Microgrid Interactive Use Case #IA-1

Information Support for Coordination of EPS and Microgrid Load Shedding Schemes

Version 2

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This is one of the eight (8) use cases related to interactions between advanced microgrids in connected mode and Electric Power Systems (EPS). The use cases are described in terms of information exchange requirements between the Distribution Management System (DMS)/ Distribution System Operator (DSO) and the EMS/Controllers of advanced microgrids.

The Microgrid Interactive Use Cases are

1. Information Support for Coordination of EPS and Microgrid Load Shedding Schemes
2. Coordination of Volt/var control in Connected Mode under Normal Operating Conditions
3. Update aggregated at PCC real and reactive load-to-voltage dependencies under normal operating conditions
4. Updates of capability curves of the microgrid's reactive power sources
5. Updating information on microgrid dispatchable load
6. Updates of the information on overlaps of different load management means within microgrids
7. Updating dependencies of the microgrid operational model on external conditions
8. Update aggregated at PCC real and reactive load-to-frequency and load-to-voltage dependencies in the emergency ranges

These use cases were developed by Smart Grid Operations Consulting (SGOC) on behalf of National Institute of Standards and Technology (NIST)

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1 Descriptions of the Use Case

1.1 Name of Use Case

Information support for coordination of EPS and microgrid load shedding schemes (based on Under Frequency Load Shedding)

1.2 Scope and Objectives

Scope: The Function performs data exchange between the EPS DMS and Microgrid EMS (µEMS) for the purpose of a) coordination of load-shedding remedial actions and b) logging and reporting for post-factum analyses. . The information exchanges are performed through direct interfaces between EPS DMS and µEMS. Interfaces with other internal and external to the power utility and to the µGrid ICT systems will be used by the DMS and µEMS to meet the objective of the Function.

Objective: The objective of the function is a) to provide information to the EPS operator on the states and performance of the microgrid load and DER in cases of emergency situations of EPS and b) to provide information to the operators of Advanced[1] Microgrids (μGrid) on the possible emergency operating conditions of the EPS related to the emergency performance of the microgrid's load and DER.

Rationale: By meeting its objectives in near-real time, the Function will support the coordination between EPS and Microgrid Remedial Action Schemes (RAS) for mutual benefits and contribute to the reliability of service to customers of the entire A.D.N., including the customers of the μGrid.

Status: The adaptation of the EPS RAS to the operations of the microgrids and wise versa is in its early stages. With the wider implementation of the advanced microgrids, other prosumers, and stand-alone DERs, the near-real time coordination will become critical to the reliability of the power supply.

1.3 Narrative

1.3.1 General Description

A microgrid [2] is considered here as a sub-power system comprising distributed generation/storage and load. In addition, an advanced microgrid may use internal controlling devices, such as different step-wise and/or continuous voltage and var regulators (including advanced inverters [1]-[6]), Remedial Action Schemes (RAS), such as Under-frequency/voltage Load Shedding, and elements of Information Communications Technology (ICT). An advanced microgrid can provide a number of ancillary services. It can operate either in an island mode, or in a connected to the Area Electric Power System (EPS) mode. It is also assumed that there is a microgrid EMS, which is a major actor interacting with the EPS operator (DMS and possibly EPS EMS). Some microgrids may serve comparatively large consumer base and may comprise substantial medium and low voltage circuits (see e.g., [7]-[10]). .

Another specific of a microgrid is its dual operational objectives:

1. Operational objectives in the island mode

[1] The Advanced Microgrid Integration and Interoperability, Report prepared by Sandia National Laboratories

[2] DOE Definition of a MicroGrid: "A group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid [and can] connect and disconnect from the grid to enable it to operate in both grid-connected or island mode."

2. Operational objectives in the connected mode.

For instance, the frequency management in an island mode may have different normal tolerances than in the connected mode. In the island mode, the normal fluctuations of the loads and generation (e.g., cloudy day) may result in much larger deviations of frequency, which may be more difficult to mitigate by the available generation control. In some cases, even load management can be involved to keep the frequency with the tolerances.

In the connected mode, the frequency tolerances are much smaller and an additional variable can be added to the frequency control (like in ACE). Also, the frequency control is accompanied with the change of the power flow in distribution and transmission, which impacts losses and transfer capabilities, with different prices of the alternative sources for frequency control, with the changes of the accumulated energy storage, etc. These parameters, as well as the availability of the microgrid to control frequency (or ACE), are changing in real time. Also, in emergency situations, the participation of microgrids in the mitigation actions may be different depending on the internal state of the microgrid components and on the needs of the EPS. For instance, as it is stated in [1] "Different voltage-time settings could be permitted with agreement of the DER operator and the Area EPS operator. Other Area EPS operators may select different time ranges after performing more detailed studies and tests. In particular for the lower voltage "must select ranges that are compatible with distribution system relaying or they may choose other criteria for selecting ranges". This concept should also apply to other operational issues including the emergency frequency control. Therefore, the two-way exchange of information between the microgrid controller and the EPS operators should accommodate different operational objectives of the microgrid and EPS and should correspond to the particular time frames [11] – [14].

As follows from above, the actors involved in the information exchange and the information itself are different for different modes of microgrid and EPS operations, as are the solutions for the coordination of the EPS and microgrid emergency actions.

The high penetration of DER in distribution will change the setups of the Remedial Action Schemes (RAS) in the power systems, including the Under-frequency load shedding (UFLS). Currently, when the frequency drops in the bulk power system, the UFLS schemes disconnect a number of pre-selected distribution feeders following pre-selected settings for pre-selected groups of the UFLS. The pre-selection is based on the notion that there is always load demand on the feeder, and disconnecting the feeder will always reduce the load and raise the frequency.

With high penetration of DER in distribution, shedding the entire feeder may also mean shedding generation, which may be needed to supply a portion of the load. On the other hand, if the UFLS schemes do not work before the DER protection work, the system loses a big portion of generation, and the emergency situation worsens leading to a cascading development.

Therefore, in the Smart Grid environment, the UFLS will need to be more portioned [15]. In addition to the feeder heads, the UFLS schemes may need to be located at the sectionalizing breakers/recloser in the middle of the feeder, at the feeder branches, at the micro-grid PCCs, and at the load switches inside the micro-grids. This allocation will depend on the allocation of the DERs and micro-grids along the feeders.

Consider an example of different choices of the coordination of the UFLS setups between the EPS and microgrids [15]. There is a generation-deficiency situation in an island of the bulk power system, and the frequency drops below the settings of the UFLS. Let's analyze the possible scenarios for one feeder connected to the problem portion of the power system (see Figure 1-1).

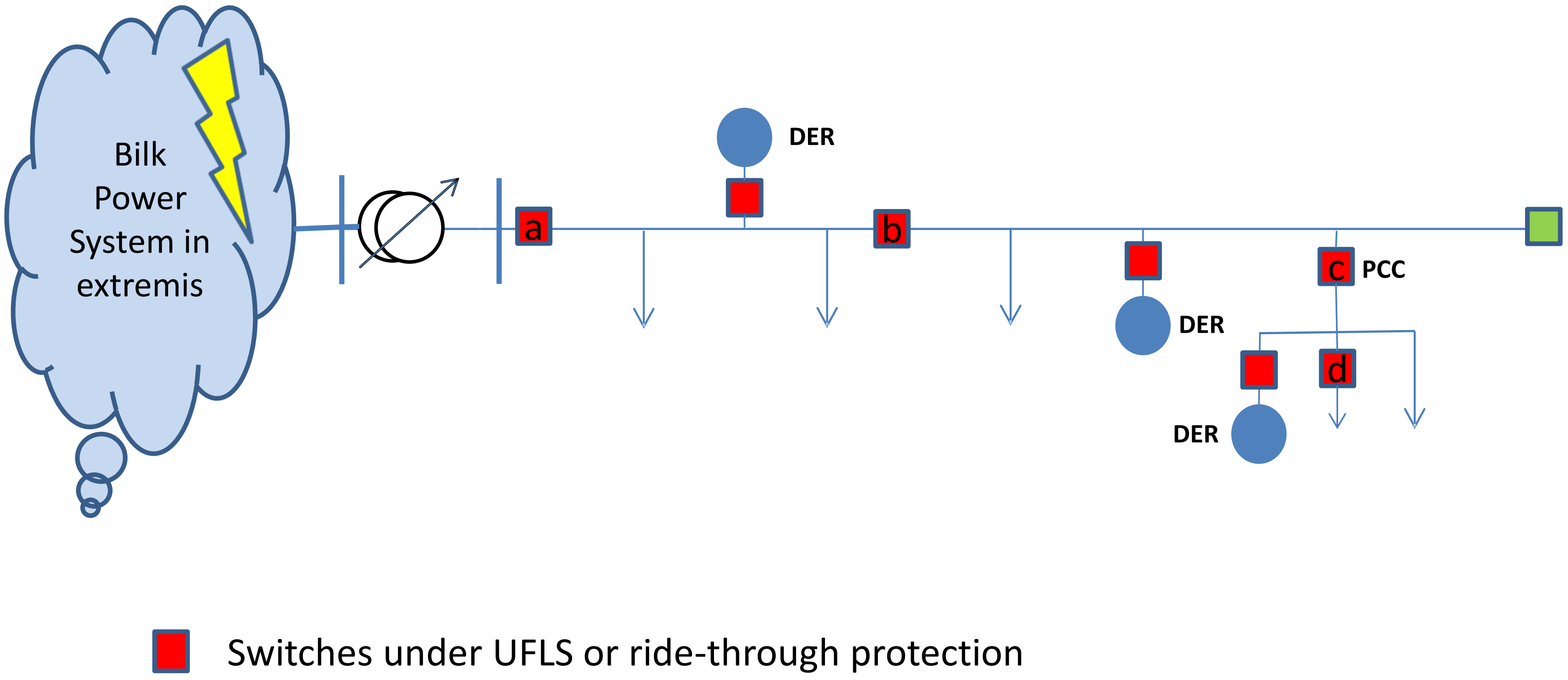

Figure 1-1. Example diagram for the coordination choices under different operational scenarios

In general, the following combinations of the load/generation conditions are possible (Table 1-1):

Table 1-1. Possible combinations of pre-shedding conditions

#	Feeder head [a]	Middle of feeder [b]	Micro-grid PCC [c]
1	load-rich	load-rich	load-rich
2	load-rich	load-rich	generation-rich
3	load-rich	generation-rich	load-rich
4	load-rich	generation-rich	generation-rich
5	generation-rich	load-rich	load-rich
6	generation-rich	load-rich	generation-rich
7	generation-rich	generation-rich	load-rich
8	generation-rich	generation-rich	generation-rich

In addition, there may be different combinations of the net load at different places, load shedding priorities, and values of load connected to the load-shedding scheme.

All these conditions change in near real time due to the changes of the compositions of load and DERs. Hence, the settings of the UFLS should also be adapted to the changes of the conditions. That requires fast communications with Remedial Action Schemes (RAS) and an optimization algorithm to manage these changes.

The situation becomes even more complicated, if the voltage significantly changes concurrently with the changes of the frequency.

Consider some scenarios from Table 1-1.

Scenario # 3: Opening of CB "a" will make the whole islanded feeder deficient. That can lead to even lower frequency in the feeder and to loss of more load and possibly distributed generation. Opening of switch "b" will create a self-sustained island downstream from "b", but will increase the deficit of portion "a" of the feeder, which can be disconnected by the UFLS in "a". In this case, the microgrid UFLS and the DER ride-through protection would not operate.

Condition # 5: If the CB (a) at the feeder head is disconnected, a portion of generation needed to support the load-rich bulk island is lost and the emergency situation deteriorates. If switch "b" is opened, the frequency in the disconnected portion of the feeder may drop even lower, which may lead to either opening switch c, or d, or the interconnection switches of stand-alone DERs in this portion of the feeder, as well as inside of the microgrid. What works first depends on the priorities of the corresponding settings. If the UFLS in point "d" can compensate the generation deficit of the portion "b" of the feeder, then the UFLS should work first at point d, and the entire portion "b" becomes a self-sustained island. If UFLS in "d" cannot compensate the deficit of portion b, but can compensate the deficit of the micro-grid in point "c", then the UFLS in point "c" should work first and in point "d" after that. If the UFLS in point "d" cannot compensate the deficit of the micro-grid, which will lead to the loss of all loads and generation in portion "b" and in the micro-grid, then the alternative of opening breaker "a " should be considered.

As seen from the examples, the relationships between the loads and UFLS in different points may change in near-real time, which means that the priorities of the UFLS in different points should also change.

The microgrid internal conditions, as well as the contractual arrangements between the microgrid and EPS operators may have a significant impact on the coordination of the microgrid's and EPS' control and protection systems.

Let's consider a number of situations as presented in Table 1-2.

Table 1-2. Changing priorities of RAS and DER protection for Microgrids

Load-generation balance of the Microgrid		EPS Operator's interest under emergency conditions	Microgrid operator's interest under emergency conditions	Comments
Microgrid is load-rich	Microgrid is connected to EPS. The load import is greater than the Under Frequency Load Shedding (UFLS) in the microgrid (in the ranges of EPS UFLS)	Assign higher priorities to the UFLS within the microgrid and lower ones to the PCC. Keep the DER protection priorities even lower. If the emergency is not mitigated after the operation of the EPS and μGrid UFLS, the μGrid will disconnect at the PCC.	Assign higher priorities to the UFLS within the microgrid and lower ones to the PCC. Have another load-shedding RAS for balancing load under island conditions	Objectives coincide. Microgrid needs to inform the EPS about the situation. EPS needs to confirm its settings.
	Microgrid is connected to EPS. The load import is smaller than the UFLS in the microgrid	Assign priorities to the UFLS within the microgrid according to the interconnection contracts and no UFLS for the PCC (after UFLS the MG may inject in the EPS)	Assign higher priorities to the UFLS for the PCC and lower for the UFLS within the microgrid (the MG may lose less load)	Objectives are different; Microgrid can trade its support to EPS. Needs to inform the EPS about the situation. EPS needs to confirm its settings.
Microgrid is generation-rich	Microgrid is connected to EPS. The microgrid injects power into EPS.	Assign priorities to the UFLS within the microgrid with higher priorities than the DER frequency protection. No UFLS for the PCC.	UFLS for the PCC only with higher priority than the DER frequency protection.	Objectives are different; Microgrid can trade its support to EPS. Needs to inform the EPS about the situation. EPS needs to confirm its settings.

As seen in the table, the coordination of the RAS and DER protection also depends on the load-generation-UFLS balance of the microgrids, on the conditions for the prioritization and sizing of the RAS and DER protection for microgrids that may change in near-real time. The information from the distribution system should be made available to the transmission EMS to provide information for the EMS contingency analysis._The Transmission Bus Load Model (TBLM) [16] can be such a source of information. The TBLM that is supported by the DMS from the distribution side should contain the relevant aggregated information from the microgrids.

The EMS contingency analysis should analyze the potential situations, taking into account the current models of the emergency behavior of the microgrids and other components of the distribution system aggregated in the TBLM and recommend preventive measures in both transmission and distribution domains.

1.3.2 Summary of requirements

The major action steps for implementing such coordination can be summarized as follows:

- The setups of the emergency responders of the microgrids aggregated at the microgrid PCCs is made available to DMS by the microgrid EMS. These setups include the dependencies of the load and generation on frequency and voltage within the emergency ranges [17]. They also take into account the overlaps of different load management means [18].
- Models of the emergency behavior of DER, Microgrids, ES, DR, and DMS applications aggregated at the transmission buses are made available to EMS through TBLM by the DMS TBLM developer [16]
- The transmission contingency/security analysis application analyzes the potential situations and recommends preventive measures, including the ones for the distribution system aggregated at the transmission buses. The first iteration of the EMS contingency/security analysis takes into account the currently aggregated in the TBLM load-to-frequency/voltage dependencies, generation- to-frequency/voltage dependencies, the dispatchable load dependencies, the DER capability dependencies, and the overlaps of the different load management means in the expected frequency and voltage ranges. The expected dynamics of the frequency, voltage, and loads at the transmission/distribution demarcation buses are submitted to the DMS through the TBLM.
- DMS application – Coordination of Emergency Actions – takes as input the dynamics of the frequency, voltage, and loads obtained from the TBLM and check the consistency of these dynamics with the availabilities expected during the next cycle of the contingency analyses. It arranges implementation of available/feasible preventive measures including the ones

for the microgrids, taking into account the near-real-time µGrid conditions, provided by the µEMS. If significant preventive measures cannot be implemented, DMS informs the EMS about the actual possibilities through the TBLM, and EMS reiterates the contingency analysis with new constraints.

- The µEMS applies the expected dynamics of the EPS frequency and voltage to the model of its µGrid and decides what actions to take. The choices can be as follows:
    - The µUFLS/UVLS is applied to the load within the µGrid, no changes of the setup of the µUFLS/UVLS and DER protection
    - The µUFLS/UVLS is applied to the load within the µGrid with changes of the setup of either the µUFLS/UVLS, or DER protection, or both
    - The µUFLS/UVLS is applied to the interconnection switch at PCC, the µGrid goes into the island mode
    - Other
- µEMS coordinates its choices with the DSO/DMS according to the contracts and makes the results available to the DMS
- DMS updates the TBLM upon the execution of the preventive measures.
- The above cycles are repeated periodically or by events.
- If an emergency situation happens, the pre-armed Remedial Actions Schemes, protection schemes, other load management means, and the DMS applications operate according to their setups.
- After the emergency is mitigated and the EPS is in a steady-state mode, DMS updates the TBLM.
- The restoration analysis and activities are started. The EMS application analyzes the possibilities of restoration and informs the DMS about existing constraints and desired (available) sequence of restoration on the by-transmission-bus basis.
- The µEMS informs DMS about the desired restoration sequences in the microgrid
- The DMS application – Coordination of Restorative Actions – optimizes the restoration based on the predefined and requested priorities within the transmission and distribution constraints.
- After the cycle of restoration is implemented, DMS updates the TBLM.

- After the situation is back to normal, the logs of the preconditions, physical and virtual events are exchanged between the EPS and microgrid for the post-factum analyses.

The conditions for emergency operations of the µGrids are changing in near-real time. Hence, the µEMS should update the aggregated at the PCC setups of the emergency responders on by exception basis.

- The structure of the exchanged data should support multi-dimensional, non-monotonous dependencies, command/request formats, and metrics of data uncertainty. The dependencies should cover practical emergency ranges of the independent variables.
- The EMS/DMS applications will use these data in their "what-if" contingency analyses of the EPS operations to derive the near-real time and short-term look-ahead coordination solutions

1.3.3 Illustrative examples

Consider some illustrations of the major steps of coordination of the UFLS between the EPS and µGgrid.

The transmission EMS contingency analysis submitted to the DMS the expected frequency dynamics in the generation-deficient bulk island (Figure 1-2). The DMS, in turn, communicates it to the µEMS. The µEMS applies it to the current µGrid conditions and setups of the emergency responders of the µGrid to the frequency dynamics of the bulk island. The expected reactions of the microgrid ES, UFLS and ride-through DER protection is illustrated in Figure 1-3 through Figure 1-7.

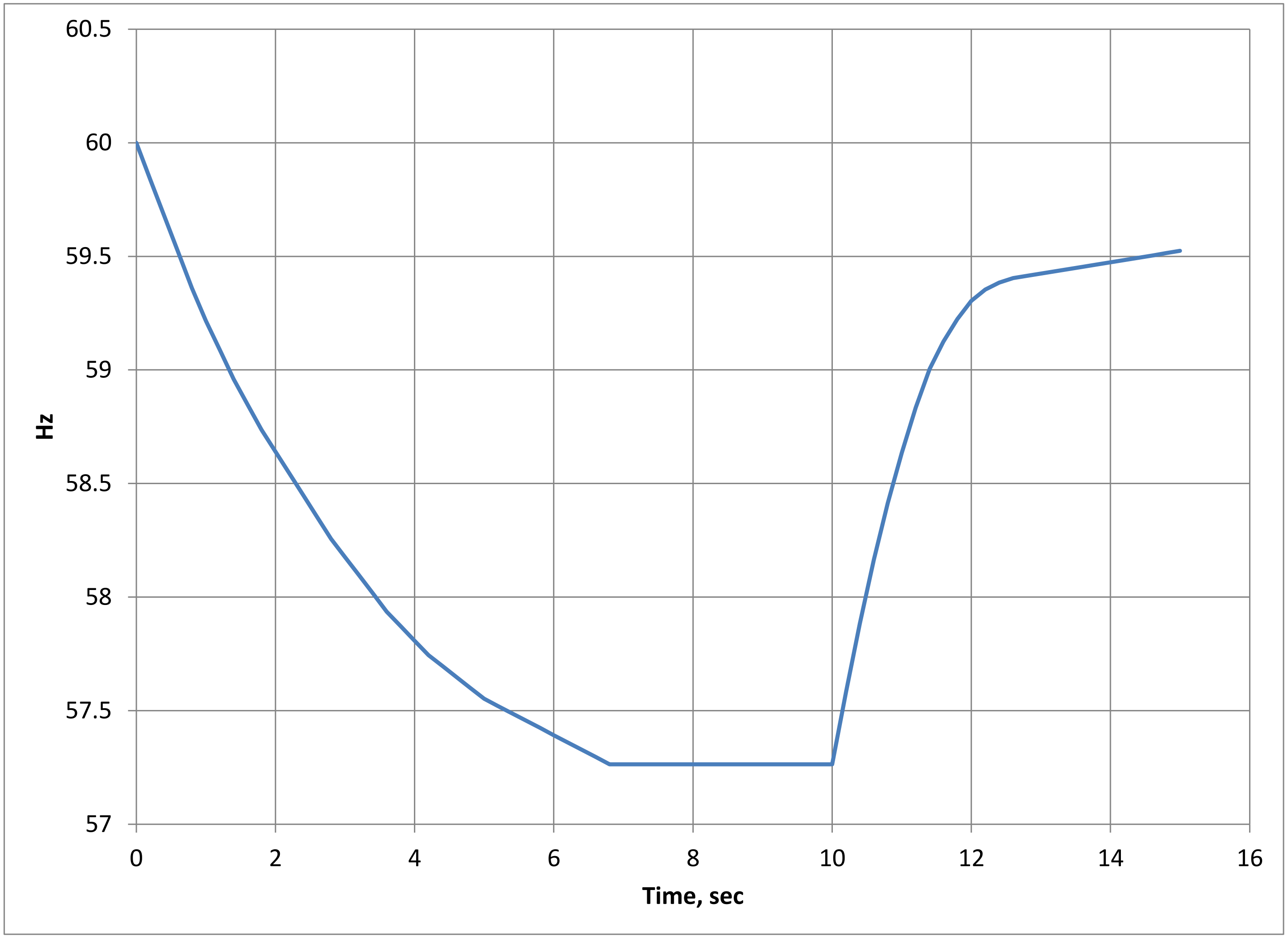

Figure 1-2. Expected frequency dynamics for the contingency in the bulk island

A generation-rich situation is illustrated in Figure 1-3. The excess of the generation is provided by the discharge of the Electric Storage (ES) responding to the drop in the frequency. If the μGrid stays connected, the μUFLS disconnects load within the μGrid and the low-frequency ride-through (LFRT) operates during the contingency disconnected the DERs in two steps, which makes the μGrid generation-deficient and adds an additional burden on the bulk island. If the μGrid goes into the island mode, disconnecting at the PCC, the μGrid will not lose load, but the EPS will lose some of the support generation. Such development of events may be not the desirable one for one or for both parties. If the summary of the development were communicated by the μEMS back to the DMS and EMS, they would adjust the corresponding contingency analyses and inform the relevant parties about the desired changes, if any.

If the there is an agreement that μGrid supports the EPS in such situations, then the settings of the LFRT should be changed to prevent the loss of the μGrid generation. Such a case, with prolonged clearing times and/or lower frequency setting of the LFRT is presented in Figure 1-4. If such changes of the LFRT are to be implemented, the μEMS updates the setups of this protection.

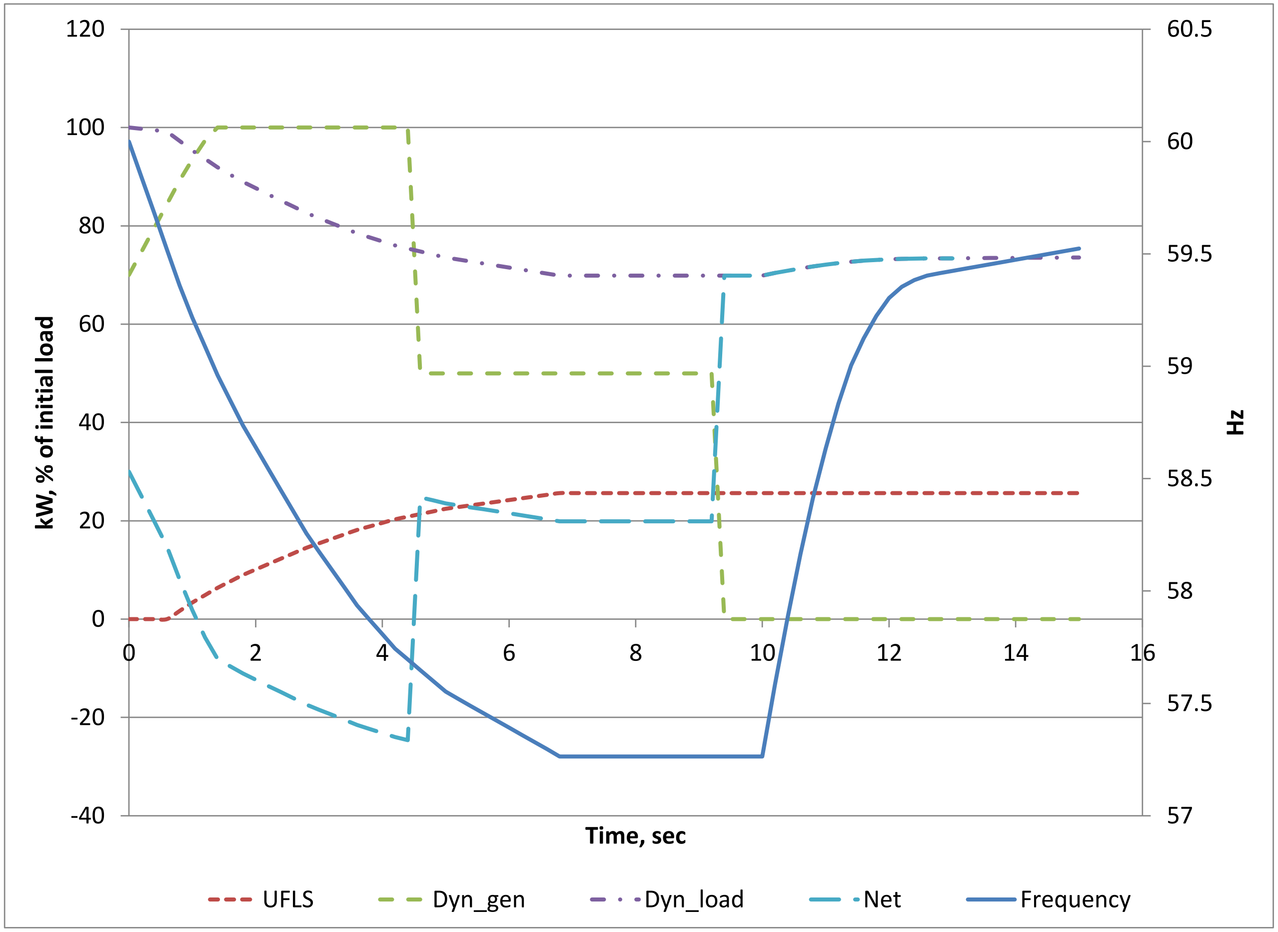

Figure 1-3. Expected dynamics of the µGrid components in the connected mode. Generation-rich situation. µUFLS disconnects load within the µGrid. Low-frequency ride-through (LFRT) operates during the contingency.

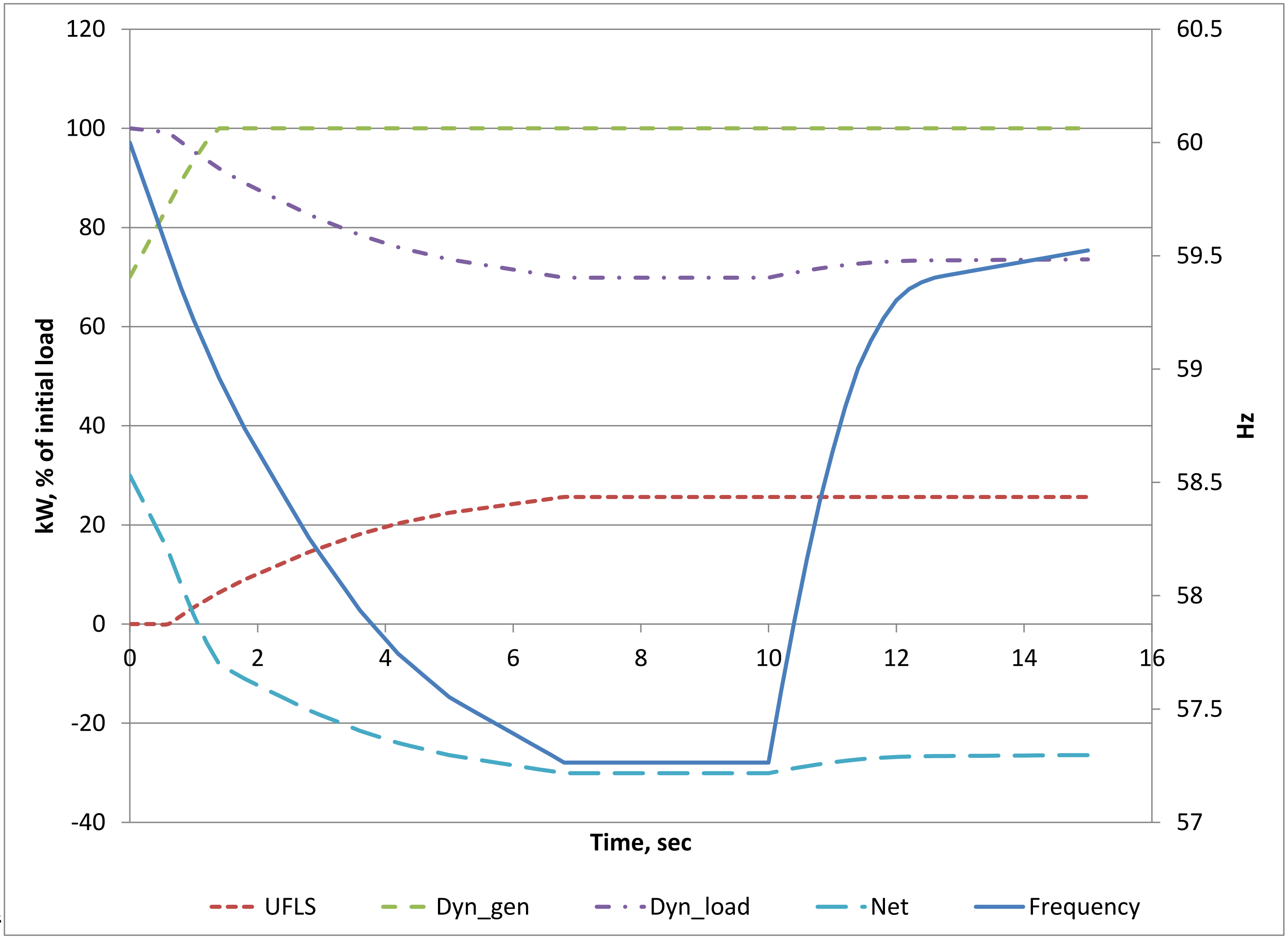

Figure 1-4. Expected dynamics of the µGrid components in connected mode. Generation-rich situation. µUFLS disconnects load within the µGrid. The settings of the low-frequency ride-through are adapted to the expected frequency dynamic so that it does not operate during the contingency. The µGrid supports the EPS in the emergency situation.

Figure 1-5 presents an illustration of a load-rich μGrid with load import smaller than the load to be disconnected by the μUFLS. In this case, the μEMS would prefer to disconnect the switch at the PCC and go into island mode, unless there is an agreement to support the EPS in such situations.

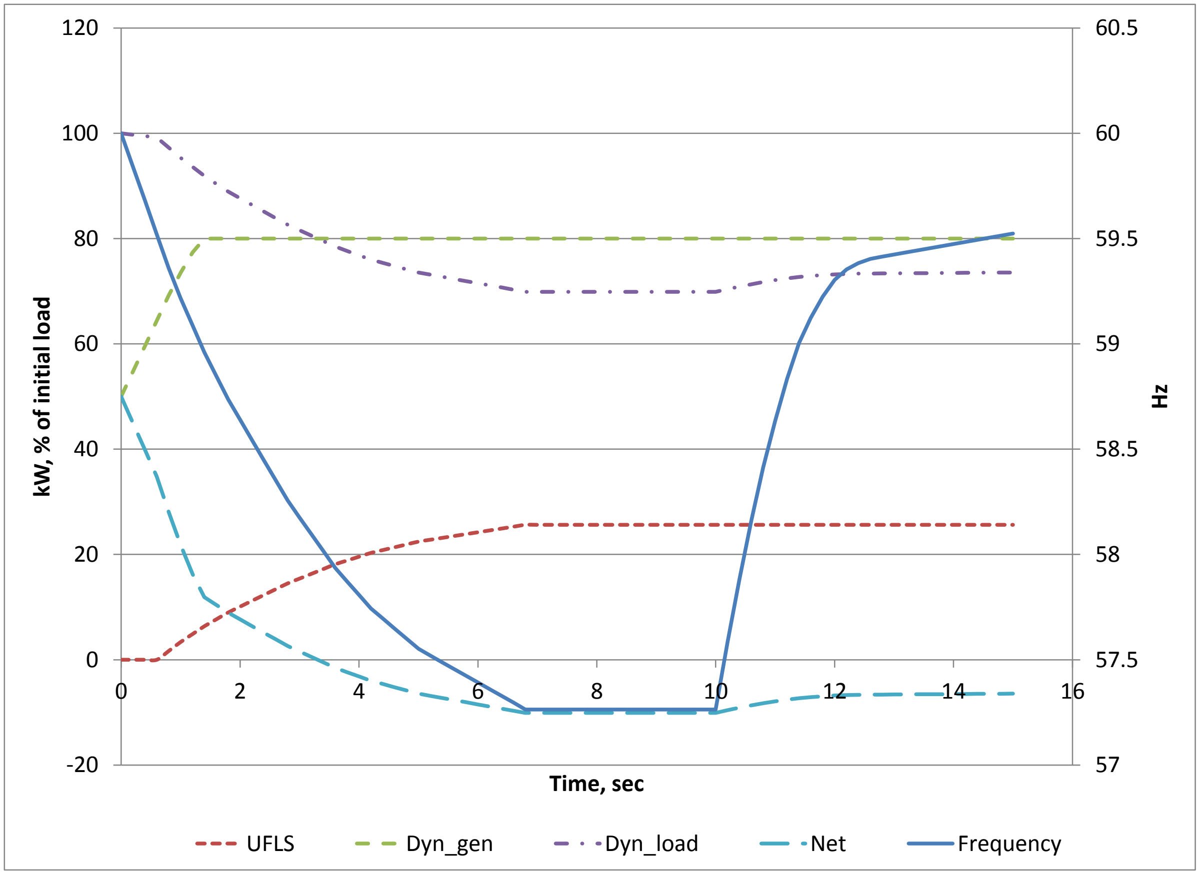

Figure 1-5. Expected dynamics of the μGrid components. Load-rich situation. The import of the load is smaller than the load to be disconnected by the μUFLS.

Figure 1-6 illustrates a case of a load-rich μGrid with the load import greater than the load to be disconnected by the μUFLS. In this case, the μEMS would prefer to stay connected, while the DSO would prefer the μGrid to go into island mode, unless there is an agreement that the EPS supports the μGrid, after it shed its share of the UFLS load. The μEMS should update the DSO on these alternatives.

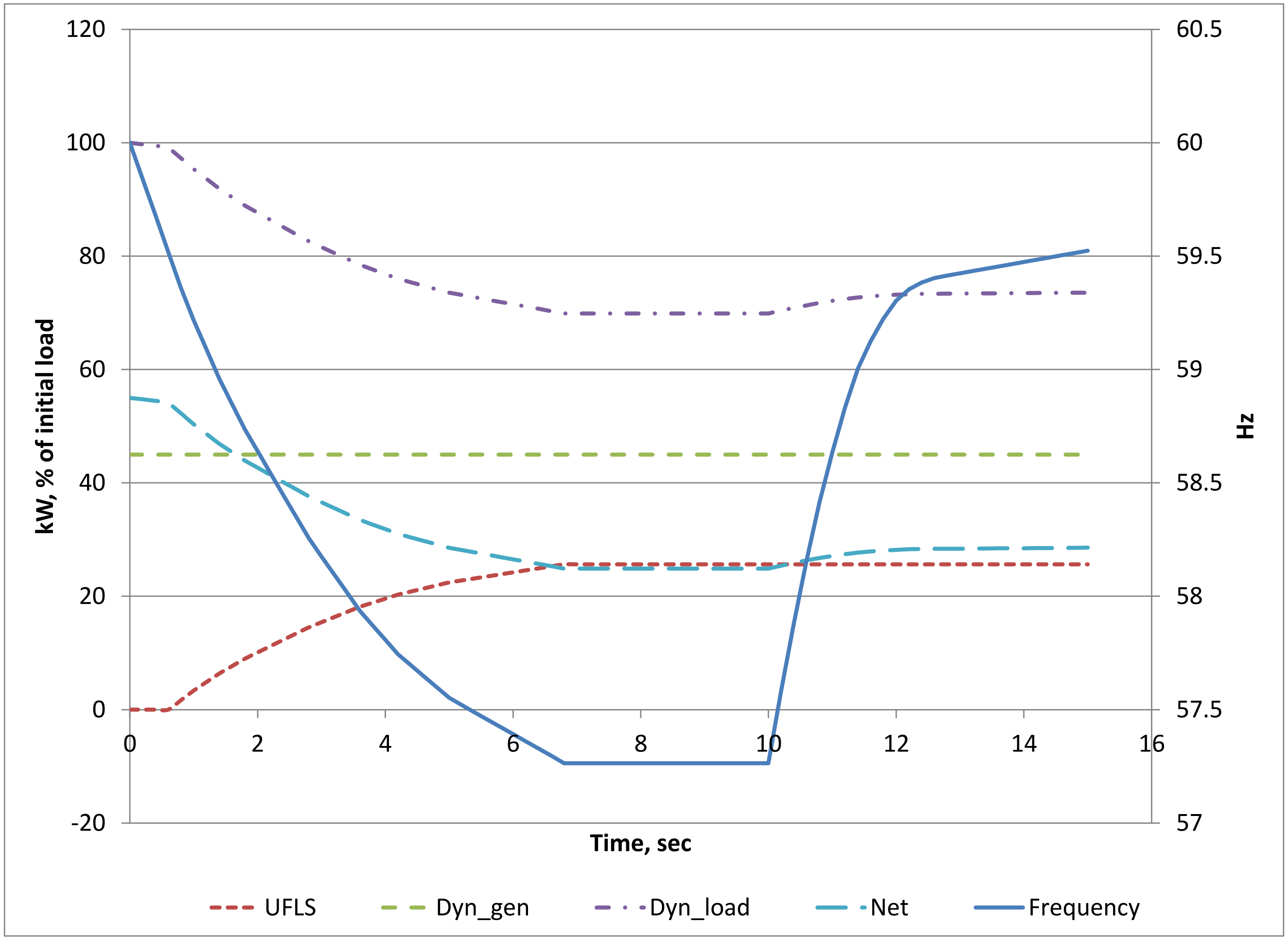

Figure 1-6. Expected dynamics of the µGrid components. Load-rich situation. The import of the load is greater than the load to be disconnected by the µUFLS. The µEMS prefers to stay in the connected mode.

Under less severe contingency, the may not be a need in changing the sensitive low-frequency ride-through settings. See the illustration below.

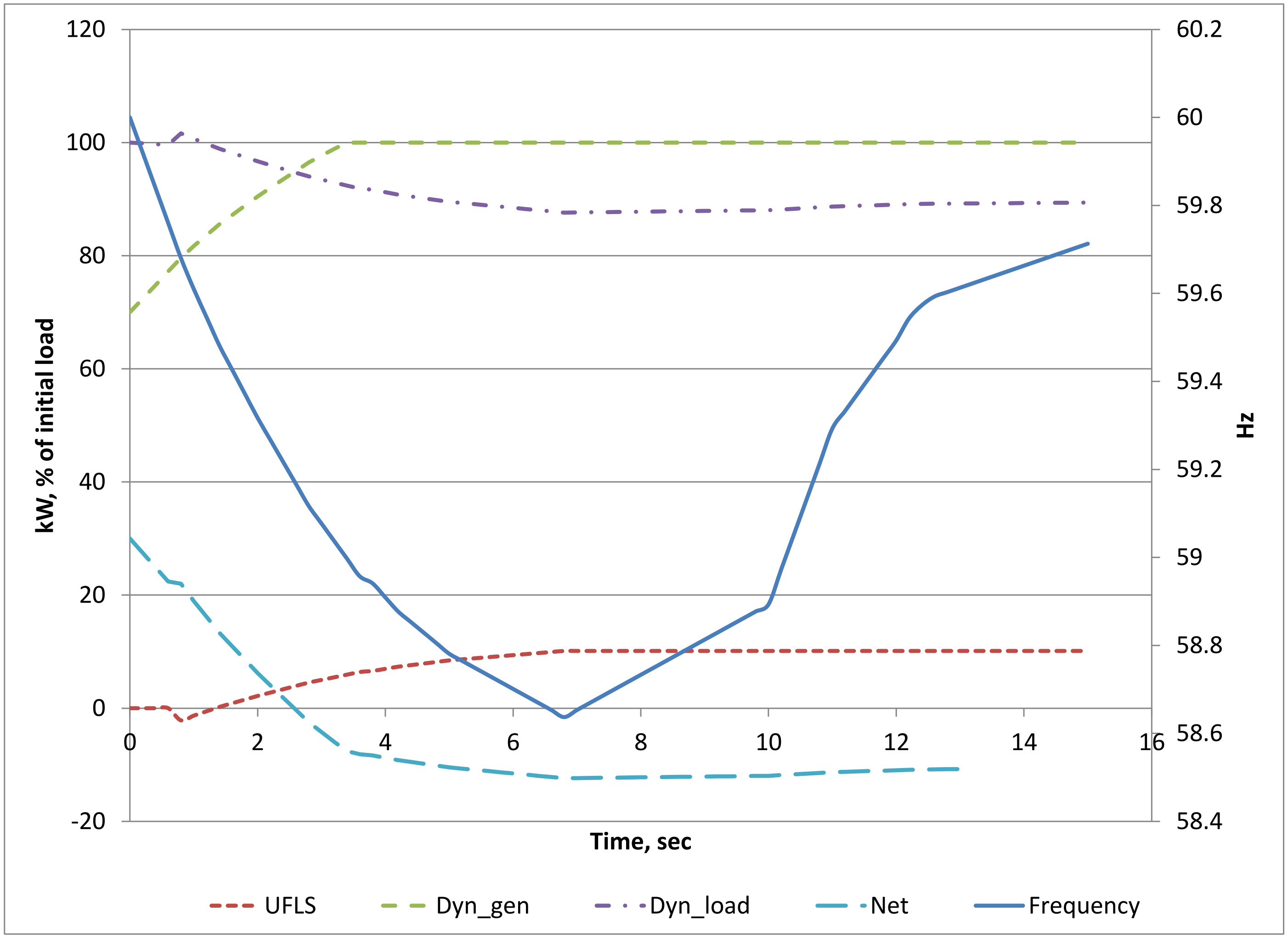

Figure 1-7. Smaller deficit in the Area EPS. The sensitive LFRT does not operate

As seen in the above illustrations, the near-real time adaptation of the setups of the RAS and protection in the distribution domain (as well as in the transmission domain) may become an efficient means for enhancing the reliability of the services in the Active Distribution Networks. Such adaptation can be accomplished only based on a fast two-way information exchange between the significant active components of the distribution domain, DMS and transmission EMS.

2 Diagrams of Use Case

Figure 2-1presents the conceptual paths for information flow between the microgrid EMS, DMS, EPS EMS, and third parties.

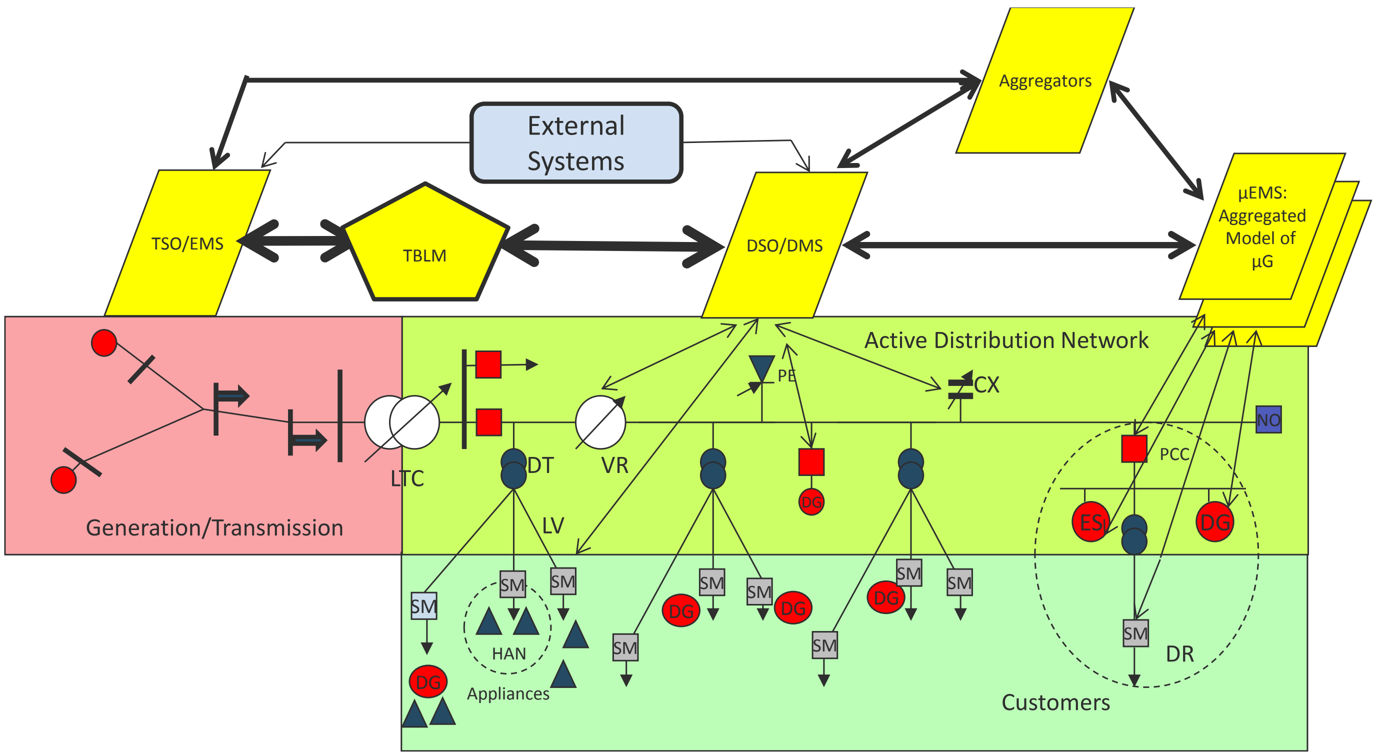

Figure 2-1. Conceptual information exchange between µEMS, other distribution active components, DMS, and EMS

Figure 2-2 through Figure 2-4 present the activity diagram for the major actors involved in transmission and distribution operations. The highlighted actors and activities represent the ones directly or indirectly associated with the operations of microgrids.

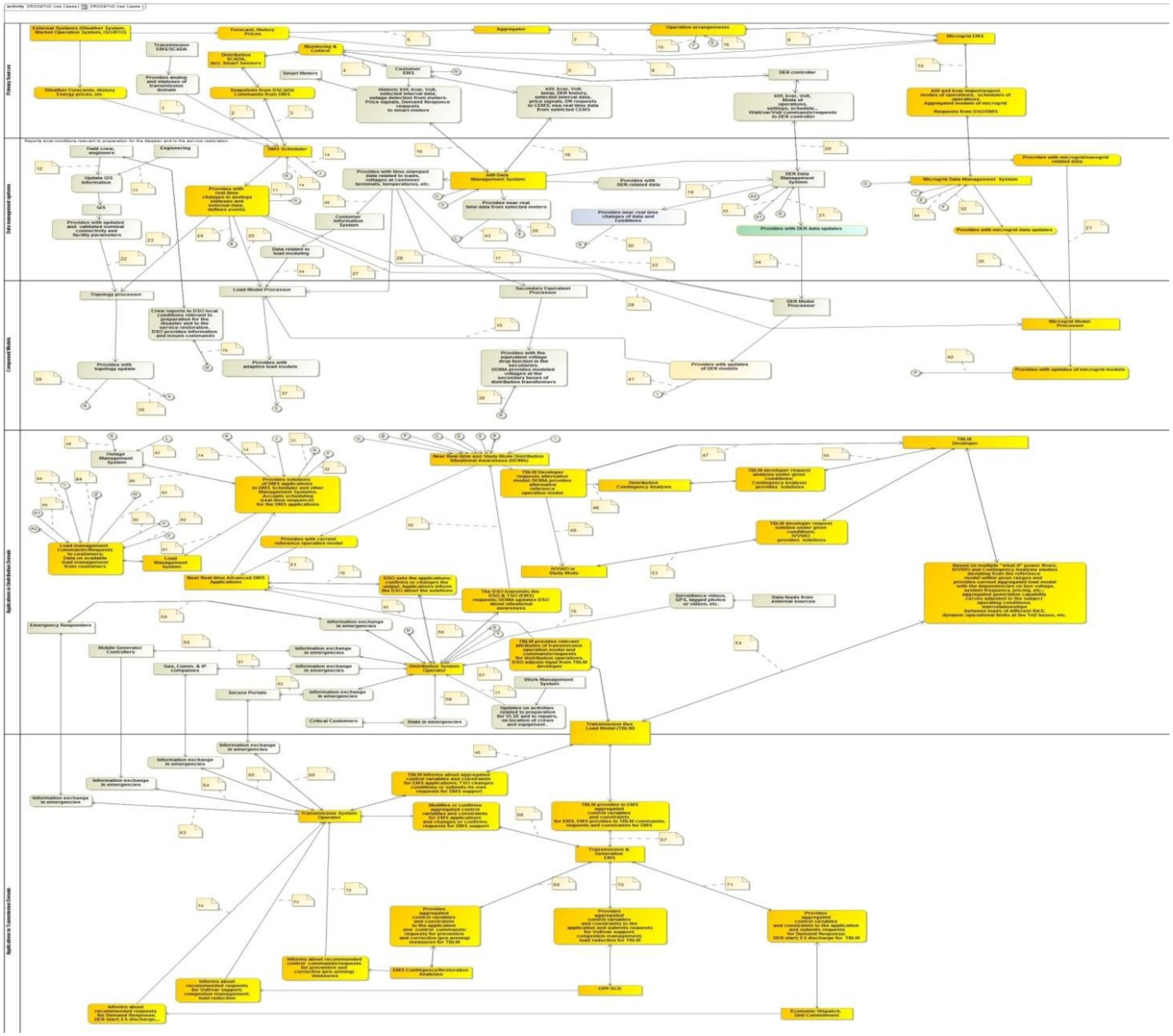

Figure 2-2. Activity diagram for use cases on interactions between customer, distribution and transmission domains

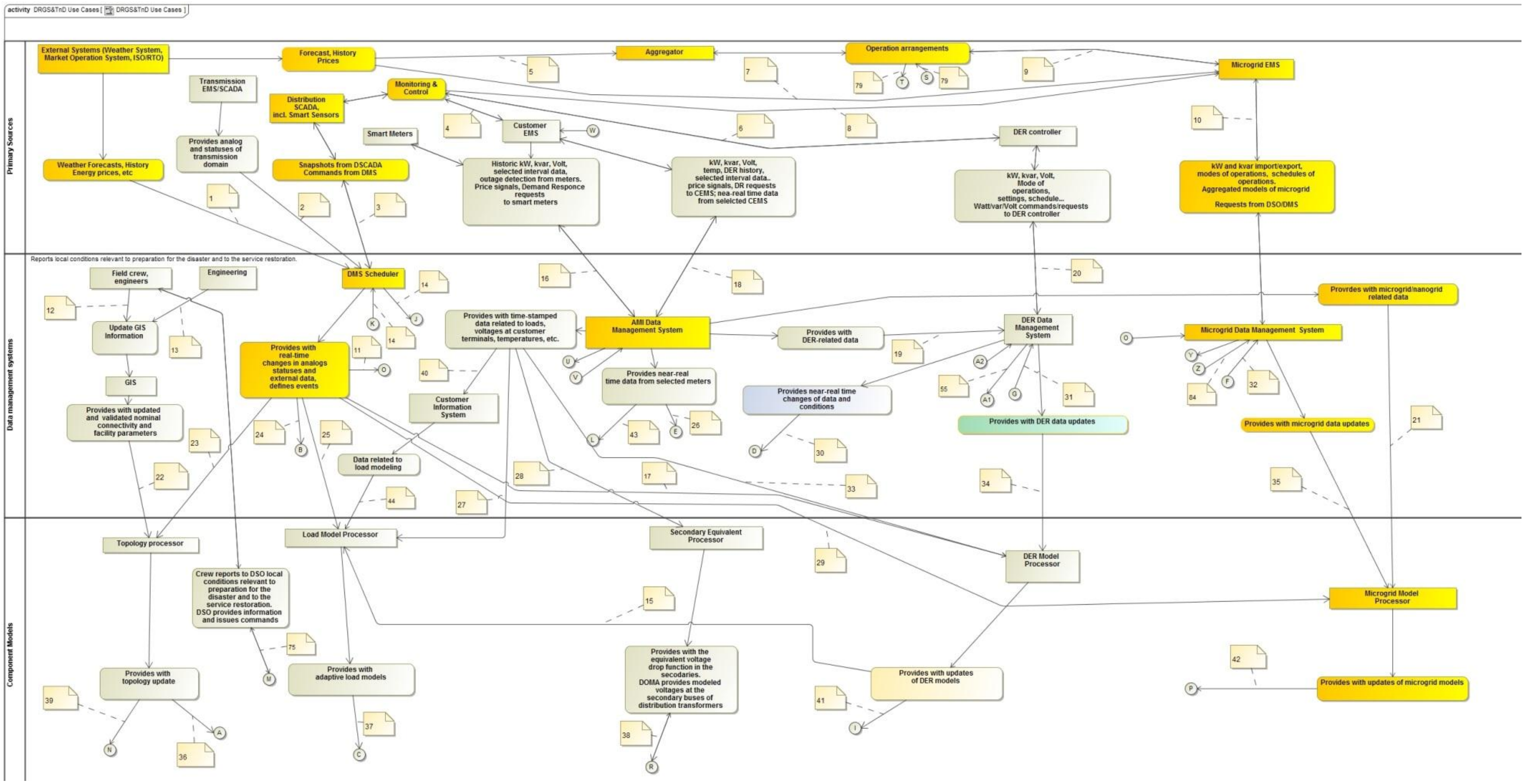

Figure 2-3. Portion 1 of activity diagram for primary information sources and back office systems

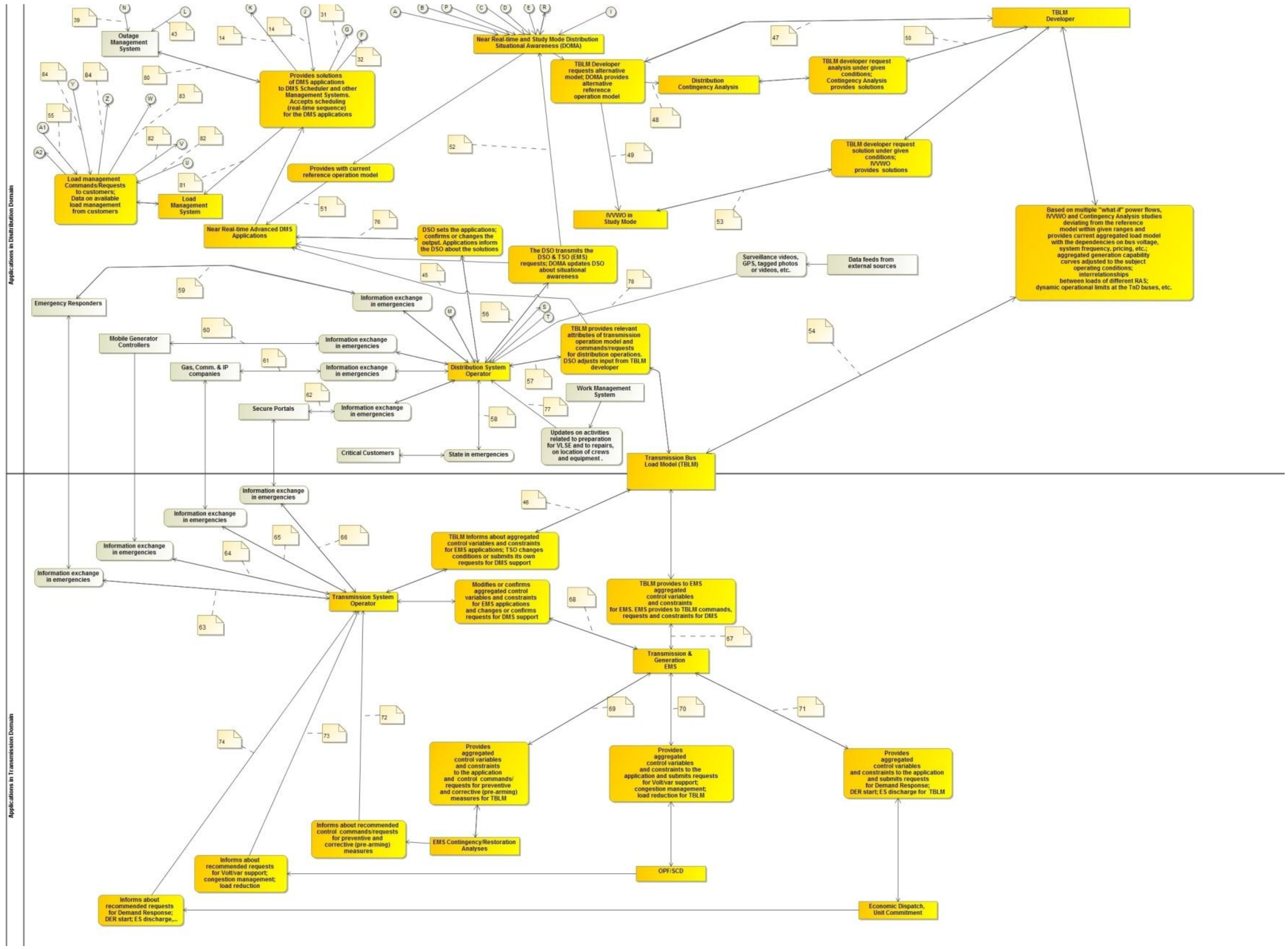

Figure 2-4. Portion of activity diagram for DMS and EMS applications and TBLM

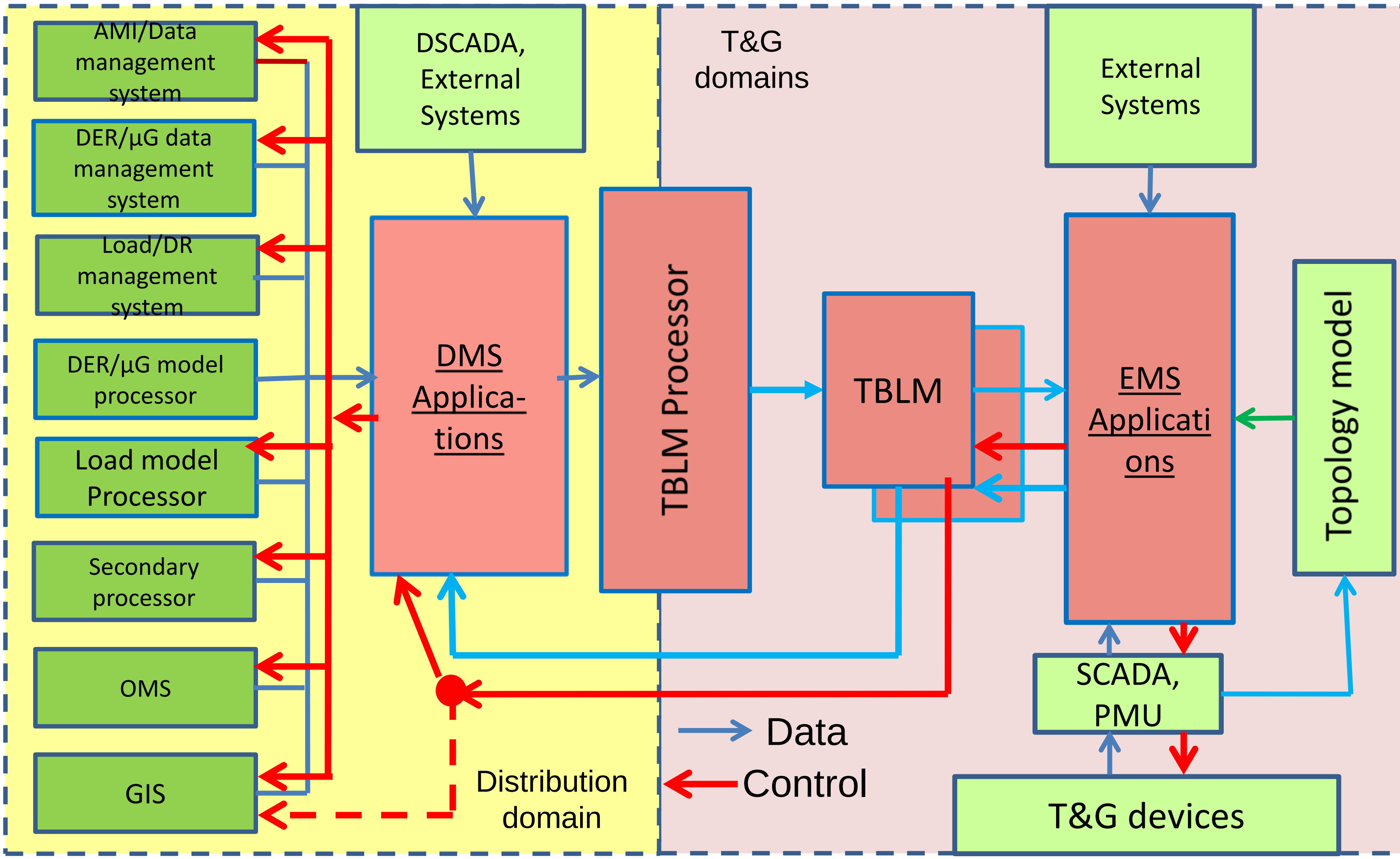

Figure 2-5. Conceptual information exchange between the DMS and EMS through TBLM

3 Technical Details

3.1 Actors

Table 3-1. List of major actors involved in interactions between a microgrid and EPS

	Actor	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
1	Distribution Operator (DSO)	Person, supported by DMS applications	Person in charge of distribution operations during the shift. The operator sets up the DMS 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 DMS applications, requests additional information, when needed, authorizes the DMS recommendations, makes decisions based on DMS 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	Additional functionalities: Communicates with µEMS, VPP operator/management systems; with community, campuses, military establishment, mobile DER systems, aggregator management systems, first responders, and communication companies; issues requests and schedules for autonomously controlled DER; issues requests, schedules and/or commands to µEMS, receives, analyzes and takes into account aggregated data from µEMS and other EMSes

2	Distribution Supervisory Control and Data Acquisition (DSCADA)	System	Distribution SCADA transmits/receives status and controls individual remote devices (IED) and sensors. Manages energy consumption by controlling compliant devices e.g., direct load control), and allows operators to directly control power system equipment. Required scope, speed, and accuracy of real-time measurements are provided, supervisory and closed-loop control is supported. It provides information to a Distributed Management System (DMS) or Customer Information System (CIS) for outage scenarios.	Additional functionalities: Communicates with large DER systems, μEMS, and other collective EMS receiving aggregated data and issuing commands/requests.
3	Transmission SCADA/EMS	System	Transmission SCADA/EMS collects data from IEDs within the T&D substation and from the TBLM. It supports remote control of controllable devices in the substation. The EMS runs the applications for analysis and control of the transmission and generation systems. EMS contains the transmission power system model on its side of the TBLM. It can provide the transmission connectivity and facility information in the vicinity of the distribution power system and outputs from other EMS applications for the use by DMS applications. It also accepts information from DMS through the TBLM for the use in the EMS applications.	Transmission SCADA/EMS collects data through the TBLM. EMS contains the transmission power system model on its side of the TBLM. It can provide the transmission connectivity and facility information in the vicinity of the distribution power system and outputs from other EMS applications for the use by DMS applications. It also accepts information from DMS through the TBLM for the use in the EMS applications

4	Aggregator/Energy Services Company (Market Participant-SGAC)	Company	A 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/μGrid will operate during pre-defined times, and the operational tolerances for control of these devices, if any	The agreement between the customers and the Aggregators, if approved by the utility, define the conditions under which the DERs/μGrid will operate during pre-defined times, and the operational tolerances for control of these devices, if any.

5	Large Customer EMS	System of a large customer	A customer EMS in typically implemented for large customers, such as large industrial or commercial company. Such customers may comprise multiple loads, distributed generation, energy storage, capacitors, volt/var controllers, load management means for normal and emergency operations, etc. The EMS 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, etc. It interfaces with internal monitoring and control systems and with DMS. Customer Energy Management System can receive pricing and other signals for managing customer devices, including appliances, DER, electric storage, and PEVs.	Customer EMS can provide DMS with an aggregated model of the customer operations, including (but not limited to) the following: • Net kW and kvar and generation kW and kvar • Net kWh and generation kWh • Net load and generation profiles • Critical interval average voltages • Critical instantaneous voltages • Instantaneous frequency • Weather data • Attributes of load shedding schemes • Attributes of Demand Response • Attributes of dispatchable load • Aggregated load-to-voltage dependencies in the normal and emergency ranges (Separately for load and generation) • Aggregated load-to-frequency dependencies in the normal and emergency ranges (Separately for load and generation) . Customer EMS can provide the following services under corresponding contracts: • Demand Response • Operating Reserve • Volt/var control • Load/frequency control • Load shedding

6	Smart Meter	Device	A Smart Meter is an advanced electric revenue meter capable of two-way communications with the utility and other parties. . It 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. The meters serve as gateways for two-way communications between the individual customer and the utility, Customer EMS, Community/Campus EMS, µEMS, and other authorized parties. 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 .	There are multi-functional Smart Meters able to frequently measure, store, and transmit kW, kvar, high accuracy Volts, voltage sags and swells, "Last Gasps", weather and higher harmonics data. . Smart Meters can support a number of services, such as: • Last Gasp/AC Out • Demand Response functions • Information for customers and third parties • Communications with HAN

7	Community EMS	System	A community may comprise multiple loads, distributed generation, energy storage, capacitors, volt/var controllers, load management means for normal and emergency operations, etc. The Community EMS includes man-machine interface for interacting with the system and allows the operator 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, etc. The EMS interfaces with internal monitoring and control systems and with DMS. The community EMS can receive pricing and other signals for managing customer load, DER, electric storage, and PEVs. The EMS also calculates, stores, and communicates to the DMS aggregated net load and generation, Demand Response, generation capability data for the community, protection settings and settings for frequency and voltage control in centrally controlled or autonomous modes of operations, other data needed for current and predictive model of community operations.	Communicates with Data Management System of DMS or other systems dedicated to manage aggregated generation and loads and with DMS applications. Supports control of frequency and voltages either in autonomous mode, or controlled by the DMS.

8	Campus EMS	System	A campus may comprise multiple loads, distributed generation, energy storage, capacitors, volt/var controllers, load management means for normal and emergency operations, etc. The Campus EMS includes man-machine interface for interacting with the system and allows the operator 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, etc. The EMS interfaces with internal monitoring and control systems and with DMS. The Campus EMS can receive pricing and other signals for managing customer load, DER, electric storage, and PEVs. The EMS also calculates, stores, and communicates to the DMS aggregated net load and generation, Demand Response, generation capability data for the campus, protection settings and settings for frequency and voltage control in centrally controlled or autonomous modes of operations, other data needed for current and predictive model of campus operations.	Communicates with Data Management System of DMS or other systems dedicated to manage aggregated generation and loads and with DMS applications. Supports control of frequency and voltages either in autonomous mode, or controlled by the DMS.

9	DER controller	Device/sub-system	The DER controller may contain a portion or entirely the object model of DER. It measures, stores and communicates current generation, generation schedules, capability curves, protection settings, mode of operations and voltage/var and frequency control settings, and other data needed for current and predictive model of DER operations. The DER controller supports different functions of DER based on either local, or remote inputs, is able to respond to utility requests, to price signals and other triggers. It controls Watts, vars, voltages and frequency according to either locally or remotely installed settings in both connected and island modes.	The DER controller communicates with DMS Scheduler and back-office systems, like DER Data Management System, DER Model Processor or other back-office systems dedicated to manage DER.

10	Microgrid EMS (μEMS)	ICT system	μEMS is a system that monitors and controls the operations of the components of advanced microgrid, analyses the operational alternatives in accordance with the EPS and contractual requirements, develops near-real-time and short-term look-ahead aggregated operational models of the microgrid, and interchanges information with the EPS DMS. The aggregated models of the microgrid contain measurements of current generation, generation schedules, DER capability curves, load-to-voltage and frequency dependencies and generation-to-voltage and frequency dependencies for normal and emergency conditions, dispatchable load, setups of protection and remedial action schemes, relationships between load management means, mode of operations and settings of voltage/var and frequency control functions, dependencies of model components on external signals, and other data needed for current and predictive model of DER operations. μEMS executes different functions of the microgrid in both connected and island modes of operations, such Watts, vars, voltages and frequency control according to either locally or remotely installed settings.	μEMS communicates with μG Data Management System and μGrid model processor of the DMS, with the DMS scheduler or other systems dedicated to manage microgrids and with DMS applications. Note: An advanced microgrid is comprising distributed generation/storage, and load. It may use internal controlling devices, such as voltage and var regulators, Remedial Action Schemes, such as Under-frequency/voltage Load Shedding, and elements of Information Communications Technology (ICT). A microgrid may provide a number of ancillary services. It can operate either in an island mode, or in a connected to the bulk power system (EPS) mode. Its μEMS is a major actor interacting with the EPS operator (DMS and possibly EPS EMS). A microgrid can belong to a customer and can be a part of a Virtual Power Plant (VPP)
11	VPP Management system	System	VPP Management system performs planning and trading an aggregation of generation and load within one control area. It calculates, stores, monitors and communicates the current and look-ahead aggregations of the Distributed Generation, Demand Response, and Micro-grids through interfaces with distribution and transmission domains and trades with the market domain.	The participation of a microgrid in a VPP should be governed under conditions of the agreements between the microgrid, VPP, and EPS. The Commercial VPP system will interface with the market categories after approval of the Technical VPP by the DSO.

12	Distribution Field Crew	Organization /person	Manual operations of field devices, repair and construction work, patrolling facilities, recording changes in facility parameters, connectivity, in mobile computers, transferring data to the operator, and corresponding database administrators. This is a class of actors. (SGAC)	Field crews are able to communicate with the distribution system operator and with GIS management via Field Crew Tools, such as mobile communications and computing.
13	Distribution Field Crew Tools	Devices	A field engineering and maintenance tool set that includes any mobile computing and hand-held devices. (SGAC)	
14	Engineering	Person/Department	Includes planning, and DMS maintenance personnel, power quality and reliability engineers, etc.	Performs DER/microgrid impact studies, recommends interconnection requirements, recommends options of setups of ADA applications, periodically inspects performance of ADA applications, troubleshoots applications, reviews report, etc.
15	Controllers/gateways of DER, PEV, and Electric Storage embedded in customer premises	Devices	Equipment and systems monitoring and controlling the DER, PEV, and ES at the customer site. These embedded resources can be just passive components of the prosumer; some may be active components providing demand response and other services.	The results of the performance of the embedded systems, in addition to be included in the net measurements by the AMI, should be also accounted separately. This is needed for the adequate load models for the customers and, consequently, for the microgrid.
16	Smart customer appliances	Devices	Equipment and systems at the customer site that could be controllable and to participate in demand response and other programs. Includes lights, pool pumps, air conditioners, electric water heaters, refrigerators, washers, electric dryers, dishwashers, etc.	Their characteristics can be used to derive components of adaptive load models that can be used for the aggregated microgrid models.

17	External Systems (e.g. Weather, DER providers)	Systems	Information systems outside the utility that 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 DMS for adjustment of the adaptive models. This information is most important for the development of the models of weather- dependent DER/ µG. Other external sources of information are the providers of the DER (e.g., the PV panel installers). If they collect data on the DER performance, this information can be used by DMS (via DER Data Management System) to determine the DER injections and separate them from the net load of the customer.	The information obtained from these systems is to be used by the modeling components of µEMS for adjustment of the adaptive models.
18	ISO/RTO	Systems	ISO: An independent entity that controls the power grid in a designated wide area 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 TSO/DSO Operators that are distributed by the TSO and DSO among individual and composite consumers and prosumers. The µEMS then distributes the requests among its participants.
19	Market Operation System (MOS)	System	Wide-area energy market management system providing high-level market signals for Tso and DSOs	Market for energy products, including bulk generation, distributed generation, electric storage, electric transportation, and demand response. A µEMS of a large microgrid can interact with MOS.

20	Geographic Information System (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 database is interfaced with the Customer Information System for linkage between the customer data and point of connection, with AMI, DER/µG, and DR data management systems for updates of secondary circuit equivalents, and relevant attributes of adaptive load models for the consumer, prosumer, DER/µG, ES, and DR. AM/FM/GIS database is also accessible to field crews via mobile computing for updates on facility connectivity and parameters. The AM/FM/GIS database is updated, proof-tested and corrected in a timely manner to provide a high probability of preparedness for supporting near-real-time DMS applications.	The future GIS should contain information on **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. The AM/FM/GIS database should be interfaced with AMI, DER/µG, and DR data management systems for updates of secondary circuit equivalents, and relevant attributes of adaptive load models for the consumer, prosumer, DER/µG, ES, and DR. AM/FM/GIS database should also be accessible to distribution field crews via mobile computing for updates on facility connectivity and parameters. GIS should also contain data aggregated at the PCCs of the µGrid (location, transfer capabilities, voltage limits, transformation ratios, etc.) How much of internal data from the µGrid should be in the EPS' GIS depends on the contractual agreements between the EPS and the prosumer.

21	Customer Information System (CIS)	System	CIS contains energy consumption and load data for each customer separate, even for 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 providing customer information including billing data, customer types, and customer numbers linked to distribution circuits and distribution transformers	CIS communicates with AMI, DER/microgrid, 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. How much of internal data from the μGrid should be in the EPS' CIS depends on the contractual agreements between the EPS operator, aggregators and the prosumer.
22	DMS	System	A set of integrated IT systems and DA applications supporting the operations, maintenance, and planning of the electric distribution system	The DA applications are the central component of DMS, being supported by DSCADA, DMS corporate databases, such as AM/FM/GIS, and interfaced with other EPS IT systems, such as OMS. The future DMS should interface for monitoring and control with the EMSa of large and composite consumers and prosumers, including μEMS.

23	DMS Scheduler	Sub-system/application	Computer-based sub-system consisting of Graphic User Interface, and an advanced scheduling application that accepts, checks, and organizes information obtained from DSCADA, Operators and other authorized personnel and triggers DA applications according to the given setups. It accepts output information from DA applications and initiates execution of their instructions . .	The DMS scheduler interfaces with External Systems, DSCADA, DA applications , back-office DMS systems, and other ICT systems including large individual and composite consumer/prosumer EMSs
24	DMS conversion and validation function (C&V)	Application	The C&V function uses standard interface between AM/FM/GIS database, converts and validates information about incremental changes implemented in the field. .	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 (e.g., if the policy is to back up 50% of maximum load any faulted feeder, and the contingency analysis shows that it cannot be done, then it is likely that the input data is wrong). With the high penetration of DER and microgrids, the C&V function should integrate these Smart Grid technologies.

25	AMI Data Management System		AMI Data Management System communicates with AMI Headends, collects, stores, and processes measurements from the Smart Meters. It is interfaced with CIS, GIS and other data management system and model processors, such as DER/μG, DR, and EV, and with the DMS applications. It gathers, validates, estimates, and permits editing of meter data such as energy usage, real and reactive loads and generation interval measurements, voltages, meter logs, and other data of multifunctional meters. It 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.	AMI Data Management System derives aggregated at the distribution transformer load profiles based on the link between the distribution transformers and the customer IDs stored in GIS; For prosumers, microgrids, and other composite customers, AMI Data Management System should collect the net real and reactive load information and the generation components of it. If the generation component is not available, the net load patterns should be analyzed involving additional information from the DER/μGrid Data Management System and or model processors to derive the component of the natural microgrid loads and the component of generation. This analysis can be done in the Load Model Processor.
26	DER data management system	DMS database/application	A specific database for DER attributes, contracts, and performance associated with the owner. DER data management system is able of controlling DER and ES charging/discharging; storing and processing data on DER attributes, operations, contracts, relevant historic information, collecting, processing, and storing power quality and reliability characteristics, etc., according to the designs of the object models and DMS applications	DER data management system is interfaced with AMI data management system, Aggregators, with the Load Management System, with DER model processor, and with the DA applications.

27	DER model processor	DMS Application	DER model processor is able of creating adaptive near-real-time and short-term look-ahead models of DER. It provides DMS applications with full object model of DER. Derives the object model from the data obtainable from the DER controller, if monitored, from the DER Data Management System, GIS, AMI Data Management System, historic measurements and external data.	Develops adaptive models of DER based on new data obtained from the snapshots of the DMS scheduler, from the attributes from the Data Management System and from DER controllers, including the setups of ancillary services provided by the DER, current protection settings, etc.
28	Microgrid Data Management System		µGrid data management system is able of storing and processing data on microgrid attributes, operations, contracts, relevant historic information, of collecting, processing, and storing power quality and reliability characteristics, etc. according to the designs of the object models and DMS applications	The µGrid data management system can issue requests and commands to the corresponding microgrid EMS based on DSO and/or DMS application input, if so designed. These messages may include the following: • Real-time prices • Demand response triggers and amount • Disconnection/reconnection command for intentional islanding • Desired kW and kvar (power factor) setpoints at PCC and/or volt/var control curves • Desired setups of Remedial Action Schemes (RAS) • Desired setups of DER ride-through functions • Data requests • Other

29	Microgrid Model Processor	DMS Application	Accumulates and updates the aggregated at PCC operational models of µG. Interfaces with µEMS, EPS' DMS, and TBLM developer.	Develops adaptive models of µGrid based on new data obtained from the snapshots of the DMS scheduler and attributes from the Data Management System and from µEMS, including the setups of ancillary services provided by the µG, current RAS and protection settings, etc.
30	Load /Demand Response Management System	Database/Application	Controls DR and other load management means based on input from the operator and DMS applications, processes and stores data on load management programs, contracts, relevant historic information, for creating adaptive models of DR, collects, processes, and stores customer-specific data according to the designs of the object models and DMS applications.	Distributes the DSO/DA commands for aggregated load control among individual/group participants. It interfaces with the Load model processor, aggregators, customer EMS, µGrid Model Processor and Data Management System, µEMS, AMI Data Management System, and DMS applications.

31	Load Model Processor	Application	Develops daily load models based on information available from CIS and GIS (currently – typical load profiles and typical load-to-voltage dependencies)) and engineering input.	The Smart Grid Load Model Processor develops adaptive individual and aggregated load model of consumers and prosumers taking into account the variety of possible load components and their dependencies on a number of factors, such as embedded distributed generators, electric storage devices, and plug-in electric vehicles, and demand response means. The real and reactive load models, individual or aggregated, reflect the behavior of these composite loads depending on the known weather, prices, voltage, time of day, and other factors. It normalizes the models to the nominal conditions and derives the dependencies of the load on the changes of these conditions. The Load Model Processor interfaces with AMI Data Management System, DER and µGrid Data Management Systems and Model processors, customer and µGrid EMSes, different sources of operational triggers, such as real-time pricing sources, reliability trigger sources, weather sensors and systems, with DMS applications and TBLM Developer

32	PEV data management system and model processor	Application	PEV data management system is encouraging or discouraging charging PEV through relevant pricing or other incentives/disincentives, processing and storing data on PEV programs, contracts, relevant historic information, creating adaptive models, collecting, processing, and storing customer-specific data according to the designs of the object models and DMS applications.	Such application may be needed in the μEMS, and other EMS of composite prosumers.
33	Secondary Equivalent processor	Application	Provides DMS with equivalents of the voltage drops and power loses in the secondary circuits fed from distribution transformers Derives the voltage drop and the power loss equivalents in the secondaries as functions of the available near-real time data, based on the historic AMI data and modeled or measured voltages at the LV bus of the distribution transformers.	Such application may be needed in the μEMS, and other EMS of composite prosumers
34	Topology processor, including topology validation processor	Software program	Provides DMS with near-real time connectivity model. Derives and validates the connectivity model based on GIS, DSCADA data and on power flow analysis	Such application may be needed in the μEMS, and other EMS of composite prosumers

35	Energy Services Interface (ESI)	Application	Network communications application device which provides a gateway from the utility (or other energy service provider) to the customer site. Provides cyber security and coordinates functions that enable secure interactions between relevant Home Area Network (HAN) Devices, meters and the Utility/ESP. Permits applications such as remote load control/Demand response, 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. This service is also a specialized class of services potentially included in HAN gateways. Also commonly referred to as a Home-Area Network Gateway.	May a part of µEMS, and other EMS of composite prosumers, or may interface with these EMSes.

36	Transmission Bus Load Model (TBLM)	Data model	The TBLM is a composite model of the distribution system operations aggregated at the demarcation bus between the transmission and distribution domains. It consists of the following components: • Net real and reactive load at the bus • Real and reactive generation components • Load management components • RAS load components and attributes • Aggregated DER/μGrid capability curves • Aggregated real and reactive load-to-voltage/frequency dependencies • Aggregated real and reactive load dependencies on other external factors • Technical and economic functions and attributes of composite prosumers • Aggregated dispatchable real and reactive loads • Overlaps of different load management functions, which use the same load under different conditions. • Degree of uncertainty of the distribution model • Other	The operational models of the μGrid and other composite prosumers should be aggregated in the TBLM

37	Distribution Situational Awareness	DMS application	The Distribution Situational Awareness is based on two major DMS applications: Distribution Operation Modeling and Analysis (DOMA) and Distribution Contingency Analysis (DCA). DOMA is an advanced DMS application. It runs periodically and by event, or in study mode for given conditions, including short-term look-ahead analysis. It models and analyzes unbalanced power flow; it analyzes the operations of the distribution system from the standpoints of adequacy, power quality, and economic efficiency; provides situational awareness of distribution operations under normal and contingency conditions; provides background models for other DMS applications. The DCA performs an N-m contingency analysis in the relevant portion of distribution and provides situational awareness on the status of real-time distribution system reliability. 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 isolation and service restoration.	The Distribution Situational Awareness utilizes adaptive nodal load, DER/Micro-grid, and PV models and secondary equivalents. Communicates with AMI, DER/microgrid, and DR data management systems. Supports TBLM developer. The new functionalities of the DCA are as follows: 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 Microgrids to maximize the amount of energized loads With significant penetration of DER and microgrids, there will be a new kind of contingencies associated with a loss of a significant generation by the DER generation due to the disturbances in the bulk EPS. The DCA will need to include optimal distribution of the EMS requests for coordination of the EPS' emergency actions and the emergency actions of the composite prosumers. Thus, the new DCA will include the Relay Protection and Remedial Action Schemes Re-coordination.

38	Fault Location Isolation and Service Restoration (FLISR)	DMS application	Fault Location, Isolation, and Service Restoration identifies and locates the fault, isolates the faulted element from healthy sections and restores services to the customers connected to the healthy sections. It assesses, for the duration of repair, the situation with loads, DER, Demand response and Micro-grids	The application should include the modeling and control of the operations of DER, μGs, and DR.
39	Multi-level Feeder Reconfiguration (MFR)	DMS application	MFR performs a multi-level feeder reconfiguration to meet one of the following objectives or a weighted combination of these objectives: • Optimally restore service to customers utilizing multiple alternative sources. The application meets this objective by operating as part of FLISR • Optimally unload an overloaded segment • Minimize losses • Minimize exposure to faults • Equalize voltages. • Swap loads to reduce LMPs and assist in congestion management	The application should include the modeling and control of the operations of DER, μGs, and DR.

40	Integrated Voltage, Var, and Watt Optimization (IVVWO)	DMS application	IVVWO is a multi-objective DMS application. It runs periodically and by event, as well as in the study mode for given conditions. It optimizes states of voltage and var controlling devices of the EPS and takes into account the states of the DER, μG, and DR. IVVWO communicates with DOMA, Demand Response/Load Management System, field IEDs.	It should model the behavior of the autonomously controlled DER systems and composite prosumers, as well as DR means in the course of volt/var optimization. It should also optimize the modes of operations and settings of the centrally controlled DER and composite prosumer systems, as well as the DR associated with IVVWO. It should communicate with the composite prosumer EMS/Controllers either directly, or through the corresponding data management systems and model processors.
42	Pre-arming of Remedial Action Schemes (RAS)	DMS Application	The applications will receive pre-arming signals from the EMS Contingency/Security analyses through the TBLM and DMS scheduler and will change the setups of distribution-side remedial action schemes.	The EMS Contingency/Security Analyses applications will take into account the protection (ride-through) and RAS settings of the DERs and μGs, as well as the generation-load balances of microgrids and other composite prosumers. The existing contractual agreements between the EPS and prosumers of different categories should be respected. The relevant information on the RAS of the composite prosumers will reside in their EMSes, which will be interfaced with the DMS. The input information for the EMS applications will be aggregated by the DMS and will reside in the TBLM. This application can be a part of the Distribution Contingency Analysis.

43	Coordination of emergency actions (CEA)	DMS application	CEA will receive critical statuses, measurements, and requests for preventive and corrective actions needed for the coordinated self-healing management of bulk power system contingencies. CEA will coordinate the objectives, modes of operation, and constraints of other advanced DMS applications in concert with the RAS in distribution. For instance, the function can change the mode of operation of the IVVWO from normal to emergency, change its settings, or trigger the use of dispatchable real and/or reactive load, etc.	The application should include the modeling and control of the operations of DER, µGs, DR, and relevant DMS applications under the emergency conditions. The models should include the aggregated at the microgrid PCCs load-to-voltage/frequency dependencies, the generation-to-voltage/frequency dependencies, and the overlaps of different load management means. The models should be adapted to other external conditions, like weather and prices, at the corresponding time The existing contractual agreements between the EPS and prosumers of different categories should be respected.
44	Coordination of restorative actions (CRA)	DMS application	CRA coordinates the restoration of services and normal operations based on the availabilities in distribution, transmission, and generation domains after the emergency conditions are fully or partially eliminated. The availabilities of restoration in transmission and generation domains are submitted to the DMS by the transmission/generation EMS.	The application determines the sequence of restoration based on the available control of the DER, µG, DR, and IVVWO within the transmission, generation, and distribution constraints and in accordance with the contractual agreements between the EPS and other parties involved.

45	DMS application: TBLM developer	DMS Application	The application provides the aggregated transmission bus model, including: Load components; VPP technical and economic functions and attributes, including prices; Aggregated capability curves; Aggregated real and reactive load-to-voltage dependencies; Aggregated real and reactive load-to-frequency dependencies; Aggregated real and reactive load dependencies on Demand response control signals, Dynamic prices, Weather, etc.; Aggregated dispatchable load; Model forecast; Overlaps of different load management functions; Degree of uncertainty. It derives the aggregated current states and the dependencies of the model attributes on the impacting factors retrieved from the real-time measurements and from the DMS applications in near-real time and study modes.	The application aggregates the attributes of the models of the DER. μGrid, and other composite prosumers in the normal and emergency ranges taking into account the specifics of different DER categories

3.2 Information exchange

The list of interfaces presented in Table 3-2 is consistent with the activity diagram presented in Figure 2-2 through Figure 2-4.

Table 3-2. List of logical interfaces for information support of the transmission and distribution operations

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
1	External Systems	DMS Scheduler	Environmental data by locations; Other information affecting the behavior of the customer loads.	Medium to Large	Periodically and by significant changes.	
2	Transmission SCADA/EMS	DMS Scheduler	Analog and statuses from the transmission domain;	Medium	Periodically and by significant changes.	

3	DMS Scheduler	DSCADA	Control commands from ADA applications executable by DSCADA	Small to Medium	Minimum exchange times	
3	DSCADA	DMS Scheduler	Near real-time analog and status information from the observable portions of the distribution power system Protection and Remedial Action Schemes data	Medium to Large	Minimum exchange times	According to efficient utilization
4	Customer EMS	Distribution SCADA	Monitoring data	Small to Medium	Near real-time	
4	Distribution SCADA	Customer EMS	Control commands and requests	Small	Near real-time	
5	External Systems	Aggregator	Weather and Market data	Small	As needed due to significant changes	
6	DER controller	Distribution SCADA	Monitoring data	Small to Medium	Near real-time	
6	Distribution SCADA	DER controller	Control commands and requests	Small	Near real-time	
7	External Systems	Microgrid EMS	Weather and Market data	Small	As needed due to significant changes	
8	Distribution SCADA	Microgrid EMS	Control commands and requests	Small	Near real-time	
8	Microgrid EMS	Distribution SCADA	Monitoring data	Small to Medium	Near real-time	
9	Aggregator	Microgrid EMS	Suggested operation arrangements	Small	By schedules	
9	Microgrid EMS	Aggregator	Accepted and executed operation arrangements	Small to Medium	Up to near real-time	
10	Microgrid Data Management System	Microgrid EMS	Real-time prices Demand response triggers and amount Disconnection command for intentional islanding Desired kW and kvar setpoints Desired voltage setpoints	Small to average	Immediately after change	

			Data requests			
10	Microgrid EMS	Microgrid Data Management System	Aggregated for Microgrid net load and generation of kW and kvar Net, load and generation kWh 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 Microgrid operations, e.g., electric storage parameters, load-shedding RAS parameters.	Small to average	Once a day	Revenue accuracy for kW and kvar; 0.5%-0.2% accuracy for Voltages
10	Microgrid EMS	Microgrid Data Management System	Lowest instantaneous voltages from included Smart Meters Instantaneous frequency Last Gasp/AC Out from selected Smart Meters Changes in relay protection and RAS settings, volt/var control modes and settings,	Small to average	Last gasp - immediately from selected first-reporters; Instantaneous voltages within minutes after fault;	0.5%-0.2% for Volt; 0.1% for Hz

			ride-trough settings, and electric storage parameters.		Instantaneous frequency – report by exception in autonomous mode of operations. Changes - immediately	
11	DMS Scheduler	Microgrid Data Management System	Provides with real-time changes in analogs statuses and external data, defines events	Small	As needed due to significant changes	
12	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
13	Engineering	GIS	Updates of GIS data	Small	As needed	
14	DMS Applications	DMS Scheduler	Provides solution of DMS applications to DMS Scheduler and other Management Systems.	Small	After DMS applications run and determine a need in control (periodically and by event)	Verified information
14	DMS Scheduler	DMS Applications	Provides scheduling (real-time sequence) for the DMS applications, defines events	Small	As needed	
15	DER Model processor	Load management system	Updates the information on load management means	Small	Provides with updates of DER models	
16	AMI Data Management System	Smart Meter/AMI	Real-time prices Demand response triggers and amount Data requests	Small to average	Immediately after change	

16	Bellwether Smart Meter/AMI	AMI Data Management System	Instantaneous kW and kvar Weather data Instantaneous voltages Instantaneous frequency from dedicated meters in autonomous mode of Microgrid 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
16	Smart Meter/AMI	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
17	DMS Scheduler	DER model processor	Provides analogs and external data relevant to DER operation modeling, e.g., weather parameters, prices, DR requests, etc.	Average	Periodically and by events	Verified data
18	AMI Data Management System (including Last Gasp service)	Customer EMS	Real-time prices Demand response triggers and amount (Demand response can be executed via load reduction, or DER/ES generation increase, or both) Data requests	Small to average	Immediately after change	
18	Customer EMS	AMI Data Management	Aggregated from Smart	Small to average	Once a day	Revenue

		System	Meters: kW and kvar 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). Protection and Remedial Action Schemes data			accuracy for kW and kvar; 0.5%-0.2% accuracy for Voltages
18	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
19	AMI Data Management System	DER Data Management System	Provides the DER Data Management System with relevant data on customer owned/embedded DER	Average to large	Once a day and by defined events	
20	DER Controller	DER Data Management System	Generation kW and kvar Generation kWh Generation profiles Interval average voltages Weather data. Generation change triggers received with timestamps;	Small to average	Once a day	Revenue accuracy for kW and kvar; 0.5%-0.2% accuracy for Voltages

			Active protection settings and mode of operations and settings for volt/var control in the connected mode of operations and voltage and frequency control settings for island mode of operations, settings for ride-through operations Capability curve Electric storage parameters Synchronization settings O&M cost functions			
20	DER Controller	DER Data Management System	Lowest instantaneous voltages before disconnection Instantaneous frequency in island mode Last Gasp/AC Out or protection actions Changes in relay protection settings, volt/var control modes and settings, ride-trough settings, electric storage parameters	Small	Immediately after change	0.5%-0.2% for Volt; 0.1% for Hz
20	DER Data Management System	DER Controller	Real-time prices Desired kW and kvar setpoints (reference points) Desired volt/var mode of operation and setpoints Desired ride-through settings Data requests Synchronization commands	Small	Immediately after change	

21	AMI Data Management System	Microgrid Model Processor	Provides with microgrid/nanogrid related data	Small to medium	As needed due to significant changes	Statistics
22	GIS	Topology processor	Provides with updated and validated nominal connectivity and facility parameters	Small to average, if incrementally; Large, if globally	One a day, and by significant events	Verified data
23	DMS Scheduler	Topology processor	Provides with real-time changes in topology	Small	Immediately after change	Verified data
24	DMS Scheduler	Distribution Situational Awareness (DOMA)	DSCADA/SCADA/EMS analog and status snapshots;	Medium to Large	1-2 seconds updates	Verified data
25	DMS Scheduler	Load model processor	Provides with real-time changes in analogs and external data related to adaptive load modeling, e.g., weather and prices	Small to Medium	Periodically every 5-15 minutes and by defined events	
26	AMI Data Management System	Distribution Situational Awareness (DOMA)	Provides with near-real time data from selected meters and changes of external conditions	Small	By event. This information is based on the input from bellwether meters monitoring local weather and sunshine conditions	Verified data
27	AMI Data Management System	Load Model Processor	Load impacting factors with time stamps, e.g., local weather data, Demand Response requests with start and stop times, other related events with timestamps	Large	Once a day	Verified historic data
28	AMI Data	Secondary Equivalent	Daily kW and kvar load	Large	Once a day	

	Management System	processor	profiles from individual Smart meters and aggregated at the distribution transformer load profiles Daily profiles of interval-average voltages			
29	DMS Scheduler	Microgrid Model processor	Provides with real-time changes in external data related to adaptive microgrid modeling, e.g., weather and prices	Small	As needed due to significant changes	
30	DER Data Management System	Distribution Situational Awareness (DOMA)	Provides with near-real time changes of external conditions for DER operations.	Average	By event. This information is based on the input from selected DER monitoring local weather and sunshine conditions	
31	DMS applications	DER Data Management System	Provides solution of DMS applications for execution	Small	After DMS applications run and determine a need in control	Verified information
32	DMS applications	Microgrid Data Management System	Provides solution of DMS applications for execution	Small	After DMS applications run and determine a need in control	
33	AMI Data Management System	DER Model processor	Provides with time-stamped historic loads aggregated at DT bus, voltages at customer terminals, temperatures, etc.	Medium	As needed due to significant changes	Statistics
34	DER Data Management System	DER model processor	Provides with updates on DER parameters relevant for DER modeling	Small to average	Once a day and by events	Verified data

35	Microgrid Data Management System	Microgrid Model Processor	Provides with updates on microgrid parameters relevant for microgrid modeling	Small to average	Once a day and by events	Verified data
36	Topology processor	Distribution Situational Awareness (DOMA)	Provides with topology updates	Small	By event	Verified data
37	Load model Processor	Distribution Situational Awareness (DOMA)	Provides with adaptive load models	Average	Once a day	
38	Distribution Situational Awareness (DOMA)	Secondary Equivalent processor	Provides modeled voltages at the secondary buses of distribution transformers	Large	On request by Secondary Equivalent processor (once a month or less frequent)	
38	Secondary Equivalent processor	Distribution Situational Awareness (DOMA)	Provides with dependencies of voltage drops and losses in secondaries on nodal loads	Large		
39	Topology processor	Outage Management System	Provides with topology update	Small	By event	Verified data
40	AMI Data Management System	Customer Information System	Provides customer load and consumption data	Large	Daily	
41	DER model processor	Distribution Situational Awareness (DOMA)	Provides with updates of DER models	Average	After significant change	
42	Microgrid model processor	Distribution Situational Awareness (DOMA)	Provides with updates of microgrid models	Average	After significant change	
43	AMI Data Management System	Outage Management System	Provides near-real time data from selected meters, including outage detections	Small	By event	
44	Customer Information System	Load Model Processor	Load and consumption data aggregated at Distribution Transformer buses	Medium	Daily	
45	TBLM	DMS Advanced Applications	TBLM provides relevant attributes of transmission operation model and			

			commands/requests for distribution operations.			
46	Transmission System Operator	TBLM	TBLM Informs about aggregated control variables and constraints for EMS applications; TSO changes conditions or submits its own requests for DMS support	Small	Periodically and by event	
47	Distribution Situational Awareness (DOMA in study mode)	TBLM Developer	Provides with the current and alternative reference operation models	Large	Every run of State Estimation, e.g., every 5-10 min and by events	Verified information
47	TBLM Developer	Distribution Situational Awareness (DOMA in study mode)	Requests alternative model	Small	By event	
48	Distribution Situational Awareness (DOMA in study mode)	Distribution Contingency Analysis in study mode	Provides the alternative operational model.	Medium	By events, for multiple scenarios	Verified information
49	Distribution Situational Awareness (DOMA in study mode)	Integrated Volt/var/Watt Optimization in study mode	Provides the alternative operational model.	Medium	When there is a change in the requirements	
50	Distribution Contingency Analysis in study mode	TBLM Developer	Provides solutions under requested conditions	Small to medium	By event	
50	TBLM Developer	Distribution Contingency Analysis in study mode	Request analysis under given conditions	Small	By event	
51	Distribution Situational Awareness (DOMA)	Advanced DMS applications	Provides with the current reference operation model components	Large	Every run of State Estimation and IVVWO, e.g., every 5-10 min and by events	Verified information
52	Distribution Situational	Distribution System Operator	DOMA updates DSO about	Small	Periodically and by event	

	Awareness (DOMA)		situational awareness			
52	Distribution System Operator	Distribution Situational Awareness (DOMA)	Transmits the DSO & TSO (EMS) requests;	Small	By event	
53	Integrated Volt/var/Watt Optimization (IVVWO) in study mode	TBLM Developer	Provides solutions under requested conditions	Small to medium	By event	
53	TBLM Developer	IVVWO in study mode	Request solution under given conditions for a series of runs for different operating conditions, e.g., within and beyond the LTC capabilities to adjust distribution bus voltage according to current setting; for load reduction objective, etc.	Small	By event	
54	TBLM Developer	Transmission Bus Load Model	Based on multiple "what-if" power flows, IVVWO and Contingency Analysis studies deviating from the reference model within given ranges and provides current aggregated load model with the dependencies on bus voltage, system frequency, pricing, etc.; aggregated generation capability curves adjusted to the subject operating conditions; interrelationships between loads of different RAS; dynamic operational	Large	Every update of the State Estimation, e.g., every 5-10 min and by events, for multiple scenarios	Verified information

			limits at the TnD buses, etc.			
54	Transmission Bus Load Model	TBLM Developer	Delivers results of steady-state and Dynamic EMS Contingency Analyses	Small	Every run of the EMS CA	
55	Load Management System	DER Data Management System	Triggers of Demand Response for dispatchable DERs (ES)			
55	DER Data Management System	Load Management System	Customer choices, contractual conditions, and DER/ES attributes, available Demand Response			
56	Distribution System Operator	Advanced DMS applications	Transmits Operator's requests, changes to EMS requests, etc.	Mall	As needed for a portion of EMS requests,	Verified information
57	Distribution System Operator	Transmission Bus Load Model `	Authorizes and/or changes the components in the TBLM	Small	By event	
57	Transmission Bus Load Model	Distribution System Operator	Informs the operator about the changes in TBLM	Small	As needed based on pre-defined criteria	
58	Critical Customers	Distribution System Operator	State and preparedness of the customer for emergencies	Small	By event	
58	Distribution System Operator	Critical Customers	Warning about emergencies	Small	By event	
59	Distribution System Operator	Emergency Responders	Information exchange in emergencies	Small	By event	
59	Emergency Responders	Distribution System Operator	Information exchange in emergencies	Small	By event	
60	Distribution System Operator	Mobile Generator Controllers	Information exchange in emergencies	Small	By event	
60	Mobile Generator	Distribution System	Information exchange in	Small	By event	

	Controllers	Operator	emergencies			
61	Distribution System Operator	Gas, Communications, Internet Provider companies	Information exchange in emergencies	Small	By event	
61	Gas, Communications, Internet Provider companies	Distribution System Operator	Information exchange in emergencies	Small	By event	
62	Distribution System Operator	Secure portals with officials	Information exchange in emergencies	Small	By event	
62	Secure portals with officials	Distribution System Operator	Information exchange in emergencies	Small	By event	
63	Emergency Responders	Transmission System Operator	Information exchange in emergencies	Small	By event	
63	Transmission System Operator	Emergency Responders	Information exchange in emergencies	Small	By event	
64	Mobile Generator Controllers	Transmission System Operator	Information exchange in emergencies	Small	By event	
64	Transmission System Operator	Mobile Generator Controllers	Information exchange in emergencies	Small	By event	
65	Gas, Communications, Internet Provider companies	Transmission System Operator	Information exchange in emergencies	Small	By event	
65	Transmission System Operator	Gas, Communications, Internet Provider companies	Information exchange in emergencies	Small	By event	
66	Secure portals with officials	Transmission System Operator	Information exchange in emergencies	Small	By event	
66	Transmission System Operator	Secure portals with officials	Information exchange in emergencies	Small	By event	
67	Transmission & Generation EMS	Transmission Bus Load Model	Provides commands and requests to TBLM	Small	As the requirements change, may be up to several times a day	Verified information
67	Transmission Bus	Transmission & Generation EMS	Provides aggregated control variables and constraints for	Small	After every update of TBLM	Verified information

	Load Model		EMS			
68	Transmission & Generation EMS	Transmission System Operator	Informs about aggregated control variables and constraints for EMS applications	Small	After every update of TBLM	Verified information
68	Transmission System Operator	Transmission & Generation EMS	Changes conditions or submits its own requests for DMS support	Small	In special cases. Typically, the operator is not in the loop of automated control	
69	EMS Steady-state and dynamic Contingency Analyses	Transmission & Generation EMS	Submits control commands/ requests for preventive and corrective (pre-arming) measures	Small	When preventive and corrective measures in distribution are needed	Verified information
69	Transmission & Generation EMS	EMS Steady-state and dynamic Contingency Analyses	Provides aggregated control variables and constraints for EMS applications	Small	After every update of TBLM	Verified information
70	Optimal Power flow/ Security Constraint Dispatch	Transmission & Generation EMS	Submits requests for Volt/var support; congestion management; load reduction	Small	When Volt/var support; congestion management in distribution are needed	Verified information
70	Transmission & Generation EMS	Optimal Power flow/ Security Constraint Dispatch	Provides aggregated control variables and constraints for EMS applications	Small	After every update of TBLM	Verified information
71	Economic Dispatch/ Unit commitment (or	Transmission &	Submits requests for Demand Response; DER start; ES	Small	When Demand Response; DER start; ES	Verified information

	equivalent)	Generation EMS	discharge, etc.		discharge in distribution are needed	
71	Transmission & Generation EMS	Economic Dispatch/ Unit commitment (or equivalent)	Provides aggregated control variables and constraints for EMS applications	Small	After every update of TBLM	Verified information
72	EMS Steady-state and dynamic Contingency Analyses	Transmission System Operator	Informs about recommended control commands/requests for preventive and corrective (pre-arming) measures	Small	When preventive and corrective measures in distribution are needed	Verified information
73	Optimal Power flow/ Security Constraint Dispatch	Transmission System Operator	Informs about the recommended requests for Volt/var support; congestion management; load reduction	Small	When Volt/var support; congestion management in distribution are needed	Verified information
74	Economic Dispatch/ Unit commitment (or equivalent)	Transmission System Operator	Informs about recommended requests for Demand Response; DER start; ES discharge,	Small	When Demand Response; DER start; ES discharge in distribution are needed	Verified information
75	Field crew	DSO	Crew reports to DSO local conditions relevant to preparation for the disaster and to the service restoration. DSO provides information and issues commands	Small	By event	
76	DSO	DMS Advanced applications	DSO sets the applications; confirms or changes the output. Applications inform the DSO about the solutions	Small	As needed	
77	Work Management System	DSO	Updates on activities related to preparation for VLSE and to	Small	As needed	

			repairs, on location of crews and equipment.			
78	Data feeds from external sources	DSO	Surveillance videos, Global Positioning System (GPS) tagged photos or videos, etc.	Small to medium	By events	
79	Aggregator	DSO	Data on coordination of Aggregator's operational plans with distribution system operations	Small to medium	Periodically and by events	
80	Outage Management System	Advanced DMS applications	Data on outage and restoration management	Small to medium	By events	
81	DMS Advanced Applications	Load Management System	Requests/Commands for Demand Response, other load management means	Small to medium	By events	
82	Load Management System	AMI Data Management System	Triggers of Demand response for selected nodes			
82	AMI Data Management System	Load Management System	Customer choices, contractual conditions, and available Demand Response			
83	Load Management System	Customer EMS	Desired amount of Demand Response in selected nodes			
83	Customer EMS	Load Management System	Customer choices, contractual conditions, and available Demand Response			
84	Load Management System	Microgrid Data Management System	Triggers of Demand Response for aggregated loads of Microgrid			
84	Microgrid Data Management System	Load Management System	Microgrid choices, contractual conditions, and available Demand Response			

3.3 Scenarios

1) Microgrid is load-rich. Microgrid is connected to EPS. The load import is greater than the Under Frequency Load Shedding (UFLS) in the microgrid (in the ranges of EPS UFLS)
2) Microgrid is load-rich. Microgrid is connected to EPS. The load import is smaller than the UFLS in the microgrid
3) Microgrid is generation-rich. Microgrid is connected to EPS. The microgrid injects power into EPS.

3.4 Step-by-step actions

The step-by-step actions presented in **Error! Reference source not found.** do not cover all the possible scenarios and conditions. The table is an illustration of possible exchanges of information between the μEMS and DMS

Table 3-3. Illustrative step-by-step actions

#	Event [i]	Primary Actor [ii]	Name of Process/Activity [iii]	Description of Process/Activity [iv]	Information Producer [v]	Information Receiver [vi]	Name of Info Exchanged [vii]	Additional Notes [viii]

1	The setups of the emergency responders of the microgrids aggregated at the microgrid PCCs is made available to DMS by the microgrid EMS.	μEMS	Update of the μGrid setups of emergency means	These setups include the setups of the remedial action schemes in the μGrid, of the Ride-through functions, and the overlaps of different load management means.	μEMS, Aggregators	DMS	Updates of setups of emergency means of the μGrid	
2	Models of the emergency behavior of distribution system components aggregated at the transmission buses are made available to EMS through TBLM	TBLM developer	Update of TBLM	The updates include aggregated dependencies of the emergency means in distribution	TBLM developer , DMS applications	TBLM	Updates of setups of emergency means of the distribution system	
3	The transmission contingency/security analysis provides the dynamics of the emergency and recommends preventive measures for the distribution system aggregated at the transmission buses.	TBLM	Expected dynamic of emergency situation	The expected dynamics of the frequency, voltage, and loads at the transmission/distribution demarcation buses are submitted to the DMS through the TBLM.	TBLM, EMS contingency analysis, TSO	DMS	Dynamics of emergency situation	

4	DMS application checks the acceptance of these dynamics and preventive measures	DMS Applications	Check of the acceptance of the submitted emergency dynamics and preventive measures	DMS applications apply the submitted conditions to the distribution operation model and analyzes the results	DMS Applications, DSO	TBLM developer	Updates of the status for the mitigation of emergency situation	
4.1	DMS informs µEMS about the emergency conditions	DMS	Information about possible emergency conditions	DMS informs the µEMS about the dynamics of the emergency condition adjusted by DMS, if needed	DMS, DSO	µEMS	Updates of emergency conditions for µEMS	
4.2	The µEMS applies the expected dynamics of the EPS frequency and voltage to the model of its µGrid and decides what actions to take.	µEMS	Check of the acceptance of the submitted emergency dynamics and preventive measures	µEMS applies the submitted conditions to the µGrid model and analyzes the results and coordinates its choices with EPS	µEMS, Aggregators	DMS, DSO	Updates of the status for the mitigation of emergency situation	
4.3	DMS informs the EMS about the actual possibilities through the TBLM	TBLM developer	Updates of the actual possibilities for mitigating the emergency	DMS application and the DSO inform the EMS and TSO about the possible measures	TBLM developer, DSO	TBLM, TSO	Updates of the status for the mitigation of emergency situation	

5	EMS reiterates the contingency analysis with new constraints.	TBLM	Adjusted dynamic of emergency situation	The adjusted dynamics of the frequency, voltage, and loads at the transmission/distribution demarcation buses are submitted to the DMS through the TBLM.	TBLM, EMS contingency analysis, TSO	DMS	Adjusted dynamics of emergency situation	
6	DMS updates the TBLM upon the execution of the preventive measures.	TBLM developer	Updates of the distribution model	DMS updates the TBLM on the implemented preventive measures	TBLM developer, DSO	TBLM, TSO		
	The above cycles are repeated periodically or by events.							
7	An emergency situation happened and is mitigated, the EPS is in a steady-state mode	DMS	Updates the TBLM on post emergency situation	DMS updated the TBLM with a post-emergency distribution operation model	DMS, DSO	TBLM, TSO	Update on post-emergency situation	

8	The restoration analysis and activities are started.	EMS, TSO	Possibilities of restoration from the transmission side	The EMS application analyzes the possibilities of restoration and informs the DMS about existing constraints and desired (available) sequence of restoration on the by-transmission-bus basis.	EMS, TSO	DMS, DSO	Possibilities of restoration from the transmission side	
9	The µEMS informs DMS about the desired restoration sequences in the microgrid	µEMS	Request for restoration from the µEMS	Desired restoration sequences in the microgrid	µEMS, Aggregators	DMS	Desired restoration sequences in the microgrid	
10	The DMS application – Coordination of Restorative Actions – optimizes the restoration based on the predefined and requested priorities within the transmission and distribution constraints.	DMS	Sequence of restoration	DMS defines the sequence of restoration	DMS, DSO	DSO, DMS applications, µEMS, TBLM, TSO	Sequence of restoration	

11	The restoration process is complete	µEMS	Post-factum information about the sequence of event related to the µGrid	µEMS provides DMS with the logs of µEMS activities and other records for the post-factum analyses of the VLSE.	µEMS, microgrid operator	DMS, DSO	Post-factum information about the sequence of event related to the µGrid	

4 Version Management

Version	Date	Author	Changes	Comments
1	03/17/2014	Nokhum Markushevich	Draft Narrative of Use Case	Presented to DRGS Sub-group C
1a	03/26/2014	Nokhum Markushevich	Draft list of actors, scenarios	
1b	03/27/2014	Nokhum Markushevich	Draft use case diagrams	
1c	03/29/2014	Nokhum Markushevich	Actor description	
1c	04/02/2014	Nokhum Markushevich &DRGS Subgroup C		Presented and discussed by Sub-group C
1d	04/03/2014	Nokhum Markushevich	Added Actor description	

1e	04/28/2014	Nokhum Markushevich	Added Actor description	
2a	05/08/2014	Nokhum Markushevich	Added to the major steps, illustrations	
2b	05/12/2014	Nokhum Markushevich	Edited actor list	
2c	05/13/2014	Nokhum Markushevich	Added more clarifications and illustrations.	
2c	06/27/2014	Nokhum Markushevich	Updated the activity diagram	
2d	08/04/2-14	Nokhum Markushevich	Added to the narrative	
2e	09/11/14	Nokhum Markushevich	Edited the graphs	
3	12/2015-1/2015	Member of DRGS DEWG	Review of the draft use cases	
4	01/21/15	Nokhum Markushevich	Version 2. Modified based on review.	
5	03/22/15	Nokhum Markushevich	Version 2. Revised the activity diagram. Added list of interfaces	
6	03/26/15	Nokhum Markushevich	Developed the step-by-step action table	

7	07/07/15	Jim Reilly and Nokhum Markushevich	Formatted for posting	

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[i] Triggering Event corresponds to a Classifier Role that serves as an Activator.

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

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

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

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

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

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