IEEE ENERGY CON 2014-Invited Talk

Robust Power System Operation: Needs and Solutions

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Texas A&M University

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Outline

• The big picture and focus
• Status of legacy solution
• Automated assessment
• Mitigation approaches
• Use cases
Outline

THE BIG PICTURE
The big picture

Infrastructure

Markets

Service Provider

Bulk Generation

Customer

Operations

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## Disturbance classification

<table>
<thead>
<tr>
<th>Disturbance Cause Impact/Action</th>
<th>Fault</th>
<th>Cascade</th>
<th>Operating condition</th>
<th>Malicious attack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>De-energize, isolate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System collapse</td>
<td></td>
<td>Arrest cascade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unwanted conditions</td>
<td></td>
<td></td>
<td>Correct conditions</td>
<td></td>
</tr>
<tr>
<td>Intended Damage</td>
<td></td>
<td></td>
<td>Prevent intended damage</td>
<td></td>
</tr>
</tbody>
</table>
Expectations

- Customer
- Asset Owner
- Market Operator
- Regulator
- Public
Focus

Customer

Cost to customers: Transparent

Safety: No harm to humans and animals

Environment: No harm to ecosystem

Resiliency: Graceful degradation

Security: Awareness

Privacy: Trustworthiness

Continuity of service: Perfect Power

Reporting: What went wrong
Asset Owner

Minimize damage to equipment
Reduce restoration time
Reduce inspection cost
Avoid collateral damage
Avoid loss of income
Decrease outage time
Avoid penalties
Improve image
Focus

Market Operator

GRIDMARKET

GRID

MARKET
Focus

Regulator

Check whether utilities did their best
Accommodate changes in regulation
Make sure lessons are learned
Confirm technical competence
Maintain public confidence
Avoid major disasters
Provide transparency
Keep statistics
Focus

Public

Transparency across social groups
Be informed what the reasons are
Assure negligence is not a cause
Public is not at-risk
Avoid public unrest/riot
Health is not affected
Environment is not affected
Media coverage is trustworthy
Ubiquitous service
Outline

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What is the status
Future Electricity Grid

Operations

- Energy Management Systems, used by TOs and ISOs for 50 years are designed for normal operation
- Distribution Management Systems (DMS), used by distribution companies for 10 years are not mature yet
- Synchrophasor Wide-Area Measurement Systems (WAMS), primarily used by TO and ISOs over 5 years are still underutilized
- Smart Meter Systems (SMS) are used by utilities for 5 years but primarily for remote reading
- Intelligent (all-digital) substation automation (SA), used at T&D level for 15 years are still underutilized
- Digital protective relays (DPR) used at all voltage levels for 30 years are still mimicking legacy concept
- Power flow controllers (FACTs, SVCs, LTCs, Rectors, Capacitors), known for 30 years, are still pretty expensive
Future Electricity Grid

Markets

<table>
<thead>
<tr>
<th>Type</th>
<th>Configuration</th>
<th>Market Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>All MPs Complete</td>
<td>Within limits</td>
</tr>
<tr>
<td>Emergency</td>
<td>All MPs Complete</td>
<td>One or more parameters violate the limits</td>
</tr>
<tr>
<td>Restorative</td>
<td>Structure incomplete</td>
<td>Within limits</td>
</tr>
</tbody>
</table>

*MPs (Market Participants) include generator companies, transmission owners, load serving entities and other nonasset owners such as energy traders.
Future Electricity Grid

Customer

Network
Three US Interconnections

Transmission

Distribution

MicroGrid
Solar 
μTurbine
Fuel Cell

Centralized Bulk Generation

Independent Power Producers

Distributed Generation

EMS
DMS
ISO

Wind
Solar
Storage

FLEX-A
FLEX-S

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Automated assessment

Tasks

- Detect and classify events
- Track status of power apparatus
- Track performance of control equipment
- Track environmental conditions
- Understand cause-effect
- Predict, correct, adapt
Outline

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  • Mitigation approaches
  • Use cases
Mitigation Approaches

Tasks

• De-energize and isolate a faulted segment
• Use flexible load as a resource
• Monitor condition and reduce risk
• Switch topology
• Take SIPS decision on a fly
• Arrest cascade
• Anticipate and avoid failure
Outline

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  • Use cases
Use Cases

Examples

• Hierarchically coordinated protection
• Automated analysis of faults
• Economic alarms processor
• Detection of cascades
• Transmission line switching
• Use electrical vehicles in V2B
• Model-based fault location
• Risk-based CB assessment

Examples

Hierarchically coordinated protection

M. Kezunovic, B. Matic Cuka, "Hierarchical Coordinated Protection With High Penetration of Smart Grid Renewable Resources (2.3)," PSerc/DOE Workshop, Madison, WI, May 2013.
Examples

Automated analysis of faults

1. File Format Conversion (Import)
2. Identify IED and Event Time Stamp
3. Resolve Configuration Settings

IED Specific Settings
Power System Component Parameters

Automated Fault and Disturbance Analysis

Examples

Detection of cascades

Examples

Transmission Line Switching

Day-Ahead to Real-Time

Security constrained unit commitment

Economic RATC

AC PF + contingency analysis

Corrective RATC

Day-ahead process

Out-of-market corrections

Failed?

Check system stability

Report switching actions

Real-time economic dispatch

Post-contingency corrective RATC

Check AC feasibility + stability

Failed?

Implement

Use of electrical vehicles in V2B

<table>
<thead>
<tr>
<th>Auto Model</th>
<th>Battery Type</th>
<th>Capacity (minimum)</th>
<th>Range</th>
<th>Charging Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chevy Volt</td>
<td>Lithium Ion</td>
<td>16 kWh</td>
<td>40 miles</td>
<td>6-6.5 hours (240V)</td>
</tr>
<tr>
<td>Nissan Leaf</td>
<td>Lithium Ion</td>
<td>24 kWh</td>
<td>73 miles</td>
<td>7 hours (240V) 30 minutes (quick charger)</td>
</tr>
</tbody>
</table>

Model-based fault location

Examples

Risk-based CB assessment

<table>
<thead>
<tr>
<th>Event</th>
<th>Event Description</th>
<th>Signal Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trip of close operation is initiated</td>
<td>$t_1$</td>
</tr>
<tr>
<td>2</td>
<td>Trip coil current picks up</td>
<td>$t_2$</td>
</tr>
<tr>
<td>3</td>
<td>Trip coil current dips after saturation</td>
<td>$t_3$</td>
</tr>
<tr>
<td>4</td>
<td>Trip coil current drops off</td>
<td>$t_4$</td>
</tr>
<tr>
<td>5</td>
<td>B contact breaks or makes (a change of status from low to high or vice verse)</td>
<td>$t_5$</td>
</tr>
<tr>
<td>6</td>
<td>A contact breaks or makes</td>
<td>$t_6$</td>
</tr>
<tr>
<td>7</td>
<td>Phase current breaks or makes</td>
<td>$t_7$</td>
</tr>
</tbody>
</table>

Conclusions

• Maintaining robustness of power system operation under varying operating and fault conditions is a challenge going forward
• Advanced concepts such as predictive, adaptive and corrective control, as well as model and data based techniques will have to be used
• High level of automation is needed, which also demands the use of Big data, edge processing, high performance computing, flexible load, etc.
• Concepts have also to change in the use and design of monitoring, control and protection systems in the future
Thank you!

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