Smart Reconfiguration and Protection in Advanced Electric Distribution Grids

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Outline

• Smart Reconfiguration
• Protection Systems
• Demonstration Project in Idaho Falls Power Grid
  – Project Objectives & Partners
  – Distribution Grid Overview
  – Critical Loads
  – Micro-PMUs
  – Hardware-in-the-Loop Testing
  – Co-simulation with Communication
• Concluding Remarks
Smart Reconfiguration

- **Reconfiguration**
  - **Concept**
    - (Initiate) Change in topology → OPEN/CLOSE Breakers
  - **Criteria**
    - Can be multiple (Economic, Load served, Operation-based Criticality, Reliability, Resiliency)
    - Short-term (Instantaneous), Longer-term (‘x’ hour-ahead)
  - **Constraints**
    - Physical stability (Steady-state, Dynamic)
Smart Reconfiguration

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- [+] Smart Reconfiguration for Advanced Electric Distribution Grids
  - Advanced measurement (micro-PMUs)
  - (near) Real-time decision-making: Pre-programmed, On-line
  - Under the conditions: Local generation, Bi-directional power flow, Adaptive protection
Protection Systems

• Some special considerations
  – Local generation, bi-directional power flow
  – Micro-PMUs
  – Adaptive or setting-less schemes

• Practical Challenges
  – Including micro-PMUs for protection systems
  – Communication and control
    • Synchronization of high sample rate data
    • Communication channel
  – Protection scheme co-ordination
Demonstration Project in Idaho Falls Power Grid

- Develop methods for keeping as much of the system operating as possible during system events at transmission or distribution level by using functionalities such as **smart reconfiguration**, controlled and seamless **islanding**, intelligent demand response utilizing loads as a resource, **black start** for emergency, and **resynchronization** in presence of DERs.

- Provide a **generalized roadmap**, including **best practices**, based on regional **case for IFP**, which utilities and system operators across the United States can apply to their respective distribution networks.

- Show effectiveness of implemented **smart reconfiguration** by comparison with existing power system performance.
Demonstration Project in Idaho Falls Power Grid

Grid Modernization project 1.3.09

Future Work
[IFP Lead, INL Support]

IFP & Northwest Utility Infrastructure Analysis
- Gather relevant data from IFP & other stakeholders
- Existing distribution model development

Develop Advanced Reconfiguration and Protection Algorithm
- Sensor placements, islanding for better quality of service
- Measurement based control

Lab Implementation
- Hardware-in-the-loop implementation
- Simulate Grid Events and Scenarios
- Embed the validated algorithms in hardware

Future Idaho Falls Power hardware deployment

INL Idaho National Laboratory
Pacific Northwest National Laboratory
Washington State University
Idaho Falls Power
SEL Schweitzer Engineering Laboratories
Idaho Falls Power Distribution Grid Overview

- 4 hydroelectric generators ~25% local load demand
- 2 transmission interconnects
- Currently not configured to operate in islanded mode
Critical Loads

• Critical loads as identified by Idaho Falls Power

<table>
<thead>
<tr>
<th>Priority</th>
<th>Description</th>
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<tbody>
<tr>
<td>1 – 4</td>
<td><strong>Very High Priority Loads</strong> <em>(Examples: Hospitals, Control/Command center, Emergency Response/Dispatch)</em></td>
</tr>
<tr>
<td>5 – 9</td>
<td><strong>High Priority Loads</strong> <em>(Examples: Airport, Correctional Facilities, Police Department, Fire Station)</em></td>
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<tr>
<td>10 – 12</td>
<td><strong>Medium Priority Loads</strong> <em>(Examples: Fire Station, State Services)</em></td>
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<tr>
<td>13 – 16</td>
<td><strong>Low Priority Loads</strong> <em>(Examples: Water Treatment, Community Care)</em></td>
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Distribution Level PMUs

- Placement and use of micro-PMUs
  - An approach: State-estimation under topology changes (steady-state)
  - Criticality-based
  - Dynamics-based
Hardware-in-the-Loop Testing

- Hardware provided by SEL
  - six relays and one controller are proposed to be tested as HIL
Hardware-in-the-Loop Testing

- Black Start scenario is investigated to test synchronization of City Bulb generator to grid while serving the local command center critical loads.
- Synchronization controls are modeled in RTDS-RSCAD for seamless resynchronization.
- SEL 700GT+ Relay is used as HIL interfaced with RTDS.
Co-simulation with Communication

- NS3-based communication layer is emulated for co-simulation of power systems and control/communication network between hardware devices.

![Diagram of the Co-simulation with Communication setup]

- Controls Interface
- Hardware Protection Relays
- Controller HIL
- V,I-AMPs
- NS3-based Communication Layer
Concluding Remarks

• Advanced measurement-based approach for
  – Maintaining supply to critical loads during loss of generation due to faults/events
  – Improved reliability and resiliency in advanced electric distribution grids

• Integrated Real-time HIL testing for smart **reconfiguration** and **protection** system

• Hardware controller implementation/testing of smart **islanding**, **resynchronization**, and **black startup** algorithms

• Optimal co-ordination of schemes under real-time operation

• **Successful implementation**: Generalized approach for developing and deploying advanced distribution grid
THANK YOU & QUESTIONS

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