2016 Smart Grid R&D Program Peer Review Meeting

Structuring a demonstration project to Integrate DER, Microgrid EMS, DERMS, and DMS

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in collaboration with NREL and EPRI
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Structuring a demonstration project to Integrate DER, Microgrid EMS, DERMS, and DMS

Objectives & Outcomes

- Develop integrated control and management systems for distribution systems
- Address high penetrations of interconnected DER.
- Outcome of the project will include:
  - Gap analysis
  - Architectures and use cases of integrated DMS system
  - Test plan and HIL Test setup @NREL
  - Proof-of-concept system integration through modeling & simulation & HIL performance verification Testing
  - Site Demonstration and validation

Life-cycle Funding Summary ($K)

<table>
<thead>
<tr>
<th>Prior to FY 16</th>
<th>FY16, authorized</th>
<th>FY17, requested</th>
<th>Out-year(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>$500K</td>
<td>$900K</td>
<td>TBD</td>
</tr>
</tbody>
</table>

(Note: The life-cycle funding table above should include all FY funds received and to be requested, from the project beginning year to the project ending year)

Technical Scope

- Extract findings on current gaps for integrating DMS, μEMS and DERMS
- Identify and define the interactive functions of controllers to fill those gaps;
- Evaluate the effectiveness of integrating the control and management systems
- Establish the criteria for the selection of site(s) suitable for field testing integrated microgrid and utility operations.
Problems & Stakeholder Needs

- Existing DMS functions cannot handle the DER integration
- Currently, the DMS, OMS, DERMS and µEMS (microgrid) are separate entities
- Efficient management of DER requires an integrated system consisting of DMS, OMS, DERMS and µEMS controllers
- Different stakeholders have different needs from the integrated system
- In order to meet the requirements of different stakeholders, the project aims at:
  - Developing an architecture of integrated system (Functions, communication, control, interoperability, security)
  - Establishing the relationship between different components
  - Identifying the gaps in integration of DMS, OMS, µEMS and DERMS
# Needs of Stakeholders

## Utilities
- Some of them do not currently have but plan to use DMS.
- They directly participate in the integration of µEMS and DMS.

## Microgrid owners/developers/vendors
- They need to know the requirements and standards of integrating their µEMS and DERMS into DMS.
- The potential benefits of integrating µEMS and DERMS into DMS should be identified.

## Vendors
- They need to identify the necessary changes of their products for the integration of µEMS, DERMS and DMS.
- They need to participate in the development of the related standards.
Project Approach

Phase 1
- Stakeholder Advisory Group
- Solution Design
- Test Approach
  - Gap analysis
  - State-of-art in DMS technology
  - Control architecture
  - Functional requirements

Phase 2
- HIL Performance Verification Testing
- System Design and Simulation
- Structure test approach and plan
- Performance metrics
- Design test setup
- Engage with vendors and utilities

Phase 3
- Site Demo
- Performance Assessment & Impact Analysis

Develop, test, and demonstrate integrated control and management systems for distribution
Phase 1 Work Plan

- **Task 1**: Finalize the Stakeholder Advisory Group

- **Task 2**: Gap Analysis for the integration of DMS, μEMS and DERMS
  - Extract and consolidate from the 2015 Argonne and EPRI reports
    - Current gaps for integrating DER within the three platforms
      - DMS,
      - μEMS
      - DERMS
    - State-of-art in DMS technology
  - Finalize
    - Interactive DER functions
    - Architecture variations
Phase 1 Work Plan (cont’d)

- **Task 3:** Finalize work streams, and interactive functions in DMS, μEMS and DERMS
  - Identify the most **relevant Core and Advanced DMS applications** (*Minimum and Preferred*) that will affect DMS, DERMS, local controller/μEMS integration.
    - Focus the Objective/Driver around
      - Reliability/Resiliency (east coast focus - Public Purpose/Society benefits)
      - Capacity/Energy
  - Identify different utility feeders types that will be considered in the evaluation
    - Partial Feeder (O/H versus Underground)
    - Single Feeder (O/H versus Underground)
    - Clustered operation
    - Secondary n/w
Phase 1 Work Plan (cont’d)

- **Task 4**: Conduct a workshop with Stakeholder Advisory Group

- **Task 5**: Structure the test approach and plan for integrated system characterization

- **Task 6**: Identify candidate sites to verify the integration of the three control and management systems in field operations at a distribution utility
  - Vendors with interoperable μEMS, DERMS, and DMS.
  - Options:
    - PECO/Exelon, Navy Yard, Alstom, Schneider (PJM)
    - SDG&E, Borrego Springs, Spirae, Oracle (CAISO)
    - SCE, UCI (CAISO)
    - National Grid, Buffalo Niagara Medical Campus (NYISO)
Roles and Responsibilities

Jianhui Wang, Ravindra Singh, Xiaonan Lu, Ning Kang (ANL)
Arindam Maitra, Sal Martino, Tanguy Hubert (EPRI)
Murali Baggu, Annabelle Pratt (NREL)
Jim Reilly (Consultant)
First advisory group meeting held at DistribuTech 2016 with more than 30 participants and great feedback received
ANL Report: Guidelines for Implementing Advanced Distribution Management System

- Chapter 1: Introduction
- Chapter 2: DMS – Current Status and New Challenges
- Chapter 3: Microgrid Operation
- Chapter 4: Distributed Energy Resources
- Chapter 5: Distributed Energy Resources Management Systems
- Chapter 6: DMS Integration with Microgrid
- Chapter 7: DMS Integration with DERMS
- Chapter 8: DMS Design Principles for Integration with DERMS and Microgrids
- Chapter 9: Summary and Conclusion
EPRI Project:
Relationship of Microgrid Controller with DERMS and the Utility DMS

Grid Interactive Microgrid Controllers and the Management of Aggregated Distributed Energy Resources

August 2015

This report was prepared by:
Electric Power Research Institute
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Principal Investigators:
A. Malan
I. Simms
E. Seal
R. Starf
L. Motrys

This report describes research sponsored by the Department of Energy (DOE)
The reports on ADMS in this numbered series of Argonne reports are as follows

- *Importance of DMS for Distribution Grid Modernization* (ANL/ESD-15/16)
- *DMS Functions* (ANL/ESD-15/17)
- *High-Level Use Cases for DMS* (ANL/ESD-15/18)
- *Business Case Calculations for DMS* (To Be Published)
- *Implementation Strategy for DMS* (To Be Published)
- *DMS Integration of Microgrids and DER* (To Be Published)
- *DMS Industry Survey* (To Be Published)
Different Levels of Controls

- **Microgrid Controller.** When some of the distributed resources on the distribution system are configured into microgrids, then these resources will need a controller to manage their operation and coordination with local loads as well as coordinate the connection and disconnection of the microgrid from the overall distribution system.

  - **Local Controller.** The local controller will manage the local distributed resources and local loads to coordinate operation during islanded mode and also possibly coordinate the participation of these resources in broader system functions.

- **Distribution Management System (DMS).** The system level controller coordinates the operation of one or more microgrids with the overall DMS. This function can be integrated with the DERMS function with the additional requirement that the microgrid controller must recognize the unique features of microgrids that may include forecasting, scheduling, protection, synchronization, and local coordination of resources that may have different optimization functions than the distribution level optimization.
Responsibilities of microgrid for DMS

- Microgrid controllers are responsible for managing DER availability, maintaining real and reactive power exchange, and voltage profiles at POI.
- Microgrids should automatically disconnect from the grid in any grid fault condition beyond the threshold of ride-through.

Responsibilities of DMS for microgrid

- DMS should provide operation guidance, including the voltage ranges and power exchange fluctuation tolerance around the scheduled targets at active POI to the microgrids.
- DMS can initiate emergency requests to microgrids for clearly defined specific emergency support.

Data interaction between MC and DMS

- Normal Condition:
  - Available DER resources at the POI
  - Real-time data and setpoints at the POI, e.g., voltage, current, active and reactive power, etc.

- Fault Condition:
  - Emergency support to the distribution grid
  - Disconnection under severe fault condition
  - Intentional islanding: load balancing and voltage profile recovery
  - Intentional islanding: notify DMS to prepare for the disconnection; balance the active and reactive demand in the Microgrid
  - Reconnection: notify DMS for the reconnection

- Normal Condition:
  - Real-time data and setpoints at the POI, e.g., voltage, current, active and reactive power, etc.

- Fault Condition:
  - Emergency support to the Microgrid when necessary
  - Severe fault is either not detected or not cleared by the microgrid protection devices
  - Unintentional islanding events
  - Intentional islanding: prepare for the disconnection when receiving the request from the Microgrid; balance the active and reactive demand in the distribution grid
  - Reconnection: prepare for the microgrid reconnection and start the normal operation when the reconnection is terminated

- Data communication
- Operation rules
- Synchronization and connection/disconnection
- Microgrid control
- Resource optimization
<table>
<thead>
<tr>
<th>DMS Function</th>
<th>System Adjustment (Dispatch, Energy Efficiency, Load-Generation)</th>
<th>Protection/Reliability</th>
<th>Situational Awareness</th>
<th>Reasoning for Group Assignment</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>VVO</td>
<td>❑</td>
<td></td>
<td></td>
<td>Performs action of making adjustments based on information provided</td>
<td>Volt Var Optimization</td>
</tr>
<tr>
<td>CVR</td>
<td>❑</td>
<td></td>
<td></td>
<td>Performs action of making adjustments based on information provided</td>
<td>Conservation Voltage Reduction</td>
</tr>
<tr>
<td>Power Factor Correction</td>
<td>❑</td>
<td></td>
<td></td>
<td>Performs action of making adjustments based on information provided</td>
<td>Power Factor adjustment through caps, VAR absorption, etc.</td>
</tr>
<tr>
<td>Load Balancing</td>
<td>❑</td>
<td></td>
<td></td>
<td>Performs action of making adjustments based on information provided</td>
<td>Load balancing through reconfiguration of circuits or how load is energized</td>
</tr>
<tr>
<td>Phase Balancing</td>
<td>❑</td>
<td></td>
<td></td>
<td>Performs action of making adjustments based on information provided</td>
<td>Phase balancing by reconfiguration of circuit at switch points...can also advise movement of spur line taps between phases</td>
</tr>
<tr>
<td>OLPF</td>
<td></td>
<td>❑</td>
<td></td>
<td>Provides information to other functions and operators to make decisions - this function does not perform actions</td>
<td>Information about the current power flow used by other functions to make decisions</td>
</tr>
<tr>
<td>Medium Voltage State Estimation</td>
<td></td>
<td></td>
<td>❑</td>
<td>Provides information to other functions and operators to make decisions - this function does not perform actions</td>
<td>Information about the estimated state used by other functions to make decisions</td>
</tr>
<tr>
<td>Contingency Analysis</td>
<td></td>
<td></td>
<td>❑</td>
<td>Provides information to other functions and operators to make decisions - this function does not perform actions</td>
<td>Reviews plausible overload conditions and outage events that could produce unacceptable conditions on the distribution system and provides information to operator for decisions</td>
</tr>
<tr>
<td>FLISR</td>
<td></td>
<td></td>
<td>❑</td>
<td>Performs the actions of reconfiguring the system when reliability/protection is a concern</td>
<td>Fault Location, Isolation, and Service Restoration</td>
</tr>
<tr>
<td>Emergency Load Shedding</td>
<td>❑</td>
<td></td>
<td></td>
<td>Performs action of making adjustments based on information provided</td>
<td>In response to power-system level emergency, load is removed from system</td>
</tr>
<tr>
<td>DMS Function</td>
<td>System Adjustment (Dispatch, Energy Efficiency, Load-Generation)</td>
<td>Protection/Reliability</td>
<td>Situational Awareness</td>
<td>Reasoning for Group Assignment</td>
<td>Note</td>
</tr>
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</tr>
<tr>
<td><strong>Switch Order Management</strong></td>
<td></td>
<td></td>
<td></td>
<td>Performs the actions of reconfiguring the system when reliability/protection is a concern.</td>
<td>Manages the switching steps for planned work and system restoration. Can perform some of the switching steps with connected equipment.</td>
</tr>
<tr>
<td><strong>Short Term Load Forecast</strong></td>
<td></td>
<td></td>
<td>✓</td>
<td>Provides information to other functions and operators to make decisions - this function does not perform actions.</td>
<td>Based on current weather conditions, predicted weather conditions, current load, and historical load - this function will provide a &quot;best guess&quot; of predicted load which can be used to make decisions by functions and operators.</td>
</tr>
<tr>
<td><strong>Short Term Generation Forecast</strong></td>
<td></td>
<td></td>
<td>✓</td>
<td>Provides information to other functions and operators to make decisions - this function does not perform actions.</td>
<td>Based on current weather conditions, predicted weather conditions, and connected DG on system - this function will provide a &quot;best guess&quot; of predicted generation which can be used to make decisions by functions and operators.</td>
</tr>
<tr>
<td><strong>Demand Response</strong></td>
<td>✓</td>
<td></td>
<td></td>
<td>Performs the actions of reconfiguring the system when reliability/protection is a concern.</td>
<td>To reduce peak demand, system will reconfigure itself to reduce the peak demand (i.e. peak shaving).</td>
</tr>
<tr>
<td><strong>SCA</strong></td>
<td></td>
<td></td>
<td>✓</td>
<td>Provides information to other functions and operators to make decisions - this function does not perform actions.</td>
<td>Short Circuit Analysis - provides information to other functions for decisions. Is this redundant with Predictive Fault Location?</td>
</tr>
<tr>
<td><strong>Voltage Correction</strong></td>
<td>✓</td>
<td></td>
<td></td>
<td>Performs action of making adjustments based on information provided.</td>
<td>When voltage violations occur, this will correct the situation.</td>
</tr>
<tr>
<td><strong>Predictive Fault Location</strong></td>
<td></td>
<td></td>
<td>✓</td>
<td>Provides information to other functions and operators to make decisions - this function does not perform actions.</td>
<td>Is this redundant with SCA?</td>
</tr>
</tbody>
</table>
| **Optimal Network Reconfiguration** |                                                               | ✓                      | ✓                     | Performs action of making adjustments based on voltage/VAR information provided and can reconfigure the system based on reliability/protection concerns - depends on intent of reconfiguration. | Will configure the system to its optimal state depending on the goal of optimization:  
1) CVR  
2) Reliability  
3) Energy Efficiency  
4) Peak Shave |
| **Dynamic Equipment Rating**  |                                                               |                        | ✓                     | Provides information to other functions and operators to make decisions - this function does not perform actions. | Provides information to other functions and operators about the rating for transformers and cables to make decisions about how to load equipment. |
### DMS Function Groups Assignment (cont.)

<table>
<thead>
<tr>
<th>System Adjustment (Dispatch, Energy Efficiency, Load-Generation)</th>
<th>Protection/Reliability</th>
<th>Situational Awareness</th>
</tr>
</thead>
<tbody>
<tr>
<td>VVO</td>
<td>FLISR</td>
<td>OLPF</td>
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<tr>
<td>CVR</td>
<td>Switch Order Management</td>
<td>Medium Voltage State Estimation</td>
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<tr>
<td>Power Factor Correction</td>
<td>Optimal Network Reconfiguration</td>
<td>Contingency Analysis</td>
</tr>
<tr>
<td>Load Balancing</td>
<td></td>
<td>Short Term Load Forecast</td>
</tr>
<tr>
<td>Phase Balancing</td>
<td></td>
<td>Short Term Generation Forecast</td>
</tr>
<tr>
<td>Emergency Load Shedding</td>
<td></td>
<td>SCA</td>
</tr>
<tr>
<td>Demand Response</td>
<td></td>
<td>Predictive Fault Location</td>
</tr>
<tr>
<td>Voltage Correction</td>
<td></td>
<td>Dynamic Equipment Rating</td>
</tr>
<tr>
<td>Optimal Network Reconfiguration</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Use Cases: Impact of DERs on High Level DMS Functions

Developed use cases:
1) Online Power Flow (OLPF); 2) Fault Location, Identification, and System Restoration (FLISR); 3) Voltage Var Optimization (VVO); 4) Short Circuit Analysis (SCA); 5) Data Acquisition and Control (DAC); 6) Distribution State Estimation (DSA)

Use cases include:
• Scenarios for use cases
• Use case description
• Actors and their role
• Impact/Gap analysis
• Architecture variation
• Data flow

Three scenarios:
• Scenario I: DERs are interconnected to the distribution system but non-dispatchable
• Scenario II: DERs are interconnected to the distribution system and dispatchable
• Scenario III: DERs are integrated in a microgrid and controlled by a microgrid controller
Use Case 1: OLPF

Impact Analysis: High penetration of DER

The OLPF function should be modified to consider the
• Variability in DER output
• Reverse Power flow
• Real-time vs event/operator triggered operation
• Stochastic vs deterministic algorithm

Actors
• DMS
• GIS
• HMI
• DSCADA
• Microgrid controller
• DERMS
Use Case 1: OLPF

Data Flow

From DERMS to DMS
- DER measurements
- DER forecast
- DER status
- DERMS control action
- DER constraints

From DMS to DERMS and microgrid
- Control action
- Dispatch command

From MGC to DMS
- DER measurements
- DER status
- MGC control action

Architecture Variation

Configuration I: DMS + DER
- Network parameters
- Load allocation
- Analog/Status Value
- DER Status
- DER measurements
- DER Forecast
- DER Constraints

Configuration II: DMS + Microgrid Controller
- DER output
- DER forecast
- DER status
- DERMS control action
- DER constraints

Configuration III: DMS + DERMS
- DER output
- DER forecast
- DER status
- DERMS control action
- DER constraints

With DER/DERMS and microgrid
Use Case 2: FLISR

Impact Analysis: High penetration of DER
FLISR function should consider the
• Intermittence and power variation induced by non-dispatchable DERs;
• Bi-directional power flow that influences the conventional protection schemes;
• The impact of microgrid controllers that are used to locally aggregate the DERs and loads.
• Inclusion of DER forecast

Architecture Variation

Configuration I: DMS + DER
- DER output
- DER forecast
- DER status
- DERMS control action
- DER constraints

Configuration II: DMS + DMS
- Control Command
- Measurements

Configuration II: DMS + Microgrid Controller
- Control Command
- Analog Status Value

Actors
• DMS
• GIS
• HMI
• DSCADA
• Microgrid controller
• DERMS

From MGC to DMS
- DER Measurements
- DER Status
- MGC control action

From DMS to MGC
- MGC control command
Use Case 3: VVO

Impact Analysis: High penetration of DER

The VVO function should consider the
- Variability in non-controllable DER output and interface inverter functions
- Reverse Power flow
- Both continuous as well as discrete control (Mixed integer optimization)
- Coordination between tap changer, capacitor bank and inverter control

Actors
- DMS
- GIS
- HMI
- DSCADA
- Microgrid controller
- DERMS
- AMI
- Capacitor bank controller
- Voltage regulator and substation transformer

*Variation of SCA architecture is similar to OLPF/FLISR
Use Case 4: SCA

Impact Analysis: High penetration of DER

The SCA function should consider the
- Dynamic models of the DER generators in the calculations, especially for rotational machine-based DERs.
- Reverse Power flow
- Variability of DER power output
- Include the DG terminal fault in SC calculation
- For inverter-based DER, their short-circuit current contributions may be ignored because power electronic devices in the DER can respond quickly to effectively limit the fault current contribution.
- The protective devices and equipment need to be tested and their settings need to be configured for DER fault current characteristic (Fast time response and variable time constant).

<table>
<thead>
<tr>
<th>Actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMS</td>
</tr>
<tr>
<td>GIS</td>
</tr>
<tr>
<td>HMI</td>
</tr>
<tr>
<td>DSCADA</td>
</tr>
<tr>
<td>Microgrid controller</td>
</tr>
<tr>
<td>DERMS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>From Field to DMS</strong></td>
</tr>
<tr>
<td>Field measurements</td>
</tr>
<tr>
<td>SC characteristic of devices</td>
</tr>
<tr>
<td>DER Measurements</td>
</tr>
<tr>
<td>DER status</td>
</tr>
<tr>
<td>MGC control action</td>
</tr>
<tr>
<td><strong>From DMS to Field Devices</strong></td>
</tr>
<tr>
<td>Protection device settings</td>
</tr>
</tbody>
</table>

Architecture Variation

Configuration I: DMS + DER
Configuration II: DMS + Microgrid Controller
Configuration III: DMS + DERMS
NREL test setup concept

- Identify target integrated system and use case(s) - *in process*
  - Provided feedback on use cases developed by ANL & EPRI
  - Meeting at NREL Aug 23 with leading system candidates
    - PECO, Navy Yard, GE, Schneider

- Real-time co-simulation of DMS power flow and transient on RTDS
- Controller and Power Hardware-in-the-Loop (CHIL/PHIL)
Phase II (FY17): Performance Evaluation through testing

Proof-of-Concept evaluation in a controller laboratory environment
- Establish and prepare software hardware test platform
- Establish interfaces, monitoring, and communication needs for testing
- Develop external virtual machine interfaces and external data portals
- Obtain data for one utility that will be utilized for simulations
- Identify the microgrid boundaries and DER scenarios and test cases that will be evaluated through software and hardware testing
- Establish end-to-end interface and connectivity
- Conduct simulation and hardware tests of the integrated system based on the test plan indicated in Phase 1
- Identify the validation criteria and performance indicators to verify the effectiveness of the integration of DMS, μEMS and DERMS
Phase II: Performance Evaluation through Testing (cont’d)

- **Evaluation of Test Results**
  - Data analysis and model validation
  - Identify the settings of each DERs for different operational modes
  - Develop a distribution planning guide for DMS, μEMS and DERMS integration
  - Summarize the gaps and enabling solutions of integrating DMS, μEMS and DERMS based on the simulation results

- **Demonstration Project Requirements**
  - Create technical objectives for the demonstration project
  - Identify the criteria for site selection – microgrid and utility
  - Finish Demonstration Project Requirements

- **Final Report**
Thank you!

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