Integrating Grid Monitoring and P&C

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Agenda

- Synchrophasor & Grid Stability Vision
- Synchrophasor Applications for Real-Time Operations
- Integrating Synchrophasors into EMS & Visualization
- Synchrophasors for Wide Area Protection & Control
The Evolution of Grid Stability Analysis

**Past:** Offline Planning Studies
- Traditionally, a planning function based on offline engineering studies
- Needed to accommodate unknown/unforeseen grid conditions
- Pre-defined static stability limits
  - Conservative margins

**Present:** Real-Time Measurement-based Stability Metrics
- Phasor Measurement Units (PMUs) offer real-time observability into grid dynamics (not possible in SCADA)
- Innovative real-time measurement-based analytics monitor key grid stability metrics (i.e. damping) in real-time

**Future:** Predictive Analysis & Corrective Actions
- An integrated “measurement-based” and “model-based” approach to grid stability management
- Leveraging “what-if” capabilities to provide predictive capabilities and corrective actions to mitigate instability conditions
- Automated PMU-based wide area control schemes
- Proactive grid stability management
Alstom Solutions: WAMS Functional Blocks

**SUBSTATION**
Measurements & Controls

- **Substation**
  - PMU
  - RTU

**CONTROL ROOM NETWORK**
Operations

- **Monitoring**
  - SCADA
  - e-terraplatform
  - e-terratreansmission (GSA)
  - On-line DSA
  - e-terrasmulator

- **Analytics**
  - Phasor Data Concentrator
  - e-terrasorpoint
  - Application Services
  - Historian
  - Replay

- **Model-Based**
- **Measurement-Based**

**BUSINESS NETWORK**
Planning

- Corporate Historian

- Analysis Tools
  - e-terrasoranalytics
  - e-terrasorpoint Replay
  - Off-line DSA

**VISUALIZATION**

- e-terravision
WAMS and On Line Stability Control Room Operations

The Next Generation Energy Management System!

EMS
MODEL-BASED Analysis

- SCADA & Alarms
- State Estimator
- Small Signal Stability
- Transient & Voltage Stability
- Island Management

PhasorPoint
PMU MEASUREMENT-BASED Analysis

- WAMS Alarms
- State Measurement
- Oscillation Monitoring
- Stability Monitoring & Control
- Island Detection, Resync, & Blackstart

Transitioning from traditional “steady-state” view to enhanced “dynamic” situational awareness.
Oscillatory Stability Monitoring

Concept
Characterize low-frequency oscillations from PMU data.
Utilize model-based stability assessment to assess margins.

Benefits
- Real-time monitoring of oscillatory stability modes:
  - Mode frequency.
  - Mode damping levels.
  - Mode shape (amplitude and phase)
- Quickly detect sudden oscillations observable from grid measurements (e.g. forced oscillations) indicative of performance/control issues.
Full oscillation detection

**Concepts**

- **4-46Hz**: Sub-Synchronous Oscillations (SSO) from series capacitors, torsional modes, control interaction, etc. to identify precursors.

- **0.005-0.1Hz**: Manage governor-frequency control stability risk by oscillation detection & angle-based

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**Benefits**

- **SSO Early warning**
  - Avoid network tripping
  - Natural frequencies for model tuning and scenario selection

- **Assess system tests of control tuning and control tuning effect**

- **Identify & correct plant malfunction or misconfiguration quickly**

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![Frequency Spectrum](image)

- **Governor Control**: 0.005 – 0.1Hz
- **Electromech & V. Control**: 0.1 – 4Hz
- **Sub-Synch Osc**: 4 – 46Hz

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- **Detection & early warning**
- **Source Location** for identifying contributions (unique Alstom)
- **Geographic View** presents participation and contributions
- **Analysis** information for scenario selection, problem location, modelling
### Concept

Uses Oscillation **Phase** as identification of largest contributions to oscillation. Define largest group contribution, then finds closest PMU to largest contribution in group.

### Benefits

- **Targeted action** - on-line or planning
- Applicable to interconnection. Defines if problem in own control area.
- Supports **operational process** to manage unexpected behaviour
- Supports **control tuning process**

Oscillation Phase Relations for a Single Machine

- P and δ lag ω by about 90°, determined by damping. E.g. damping ratio 20%, angle lags 90°+12° and power lag speed by 90°-12°
- Power (P) in phase with speed (ω) produces positive damping.
- Power out of phase with speed produces negative damping.
Islanding & Restoration

Concept

PMU-based methods to quickly detect an islanding condition, and assist with the re-synchronization process.

Model-based topology processing to identify the islanded boundaries, and generation/load resources in each island.

Benefits

• Real-time alerts/alarms on islanding condition.
  ▪ Identify boundaries of the islanded regions.
  ▪ Summarize available resources within each island.
  ▪ Assist with the overall system restoration process.
System Disturbance Management

Concept

Enhance location and add disturbance impact measures based on static & dynamic stress. Metrics compared with baseline to show severity. Real-time & off-line performance indicators, with event severity & clustering. Angle-change view to assist restoration strategy.

Benefits

Real-time

- Present severe events or sequences, assess risk. High level warnings
- Identify restoration strategy, especially following multi-contingency

Analysis

- Long-term performance statistics & risk
- Select events for reporting

Location, sequence, static & dynamic impact, alarm level. Angle-shift view.
All alarms (including WAMS alerts/alarms) maintained and managed at a centralized location with the EMS Alarm Management System.

### Oscillatory Stability
- Mode Damping/Amplitude Thresholds

### Islanding

### Disturbances
- General Rate of Change
- Disturbance Characterization

### Composite Events
- User Defined

### Magnitude Threshold Violations
- Voltage Magnitude
- Calculated Data
- Angle Difference
- Frequency / ROCOF
- P&Q / Power Corridors
Benefits of an Integrated WAMS/EMS Solution
Holistic Approach from Monitoring to Operator Guidance

- Sub-second: WAMS
- Second: Network Topology
- Minute: SE/DSA

Operator Guidance
- Enhanced Situational Awareness
- Monitoring
- Predict
- Monitor
- Assess
- Correct

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Example Application
Angle-based Grid Stability Management

- Correct
- Predict

Dynamic/Static Limit (DSA Tools)

Angle Monitoring
Real-time Angle-based Stability Constraints

Dynamic Stability Limits

Concept

Stability constraints are more directly related to angle than corridor power transfers.

Benefits

- Relieve transmission capability
- Reduce uncertainty in limit as conditions change, e.g. line outages, wind generation
- Corrective Actions
Operator Training Environment
Integrated Dynamic DTS

Integrated Dispatcher Training System:
- Real-time simulator based on Powertech TSAT
- Simulated data is fed directly into PP as C37.118 streams
- Data is also downsampled and sent to the EMS & DSA Tools
- EMS integrated with PhasorPoint and DSA tools

EMS Platform
- Load Flow Simulation
- Dispatch Control
- ET Engine

DSA tools

PhasorPoint Training Server
- Central PDC
- Application Services
- Data Services

- IEEE C37.118
- IEC 60870-5-104
- PhasorPoint HMI Services
- e-terra services
- Control
- Observe

Operator in Training
Wide Area Control

Bridging the grid control gap!

Protection
- 16-200ms Equipment Protection
- 200-600ms Wide-Area Defence

Automated Wide Area Control
- 0.6-3s Automated Trip
- 3-15s Automated Dispatch

Control Room EMS/WAMS
- 15 minutes Operator Dispatch
- Human Response

Stability Categories
- Frequency Stability
- Oscillatory Stability
- Long-Term Voltage Stability
- Short-Term Voltage Stability
- N-x Transient Stability
- Transient Stability
- Local & Differential Fault Protection
Vision for Phasor-based “Hybrid” Control
Requirement for India GSES Opportunity