Distribution Grid Management (Advanced Distribution Automation) Functions
Use Case Description[1]

1 Descriptions of DGM Set of Functions

All prior work (intellectual property of the company or individual) or proprietary (non-publicly available) work should be so noted.

1.1 Function Name[1]

Name of Function

The set of Distribution Grid Management functions is named **Advanced Distribution Automation (ADA) Functions**.

1.2 Function ID[2]

IECSA identification number of the function

1.3 Brief Description[3]

Describe briefly the scope, objectives, and rationale of the Function.

Objective: The objective of Advanced Distribution Automation Functions in the Smart Grid Environment is to provide situational awareness and dynamic optimization of operations of Active Distribution Networks (AND) to enhance the reliability of power system service, power quality, power system efficiency, and cyber security with integration of Smart Grid technology, such as:

- Advanced Metering Infrastructure (AMI)
- Distributed resources and generation, including renewable resources (DER)
- Demand response (DR)
- Advanced electricity storage, including plug-in electric and hybrid electric vehicles (ES)
- Provision to consumers of timely information and control options,

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[1] Background information includes prior UCI work

by automating data preparation in near-real-time; optimal decision-making; and the control of distribution operations in coordination with transmission and generation systems operations.

Scope: The ADA Function performs a) data gathering, along with data consistency checking and correcting; b) integrity checking of the distribution power system model; c) periodic and event-driven system modeling and analysis; d) current and predictive alarming; e) contingency analysis; f) coordinated Volt/Var/Watt optimization: g) fault location, isolation, and service restoration; h) multi-level feeder reconfiguration; i) pre-arming of RAS and coordination of emergency actions in distribution; j) pre-arming of restoration schemes and coordination of restorative actions in distribution, and k) logging and reporting. These processes are performed through direct interfaces with different databases and systems, (AMI, EMS, OMS, CIS, MOS, SCADA, AM/FM/GIS, AMS, WMS, and other internal and external to the power utility IT systems), comprehensive near real-time simulations of operating conditions, near real-time predictive optimization, and actual real-time control of distribution operations.

Rationale: By meeting its objectives in near-real time, the ADA functions make a significant contribution to sustainability of the ADN and to improving the power system operations, which cannot be achieved using non-automated operational methods.

Status: The methodology and specification of the ADA function for current power system conditions have been developed, and prototype (pilot) and system-wide project in several North-American utilities have been implemented. The applications need significant upgrades to meet the Smart Grid requirements. This document presents the ADA functions with the upgrades suggested for meeting these requirements.

1.4 Narrative[4]

A complete narrative of the Function from a Domain Expert's point of view, describing what occurs when, why, how, and under what conditions. This will be a separate document, but will act as the basis for identifying the Steps in Section 2.

1.4.1 Overview of ADA Functions

The ADA functions operate in close coordination of the following applications:

1. Real-time Distribution Operation Model and Analysis (DOMA)
2. Fault Location, Isolation and Service Restoration (FLIR)
3. Voltage/Var/Watt Optimization (VVWO)
4. Distribution Contingency Analysis (DCA)
5. Multi-level Feeder Reconfiguration (MFR)
6. Relay Protection Re-coordination (RPRC)

7. Pre-arming of Remedial Action Schemes (PRAS)
8. Coordination of Emergency Actions (CEmA)
9. Coordination of Restorative Actions (CRA)
10. Intelligent Alarm Processing (IAP)

1.4.1.1 Overall Preconditions

Actor/System/Contract	*Preconditions or Assumptions*
Distribution SCADA	Distribution SCADA database is updated via remote monitoring and operator inputs. Required scope, speed, and accuracy of real-time measurements are provided, supervisory and closed-loop control is supported. Distribution SCADA communicates with substation RTU (controllers), field IEDs, large DER and micro-grid controllers, and with large customer EMS.
AM/FM/GIS databases	AM/FM system contains the geographical information of the distribution power system circuit connectivity, as well as the parameters describing the power system facilities, including all electric characteristics of distribution transformers, as well as circuit connectivity and parameters of secondary circuits between the distribution transformers and customers or their equivalents consistent with voltage drops and power losses. Conceptually, the AM/FM/GIS database can contain transmission connectivity and facility data and relevant to distribution operations customer-related data. M/FM/GIS databases is interfaced with the Customer Information System for linkage between the customer data and point of connection, with AMI, DER, and DR data management systems for updates of secondary circuit equivalents, and behavioral models of load, DER, ES, and DR. Alternative interfaces between these data management systems and ADA are possible. AM/FM/GIS databases are also accessible to field crews via mobile computing for updates on facility connectivity and parameters. The AM/FM/GIS databases are updated, proof-tested and corrected in a timely manner to provide a high probability of preparedness for supporting near-real-time ADA applications.

Actor/System/Contract	*Preconditions or Assumptions*
AMI	There is a significant penetration of multi-functional Smart Meters able to frequently measure, store, and transmit kW, kvar, high accuracy Volts, voltage sags and swells, "Last Gasps", and higher harmonics data. The meters also serve as gateways for two-way communications between the utility and other authorized parties with the customers. They also can be used for transmitting prices and other triggering signals for enabling DR, control of customer-side DERs, ES, and PEVs. The meters can be used by the customers for communication to the utility and other parties their choices regarding participation in DR, DER, ES, and PEV controls.
AMI Data Management System	AMI Data Management System communicates with Smart Meters, collects, stores, and processes measurements from the Smart Meters. It is interfaced with other data management system, such as DER, DR, and PV and with the ADA system, through which it provides and receives information in accordance with the designs if the relevant object models and ADA applications.
CIS database	CIS contains energy consumption and load data for each customer separate, even fir the ones, which are included in consolidated accounts, based on measurement interval established for the Smart Meters and also aggregated for established billing periods. CIS interfaces with GIS and other data management systems according to the designs of the object models used in ADA and the designs of the ADA applications.
DER	Large DER are able to generate real and reactive power, absorb reactive power, and are equipped with gateways able to communicate with SCADA and with controllers able to monitor and control the operations of DER based on either local, or remote inputs, and may contain a portion or entirely the object model of DER. DER embedded in the customer domain are interfaced with other parties through a Smart Meter or another customer-oriented gateway, are able to respond to utility requests, to price signals and other triggers, some DER are also able to generate and absorb reactive power, including some at times, when the DER does not generate real power.

Actor/System/Contract	*Preconditions or Assumptions*
DER data management system	Controlling DER and ES charging/discharging; processing and storing data on contracts, relevant historic information, creating behavioral models of DER, collecting, processing, and storing power quality and reliability characteristics, etc. according to the designs of the object models and ADA applications
DR data management system	Controlling DR, processing and storing data on load management programs, contracts, relevant historic information, creating behavioral models, collecting, processing, and storing customer-specific data according to the designs of the object models and ADA applications.
PEV data management system	Encouraging or discouraging charging PEV through relevant pricing or other incentives/disincentives, processing and storing data on PEV programs, contracts, relevant historic information, creating behavioral models, collecting, processing, and storing customer-specific data according to the designs of the object models and ADA applications.
SCADA/EMS	EMS system contains the transmission power system model, and can provide the transmission connectivity facility information in the vicinity of the distribution power system and outputs from other EMS applications and accept information from ADA for the use in the EMS applications in accordance with the design of the ADA applications.
Customer Energy Management System	Customer Energy Management System can receive pricing and other signals for managing customer devices, including appliances, DER, electric storage, and PEVs.
Energy Services Interface (ESI)	Provides cyber security and, often, coordination functions that enable secure interactions between relevant Home Area Network Devices and the Utility. Permits applications such as remote load control, monitoring and control of distributed generation, in-home display of customer usage, reading of non-energy meters, and integration with building management systems. Provides auditing/logging functions that record transactions to and from Home Area Networking Devices. Can also act as a gateway.
ADA conversion and validation function (C&V)	The C&V function uses standard interface between AM/FM/GIS database and converts and validates information about incremental changes implemented in the field.

Actor/System/Contract	*Preconditions or Assumptions*
ADA: Distribution Operation Modeling and Analysis (DOMA)	**Preconditions:** Distribution SCADA with several IEDs along distribution feeders, reporting statuses of remotely controlled switches and analogs including Amps, kW, kvar, and kV. Operator's ability for updating the SCADA database with statuses of switches not monitored remotely. Substation SCADA with analogs and statuses from CBs exists. EMS is interfaced with ADA. ADA database is updated with the latest AM/FM/GIS/CIS data and operators input. The options for DOMA performance are selected. DOMA includes behavioral load models, including Demand Response with all dependencies on external factors, and behavioral DER and ES models. These models are updated by the corresponding data management systems. The DOMA database is updated by the real-time state of communication with IEDs and the availability of switch control.
ADA: Fault Location Isolation and Service Restoration (FLIR)	Fault Location **Preconditions:** Distribution SCADA with fault detectors, Distribution Operation Model and Analysis with fault analysis, fault location relays (schemes) including high impedance relays and Some Distributed Intelligence schemes and Trouble call system exist. AMI supplies FLIR with the results of outage detection and fault location analyses. Fault Isolation and Service Restoration **Preconditions:** Distribution SCADA with ability to control a defined number of switching devices, Fault Location, Distribution Operation Model and Analysis, Voltage, Var, and Watt Optimization for adjusting voltage and var after reconfiguration. Supervisory and closed-loop control of switches is available. Some Distributed Intelligence schemes exist. FLIR is able to include DER and micro-grids in the service restoration and back-to-normal solutions.
ADA: Multi-level Feeder Reconfiguration (MFR)	**Preconditions:** Distribution SCADA with ability to control a definite number of switching devices, Distribution Operation Model and Analysis, Voltage, Var, and Watt Optimization for adjusting voltage and var after reconfiguration. Supervisory and closed-loop control of switches is available. The options for the application are selected. MFR is able to include DER and micro-grids in the MFR solutions. Voltage angles are provided by EMS State estimation and taken into account by MFR.

Actor/System/Contract	*Preconditions or Assumptions*
ADA: Relay Protection Re-coordination (RPR)	The settings and modes of operation of the switching devices and large DER are reported by SCADA and can be controlled via SCADA.
ADA: Voltage, Var, and Watt Optimization (VVWO)	**Preconditions:** Distribution SCADA, Distribution Operation Model and Analysis, capability to monitor and control all or a portion of voltage, capacitor, DER/ES, DR and power electronic controllers in closed-loop mode exists.
ADA: Pre-arming of Remedial Action Schemes (RAS)	**Preconditions**: ADA is interfaced with the RAS schemes with the capability of changing the priorities of RAS actions and settings. The use of DER, Micro-grids, and DR can be taken into account.
ADA: Coordination of emergency actions (CEA)	**Preconditions:** ADA is interfaced with EMS and receives critical statuses, measurements, preventive and corrective actions. The use of DER, Micro-grids, and DR can be taken into account.
ADA: Coordination of restorative actions (CRA)	**Preconditions:** ADA is interfaced with EMS and receives information about restoration conditions. The use of DER, Micro-grids, and DR can be taken into account.
ADA: Intelligent Alarm Processing (IAP)	**Preconditions:** ADA receives synchronized (time stamped) status and analog data from IEDs, AMI, Customer EMS, DER and Micro-grid controllers, including uploads from event recorders.
ADA: Distributed Intelligence Schemes (DIS)	**Preconditions:** Distribution Intelligence Schemes are equipped with pear-to-pear communications and interfaced with ADA for pre-arming and coordination.
LMS: Load Management systems (LMS)	**Preconditions:** LMS is interfaced with ADA, can be prioritized by ADA. Controlling DR, DER, PEV and ES charging/discharging; processing and storing data on load management programs, contracts, relevant historic information, creating behavioral models, collecting, processing, and storing customer-specific power quality and reliability characteristics, etc.

Actor/System/Contract	*Preconditions or Assumptions*
UFLS: Under-Frequency Load Shedding Schemes	**Preconditions:** UFLS is interfaced with ADA, can be prioritized and pre-armed by ADA. UFLS within the Micro-grids are known. UFLS can be coordinated with UVLS, SLS, DR, DER and VVWO operations.
UVLS: Under-Voltage Load Shedding Schemes	**Preconditions:** UVLS is interfaced with ADA, can be prioritized and pre-armed by ADA. UVLS within the Micro-grids are known. UVLS can be coordinated with UFLS, SLS, DR, DER and VVWO operations.
SLS: Special Load Shedding Schemes	**Preconditions:** SLS is interfaced with ADA, can be prioritized and pre-armed by ADA. SLS within the Micro-grids are known. SLS can be coordinated with UFLS, UVLS, DR, DER and VVWO operations.

1.4.1.2 Overview of Post Conditions

Actor/Activity	*Post-conditions Description and Results*
SCADA Distribution	Works continuously
ADA: Distribution Operation Modeling and Analysis	All details of the real-time unbalanced distribution power flow are available for engineering review. The operator is provided with the summary of analysis. Other applications receive the pseudo-measurements for each distribution system element down to load centers in the secondaries practically replacing hundreds thousands of measurements. The database is updated via real-time topology data. The observability of distribution operating conditions is increased multifold. The dynamic voltage limits are calculated; aggregated load models for EMS are provided; dispatchable load is estimated. Results of contingency analysis of the relevant portion of distribution system are provided for engineering review and for use by other applications. Expected overload is determined; solutions are recommended. Planned outages are better prepared.
ADA: Fault Location, Isolation	Faulted section is identified. A solution for an optimal isolation of faulted portions of distribution feeder and restoration of services to healthy portions is provided to the operator;

Actor/Activity	*Post-conditions Description and Results*
and Service Restoration	closed-loop execution of switching orders is available; Outage time for the majority of customers is reduced to several minutes. DER, Micro-grids, and DR are used for service restoration.
ADA: Multi-level Feeder Reconfiguration	Optimal selection of feeder(s) connectivity for a given objective is provided to the operator; Closed-loop execution is available. Reliability is increased, losses are reduced, voltages are improved; room for voltage optimization is increased; utilization of distribution facilities is enhanced; DER, Micro-grids, and DR are ken into account by MFR.
ADA: Relay Protection Re-coordination	Relay protection settings adjusted to the real-time conditions based on the preset rules are sent to relevant protective relaying. The relay coordination is adaptive to the real-time condition; the reliability of service is increased. DER, Micro-grids, and DR are ken into account.
ADA: Voltage, Var, and Watt Optimization	Optimal voltage controller and DER controller settings and capacitor statuses for a given objective(s) are sent to respective devices. The power quality is enhanced; The distribution facilities are better utilized; the transmission and generation systems are better supported by volt and vars; the load management is integrated with volt/var optimization and is less intrusive; the peak load is reduced; the energy is conserved.

1.4.2 Distribution Operation Modeling and Analysis (DOMA)

The objectives of DOMA application are as follows:

- Generate and analyze the distribution operation model that is adequate for the near real-time monitoring of the essential behavior of the distribution system.
- Provide situational awareness of the distribution system operations by submitting concise and essential information to the operators.
- Generate component and aggregated behavioral object/data models for the use by other advanced DA and EMS applications.
- Determine dynamic operational limits to be used by DA and EMS applications.
- Analyze the operations of the distribution system from the standpoints of adequacy, power quality, and economic efficiency

This application is based on a real-time unbalanced distribution power flow for dynamically changing distribution operating conditions. It analyzes the results of the power flow simulations and provides the operator with the summary of this analysis. It further provides other applications with pseudo-measurements for each distribution system element from within substations down to load centers in the secondaries. The model is kept up-to-date by real-time updates of topology, facilities parameters, behavioral load models, current and short-term look-ahead forecasted weather and markets condition, other external dominant factors, if any, and relevant components of the transmission system and its operations.

The Distribution Operation Modeling and Analysis supports three modes of operation:

1. Real-time mode, which reflects present conditions in the power system.
2. Look-ahead mode, which reflects conditions expected in the near future (from one hour to one week ahead)
3. Study mode, which provides the capability of performing the "what if" studies.

In the Smart Grid environment, the multifunctional AMI system, customer EMS, DER and Micro-grid controllers in the Point of Common Coupling (PCC), and the market and weather IT systems will become significant sources of information support for the ADA applications. DOMA will processes these various input data into a near-real- time and short-term look-ahead comprehensive models of distribution operations to be used as a base for other ADA applications and to provide the operators with the situational awareness of the ADN operations.

The key sub-functions performed by the application are as follows:

1.4.2.1 Modeling Transmission/Sub-Transmission System Immediately Adjacent to Distribution Circuits

This sub-function provides topology and electrical characteristics of those substation transformers and transmission/sub-transmission portions of the system, where loading and voltage levels significantly depend on the operating conditions of the particular portion of the distribution system. The model also includes substation transformers and transmission/sub-transmission lines with load and voltage limits that should be respected by the application. The model of the rest of the bulk transmission system is included as sensitivity functions determined by the Energy Management System (EMS) Network Sensitivity application. The transmission related information exchange is accomplished over the EMS – Distribution Management System (DMS) interface.

The Model of transmission/sub-transmission system is needed to account for the impact of the distribution operations on transmission operations. With high penetration of DER and DR in distribution, the power flows, the voltages and voltage angles in transmission will significantly depend on the aggregate state and operations of the DERs. The Locational Marginal Prices (LMP) at the buses feeding the distribution system will depend on the DER operations and will impact their operations.

1.4.2.2 Modeling Distribution Circuit Connectivity

This sub-function provides a topological model of distribution circuits, starting from the distribution side of the substation transformer and ending at the equivalent load center on the secondary of each distribution transformer. A topological consistency check is performed every time connectivity changes. Presently, the model input comes from SCADA/EMS, Distribution SCADA, from field crews, from DISCO operator, from AM/FM/GIS, WMS, and OMS databases, and engineers. In the Smart Grid environment, additional information may come from processing outage detections by AMI and from secondary equivalents derived based on AMI-processed data. The AM/FM/GIS databases were not designed for real-time operational use. They lack many objects and attributes needed for ADA. The population of the databases is not supported by a comprehensive interactive consistency check. The existing extractors of data and the converters into ADA databases do not determine all data errors. The ADA applications must conduct additional data consistency checking and data corrections before recommendations and controls are issued. Typically utility do not have established procedures for regular update of the AM/FM/GIS databases by the operation and maintenance personnel. Therefore many changes implemented in the field remain unnoticed by the databases. Synchronization of the field state with the ADA database is a challenge in many utilities. Most of these databases do not include or do not update timely the data on the secondary distribution circuits

1.4.2.3 Modeling Distribution Nodal Loads

At the present time, the nodal load modeling in distribution is based on ‘typical’ real load shapes and expert estimates of the power factors for a number of load categories and on the monthly billing data. In the Smart Grid environment, the concept of ‘typical’ load shape is not applicable due to the variety of possible behavior of the many small distributed generators, electric storage devices, and plug-in electric vehicles, and demand response means scattered among many customers. The real and reactive load models, individual or aggregated, shall reflect the behavior of these composite loads depending on the known weather, prices, voltage, time of day, and other factors. In many cases, the models of the DER embedded in the customer systems can be considered as component of the behavioral load model. For instance, the model of a customer load with solar panels (passive, non-controllable, DER) would be a function of the sunlight (or time of day) and cloudiness, while the model of a customer load with a passive DER and with Demand Response would be, in addition, a function of the Demand Response conditions, e.g., energy price. However, if the DER is partially or fully controllable, it is preferable that its object model is separated from the load model.

With the penetration of the weather-sensitive DER in the customer domain, the nodal loads will become irregular due to the fluctuations of the embedded generation caused by variable cloudiness or wind changes. These fluctuations are random, however some of their statistics can be modeled based on their known parameters and weather forecast. Based on these statistics, the random component of the load should be accounted for in a way that is minimally detrimental to the optimization process. The maximum and minimum possible fluctuations can be derived from the nominal output of the DER under the predicted weather conditions at the particular times. The probability distribution of the fluctuations can be assessed based on historic data.

The load-to-voltage dependency is a critical attribute of the nodal load models in distribution. The presence of embedded DERs in the customer loads creates another level of complexity and variations of the net load-to-voltage dependency. The differences can be significant. Hence, corresponding information should be collected to define the applicable dependency at the specific time and under specific conditions.

In the Smart Grid environment, when many loads become “active” loads, behavioral load models depending on different triggers and conditions for load management should be developed. The input information for such models should be collected from the Smart Meters, including data collected via HANs, if permitted, customer EMS devices, from different sources of operational triggers, such as real-time pricing sources, reliability trigger sources, weather sensors and systems, contractual agreements with customers, DER schedules and characteristics, field test results, etc. Based on these conditions and historic data, the load models should be normalized to the nominal conditions, and dependencies of the load on the changes of these conditions should be derived. This will create the composite behavioral load models, which can be used in the DA applications, for which the actual near-real time and/or predicted impacting conditions would become available. Hence, collection of AMI data in the near-real time fashion for the direct use in the advanced DA applications, may not meet the requirements for information support of the advanced DA applications. A sophisticated pre-processing of AMI data along with other associated information will be needed.

1.4.2.4 Modeling Distributed Energy Resources (DER) and Micro-grids

This sub-function provides characteristics of real and reactive load generated by DER, connected to the secondary side of distribution transformer or to primary distribution circuits. These characteristics shall be sufficient to estimate the generated kW and kvars at a distribution node at any given time and shall include the generation schedules for short-term look-ahead timeframes, the current and possible modes of operation, the setpoints of automatic control, the availability of remote control, and the corresponding financial attributes. They also shall include capability curves.

Modeling Micro-grids is a more complex task. Micro-grids are small power systems embedded in a utility grid. A micro-grid has one or more distributed energy resources and loads and can operate either in parallel with the utility grid, or independently of the utility as an intentionally created electric island. The micro-grid is connected to the utility grid via an interconnection switch, which may be supplemented with a control system. Individual controllers with different functionalities can be installed for each of the distributed energy resources. The loads within the micro-grid may participate in different demand response programs and may be connected to different load shedding schemes. When the micro-grid operates in parallel, its object/data models are a part of the utility information infrastructure. The models of the micro-grids are different depending on the operational conditions.

The micro-grid can be viewed by the utility as an aggregated object behind the PCC. Then, the object models of the micro-grid shall represent the behavior of the net real and reactive powers flowing through the PCC under different normal and emergency conditions. The aggregated model is comprised of many micro-grid-internal component models representing the behavior of the loads, distributed generation, and electric storage. If the interior of the micro-grid is supposed to be transparent to the utility, then information infrastructure of the utility shall include the individual models of loads and DER devices the same as for other distribution system objects. However, even when utility performs individual monitoring and control of the micro-grid components, the behavior of the aggregated at the PCC model shall be known to the utility. The micro-grid can be disconnected from the utility at any moment and under different conditions, and the utility should know the aggregated impact of such separation on both the utility and on the micro-grid.

1.4.2.5 Modeling Distribution Circuit Facilities

These models, in addition to the conventional facility models, include the models of local controllers and of the secondary circuit equivalents. The local controllers of the DER are considered as a part of the DER object model. Currently, the most common controllable devices in distribution operating under the steady-state conditions are the locally controlled capacitors and voltage regulators. In the future, the different types of the DER may become automatically controlled devices operating under different contractual or user-defined conditions. For instance, the stand-alone DER may operate in a PQ mode, or in a PV mode, or in constant

Power Factor mode, or in maximum reactive power generation mode, etc. The DER located in a micro-grid may operate under individual conditions or can be controlled by an energy management system of the micro-grid following similar to the above net values. These controllable devices are component models of DOMA and shall be used in accord with the iterative results of the power flow calculations. Another important facility of the distribution models is the equivalent of the secondary circuits between the distribution transformer and the customer or DER. The secondary circuit equivalent models are critically important for modeling the voltage drop in the secondary and the impact of the DERs connected to the secondaries on the local voltages and on other operational parameters. Currently, the models of the secondary equivalents are predominantly determined based on expert estimates and may significantly differ from the real objects, resulting in large errors of voltage modeling and, consequently, in reducing the operational tolerances. Based on the voltages and powers measured by Smart Meters and other DER gateway means, adequate secondary equivalents can be derived. The secondary equivalents should be, at least, consistent with voltage drop and losses in the secondary. Such models can be derived based on AMI-collected data combined with valid voltage models at the distribution transformer buses.

All facilities should be modeled with sufficient details to support the required accuracy of Distribution Operation Modeling and Analysis application.

1.4.2.6 Distribution Power Flow

The sub-function models the power flow including the impact of automatically controlled devices (i.e., LTCs, capacitor controllers, voltage regulators), and solves both radial and meshed networks, including those with multiple supply busses (i.e. having Distributed Energy Resources interconnected to the power system and operating in different modes). Under conditions of the Smart Grid, the power flow/state estimation will need to additionally integrate the model components dependent on different external signals (price, utility desired modes, weather, etc.).

1.4.2.7 Analysis of adequacy of distribution system operations

The adequacy of the operations is defined by the loading of the distribution elements, by the transfer capacity of normally open ties, and by the consistency of the fault currents with the capabilities of distribution facilities and protection settings.

- Loading analysis. In this sub-function, the currents through the distribution elements are compared with the corresponding limits, based on the results of the power flow calculations.
- Evaluation of transfer capacity. This sub-function estimates the available bi-directional transfer capacity for each designated tie switch. The determined transfer capacity is such that the loading of a tie switch does not lead to any voltage or current violations along the interconnected feeders. The transfer capacity analysis shall take into account the availability and cost of

involvement of DER, Micro-grid, DR, PEV, ES, Volt/Var/Watt control and Multi-level Feeder Reconfiguration in the transfer of loads from feeder(s) to feeder(s).

- Fault analysis. This sub-function calculates a bolted three-phase, line-to-line-to-ground and line-to-ground fault currents for each protection zone associated with feeder circuit breakers and field reclosers. The minimum fault current is compared with protection settings while the maximum fault current is compared with interrupting ratings of breakers and reclosers. If the requirements are not met, the message is generated for the operator. With the distributed generation in the distribution systems, the fault current calculations shall take into account the impact of the DER, and the application shall check the coordination of the settings of different protection devices

1.4.2.8 Analysis of reliability - Contingency Analysis (CA)

This function performs an N-m contingency analysis in the relevant portion of distribution. The function shall run in the following modes:

1. Periodically
2. By event (topology change, load change, availability of control change)
3. Study mode, in which the conditions are defined and the application is started by the user.

The application informs the operator on the status of real-time distribution system reliability and shall be used for operation planning. For each contingency, the application returns optimum restoration solution based on the short-term forecast of the operating conditions covering the expected time of repair, thus providing dynamically optimal fault location and service restoration.

The updates needed to meet the Smart Grid requirements include the following:

- Handling of the Distributed Energy Resources, Demand Response, Electric Storage, and Electric Transportation as generation resources available for backup of the load, when needed
- Using the capability for intentionally created Micro-grids to maximize the amount of energized loads
- With significant penetration of DER, there will be a new kind of contingencies associated with a loss of a significant DER or with a loss of several DERs. The loss of several DERs or Micro-grids may happen due to a significant distortion of the operating conditions in the adjacent transmission systems. IEEE 1547 defines the voltage and frequency distortions, under

which the DER shall be automatically disconnected. These distortions can propagate to a large number of DER connected to the affected distribution system. The disconnection of these DERs may cause overloads and under-voltages in distribution and can worsen the situation in the transmission system. The severity of the contingency depends, among other conditions, on the DER protection settings, on the point of disconnection, and on balance between generation and loads in the point of disconnection. The transmission static contingency analysis or dynamic security analysis will defined the possible distortions caused by contingencies in transmission system. If the distortion can cause changes in distribution operations, which may include disconnection of DER and/or Micro-grids, or certain reactions of other controlling devices, these changes shall be accounted for in the transmission contingency analyses. Therefore, the aggregated at the buses of the transmission model characteristics of the emergency behavior of DER and other controlled devices shall be made known to Wide Area Situational Awareness function. On the other hand, the expected distortions of transmission operations shall be made known to the DMS for the distribution contingency analysis application to analyze the possible consequences.

1.4.2.9 Power Quality Analysis

Power quality analysis. This sub-function performs the power quality analysis by:

- Comparing voltages measured by AMI with the defined limits
- Comparing voltages calculated by validated power flow models with the limits
- Monitoring and summarizing the voltage sags (and swells, if available) measured by smart meters
- Monitoring and summarizing higher voltage and current harmonics measured by smart meters
- Monitoring and summarizing voltage imbalance in three-phase installations either measured by smart meters, or calculated by validated power flow models.
- Analyzing the correlations between higher harmonic levels and operations of shunt devices and power electronics, including converter-based DER devices.
- Determining the portion of time the power quality parameters are outside the limits
- Determining the amount of energy consumed during various power quality violations
- Recording the time when power quality violations occur

The sub-function shall provide the ability to estimate the expected power quality parameters during planned changes in circuit connectivity, reactive power compensation, DER and other power electronics operations. To accomplish the predictive power quality analysis, corresponding correlation models based on data collected by AMI and other information sources shall be developed and included in the information infrastructure for the distribution grid.

The sub-function should provide the ability to estimate the expected voltage quality parameters during the planned changes in connectivity, reactive power compensation, DER operations, DR executions, etc.

1.4.2.10 Analysis of the economic efficiency

The economic efficiency can be determined in different ways depending on the utility objectives, which, in turns, depend on the economic structure of the utility, whether it is an independent DISCO, or it is a part of a T&D company, or a cooperative, etc. Three components of the economic analysis will be discussed below.

- Evaluation of the cost of distribution operations. In different utilities the cost of operations can be defined differently. In the near-real time frame, it may include the cost of supply from both bulk energy sources and distributed energy sources, the incremental cost of demand response incentives, the penalties for limit violations, and the incremental payments by the customers. If the latter component is included, it should have an opposite sign than the cost of supply. In the retrospect, the actual AMI data can be used for more accurate evaluation of the cost of operations
- Evaluation of the incremental benefits due to a particular change in distribution operations implemented in the utility. The DOMA application can be setup to run “what-if” studies based on the near real-time conditions with a given difference of these conditions and compare the results with the actual near real-time conditions. For instance, a condition with implemented feeder reconfiguration for the purpose of reducing the Locational Marginal Prices can be compared with a condition without this reconfiguration, or the conditions with implemented conservation voltage reduction can be compared with the conditions without such voltage reduction, etc. If this comparison is executed every time the DOMA application runs, the incremental benefits can be accumulated for a given time interval.
- Energy loss analysis. This sub-function bases its analysis on calculations of technical losses (e.g., I2R, core, dielectric) for different elements of the distribution system (e.g., per feeder or substation transformer). For the defined area, these losses are accumulated for a given time interval (month, quarter, year, etc.). They can further be compared with the difference between the energy input (based on measurements) into the defined area and the total of relevant billed kWh (obtained from CIS and AMI), normalized to the same time interval. The result of the comparison is an estimate of commercial losses (e.g., metering errors and theft). The calculation of technical losses includes calculation of the I2R, core, and dielectric losses in primary distribution feeders, distribution transformers, capacitors, reactors, voltage regulator, step-down and step-up transformers, and

in the utility-owned secondary circuits. All the component data, except for the secondary circuits, can be made available from the corporate databases. The data on the secondaries are usually not adequately supported by these databases. With the significant penetration of the highly accurate smart meters, it may become possible to estimate the losses in the secondaries with an acceptable accuracy. If adequate models of these losses cannot be developed based on the combination of AMI data and other available sources, additional smart meters installed in the distribution circuits may be required.

1.4.2.11 Determining the dynamic T&D bus voltage limits

The dynamic optimization of the distribution system operations results in an optimum voltage at the distribution side of the Transmission and Distribution (T&D) substation. In most of the situations, this voltage can be supported by the voltage-regulating devices in the substation within a certain range of the transmission-side voltages. This range defines the transmission-side voltage limits at the time for which the distribution operations were optimized. For another time, the optimal voltage can be different, and the limits will be different also. That's why these limits are dynamic limits. There may be another set of dynamic voltage limits dependent on distribution system operations: the power quality limits, when the voltage at the buses shall satisfy the standard voltage tolerances at the customer terminals. These bus voltage limits depend on the loading and on the connectivity of the distribution system, which is dynamic by itself, and, therefore, these bus limits are also dynamic. The deviations from the optimal dynamic limits toward the quality dynamic limits result in additional operational cost and in the change of the total bus load due to load-to-voltage dependencies, as well as in the changes of the dynamic optimization in distribution. The latter may involve changes in demand response and DER operations. The deviations of the transmission-side bus voltage limits beyond the quality limits results in voltage violations at the customer terminals and in additional change of bus loads and in behavior of the DA applications, demand response, and DER operations. The cost of such violations is much higher than the cost of just non-optimum voltages.

1.4.2.12 Determining the aggregated available dispatchable real and reactive load at the T&D buses

The significant penetration of DER, Demand Response, and PEVs in combination with Volt/Var/Watt control and Feeder Reconfiguration applications will provide wide ranges of dispatchable loads at the T&D buses. These loads will be dependent on a number of conditions, such as real-time energy price signals, reliability signals (can be price also), ancillary service conditions, acceptable temporary voltage limit for peak load reduction, etc. These models will also be highly dynamic and shall be updated based on the component behavioral models of distribution and customer-side objects.

1.4.2.13 Determining the aggregated at the T&D buses load-to-voltage dependencies.

In many cases the EMS model of the transmission system is extended to the distribution buses of T&D substations. In this case, the load models are aggregated at this bus and shall represent the load-to-voltage dependencies at this level. These dependencies are composite dependencies constituted from the end-user load-to-voltage dependencies, loss-to-voltage dependencies in all elements of the distribution system, and DER and Demand Response reactions to changes of distribution voltage. It must be noted that the reactive load-to-voltage dependency may be much more responsive to voltage changes. These aggregated load-to-voltage dependencies should be submitted to the transmission domain for use in the Wide Area Situational Awareness applications (e.g., Contingency Analysis with Security Constrained Dispatch, Optimal Power flow).

1.4.2.14 Determining the aggregated at the T&D buses remedial action schemes parameters.

In many cased the actuators for Load-shedding Remedial Action Schemes (RAS) are located in the distribution system on per feeder basis. In the future, the load shedding could be done in a more refined manner moving it closer to the end users, and to micro-grids, operating in absorbing mode. This would improve the prioritization of load shedding and load restoration. The loads of the feeders are typically dynamic and will be more dynamic with significant penetration of DER, Micro-grids, and Demand Response. The Wide Area Measurement and Control System (WAMCS), which is the corner stone of the Wide Area Situational Awareness function, shall define for each moment the amount of load to be armed at different RAS schemes to satisfy the power security requirements. DA application shall support the model of available loads under different RAS, their interrelationships (the same load may be connected to different RAS), and their behavior under different circumstances. Note, that WAMCS is also a system which performs predictive optimization, and needs the behavioral models for the "what-if" look-ahead studies.

1.4.3 Fault Location, Isolation and Service Restoration (FLIR)

This application detects the fault, determines the faulted section and the probable location of fault, and recommends an optimal isolation of the faulted portions of the distribution feeder and the procedures for the restoration of services to its healthy portions. The key sub-functions performed by the application are as follows:

The objective of the fault location sub-function is most accurately identifying, in minimum time, the location of the fault. This Fault Location sub-function is initiated by SCADA inputs, such as lockouts, fault indications/location, and, also, by inputs from OMS, and, in the future, by inputs from Smart Meter outage detections and from fault-predicting devices. It determines the specific protective device, which has cleared the sustained fault, identifies the de-energized sections, and estimates the probable place of the actual or the expected fault. It distinguishes faults cleared by controllable protective devices from those cleared by fuses, and identifies momentary outages.

The objective of the fault isolation sub-function is de-energizing the faulted element of the distribution system with minimum de-energized load. It may involve opening of remotely controlled switching devices first and later, when the crew arrives, opening of locally controlled switches.

The objectives of the service restoration sub-function are as follows:

a. Minimum number and duration of customer interruptions due to the fault
b. Minimum switching operations
c. Minimum losses after reconfiguration

FLIR is constrained by the following operational parameters:

a. Loading of distribution facilities
b. Voltages at customer terminals
c. Loading of transmission facilities
d. Voltage angle differences for adjacent transmission buses
e. Demand response limitation
f. DER operational limitations
g. Electric storage discharge limitations

In the Smart Grid environment, the controllable variables for FLIR are as follows:

a. Switching devices within T&D substations
b. Switching devices in distribution feeders
c. Switching devices in DER Points of Common Coupling
d. Switching devices of individual DER
e. Demand response direct control triggers
f. Setpoints of DER controllers
g. Setpoints of micro-grid controllers
h. Setpoints of customer EMS
i. Reliability price signals.

j. Synchronization switching devices

It is assumed here that the VVWO application will be automatically involved by FLIR, if needed for volt/var and phase angle support.

The Fault Isolation and Restoration sub-function shall support three modes of operation:

1. Closed-loop mode, in which the sub-function is initiated by the Fault Indication sub-function. It generates a switching order (i.e., switching sequence) for the remotely controlled switching devices to isolate the faulted section, and restore service to the non-faulted sections. The switching order is automatically executed via distribution SCADA.

2. Advisory mode, in which the sub-function is initiated by the Fault Indication sub-function. It generates a switching order for remotely- and manually-controlled switching devices to isolate the faulted section, and restore service to the non-faulted sections. The switching order is presented to the operator for approval and execution.

3. Study mode, in which the sub-function is initiated by the user. It analyzes a saved case modified by the user, and generates a switching order under the operating conditions specified by the user.

The generated switching orders are based on considering the availability of remotely controlled switching devices, feeder paralleling, DER, and creation of intentional islands supported by distributed energy resources. The solutions are dynamically optimized based on the expected operating conditions during the time of repair.

If during execution, there is change in connectivity, the sub-function interrupts the execution and re-optimizes the solution based on new conditions. If during service restoration, there is another fault, the sub-function runs again considering a new fault scenario.

After the faulted element is repaired, the application shall recommend and execute, if so opted, the restoration of the distribution circuits to the state, which is the normal for the time of restoration.

The updates needed to meet the Smart Grid requirements include the following:

- Using the AMI outage detection capabilities for fault location
- Handling of the Distributed Energy Resources, Demand Response, Electric Storage, and Electric Transportation as generation resources available for backup of the load, when needed

- Using the capability for intentionally separated Micro-grids to maximize the amount of energized loads.
- Determine the timing and sequence of operations for restoration to the normal state including restoration of loads reduced by the Demand Response, and restoration of normal operations (synchronization) of the DERs and Micro-grids.

1.4.4 Multi-level Feeder Reconfiguration (MFR)

This is a multi-objective application, which dynamically optimizes the connectivity of the distribution systems.

The application recommends an optimal selection of feeder(s) connectivity for different objectives. It supports three modes of operation:

1. Closed-loop mode, in which the application is initiated by the Fault Location, Isolation and Service Restoration application, unable to restore service by simple (one-level) load transfer, to determine a switching order for the remotely controlled switching devices to restore service to the non-faulted sections by using multi-level load transfers, DER starts, and intentional islanding.
2. Advisory mode, in which the application is initiated by SCADA alarms triggered by overloads of substation transformer, segments of distribution circuits, or by DOMA detecting an overload, or by operator who would indicate the objective and the reconfiguration area. In this mode, the application recommends a switching order to the operator.
3. Study mode, in which the application is initiated and the conditions are defined by the user.

The application performs a multi-level feeder reconfiguration to meet one of the following objectives or a weighted combination of these objectives:

a. Optimally restore service to customers utilizing multiple alternative sources. The application meets this objective by operating as part of Fault Location, Isolation and Service Restoration.

b. Optimally unload an overloaded segment. This objective is pursued if the application is triggered by the overload alarm from SCADA, or from the Distribution Operation Modeling and Analysis, or from Contingency analysis. These alarms are generated by overloads of substation transformer or segments of distribution circuits, or by operator demand.

c. Minimize losses

d. Minimize exposure to faults

e. Equalize voltages.

The updates needed to meet the Smart Grid requirements include the following:

- Using MFR for swapping loads to reduce energy cost and assist in congestion management
- Taking into account the Distributed Energy Resources, Demand Response, Electric Storage, and Electric Transportation as generation resources or as dispatchable loads
- Using the capability for intentionally creating Micro-grids to accommodate feeder reconfiguration

1.4.5 Relay Protection Re-coordination (RPR)

This application adjusts the relay protection settings to real-time conditions based on the preset rules. This is accomplished through analysis of relay protection settings and operational mode of switching devices (i.e., whether the switching device is in a switch or in a recloser mode), while considering the real-time connectivity, tagging, and severe weather conditions. The application is called to perform after feeder reconfiguration, and, in case, when conditions are changed and fuse saving is required. The updates needed to meet the Smart Grid requirements include coordinating feeder protection and re-synchronization with Distributed Energy Resources and with Micro-grids.

1.4.6 Voltage, Var, and Watt Optimization (VVWO)

This is a major multi-objective and multi-faceted advanced DA application performing dynamic optimization of the distribution operations. As seen in the figure below, VVWO application has an impact on the operations of the generation, transmission, distribution, and customers systems. It also impacts some parameters of the energy market systems.

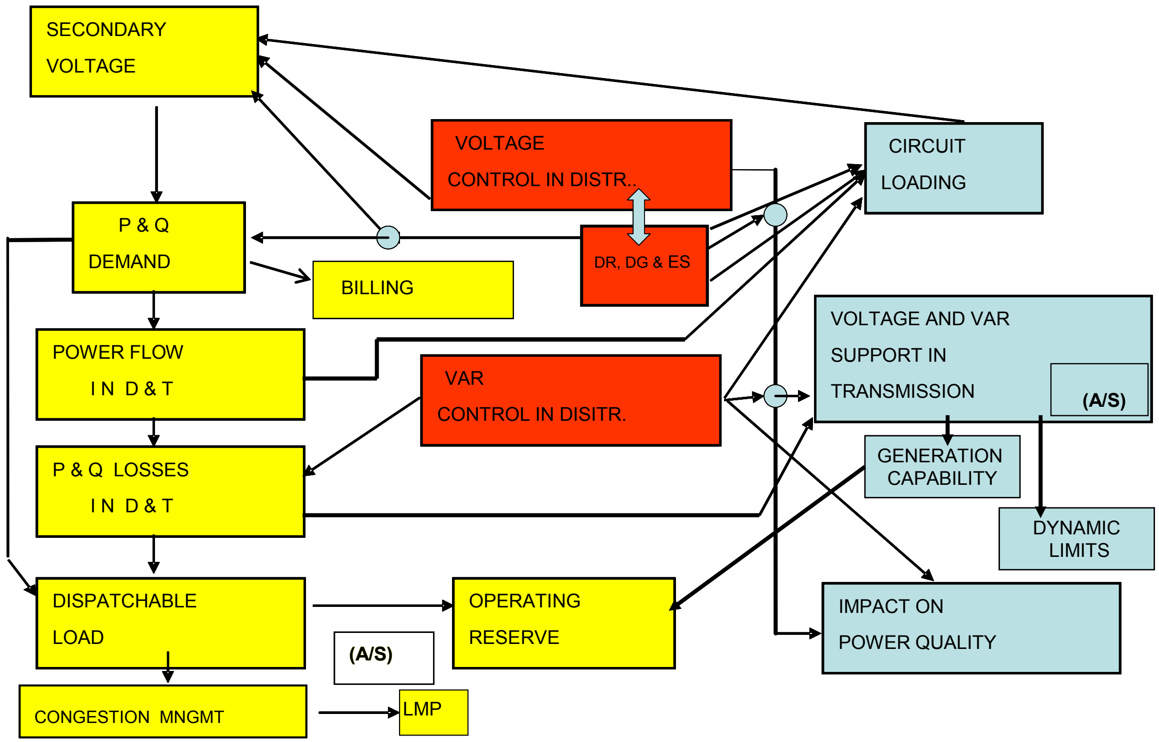


Figure 1

The VVWO application is capable of supporting the following objectives, which can be changed at different times following present scenarios, operator requests, or other application triggers:

- Minimize kWh consumption at voltages beyond given voltage quality limits (i.e., ensure standard voltages at customer terminals)
- Minimize feeder segment(s) overload
- Reduce load by a given value while respecting given voltage tolerance (either normal, or emergency)
- Conserve energy

- Reduce or eliminate overload in transmission lines
- Reduce or eliminate voltage violations on transmission lines
- Provide reactive power support for transmission/distribution bus
- Provide spinning reserve support
- Minimize cost of energy
- Reduce energy losses
- Expand the operational tolerances for generation/transmission operations
- Expand the operational tolerances for feeder paralleling in distribution
- Provide compatible combinations of above objectives

The VVWO application is constraint by the following limits:

- Loading limits of model elements
- Voltage limits at the equivalent customer terminals. These limits can be different for different customers or group of customers. By default, the standard voltage limits are assumed to be the customer-terminal limits. However, it is possible that some customers may have different from the standard limits. In this case, the individual limits shall be associated with the corresponding smart meter and the secondary circuit equivalent may be defined by the most critical voltage limit.
- Voltage limits in selected point of distribution primaries, including the distribution bus of the T&D substation
- Loading and voltage limits of selected transmission facilities
- Reactive power or power factor limits at selected busses in T&D
- Capability limits of distributed energy resources
- Operating reserve limits, if included in the model
- Limits of controllable devices:

– LTC limits

- Voltage regulator limits
- Capacitor control limits
- Demand response limits
- Electric storage limits
- Distributed generation control limits
- Power electronics limits

This VVWO application calculates the optimal states of the following controllable devices:

- Voltage controller of LTCs,
- Voltage regulators,
- DER controllers,
- Demand Response controllers
- Power electronic device controllers
- Capacitor controllers
- Electric Storage controllers
- Electric Vehicle controllers
- Micro-grid controllers

The application supports three modes of operation:

1. Closed-loop mode, in which the application runs periodically (e.g., every 15 min) and is triggered by an event (i.e., topology or objective change), based on real-time information. The application's recommendations are executed automatically via SCADA control commands.
2. Study mode, in which the application performs "what-if" studies, and provides recommended actions to the user.

3. Look-ahead mode, in which conditions expected in the near future can be studied (from one hour through one week) by the user.

The updates needed to fully meet the Smart Grid requirements are as follows:

- The application shall be based on dynamically changed behavioral models of the real and reactive load, Demand Response means, DER, and Micro-grid, and power flow models derived based on AMI-provided data.
- The application shall be able to include as controllable variables the Demand Response means and DER parameters and issue corresponding signals to these variables in the close-loop control sequences.

If, during optimization or execution of the solution, the circuit status changes, the application is interrupted and solution is re-optimized. If, during execution, some operations are unsuccessful, solution is re-optimized without involving the malfunctioning devices. If some of the controllable devices are unavailable for remote control, solution does not involve these devices but takes into account their reaction to changes in operating conditions.

1.4.7 Pre-arming of Remedial Action Schemes (RAS)

This application receives pre-arming signals from an upper level of control and changes the settings (tuning parameters) of distribution-side remedial action schemes (RAS), e.g., load-shedding schemes (a component of self-healing grid) or intentional islanding of DER and loads into Micro-grids. The protection settings of the DER leading to unintentional separation of the DER with or without loads shall be taken into account.

To meet the Smart Grid requirements, the application shall provide coordination of remedial action schemes with Distributed Energy Resources, Demand Response, Electric Storage, Electric Transportation, and Micro-grids. The coordination shall take into account the available extent and timing of their involvement to determine which fast-acting remedial schemes shall be armed and which slow-acting means are available and can be counted on.

1.4.8 Coordination of Emergency Actions

This application recognizes the emergency situation based on changes of the operating conditions or on reaction of some RAS to operational changes and coordinates the objectives, modes of operation, and constraints of other Advanced Distribution Automation applications. For example, Under-frequency Load Shedding Schemes trigger emergency load reduction mode of Volt/var/Watt control, or the under-frequency protection of Distributed Energy Resources triggers the pre-armed intentional islanding. These are post-disturbance activities.

To meet the Smart Grid requirements the application shall include coordinating emergency actions between the RAS, DA applications, Distributed Energy Resources, Demand Response, Electric Storage, Electric Transportation, and micro-grids.

1.4.9 Coordination of Restorative Actions

This application coordinates the restoration of services after the emergency conditions are eliminated. For example, Advanced Distribution Automation System changes the order of feeder re-connection, after they have been disconnected by the RAS, based on current customer priorities or inhibits return to normal voltage until there are disconnected feeders.

To meet the Smart Grid requirements the application shall include the following:

- Restoration of loads disconnected by RAS coordinated with the dynamically changing availabilities provided by the transmission, generation and distribution systems.
- Restoration of loads changed by DA applications and Demand Response to normal levels based on the dynamically changing restorative operating conditions
- Re-synchronization of Distributed Energy Resources and micro-grids based on the post-contingency operating conditions.

There is a number of planning function involving DA applications. Implementing the advanced DA functions to their maximum extent will require optimal allocation and prioritization of controllable equipment in the distribution system (automated switching devices, controllable capacitors, voltage regulators, demand response installations, etc.). These planning activities cannot be accomplished without knowing what is expected from the DA applications, because different stakeholders may have different dominant objectives and other requirements for these applications. The outcome of the planning applications developed based on better input information due to AMI would provide greater benefits of the DA applications also attributable to AMI.

1.4.10 Intelligent Alarm Processing

This application analyzes SCADA and DOMA-generated alarms and other rapid changes of the operational parameters in distribution and transmission and summarizes the multiple alarms into one massage defining the root cause of the alarms. For example, multiple sudden voltage violations along a distribution feeder and overloads of some feeder segments may be caused by a loss of DER excitation, or successful reclosing of a portion of feeder with loss of significant load may be caused by miss-coordination of the recloser settings and a particular fuse protecting a loaded lateral. The outage detection by the Smart Meters, the relay protection signals from DER controllers and customer EMS will contribute to the information support of the application..

1.5 Actor (Stakeholder) Roles[2]

Describe all the people (their job), systems, databases, organizations, and devices involved in or affected by the Function (e.g. operators, system administrators, technicians, end users, service personnel, executives, SCADA system, real-time database, RTO, RTU, IED, power system). Typically, these actors are logically grouped by organization or functional boundaries or just for collaboration purpose of this use case. We need to identify these groupings and their relevant roles and understand the constituency. The same actor could play different roles in different Functions, but only one role in one Function. If the same actor (e.g. the same person) does play multiple roles in one Function, list these different actor-roles as separate rows.

#	Actor	Actor Type	Description	Functionality related to ADA applications
1	Distribution Operator	Person	Person in charge of distribution operations during the shift	The operator sets up the ADA applications, defining the objectives, the modes of operations, the contents of application results presented to the operator, provides certain input data, monitors the results of ADA applications, requests additional information, when needed, authorizes the ADA recommendations, makes decisions based on ADA recommendations, etc. Normally, the operator defines the options for the close-loop control in advance, but does not take a part in the close-loop control.
2	Distribution SCADA	System	DSCADA collects data from IEDs beyond the fence of the T&D substation and supports remote control of controllable devices in the field either in supervisory or close-loop modes. The field IEDs include utility DER and Micro-grid controllers, may include customer EMS.	Distribution SCADA database is a major source of input data for the ADA applications. It is updated via remote monitoring and operator inputs. DSCADA is used for execution of ADA application solutions either in supervisory, or in close-loop modes.
3	Transmission SCADA/EMS	System	SCADA/EMS collects data from IEDs within the T&D substation and supports remote control of controllable devices in the	Transmission and generation management system providing DA with transmission/generation-related objectives,

[2] Includes excerpts from an ongoing UCI study sponsored by EPRI

			substation. The EMS runs the applications for analysis and control of the transmission and generation systems.	constraints, and input data. EMS system contains the transmission power system model, and can provide the transmission connectivity information for facilities in the vicinity of the distribution power system facilities and with outputs from other EMS applications.
4	Aggregator/ Energy Services Company	Company	A person or company combining two or more customers into a single purchasing unit to negotiate the purchase of electricity from retail electric providers, or the sale to these entities. The transaction may include electricity consumption and demand, DER/Micro-grid generation, Demand Response "Nega-watts", and ancillary services. Aggregators also combine smaller participants (as providers or customers or curtailment) to enable distributed resources to play in the larger markets.	The agreement between the customers and the Aggregators, if approved by the utility, define the conditions under which the DERs will operate during pre-defined times, and the operational tolerances for control of these devices, if any.
5	3rd Party, External Systems (e.g. Weather)	Systems	Public information systems outside the utility, provides the utility with information on weather and major event relevant to utility operations.	The information obtained from these systems is used by the modeling components of ADA for adjustment of the behavioral models. This information is most important for the development of the models of weather-dependent DERs.
6	DMS	System	A set of integrated IT systems and ADA applications supporting the operations, maintenance, and planning of the electric distribution system	ADA applications are a central component of DMS, being supported by DMS corporate databases, such as AM/FM/GIS, and interfaced with other IT systems, such as OMS and WMS.
7	DMS Gateway	Sub-system	Computer-based system consisting of Graphic User Interface, interface with	Accepts, checks, and organizes information obtained from DSCADA, Operators and other

			distribution SCADA, and ADA applications	authorized personnel and triggers ADA applications according to the given setups. Accepts output information from ADA applications and initiates execution of their instructions.
8	Customer EMS	System	A customer supplied system for monitoring and managing energy use at their residence or business. It includes human interface displays for interacting with the system and allows the customer to program functions, control loads, and display energy costs, usage, and related information. It can be programmed to take action based upon price inputs or event messages from the utility, or changes to customer's load. Interfaces with HAN devices and the Smart Meter	Measurements and storage of aggregated data from Smart Meters: kW and kvar kWh Load profiles Interval average voltages Instantaneous voltages Instantaneous frequency Weather data. Services: DER monitoring and control functions Demand Response functions Information for customers and third parties Communications with HAN and Smart Meters
9	DER controller/gate way	Device	Measures, stores and communicates current generation, generation schedules, capability curves, protection settings, mode of operations and voltage/var control settings, and other data needed for current and predictive model of DER operations	Communicates with DER Data Management System or other systems dedicated to manage DER and with DA applications. Supports control of frequency and voltages if included in an intentionally created electric island.
10	Micro-grid interconnectio n controller in PCC	Device	Calculates, stores, and communicates aggregated load, Demand Response, Generation data for the Micro-grid, Protection settings and settings for frequency and voltage control for connected and for autonomous modes of operations,	Communicates with Data Management System or other systems dedicated to manage Micro-grids and with DA applications. Supports control of frequency and voltages in autonomous mode of operations.

			other data needed for current and predictive model of Micro-grid operations.	
11	Smart Meter	Device	Advanced electric revenue meter capable of two-way communications with the utility. Serves as a gateway between the utility, customer site, and customer's load controllers. Measures, records, displays, and transmits data such as energy usage, generation, text messages, and event logs to authorized systems and provides other advanced utility functions.	Measurements and storage of: kW and kvar kWh Load profiles Interval average voltages Instantaneous voltages Instantaneous frequency Weather data. Services: Last Gasp/AC Out Demand Response functions Information for customers and third parties Communications with HAN
12	Customer appliances, embedded in customer premises	Devices	Equipment and systems at the customer site that could participate in demand response and other programs	Components of behavioral load models for ADA applications
13	DER, PEV, and Electric Storage embedded in customer premises	Devices	Equipment and systems at the customer site that could participate in demand response and other programs	

14	AM/FM/GIS	System	Repository of distribution system assets, their relationships (connectivity), ownerships, nominal states, and links to associated objects.	AM/FM system contains the geographical information of the distribution power system circuit connectivity, as well as the parameters describing the power system facilities, including all electric characteristics of distribution transformers, as well as circuit connectivity and parameters of secondary circuits between the distribution transformers and customers or their equivalents consistent with voltage drops and power losses. Conceptually, the AM/FM/GIS database can contain transmission connectivity and facility data and relevant to distribution operations customer-related data. AM/FM/GIS databases is interfaced with the Customer Information System for linkage between the customer data and point of connection, with AMI, DER, and DR data management systems for updates of secondary circuit equivalents, and behavioral models of load, DER, ES, and DR. Alternative interfaces between these data management systems and ADA are possible. AM/FM/GIS databases are also accessible to field crews via mobile computing for updates on facility connectivity and parameters. The AM/FM/GIS databases shall be updated, proof-tested and corrected in a timely manner to provide a high probability of preparedness for supporting near-real-time ADA applications.

15	Connectivity and facility parameters validation processor	Process	GIS information should be validated on two levels: 1) validation of connectivity and distribution transformer loading, and 2) integrated validation on operational reasonability.	The first level of validation can be performed by analyzing the consistency of connectivity (de-energized elements, loops, wrong phasing, etc.) and by analyzing the consistency of customer association with the distribution transformers and of its loading. The second level of validation is based on the consistency of the power flow and contingency analysis results with the utility policies.
16	Customer Information System (CIS)	System	Customer information including billing data, customer types, links to distribution circuits	CIS communicates with AMI, DER, and DR data management systems. It contains consumption and demand data on per customer basis for pre-defined time intervals of measurements by the Smart Meters, as well as composite data for billing periods. It also contains information on other customer properties, like customer type, rate schedules, etc.
17	DER data management system	System	A specific database for DER attributes, behavioral models, contracts, and performance associated with the owner.	DER data management system is interfaced with AMI data management system, Aggregators, with the Load Management System, and with the ADA applications providing DER behavioral models.
18	AMI Data Management System	System	Gathers, validates, estimates, and permits editing of meter data such as energy usage, generation and meter logs. Stores this data for a limited amount of time before it goes to the Meter Data Warehouse and makes the data available to authorized systems.	Derives aggregated at the distribution transformer load profiles Communicates either directly or through a network Management system with the Smart meters Communicates with DA applications

			Includes load model processor and secondary equivalent processor.	Provides ADA with behavioral load models.
19	Load Management/ Demand Response System	System	Executes and monitors requested demand response resources. Sends out demand response event notifications to Smart Meters and customers. Controls DR, DER, PEV and ES charging/discharging.	Executes ADA commands for aggregated load control, is interfaced with the Aggregators, and ensures execution of the market-related contracts.
20	Demand Response Data Management System	System	Stores and processes data on load management/Demand Response programs, contracts, relevant historic information, creating behavioral models for Demand Response.	Is interfaced with AMI Data Management System. Communicates with Load model processor; Communicates with ADA applications.
21	DOMA	Application	Distribution Operation Model and Analysis is an advanced DA application. It runs periodically and by event; models near real-time power flow; Provides situational awareness of distribution operations; Provides background models for other ADA applications.	Utilizes behavioral nodal load, DER Micro-grid, and PV models and secondary equivalents. Communicates with AMI, DER, and DR data management systems..
22	VVWO	Application	Volt/var/Watt Optimization is an ADA application. It runs periodically and by event; optimizes states of voltage, var, DER, Micro-grid controllers, and Demand response means;	Communicates with DOMA, Demand Response/Load Management System, Customer EMS, and with interconnection controllers at the PCCs.
23	FLIR	Application	Fault Location, Isolation, and Service Restoration. An ADA application. Identifies and locates the fault, isolates the faulted element from healthy sections and restores services to the customers connected to the healthy sections. Assesses, for the duration of repair, the situation with loads, DER,	Communicates with DOMA, Demand Response/Load Management System, Customer EMS, and with interconnection controllers at the PCCs.

			Demand response and Micro-grids	
24	Field Crew	Persons	Manual operations of field devices, repair, construction work, patrolling and other assignment in the field	Field crews are able to communicate with the distribution system operator and with GIS management via mobile communications and computing
25	Market Operation System (MOS)	System	Wide-area energy market management system providing high-level market signals for DisCos	Market for energy products, including bulk generation, distributed generation, electric storage, electric transportation, and demand response.
26	ISO/RTO	Systems	ISO: An independent entity that controls a power grid to coordinate the generation and transmission of electricity and ensure a reliable power supply. RTO: An independent organization that coordinates, controls, and monitors the operation of the electrical power system and supply in a particular geographic area; similar to Independent System Operator.	Issues aggregated load management requirement to EMS/DMS/Operators;
27	Engineering	Person	Planning, and DMS maintenance personnel, power quality and reliability engineers, etc.	Recommends setups of ADA applications, monitors performance of ADA applications, troubleshoots applications, reviews report, etc.

Replicate this table for each logic group.

1.6 Information exchanged[3].

Fig. 1 presents the logical interfaces between the major actors for the DGM use case.

[3] Includes except from an ongoing UCI study sponsored by EPRI.

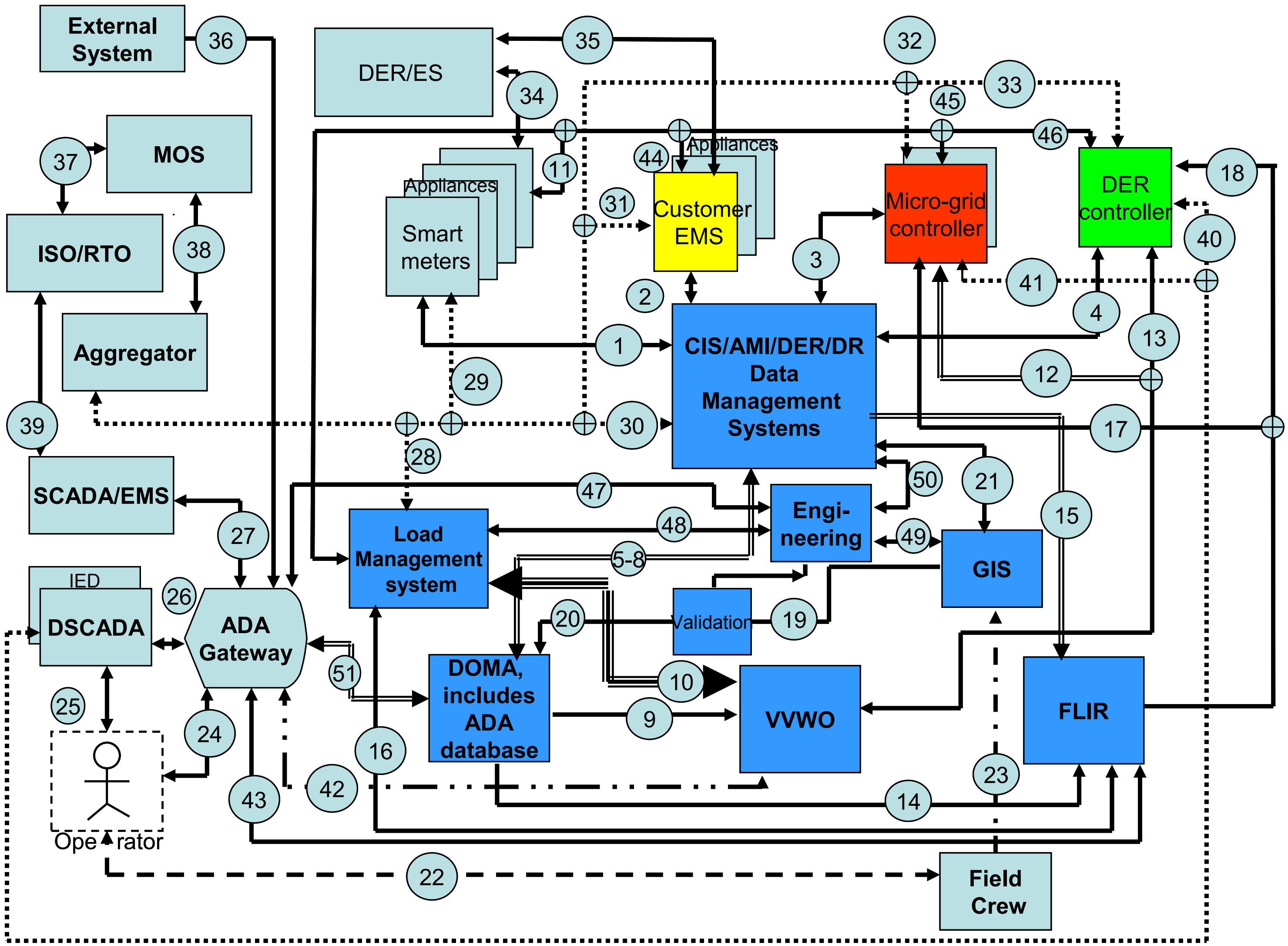


Figure 1. Interface diagram for DGM use case

Table 1. Description of Interfaces.

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
1		Smart Meter	AMI Data Management System (including Last Gasp service)	kW and kvar kWh Load profiles Interval average voltages Weather data Demand response triggers received with timestamps; Commands issued for Demand Response (thermostat, appliances, DER, Storage).	Large	Once a day	Revenue accuracy for kW and kvar; 0.5%-0.2% accuracy for Voltages
1		Smart Meter	AMI Data Management System	Instantaneous voltages Instantaneous frequency from dedicated meters in autonomous mode of Micro-grid Last Gasp/AC Out	Small to average	Last gasp -immediately from selected first-reporters; Instantaneous voltages within minutes after fault; Instantaneous frequency from dedicated meters – report by exception	0.5%-0.2% for Volt; 0.1% for Hz
1		AMI Data Management System	Smart Meter	Real-time prices Demand response triggers and amount Data requests	Small to average	Immediately after change	
2		Customer EMS	AMI Data Management	Aggregated from Smart Meters: kW and kvar	Small to average	Once a day	Revenue accuracy for

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
			System	kWh Load profiles Interval average voltages Weather data. Demand response triggers received with timestamps; Commands issued for Demand Response (customers' Smart Meters, thermostat, appliances, DER, Storage).			kW and kvar; 0.5%-0.2% accuracy for Voltages
2		Customer EMS	AMI Data Management System (including Last Gasp service)	Lowest instantaneous voltages from included Smart Meters Instantaneous frequency Last Gasp/AC Out from selected Smart Meters	Small to average	Last gasp -immediately from selected first-reporters; Instantaneous voltages within minutes after fault; Instantaneous frequency – report by exception	0.5%-0.2% for Volt; 0.1% for Hz
2		AMI Data Management System (including Last Gasp service)	Customer EMS	Real-time prices Demand response triggers and amount Data requests	Small to average	Immediately after change	
3		Micro-grid interconnection controller in PCC	AMI Data Management System	Aggregated for Micro-grid, Net, load and generation kW and kvar Net, load and generation kWh	Small to average	Once a day	Revenue accuracy for kW and kvar; 0.5%-

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
				Net, load and generation load profiles Interval average voltages from selected Smart Meters Weather data. Demand response triggers received with timestamps; Commands issued for Demand Response (customers' Smart Meters, thermostat, appliances, DER, Storage) Protection settings and settings for frequency and voltage control for connected and for autonomous modes of operations, Operational limits O&M cost functions Other data needed for current and predictive model of Micro-grid operations.			0.2% accuracy for Voltages
3		Micro-grid interconnection controller in PCC	AMI Data Management System	Lowest instantaneous voltages from included Smart Meters Instantaneous frequency Last Gasp/AC Out from selected Smart Meters	Small to average	Last gasp -immediately from selected first-reporters; Instantaneous voltages within minutes after fault; Instantaneous frequency – report by exception in autonomous mode of	0.5%-0.2% for Volt; 0.1% for Hz

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
						operations.	
3		AMI Data Management System	Micro-grid interconnection controller in PCC	Real-time prices Demand response triggers and amount Disconnection command for intentional islanding Desired kW and kvar setpoints Desired voltage setpoints Data requests	Small to average	Immediately after change	
4		DER &Controller	AMI Data Management System	Generation kW and kvar Generation kWh Generation profiles Interval average voltages Weather data. Generation change triggers received with timestamps; Active protection settings and settings for voltage control in the connected mode of operations and voltage and frequency control settings for island mode of operations, Capability curve Synchronization settings O&M cost functions	Small to average	Once a day	Revenue accuracy for kW and kvar; 0.5%-0.2% accuracy for Voltages
4		DER &Controller	AMI Data Management System	Lowest instantaneous voltages before disconnection Instantaneous frequency in island	Small	Immediately after change	0.5%-0.2% for Volt; 0.1% for Hz

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
				mode Last Gasp/AC Out or protection actions			
4		AMI Data Management System	DER &Controller	Real-time prices Desired kW and kvar setpoints Desired voltage setpoints Data requests Synchronization commands	Small	Immediately after change	
5		AMI Data Management System	Load model Processor	kW and kvar profiles for every day Impacting factors with time stamps Weather Demand response with start and stop times Other related events with timestamps	Large	Once a day	
6		Load model Processor	DOMA	List of nodes in clusters Name of clusters Representative nodal load models for clusters of similar loads	Average	Once a day	
7		AMI Data Management System	Secondary Equivalent processor	Daily kW and kvar load profiles from individual Smart meters and aggregated at the distribution transformer load profiles Daily profiles of interval-average voltages	Large	Once a day	

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
8		DOMA	Secondary Equivalent processor	Modeled voltages at the secondary buses of distribution transformers	Large	On request by Secondary Equivalent processor (once a month or less frequent)	
8		Secondary Equivalent processor	DOMA	Dependencies of critical voltages on nodal loads Dependencies of losses in secondaries on nodal loads	Large	After significant change (once a month or less frequent)	
9		DOMA	VVWO	All component of operation models (can be integrated in VVWO)	Large	Every run of DOMA and VVWO (e.g., every 5-15 min.)	
10		VVWO	Load Management System	Triggers of Demand response for selected nodes Desired amount of Demand Response in selected nodes	Low	Up to every run of VVWO. Immediately after successful execution of previous steps.	
10		Load Management System	VVWO	Available Demand Response per node Constraint of Demand Response per node	Average	After significant change	
11, 44, 45, 46		Load Management System	Smart Meters; Customer EMS; Micro-grid controller; DER controller	Triggers of Demand response for selected nodes Desired amount of Demand Response in selected nodes Triggers of Demand Response for aggregated loads of Micro-Grid to Micro-grid controllers Triggers of Demand Response for aggregated loads to Customer	Small	Immediately after receiving solution.	

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
				EMS Information on assigned emergency voltage limit (In case of emergency load-reducing VVWO)			
11, 44, 45, 46		Smart Meters; Customer EMS; Micro-grid controller; DER controller	Load management system	Customer choices, contractual conditions, and DER/ES attributes.	Small to Medium	After significant changes	
12		VVWO	Micro-grid interconnection controller in PCC	Triggers of Demand response for selected nodes in connected mode Desired amount of Demand Response in selected nodes Desired net kW and kvar exchange Desired settings or mode of operation for var or voltage control	Small	Up to every run of VVWO. Immediately after successful execution of previous steps.	
12		Micro-grid interconnection controller in PCC	VVWO	Available Demand Response per PCC Constraint of Demand Response per PCC Constraints of kW and kvar exchange Constraints on voltage control	Small	After significant change	
13		VVWO	DER controller	Desired state of DER (On/Off)	Small	Up to every run of	

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
				Desired kW and kvar generation Desired settings or mode of operation for var or voltage control		VVWO. Immediately after successful execution of previous steps.	
13		DER controller	VVWO	Actual state of DER Actual kW and kvar Schedule of kW and kvar for look-ahead times Actual settings and mode of operation for var and voltage control	Small	Up to every run of DOMA	
14		DOMA	FLIR	All component of operation models (can be integrated in FLIR)	Large	Every run of DOMA (e.g., every 5-15 min.)	
15		AMI Data Management System	FLIR	Last Gasp/AC Out Instantaneous voltages	Small to average	Last Gasp – immediately after lock out Instantaneous voltages – within minutes after fault	
16		FLIR	Demand Response System	Triggers of Demand response for selected nodes Desired amount of Demand Response in selected nodes	Small	After fault, and after repair. Up to every run of FLIR.	
16		Demand Response System	FLIR	Available Demand Response per node Constraint of Demand Response per node	Small to average	After significant change	
17		FLIR	Micro-grid	Desired state of Micro-grid	Small	After fault and after	

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
			interconnection controller in PCC	(Connected or autonomous) Triggers of Demand response per Micro-grid Desired amount of Demand per Micro-grid Desired net kW and kvar exchange		repair. Up to every run of FLIR	
17		Micro-grid interconnection controller in PCC	FLIR	Available Demand Response per PCC Constraint of Demand Response per PCC Constraints of kW and kvar exchange	Small	After significant change	
18		FLIR	DER controller	Desired state of DER (On/Off) Desired kW and kvar generation	Small	After fault and after repair. Up to every run of FLIR	
18		DER controller	FLIR	Actual state of DER Actual kW and kvar Schedule of kW and kvar for look-ahead times Protection settings	Small	After significant change	
19		GIS	Validation	Circuit connectivity, facility parameter, customer association with the network data;	Large volume initially, medium volume for updates	Initially before commissioning DMS, and regularly after significant changes (once a day, or more frequently) and after corrections	High
19		Validation	GIS	Reports on inconsistent data	Small to	Initially before	N/A

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
					Medium	commissioning DMS, and regularly after significant changes (once a day, or more frequently)	
20		Validation	DOMA	Validated data on circuit connectivity, facility parameter, and customer association with the network	Large volume initially, medium volume for updates	Immediately after full validation	
21		GIS	Data Management Systems	Connectivity and parameter data on DER, ES, DR	Small to Medium	After significant change	
21		Data Management Systems	GIS				
22		Field Crew	Operator	Work-related information according to the ticket	Small	According to safety and maintenance rules	
22		Operator	Field Crew	Work-related information according to the ticket	Small	According to safety and maintenance rules	
23		Field Crew	GIS	States and parameters of the corresponding equipment observed in the field according to pre-defined instructions (template)	Small	During the presence at the subject in the field	Verified information
24		Operator	DMS	Setup of the ADA applications, requests for particular information	Small	As needed	
24		DMS	Operator	Pre-defined output data and messages from ADA applications,	Small	On pre-defined periodicity for normal	

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
						output; immediate after an alarming/warning event and on operator's demand	
25		Operator	DSCADA	Supervisory control commands, requests for particular information, setup of SCADA functions	Small	Minimum response time	
25		DSCADA	Operator	Analog and Status data in predefined screens of the graphical user interface, output of SCADA functions	Medium to Large	Minimum reporting and response times	According to efficient utilization
26		DSCADA	DMS	Near real-time analog and status information from the observable portions of the distribution power system	Medium to Large	Minimum exchange times	According to efficient utilization
26		DMS	DSCADA	Control commands from ADA applications executable by DSCADA	Small to Medium	Minimum exchange times	
27		SCADA/EMS	DMS	Near real-time analog and status information from the observable portions of the transmission and generation systems	Medium to Large	Minimum exchange times	According to efficient utilization
27		DMS	SCADA/EMS	Dynamic limits, multi-attribute aggregated bus load models	Medium to Large	After each run of ADA application	<=1% for voltage
28		Aggregator	DR System	Market/Contractual conditions for participation in capacity, ancillary service markets and related information	Medium	According to market rules	
28		DR System	Aggregator	Individual and aggregated	Medium	According to market	

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
				customer choices, contractual agreement, etc.		rules	
29		Aggregator	Smart Meters	Information relevant to participation in the market	Medium	According to market rules	
29		Smart Meters	Aggregator	Information relevant to participation in the market	Medium	According to market rules	
30		Aggregator	Data Management Systems	Contractual information needed for development of behavioral models	Medium	According to market rules	
30		Data Management Systems	Aggregator	Historic information relevant to performance of market participants	Medium	According to market rules	
31		Aggregator	Customer EMS	Information relevant to participation in the market	Medium	According to market rules	
31		Customer EMS	Aggregator	Information relevant to participation in the market	Medium	According to market rules	
32		Aggregator	Micro-grid controller	Information relevant to participation in the market	Medium	According to market rules	
32		Micro-grid controller	Aggregator	Information relevant to participation in the market	Medium	According to market rules	
33		Aggregator	DER controller	Information relevant to participation in the market	Medium	According to market rules	
33		DER controller	Aggregator	Information relevant to participation in the market	Medium	According to market rules	
34		Smart meters	Customer Appliances	Control commands for Demand response and Energy Efficiency	Small		

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
34		Customer Appliances	Smart meters	Statuses of appliances	Small		
35		Customer Appliances	Customer EMS	Control commands for Demand response and Energy Efficiency	Small		
35		Customer EMS	Customer Appliances	Statuses of appliances	Small		
36		External Systems	DMS	Environmental data by locations; Other information impacting the behavior of the customer loads	Medium to Large	Periodically and by significant changes.	
36							
37		MOS	ISO/RTO	Price signals and other market-related information	Medium		
37		ISO/RTO	MOS	Authorization of transactions and other relevant information	Medium		
38		MOS	Aggregator	Price signals and other market-related information	Medium		
38		Aggregator	MOS	Information on behalf of customers	Medium		
39		ISO/RTO	SCADA/EMS	Prices and congestion related information, aggregated load management requirements	Medium	Day-ahead, hour-ahead; 5-15 minute-ahead	
39		SCADA/EMS	ISO/RTO	Near-real time operation models, reports on load management, available dispatchable load by areas, etc.	Large	Very short update times (~ 1sec)	
40		DSCADA	DER	Control commands for start, stop, change of kW and kvar, change of	Small	1-2 sec.	

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
				mode of operations, change of setpoints.			
40		DER	DSCADA	Analog and status of DER elements, alarms, setpoints of control and protection, etc.	Small to Medium	1-2 sec	
41		DSCADA	Micro-grid	Control commands for open/close of PCC switches, change of net kW and kvar, change of mode of operations, change of setpoints.	Small	1-2 sec	
41		Micro-grid	DSCADA	Analog and status of Micro-grid elements, alarms, setpoints of control and protection, etc.	Small to Medium	1-2 sec	
42		DMS Gateway	VVWO	VVWO options	Small	1 - 2 sec after change	
42		VVWO	DMS Gateway	Optimal setpoints and statuses, heartbeats, summary output data for the user	Small	1- 2 sec after VVWO solution	
43		DMS Gateway	FLIR	FLIR options, fault indicators, lock-out signals, Fault location,			
43		FLIR	DMS Gateway	Switching sequences	Small	1-2 sec after the lockout signal	
47		DMS Gateway	Engineering	Selected information for review based on authorization. Results of case studies	Small		
47		Engineering	DMS Gateway	Request and input data for case studies, review of case studies results. Setup of ADA applications according to authorization.	Small	1-2 seconds respond times.	
48		Engineering	Load	Engineering conditions for load	Small		

#	# in the SD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
			Management System	management; Plans for load management			
48		Load Management System	Engineering	Reports on load management and other relevant information for engineering designs and planning	Small to Medium		
49		Engineering	GIS	Information on future installation; Correction and update on existing information	Small to Medium		
49		GIS	Engineering	Diagrams, connectivity, parameters, associated loads for design, studies and planning purposes	Medium		
50		Engineering	Data Management Systems	Software and relevant input data for data management systems	Medium		
50		Data Management Systems	Engineering	Reports and selective extracts on data management system performance			
51		DMS Gateway	DOMA	DSCADA/SCADA/EMS analog and status snapshots; operators options for ADA applications	Medium to Large	1-2 seconds updates	
51		DOMA	DMS Gateway	Results of DOMA for the operators and for SCADA/EMS	Small to Medium	1-2 sec after DOMA run	

1.7 Activities/Services

Describe or list the activities and services involved in this Function (in the context of this Function). An activity or service can be provided by a computer system, a set of applications, or manual procedures. These activities/services should be described at an appropriate level, with the understanding that sub-activities and services should be described if they are important for operational issues, automation needs, and implementation reasons. Other sub-activities/services could be left for later analysis.

Activity/Service Name [5]	*Activities/Services Provided* [6]
DOMA: ADA updates power system model and analyzes distribution operations	• Update of a) topology model b) facilities model c) load models, based on AMI processed data d) relevant transmission model • Analysis of real-time operating conditions using distribution power flow/state estimation • Evaluation of service restorability using feeder reconfiguration, micro-grids, demand response, DERs, and VVWO. Evaluation of system transfer capacity based on real-time measurements • Issue of alarming/warning messages to the operator • Generation of distribution operation reports and logs
FLIR: ADA performs fault location, fault isolation, and service restoration	• ADA indicates faults cleared by controllable protective devices by distinguishing between: a) faults cleared by fuses b) momentary outages c) inrush/cold load current

Activity/Service Name [5]	*Activities/Services Provided* [6]
	• ADA determines the faulted section based on SCADA fault indications, protection lockout signals, AMI data support • ADA estimates the probable fault locations based on AMI data support, SCADA fault current measurements and real-time fault analysis • ADA determines the fault-clearing non-monitored protective device based on AMI data support, • trouble call inputs and dynamic connectivity model • ADA generates switching orders for fault isolation, service restoration, and return to normal (taking into account the availability of remotely controlled switching devices, feeder paralleling, intentional islanding, enabling demand response, and the cold-load pickup): . a) Operator executes switching orders by using SCADA b) Operator authorizes ADA application to execute switching orders in closed-loop mode • ADA isolates the fault and restores service automatically by-passing the operator based on operator's authorization in advance • ADA pre-arms Distributed Intelligence schemes • ADA considers creation of islands supported by distributed resources for return to service restoration.
MFR: ADA performs multi-level feeder reconfiguration for different objectives	• The objectives are a. Service restoration b. Overload elimination c. Loss minimization d. Voltage balancing e. Reliability improvement • MFR takes into account the voltage angles from adjacent buses and enables VVWO if needed

Activity/Service Name [5]	*Activities/Services Provided* [6]
	for widening the acceptable angle differences • MFR tales into account the operations and connection agreements for DER • MFR tales into account the synchronization points
RPR: ADA performs relay protection re-coordination	• ADA changes relay protection settings and modes of operation of switching devices after feeder reconfiguration • ADA changes relay protection setting in case of changed conditions for fuse saving • ADA coordinates the relay protection with DER protection
VVWO: ADA optimally controls Volt/var/Watt by changing the states of voltage controllers, shunts, distributed resources and Demand responses in a coordinated manner for different objectives under normal and emergency conditions	• Power quality improvement • Overload elimination/reduction • Load management • Transmission operation support in accordance with T&D contracts • Loss minimization in distribution and transmission • Increase of tolerance of the voltage angle difference
CEA: Protection equipment performs system protection actions under emergency conditions	Based on real-time distribution system connectivity, current composition of customers, and signals from an upper level of control, ADA provides protection system with information needed for properly performing under-frequency and under-voltage load shedding. Demand response, VVWO, DER, and Micro-grids are taken into account.
IAP: Intelligent alarm processing	Alarms, measurements, and messages produced by SCADA, AMI, and ADA are processed by IAP to determine the root cause of the problem and deliver the summary message to the appropriate recipients of this information.
SCADA: system performs disturbance monitoring _	• . Fault current recording • Fault location

Activity/Service Name [5]	*Activities/Services Provided* [6]
	• Event recording • Disturbance analysis
Op Dispatch: Operators dispatch field crews to troubleshoot power system and customer power problems	Operators perform emergency switching operations to rapidly restore normal operating conditions by dispatching crews using • Mobile radio system • Mobile computing
LMS in emergencies: Operators performs intrusive load management activities	• Operators or planners identify critical loads (hospitals, etc.) in advance • DA system locks out load shedding of critical loads • Operators activate direct load control, prioritized by ADA • Operators activate load curtailment, prioritized by ADA • Operators apply load interruption, prioritized by ADA • Operators enable emergency load reduction via ADA Volt/var/Watt control • Operators apply manual rolling blackouts
Operators enable emergency (major event) mode of operations for maintenance personnel and major event emergency mode of operation of ADA	Prepare personnel and automated system for actions under severe emergency conditions.
Outage management systems collect trouble calls, generate outage information, arrange work	Expedite fault location based on AMI and customer call-in information by using dynamic connectivity models

Activity/Service Name [5]	*Activities/Services Provided* [6]
for troubleshooting	
Interactive utility-customer systems inform the customers about the progress of events	• Price and reliability triggers are issued to the customers through AMI • Timely customers update about the progress of service restoration • Automated messaging based on service restoration progress and association of customers' communication nodes with the faulted area
ADA performs in major event emergency mode	• Automated data preparation, optimal decision making, and control of distribution operations in a coordinated with other systems manner under conditions of major events with more challenging safety and timing requirements • Pre-arming of automatic/automated systems for operations under major event conditions and fast acting fault location, isolation, service restoration, feeder reconfiguration, volt/var control, and operation analysis

1.8 Contracts/Regulations

Identify any overall (human-initiated) contracts, regulations, policies, financial considerations, engineering constraints, pollution constraints, and other environmental quality issues that affect the design and requirements of the Function.

Contract/Regulation [7]	*Impact of Contract/Regulation on Function* [8]
Contract between DISCO and TRANSCO	**Operational boundaries**. If the boundaries are at the circuit breaker level, then ADA has no direct access to substation capacitors and voltage regulators within the substation fence. In order to execute coordinated Volt/Var control, feeder reconfiguration, service restoration, ADA needs information about the substation connectivity, substation transformer loading, state of voltage regulators and capacitors, and their controllers. Furthermore, ADA should have capabilities for controlling these devices in a closed-loop mode. If the boundaries are at the high-voltage side of the substation transformer, then ADA has access to the substation devices and corresponding information. **Volt/Var Agreement.** Defines the voltage limits at the transmission side and reactive power requirements for distribution side. If the contractual parameters are not respected, the Volt/Var application may not meet its

Contract/Regulation [7]	*Impact of Contract/Regulation on Function* [8]
	objectives, and the voltage limits at the customer side may be violated.
Contracts between DISCO and DER owners	**Schedules**. Defines amount of kW generated by DER at different times and constraints for power flow at PCC. Deviation from schedules must be timely detected and compensated by other reserve capabilities of the distribution system. **Volt/Var control agreement.** Defines modes of DER operation and setting for Volt/Var control. Defines rules for changes of modes of operation and setting (local/remote, DER/EPS). Deviation from agreement must be timely detected and compensated by other reserve capabilities of the distribution system. **Standard 1547.** Defines rules for interconnection between DER and DISCO (EPS). Deviation from the rules may result in violation of power quality limits, delays in service restoration, damage of DER equipment. Deviation from the standard must be timely detected and remedial actions must be implemented.
Contracts between Disco and Customers	**Standard 519.** Defines power quality requirements at customer terminals. ADA functions are designed to respect these requirements. ADA must be capable of monitoring or accurately estimating the power quality parameters at the customer terminals, report and eliminate (or significantly reduce) the violations. **Performance based rates**. Defines the target level of service reliability. The distribution system and the ADA function should be design to meet the target. **Reliability guarantees.** ADA function should distinguish the customers with reliability guarantees from those without and focus the service restoration solution on meeting the guarantees, while providing other customers with target service reliability. Load management agreements. Defines the conditions, amount, and frequency of direct load control, load curtailment, interruption, and shedding.

Policy [9]	*From Actor* [10]	*May* [11]	*Shall Not* [12]	*Shall* [13]	*Description (verb)* [14]	*To Actor* [15]
ProvideEnergy	ESP			X	Provide power on demand	Customer

Constraint [16]	***Type*** [17]	***Description*** [18]	***Applies to*** [19]

2 Step by Step Analysis of Function

Describe steps that implement the function. If there is more than one set of steps that are relevant, make a copy of the following section grouping (Preconditions and Assumptions, Steps normal sequence, and Steps alternate or exceptional sequence, Post conditions)

2.3 DGM Set of Functions

2.3.1 DGM Preconditions and Assumptions

Describe conditions that must exist prior to the initiation of the Function, such as prior state of the actors and activities

Identify any assumptions, such as what systems already exist, what contractual relations exist, and what configurations of systems are probably in place

Identify any initial states of information exchanged in the steps in the next section. For example, if a purchase order is exchanged in an activity, its precondition to the activity might be 'filled in but unapproved'.

Actor/System/Information/Contract [20]	*Preconditions or Assumptions* [21]
AM/FM/GIS system	AM/FM system contains the geographical information of the distribution power system circuit connectivity, as well as the parameters describing the power system facilities. Conceptually, the AM/FM/GIS database can contain transmission connectivity and facility data and relevant to distribution operations customer-related data. The AM/FM/GIS database is updated with the latest changes. Updates from the field crews are updated by using standard mobile computing messages.
CIS, AMI, DER, DR Data Management systems.	The systems are updated and contain corresponding behavioral models.
EMS SCADA	EMS system contains the transmission power system model, and can provide the transmission connectivity information for facilities in the vicinity of the distribution power system facilities and with outputs from other EMS applications. The latest data are submitted to the ADA gateway
Distribution SCADA	Distribution SCADA with several IEDs along distribution feeders reports statuses, including availability of control, modes of DER operations and analogs, including

Actor/System/Information/Contract [20]	*Preconditions or Assumptions* [21]
	Amps, kW, kvar, and kV, setpoints, from remotely monitored and controlled objects. Distribution SCADA database is updated via remote monitoring and operator inputs. Required scope, speed, and accuracy of real-time measurements are provided, supervisory and closed-loop control is supported. The latest data are submitted to the ADA gateway.
External systems	Submitted the current and short-term forecasted data to ADA Gateway
ADA conversion and validation function (C&V)	The C&V function extracted and validated the latest incremental changes from AM/FM/GIS/CIS and other data management system databases and submitted the data to DOMA
ADA gateway	ADA gateway consolidated and synchronized data received from DSCADA, SCADA/EMS, and external systems into a snapshot for ADA applications
Distribution Operator	The operator selected the setups and the option of ADA applications and entered them in the ADA gateway
Distributed Intelligence Schemes, if any	The Distributed Intelligence Schemes are setup for fast fault isolation and service restoration under pre-defined connectivity and loading conditions. The block out if the conditions are not met and are able to inform DSCADA/ADA Gateway and the operator about the block out and about the possible violations of the operational limits. In addition to the internal mini-communication system, the switching devices of the Distributed Intelligence Schemes are monitored and can be controlled by DSCADA.
ADA: Distribution Operation Modeling and Analysis (DOMA)	DOMA database is updated with the latest data from GIS/AM/FM/CIS and other data management systems and operators input. The options for DOMA performance are selected.
VVWO and FLIR	The ADA applications are ON. VVWO objective is "Reduce load by a given value

Actor/System/Information/Contract [20]	*Preconditions or Assumptions* [21]
	while respecting given voltage tolerance"

2.3.2 Use case steps for the DGMI function

#	Event [22]	Primary Actor [23]	Name of Process/Activity [24]	Description of Process/Activity [25]	Information Producer [26]	Information Receiver [27]	Name of Info Exchanged [28]	Additional Notes [29]
#	*Triggering event.: Identify the name of the event.*[4]	*What other actors are primarily responsible for the Process/Activity. Actors are defined in section1.5.*	*Label that would appear in a process diagram. Use action verbs when naming activity.*	*Describe the actions that take place in active and present tense. The step should be a descriptive noun/verb phrase that portrays an outline summary of the step. "If …Then…Else" scenarios can be captured as multiple Actions or as separate steps.*	*What other actors are primarily responsible for Producing the information. Actors are defined in section1.5.*	*What other actors are primarily responsible for Receiving the information Actors are defined in section1.5. (Note – May leave blank if same as Primary Actor)*	*Name of the information object. Information objects are defined in section 1.6*	*Elaborate architectural issues using attached spreadsheet. Use this column to elaborate details that aren't captured in the spreadsheet.*
1.1	ADA Gateway polls DSCADA database for data relevant to ADA	ADA Gateway	Polling near real-time data from DSCADA	ADA retrieves data pertinent to the scope of ADA for the subject area	DSCADA	ADA Gateway	DSCADA snapshot	Data include analogs and statuses collected by DSCADA from remotely monitored devices in distribution
1.2	ADA Gateway polls EMS/SCADA database for data relevant to ADA	ADA Gateway	Polling near real-time data from EMS/SCADA	ADA retrieves data pertinent to the scope of ADA for the subject area	EMS/SCADA	ADA Gateway	EMS/SCADA snapshot	Data include analog and statuses collected by EMS/SCADA from substations and data from EMS and MOS applications

[4] Note – A triggering event is not necessary if the completion of the prior step leads to the transition of the following step.

1.3	ADA Gateway polls External system database s for data relevant to ADA	ADA Gateway	Polling near real-time databases from external data bases	ADA retrieves data pertinent to the scope of ADA for the subject area	External systems	ADA Gateway	External data snapshot and short-term forecast	Data include current and forecast weather data by relevant areas
2.	Last snapshot received by ADA Gateway	ADA Gateway	Consolidating snapshots	ADA Gateway consolidates and synchronized received snapshots and analyzes the snapshots for pre-defined events and for periodic times of DOMA execution	ADA Gateway	ADA Gateway	Internal process in the ADA Gateway	
3.1	There are changes of statuses in distribution and/or there are changes of external data in the consolidated snapshot, or it is the time for a periodic run of an application. No fault indicators either from field IEDs, or from AMI.	ADA Gateway	Launching ADA applications	ADA Gateway sends o command to start DOMA due to pre-defined changes in the consolidated snapshot	ADA Gateway	ADA application	Commands for starting DOMA	

3.2	There are changes of statuses in distribution and/or there are changes of external data in the consolidated snapshot. No fault indicators either from field IEDs, or from AMI.	ADA Gateway	Back to 1-2					

4	DOMA received the command to start	DOMA	DOMA adjusts the component models	DOMA adjusts the topology and behavioral models in the ADA database based on the latest snapshot from DSCADA, EMS/SCADA and External systems: the following models are updated: • Transmission/Sub-Transmission System Immediately Adjacent to Distribution Circuits • Distribution Circuit Connectivity • Distribution Nodal Loads • Distributed Energy Resources (DER) and Micro-grids • Distribution Circuit Facilities	DOMA	ADA database	Update of ADA database	
5	DOMA finished updates of the models	DOMA	DOMA runs	DOMA updates the model of the Distribution Power flow and the analysis of operations	ADA Gateway	DOMA	DOMA process	
6.1	DOMA finished run	DOMA	DOMA publishes results	DOMA transmits the power flow results to other ADA applications as a base case	DOMA	VVWO, FLIR	Creating the base case for ADA applications	

6.2	DOMA finished run	DOMA	DOMA publishes results	DOMA sends results of analysis to the ADA gateway. The following results are sent: • Analysis of adequacy of distribution system operations • Analysis of reliability - Contingency Analysis (CA) • Power Quality Analysis • Analysis of the economic efficiency • The dynamic T&D bus voltage limits • The aggregated available dispatchable real and reactive load at the T&D buses • The aggregated at the T&D buses load-to-voltage dependencies • The aggregated at the T&D buses remedial action schemes parameters	DOMA	ADA Gateway	DOMA updates the situational awareness of distribution operations	

6.3	DOMA finished run	DOMA	DOMA publishes results	DOMA stores the results of the modeling and analysis in the DOMA reports, and in historic databases	DOMA	DOMA reports, Historic databases	Reporting DOMA results	One run of DOMA may generate about 25,000 values per average distribution feeder
6.4	DOMA finished its run	DOMA	Update of the Gateway on the statuses of ADA applications	DOMA informs the ADA Gateway on readiness of ADA applications	DOMA	ADA Gateway	Flagging the completion of processes	
7.1	ADA gateway received an update of situational awareness of distribution operations	ADA gateway	Presenting DOMA results to the Operator	Displaying selected results to the operator according to the operator's requests, such as: • Analysis of adequacy of distribution system operations • Analysis of reliability - Contingency Analysis (CA) • Power Quality Analysis • Analysis of the economic efficiency	ADA Gateway	Operator via Graphic User Interface	Updating the operator on situational awareness on distribution operations	

7.2	ADA gateway received an update of situational awareness of distribution operations	ADA gateway	Presenting DOMA results to the EMS/SCADA	Transmission of relevant data to EMS, such as: • The dynamic T&D bus voltage limits • The aggregated available dispatchable real and reactive load at the T&D buses • The aggregated at the T&D buses load-to-voltage dependencies • The aggregated at the T&D buses remedial action schemes parameters	ADA Gateway	EMS/SCADA	Updating the EMS on data needed for Wide Area Situational Awareness (WASA)	
7.3	ADA Gateway received the flag on VVWO readiness	ADA Gateway	Starting VVWO	Sending a command to VVWO to start	ADA Gateway	VVWO	Command to start VVWO under given objective	
8	VVWO received a command to start	VVWO	VVWO runs	VVWO determines the setpoints of voltage and var controlling devices, the statuses of discrete devices, the locations and volumes of utilization of controllable DER, ES, and Demand Response	VVWO	VVWO	VVWO process	

9	VVWO completed the calculations	VVWO	VVWO issues first group of commands	Issuing the first group of commands to management systems.	VVWO	ADA Gateway or Load Management, or DER management system	VVWO output	The first group of commands can be executed at the same time or in any order. The second group of command can be executed only after the first group is successfully executed, etc.
10.1	ADA gateway received VVWO output with new setpoints	ADA gateway	Issuing commands to field devices	Issuing commands to field devices, like to voltage, capacitor, and large DER/ES controllers	ADA (DMS) Gateway	Field actuators	Setpoints, Statuses, Modes of DER operations	The first group of commands can be executed at the same time or in any order. The second group of command can be executed only after the first group is successfully executed, etc.
10.2	Load Management received a request to enable particular demand response means	Load Manage ment system	Issuing request to defined Demand response installations	VVWO issues the nodes, where the Demand Response is needed first, if any.	Load Management system	Gateways of DR installations (Customer EMS, Smart Meters)	Triggering or requesting load reduction through demand response	It can be a price signal or another agreed upon demand response trigger

10.3	DER Management system received request for DER control	DER Manage ment system	Issuing request to defined DER installations	Controlling DER Watt and var	DER Management system	Gateways of DER installations (DER controller, Customer EMS, Smart Meters).	Triggering or requesting load change of DER, and/or var control mode, and/or var setpoint	It can be a price signal or another agreed upon DER control trigger, or a mode of var control, or a setpoint for Watt and for var control. In case of many small DERs with the ability of var control, the request is issued to clusters of many
11.1	ADA gateway received snapshots confirming the execution of the first group of commands	ADA gateway	Confirmation of execution	ADA gateway verifies that the field devices reported acceptance of the previous command; corresponding changes of analogs; changes of statuses and informs VVWO	ADA gateway	VVWO	Confirmation of acceptance and execution of commands	The conformation of acceptance and execution by different devices can come in different snapshots. A waiting time for collecting the confirmation should be assigned.
12.1	VVWO receives confirmation of successful execution of the commands issued to the field devices	VVWO	Issuing the second group of commands, if needed	VVWO verifies whether after receiving the confirmation of execution of the first group of commands, another group of commands should be issued. If yes, it issues the second group of commands. If not, VVWO waits for execution of the previously issued remaining commands/requests.	VVWO	ADA gate way	Issuing the second group of commands	

13.1	ADA gateway received VVWO output with new setpoints	ADA gateway	Issuing additional commands to field devices	Issuing additional commands to field devices, like to voltage, capacitor, and large DER/ES controllers	ADA (DMS) Gateway	Field actuators	Setpoints, Statuses, Modes of DER operations	
11.2	Load Management system confirms the receipt of DR control requests and the issuing the requests to the DER installations	Load Manage ment system (LMS)	Confirmation of execution of DR	LMS confirms the transmission of the requests to the customers and informs DOMA	Load Management system	DOMA	Confirmation of DR requests	The behavioral load models including DR are dependent on
12.2	DOMA receives confirmation of enabling the DR	DOMA	Adjustment of DOMA	DOMA adjusts the load models based on the issued requests for Demand Response. Actually, the expected behavior of the loads with enabled Demand Response was assumed for the initial VVWO solution. However, the execution of DR takes time, during which the operating conditions and/or the external circumstances can change. Therefore, after the requests for Demand Response are transmitted (or some of them are not transmitted for some reasons) to the customers, DOMA should update the load models and resubmit to VVWO the new base case.	LMS	DOMA	Model updates	The behavioral load models including DR are dependent on the Demand response triggers and on other external conditions. The actual execution of DR and the reports on the executions may take time and will be far after the fact. Therefore, DOMA updates the models for the current and near-look-ahead times based on the load dependencies on the external factors.

12.3	DOMA receives confirmation of enabling the DER	DOMA	Adjustment of DOMA	DOMA adjusts the load models based on the issued requests for the embedded in the load DER control. Actually, the expected behavior of the loads with embedded DERs was assumed for the initial VVWO solution. However, the execution of requests to the DER may be different from the assumed, especially during intermittent ambient conditions. Therefore, after the requests for DER control are transmitted by the DER management system (or some of them are not transmitted for some reasons) to the customers, DOMA should update the load models with embedded DER sand resubmit to VVWO the new base case.	DER management system	DOMA	Model updates	
13.2	VVWO received a new base case	VVWO	Continuation of optimization of Volt/var/Watts	VVWO runs on an updated operation model.	DOMA	VVWO	Continuation of VVWO runs after changes in DR and DER	
14	VVWO finished runs on the updated model	VVWO	Continued run of VVWO	Issuing additional commands and requests based on VVW runs on updated models until the objective are met or the tolerances are exhausted.	VVWO	ADA Gateway, LMS and DER management systems	Setpoints, statuses, modes of operations, requests for DR and DER control	

15.1	ADA gateway received VVWO output with new setpoints and statuses	ADA gateway	Issuing commands to field devices	Issuing commands to field devices, like to voltage, capacitor, and large DER/ES controllers	ADA (DMS) Gateway	Field actuators	Setpoints, Statuses, Modes of DER operations	
15.2	Similar to 10.2	Similar to 10.2	Similar to 10.2	Similar to 10.2	Similar to 10.2	Similar to 10.2	Similar to 10.2	
15.3	Similar to 10.3	Similar to 10.3	Similar to 10.3	Similar to 10.3	Similar to 10.3	Similar to 10.3	Similar to 10.3	
11.3	ADA Gateway received information on failure of execution of one or more issued commands	ADA gateway	Update of the availability of controllable devices due to failure of some of them	Change of the array of controllable devices	ADA gateway	VVWO and DOMA	Change of input data for VVWO	
12.3	VVWO received a change on availability of controllable devices	VVWO	Re-optimization with another set of controllable devices	VVWO runs with new input data	ADA gateway	VVWO	Re-optimization of VVWO	Repeat 8 -15
16.1	A circuit breaker (feeder recloser) opened and locked out	ADA	Fault detection	A fault indication is received via a snapshot from DSCADA, or/and from AMI management system	SCADA	ADA gateway	Fault detection	ADA gateway analyzes the snapshots for indications of a sustained outage, and, if it is present, triggers FLIR

17.1	Distributed Intelligence schemes , if any, detected the fault and the outage	Distributed Intelligence schemes	Outage detection and analysis by Distributed Intelligence schemes	Distributed intelligence schemes analyze whether the outage conditions meet the setup of the schemes	Distributed Intelligence schemes	Members of the Distributed Intelligence teams	Analysis of the pre-fault conditions in relation to the setup of the Distributed Intelligent schemes	The Distributed Intelligence scheme analyzes whether the new connectivity does not result in unacceptable operational parameters, e.g., in overload of the backup feeders..
18.1	The pre-fault conditions meet the requirements of the Distributed Intelligence schemes	Distributed Intelligence schemes	Service restoration	Distributed intelligence schemes issues commands to their team member switching devices to execute the isolation of the fault	Distributed Intelligence schemes	Members of the Distributed Intelligence teams	The Distributed intelligence schemes transmit commands to open switching devices of the team to isolate the fault and to prepare the healthy portions of the circuit for restoration by the backup feeders.	

18.2	The pre-fault conditions do not meet the requirements of the Distributed Intelligence schemes	Distributed Intelligence schemes	Blocking the Distributed Intelligence schemes	Distributed intelligence schemes block the fault isolation and service restoration actions and inform the DSCADA/Operator on the blocking	Distributed Intelligence schemes	DSCADA/ADA gateway/ Operator	Message on blocking the Distribution Intelligence schemes and warning on possible overloads	
19.1	The Distributed Intelligence schemes successfully restored services to the healthy sections of the faulted feeder.	The Distributed Intelligence schemes	The Distributed Intelligence schemes inform the ADA Gateway/ operator about successful service restoration	The Distributed Intelligence schemes divided the healthy portion of the faulted feeder into switchable sections with open ties to available backup feeders and energized these sections by closing the tie switches.	The Distributed Intelligence schemes	ADA gateway	Information about successful completion of Service restoration by the Distributed Intelligence schemes	
20.1	DOMA received a change of Statuses	DOMA	DOMA is triggered by event	Change of connectivity due to the operations of the Distributed Intelligence schemes triggers DOMA application	DSCADA/ADA Gateway	DOMA	Snapshots with new statuses and analogs	DOMA runs with new data and submits the new operation model to other ADA applications
21.1	VVWO received new operation model	VVWO	VVWO is triggered by event	Change of connectivity due to the operations of the Distributed Intelligence schemes triggers new VVWO run based on the new operation model	DOMA, DSCADA/ADA Gateway	VVWO	New base model for VVWO	VVWO runs based on the new operation model and issues commands to the corresponding controllable devices to adjust the optimal Volt/var/Watt to the new conditions.

22.1	ADA gateway received a report, from DOMA and VVWO, that no overload or intolerable voltage violation are expected during the time of repair of the faulted facility	ADA gateway	Reporting operating conditions during repair time	The repair may last several hours. During this time, the load may increase, and the backup feeders can be overloaded. DOMA checks the look-ahead adequacy of the operating conditions and if there are possible violations enables the look-ahead VVWO to eliminate them.	DOMA/VVO	ADA Gate way	Message about operational violations, which cannot be eliminated by VVWO	
22.2	ADA gateway received a report, from DOMA and VVWO, on an overload or an intolerable voltage violation during the time of repair of the faulted facility	ADA gateway	Reporting operational limit violations	The repair may last several hours. During this time, the load may increase, and the backup feeders can be overloaded. This overload (or under-voltage) forces the VVWO application to try to eliminate these violations firstly, by non-intrusive means, (voltage control, var control, DER control). ADA gateway starts Multi-level feeder reconfiguration.	DOMA/VVO	ADA Gate way	Message about operational violations, which cannot be eliminated by VVWO	
23	MFR receives a command to start with the objective of load balancing.	MFR	Mitigation of operational violations by using feeder reconfiguration	MFR runs optimization of feeder configuration to eliminate operational violations.	ADA Gateway	MFR	Triggering MFR on a new base operational model for the maximum load during the repair time	

24	MFR started running	MFR	MFR analyzes alternative connectivities including transfer of portion of load from one healthy feeder to another	To eliminate overloads of feeder segments, portions of the overloaded feeder should be transferred to other healthy feeders. This operation may need a sequence of pair-operations: "parallel-break". The paralleling is not always permissible due to voltage angle differences between the interconnected substation buses. For each alternative requiring paralleling, the MFR applications checks whether the paralleling is permissible.	EMS/PMU/State estimation	MFR	Voltage angles, used in MFR internal process	
25.1	Paralleling is permissible	MFR	Searching the best configuration for unloading the overloaded feeder	MFR searches for ways to distribute the overload among other feeders of the same or other substations. If such a solution exists and it satisfies all pre-defined conditions, MFR recommends a switching sequence to the ADA gateway, operator	MFR	ADA gateway	Switching sequence	
25.2	Paralleling is not permissible	MFR	Enabling VVWO to assist in paralleling and unloading	VVWO may be able to increase the critical angle difference and/or enable demand response to unload the overloaded segments	MFR	VVWO	Calling VVWO to assist in unloading	

26.1	ADA/Operator receives a new switching sequence	ADA	Implementation of new feeder reconfiguration	The new feeder configuration can be implemented in close-loop mode by using SCADA switching procedure, or by supervisory control, of it involves remotely control switches only. If manual switches are involved, and the overload can be tolerated for the time of manual switching operations, the switching order can be implemented by field crews.	Operator	SCADA, Field crews	Reconfigurati on commands	
26.2	ADA/Operator receive a message that no solution of unloading the overloaded feeder is found	ADA/VV WO	ADA triggers VVWO with Demand Response option	VVWO searches for a solution to unload overloaded segments of the feeders by enabling reliability-required demand response	ADA/VVWO	VVWO	Internal VVWO process	
27.1	VVWO finds a solution with Demand response	VVWO	VVWO includes the controls demand response	VVWO re-optimizes the distribution power flow and includes available demand response in the controllable variables	VVWO	Controllable by VVWO field equipment and load Management System	Commands to Controllable by VVWO field equipment and requests to load Management System	

27.2	VVWO does not find a solution with Demand response	VVWO	VVWO includes the controls demand response	VVWO re-optimizes the distribution power flow and includes available demand response in the controllable variables	VVWO	ADA Gate way	Message that no solution is found; Results of re-optimization issued to the controllable devices, if it improves the situation	
28	ADA receives a "no-solution" message from VVWO	ADA/FLIR	Start FLIR for minimization of shed load	FLIR searches for ways to unload the overloaded feeder by shedding a minimal portion of load in a least intrusive manner	FLIR	Load management system, load shedding schemes, sectioning switching devices	Load shedding to unload overloads	New statuses and load models will trigger DOMA and VVWO runs by event.
17.2	FLIR receives a command to start fault location	FLIR	Initiation of FLIR	FLIR received information on the fault indicators, on changes of statuses of the switching devices and on fault parameters, if any, and starts fault location sun-function	ADA gateway	FLIR	Triggering FLIR	Circuit breakers can be equipped with fault current recording devices, such as current values, fault current (voltage) "signature", etc. This information can be transmitted to the ADA gateway within the SCADA snapshots or in other forms concurrently with the snapshots.

18.3	FLIR receives data on outage detection and fault location from AMI data management system	FLIR	Outage detection and location	FLIR uses the combination of outage detection and location data received from SCADA and from AMI data management system and determines the fault location	FLIR	ADA gateway and Distribution operator via the ADA gateway	Fault location	In some cases, FLIR defines several possible fault locations with equal fault parameters. In these cases, additional information is required.
16.2	A non-monitored protective device (fuse) opened	AMI data managem ent system	Outage detection (LastGasp/ACou t) and other fault-related data received from Smart Meters	Smart Meters report outages	Smart Meters	AMI data management system	Outage detections and other fault-related data recorded by Smart Maters	
18.4	FLIR receives data on outage detection and fault location from AMI data management system	FLIR	Initiation of FLIR	FLIR received information on the fault detection by Smart Meters and on fault parameters, if any, and starts fault location sun-function	AMI data management system	FLIR	Triggering FLIR and the fault location sub-function	
19.2	The fault is initially located	FLIR	Fault isolation	FLIR determines the initial fault isolation by remotely controlled switching devices	FLIR	ADA gateway and Distribution operator and the IEDs of the switching devices via DSCADA	Commands to remotely controlled switching devices and confirmation feedback on execution	If the execution is unsuccessful, FLIR finds other backup isolating switching devices and resends the commands.

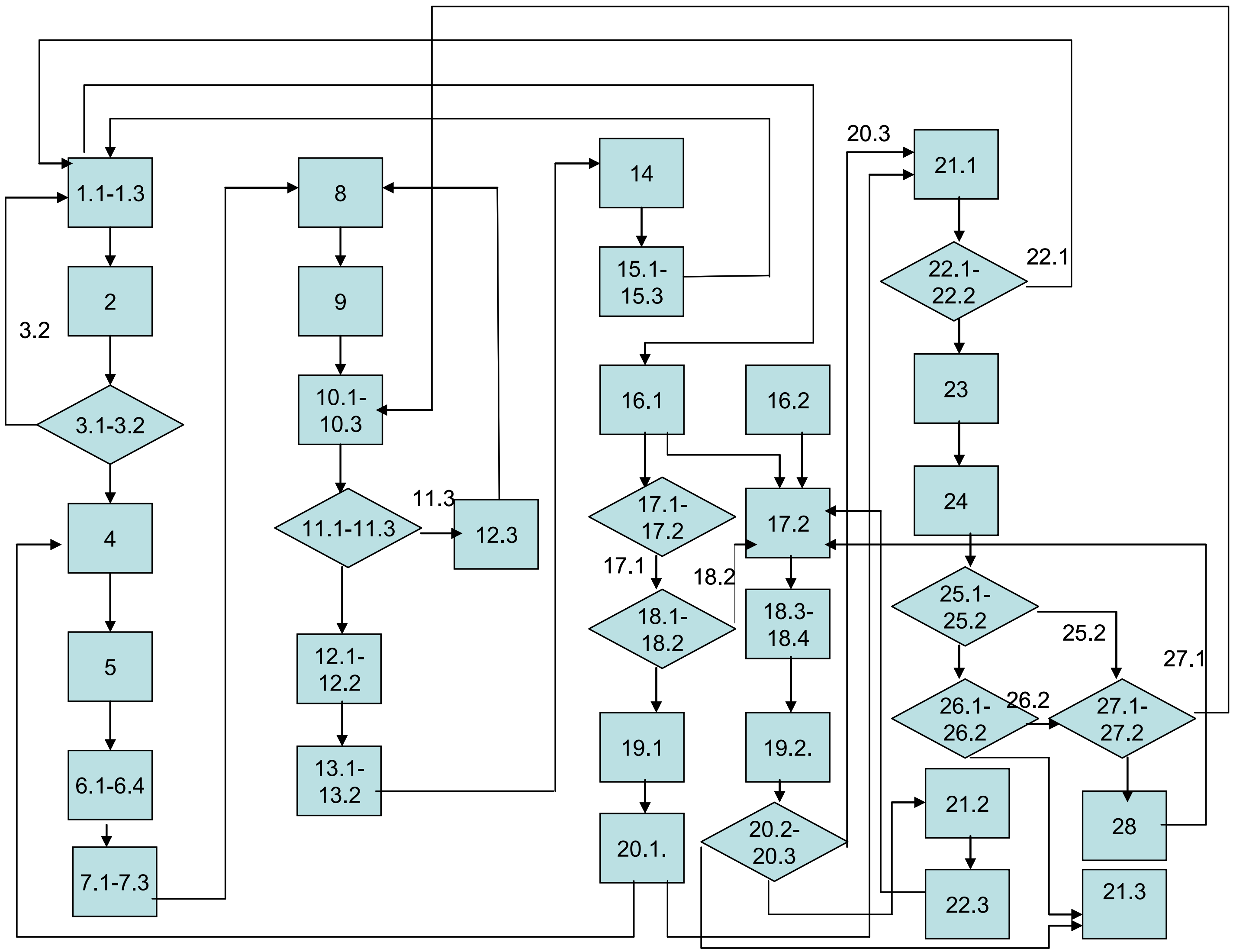
20.2	Fault is isolated	FLIR	Service restoration to healthy sections	FLIR determines via look-ahead mode of operations the worst conditions expected during the time of repair and finds the best service restoration scenario for these conditions..	FLIR	ADA gateway, Distribution operator and the IEDs of the switching devices via DSCADA	A set of compatible groups of commands to remotely controlled switching devices and execution confirmation feedback from the field IEDs	If the execution is unsuccessful, FLIR finds other backup restoration switching devices and resends the commands.

20.3	Fault is isolated	FLIR	Service restoration to healthy sections	FLIR determines via look-ahead mode of operations the worst conditions expected during the time of repair and cannot find a service restoration scenario for these conditions without shedding part of the load and/or without enabling Demand Response.	FLIR	ADA gateway, Distribution operator and the IEDs of the switching devices via DSCADA and the Load Management system	A set of compatible groups of commands to remotely controlled switching devices and requests for Demand Response in particular points; and execution confirmation feedback from the field IEDs and from the Load Management system.	If the execution is unsuccessful, FLIR finds other backup restoration switching devices and demand response means and resends the commands. If there is no solution, FLIR finds the minimally intrusive load shedding. If the solution includes intermediate paralleling, FLIR checks whether the paralleling is permissible, and if not, sends a request to other applications (e.g., VVWO) to increase the tolerance for paralleling (see steps …….).
21.2	Operator dispatches a crew to repair the faulted facility	Operator	Dispatching the field crew	The operator instructs the crew on the fault location or on the possible locations and on the route to the possible fault locations, if they are more than one.	Operator	Field crew	Crew dispatch	

21.3	FLIR generates a switching order	FLIR	Switching order	FLIR sends the switching order to the ADA gateway for execution	FLIR	ADA gateway, DSCADA	Delivery of switching order	
22.3	The crew reports the exact location of the fault and the estimate of the time of repair	Operator	Exact isolation	The operator (or an additional ADA function or sub-function) determines the feasibility of more accurate fault isolation by using manual switches and of the pickup of additional healthy feeder segments by backup feeders. If it is feasible, the operator/ADA function triggers FLIR and provides FLIR with new information.	Operator or ADA function	FLIR	New fault isolation conditions in a look-ahead time (when the manual isolating devices are opened)	

23.2	FLIR receives new isolation conditions	FLIR	Reconfiguration to pickup more healthy sections	FLIR finds a solution, if any, to pickup the additional load (accounting for the cold load pickup portion)	FLIR	ADA gateway, operator, DSCADA	A set of compatible groups of commands to remotely controlled switching devices and requests for Demand Response in particular points, if needed; and execution confirmation feedback from the field IEDs and from the Load Management system.	

2.4 Action Diagram (draft)



3 Auxiliary Issues

3.1 References and contacts

Documents and individuals or organizations used as background to the function described; other functions referenced by this function, or acting as "sub" functions; or other documentation that clarifies the requirements or activities described. All prior work (intellectual property of the company or individual) or proprietary (non-publicly available) work must be so noted.

3.1.1 Publications for Further Reading

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20. The Specifics Of Coordinated Real-Time Voltage And Var Control In Distribution, by Nokhum S. Markushevich, presented at Distributech 2002 Conference

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22. Capacitor Control In Distribution Automation At OG&E, by Aleksandr P. Berman, Nokhum S. Markushevich (UCI), and James C. Clemmer (OG&E), presented at Distributech 2001 Conference

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. ID	Title or contact [30]	Reference or contact information [31]
[1]		
[2]		

3.2 Action Item List

As the function is developed, identify issues that still need clarification, resolution, or other notice taken of them. This can act as an Action Item list.

ID	Description [32]	Status [33]
	Distribution Operation Modeling and Analysis (DOMA)	Developed by UCI; successfully tested in a number of pilot projects, is in permanent use at B.C. Hydro; specified by UCI for development by DMS vendors; Partially developed by

		Siemens and Areva based on UCI specification, implemented in FPL. Needs additional development for distribution with significant penetration of AMI, DER, DR, ES, and power electronics. The updates needed for the Smart Grid are addressed in a number of UCI works. EMS applications should be modified to utilize the output from DOMA and provide inputs to DOMA.
2	Fault Location, Isolation and Service Restoration (FLIR)	Developed by UCI; successfully tested in a number of pilot projects; specified by UCI for development by DMS vendors; Partially developed by Siemens and Areva based on UCI specification, implemented in FPL. EMS applications should be modified to provide inputs to FLIR. Needs additional development for distribution with significant penetration of DER, DR, ES, and power electronics.
4	Multi-level Feeder Reconfiguration (MFR)	Developed by UCI and also by Siemens; specified by UCI for development by DMS vendors; EMS applications should be modified to provide inputs to MFR. Needs additional development for distribution with significant penetration of DER, DR, ES, and power electronics.
5	Relay Protection Re-coordination (RPR)	Developed by UCI for the pilot project at JEA. Needs additional development for distribution with significant penetration of DER, DR, ES, and power electronics.
6	Voltage, Var, and Watt Optimization (VVWO)	Developed by UCI; successfully tested in a number of pilot projects, is in permanent use at B.C. Hydro; specified by UCI for development by DMS vendors; Partially developed by Siemens and Areva based on UCI specification, implemented in FPL. Needs additional development for distribution with significant penetration of AMI, DER, DR, ES, and power electronics. The updates needed for the Smart Grid are

		addressed in a number of UCI works. EMS applications should be modified to utilize the output from VVWO and provide inputs to VVWO.
7	Pre-arming of Remedial Action Schemes (RAS)	Needs to be developed and interfaced with the emergency control function of EMS (WAMCS) and with intelligent RAS
8	Coordination of emergency actions	Needs to be developed and interfaced with the emergency control function of EMS (WAMCS) and with intelligent RAS
9	Coordination of restorative actions	Needs to be developed and interfaced with the emergency control function of EMS (WAMCS) and with intelligent RAS
10	Intelligent Alarm Processing	Needs to be developed for distribution with ADA..

3.3 Revision History

For reference and tracking purposes, indicate who worked on describing this function, and what aspect they undertook.

No [34]	**Date** [35]	**Author** [36]	**Description** [37]
01.	10/16/03	Nokhum Markushevich, Mark Lachman	Draft 01 prepared. Needs more formatting.
02	10/19	Frances Cleveland	Review 2.1,Revised 2.4, added Fig.2
0.3	10/20	Nokhum Markushevich	Revised 2.1, edited Fig. 2
0.4	10/21	Nokhum Markushevich	Amended 2.4 and Fig.1

No [34]	**Date** [35]	**Author** [36]	**Description** [37]
05	10/29	Nokhum Markushevich	Added X.8 to 2.3 and amended 2.4 with more details for X.7 and with X.8.
06	11/7	Frances Cleveland	Reorganized and elaborated on functions
06		Mark Lachman	Reorganized and elaborated on functions
07	12/09	Nokhum Markushevich	Revised the elaborated functions, added Fig.2.1
08	02/29/04	Mark Lachman Nokhum Markushevich	Developed UMS diagrams, added power point illustrations and clarifications, revised the step-by-step descriptions of the sub-functions.
SG1	12/12/09	Nokhum Markushevich	Upgraded the introduction to the set of ADA functions and partially the preconditions for DOMA
SG2	12/19/09	Nokhum Markushevich	Upgraded the narratives for DOMA function and its sub-functions.
SG3	12/20/09	Nokhum Markushevich	Upgraded the narrative of FLIR, VVWO, DCA, MFR, RPRC, PRAS, CEmA, CRA, IAP (10 functions).
SG4	12/26/09	Nokhum Markushevich	Defined the actors and developed the interface diagram for a DOMA_VVWO_FLIR use case involving DOMA, FLIR, and VVWO
SG5	1/2/10	Nokhum Markushevich	Started the description of interfaces for the DOMA_VVWO_FLIR -use case.

No [34]	Date [35]	Author [36]	Description [37]
SG6	1/10/10	Nokhum Markushevich	Started the description of steps for the DOMA_VVWO_FLIR -use case
SG7	1/16/10	Nokhum Markushevich	Continued the description of steps for the DOMA_VVWO_FLIR -use case. Updated the pre and post-conditions.
SG8	1/24/10	Nokhum Markushevich	Updated the Activities/Services table and the Action Item List.
SG9	1/26/10	Nokhum Markushevich	Continued the description of steps for the DOMA_VVWO_FLIR case.
SG10	1/30/10	Nokhum Markushevich	Continued the description of steps for the DOMA_VVWO_FLIR case.
SG11	2/7/10	Nokhum Markushevich	Continued the description of steps for the DOMA_VVWO_FLIR case.
SG12	4/16/10	Nokhum Markushevich	Prepared a draft action diagram and edited the steps for coordinated DOMA-VVWO-FLIR-MFR

[1] Function Name corresponds to the name attribute of a Use Case.

[2] Function ID corresponds to the tagged value “id” attached to the Use Case.

[3] Function description corresponds to the documentation attribute of a Use Case.

[4] TBD - Documentation attribute of the Collaboration Diagram or perhaps the documentation element of the use case.

[5] The Service Name corresponds to a Use Case which is associated with the main domain template use case using the <<includes>> relationship.

[6] The Service Description corresponds to the documentation attribute of a Use Case.

[7] Contract [RMODP: Contract] corresponds to a Classifier that aggregates owned Policy Classifiers.

[8] Contract Description corresponds to the documentation attribute of a Contract Classifier.

[9] Policy [RMODP: Policy] corresponds to a Classifier. A Policy Classifier is an associated classifier using the Permission association.

[10] The “From Actor” corresponds to an existing Actor.

[11] Permission [RMODP: Permission] corresponds to a policy classifier operation with the <<permission>> stereotype assigned.

[12] Prohibition [RMODP: Prohibition] corresponds to a policy classifier operation with the <<prohibition>> stereotype assigned.

[13] Obligation [RMODP: Obligation] corresponds to a policy classifier operation with the <<obligation>> stereotype assigned.

[14] Description of the Policy Permission, Prohibition, or Obligation corresponds to the documentation attribute of the Policy Classifier Operation.

[15] The “To Actor” corresponds to an existing Actor.

[16] Constraint corresponds to the Constraint Attribute of the Actor/Classifier/Interface that its applied to.

[17] TBD – Probably Ignored ?

[18] Description of the Constraint corresponds to the documentation attribute of Constraint.

[19] “Applies to” corresponds to the named Actor/Classifier/Interface the constraint is bound to.

[20] TBD

[21] TBD

[22] Triggering Event corresponds to a ClassifierRole that serves as an Activator.

[23] Information receiver corresponds to a ClassifierRole having a base Classifier assigned to an existing Actor, Classifier or Interface.

[24] Name of Activity corresponds to name attribute of an Action.

[25] Description of Activity corresponds to documentation attribute of an Action.

[26] Information receiver corresponds to a ClassifierRole having a base Classifier assigned to an existing Actor, Classifier or Interface.

[27] Information producer corresponds to a ClassifierRole having a base Classifier assigned to an existing Actor, Classifier or Interface.

[28] Name of Info Exchanged corresponds to the name attribute of a Message.

[29] TBD – Constraint attribute of some or multiple relationships?

[30] Reference corresponds to the name attribute of an Artifact having the <<document>> stereotype assigned.

[31] Reference corresponds to the documentation attribute of an Artifact having the <<document>> stereotype assigned.

[32] No correspondence

[33] No correspondence

[34] Revision Number corresponds to the documentation attribute of an Artifact having the <<document>> stereotype assigned. All information added to the model will utilize the "reference" tagged value to refer to the Artifact. The Artifact representing this domain template will utilize the "reference" tagged values to refer to the source material.

[35] Date corresponds to the documentation attribute of an Artifact having the <<document>> stereotype assigned. All information added to the model will utilize the "reference" tagged value to refer to the Artifact. The Artifact representing this domain template will utilize the "reference" tagged values to refer to the source material.

[36] Author corresponds to the documentation attribute of an Artifact having the <<document>> stereotype assigned. All information added to the model will utilize the "reference" tagged value to refer to the Artifact. The Artifact representing this domain template will utilize the "reference" tagged values to refer to the source material.

[37] Description corresponds to the documentation attribute of an Artifact having the <<document>> stereotype assigned. All information added to the model will utilize the "reference" tagged value to refer to the Artifact. The Artifact representing this domain template will utilize the "reference" tagged values to refer to the source material.