WAMS Applications for The Control Room of The Future using the Next Generation Grid Operations Framework

DNV Energy Systems

Lino Prka, Jan Vit Suntar
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Agenda

• Next Generation Grid Operations (NextGen GridOps) Framework Introduction
  • Future system operations
  • Building a machine
  • Modular architecture

• WAMS and NextGen GridOps Framework
  • Knowledge Preservation
  • Applications

• Q&A
Next Generation Grid Operations (NextGen GridOps Framework) Introduction
System Operations are becoming more COMPLEX and DEMANDING

Smart cost-efficient strategy in dealing with increasing grid ops complexities

- New market & system requirements
- Integrate to existing + new applications
- Real time performance + response
- RT data integration + exchange (data model)
- Data quality + compatible data sets
- Project realization time + budget

Building the Next Generation
Grid Operations Machine

CIMbion Automated Data Testing
BUILDING the MACHINE
Migrate to the NEW DIGITAL GRID OPERATIONS MODEL

How to MIGRATE to – steps to define

CURRENT
Monolith
Single Vendor

SCADA EMS/DMS
- Substation 1
- Substation 2
- Substation N

NEXTGEN Grid Operations
Multi-vendor Application Data
Integrated System Architecture
Modular and Service Oriented

Data & information Security – Secure Architecture + Applications
A modular, flexible and secure architecture allows high interoperability enabling interaction between different applications & departments

- High interoperability allows **data to be shared** and new business functions to be introduced
- **Clear segregation** between corporate network (which contains most users & applications) and technology & control networks
- Applications in the control network should be **able to operate** when other networks fail
- Applications in the corporate network aren’t able to directly influence applications in the control network (only information provisioning)
- Applications communicate with each other via an integration layer, unless very specifically approved. In principle there are **no point-to-point connections** between applications
- Any data shared between networks flows via **integration layers, incl. security principles**
Our understanding – creating more value with data in increasing grid complexity with many stakeholders and renewable energy integration

<table>
<thead>
<tr>
<th>Core KPI</th>
<th>Existing challenges &amp; opportunities</th>
<th>Strategic priorities</th>
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<tbody>
<tr>
<td>Security of Supply</td>
<td><strong>Data &amp; process standardisation</strong> required to reduce complexity with many stakeholders</td>
<td>▪ Creating value with WAMPAC</td>
</tr>
<tr>
<td>Quality of Supply</td>
<td><strong>Improved interoperability</strong> required between the different solutions and new renewables to improve existing monitoring &amp; control functions and to allow (real-time) calculations &amp; simulations</td>
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<td>Safety</td>
<td><strong>Improved data quality</strong> to allow better (automated) decision-making</td>
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<tr>
<td>TCO</td>
<td><strong>New digital technology</strong> to be infused in the core processes of the company</td>
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<td>Regulation &amp; compliancy</td>
<td><strong>Improved grid development and resiliency improvement</strong></td>
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<td>Public image</td>
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<td>Sustainability</td>
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WAMS and NextGen GridOps Framework
WAMS Practical Examples

Modelling of Business Processes by Using BPMN 2.0 in Enterprise Architect

- Definition of information implementation process by using ArchiMate 3.0 in Enterprise Architect
- Definition of Roadmaps
- Using information for practical examples
Example process flow:
• Clear business processes for WAMPAC,
• including its integration with peripheral systems.
WAMPAC Applications diagram

WAMPAC Real-Time Monitoring & Alarming Applications
- Event (Disturbance)
- Phase Angle Difference
- Effective Area Inertia Estimation
- Islanding Detection
- Line Parameter Estimation
- Linear State Estimation (Online)

Visualization
- Situation Awareness (Dashboard)
- Real-time Performance Monitoring
- Trends (Dashboard)
- Trend Comparison (Measured vs. Estimated)

WAMPAC Model Management
- WAMPAC Model
- PMU Data

WAMPAC Offline Applications
- Linear State Estimation (Study)
- Dynamic Model Validation
- Data mining
- Study Mode
- Post Event Analysis

WAMPAC Performance and Data Quality Monitoring
- PMU Data Quality
- PDC Data Quality
- LSE Dashboard
- PMU Data

WAMPAC Performance and Data Quality Monitoring
- Dynamic Model Validation
- Data mining
- Study Mode
- Post Event Analysis

WAMPAC Offline Applications
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WAMPAC Performance and Data Quality Monitoring
- PMU Data Quality
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- LSE Dashboard
- PMU Data
Process of Information Implementation

**Motivators behind the project:**
- Carbon neutrality
- Distributed generation
- High share of energy from RES

**Obstacles introduced due to new technologies:**
- Reduced damping
- New power oscillations
- Decrease of inertia

**Highly affected areas by newly occurred issues:**
- Highly dynamic behaviour
- High RoCoF
- Reduction of maximum power flow

**Enhancement or a solution of issues and impacts:**
- Wide Area Monitoring System (WAMS)
- Supplementary damping control
- Synchrophasor technology

**Objective when implementing mitigations:**
- System stability $\rightarrow$ rotor angle stability $\rightarrow$ transient stability
- Security of supply
- Grid reliability

**Requirements for mitigation implementation:**
- Dynamic performance of a Type IV wind turbine
- Real-time use of wide-area monitoring data
- Simulation of transient behaviour
Rotor Angle Stability – Framework Implementation

Future Scenarios

- Reduction of CO2 Emissions
- Enforcement of PE-Interfaced Generation/RES Generation
- Decommission of Synchronous Generation

Legend
- Driver
- Issue
- Impact
- Mitigation
- Goal
- Requirement
- Reference
- Device

Rotor Angle Stability
- Reduced Damping and New Power Oscillations
- Reduction on Transient Stability Margins

Frequency Stability
- Decrease of Inertia
- Missing or Wrong Participation of PE Generators and Loads in Frequency Containment

Voltage Stability
- Lack of Reactive Power
- Voltage Dip Induced Frequency Dip
- Loss of Devices in Context of FRT Capabilities
- Excess of Reactive Power
- Altered Static and Dynamic Voltage Dependency of Loads

Controller Interaction
- PE Controller Interactions/Harmonic Stability
- Resonances due to Cables and PE

Enforcement of PE-Interfaced Generation/RES Generation

Decrease of Inertia

Missing or Wrong Participation of PE Generators and Loads in Frequency Containment

Reduction on Transient Stability Margins

Controller Interaction
Rotor Angle Stability – Framework Implementation
Application of WAMS Information from NextGen GridOps Framework

• Context:
  • Case Study IEEE 39 Bus New England Test System
  • Direct Voltage Control receives a remote signal
  • The remote signal fed to the controller is voltage magnitude (due to the previously developed structure of DVC)
  • The controllability was evaluated by studying damping of critical modes of oscillation
  • Deployment of 3 PMUs and 3 WADs was considered in this project
    • Evaluation of observability and controllability of the system
    • Input / output signal selection method
Study System and WAMS Structure
Study System and WAMS Structure

Wide Area Monitoring System

- GPS
- Synchronization Signal
- Wide Area Damping Controller
- Remote Signal
- Generator Controller
- Local Signal
- Wide Area Damping Controller
- Remote Signal
- Generator Controller
- Local Signal
- Wide Area Damping Controller
- Remote Signal
- Generator Controller
- Local Signal
- PDC
- PMU
- PMU
- PMU
- Wide Area Damping Controller
- Remote Signal
- Generator Controller
- Local Signal
Input / Output Signal Selection Method

ABLE:
- Identify buses with highest controllability and highest observability
  → PMUs
  → WADC

NOT ABLE:
- Determine number of required PMUs & WADC
- Determine best inputs for WADC
- Determine best PE-interfaced device (DVC, VSM, grid-following control) for a specific bus
Case Study IEEE 39 Bus New England Test System
WAMS with 2 Synchronous Generators and 8 DVC

SETUP

- 2 synchronous generators
- 8 Direct Voltage Controllers
  - 3 Damping Controllers → WAD
- 3 Voltage measurements → PMU

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<th>Modes</th>
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Concluding Words

• Next Generation Grid Operations (NextGen GridOps) Framework was developed to support defining and designing the Grid Operations Machine with real-time data exchange between different applications and by different vendors.

• The Grid Operations Machine is based on an integrated system architecture without point-to-point connections between applications, deploying a service-oriented architecture instead.

• The NextGen GridOps Framework is structured in Enterprise Architect according to latest standards and its modular structure allows speedy redeployment of previously implemented solutions.

• Deploying the framework will help strengthen the confidence of grid operators in the future to come through better; being able to manage the ever-increasing complexity of the power grids and renewable generation and better enhancing their situational awareness operating the energy system.
Questions?
Contact Information

Lino Prka
Jan Vit Suntar

Lino.Prka@dnv.com
Janvit.Suntar@dnv.com