility of 120V Computer Equipment

This derivation was developed to show a curve that more accurately reflects the performance of typical single-phase, 60-Hz computers and their peripherals.



http://www.powerqualityworld.com/2011/04/itic-power-acceptability-curve.html

Consumer responsibilities

- **Identify Power Quality requirements for all loads.**
  - **Does customer equipment require very tight tolerances for operation?**
  - **Could customer-owned electrical facilities be generating power quality issues?**
- **Install necessary protective equipment.**

- **CenterPoint Energy is Always There to help**

CenterPoint Energy's Responsibility of Electric Service Delivery

- Chapter 5 of the PUCT-approved CNP (CEHE) Tariff
  - **Section 5.2.1** (Liability Between Company and Retail Customers)
    - CenterPoint Energy will make reasonable provisions to supply steady and continuous delivery service, but does not guarantee against fluctuations or interruptions.
  - **Section 5.5.3** (Equipment Sensitive to Voltage and Waveforms)
    - Customers with equipment that may be adversely impacted by voltage fluctuations are responsible for installing the necessary protective equipment to limit the affect of those events.
- PUCT Substantive Rules
  - **Substantive Rule 25.51** (Power Quality)
    - CNP will provide steady-state supply voltage per ANSI C84.1.
  - **Substantive Rule 25.51** (Reliability and Continuity of Service)
    - Similar to Section 5.2.1 of Tariff. CNP will make reasonable efforts to maintain electric delivery service.

Summary

- CNP (CEHE) is a regulated delivery company.
- Power flows through the Transmission, Substation and Distribution equipment to your home or business.
- There are many different types of faults that cause outages.
  - The type and location of the faults will dictate impact of the outage.
- Reliability metrics show how utilities are performing.
- As equipment becomes more sensitive, power quality issues are more common.

Summary

THANK YOU!

Design for Reliability Planning and Implementation

Elizabeth Martinez

Engineer, Power Quality & Solutions

October 24, 2017

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Show me the money!

- Customers will gain realistic understanding of both utility reliability and common PQ problems/solutions.
- Ultimately it's a business decision.
- How much does it cost me to do nothing?
- How much do I save if I do something?

Every Problem has a Solution

- Identify the problem – What equipment / process is affected?
- What solution provides the best life time value?
- You get what you pay for – Make sure what you get is what you need.

“The Lineup”

- Momentary Interruptions
- Voltage Transients
- Voltage Sags & Swells
- Extended Outages

The Solutions

Once you know……

- **Momentary Interruptions** – Battery UPS, Rotary, DRUP, Static Switch
- **Voltage Transients** – TVSS, Isolation/Constant voltage transformers
- **Voltage Sags / Swells** – Voltage compensators, dip proofing inverters, dynamic sag corrector, static var compensator
- **Extended Outages** – back up generator, static switch, redundant sources

Failure to Plan…….

- Location, Location, Location
- Invest in mitigation early
- Ask for help
- Engineering Rule #2

Disturbance in Terminal B

A Power Quality Case Study

Antony Parsons, Ph.D., P.E.
Technical Consultant
Schneider Electric Engineering Services

Background

- Late 2016: Power Quality study at mid-size US Airport
- History of some issues with reliability / power quality:
  - Minor interruptions not uncommon – frequency had grown in recent years
  - November 2016 – more severe issue
    - Outage caused transfer to Alternate Utility Feeder
    - Dump truck then hit pole on the remaining circuit…leaving facility in the dark
    - Utility service restored fairly quickly…but Airport took ~3 hours to get back up and running
    - Then…similar issue the next morning (customer side)
- Significant disruptions: delays, fines, etc.
- Schneider Electric called in to assist both Utility and Airport in developing improvement plan

Disclaimers

- This Case Study – I'm going to talk about actions that both the Utility and Customer took
  - Utility – in this case, had some issues that were easily corrected
  - Customer had resisted change…but 3rd party report helped in that regard
- Don't read too much into the specifics of the Case Study – it's an example to show the process
- Remember, there are almost always issues on both sides of the meter
- Utility solutions / modifications are confined to the limits of the regulatory tariff in place

- Also – Hospitals / Health Care facilities already have many rules in the NEC and elsewhere about emergency power, etc. The ideas in my presentation do not substitute for a well-designed Essential Electrical System. Likewise, an effective EES does not address all Power Quality issues.

Solving the Problem: As Easy As 1, 2, 3!

Solution Step #1

- Define the problem
  - Understand system layout
  - Understand critical loads/processes

Solution Step #2

- Review the Data
  - Ask questions
  - Review any logged data
- Extract Useful Information

Solution Step #3

- Evaluate Potential Solutions
- If you've done a good job of #1 and #2, this should be easy…

Solution Step #1 – Define the Problem

What does the Electrical System actually look like?

- On the Utility side:
  - Dual 13.8kV feeders to Airport Campus – loads more or less evenly split between the two
  - Utility-owned ATO system
  - Overhead lines – implies that there will always be some exposure to weather, etc.
- On the Customer Side:
  - Critical Loads: Control Tower, Site Utilities (i.e., heating & cooling), Passenger Terminals
  - Level of protection varied widely
  - Some key systems (e.g., Baggage Handling) left basically unprotected

Defining the Problem – Key Questions

- Get a handle on the Critical Loads in the facility
  - What are they, what are their characteristics?
  - Where are they fed from?
  - What kind of protection is present?
    - UPS? Generator? Surge Protection?

- Try and understand the vulnerability of Critical Loads, and their effect on the Process
  - Some critical loads were relatively insensitive to power disruptions (lighting, chillers)
  - Some were sensitive but were already well-protected (control tower, TSA checkpoints)
  - Some were sensitive but were unprotected (baggage handling system)

Applying Step #1

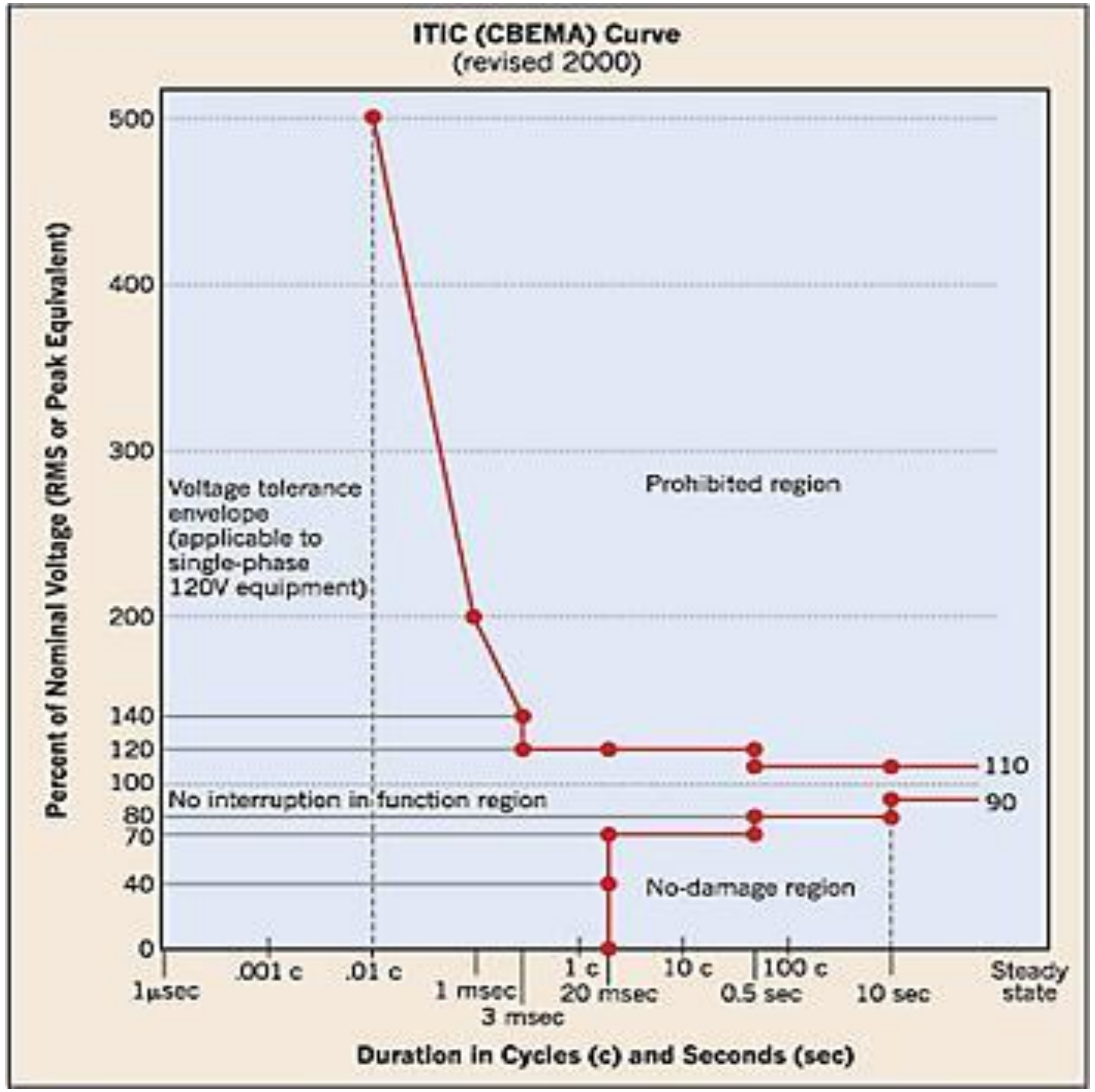
- Customer not immediately sure about details on critical loads – had not done an adequate Risk Assessment. Always good to think through what could go wrong & its impact.
- Little to no planning on how to serve critical loads:
  - Some loads were generator-backed, but not many
  - Baggage Handling System – large load, fed from 2 or 3 places – hard to get centralized protection
  - Practice seemed to be to feed things from wherever there was available space
- Good things:
  - Knowledgeable employees that did know answers to questions when asked
  - They had a decent set of one-lines on both the Customer and Utility side
  - Customer even found 30-year-old switchgear record drawings within 10 minutes!!

Solution Step #2 – Review the Data

- We sought out first-hand accounts of individuals involved with the November outage
  - This is IMPORTANT! The problem is *never* as initially described…
  - Power System Specialist finds information in the details that others overlook
- Review Power Monitoring data
  - Electrically, what actually happened? Or didn't happen?
  - Ideally – some sort of "trouble log" exists so that electrical data can be correlated to observed events
- Ultimate goal – develop some kind of idea about what kinds of disturbances actually disrupt the Process, and how often they may occur

NOT an interrogation…

ITIC Curve – Common PQ Performance Measure



- Provides information on vulnerability of typical IT Loads – so it's a good general starting point
- Some monitoring software can plot observed disturbance characteristics vs. the ITIC curve

Data Mining

- In our Case Study:
  - The site was not affected by faults on the Transmission System
  - The site was sometimes affected by faults on neighboring Distribution Circuits
  - The site was always affected by faults on the circuit that feed the Critical Loads
- Other information emerged, not necessarily related to Power Quality:
  - Customer 4000A main fusible switch tripped after one utility interruption – shouldn't have happened
  - Customer 4000A main tripped again next morning as concessions were coming on-line
  - Ultimate issue – combination of Neutral Current being sensed as ground current, plus a bad Ground Fault Relay setting.

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Applying Step 2

- Is there monitoring equipment on the customer side? Is it configured properly?
- Is there metering on the utility side…and is any of that data available to the end user?
- The “problem log” is vital – human memories are short and imprecise
- Other case studies:
  - A Hospital in South Texas:
    - Repeated issues with Imaging Machine – young technician was blamed, was about to be fired
    - Power Quality investigation showed correlation between issues and weather events
  - Hospital in New Orleans area – issues with MRI, vendor initially pointed to utility. Monitoring data and site records showed no correlation of issues with power events. Vendor called in again and ultimately found issue with machine itself.

Step #3 – Evaluate Potential Solutions

- By now we know <u>What</u> is affected, and have at least some idea of <u>When</u>
- Both are important for finding an “optimal” solution
- Other things to consider at this point:
    - Reliability vs. Power Quality
    - Voltage Sags vs. Interruptions
    - The “Pareto Principle” (aka the 80/20 rule)
    - Practicalities

Reliability vs. Power Quality

- Protecting against extended outage due to a Hurricane is much different than protecting against a "circuit operation"
  - In the typical hospital, the EES should be well protected against the extended outage…as long as the generators start and the fuel supply holds out
  - Simply expanding the amount of emergency generation in a facility will not address Power Quality concerns – by the time the generators start up, the problem is gone but the effects remain
- They're really two different problems – and understanding which problem you're trying to solve is the first step in finding a solution

Voltage Sags vs. Interruptions

- Voltage Sag – reduction, but not total loss, in voltage for a brief period of time
  - Incandescent lights – dim
  - Electronic loads – shut down
- Interruption – total loss of voltage
  - Effects on sensitive loads may be similar
- These disturbances may require different solutions – Voltage Conditioning equipment (e.g., “Sag Fighter”) may not protect against a total interruption

The Pareto Principle, aka the 80/20 Rule

- Our Case Study: Airport site saw ~26 power quality events in 2016
  - Immediate, low-cost solutions: modify utility ATO operation, change customer Ground Fault settings
  - Projected improvement: > 80% of observed events would not have impacted the Baggage System if these changes had been made a year sooner
- Protecting against the remaining 20% - we looked at both Customer and Utility options
  - Customer cost – initial solution cost estimates ranged from $500k to $3M depending on how much of that remaining 20% to address
  - Utility cost – roughly same range for improvements on their side of the meter

Vilfredo Pareto

Practicalities

- Will it Fit?
- Will system reconfiguration be necessary?
- What kind of downtime is required?
- How does this all fit into the available budget?
- Etc…

Consider Characteristics of Common Solutions

- UPS – up to 15 minute ride through, but traditional Static UPS is not good for serving motor loads. Rotary UPS can do this, but is more expensive. DRUPS can serve whole facility but at high cost.
- Voltage Conditioning – relatively simple and inexpensive, but does not address interruptions
- Standby Generation – large, noisy, slow, and they need fuel. But if you need protection for outages of more than a few minutes, it's the only realistic solution.
- Miscellaneous:
  - Harmonic Control – filters, line reactors, etc. But we've seen much money wasted over the years solving non-existent harmonic problems.
  - Surge Suppression – important, but needs proper installation. And an effective Grounding and Bonding system. When was the last time you had yours checked out?

Applying Step 3

- Advantage of actually trying to match Solution to Problem: you get a solution that actually fixes your issue and you don't have to spend more $$$ than required in order to do it
- In many cases:
    - People don't understand the true nature of their problem (Step 1 and Step 2), which makes it extremely difficult to efficiently solve it
    - It's hard to fight Marketing Literature (If your only tool is a hammer, every problem is a nail…)
    - Planning for these kinds of issues in the early stages of an installation is much easier and cheaper…but not if ride through capabilities or other features get "value engineered" out of a project

Case Study: Recommendations

- Short-Term:
  - Utility – reconfigure system so that critical load is on the more reliable feeder
  - Customer – address Ground Fault issues
- Medium-Term:
  - Utility – address unreliability of other feeder (e.g., bring in new, dedicated circuit)
  - Customer – protect BHS. But…easier said than done. Work underway to better understand BHS operation to ID correct ride-through solution.
- Long-term:
  - Both Utility & Customer – opportunities to upgrade and modernize their power systems. Plan for replacement of end-of-life gear.

General Recommendations

- Monitor & Log Data to help characterize problems
- Discuss with Utility – they’re going to need to be at least a part of the solution
- Be selective with solutions – don’t UPS the entire hospital, for example
- Don’t be “penny wise and pound foolish”

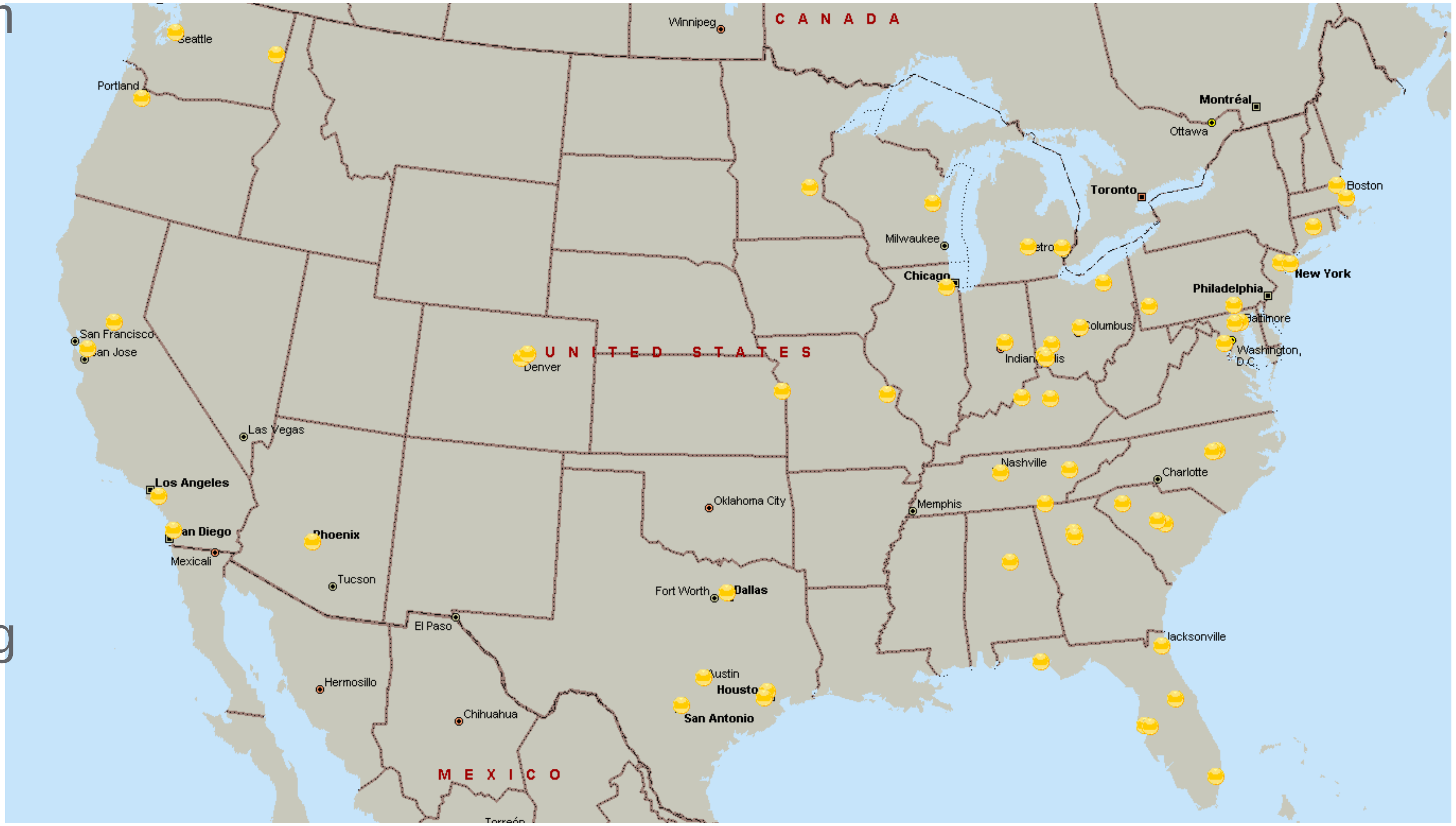
Schneider Electric Engineering Services – Who We Are

National > Experienced > Knowledgeable

- 200+ professional power system engineers provide nationwide coverage.

- Collectively registered in every state to meet state licensing requirements.

- Having a power system engineer close by assures familiarity with authorities having jurisdiction, local codes and standards, utility systems and operations.



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Schneider Electric Engineering Services – What We Do

- Our registered professional engineers, safety trained and equipped, will perform a comprehensive investigation of your power quality issues.
- Square D Services from Schneider Electric offers a broad range of service solutions to support any manufacturers' electrical distribution equipment. Whether the solution is refurbishment, replacement, maintenance or recommendations to optimize your existing system, our nationwide network of qualified experts offers a complete service package.
- We will:
  - Document the symptoms leading to your concern and develop a plan to investigate
  - Examine damaged equipment and/or review the equipment vendor's damage analysis
  - Assess the power and grounding system to confirm it is adequate
  - Install temporary power monitors (if needed) to characterize possible power disturbances
  - File a report describing the findings and the most probable cause
    - The report will include cost-effective mitigation to prevent future occurrences of the problem

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