Effect of Distribution Automation on Protective Relaying

Power System Relay Committee
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Presented by Fred Friend
# Working Group D11

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Effect of Distribution Automation on Protective Relaying

- Introduction
- History of Distribution Automation
- Effects on Application and Settings
- Impact of System Maintenance
- Bibliography and Annexes
Effect of Distribution Automation on Protective Relaying
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
  - DA defined as sectionalization and reconfiguration of distribution circuits using:
    - Auto or remote controlled transfer switches
    - Reclosers, fault interrupters, sectionalizers, cap controls, etc
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 mini computer
    - 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 motor operated switches, line reclosers, line caps & regulators and defined a 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

- Microprocessor-based Relays
  - Developed pole mounted controls for reclosers
  - Perform protection & communications simultaneously
  - Feasible to perform fault isolation and feeder reconfigure without control center intervention
  - Allows switching portion of one feeder to another
  - Settings Groups to Enable Reconfiguration
  - Action Based on Dynamic Current Ratings
  - Single-Phase and Three-Phase Recloser Operation
  - Coordination issues with legacy relays
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
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

- Line A: 1
- Line B: 2
- Line C: Z
- Load
- T (N.O.)
- X
- Y

Diagram:

- Line A connected to Line B
- Line C connected to Line A
- T connected to X
- Y connected to Z
- Z connected to N.O.
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
Intelligent Communication

Line A

1

X

N.O.

Load

T

N.O.

Y

Load

Line B

2

Line C

Z

N.O.

IEEE
Hierarchy of Intelligence

- **Centralized Intelligence**
  - Concepts are applied across larger control areas
  - Scheme determines optimal switching sequences
  - Numerous possibilities have to be analyzed
    - In advance & logic designed into central controller
  - Intelligence Resides at a Remote Location
    - Control or Data Center
  - Reliable, robust, secure communication system required
Central Intelligence

Volt-Var Optimization

Dynamic Equipment Rating

Optimal Network Configuration

Fault Location Isolation and Service Restoration
Effects on Application and Settings

- Circuit Reconfiguration
- Protection Considerations
Circuit Reconfiguration

- **Proactive**
  - Prepare circuits for permanent or temporary change
    - To improve the operating condition of the system
  - Driving Factors
    - Improve voltage profile
    - Energy loss reduction
    - Maintenance or repair
    - Temporary Overload
  - Relaying has been assessed and changes made
Circuit Reconfiguration

- Automatic (Reactive)
  - Reaction to system condition
  - Requires automatic control & intelligence to analyze fault condition
  - Provide alternate to restore max number of customers
  - May require new preprogrammed protection settings, new setting group or reverse power protection
Circuit Reconfiguration Protection Considerations

- FLISR must coordinate with auto 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
Load Sectionalizing Considerations

Substation A

- Normal closed
- Normal open
- Loads

IEEE Power & Energy Society
Possible Issues with Serving Load

- Close-Transition Switching
  - Voltage differences
  - Short circuit levels

- Changes in Load without Relay Changes
  - Overloaded devices

- Reverse Power Flow
  - Non directional relays

- Network Configuration
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
FLISR Requirements

- Transformer and line currents remain within specified limits
- Voltage drop stays inside an established margin
- A radial system is maintained
- Reduce number of equipment operations
- System balance is maintained
- Protection coordination is maintained
- System protection maintained for all reconfigurations
- Harmonic content and power factor are within established limits
FLISR

INITIAL CONFIGURATION

- Breaker
- Closed switch
- Open switch
- Bx Feeder
- Zx Feeder section
FLISR

FINAL CONFIGURATION AFTER FAULT IN Z2 HAS BEEN CLEARED AND ISOLATED

- Breaker
- Closed switch
- Open switch
- Bx Feeder
- Zx Feeder section
Protection Considerations

- Multiple Settings Groups – D and T
- Adaptive Relay Applications and Considerations
- Zone of Protection
  - Instantaneous Overcurrent
  - Time Delayed Overcurrent
  - Cold Load Pickup
  - Arc Flash Requirements
- Fuse Saving/Sacrificing
- Distance to Fault Calculation
Protection Considerations - DR

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