Synchrophasor-based Emergency Generation Dispatch

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Outline

• Motivation
  – Typical EMS communication network
  – Loss of SCADA/EMS

• Overview of ISO-NE’s synchrphasor infrastructure

• Synchrophasor-based emergency operation
  – Automatic Generation Control (AGC)
  – Emergency dispatch

• Prototype implementation

• Conclusions and future plans
Typical EMS Communication Network

- **EMS**
  - Transmission data
  - Dispatch and Generation data

- **INTRAPOOL ICCP Servers**
  - ICCP protocol

- **INTERPOOL ICCP Servers**
  - ICCP protocol

- **ICCP Network**
  - LCC₁
  - LCC₂
  - LCCₙ

- **EINET Network**
  - PJM
  - NYISO
  - HQ
  - NBP

- **ED Network**
  - DNP 3.0 protocol
  - Plant RTUs
318 EMS events (October 2013 – April 2017) from 130 NERC Compliance Registries

NERC report: Risks and Mitigations for Losing EMS Functions
Loss of SCADA/ICCP/EMS

• Low probability events, such as coordinated cyber or physical attack, EMP or natural hazards may cause complete failure of the SCADA/EMS system.

• Loss of monitoring and control capability
  – No SE, RTCA, SCED, AGC, etc.

• Staffing of key substations by LCCs, with a periodic update of meter reading and topology to the ISO

• ISO will determine the merit order dispatch manually for the expected change in load or tie schedule to maintain ACE
  – Manual DDP, if ED network is still available
  – Verbal manual dispatch by contacting the DE, if ED network is unavailable
Synchrophasor Technology

• Synchrophasor:
  – Phasor (magnitude and angle)
  – Precise GPS time stamp
  – High sampling rates
    • 30 to 120 samples per second

Synchrophasor = Phasor + GPS + high sampling rate

• PMU - Phasor Measurement Unit
New England Synchrophasor System

- NYISO
- PJM
- MISO

ISO-NE PDC

- DQMS
- Phasor Point
- OSL
- State Estimation
- APPMV

7 point-to-point T1 Circuits

- PDC
- BHE
- CMP
- NU
- VELCO
- NSTAR
- NGRID
- UI

New England PMUs

- 44 stations
- 86 PMUs
- 429 Phasors
New England Synchrophasor System (Cont.)

• Approved Operating Procedure 22 changes, effective December 2017, requiring TOs to install new PMUs at:
  – All new 345 kV substations
  – Point of Interconnection (POI) for all new and existing power plants above 100 MVA
  – Other locations as designated by the ISO, mainly for IROL and SOL monitoring

• OP 22 changes will double the existing number of PMUs in the next five years.
Independent Synchrophasor Infrastructure

• The synchrophasor infrastructure is independent from the SCADA/EMS system
  – Separate communication infrastructure with its own circuits, routers, firewalls, encryption, etc.
  – Time aligned and synchronized with the GPS clock
  – MW flow and frequency of tie lines
  – MW and MVAr Outputs of large power plants at POI (100 MW and above)
  – All 345 kV and some 115 kV line flows

• Ideal as a backup for emergency monitoring and control when there is a complete loss of SCADA/EMS
Synchrophasor-based Automatic Generation Control (AGC)

- **Area Control Error (ACE)** is an indicator of a BA to meet its obligation to continuously balance its generation and interchange schedule with its load

\[
ACE_p = \left( P_{tie}^{schedule} - P_{tie(p)} \right) + 10B \left( f_{area}^{schedule} - f_{area(p)} \right)
\]

- \( P_{tie}^{schedule} \) - Scheduled net interchange
- \( P_{tie(p)} \) - PMU measured actual net interchange
- \( f_{area}^{schedule} \) - Scheduled system frequency (60 Hz)
- \( f_{area(p)} \) - PMU measured weight-averaged frequency
- \( B \) - Frequency bias setting (MW/0.1 Hz)

- **AGC**: dead band, PI controller, low pass filter, AGC setpoints
Synchrophasor-based Emergency Generation Dispatch

\[
\min \sum c_i \Delta P_i
\]

s.t. \[
\sum \Delta P_i = \Delta L(T) - ACE_{control}
\]

\[
\left| \frac{\Delta P_i}{R_i} \right| \leq T
\]

\[
P_{\text{min}} \leq P_i^0 + \Delta P_i \leq P_{\text{max}}
\]

- \(i\) -- PMU monitored generators
- \(c_i\) -- generator incremental cost
- \(\Delta P_i\) -- generator delta dispatch amount
- \(P_i^0\) -- generator output
- \(T\) -- dispatch look ahead time (5 minutes)
- \(R_i\) -- generation ramp rate
- \(\Delta L\) -- short term forecasted load change
- \(P_{\text{min}}, P_{\text{max}}\) -- generator economic minimum and maximum operating limits
# Synchrophasor-based Emergency Operation

<table>
<thead>
<tr>
<th></th>
<th>Loss of SCADA/EMS; ED network is available</th>
<th>Loss of SCADA/EMS; ED network is unavailable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchrophasor-based Automatic Generation Control (AGC)</td>
<td>Yes (every 4 seconds)</td>
<td>No</td>
</tr>
<tr>
<td>Synchrophasor-based Emergency Dispatch</td>
<td>Yes (every 5 or 10 minutes); only PMU monitored units</td>
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</tr>
</tbody>
</table>
Prototype - A Closed-Loop Simulation Platform

Network model

Dynamic model

Governor model

P Mech

Tie-line meas.
Bus freq meas.
Generator output meas.

DDP signals

Online TSAT

ePMU

PMU streaming
Compliant with IEEE C37.118

PMU-based Emergency Dispatch

Desired Dispatch Points
4/22/2018, 16:00 hr. – 17:00 hr., about 900 MW increase
Test Case – w/o Emergency Dispatch

- ACE [MW]
- CPS1 [%]
- Frequency [Hz]
- ACE Limit
Test Case – with Emergency Dispatch

ACE [MW]

Frequency [Hz]

CPS1 [%]

ACE [MW]

Frequency [Hz]

BAAL

High Limit

BAAL

Low Limit
Test Case – Emergency Dispatch (DDP)
Test Case – Emergency Dispatch (MW outputs)
Conclusions and Future Plans

• Synchrophasor infrastructure is independent from the SCADA/EMS system

• Synchrophasor based AGC and emergency dispatch can be an ideal backup tool for monitoring and control when there is a complete loss of SCADA/EMS

• Once validated on the closed-loop simulation platform, the data source will be switched from simulation to real time PMU

• On-premises production implementation

• Future cloud hosted environment

Eugene Litvinov, Song Zhang, Xiaochuan Luo, “Synchrophasor-based generation dispatch for emergency area balancing”, accepted for publication in 2018 IEEE PES General Meeting
Questions