POWERMAX® [ˈpou (ə)r ˈmaks] noun: a system designed to maintain stability

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Agenda

- POWERMAX – Power Management System Introduction
- POWERMAX – Functionalities (IDDS, LSP, GCS, A25A)
- POWERMAX – Simulators
- MOTORMAX – LV Motor Management System Introduction
Agenda

- POWERMAX – Power Management System Introduction
- POWERMAX – Functionalities (IDDS, LSP, GCS, A25A)
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What Is POWERMAX?

- HMI / SCADA
- IDDS
- GCS
- A25A and Tie Flow
- High-Speed Load Shedding
- Engineering Management
POWERMAX Operation

- Grid-Tied Operation
- Islanded Operation
- Subcycle (Fast)
- Automatic Decoupling
- Load Shedding

Synchronization Systems

Controller

Relay

Status
Trip
Power Management System (PMS)
- Heavy Industries
- Blackout Prevention
- Process Survivability

Remedial Action Scheme (RAS)
- Utilities
  - Blackout Prevention
  - Wide-Area Schemes
  - Efficiency
  - Security

Microgrid
- Small Communities
  - Resiliency
  - Economics
  - Renewables
  - Speed of Operation
  - Adaptive Protection
Controller Provides Many Features

**Hardware**
- Linux OS
- Multithread Processing
- 2 ms Scan
- Self-Diagnostics
- Substation Graded
- No Moving Parts
- Dual Ethernet

**Software**
- IEC 61850
- SEL Protocols
- DNP3 / IP
- Modbus RTU / IP
- Web HMI
- MIRRORED BITS®
- IEC 61131 Interface
All High-Priority Controller Tasks Must Execute Each Operating Cycle
Fast and Scalable Architectures Are Required

- **Small (<20 ms)**
  - Controller
    - Scan Time: 2 ms
  - 20 Relays
    - Scan Time: 2 ms

- **Medium (<30 ms)**
  - Controller
    - Scan Time: 2 ms
  - Substation FEP
    - Scan Time: 2 ms
  - 200 Relays
    - Scan Time: 2 ms

- **Large (<40 ms)**
  - Controller
    - Scan Time: 2 ms
  - Central FEP
    - Scan Time: 2 ms
  - Substation FEP
    - Scan Time: 2 ms
  - 1,000 Relays
    - Scan Time: 2 ms
Redundancy

All dual systems can be hot, standby, or dual primary
Agenda

- POWERMAX – Power Management System Introduction
- POWERMAX – Functionalities (LSP)
- POWERMAX – Simulators
- MOTORMAX – LV Motor Management System Introduction
POWERMAX Functions

- HMI / SCADA
- IDDS
- GCS
- A25A and Tie Flow
- High-Speed Load Shedding
- Engineering Management
High-Speed Load Shedding
Objectives

• Power system frequency stability
  ▪ Shed the correct amount of load
  ▪ Quickly shed load

• Process survivability
  ▪ Intelligently select loads that minimize the effect on the production process
SEL Load Shedding

Features

- Subcycle speed
- Dual primary mechanism
- Primary CLSP
- Backup UFLSP / ICLT
- Asset overload shedding
- Multiple simultaneous contingencies
- SOEs and event records
- Backup Web HMI
Contingency Load Shedding

- System contingencies
  - Tie line
  - Bus tie
  - Generator breaker
  - Turbine trip
  - Asset overload

- Primary load shedding
  - Blackout prevention
  - Fastest – independent
  - Decision based on topology, contingency and load calculations
Contingency Breaker Opening Is Determined by 52A and 52B Limit Switches

Flow of Current

Breaker in “CLOSE” condition

SPINDLE

Limit Switch in “CLOSE” position

Limit Switch in “OPEN” position

Closed

Open

52B

52A
$L_n = P_n - \sum_{g=1}^{m} IRM_{ng}$

$n = \text{contingency (event) number}$

$m = \text{number of sources (generators) in system}$

$g = \text{generator number, 1 through } m$

$L_n = \text{amount of load selected for } n \text{ event (kW)}$

$P_n = \text{power disparity caused by } n \text{ event (kW)}$

$IRM_{ng} = \text{incremental reserve margin of all generators (sources) remaining after } n \text{ event (kW)}$
## Typical CLSP Contingency Screen

<table>
<thead>
<tr>
<th>Contingency Number</th>
<th>Contingency Description</th>
<th>Breaker Status</th>
<th>Bus Connection</th>
<th>Present Power (MW)</th>
<th>IRM Set Point (MW)</th>
<th>IRM Maximum (MW)</th>
<th>IRM Actual (MW)</th>
<th>Current Maximum (MW)</th>
<th>Contingency Status</th>
<th>Available Capacity (MW)</th>
<th>Measured Load (MW)</th>
<th>Required To Shed (MW)</th>
<th>Selected to Shed (MW)</th>
<th>Contingency Satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Generator GT-101A Turbine Trip</td>
<td>Close</td>
<td>Bus 0</td>
<td>21.96</td>
<td>2.00</td>
<td>4.00</td>
<td>2.00</td>
<td>23.96</td>
<td>Enabled</td>
<td>71.45</td>
<td>41.58</td>
<td>0.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
<tr>
<td>C2</td>
<td>Generator GT-101B Turbine Trip</td>
<td>Open</td>
<td>Bus 0</td>
<td>0.00</td>
<td>2.00</td>
<td>4.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Disabled</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
<tr>
<td>C3</td>
<td>Generator GT-101C Turbine Trip</td>
<td>Close</td>
<td>Bus 1</td>
<td>20.45</td>
<td>1.00</td>
<td>4.00</td>
<td>1.00</td>
<td>21.45</td>
<td>Enabled</td>
<td>73.96</td>
<td>41.58</td>
<td>0.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
<tr>
<td>C4</td>
<td>T5 Breaker Trip</td>
<td>Racked Out</td>
<td>Bus 5</td>
<td>0.00</td>
<td>50.00</td>
<td>50.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Disabled</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
<tr>
<td>C5</td>
<td>T4 Breaker Trip</td>
<td>Close</td>
<td>Bus 1</td>
<td>-0.83</td>
<td>50.00</td>
<td>50.00</td>
<td>50.00</td>
<td>0.00</td>
<td>Enabled</td>
<td>45.41</td>
<td>41.58</td>
<td>0.00</td>
<td>0.00</td>
<td>No</td>
</tr>
<tr>
<td>C6</td>
<td>T4 Breaker Trip</td>
<td>Bad Breaker</td>
<td>Bus 1</td>
<td>0.00</td>
<td>N/A</td>
<td>N/A</td>
<td>0.00</td>
<td>0.00</td>
<td>Disabled</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
</tbody>
</table>
**SEL CLSP Load Screen**

<table>
<thead>
<tr>
<th>Load Number</th>
<th>Breaker Number</th>
<th>Description</th>
<th>Breaker Status</th>
<th>Test Shed Select</th>
<th>Load Priority</th>
<th>Live Power (MW)</th>
<th>Force Value Of Power (MW)</th>
<th>Toggle Live Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>L01</td>
<td>Load 1</td>
<td>Substation 1 Feeder 1</td>
<td>Open</td>
<td>Normal</td>
<td>1</td>
<td>1.89</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L02</td>
<td>Load 2</td>
<td>Substation 1 Feeder 1</td>
<td>Open</td>
<td>Normal</td>
<td>2</td>
<td>4.43</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L03</td>
<td>Load 3</td>
<td>Substation 1 Feeder 3</td>
<td>Close</td>
<td>Normal</td>
<td>3</td>
<td>6.21</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L04</td>
<td>Load 4</td>
<td>Substation 1 Feeder 4</td>
<td>Close</td>
<td>Normal</td>
<td>4</td>
<td>3.59</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L05</td>
<td>Load 5</td>
<td>Substation 1 Feeder 5</td>
<td>Open</td>
<td>Normal</td>
<td>5</td>
<td>0.00</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L06</td>
<td>Load 6</td>
<td>Substation 1 Feeder 6</td>
<td>Racked Out</td>
<td>Normal</td>
<td>6</td>
<td>0.00</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L07</td>
<td>Load 7</td>
<td>Substation 1 Feeder 7</td>
<td>Close</td>
<td>Normal</td>
<td>7</td>
<td>0.00</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L08</td>
<td>Load 8</td>
<td>Substation 1 Feeder 8</td>
<td>Close</td>
<td>Normal</td>
<td>8</td>
<td>0.97</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L09</td>
<td>Load 9</td>
<td>Substation 1 Feeder 9</td>
<td>Close</td>
<td>Normal</td>
<td>9</td>
<td>2.96</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L10</td>
<td>Load 10</td>
<td>Substation 2 Feeder 1 Breaker</td>
<td>Open</td>
<td>Test Shed</td>
<td>0</td>
<td>1.25</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L11</td>
<td>Load 11</td>
<td>Substation 2 Feeder 2 Breaker</td>
<td>Open</td>
<td>Normal</td>
<td>10</td>
<td>3.68</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L12</td>
<td>Load 12</td>
<td>Substation 2 Feeder 3 Breaker</td>
<td>Close</td>
<td>Normal</td>
<td>11</td>
<td>2.13</td>
<td>2.13</td>
<td>Normal</td>
</tr>
<tr>
<td>L13</td>
<td>Load 13</td>
<td>Substation 3 Feeder 1 Breaker</td>
<td>Bad Breaker</td>
<td>Normal</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>Normal</td>
</tr>
<tr>
<td>L14</td>
<td>Load 14</td>
<td>Substation 3 Feeder 2 Breaker</td>
<td>Close</td>
<td>Normal</td>
<td>9</td>
<td>6.16</td>
<td>0.00</td>
<td>Normal</td>
</tr>
</tbody>
</table>
Operation Example – Multiple Contingencies
Proactive Overload Load-Shedding Integrator

Figure 3-1: Integrator Load-Shedding Logic
### Proactive Overload Load-Shedding Screen

<table>
<thead>
<tr>
<th>Description</th>
<th>Setpoints</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generation Number</strong></td>
<td><strong>Integration Pickup % of MW</strong></td>
<td><strong>Available Capacity (MW)</strong></td>
</tr>
<tr>
<td>Generator GT-101A</td>
<td>98.00</td>
<td>21.75</td>
</tr>
<tr>
<td>Generator GT-101B</td>
<td>98.00</td>
<td>18.22</td>
</tr>
<tr>
<td>Generator GT-101C</td>
<td>98.00</td>
<td>21.17</td>
</tr>
<tr>
<td>Substation T6</td>
<td>98.00</td>
<td>50.00</td>
</tr>
<tr>
<td>Substation T5</td>
<td>98.00</td>
<td>50.00</td>
</tr>
</tbody>
</table>
Backup – Underfrequency Load Shedding

Why?
Strategy: Keep Frequency at Nominal

Ball in a Bowl Analogy
Advantages of POWERMAX UFLSP

• Dynamically selects loads (only active loads to shed)
• Incorporates load consumption (MW) into selection
• Tracks power system topology
• Selects correct amount of load to shed for every underfrequency threshold
• Sheds less load with better impact
• Easily changes priority of sheddable load
UFLSP Algorithm

• Detection logic monitors frequency and asserts underfrequency trigger
• Signal conditioning logic in UFLSP protects against chatter
• Event calculation logic calculates load shed for each event
• Crosspoint logic determines load trip signals
### UFLSP Screen

<table>
<thead>
<tr>
<th>Contingency</th>
<th>Description</th>
<th>Contingency Status</th>
<th>UF Pickup (Hz)</th>
<th>Frequency (Hz)</th>
<th>Required to Shed (MW)</th>
<th>Selected to Shed (MW)</th>
<th>Contingency Satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>UFC1</td>
<td>Generator GT-101A Under Frequency Level 1</td>
<td>Disabled</td>
<td>59.00</td>
<td>59.96</td>
<td>5.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
<tr>
<td>UFC2</td>
<td>Generator GT-101A Under Frequency Level 2</td>
<td>Disabled</td>
<td>58.50</td>
<td></td>
<td>5.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
<tr>
<td>UFC3</td>
<td>Generator GT-101B Under Frequency Level 1</td>
<td>Disabled</td>
<td>59.00</td>
<td>60.00</td>
<td>5.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
<tr>
<td>UFC4</td>
<td>Generator GT-101B Under Frequency Level 2</td>
<td>Disabled</td>
<td>58.50</td>
<td></td>
<td>5.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
<tr>
<td>UFC5</td>
<td>Generator GT-101C Under Frequency Level 1</td>
<td>Disabled</td>
<td>59.00</td>
<td></td>
<td>5.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
<tr>
<td>UFC6</td>
<td>Generator GT-101C Under Frequency Level 2</td>
<td>Disabled</td>
<td>58.50</td>
<td>59.97</td>
<td>5.00</td>
<td>0.00</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Inertia-Compensated Load Shedding
Do It Right!

Frequency (F)

Normal Operation

Inertia-Compensated Success

Load Shed

Traditional Failure

Time

Load Shed ~ H \cdot DFDT = 8 \cdot 1 = 8 \text{ MW}

Load Shed ~ H \cdot DFDT = 4 \cdot 2 = 8 \text{ MW}

MW Load to Shed

<table>
<thead>
<tr>
<th>DFDT</th>
<th>F</th>
<th>L1</th>
<th>L2</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.5</td>
<td>59</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>0.5–1.0</td>
<td>58</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>&gt; 1.0</td>
<td>58</td>
<td>&amp; 18</td>
<td></td>
</tr>
</tbody>
</table>

Macrogrid

Complex Grid

Microgrid
Questions?