

**TEXAS A&M UNIVERSITY**  
Relay Conference



# Effect of Distribution Automation on Protective Relaying



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# Effect of Distribution Automation on Protective Relaying

- Presenter: Gerald Johnson, P.E. –  
Basler Electric Company
  - Introduction
  - History of Distribution Automation
  - Effects on Operation, Protection and Maintenance
  - Bibliography and Annexes

# Introduction

- Origins of the Paper
  - IEEE Power System Relaying Committee
    - › Working Group D11 (D-Line Protection Subcommittee)
    - › Purpose: Explore the effect of distribution automation on protective relaying applied on primary, non-network, distribution systems

# Introduction

- Origins of the Paper
  - IEEE Power System Relaying Committee
    - › DA defined as sectionalization and reconfiguration of distribution circuits using:
      - auto or controlled transfer switches
      - Reclosers, fault interrupters, sectionalizers, cap controls, etc
    - › Viewpoints from across the continent including system operators, product developers and solution consultants

# Working Group D11

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- Calin Micu
- Charles Sufana
- Cheong Siew
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# History of Distribution Automation

- Substation Based Automation
  - Supervisory Control
    - › Used in Subs w/ coms to Manned Control Center
    - › Typically leased telephone circuits
    - › Remotely monitored & controlled Feeder Breakers
    - › Included status of each breaker
    - › Monitored one phase current/bkr & voltage
    - › Monitoring and control of Cap banks & some LTCs
    - › Expensive for distribution sub applications

# History of Distribution Automation

- Substation Based Automation
  - Project PROBE
    - › 1974 Power Resource Optimization By Electronics
    - › Varian V-72 mini computer 1974-78 La Grange Park Sub
  - Probe Phase 2
    - › Varian V-77
    - › 1978-80 First application of integrated volt/var profile
    - › Used to flatten feeders voltage profile
  - Later, EPRI Project RP 1472-1
    - › Prototype Microprocessor Relays, DPM (Distribution Protection Module) had six functions 50, 51, 79, 50BF, 25, 81

# History of Distribution Automation

- Line Distribution Automation
  - Remote Monitoring and Control
    - › Evolved to include remote monitoring and control of motor operated switches, line reclosers, line caps & regulators need for monitoring I & V at newly monitored devices
  - New Current and Voltage Sensors Developed
    - › Look of line post insulator
    - › Less bulky and costly
    - › With sensing on feeders, more data was available for locally operated logic blocks
  - On-board Logic
  - Microprocessor-based Relays

# History of Distribution Automation

- Line Distribution Automation
  - Most still operated as Sup Control until late 90's
  - On-board Logic Provides Control
    - › Allowed Dist Engs to get creative evaluating data & open/close scenarios
  - Microprocessor-based Relays
    - › Early 2000's available pole mounted controls for reclosers
    - › Perform protection & communications simultaneously
    - › Coordination issues with legacy relays
    - › Feasible to perform fault isolation and feeder reconfigure without control center intervention
    - › Allows switching portion of one feeder to another

# History of Distribution Automation

- Microprocessor-based Relays
  - › Fault Isolation and Feeder Reconfiguration
  - › Settings Groups to Enable Reconfiguration
  - › Action Based on Dynamic Current Ratings
- Single-Phase and Three-Phase Recloser Operation

# Today's Distribution Automation Applications

- Remote Monitoring
    - SCADA Protocols
    - Fault detection
    - Circuit & Load Measurements
  - Remote Monitoring with Control
  - With Circuit Reconfiguration
  - Reporting
  - Evaluation
  - DA Schemes Vary in Degree of Complexity
  - Reduce Cost, Improve Benefit of Global DA
-

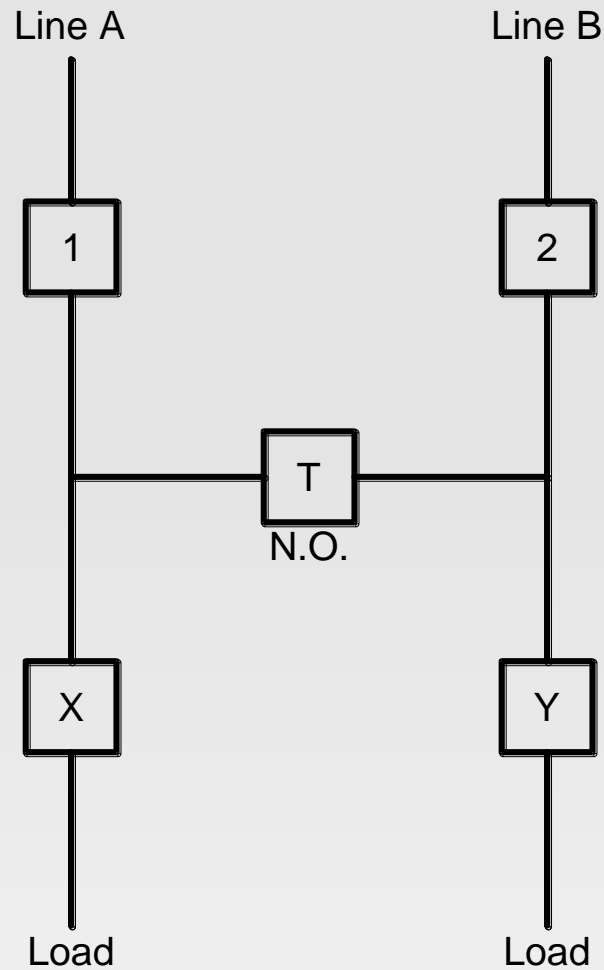
# Hierarchy of Intelligence

- Local
- Distributed
- Central

# Hierarchy of Intelligence

- Local
  - Minimal Communication Between Devices
  - Functionality Contained Within the Device
  - Occurs Based on External Conditions (V-I-Position)

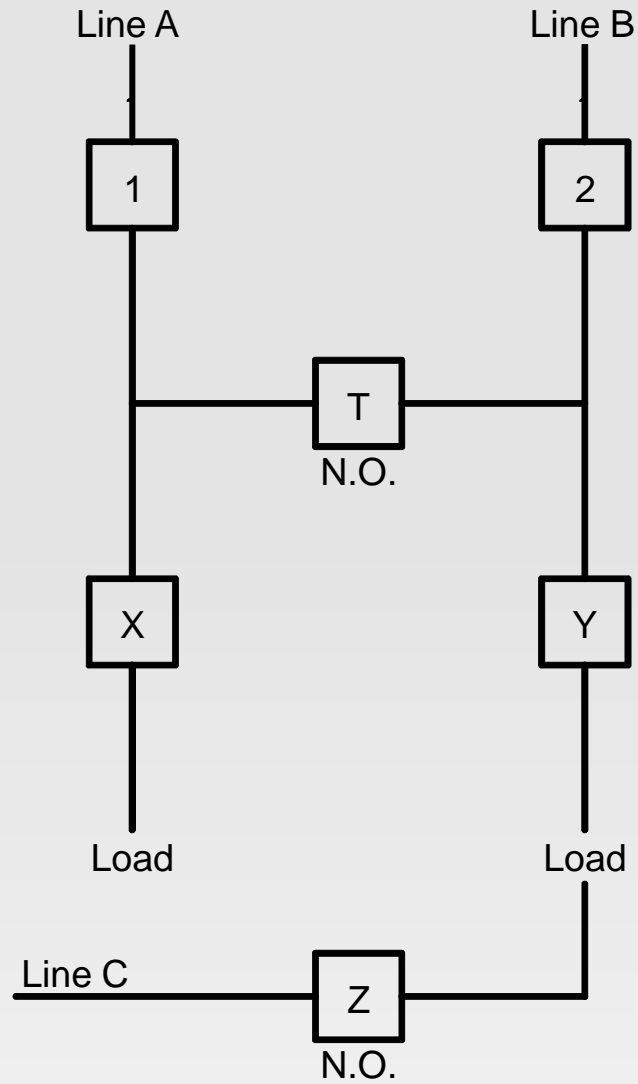
# Local Intelligence- Transfer Scheme



# Hierarchy of Intelligence

- Distributed Intelligence
  - Decentralized Intelligence
  - Communication & Software Between Devices
  - Provides Automated Control Within Defined Area
  - Shared Software & Communications distribute data
  - Utilizes Data Inputs From Communicating Devices

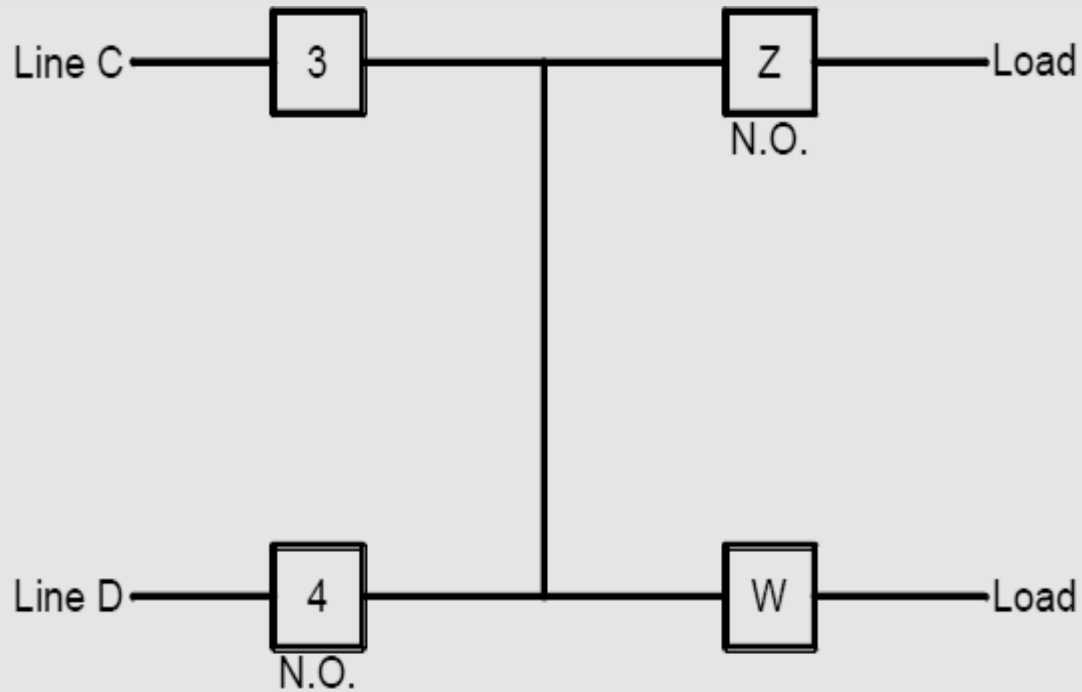
# Distributed Intelligence



# Hierarchy of Intelligence

- Centralized Intelligence
  - Concepts from localized or distributed intelligence are applied across larger control areas
  - Centralized Scheme determines optimal switching sequences
  - Various possibilities must be analyzed in advance & logic designed into central controller
  - Centralized Intelligence Resides at Remote Location such as a Control Center
  - Depends on reliable, robust, secure com system

# Central Intelligence



# Central Intelligence

# Volt-Var Optimization

## Dynamic Equipment Rating

# Optimal Network Configuration

# Fault Location Isolation and Service Restoration

# Effects on Operation, Protection and Maintenance

- Circuit Reconfiguration
- Protection Considerations
- Maintenance

# Circuit Reconfiguration

## - Proactive

- Prepare circuits for permanent or temporary change to improve the operating condition of the system
- Voltage profile, energy loss reduction, maintenance
- Relaying has been assessed and changed

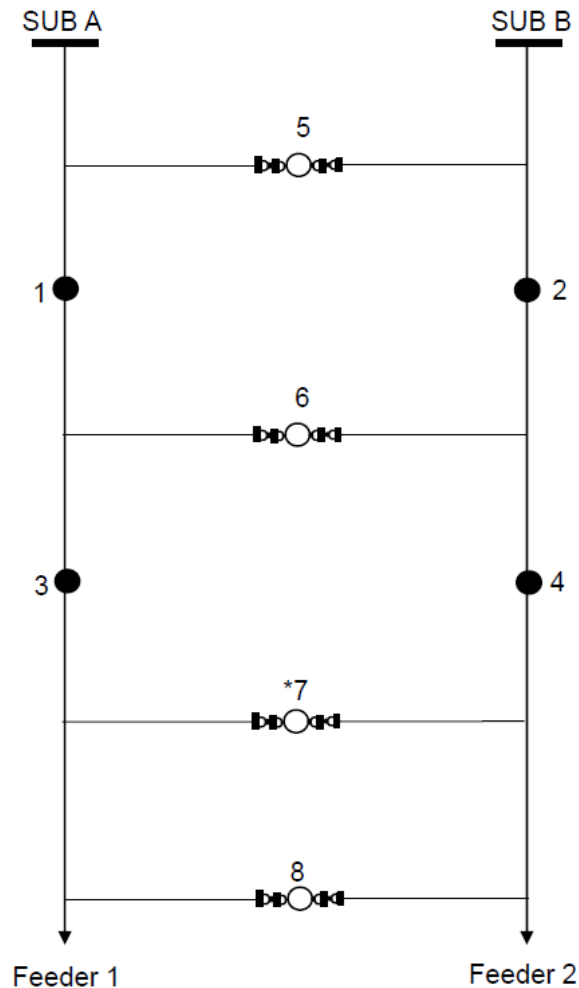
## - Automatic

- Reaction to system condition that requires auto control & intelligence to analyze fault condition.
- Provide alternate to restore max number of customers
- May require new protection settings, new setting group or other

# Circuit Reconfiguration Protection Considerations

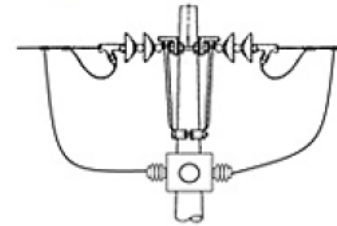
- FLISR must coordinate with reclosing
- Reconfiguration may need final reclosing shot
- Reconfiguration may need revised protection
- DA must distinguish between fault and non-fault or abnormal operations

# Load Sectionalizing Considerations



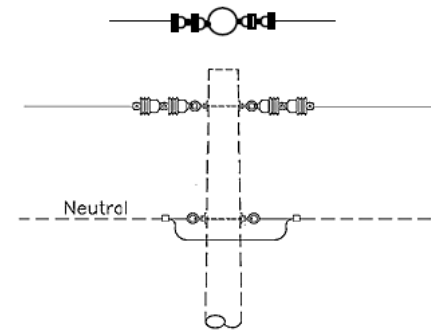
\* Preferred Location for Tie Switch

SECTIONALIZING SWITCH

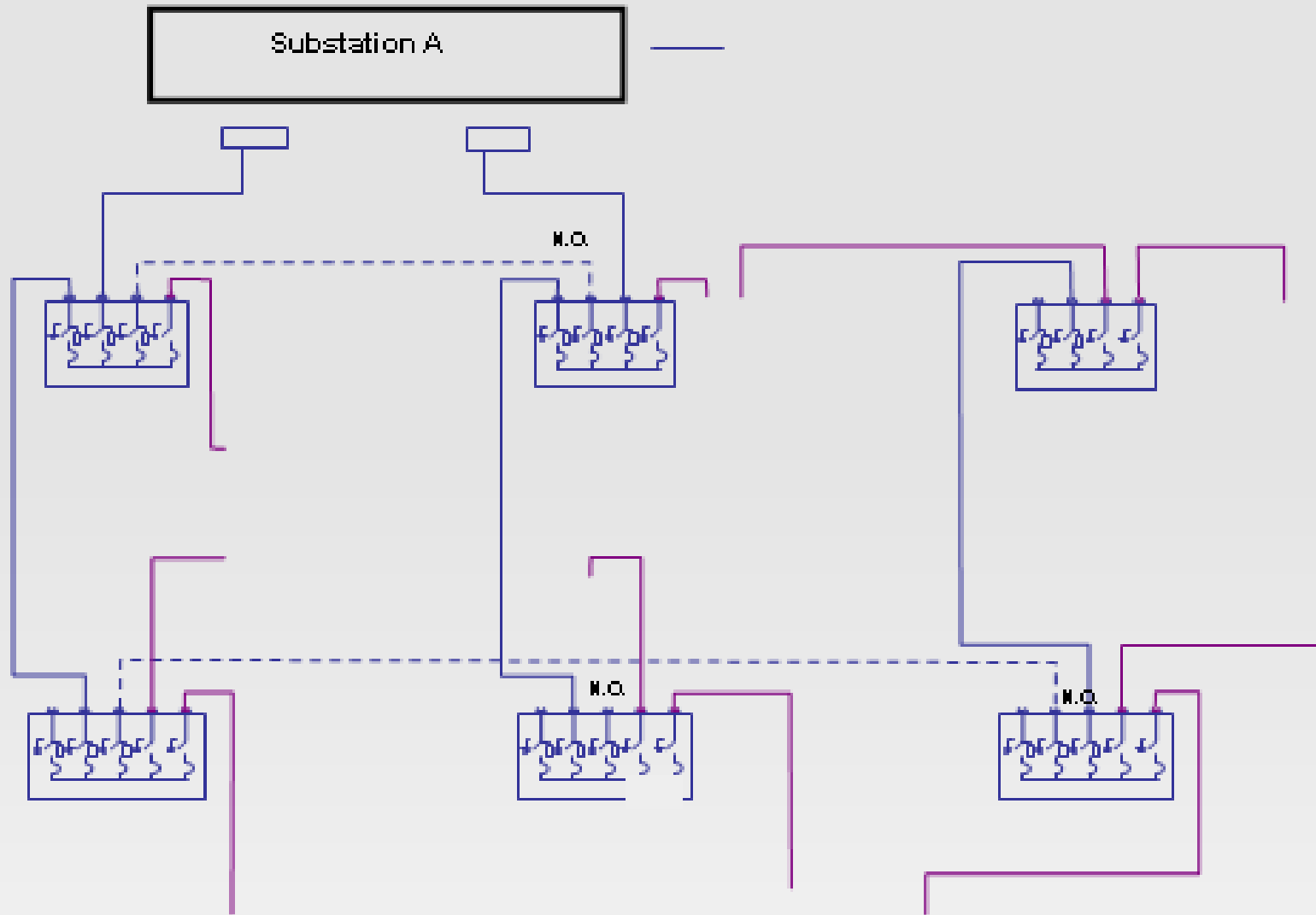


● Normally Closed (NC)  
○ Normally Open (NO)

DOUBLE DEADEND



# Load Sectionalizing Considerations



# Issues with Serving Load

- Close-Transition Switching
- Changes in Load without Relay Changes
- Reverse Power Flow
- Network Configuration

# Looping

- Short Circuit Levels
- Coordination of Non-Directional Relays

# Fault Location, Isolation and Service Restoration

## - FLISR Process

- Fault is detected, current source removed
- Fault is located and switches isolate it
- Upstream restoration
- Downstream restoration
- Faulted section repaired and system returned to normal

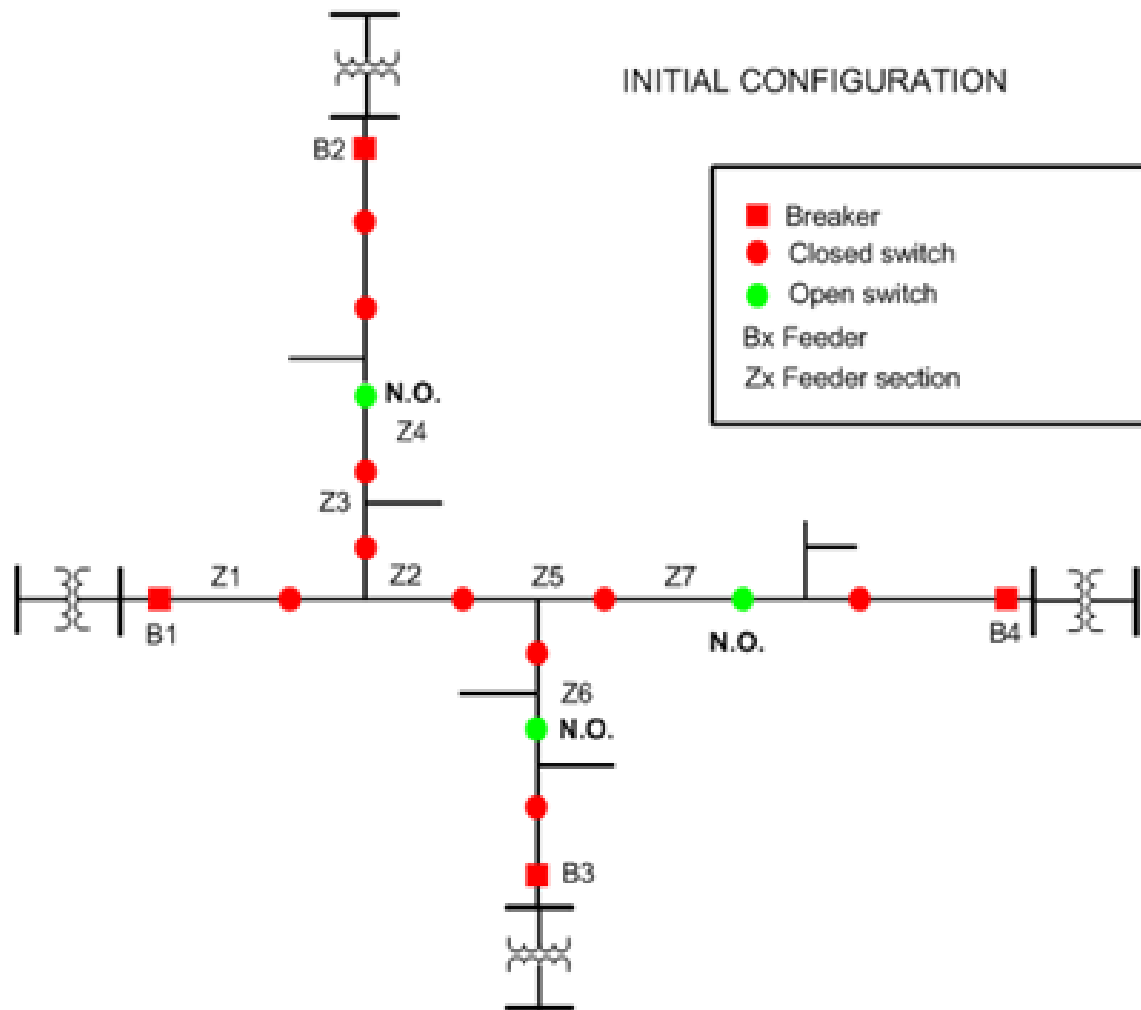
# What do you mean by restored?

- Transformer and line currents remain within specified limits
- Voltage drop stays inside an established margin
- System is maintained as radial
- Reduce number of equipment operations

# What do you mean by restored?

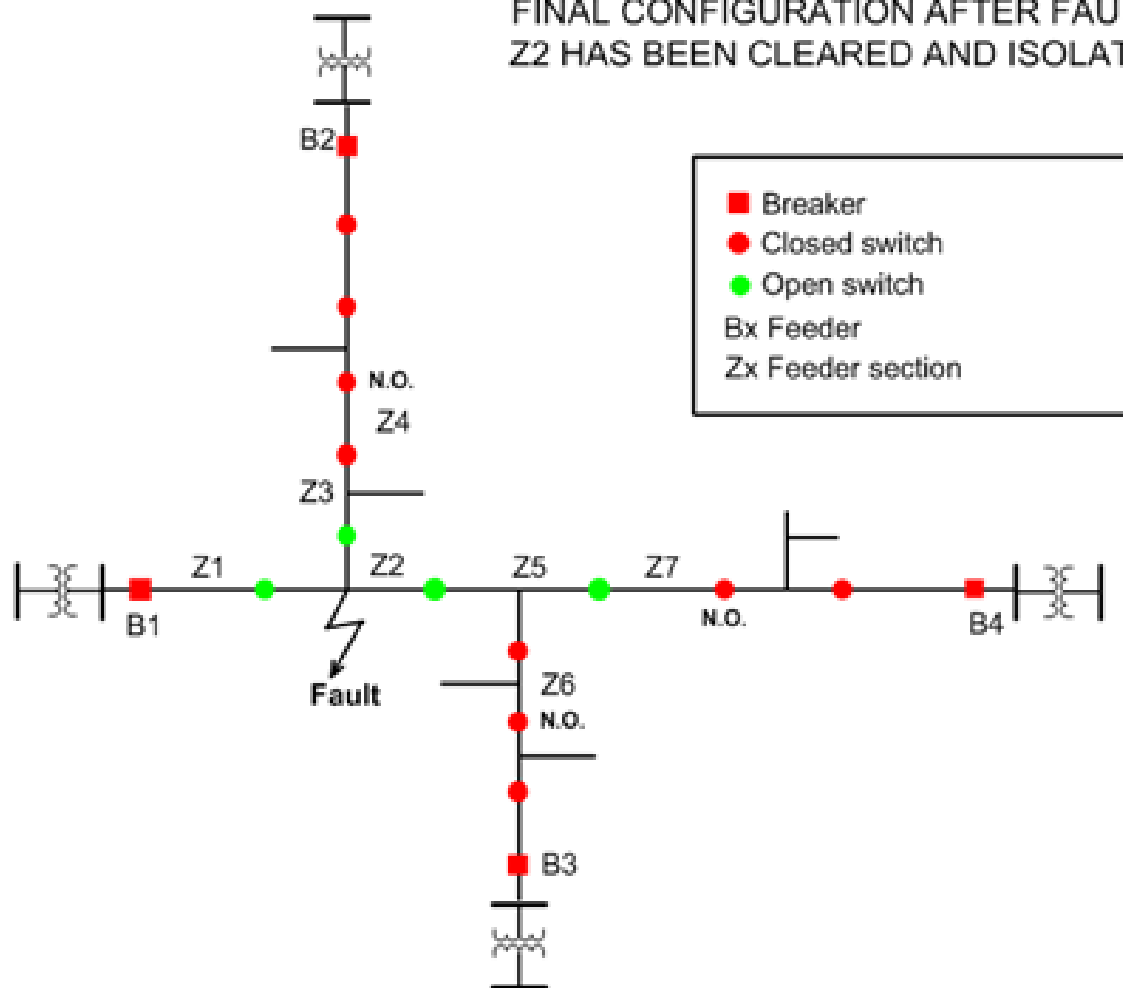
- System balance is maintained
- Protection coordination is maintained
- System protection maintained for all reconfigurations
- Harmonic content and power factor is conserved inside established limits

# FLISR



# FLISR

FINAL CONFIGURATION AFTER FAULT IN  
Z2 HAS BEEN CLEARED AND ISOLATED



# Protection Considerations

- Fuse Saving/Sacrificing
- Instantaneous Overcurrent
- Time Delayed Overcurrent
- Cold Load Pickup
- Arc Flash Requirements

# Protection Considerations

- Adaptive Relay Applications
- Adaptive Relay Considerations
- Zone of Protection
- Multiple Settings Groups – Distribution
- Multiple Settings Groups – Transmission

# Protection Considerations

- Distance to Fault Calculation
- Secondary Networks
- Distributed Resources

# Protection Considerations - DR

- Radial Design at the Source
- Radial Design on the Line
- Sync-Check
- Islanding Concerns on Reconfiguration

# Protection Considerations - DR

- Pilot Schemes
- Apparent Impedance
- Zero Sequence Influence

# System Maintenance

- Documentation
- Lock Out Tag Out Procedures
- Physical Security
- Remote Location Maintenance
- Master Station Maintenance

# Remote Location Maintenance

- Environmental Damage
- Battery System
- Error Logs
- Communication System
- Operate Bypass

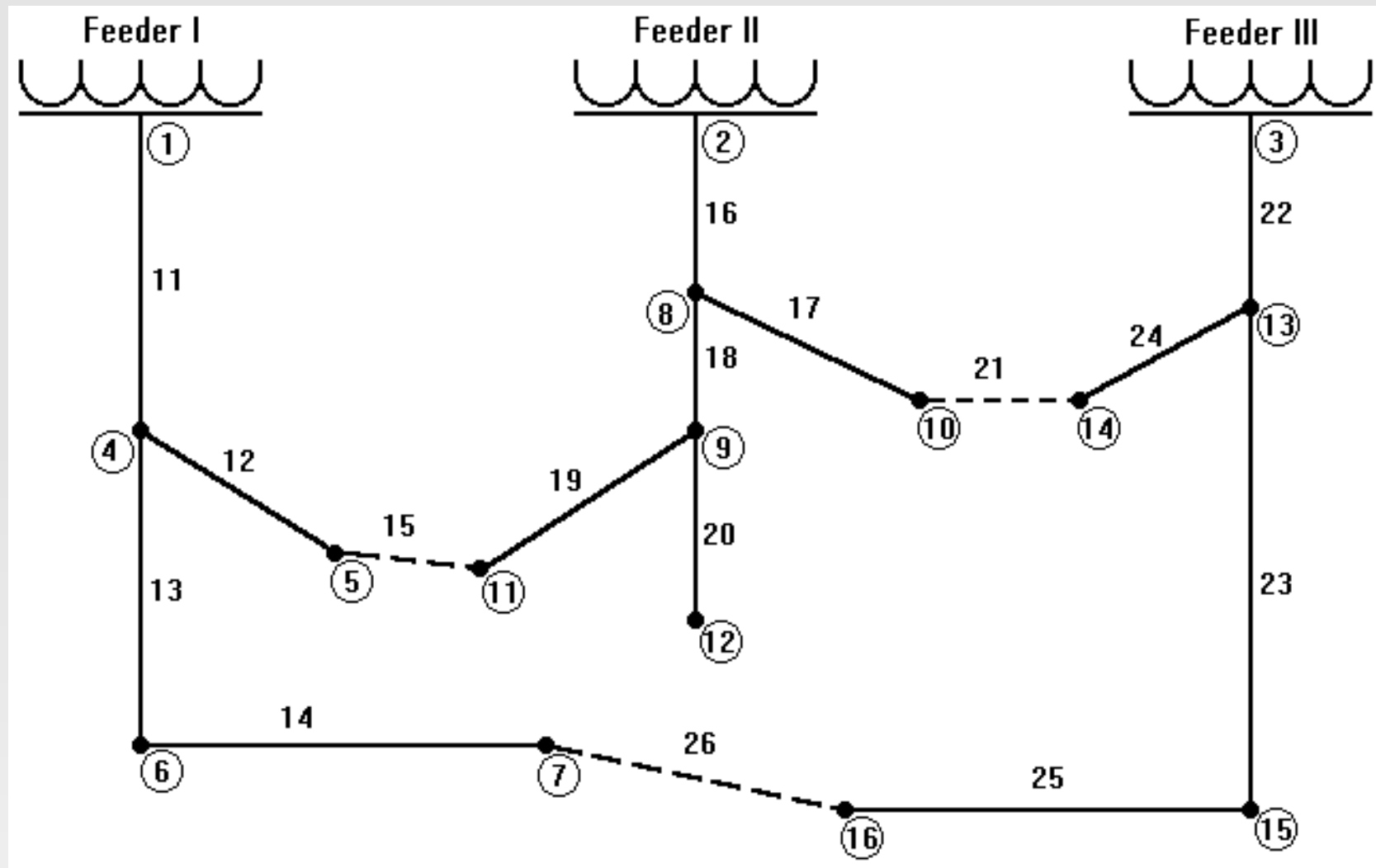
# Master Station Maintenance

- Battery System
- Nuisance Event Process
- Communication System
- Database Maintenance

# Bibliography

- 24 References
- 44 Different Authors
- 36 Years

# Annex A – Changes of Power Flow Due to Different Topology Scenarios



## **Annex B – One Company's History with Distribution Automation**

- Duquesne Light Company
  - 14 aspects to protecting the distribution circuit
  - 5 point philosophy for the distribution system
  - Operating experience
  - Results
  - Conclusions
-

**Questions?**

# Effects on Operation, Protection and Maintenance

- Circuit Reconfiguration, Proactive or Auto
  - Modification of the topology of distribution network
  - Modified with NO or NC switches & reclosers
  - Sectionalizing: NC switches allow isolation of sections
  - Load Transfer: NO switch between two feeders
- Protection Considerations
  - Automatic fault detection and restoration
  - Distinguish between fault and abnormal conditions
- Maintenance
  - DA flexibility designed in to support maintenance