Merging PMU, operational and non-operational data for interpreting alarms, locating faults and preventing cascades

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Outline

• Goal

• Background

• Why merging data matters?

• What is involved in data merging?

• How to implement data merging?
Goal

Objective:

- Improve cause-effect event analysis by merging situational (PMU), operational (SCADA) and non-operational (IED) data

Expected product:

- A set of integrated visualization tools for helping operators to deal effectively with event analysis
Merge seemingly disjoint analysis processes

- Improve alarm processing by explaining automatically cause-effect relationship
- If the alarms relate to fault, give full information needed to restore the line
- If the alarms indicate a cascade, confirm whether the lines that are healthy are being tripped
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Scanning vs Synchronous sampling
Synchronous sampling vs time tagging
Background

Time-synchronized Information:

- Synchronized Phasors
- Synchronized Samplings
- Synchronized Circuit Breaker States
Synchronized phasors

Sparse Measurement Fault Location

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Synchronized samples

GPS Satellite

Sending end

\( i_s(k) \rightarrow \text{Fault Location} \)

\( v_s(k) \leftarrow i_F(k) \)

\( d_s \)

Receiving end

\( i_R(k) \rightarrow \)

\( v_R(k) \)

\( d_R \)

Short line Model

\( R \quad L \)

Lone line Model

\( R \quad L \quad C \)

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Synchronized circuit breaker states

- CB is ON
- CB is OFF

Detailed Maintenance & Repair Information

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Layout of typical substation equipment

- **LEVEL I**
  - CENTRALIZED LOCATION
  - CFL
  - MS
  - PE
  - EMS
  - RC

- **LEVEL II**
  - SUBSTATION
  - IS
  - LMS

- **LEVEL III**
  - SWITCHYARD INTERFACE
  - FL
  - DFR
  - CBM
  - DPR
  - PMU
  - RTU
  - SOE

**Nodes:**
- A
- S
- SA

**Data Types:**
- Non operational data
- Situational awareness data
- Operational data

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Example of time synchronization

IED GPS and data exchange wiring
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Event Analysis
Cause-effect Analysis

- p1 (Unit 1 Trip)
- p2 (U1GB_4210 Open)
- p3 (U1GB_4220 Open)
- p4 (CB_4160 Open)
- p5 (CB_4170 Open)
- p6 (BLR_4920 Trip)
- P7 (CB_4920 Open)
- p10
- p11
- p13
- p14
- p15
- p16
- p17 (Unit 1 Fault)
Control center visualization tools
Control center visualization tools
Enterprise Data Integration

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Timeline: Fault is permanent

1. **Fault occurred**
2. **Data Retrieved (DFRs, DPRs)**
3. **Fault Analysis**
4. **SCADA display generated**
5. **Brief report archived**
6. **FL report archived**
7. **Summary report archived**
8. **System Back to Normal**
9. **Operator Informed**
10. **Fault Location/Equipment Misoperation identified**
11. **Protection & Maintenance informed**
12. **Normal**
13. **Normal**
14. **Work order issued**
15. **Repair**
Maintenance

Work order issued
Repair

Automated Analysis

Fault Analysis

Data Retrieved (DFRs, DPRs, CBMs)

Less time spent

Normal

New
Old

Protection

Data Retrieved (DFRs, DPRs)

Fault Analysis

SCADA display generated

Maintenance

Work order issued
Repair

Normal
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What is involved in data merging?

Data Sources

- SCADA (operational data)
- PMUs (synchronized phasors)
- IEDs (non-operational data)
- IEDs data format
- PMUs data format
- Other data format
- COMTRADE data format
- Synchrophasor data format
- Synchronized sampling data format
- Naming Convention

Applications

- Intelligent Alarm Processor
- Optimized Fault Location
- Cascading Analysis

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Control center visualization tools

Data Sources
- PMUs (synchrophasors)
- IEDs (non-operational data)
- SCADA (operational data)

Optimized Fault Location Cascading Analysis

Fault analysis reports

Control Center Data Concentrator
- Hierarchical View
- Equipment Model
- Aerial View
- Electrical View
- Topological View

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Applications using data merging
Application: *Intelligent Alarm Processor*

![Diagram of Intelligent Alarm Processor](image)

- **Fault Section Estimation Application**
- **System Topology Analysis**
- **Rough Fault Section Candidate Set**
- **FRPN Fault Diagnosis Models**
- **Refined Fault Section Candidate Set**
- **FRPN Matrix Operation**

**Real-time Data Base**

**SCADA Master Computer**

**WAN**

**Substation A**
- Front-end Computer
- Relay
- PMU
- RTU
- DFR

**Substation B**

**Substation C**

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Application: Optimized Fault Location

Control Center GUIs

Fault Location Report

Fault Location

Data Sources
- SCADA EMS PI Historian
- DFR Assistant CBM Assistant
- Synchronized Samplings Synchrophasors

Commercial Software
- PowerWorld
- PSS/E Short Circuit Program

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Application: Cascading Analysis

Synchro-phasor data format → Neural Network Based Fault Diagnosis and Classification → Synchronized Sampling based Fault Diagnosis → Event Tree Analysis → Cascading Analysis Report

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Data Exchange Structure

Data file in CIM

Fault Location Cascading Analysis  Reports in CIM  Visualization Tools

Engineering Office

Utility Groups

Other Enterprise Locations

Central Server

Data file in CIM

Data file in CIM

Data Conversion

Original Data file

Data Concentrator

PMUs Data

Sampled Data

Sampled Data

Sampled Data

IEDs Data

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Data Interpretation
Data Communication: Network Interoperability

Control Center

Visualization Tools

- Optimal Fault Location
- Intelligent Alarm Processor
- Cascading Analysis
- Optimized Maintenance

Standard for Control Center Data Communication

- IEC 61850 Substation A
- Ethernet

- Standard for Inter-station Data Communication

- IEC 61850 Substation B
- Ethernet

- Standard for Intra-station Data Communication

- IEC 61850 Substation C

Other Substations...

Ethernet

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Thanks!

Questions?