Utility System Operation

Presented by
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Utility Power System

- Utility System Overview
  - Transmission System
  - Distribution System
- How the System Works
  - Transmission
  - Distribution
- Why It Works That Way
  - Design Philosophy
  - Events & Causes
Transmission System Overview

- High Voltage
  - 500 kV
  - 230 kV
  - 115 kV
- Purchased Right-of-Way
  - Wide
  - Cleared
  - Utility Has Some Control
- Few Attachments
- Very Reliable
- Few Disturbances
Distribution System Overview

- **Medium Voltage**
  - 23 kV
  - 12 kV
- **Constructed Along Public Roads**
  - Other Utility Attachments
  - Less Clearance to Trees
  - More Public Access
  - More Exposure
- Most Customers Served This Way
- More Disturbances
System Design Philosophy

- Protect Transmission & Distribution Lines and Equipment
- Minimize Number of Extended Outages
- Minimize Number of Customers Out Due to a **Fault**
- Trade-off is More Short Duration Events

Automatic Reclosing Feeder Breakers at a T-D Substation
Protective Coordination Equipment

- Automatic Reclosing Circuit Breakers
  - Transmission & Distribution
- Automatic Line Reclosers
  - Distribution System
- Fuses - (Fused Cut-Outs)
  - Mostly On Distribution
- Grounding & Bonding
  - Critical for Safety & Protection
- Lightning Arrestors
  - Limit Voltage, Divert Current
Automatic Three Phase Line Recloser
Single Phase Line Reclosers
Three Phase Dip Pole Fuse
Tap Line Fuse - Fused Cutout
Faults cause voltage sags, interruptions and outages

- Sag
- Interruption
- Outage

- Sag
- Interruption
- Outage

- Magnitude and Duration
- Duration

- - 10% and < 1 minute
- - 90% and < 1 minute
- > 1 minute
Fault On Transmission System

Transmission @ 115 kV

Transformer

Distribution @ 23 kV

Feeder Breaker

Feeder Breaker

Transmit to Distribution Substation

Fault

Transformer

Customer Substation

Customer Substation

23 kV Feeder

Transformer

Fuse

Transformer 480 V

Customer

Fuse

Transformer 480 V

Customer

Fuse

Transformer 480 V

Customer

Fuse

Transformer 480 V

Customer

Progress Energy
Fault On Transmission System

- All customers (transmission and distribution) served by the faulted transmission line will experience a short Voltage Sag.
- Customers served by other transmission lines which connect to the faulted transmission line may also experience a voltage sag.
- Depending on the configuration of the transmission line, some customers may experience a Momentary Interruption while a fault is clearing.
Fault On Transmission Line

- Fault occurs here
- Breaker opens here
- 4 cycles (~0.067 sec)
- Breaker recloses here
- Fault cleared
Four Cycle Voltage Sag
Causes of Faults on the System
Fault On Your Feeder

Transmission @ 115 kV

115 kV Substation

Transformer

Regulator

Distribution @ 23 kV

Feeder Breaker

23 kV Feeder

Transformer

480 V

Customer

Fuse

23 kV Feeder

Customer

Fuse

23 kV Feeder

Customer

Fuse

23 kV Feeder

Momentary Interruption

Outage

Progress Energy
Fault On Your Feeder

- Fault occurs here
- Recloser opens here
- Recloses here
- Fault cleared

Voltage

0  480

Time

~ 1/3 second

7 cycles (~0.1 sec)

13 cycles (~0.2 sec)
Voltage Sag & Momentary Interruption

Event Number 174 Channel B Setup 2

Breaker Tripped

Horizontal 50 milliseconds/division

Vertical 200 Volts/division

Vrms: Prev=473.2, Min=18.00, Max=469.2

Worst Imp= 0 Vpk, 0 deg
Squirrel Guard
Fault On Adjacent Feeder

Transmission @ 115 kV

115 kV Substation

Transformer

Regulator

Distribution @ 23 kV

23 kV Feeder

Customer

Fuse

Feeder Breaker

Outage

Sag

23 kV Feeder

Customer

Fuse

23 kV Feeder

Transformer

Customer

Fuse

Transformer

Customer

Fuse

Transformer

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Transformer

Customer

Fuse
Fault on Adjacent Feeder

- Fault occurs here
- Breaker opens here
- Breaker recloses here
- Fault cleared

Voltage

0  7 cycles (~0.117 sec)

Time
Voltage Sag Due To Momentary Fault On Adjacent Feeder

Event Number 155  Channel C  Setup 2

Horizontal 25 milliseconds/division  Vertical 200 Volts/division

Vrms: Prev=452.8, Min=243.6, Max=425.7 - Worst Imp: 0 Vpk, 0 deg
Fuse Blow and Breaker Operation Due to Fault On Adjacent Feeder
Open or Blown Fused Cutout
Voltage Sag Due To Momentary Fault On Adjacent Feeder

- Fault occurs here
- Breaker opens here: 7 cycles (~0.117 sec)
- Breaker recloses here: 0.3 to 2 seconds
- Fault cleared by fuse
Fuse Blow and Breaker Operation Due to Fault On Adjacent Feeder
Permanent Fault On Distribution Feeder
Voltage During Permanent Fault

- Fault occurs
- Voltage drops to 0
- Time to lockout after 3 tries is ~1 minute
- 7 cycles: 13 cycles, 15 seconds, 35 seconds, 10 seconds
- After ~1 minute, open and close cycles continue
- Open
- Voltage range: 0 to 480
Fault On Adjacent Feeder

Transmission @ 115 kV

115 kV Substation

Distribution @ 23 kV

23 kV Feeder

23 kV Feeder

Permanent Fault
Voltage During Permanent Fault on an Adjacent Feeder

- Fault occurs
- Voltage lockout after 3 tries
- Open
- Close
- Open
- Close
- Open
- Close
- Open
- ~ 1 minute
- 7 cycles
- 12 cycles
- .3 - 2.0 seconds
- 15 seconds
- 35 seconds
- 10 seconds
- 480
- Voltage
- Time
- ~ 1 minute
- 0
- 0
- Progress Energy
Substation Voltages During a Feeder Fault

Faulted Feeder
- 68% Cleared on First Quick trip
- 6-12 cycles
- .3 - 2.0 seconds
- 13 cycles
- 15 seconds
- 35 seconds
- 5% Goes to Lock Out

Adjacent Feeder
- 27% Cleared on Second and Third Relay
- 6-12 cycles
- .3 - 2.0 seconds
- 13 cycles
- 15 seconds
- 35 seconds

Fault Initiated
- Load Current
- Quick Trip
- .3 - 2.0 seconds
- 13 cycles
- 15 seconds
- 35 seconds

Feeder Breaker Operation
- Voltage
- 100%
- 0%

Progress Energy
Single Line of Substation

Battery Voltage: 53.2 volts

230 KV WindT1 X-fmr temp 39 C

16200 KVA

125.0 volts

393 amps
402 amps
384 amps

24 kV

HQA C

BPN 13 Clube Road

A 198
B 191
C 191

BPN 12 Brier Creek

A 77
B 99
C 80

BPN 11 Alexander Drive

A 118
B 111
C 112

BPN 19 Transfer Breaker

A 1
B 1
C 1

In service 6/11/02

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Progress Energy
Utility Protection Coordination Schemes & Equipment

- Fuse Save Scheme
- Fuse Blow Scheme
- Electronic Recloser
- Hydraulic Recloser
- Underground Network
- Electronic Sectionalizer
Capacitor Banks

- Electrical utilities use capacitor banks for power factor correction and voltage support.
- Capacitors are used to meet the reactive power requirements of inductive loads such as motors.
- Switching capacitors can produce oscillatory transients which may cause tripping of adjustable speed drives.
Capacitor Bank Switching Transient
Line Capacitor Bank
Line Capacitor Bank
Utility’s Power System

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- Questions?