Automated Fault Location Analysis

Data Analysis Method

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Problem Statement

- Operating staff expressed concern with further improvement of the fault-location process, especially for their 115-kV system, which is heavily tapped with industrial customers and substations.
- They had mitigated the major time elements that were driving the outage duration metric and that the next major contributor to the time delays was the need to call out staff to run the fault-location program.
Objective

Investigate the ability to automate the protection engineers process

- Reduce the time to determine where a fault has occurred with sufficient certainty to begin sectionalizing the 115-kV transmission network and begin restoring customers in areas not directly affected by the faulted line section.
Approach

1. Document the existing manual process
2. Adjust process based on data gather method
3. Process has two paths through it and required the creation of a new table.
   1. The first path identifies the parameters of the fault such as fault type and magnitude.
   2. The other path determines what network changes are required due to grid elements out of service in the vicinity of the fault.
4. A new table was developed to essentially “connect” the operations’ field data historian with the fault study program Cape.
5. Execute automated process
Fault Location Process Flow

1. **Identify Required Fault Parameters**
   - FLparam.mac

2. **Monitor Master Fault Record Table for Line & Transformer Records**
   - Data Stored by Year / Month

3. **Identify the End Nodes**

4. **Update CAPE.cfg**

5. **Run WCAPE.exe**

6. **Create Historian Query**

7. **Launch Historian Process**

8. **Determine Network Element State**

9. **Output Fault Location(s)**

10. **Distribute Results**

**Network Changes Developed**
- NetworkChange.mac
Gather Fault Records

- When a new record arrives determine the end nodes (busses) for that element within CAPE.
Fault Parameters

- The following parameters need to be determined from the fault record:
  - Fault Time, used in the report text and file name. Use 'NA' if no time is available.
  - Bus Number for the "From" bus on the Monitored Line.
  - Bus Number for the "To" bus on the Monitored Line.
  - Circuit Number for the Monitored Line.
  - Bus Number for the "From" bus on the Faulted Line.
  - Bus Number for the "To" bus on the Faulted Line.
  - Circuit Number for the Faulted Line.
  - Fault Type:
    - PHASE_1_2, PHASE_1_2_G, PHASE_1_G,
    - PHASE_2_3, PHASE_2_3_G, PHASE_2_G,
    - PHASE_3_1, PHASE_3_1_G, PHASE_3_G,
    - THREE_PHASE
  - Fault Current Magnitude, in amps.
  - Monitored phase/value (1='Phase 1', 2='Phase 2', 4='Phase 3', 8='Residual').
- Utility developed a new table that linked CAPE bus names to historian state
- The result provides a listing of relevant network elements related to the fault
- The above listing will then be examined and used to determine state of each element
Determine Network Element State

- The previous result will be used by the process to determine the state of the network elements near the faulted element.
- Create historian query
- Launch historian process
- Determine network element state
- These results will be passed to the Network Changes Developed step where the file NetworkChanges.mac will be created.
Network Changes

Examples of Network Change command syntax

- `%% Open a branch/breaker
  nc opn 4 6005 1 x`

- `%% Outage a generator
  nc outage_shunt 5507 1 x`

- `%% Close a normally-open bus-tie/switch
  nc close_tie 41856 41384`

return
Final Steps

- Update the CAPE.cfg file as needed
- Run WCAPE.exe to locate fault
- Output results
- Distribute output
Results

- Finalized the process that transforms the relay event files into queryable database objects

- This process takes the source relay event files and extracts the data from these files and places the data into database objects.

- The script that analyzes the database records for fault characteristics that go into CAPE has been completed and is functioning.
Fault Analysis Process in Progress

Process Complete

1. Relay Event Received
2. TMDV Watchdog
3. Event Associated with Breaker?
   - Yes: Calculate I2T for Relay Event
   - No: Insert into Test Results Database
4. Event Associated with Line?
   - Yes: Calculate Fault Inputs
   - No: Stop
5. Process Under Test
   - Calculate Fault Inputs
   - Get Configuration Data for CAPE
   - Run CAPE Analysis
   - Email Results
Thank You