

Circuit Restoration/Reclosing Philosophies and Power Quality

VELCO Operating Committee
February 21, 2013

Goal



- To have a heightened awareness of how our circuit restoration operating practices and decisions impact each other's interconnected system, and how they can both enhance and potentially degrade customer service and system reliability.



Objectives



- Convey the Increasing Importance of Power Quality
- Define the Relationship Between Reclosing and Power Quality
- Explain the Concepts for Effective Automatic Reclosing
- Review Remote Control Reclosing Practices for Different Voltage Classes
- Discuss the Consequences Associated with Reclosing

Power Quality



- It's No Longer Just Keeping the Lights On
 - Microprocessor-Based Equipment More Susceptible
 - Variable Speed Drives and Other Industry Electronics
 - Moore's Law – Integrated Circuit Capacity Doubles Every 18-24 Months
 - Gordon Moore, April 13, 2005 - noted that transistors would eventually reach the limits of miniaturization at atomic levels, and we have another 10 to 20 years before we reach a fundamental limit.
- Utility Customers Need To Be More Competitive
- Interruptions of Less Than 1/10 second Can Be Costly
- A Significant Amount of the Subtransmission System in VT can Cause Power Quality Issues for Sensitive Commercial Customers

Power Quality is Impacted By



- Harmonic Distortions (Dirty Power)
 - Non-Linear Loads Such As Variable Speed Drives and Switching Power Supplies
- Interruptions
 - Both Planned and Unplanned
- Transient Disturbances
 - Lightning and Switching of Lines, Caps, and Cables
- Swells and Sags/Dips
 - Load or Source Loss, and Fault Clearing
- Voltage Fluctuations, Flicker Voltage
 - Motor Starting, Arc Furnaces



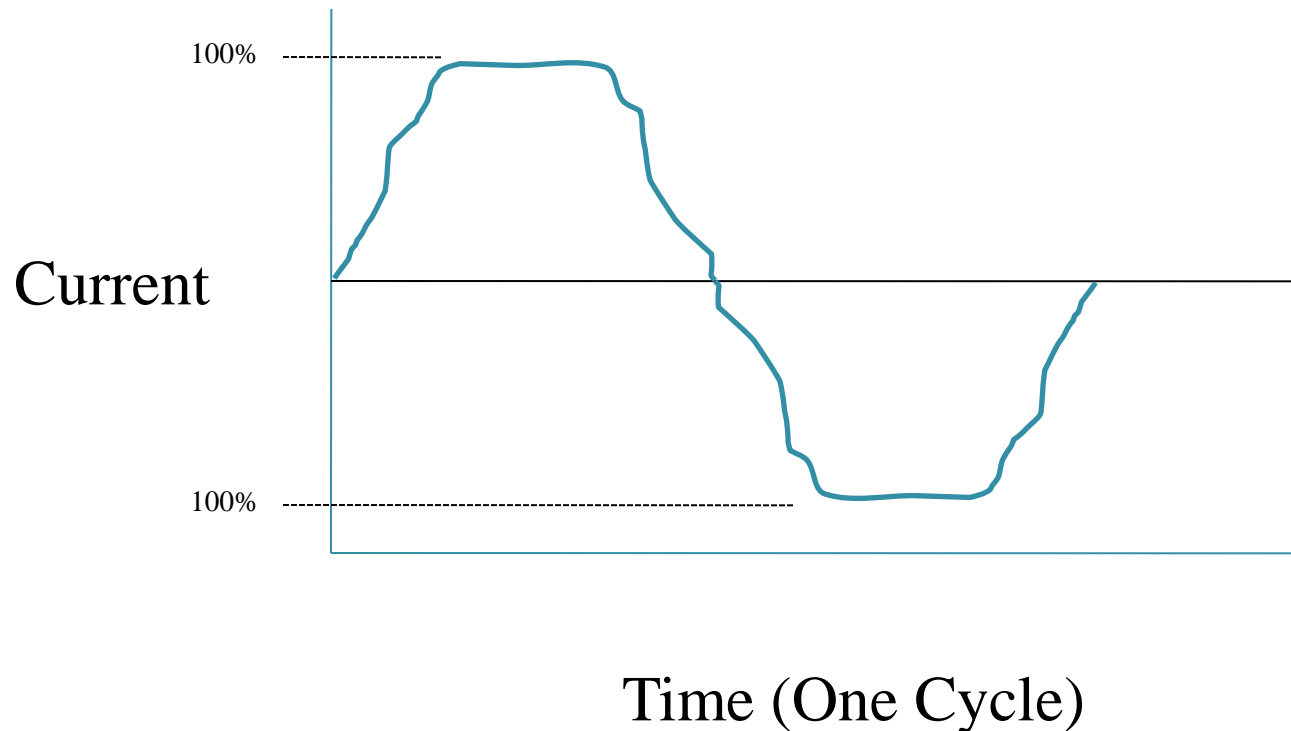
Power Quality is Measured



- PQ Measurement in “Total Harmonic Distortion” (THD)
 - Used to define the effect of harmonics on the power system voltage, expressed as percentage of the fundamental
 - $THD = \sqrt{\text{sums of all squares of amplitude of all harmonic voltages}} \div \text{square of the amplitude of the fundamental frequency}$
 - Voltage Distortion Limits, per ANSI/IEEE Standard 519
 - $\leq 69\text{kV}$, THD = 5.0%
 - 69 to 161kV, THD = 2.5%
 - $\geq 161\text{kV}$, THD = 1.5%
- *Measured at the Point of Common Coupling
- PQ is also Measured by “Total Demand Distortion” and “Telephone Influence Factor” (TIF), per Standard 519

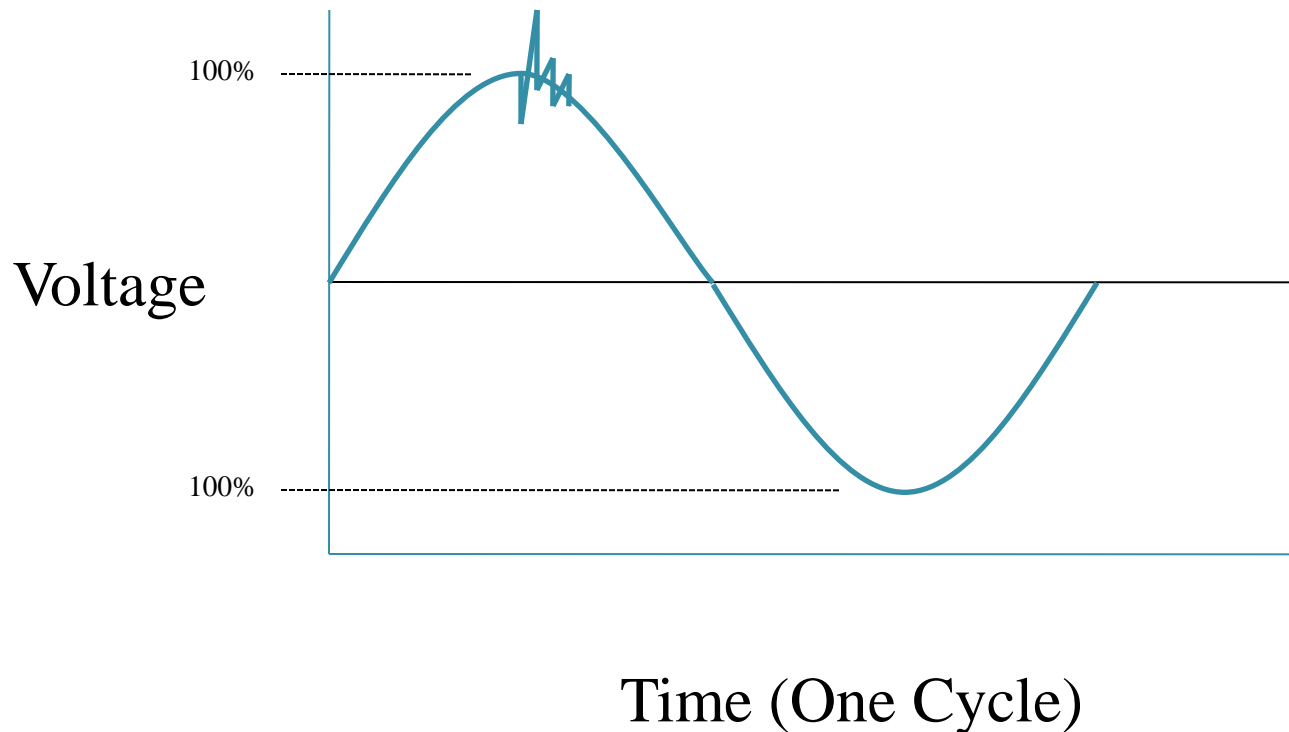
Power Quality

- Harmonic Distortion



Power Quality

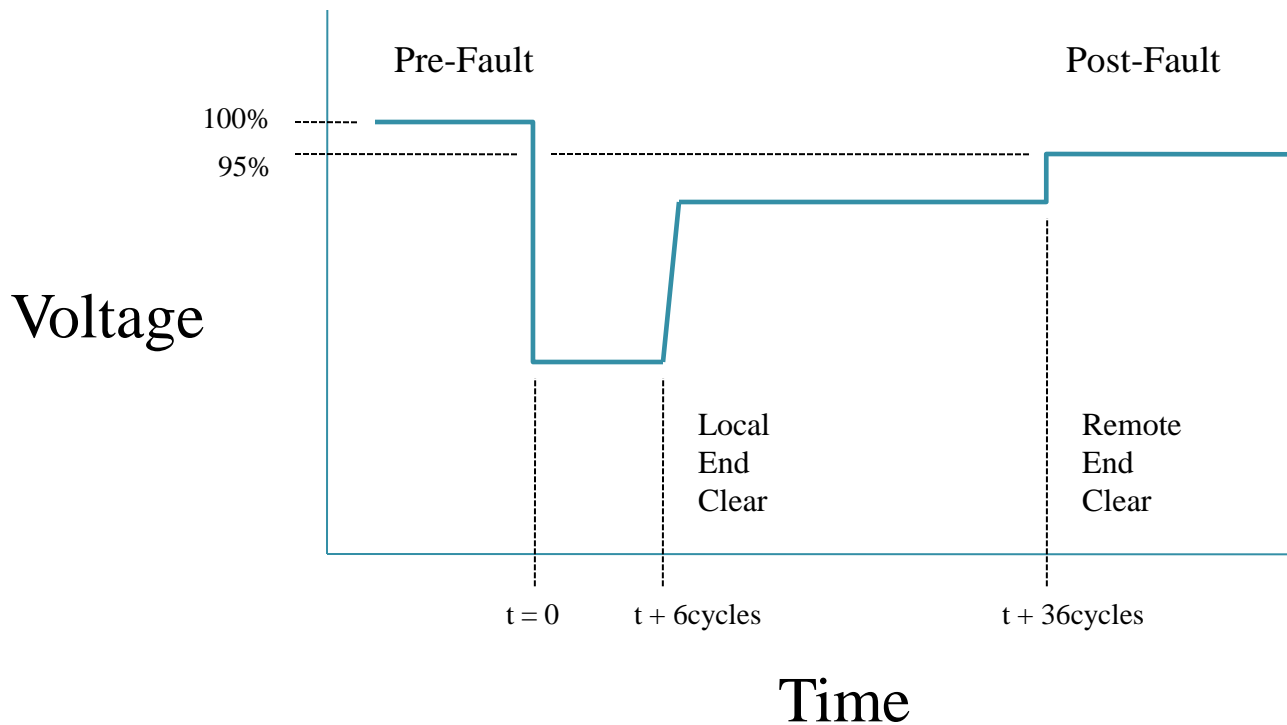
- Transient Disturbance (Cap Bank Closing)



Power Quality



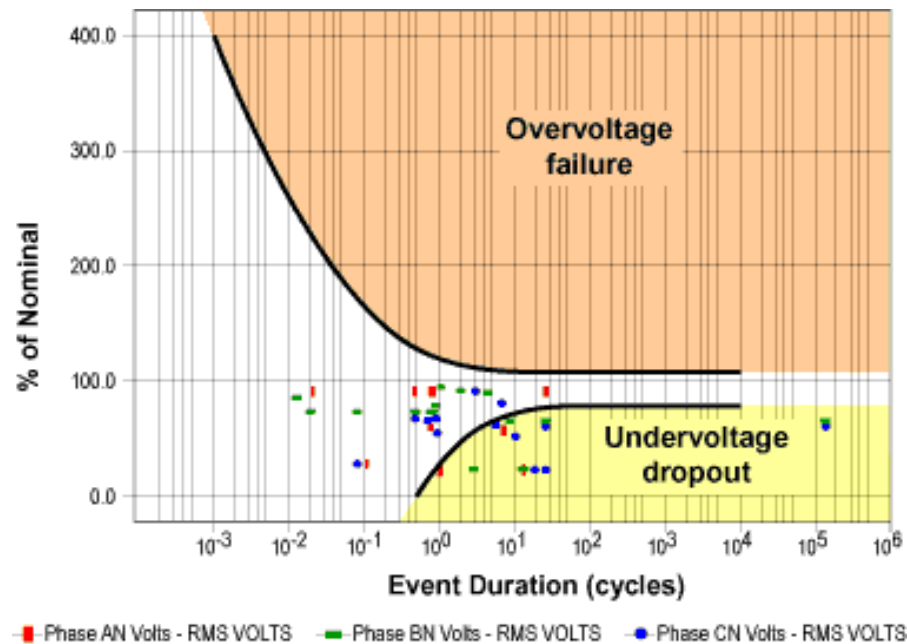
- Voltage Sag (Line Clearing for a Fault)



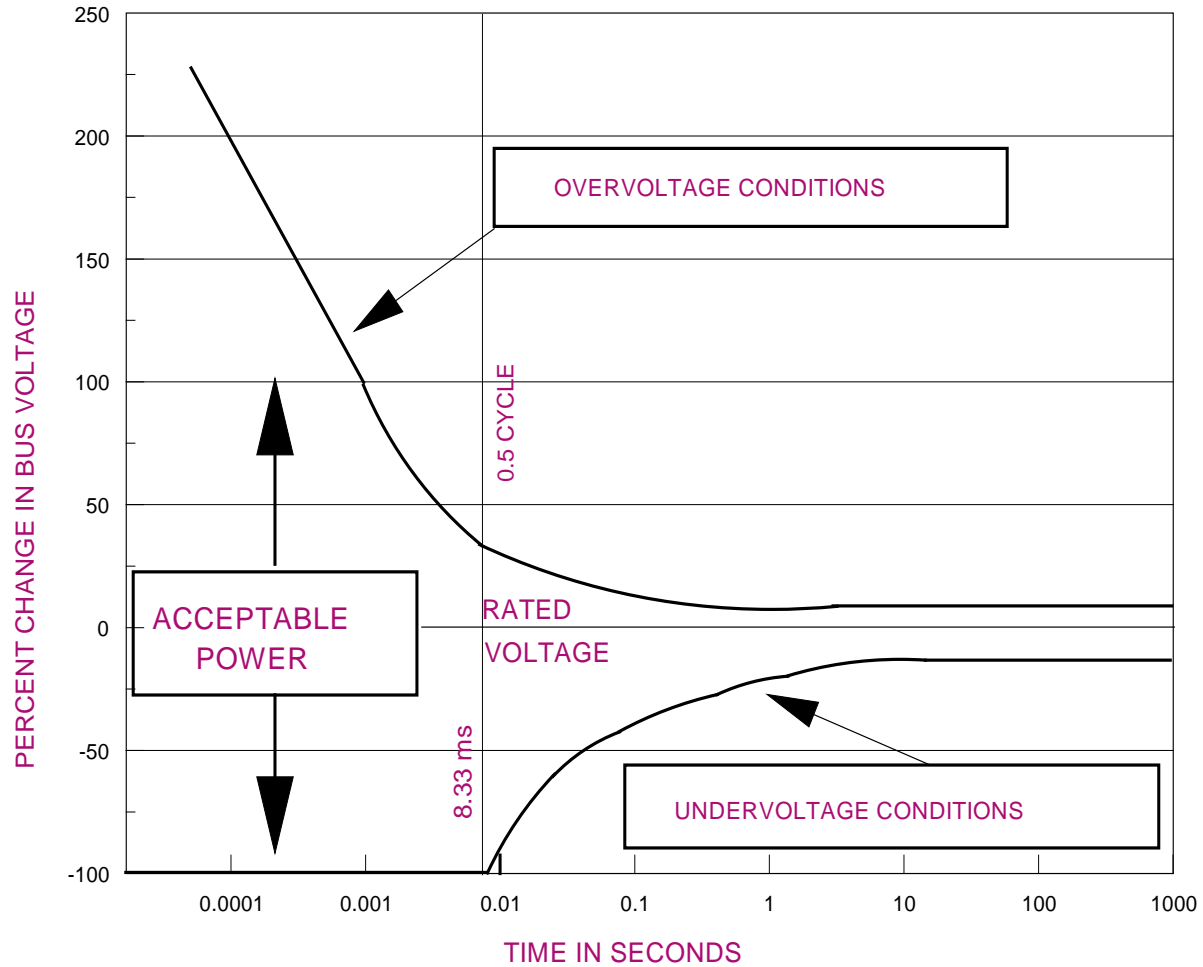
Power Quality



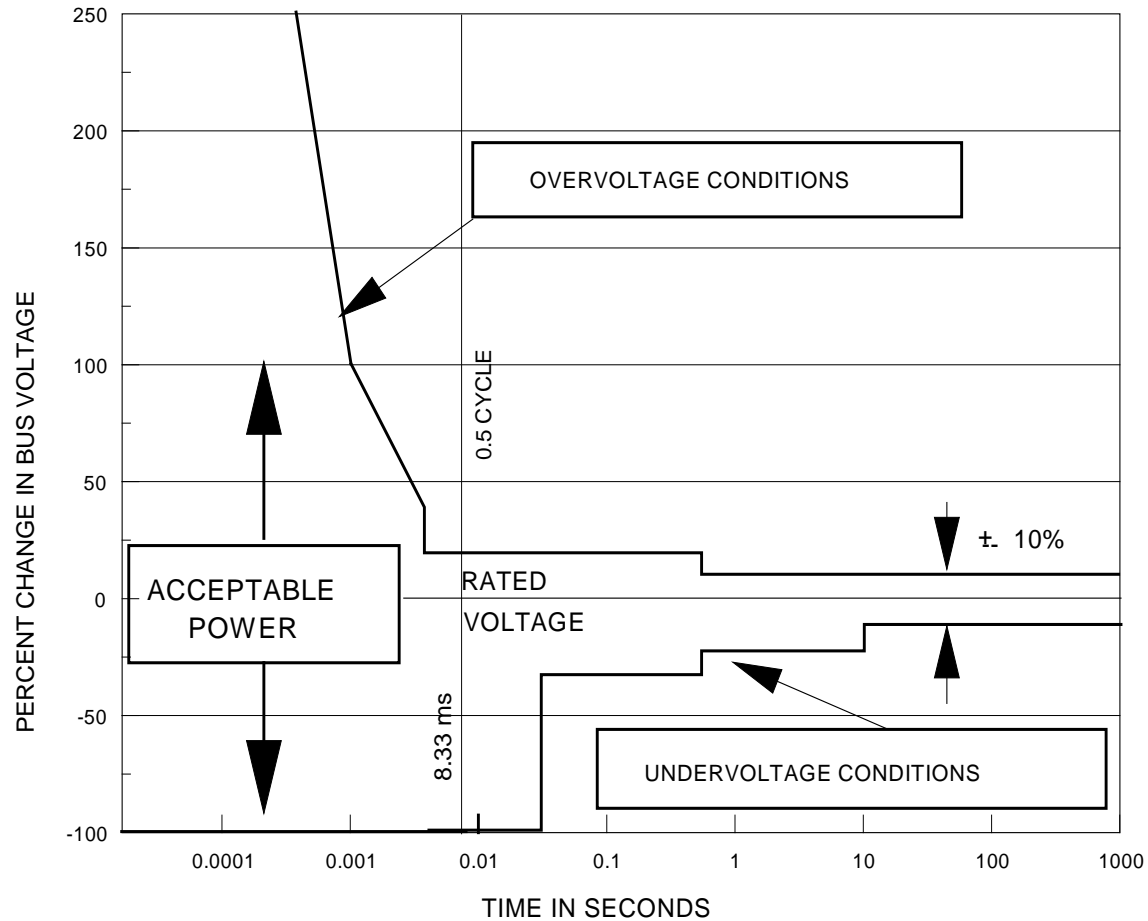
- The CBEMA (Computer Business Equipment Manufacturers Association) Curve
 - Guideline for the Industry Members in Specifying and Designing Production Equipment, e.g. Power Supplies



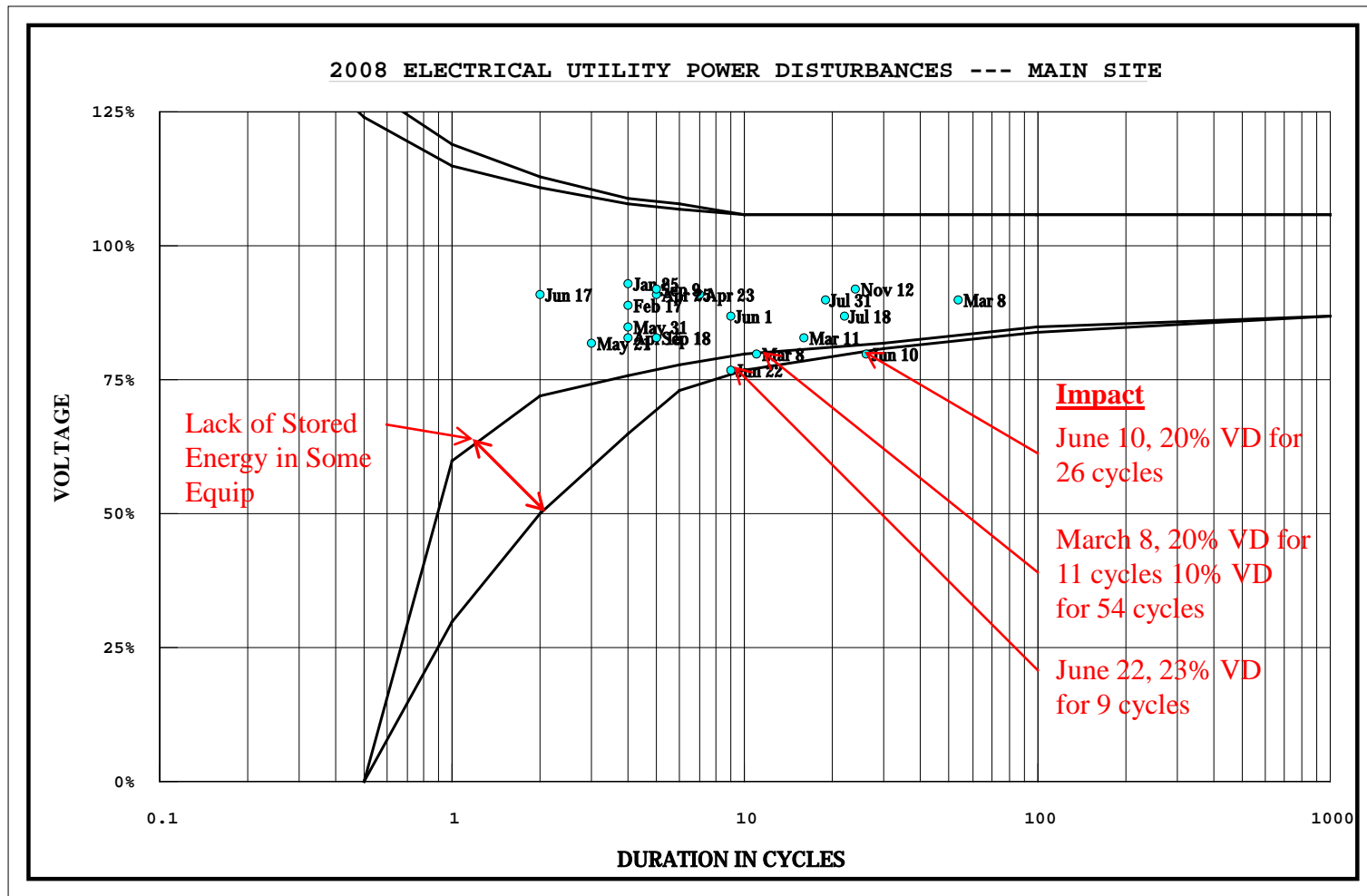
CBEMA Curve



ITIC (Information Technology Industry Council) Curve



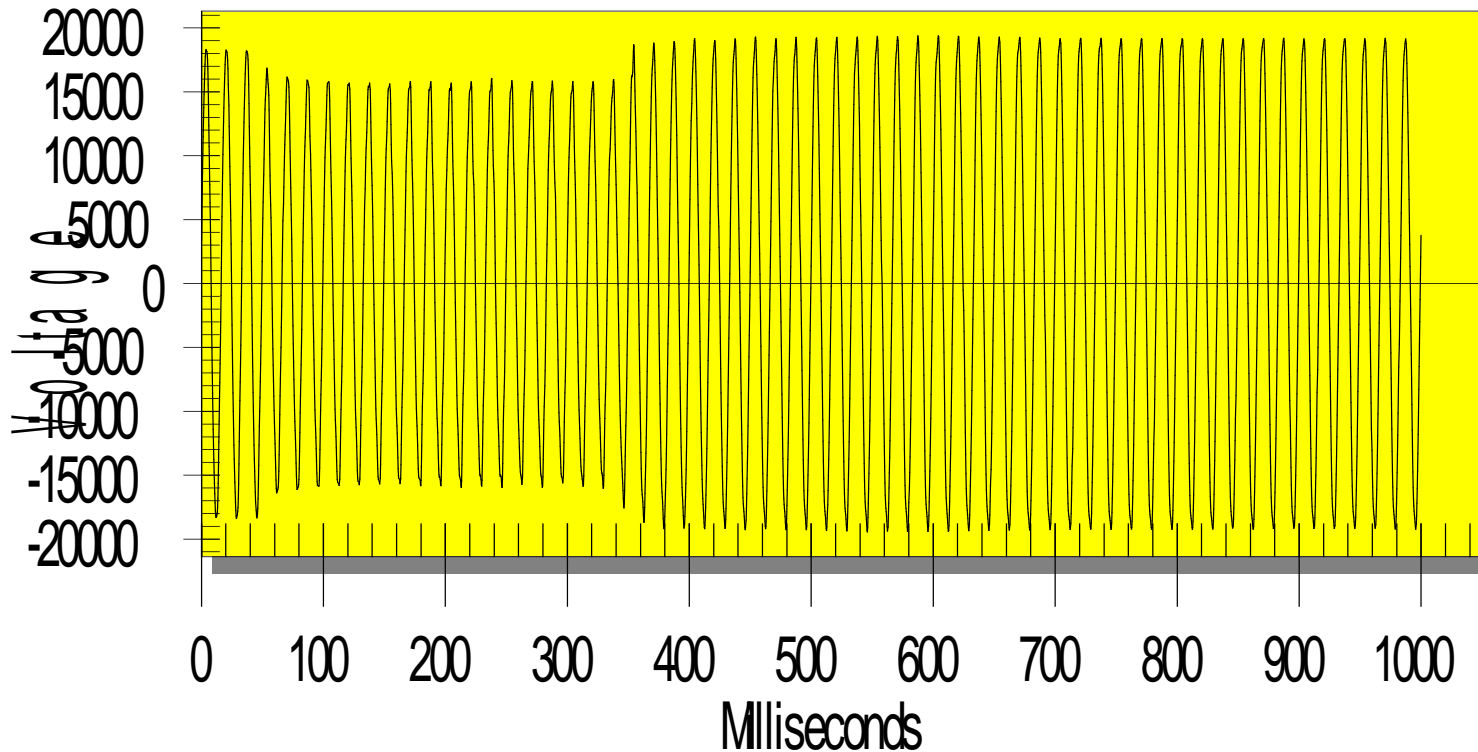
Example CBEMA Plot



Power Monitor Recording



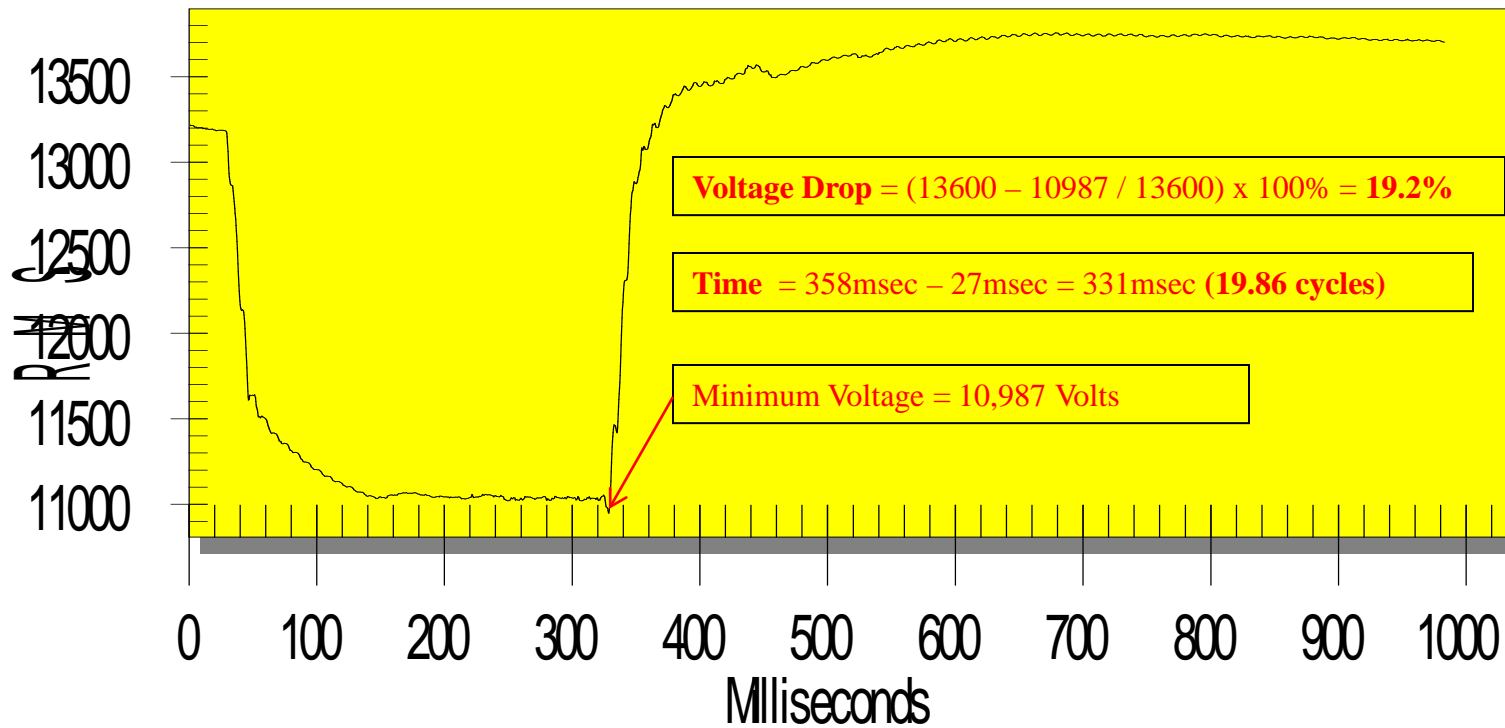
Phase A-B Voltage 64 Points / Cycle



Power Monitor Recording



Phase A-B Voltage RMS Analysis



Power System Reclosing



- Circuit Restoration is One of the Most Important Functions of an Operator, with Concern for:
 - Safety
 - ✓ Public
 - ✓ Utility Workers
 - Customer Service (e.g. SAIDI)
 - Transmission Reliability



Power System Reclosing



- Jackson, TN. The driver was attempting to throw a logging cable over the logs to secure them and hooked the electric line instead. The Logger said that the tires began to burn within seconds.



Reclosing Options



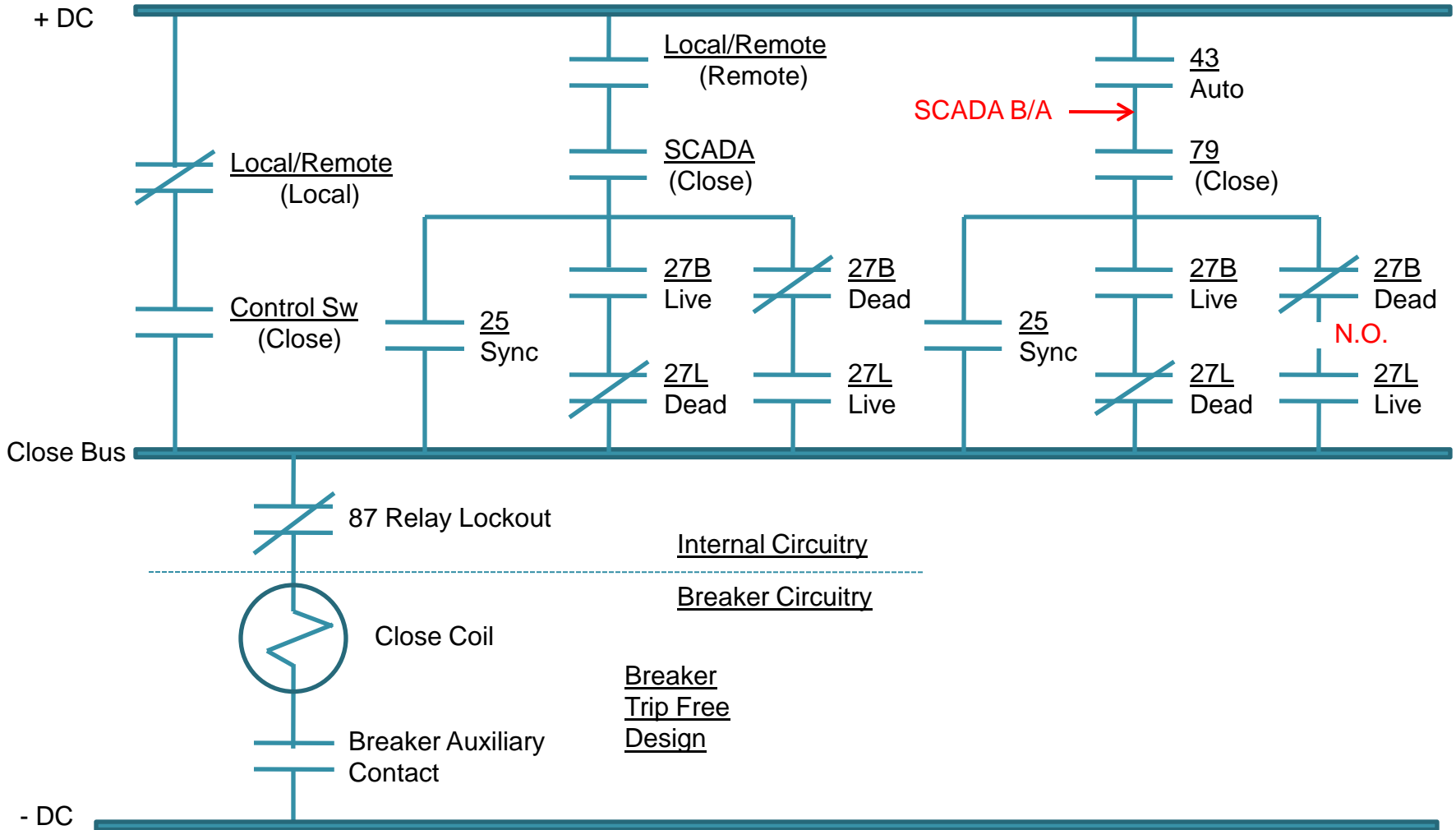
- Local Manual Control (Different Control Schemes)
 - Switchman in Control, Responsible for Checking Conditions
 - Permissive Control, Indication Relays Supervise Conditions
 - Safety Precautions, Ground Potential Rise
- Remote SCADA Control
 - Permissive Control, Indication Relays Supervise Conditions
 - Situational Awareness, Decisions Made with Information at Hand
- Automatic
 - Permissive Control, Indication Relays Supervise Conditions

Reclosing Conditions



- Conditions
 - Bus/Source Alive – Line Alive (Synch-Check)
 - phase angle must be within a specified limit and for a specified time
 - Bus/Source Alive – Line Dead
 - Bus/Source Dead – Line Alive
 - Bus/Source Dead – Line Dead
- Indication/Supervising Relays
 - Reclosing Relay (Device 79)
 - Synch-Check Relay (Device 25)
 - Bus/Source Voltage Relay (Device 27B/S)
 - Line Voltage Relay (Device 27L)
 - Multifunction Relay (Several Variations)

Typical Breaker Close Circuit



Automatic Reclosing



- Automatic Reclosing Increases Continuity of Service
- Overhead Lines
 - Distribution - 50 to 80% of Faults are Temporary
 - Transmission - $\geq 90\%$ of Faults are Temporary
 - ✓ Varies considerably with differences in climate, lightning intensity, ground conditions, voltage level, line design and etc
- Underground Lines – Virtually all Faults are Permanent
- Voltage Class Determines the Reclosing Attempts
 - Distribution – Typically 2 to 4 shots and coordinated with downstream devices
 - Subtransmission – Varies widely, typically from 1 to 3 shots
 - Transmission – Typically 1 to 2 shots

Automatic Reclosing



- Success Rates for Reclosing
 - Small Additional Percentage of Success After First Attempt
 - Number of Successful Reclosures, for a Typical “Distribution” Utility, ref ABB Applied Protection Relaying
 - ✓ One automatic reclose attempt – 83.25%
 - ✓ Second automatic reclose attempt - 10.05%
 - ✓ Third automatic reclose attempt – 1.42%
 - Reclose Success Rate for Successive Multiple Reclosures, ref IEEE std. C37.104-2002, IEEE Guide for Automatic Reclosing of Line Circuit Breaker for AC Distribution and Transmission Lines
 - ✓ One automatic reclose attempt – 90%
 - ✓ Second automatic reclose attempt - 4%
 - ✓ Third automatic reclose attempt – 1%

Automatic Reclosing



- Considerations in Applying a Reclosing Scheme
 - Circuit Configuration, Looped or Radial
 - Downstream Devices, e.g. Tapped Loads and Motor Loads
 - Critical Customer Load being Served, Proximity and PQ Impact
 - Grounded or Ungrounded System Being Served
 - Short Circuit Strength, Stronger Source
 - Upstream Relay Coordination, Ratcheting Effect
 - Transformer Through Current, e.g. forces on windings
 - Proximity to Generation, e.g. transient forces on machines
 - Voltage Across a Breaker, System Angle and Shock to System
 - Breaker or Recloser Capabilities
 - Multiple Interrupting Capability and De-Rating
 - Stored Energy and Recharge

Automatic Reclosing



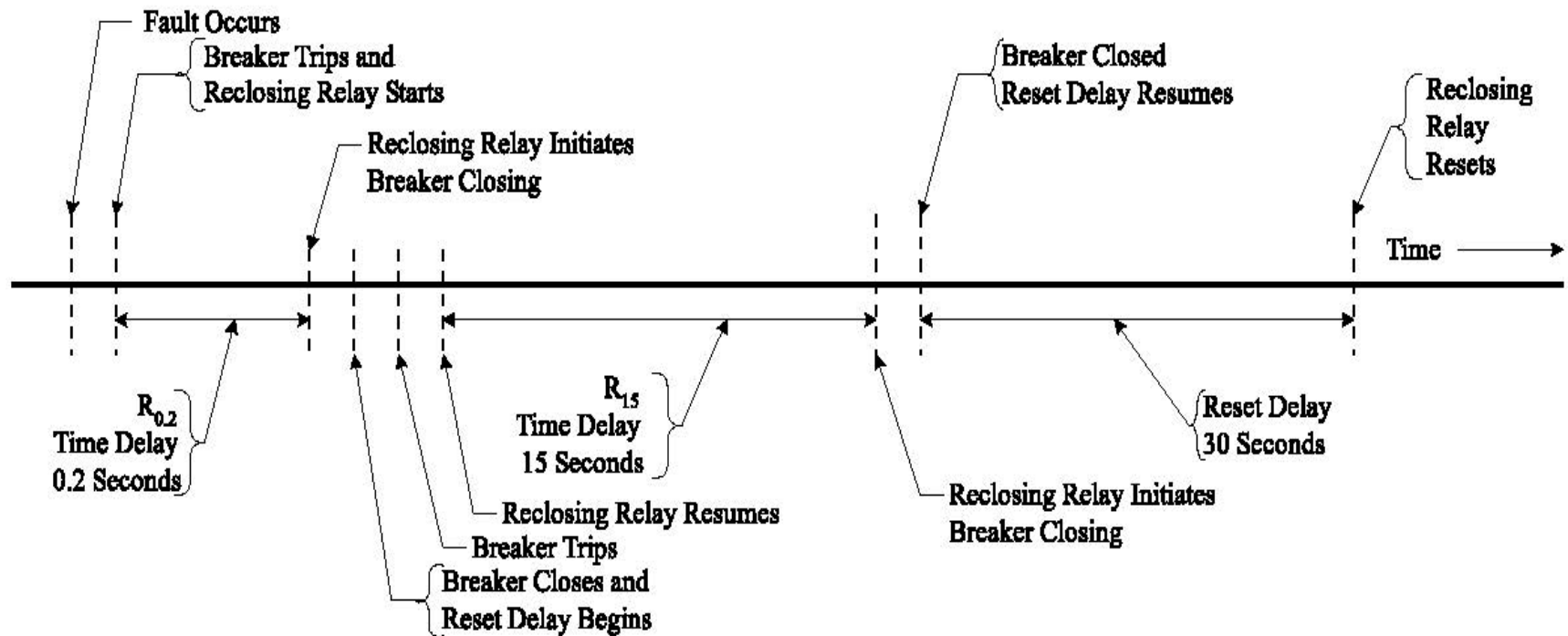
- Considerations for Blocking Automatic Reclosing
 - Manual Trip
 - Local Breaker Failure Operation
 - Receipt of Transfer Trip for Breaker Failure or Protection Scheme
 - Hot-Line Maintenance, to Include Parallel and Adjacent Lines
 - Three Phase Faults, EHV
 - Delayed Remote Backup Clearing
 - Differential Relay Operations; Busses, Transformers, and Other
 - Faults on Underground or Submarine Cables
 - Out-of-Step or Swing Conditions
 - Under-frequency and Under-voltage Load Shedding Operations
 - Switch-Onto-Fault Operations
 - High Impedance Fault Detection

Automatic Reclosing



- VELCO Standard Transmission System Reclosing
 - One Automatic Reclose Attempt on a “Dead Line” Condition from One End of Line
 - Synch-Check Reclosing from the Opposite “Remote” End
- VELCO Automatic Sectionalizing Schemes on Multi-Terminal Lines
 - Restore Transmission Continuity with Consideration for:
 - Sensitive Areas with Concern for Voltage Performance
 - Reliability Concern with Severe Weather Events Taking Out Multiple Lines, e.g. Stowe K24 Tap Line
 - Special Applications, e.g. Highgate Converter output

Automatic Reclose Cycle



Manual and SCADA Reclosing



- VELCO Reclosing Philosophy for Permanent Faults
 - Two-Terminal Transmission Lines – due to the low probability for successfully reclosing after one automatic attempt along with the concern for both public safety and further equipment damage, VELCO will not make an attempt to reclose via SCADA or manual control. For permanent faults VELCO Engineering will be immediately contacted for analyzing the fault and determining a location. At the same time, VELCO field personnel will be dispatched to inspect the line. VELCO will not reclose the line until the fault has been found and cleared, except with the noted exception below.
 - During weather conditions, such as intense lightning storms or ice unloading of conductors, it is possible that the same circuit was tripped within up to 60 seconds following a successful reclose. At the discretion of the VELCO System Operator, s/he can perform either a manual or SCADA reclose without the benefit of engineering analysis or field inspections.

Manual and SCADA Reclosing



- VELCO Reclosing Philosophy for Permanent Faults
 - Multi-terminal Transmission Lines with Sectionalizing Capability – faults will be isolated by only closing in on each section of line with downstream switches open. The closest switch shall normally be opened first during the sectionalizing process to reduce the number of system faults.

Manual and SCADA Reclosing



- VELCO Subtransmission System Reclosing Following Unsuccessful Automatic Attempt(s)
 - Looped circuit and without tapped loads
 - Normally, no reclose attempts made from VELCO end with concern for transformer through-faults and PQ impacts
 - VELCO Engineering will be immediately contacted for analyzing the fault and determining a location
 - During weather conditions, such as intense lightning storms or ice unloading of conductors, it is possible that the same circuit was tripped within up to approx 60 seconds following a successful reclose. At the discretion of the VELCO and VDU System Operators, perform either a manual or SCADA reclose without the benefit of engineering analysis or field inspections.

Manual and SCADA Reclosing



- VELCO Subtransmission System Reclosing Following Unsuccessful Automatic Attempt(s)
 - Looped Circuit with Tapped Loads and Sectionalizing Switches
 - In coordination with VDU Operator, perform sectionalizing and use source with consideration for safety and equipment
 - VELCO Engineering will be immediately contacted for analyzing the fault and determining a location
- VELCO Evaluating Best Approach for Providing Real-time Protective Relay Information to the System Operators, e.g. fault location and targets

Manual and SCADA Reclosing



- VELCO Subtransmission System Reclosing Following Unsuccessful Automatic Attempt(s)
 - Radial circuit without sectionalizing switches
 - Normally, no reclose attempts made from VELCO end with concern for transformer through-faults and PQ impacts
 - VELCO Engineering will be immediately contacted for analyzing the fault and determining a location
 - During weather conditions, such as intense lightning storms or ice unloading of conductors, it is possible that the same circuit was tripped within up to approx 60 seconds following a successful reclose. Also, during severe weather conditions, such as with high or low ambient temperatures and concern for public safety, at the discretion of the VELCO and VDU System Operators, perform either a manual or SCADA reclose without the benefit of engineering analysis or field inspections.

Manual and SCADA Reclosing



- VELCO Subtransmission System Reclosing Following Unsuccessful Automatic Attempt(s)
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Power Quality and Reclosing



- Questions?



References

- ANSI/IEEE Standard C37.90 “Relays and Relay Systems Associated with Electric Power Apparatus”
- ANSI/IEEE Standard C37.104 “Guide for Automatic Reclosing of Line Circuit Breakers for AC Distribution and Transmission Lines”
- ANSI/IEEE Standard 519-1992 “Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems”
- Kennedy, Barry W.; Power Quality Primer, McGraw-Hill, 2000
- Elmore, Walter A., et al; Protective Relaying Theory and Applications, Marcel Dekker, Inc., 1994
- Blackburn, J. L.; Protective Relaying Principles and Applications - Second Edition; Marcel Dekker, Inc., New York, 1998