AUTOMATED MODELLING OF POWER SYSTEM PROTECTION FOR ADVANCED ANALYSIS OF SYSTEM PERFORMANCE

Protection Engineering Automation

iPCGRID Workshop 2019
March 27, 2019

Chris Bolton
Utility Participant
San Diego Gas & Electric

Aaron Feathers
Utility Participant
Pacific Gas & Electric

Jeff Shiles
Utility Participant
Southern California Edison

Saman Alaeddini
Quanta Technology
Agenda

- Introductions
- Protection model in short circuit platform
- Automation and data readiness
- Challenges
- Q&A
Introductions
Focus on Data Analytics

Automated decision support

- Process relay data after fault or event
- Give fast, clear decision guidance for system operators, more information for engineers
- Assess mis-operations and correct relay margins
- Automation of NERC PRC/CIP compliance and reporting
- Automated and accurate fault location
- Improve life cycle asset replacement strategy: report failed or malfunctioning apparatus, relays, etc.

Achieve Single Source of Data and eliminate redundant manual entry/calculations

- Internal Web Applications
- Communication Platform
- ISO Reports
- Compliance Audits
- Remote Field Access
- Schematic & Drawing Repository
- Performance Management
- Nodal Network Model
- Common Information Model
- Power Flow Model
- Short Circuit Model

Data Entry Applications

Manual Input

Uni-directional Link to

Fixed Asset Data (existing & investments)
Operating Centers
Customer Connections & Asset loading
Employee Data

Uni-directional Link from

Event Logs, Line Peaks
Planned Outages
Protection & Control Device Data
Work Order Management

Bi-directional interface

Reports & Custom Views

Extracts

Internal Web Applications

Custom Views
Objectives

Single Source of data companywide

- **Standardization of data:**
  - Integrate/interface relay setting repository with other systems for protection settings that can be utilized across the landscape to enable long term governance

- **Process Improvement:**
  - Workflow increases efficiency of configuration issuance process and reduces reliance on unmanageable source

- **Automation:**
  - Relay setting repository to integrate with key applications will enable automatic data flow and reduces human data entry efforts

- **Job Efficiency and Productivity:**
  - Decreased human errors and costs associated with inaccurate data and manual processes

- **Compliance Evidence and Traceability:**
  - Host PRC/CIP data to increase accuracy and transparency of reporting on critical asset inventory and processes for compliance and audit purposes
Issues Impacting Protection & Control Today

Model
- System Planning Primary Network
- GIS Database
- Asset Management System

Settings
- Protection Setting Database
- Test Reports

Short Circuit
- Primary & Secondary Analysis

Analysis
- Relay Setting Calculation
- Compliance (PRC/CIP)
- Special requests (CB rating studies, operations, safety, etc.)

Interaction between Interfaces typically Manual!
Representing Protection in Short Circuit Platforms
How Power System Protection Model Works?

Represented in widely accepted short circuit programs

- Model as vendor specific relay or standardize on element functionality
  - Individual relay styles/firmware accurately versus simplify each relay model
  - Import native setting files by using available parsers for top vendors
  - Ideal for relay manufacturers to have a common file format (or provide decryption of setting file structure)

- Relay libraries should be validated by users before use to gain confidence on simulation results versus actual behavior

- Relay libraries are provided by short circuit programs, but can be modified and maintained by users
Complexity of the Protection Model

Any Simulation Results is as good as its Model!

- Short circuit primary network model are represented as one of the following:
  - Single bus single breaker model (most common)
  - Detailed bus configuration

- Latest trend is companywide synergy of network data
  - Protection primary network model may be aligned with planning models
  - Protection primary network model may be aligned with operational nodal network model (NNM through CIM)
  - Protection primary network model may be auto-generated from either sources (or calculated using raw data)

- Protection relay model is quite labor intensive. It requires adequate planning to define profiles based on required use cases
Three Layer Modeling Scope Profile

Low Profile

Protective Elements Included

- Distance – 21
- Overcurrent -50/51/67
- Directionality – 32
- Pilot starter & blocking elements

Selected Use cases:

- Setting Calculation Assistance
- Setting Evaluation & Automated Peer Review Process
- Sensitivity Assessment (relay reach versus utility criteria)
- Coordination Evaluation (relay operation using stepped event analysis)
- Compliance (PRC-23, PRC-25, PRC-26, PRC-27,...)
Three Layer Modeling Scope Profile

Medium Profile

Protective Elements Included

• Differential - 87
• Standard Telecommunication assisted protection schemes (pilots & transfer trips)

Selected Use cases:

• Identify mis-coordination or failure-to-operate due to current reversals/blocking elements misbehaving under stressed N-x contingencies
• Prepare a live system wide heat-map of protection vulnerabilities by performing situational risk assessment
• Complement asset replacement strategy by also prioritizing replacement of old relays on whether their settings are also incorrect
Three Layer Modeling Scope Profile

High Profile

- Primary Model Improvements:
  - Detailed Bus Configuration
  - Match protection system to AC/DC schematics (i.e. CT/VT locations, redundancy)

- Protective Elements Included:
  - Fault Detectors (including logic to AND with distance & pilot model)
  - Switch-on-to-Fault or Dead-Line-Pickup
  - Out of Step
  - Breaker Failure Operation (also includes primary detailed bus configuration)
  - Synch Check & Reclosing
  - Single Pole Tripping
  - Detailed Telecommunication assisted protection schemes (pilots & transfer trips)

Selected Use cases:

- Sensitivity analysis of auxiliary functions (FD, BF, SOTF,...)
- Breaker Failure Coordination with Line/Bank Protection
- FERC Order 754 Single Point of Failure Impact Assessment
- Transient Stability Studies (Accurate planning worst case clearing time, stable power swing simulation)
- Impact of fault current reduction due to increase in inverter based asset
Automation and Data Readiness
Implementation of Automated Protection Analysis

Engineering Automation

- **Roadmap**
  - Standardization of data
  - Define Process
  - Implementation of Solution

- **Value added**
  - Process improvement
  - Job efficiency and productivity
  - Compliance evidence and traceability
  - Improvements in system reliability
Implementation of Automated Protection Analysis

Leverage Engineering Automation Solutions

- Standardization of Data
- Define Process
- Implementation of Solution
- Value Added

- Consolidation of required data
  - Network model
  - Equipment ratings
  - Device settings

- Data cleanup
  - Apply naming convention
  - Digitize legacy settings

- Data Alignment
  - Synchronize different database (asset management, equipment ratings, setting repository, network model, short circuit model, test routines, fault records, etc.)
Implementation of Automated Protection Analysis

- Protection modeling requirements (select profile)
- Analysis specification (use cases)
- IT processes & cybersecurity requirements
- Roles and responsibilities
  - Owner of each database
  - Owner of each model
  - Owner of automated tools
- Training & knowledge transfer
- Maintenance of data and solution
Implementation of Automated Protection Analysis

Leverage Engineering Automation Solutions

- Standardization of Data
- Define Process
- Implementation of Solution
- Value Added

- Data management

- Modeling
  - Primary short circuit model
  - Protection model

- Analysis
  - Implementation of utility protection philosophy
  - Short circuit scripting
  - Post processing of simulation results
  - Documentation and reporting
Implementation of Automated Protection Analysis

Leverage Engineering Automation Solutions

1. Standardization of Data
2. Define Process
3. Implementation of Solution
4. Value Added

- Reduced risk of wide area disturbances and improved reliability of the system
- Comprehensive protection philosophy guide across all Regions and improved confidence in protective relay settings
- A single Master file that ensures a high degree of quality control
- Automation significantly increased the capabilities and productivity of the relay engineers
- Great mechanism to fast track growth of junior protection staff
- Exceeding PRC/CIP Compliance Requirements
Implementation Challenges
Typical Challenges

- Benefits may not be immediately observed after completion of initial project
- Staff trained in protection without an automated mindset
- Consolidation of relay settings (conversion of legacy PDF files)
- Standardization of Naming Conventions
Management Challenges

"People don't resist change. They resist being changed." - Peter M. Senge

Employees vs. Management
The Change Equation

Dissatisfaction  x  Vision  x  First Steps  x  Resources  >  Resistance

IF...

• No one is dissatisfied with the status quo, or...
• There is no vision for an improved future state, or...
• No one is willing to take a first step forward, or...
• You don’t have the necessary resources to make a change

THEN...

• You’ll struggle to overcome resistance when it arises
Creating Vision, First Steps, and Resources

SCE Protection Workflow Automation Roadmap 2019-2021

[Diagram showing the roadmap with various processes and timelines for 2019, 2020, and 2021, including legends for Setting Development Process, Data Management and Integrity, PRC-027 Evaluation & Compliance, and Effort (Low, Medium, High).]
Creating Dissatisfaction with the Status Quo
Discussion
Example

Holistic Assessment of Protection Settings

N-1 Contingency (Outaged Line)

Local Terminal fails to operate (faulted line)

Remote Terminal operated in 23.2 cycles (faulted line)

69kV Misoperation @ Station A
Further Short Circuit Investigation

- By outaging adjacent 345kV line (n-1 contingency), fault current drops down to 220 amps
- Local terminal active distance elements’ (zones 1 & 2) supervisory fault detectors fail to see such low current (currently set for 400 amps) and inhibit operation of Zone 1 Distance elements