Microgrid Interactive Use Case #IA-3

Update aggregated at PCC real and reactive load-to-voltage dependencies under normal operating conditions

Version 2

July 7, 2015

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)

Contents

Table of Figures

1 Descriptions of the Use Case

1.1 Name of Use Case

Update aggregated at PCC real and reactive load-to-voltage dependencies under normal operating conditions

1.2 Scope and Objectives

Scope: The Function a) performs periodic and event-driven information exchanges between the EPS operator/DMS and Microgrid operator/EMS about the aggregated at the μGrid PCC real and reactive load and generation dependencies on voltage within the PCC voltage ranges under normal operating conditions and b) provides the EPS operator with relevant data for post-factum analyses, when needed. The information exchanges are performed through direct interfaces between EPS DMS and μEMS. Interfaces between the μEMS and Aggregators may be used to meet the objective of the Function.

Objectives: The objectives of the function are as follows:

- Provide the DSO/DMS with the aggregated short-term real and reactive load-and- generation-to-voltage dependencies at the PCC for the near-real-time DMS applications within normal voltage ranges (like peak load reduction via voltage reduction)
- Provide the DSO/DMS with the aggregated long-term real and reactive load/generation-to-voltage dependencies at the PCC for the long-term DMS applications within normal voltage ranges (like for the Conservation Voltage Reduction [12])
- Provide the microgrid operator/μEMS with EPC requests for change of the microgrid load/generation-to-voltage dependencies.

The purpose of the use case is to determine the requirements for the information exchange between the EPS and microgrid regarding the near-real-time load/generation-to-voltage dependencies aggregated at the PCC, including

- The contents of the information
- The timing of information exchange
- The structure of data

Rationale: The aggregated at the microgrid load/generation-to-voltage dependencies depend on a number of changing in the near-real-time operational conditions, such as the composition of the connected reactive sources, their modes and settings of operation, DER real loads, etc.

The EPS operator/DMS needs to know the current and expected load/generation-to-voltage dependencies of the microgrid to execute its volt/var optimization, contingency analysis, service restoration, and other functions, and to support the Transmission Bus Load Model.

EMS needs to know the load/generation-to-voltage dependencies under normal conditions for its Wide Area Situational Awareness and Optimal Power Flow applications.

In some cases, the EPS operator/DMS may request a change of the microgrid load-generation –to voltage dependencies.

Hence, a function for updating the microgrid load/generation-to-voltage dependencies and the EPS requests is required.

By meeting its objective in near-real time, the Function will make a significant contribution to power quality and energy efficiency of the entire EPS, including the μGrids.

Status: The integration of μGrid operations into DMS advanced applications is in its early stages. It will become critically important under the high penetration of DERs and advanced microgrids and other Smart Grid technologies.

1.3 Narrative

1.3.1 General Description

A microgrid[1] 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]).

[1] 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.”

The specific of these dependencies for the microgrid PCCs is that they cannot be based on the net load or generation at the PCC [11]. Typically, the load-to-voltage dependencies are expressed as increments related to the load under a reference (nominal) voltage. For instance, 1% of base load increase per 1% of voltage increase. Consider an example for a microgrid PCC. The load in the microgrid under the reference voltage at the PCC is 100 kW and the generation is also 100 kW. Hence, the net load/generation at the PCC under the reference voltage is equal zero. Now, the voltage at the PCC is increased by 1%, which leads to an increase of the load by 1 kW and say, there is no change in generation. How to express the 1 kW increase in the net load as a relative increment of the base net 0 kW? As infinity? It cannot be used in the DMS and EMS applications. Therefore, DMS needs to know separately the load and the generation components of the net power flow through the PCC and their individual dependencies. This information aggregated at the PCC should be delivered to the DMS by the microgrid EMS. If this information is not directly available in the microgrid EMS, indirect information should be collected from the microgrid EMS and other sources to derive credible models of the DER and load components. For instance, the patterns of the net power at the PCC associated with the relevant ambient conditions and information from the DER/microgrid Data Management System may present sufficient input to the DER/microgrid Model Processor for the development of credible models of DER components in the net power at the PCC.

The μGrid's load/generation-to-voltage dependencies to be used by the DMS should be expressed as dependencies on the PCC voltage within given range of the PCC voltage under normal conditions. The aggregated load dependencies are composed from multiple natural load dependencies on local voltages of the end customer loads (typically monotonous functions of the local voltage). However, the specific of the dependencies of the aggregated generation and load on the PCC voltage is that the local voltages at the customer terminals may not follow the changes of voltage at the PCC due to the reactions of the microgrid volt/var controlling devices. For instance, if the microgrid's volt/var controlling devices were able to keep the local voltage close to constant values within a given range of the PCC voltage, the aggregated at the PCC load would not change for this range of the PCC voltage. Beyond this range of PCC voltage, the changes of the local voltage would be different for different portions of the PCC voltage range, dependent on the performance of the different volt/var controlling devices within the microgrid.

The short-term and the long-term load-to-voltage dependencies are different for different compositions of the load categories. For instance, an increase in the resistive load may increase the short-term sensitivity to voltage, but reduce the long-term CVR factor.

The aggregated at the PCC generation dependencies on PCC voltage are composed from the dependencies of the microgrid's Watt/var sources which are functions of the voltages of selected target buses. These dependencies may be non-monotonous, piecewise functions [1].

If the setups of the volt/var controlling devices of the microgrid are changed, the load/generation-to-voltage dependencies change too. Hence, the EPS may request a change of the dependencies, if such service is supported by the agreements.

1.3.2 Summary of requirements

- The objective of the use case is to determine the requirements for *information exchange between the microgrid and EPS operators (μEMS-DMS) on the* load/generation-to-voltage dependencies*, including*
  - The contents of the information
  - The timing of information exchange
  - The structure of data
- The suggested contents of the information exchange include the following data:
  - The μEMS should provide the DSO/DMS with near-real time and short-term look-ahead aggregated at the PCC real and reactive load-to-voltage dependencies under current and short-term look ahead microgrid volt/var control setups, DER loading, and other relevant operating conditions significantly impacting the dependencies.
  - The μEMS should provide the DSO/DMS with near-real time and short-term look-ahead aggregated at the PCC generation -to-voltage dependencies under current and short-term look ahead microgrid volt/var control setups and DER loading.
  - The μEMS should provide the DSO/DMS with near-real time and short-term look-ahead aggregated at the PCC long-term load -to-voltage dependencies under current and short-term look ahead microgrid volt/var control setups (CVR-factors).
  - The DSO/DMS should inform μGrid about the possible range of voltages at the PCC in a given timeframe
  - The DSO/DMS should provide the microgrid operator/μEMS with its requirements/requests for the load/generation-to-voltage dependencies.
  - The microgrid operator/μEMS should provide the DSO/DMS with the impacts of the change of the load/generation-to-voltage dependencies, e.g., the impact on the μGrid net kW, or on the customer power factor due to change in voltage levels at the μGrid buses, etc.
  - The sensitivities of the net load of μGrid are inadequate for use in operations analysis and control
  - The long-term CVR-factors may significantly differ from the short-term Load-to-Voltage dependencies

Some of the conditions for the load/generation-to-voltage dependencies coordination can be defined in the interconnection requirements and/or in other contractual agreements.

- The conditions for the load/generation-to-voltage dependencies of the μGrid are changing in near-real time. Hence, the μEMS should update the aggregated at the PCC dependencies on by exception basis.

  The long-term load-to-voltage dependencies (CVR-factors) are used for energy conservation. The CVR-factors may differ from the short-term load-to-voltage dependencies (LTV-factors) due to the adjustment of load to the long-lasting voltage reduction. Some appliances may reduce their demand for a short time, but increase the duration of energy consumption, thus diminishing the energy conservation effect and reducing the diversification of multiple loads, which may result in increase of the composite load. Therefore, the CVR factors depend on the composition of load and on performance of the customer appliances, which in turn may depend on ambient conditions. Field test or analytical studies should be performed by the μGrid's operator for different compositions of load and different ambient conditions. For instance, if the μGrid's load contains a high portion of active electric heating, the CVR-factor is small, but may still be positive under mild ambient conditions, and may become negative under severe conditions, when some appliances become undersized for these conditions. Hence, the CVR-factors may change by time of day, by outside temperature, by seasons, etc. Therefore, the updates of the CVR-factors should be used by the μEMS for adjusting μGrid modes of operations and should be timely submitted to the DSO.

The structure of the exchanged data should support, non-monotonous dependencies, different dependencies for different portions of the active range of the PCC voltage (interval sensitivities, - which may significantly differ from the average dependencies), and command/request formats, and metrics of data uncertainty. The dependencies should cover practical ranges of the independent variables under normal operating conditions.

1.3.3 Illustrative examples

A number of illustrations are presented below to clarify some of the requirements for information exchange between the microgrid operator/EMS and DSO/DMS in regards to the load-to-voltage dependencies. These illustrations are based on a specific simple model including inverter-based DERs as reactive power sources (**Error! Reference source not found.**).

In this example, the DERs are the only reactive sources of the microgrid. The DERs are connected close to the customer service terminals.

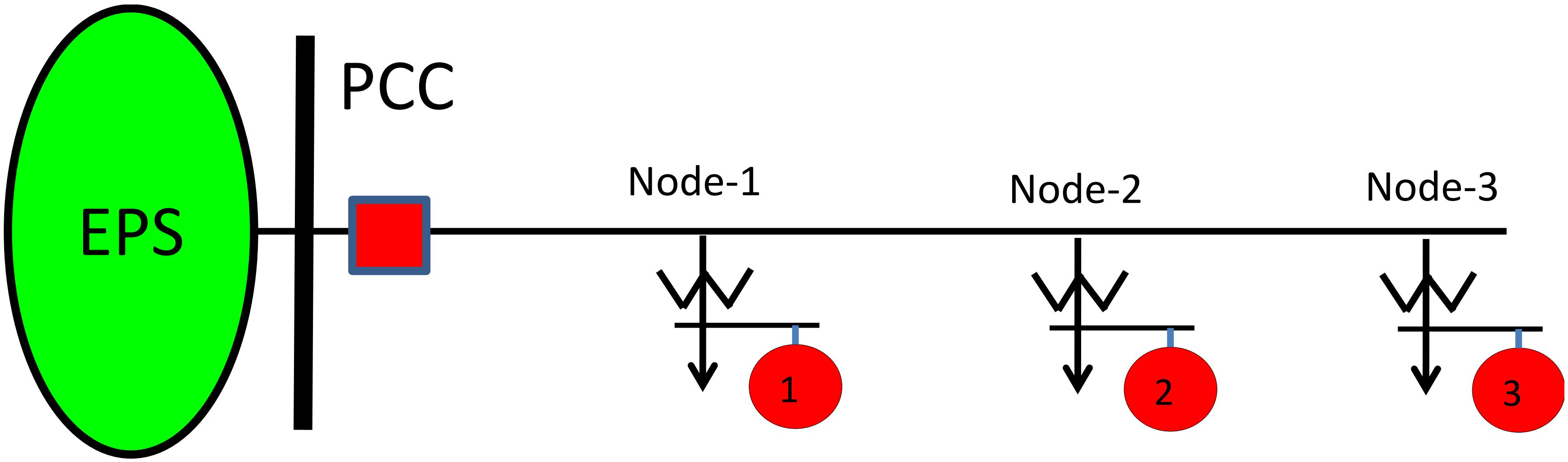


Figure 1-1. Sample diagram of microgrid

It is assumed here that the total nodal real load of the microgrid is 1. The three DERs connected to the microgrid can provide 0.9 p.u. real power to the microgrid. The rated power factor of the DERs is 0.9. The nodal real load dependency on nodal voltage (the LTV-factor) is 1 %kW/%Volt. The reactive nodal load dependency on nodal voltage is presented by the following polynomial:

$$Q = Q_{nom}\,(9 - 19.4\,\mathbf{V/V_{nom}} + \mathbf{11.4\ V2/V_{nom}^{2}})$$

It is also assumed that the DERs in the microgrid perform autonomous Volt/var control. The following three scenarios of the Volt/var control are considered:

- Conservation voltage reduction (CVR) with maximum reactive power support of the EPS,
- Super Power Quality (PQ) with maximum reactive power support of the EPS – keeping the voltages at the customer terminals close to the nominal
- Standard Voltage Quality with maximum reactive power support of the EPS

The volt/var functions of the µGrid's DER for the CVR objective are presented in **Error! Reference source not found.** and **Error! Reference source not found.**. As seen in the figures, the minimum voltage setting is 0.96 p.u., and the maximum voltage setting is 0.98 p.u. The dashed lines represent the ideal volt/var function, while the solid lines represent the real function limited by the DER capabilities. Note that the voltages in these functions are the voltages at the DER terminals, not at the PCC. The initial settings of the reactive power are set to the maximum available within the voltage settings. When the voltage deviates beyond the setting, the kvars change according to the set var/volt droop. The initial var settings are different for the greater and smaller kW loads of the DER. The greater load is assumed to be 100% of rated kW (it can be associated with sunny days for solar generation), and the smaller load is assumed to be 20% of the rated kW (it can be associated with cloudy days for solar generation). However, the examples are, in general, applicable to any inverter-based DERs, not just to solar DERs.

The volt/var functions of the µGrid's DER for the PQ objective are presented in **Error! Reference source not found.**. As seen in the figures, in this case, the minimum voltage setting is 0.99 p.u., and the maximum voltage setting is 1.01 p.u. The initial settings of the reactive power are set to the maximum available within these voltage settings. When the voltage deviates beyond the setting, the kvars change according to the set var/volt droop.

The volt/var functions of the µGrid's DER for the Standard Voltage objective are presented in **Error! Reference source not found.Error! Reference source not found.**. As seen in the figures, in this case, the minimum voltage setting is 0.96 p.u., and the maximum voltage setting is 1.04 p.u. of the voltage at the DER terminals. The initial settings of the reactive power are set to the maximum available within these voltage settings. When the voltage deviates beyond the setting, the kvars change according to the set var/volt droop.

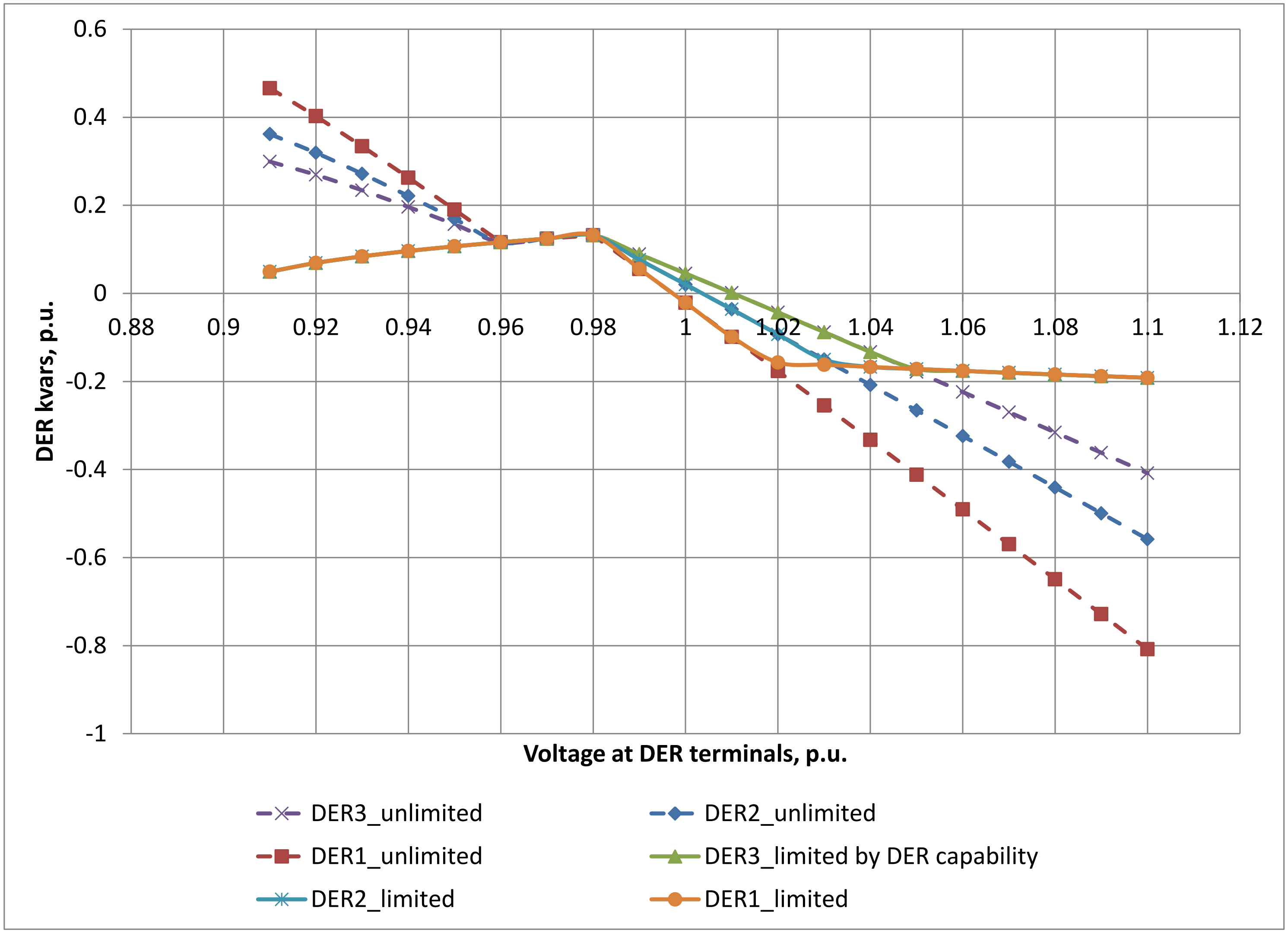


Figure 1-2. . DER volt/var function for CVR and maximum var support (Sunny Day)

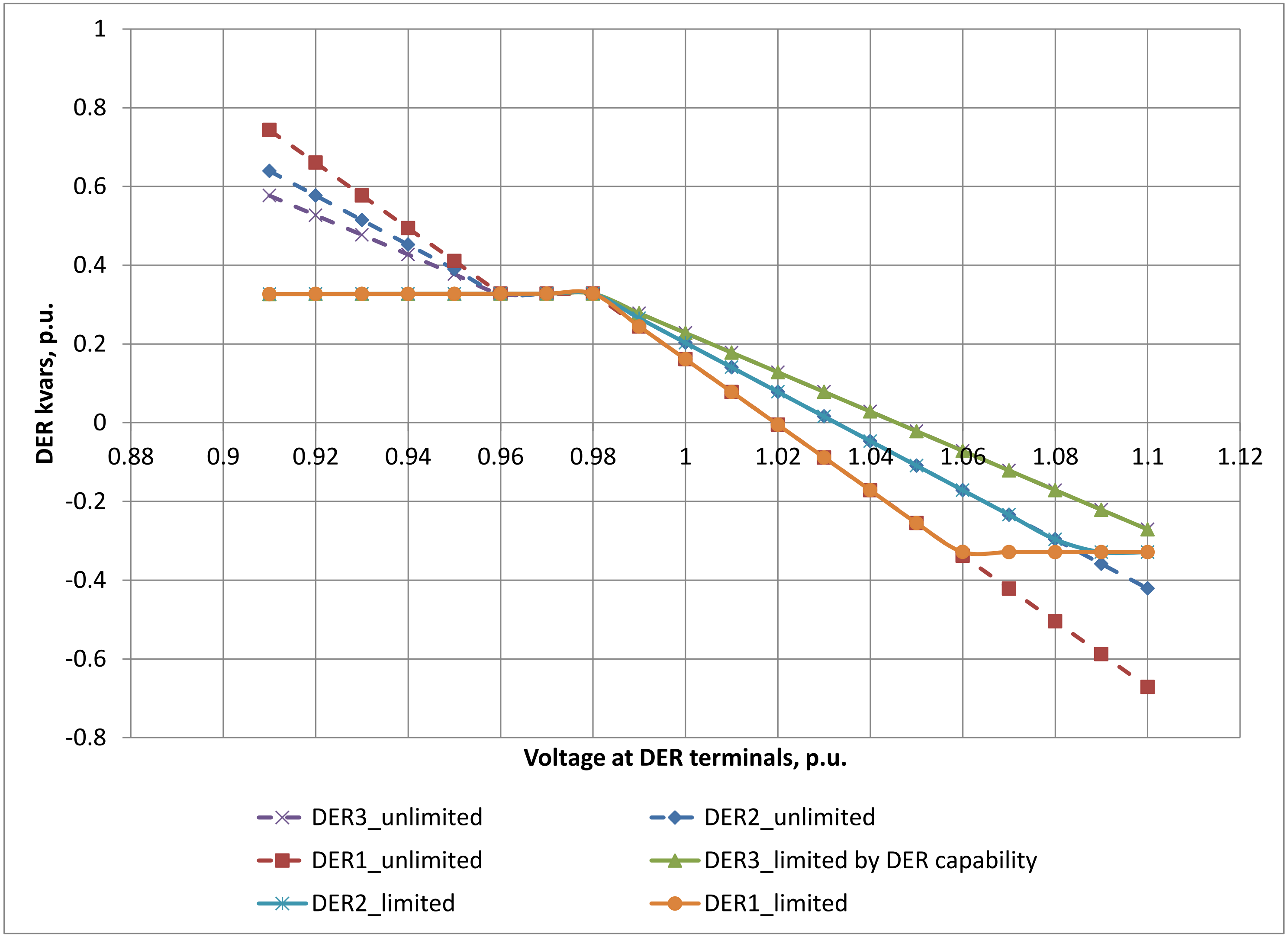


Figure 1-3. DER volt/var function for CVR and maximum var support (20% of kW load)

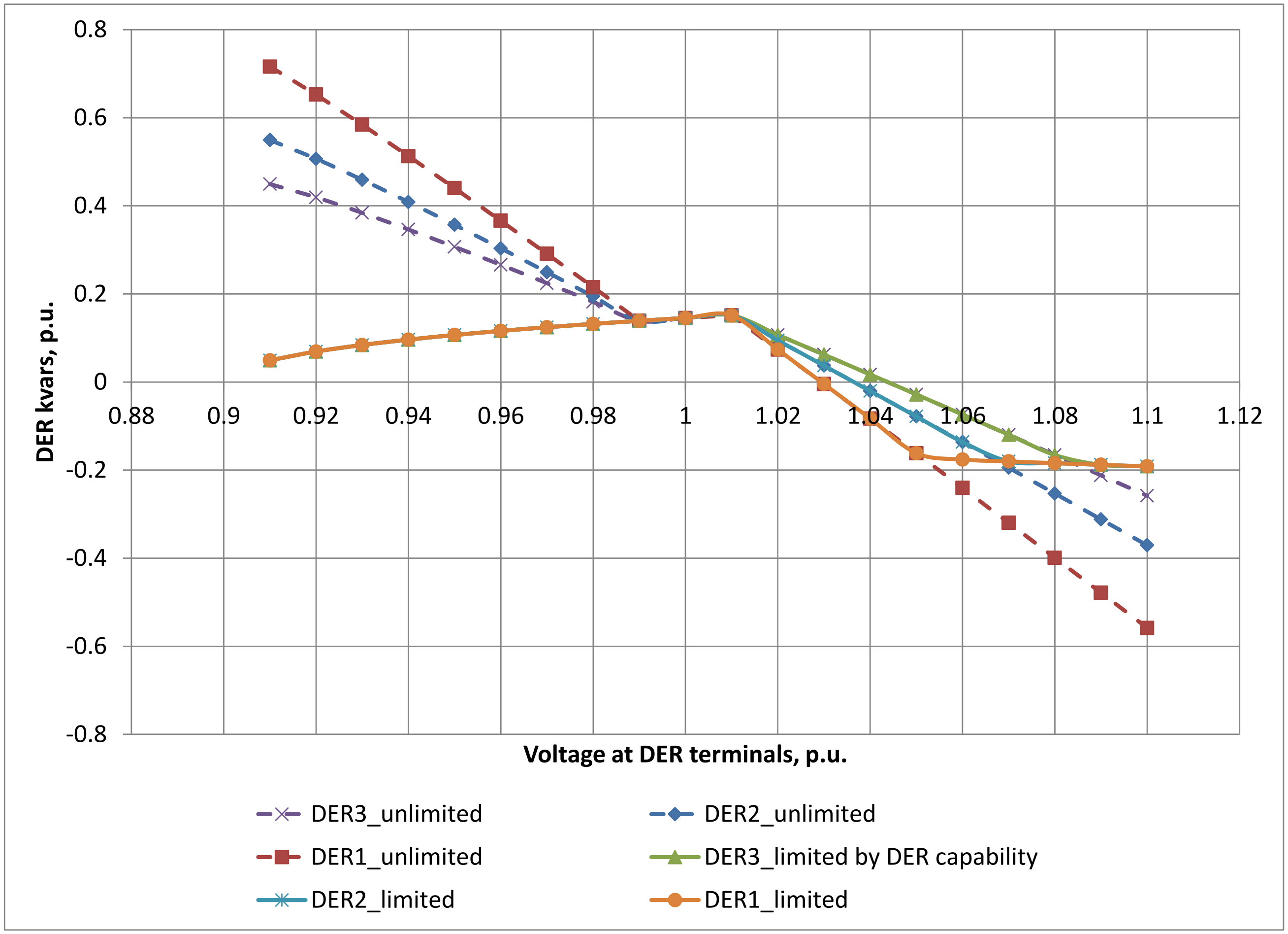


Figure 1-4. DER volt/var function for PQ and maximum var support (100% of kW load)

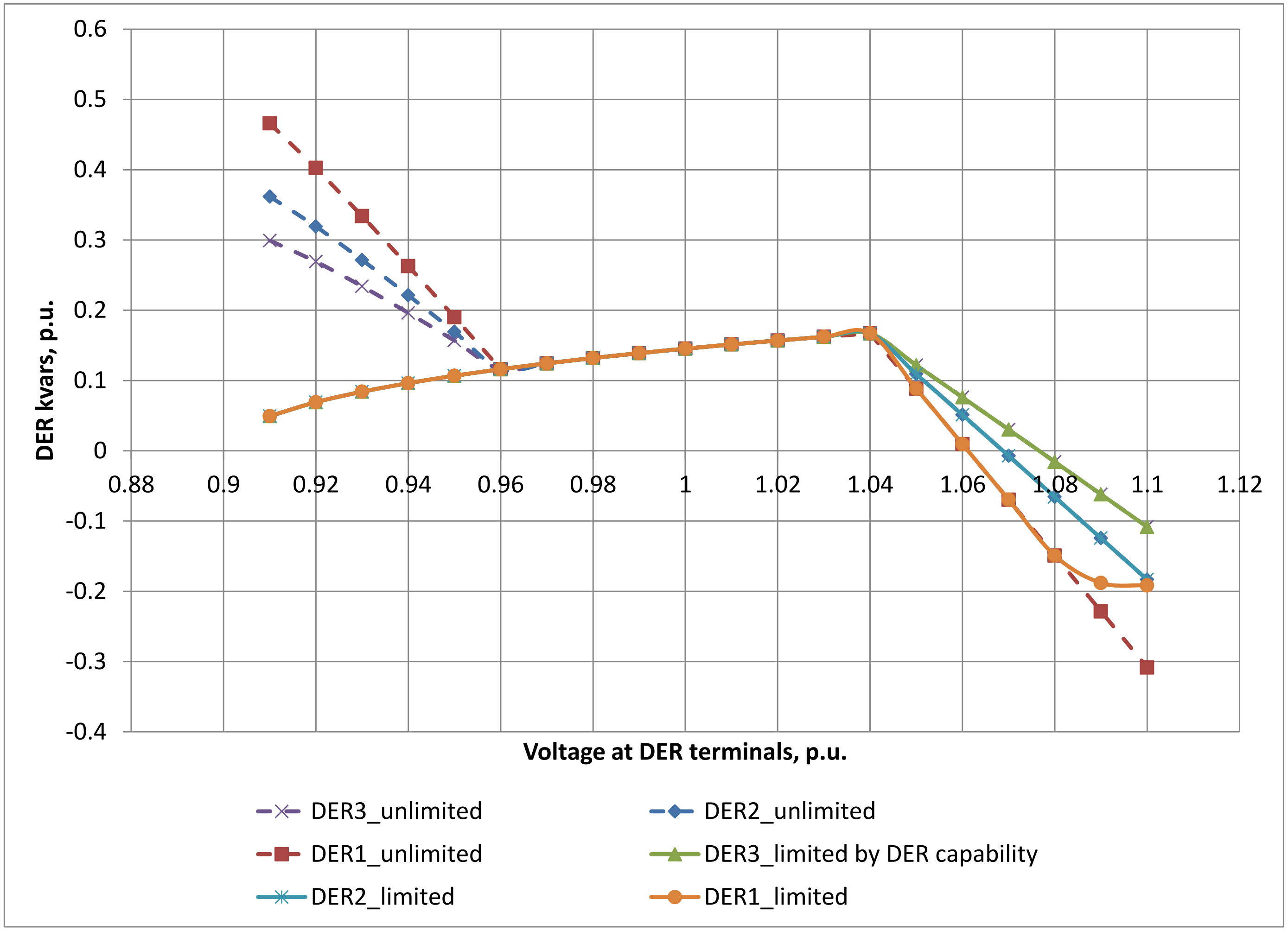


Figure 1-5. DER Volt/var Function for Standard Voltage Objective (Wide tolerance at PCC and max kvar support-100% of kW load)

The load-to-voltage dependencies aggregated at the PCC are functions of the voltage at the PCC. The relationship between the nodal voltages and the voltage at the PCC are presented in

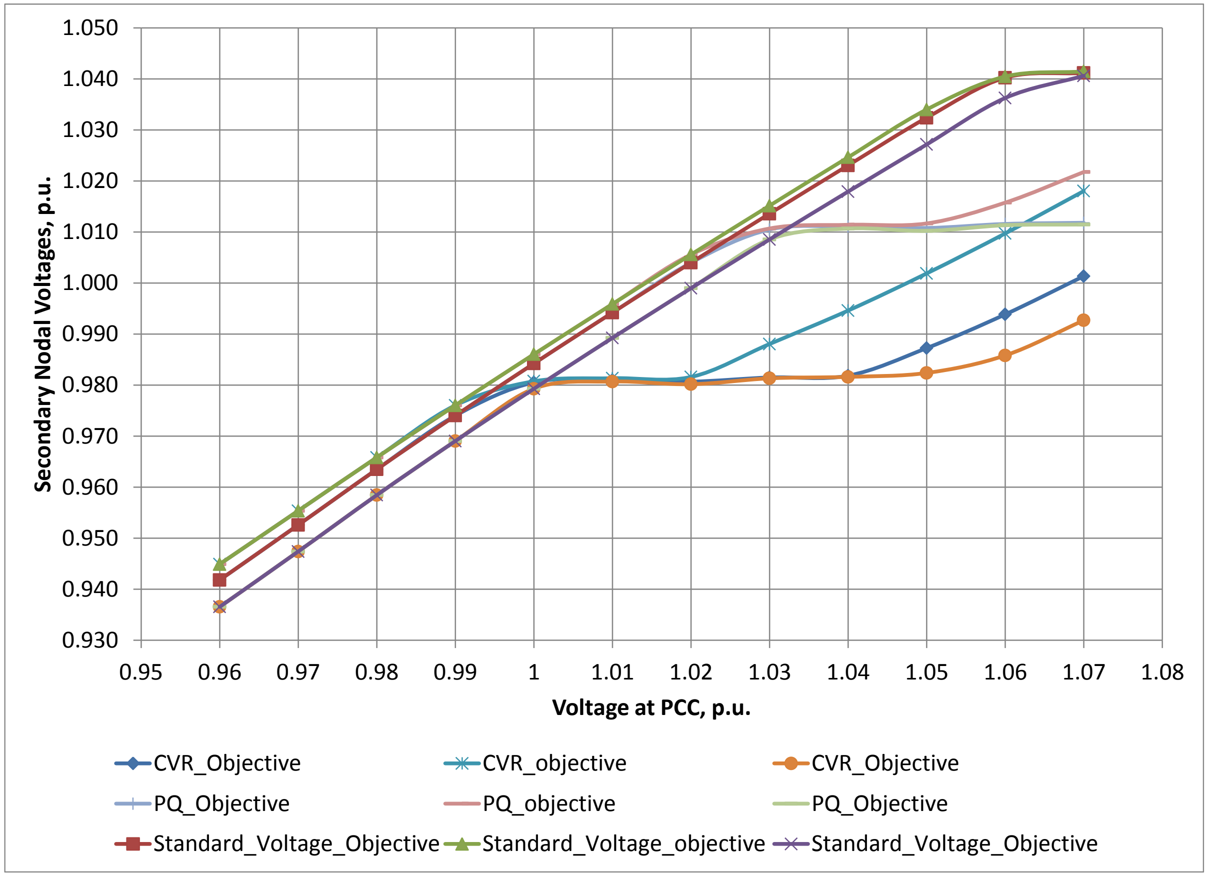


Figure 1-6. These relationships define the differences between the aggregated at the PCC dependencies and the nodal (natural) dependencies.

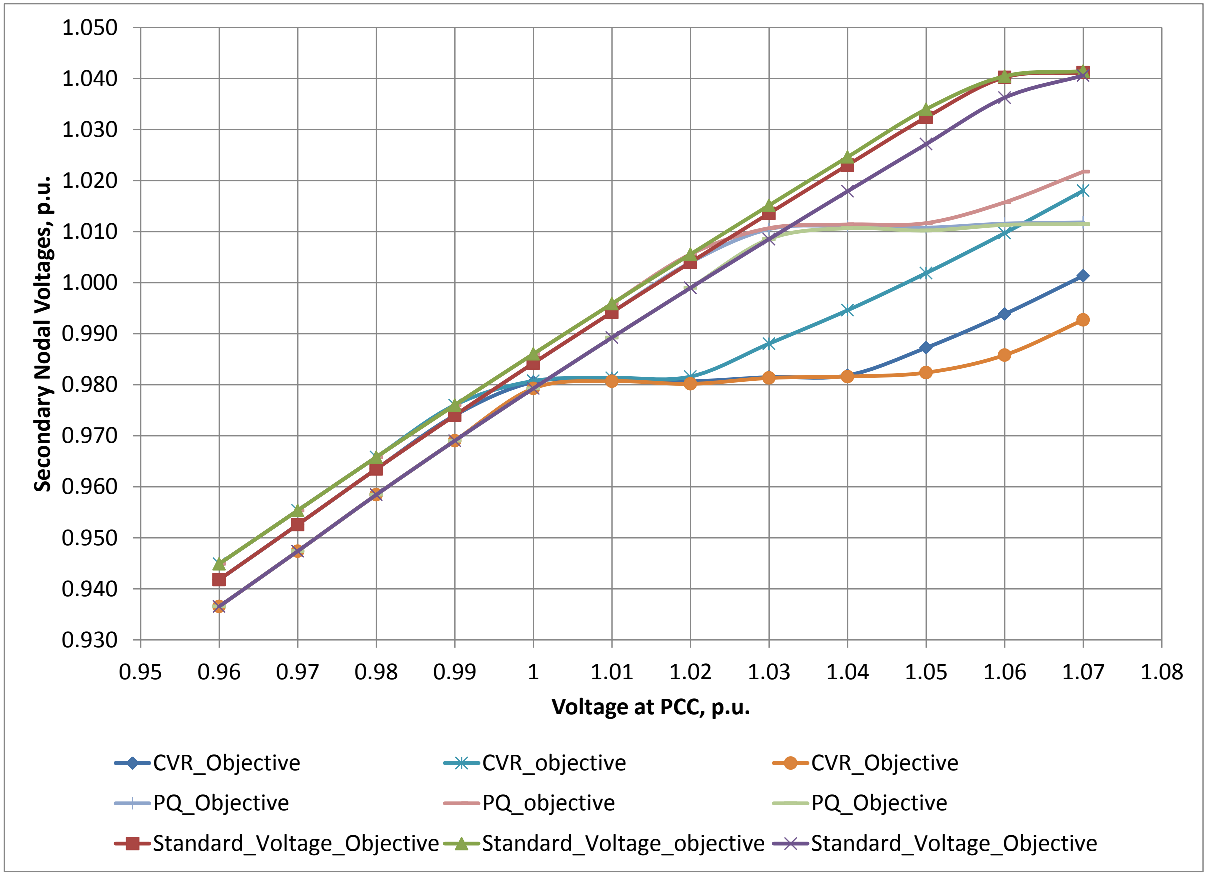


Figure 1-6. Voltage at Service Terminals vs Voltage at PCC

The relationships between the increments in voltages at the customer terminals (nodal voltages) to the increment in PCC voltage is not 1-to-1 and is different for different modes of operations of the DERs (see Figure 1-7 - Figure 1-9). As seen in the figures, under some conditions, the increments of nodal voltages per 1% increment in the PCC drop to zero. The change in nodal real and reactive loads follows the change in the nodal voltage.

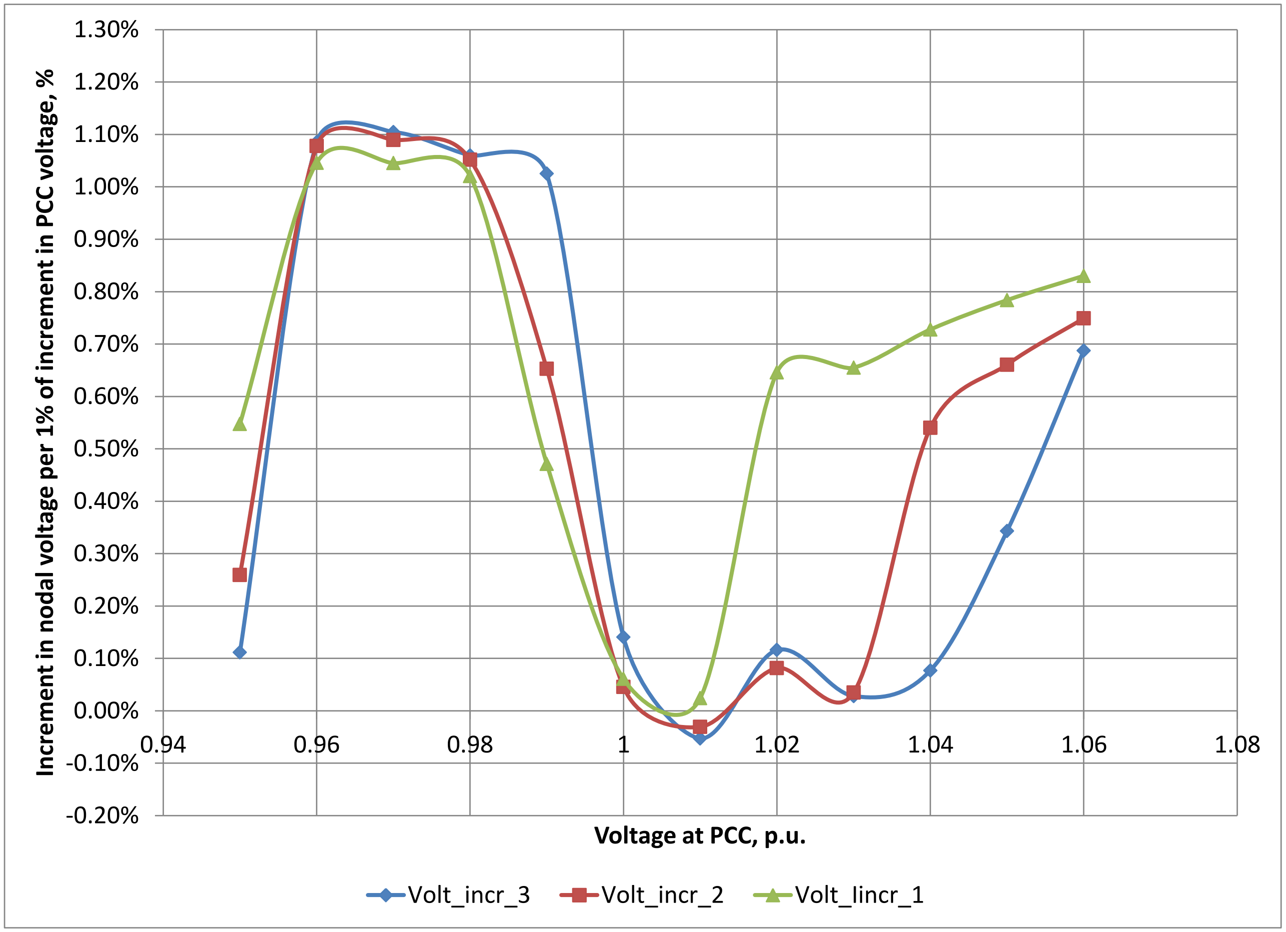


Figure 1-7. Nodal voltage increments vs PCC increments for the CVR objective

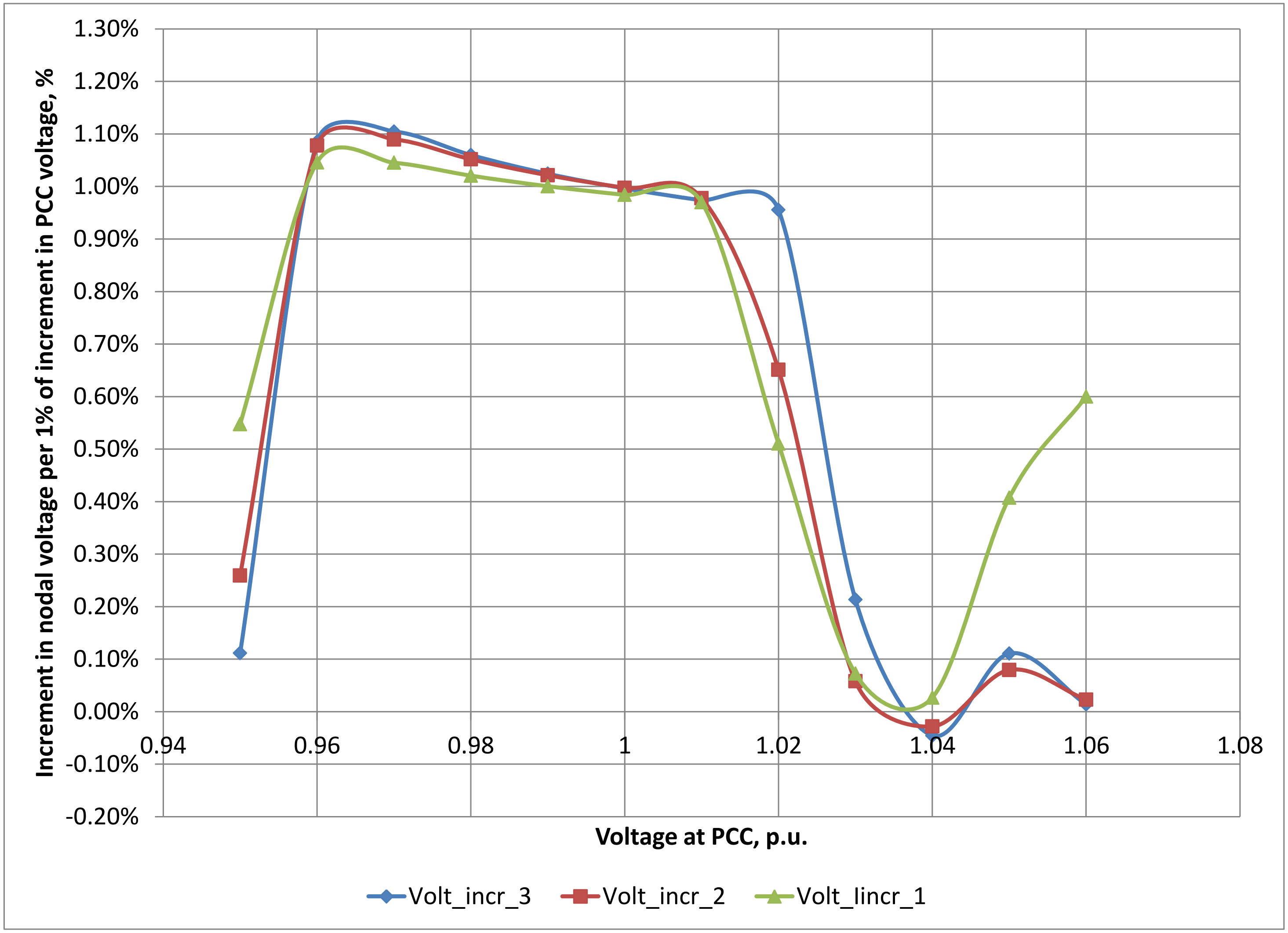


Figure 1-8. Nodal voltage increments vs PCC increments for the PQ objective

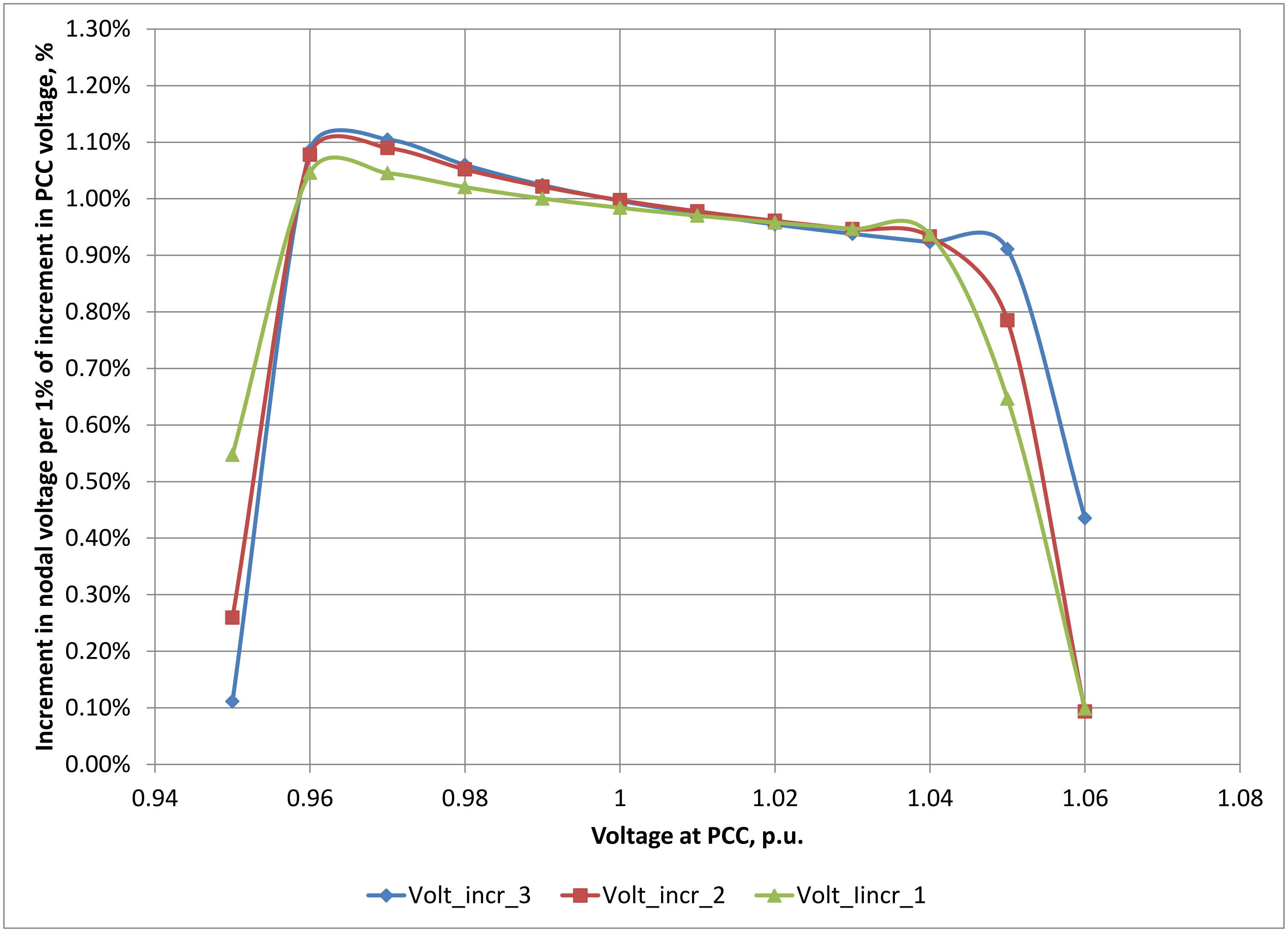
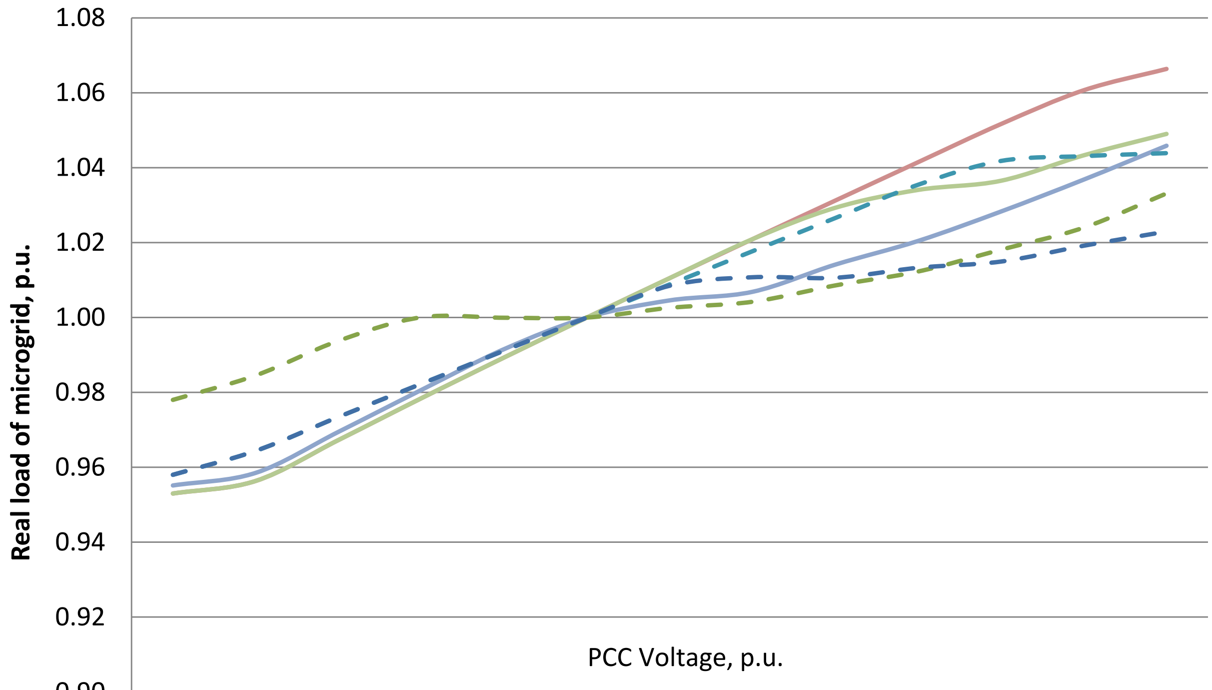


Figure 1-9. Nodal voltage increments vs PCC increments for the Standard Voltage objective

Figure 1-10 presents the real load dependencies on PCC voltage for the three modes of DER Volt/var control and for two levels of real power injections by the DERs. As seen in the figure, the dependencies are different and not linear, though the natural load-to-voltage dependencies were assumed to be linear (1%kW/1%Volt).



	0.95	0.96	0.97	0.98	0.99	1	1.01	1.02	1.03	1.04	1.05	1.06	1.07
CVR_kW=100%	0.96	0.96	0.97	0.98	0.99	1.00	1.00	1.01	1.01	1.02	1.03	1.04	1.05
SQ_kW=100%	0.95	0.96	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.04	1.05	1.06	1.07
PQ_kW=100%	0.95	0.96	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.03	1.04	1.04	1.05
CVR_kW=20%	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.02	1.02	1.03
SQ_kW=20%	0.96	0.96	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.04	1.04	1.04	1.04
PQ_kW=20%	0.96	0.96	0.97	0.98	0.99	1.00	1.01	1.01	1.01	1.01	1.01	1.02	1.02

Figure 1-10. Dependencies of the µGrid real load on PCC voltage, p.u.

The dependencies in Figure 1-10 can be approximated by linear regression equations, as follows:

For the 100% of rated kW load:

$$P_{CVR,\ p.u.} = 0.74V_{p.u.} + 0.26$$

$$P_{PQ,p.u.} = 0.85V_{p.u.} + 0.15$$

$$P_{SQ,\ p.u.} = 1.00V_{p.u.}$$

For the 20% of rated kW load:

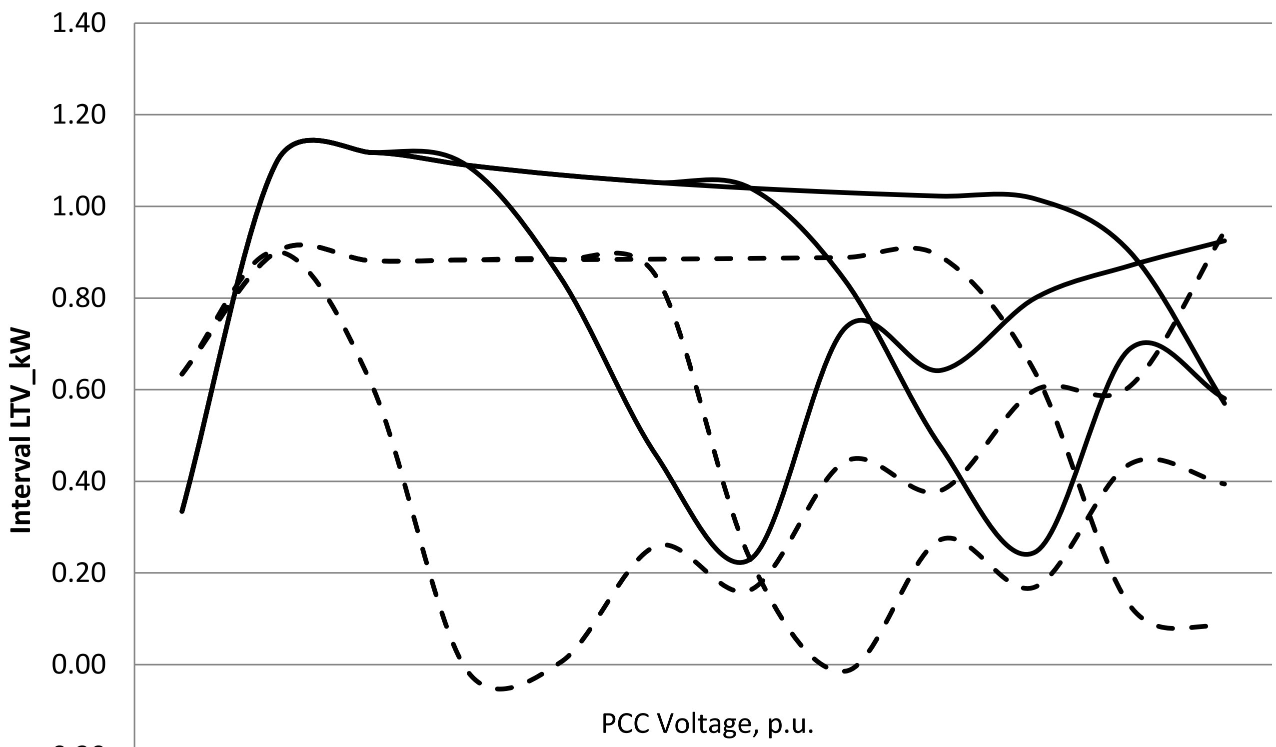
$$P_{CVR,\ p.u.} = 0.38V_{p.u.} + 0.62$$

$$P_{PQ,p.u.} = 0.54V_{p.u.} + 0.46$$

$$P_{SQ,\ p.u.} = 0.79V_{p.u.} + 0.21.00V_{p.u}$$

The R^2 correlation factors for all these equations are above 0.9. These equations imply that the average load-to-voltage sensitivity (LTV-factors) for the CVR objective ranges between 0.38 and 0.74 %kW/1%Volt, between 0.054 and 0.85%kW/1%Volt for the PQ objective, and between 0.79 and 1%kW/1%Volt for SQ objective. These numbers of μGRid real load sensitivities to the PCC voltages significantly deviate from the nodal load sensitivities to the nodal voltages.

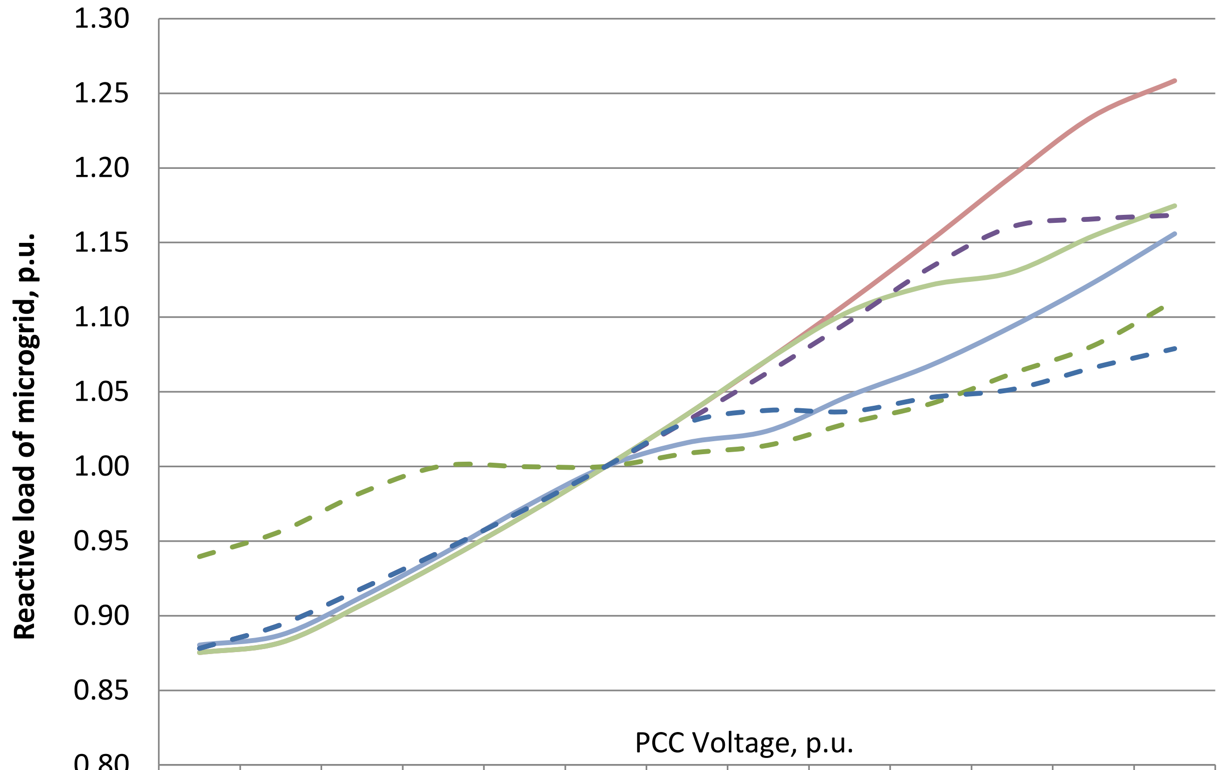
However, if we analyze the change in load due to 1% of change in the PCC voltage for different voltage intervals within the entire range of PCC voltages, we will see that the LTV-factors may be significantly different for different intervals (see **Error! Reference source not found.**). As seen in the figure, the LTV-factor can significantly deviate from the average, changing within the ranges from 1.1 to 0%kW/%Volt. These differences may have a significant impact on the modeling and management of distribution operations. If this is the case, the interval LTV factors should be provided by the μEMS to the DSO/DMS.



	0.95	0.96	0.97	0.98	0.99	1	1.01	1.02	1.03	1.04	1.05	1.06
LTV_P=20%_PQ	0.63	0.90	0.88	0.88	0.88	0.85	0.23	-0.01	0.27	0.17	0.44	0.39
LTV_P=100%_CVR	0.33	1.10	1.12	1.09	0.84	0.46	0.23	0.74	0.64	0.80	0.87	0.92
LTV_P=100%_SQ	0.33	1.10	1.12	1.09	1.07	1.05	1.04	1.03	1.02	1.02	0.90	0.57
LTV_P=100%_PQ	0.33	1.10	1.12	1.09	1.07	1.05	1.04	0.84	0.48	0.25	0.69	0.58
LTV_P=20%_CVR	0.63	0.90	0.61	-0.01	0.01	0.26	0.16	0.44	0.38	0.60	0.61	0.95
LTV_P=20%_SQ	0.63	0.90	0.88	0.88	0.88	0.88	0.89	0.89	0.89	0.64	0.13	0.08

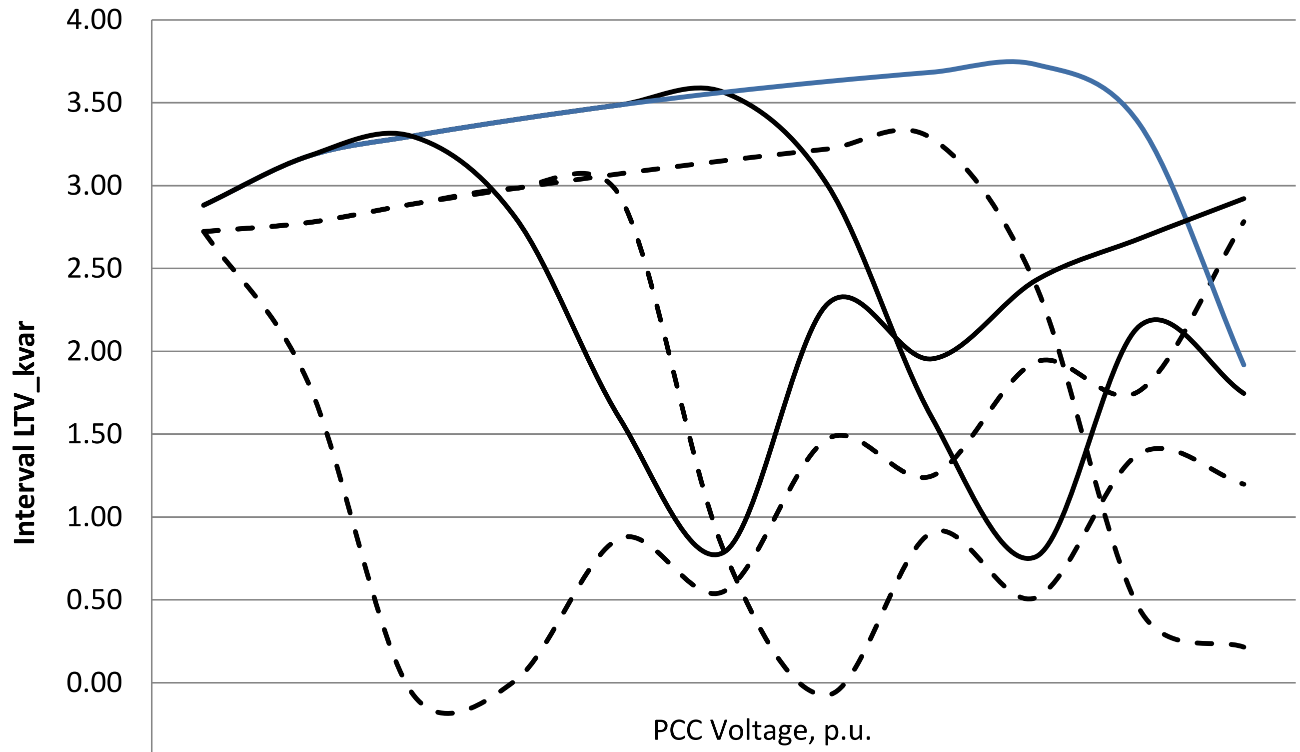
Figure 1-11. Interval real LTV-factors for different modes of DER Volt/var control

Similar situation is observed for the reactive load-to-voltage dependences (See Figure 1-12 and Figure 1-13)



	0.95	0.96	0.97	0.98	0.99	1	1.01	1.02	1.03	1.04	1.05	1.06	1.07
Reactive load_CVR	0.88	0.89	0.91	0.94	0.97	1.00	1.02	1.02	1.05	1.07	1.09	1.12	1.16
Reactive load-SQ	0.88	0.88	0.91	0.94	0.97	1.00	1.03	1.07	1.11	1.15	1.19	1.23	1.26
Reactive load_PQ	0.88	0.88	0.91	0.94	0.97	1.00	1.03	1.07	1.10	1.12	1.13	1.15	1.17
Reactive load_CVR_P=20%	0.94	0.96	0.98	1.00	1.00	1.00	1.01	1.01	1.03	1.04	1.06	1.08	1.11
Reactive load-SQ_P=20%	0.88	0.89	0.92	0.94	0.97	1.00	1.03	1.06	1.10	1.13	1.16	1.17	1.17
Reactive load_PQ_P=20%	0.88	0.89	0.92	0.94	0.97	1.00	1.03	1.04	1.04	1.05	1.05	1.07	1.08

Figure 1-12. Dependencies of the μGrid reactive load on PCC voltage, p.u



	0.96	0.97	0.98	0.99	1	1.01	1.02	1.03	1.04	1.05	1.06
LTV_Q_PQ_P=20%	2.72	2.78	2.89	2.98	2.94	0.80	-0.07	0.91	0.51	1.38	1.20
LTV_Q_SQ_P=20%	2.72	2.78	2.89	2.98	3.07	3.15	3.22	3.28	2.40	0.44	0.22
LTV_Q_CVR_P=20%	2.72	1.82	-0.06	0.02	0.87	0.55	1.47	1.25	1.94	1.76	2.78
LTV_Q_PQ	2.88	3.18	3.30	3.40	3.49	3.56	3.00	1.60	0.76	2.15	1.75
LTV_Q_SQ	2.88	3.18	3.30	3.40	3.49	3.56	3.63	3.68	3.73	3.37	1.92
LTV_Q_CVR	2.88	3.18	3.30	2.80	1.59	0.79	2.29	1.95	2.43	2.68	2.92

Figure 1-13. Interval reactive LTV-factors for different modes of DER Volt/var control

Figure 1-14 and Figure 1-15 present the net kW and kvar dependencies on the PCC voltage. In this case, the differences in the LTV-factors are much more drastic, ranging from close to zero to large positive numbers. With the net load heading to 0, the LTV-factors are heading to infinity. Therefore, if the DSO applications deal with the net load at the microgrid PC only, the microgrid EMS should provide the DSO with the near-real-time updates of the sensitivities of the net load not in %kW/%Volt, but in kW/%volt, and the DSO application should accommodate such parameters. If the DSO applications deal with the microgrid load aggregated at the PCC (without the DER component), then the microgrid EMS should provide the DSO with the updates of load sensitivities to the PCC voltage in the traditional way - %kW/%Volt.

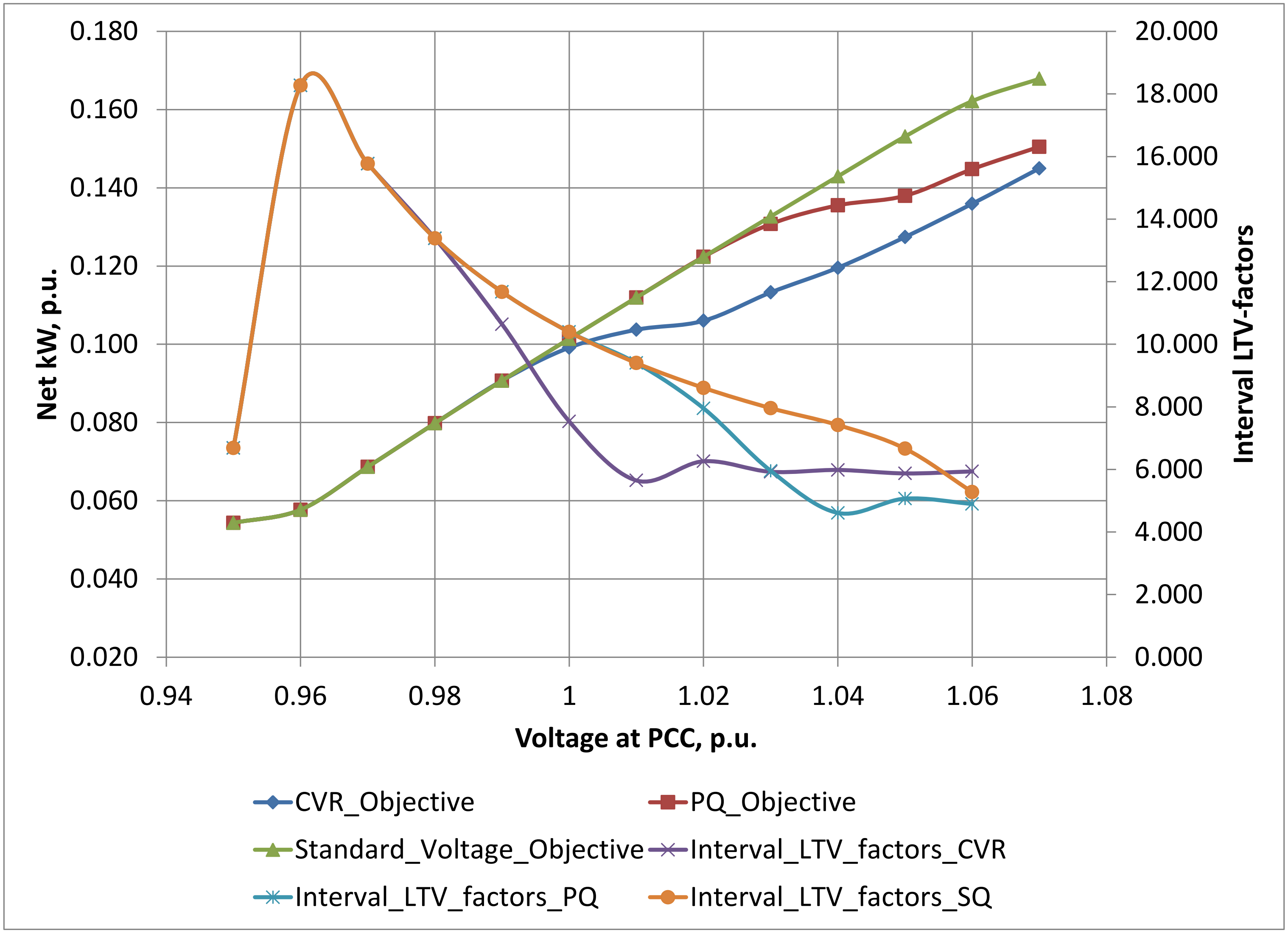


Figure 1-14. Net µGrid kW and interval sensitivities to voltage at PCC

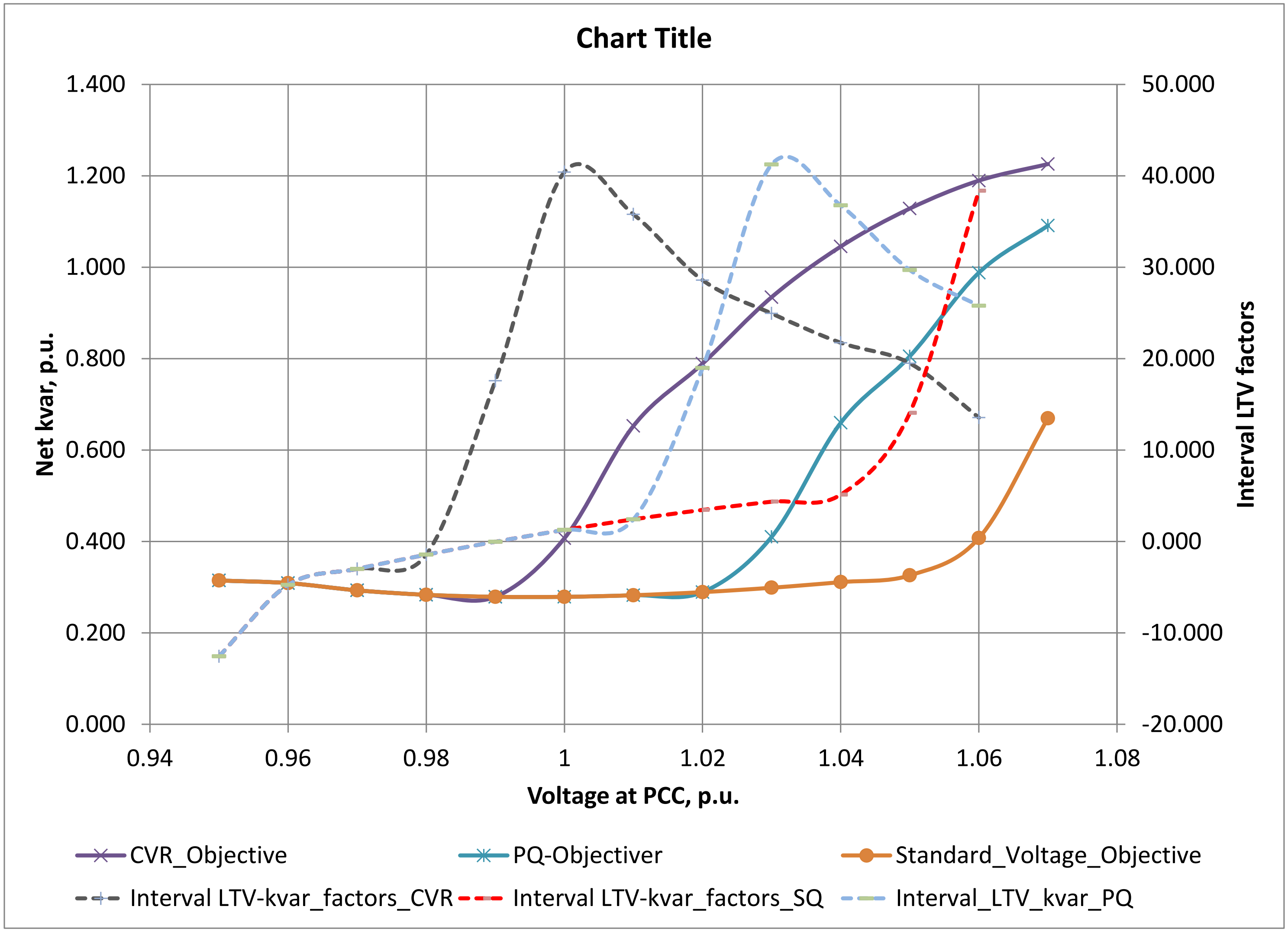
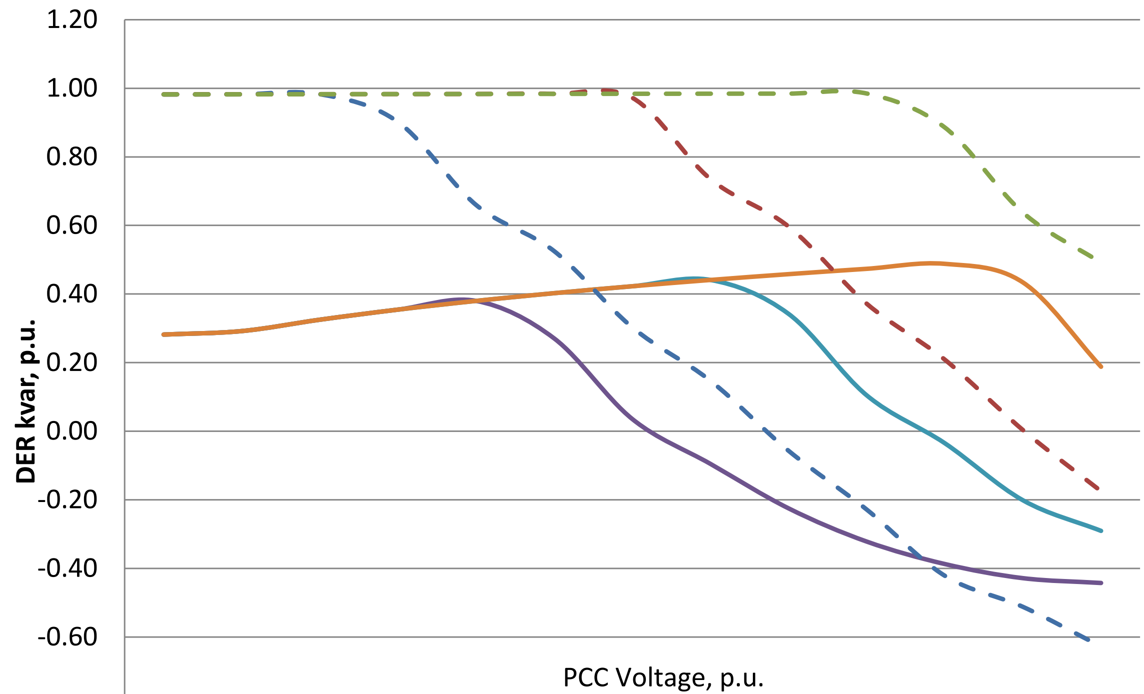


Figure 1-15. Net µGrid kvar and interval sensitivities to voltage at PCC

Other dependencies can be of interest to the DSO and to the μGrid operator, such as DER reactive generation (**Figure 1-16**), loss dependencies (**Figure 1-17**).



	0.95	0.96	0.97	0.98	0.99	1	1.01	1.02	1.03	1.04	1.05	1.06	1.07
DER_kvar_CVR	0.28	0.29	0.33	0.35	0.38	0.27	0.04	-0.10	-0.22	-0.32	-0.39	-0.43	-0.44
DER_kvar_PQ	0.28	0.29	0.33	0.35	0.38	0.40	0.42	0.44	0.34	0.10	-0.04	-0.20	-0.29
DER_kvar_SQ	0.28	0.29	0.33	0.35	0.38	0.40	0.42	0.44	0.46	0.47	0.49	0.43	0.19
DER_kvar_CVR_P=20%	0.98	0.98	0.98	0.90	0.66	0.53	0.30	0.15	-0.06	-0.23	-0.42	-0.51	-0.63
DER_kvar_PQ_P=20%	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.74	0.60	0.37	0.21	0.00	-0.18
DER_kvar_SQ_P=20%	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.89	0.64	0.49

Figure 1-16. Generation of kvars by DERs under different modes of Volt/var control

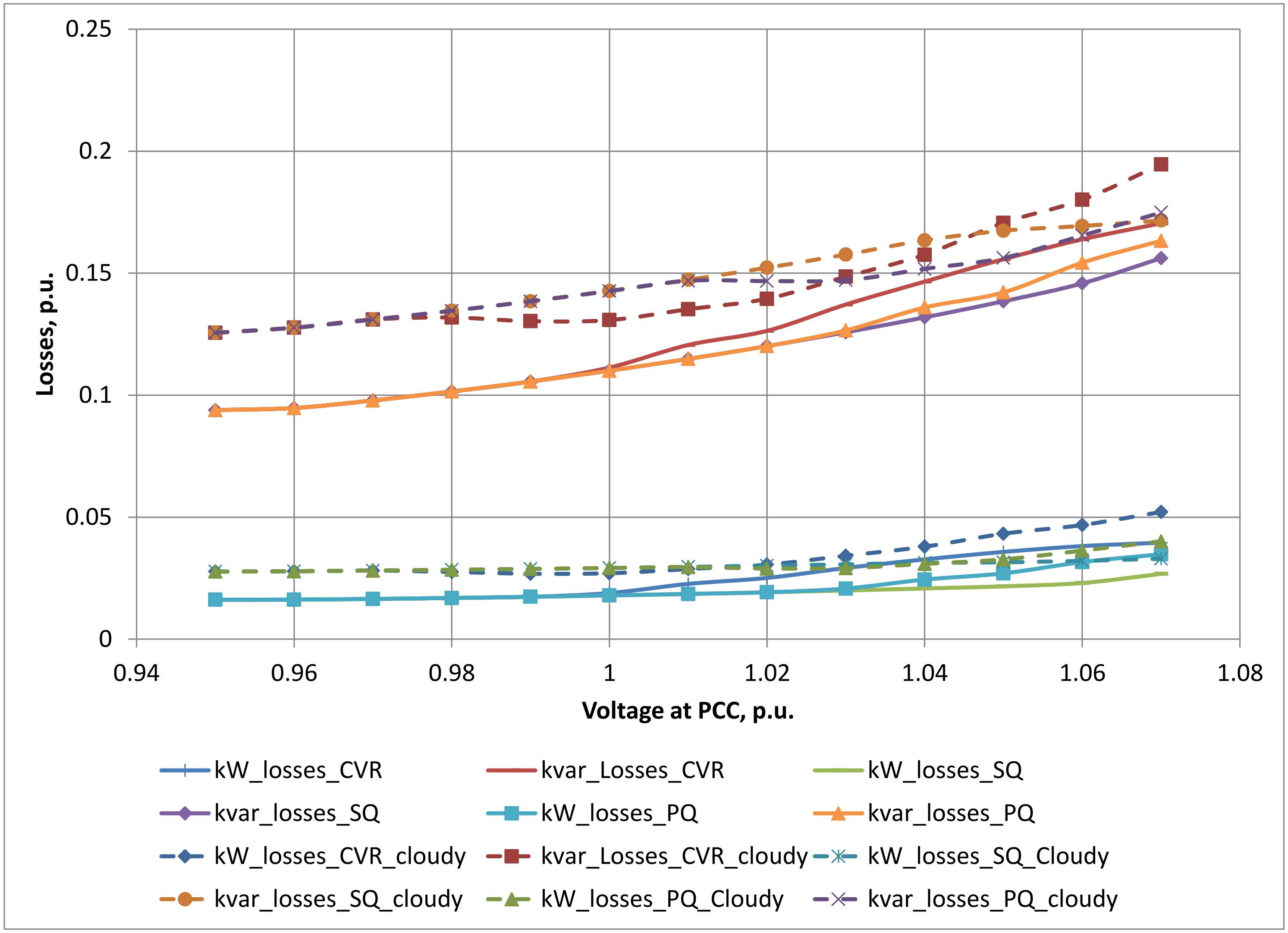


Figure 1-17. Loss dependencies on PCC voltage

2 Diagrams of Use Case

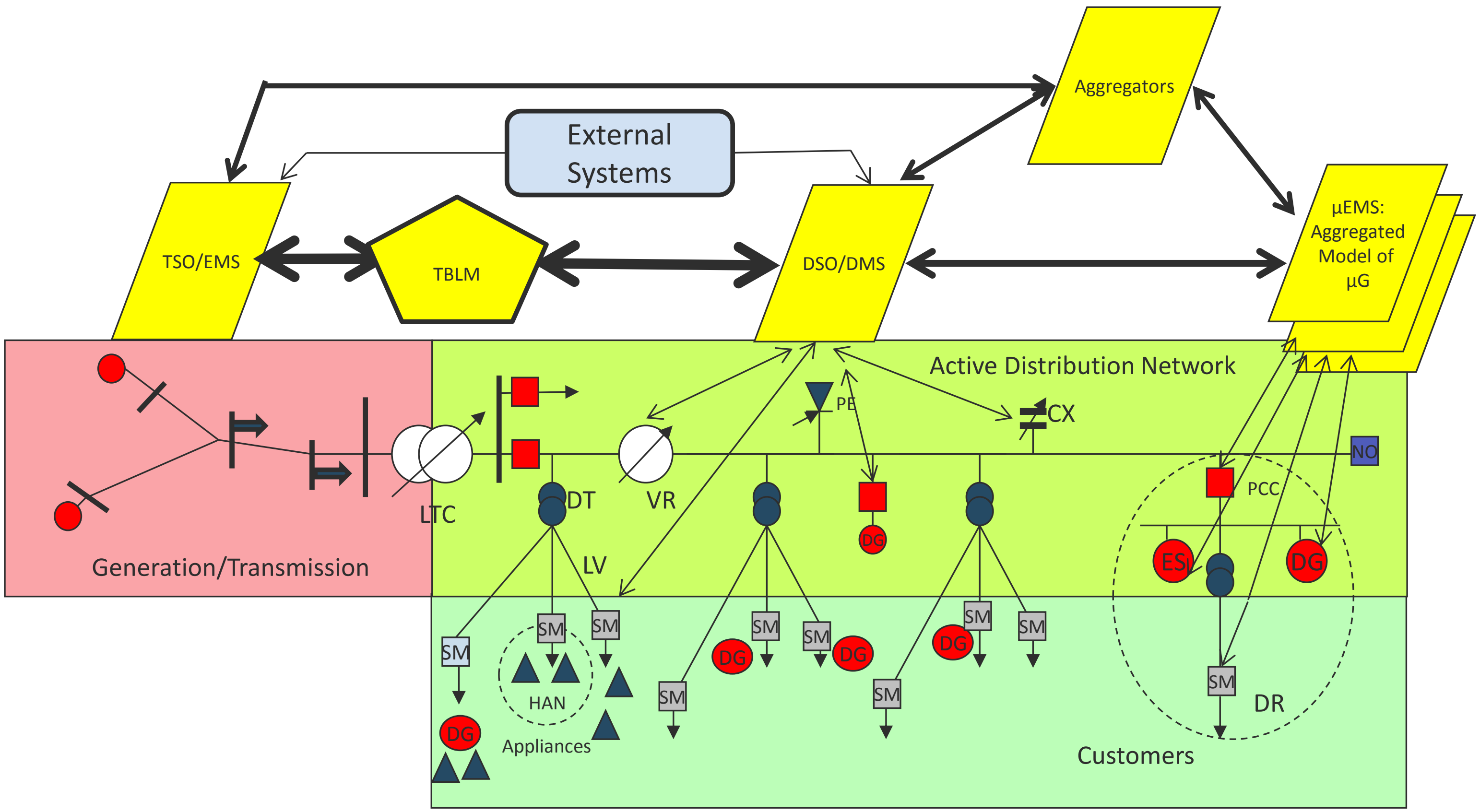


Figure 2-1. Conceptual information exchange between µEMS, other distribution active components, DMS, and EMS

Microgrid Interactive Use Case #IA-3

Error! Reference source not found. through **Error! Reference source not found.** 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.

Microgrid Interactive Use Case #IA-3

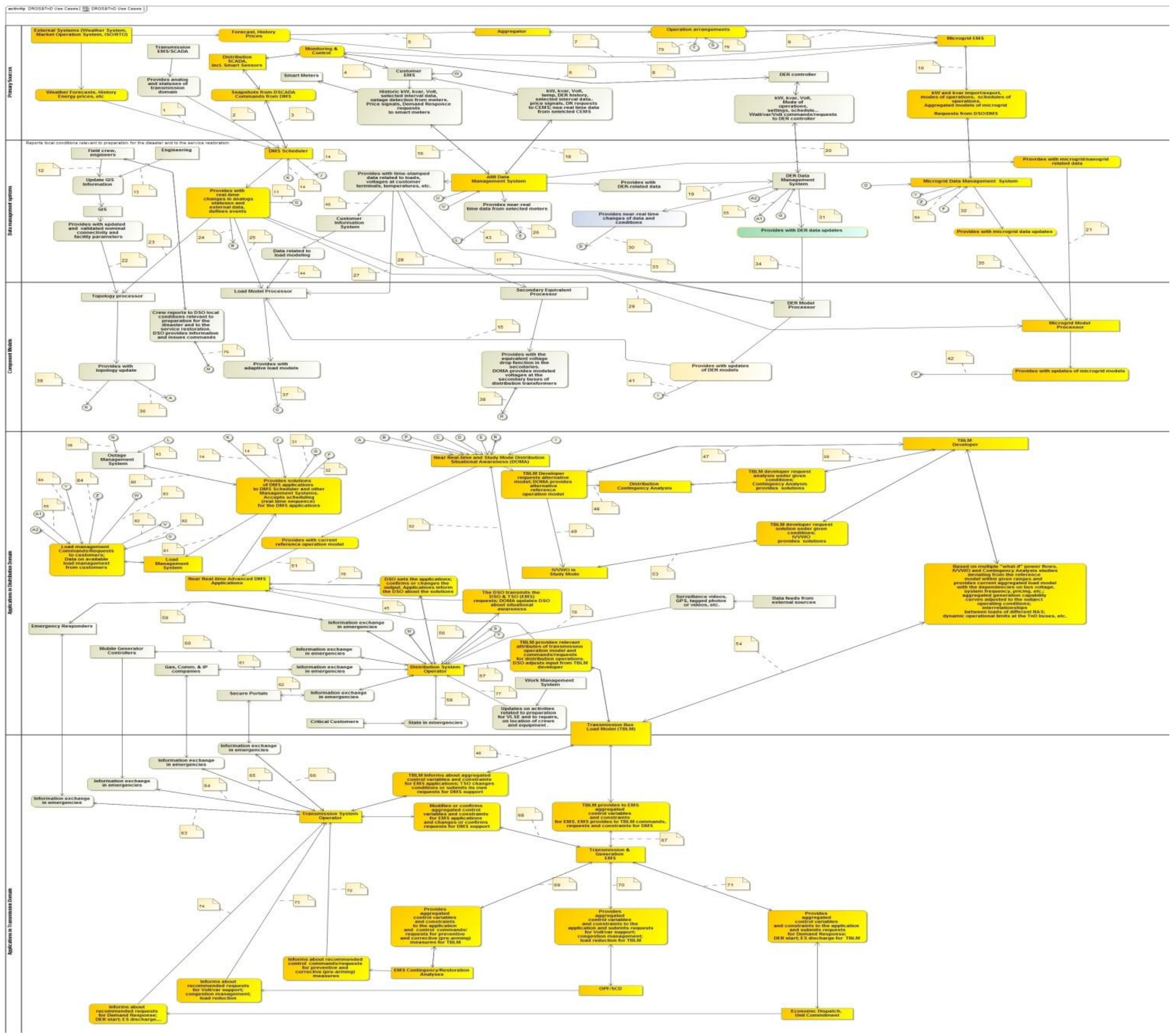


Figure 2-2. Activity diagram for use cases on interactions between customer, distribution and transmission domains

Microgrid Interactive Use Case #IA-3

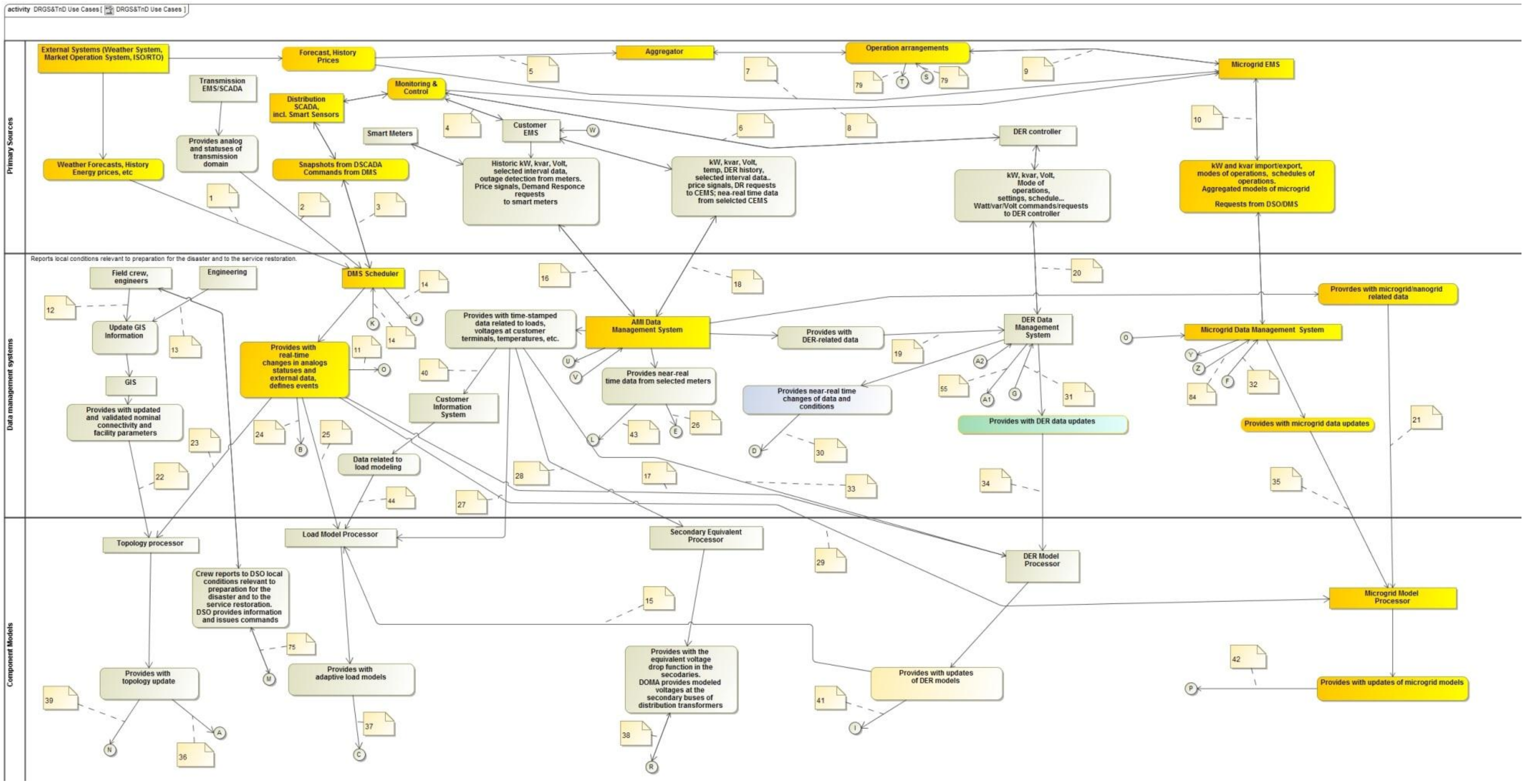


Figure 2-3. Portion of activity diagram for primary information sources and back office systems

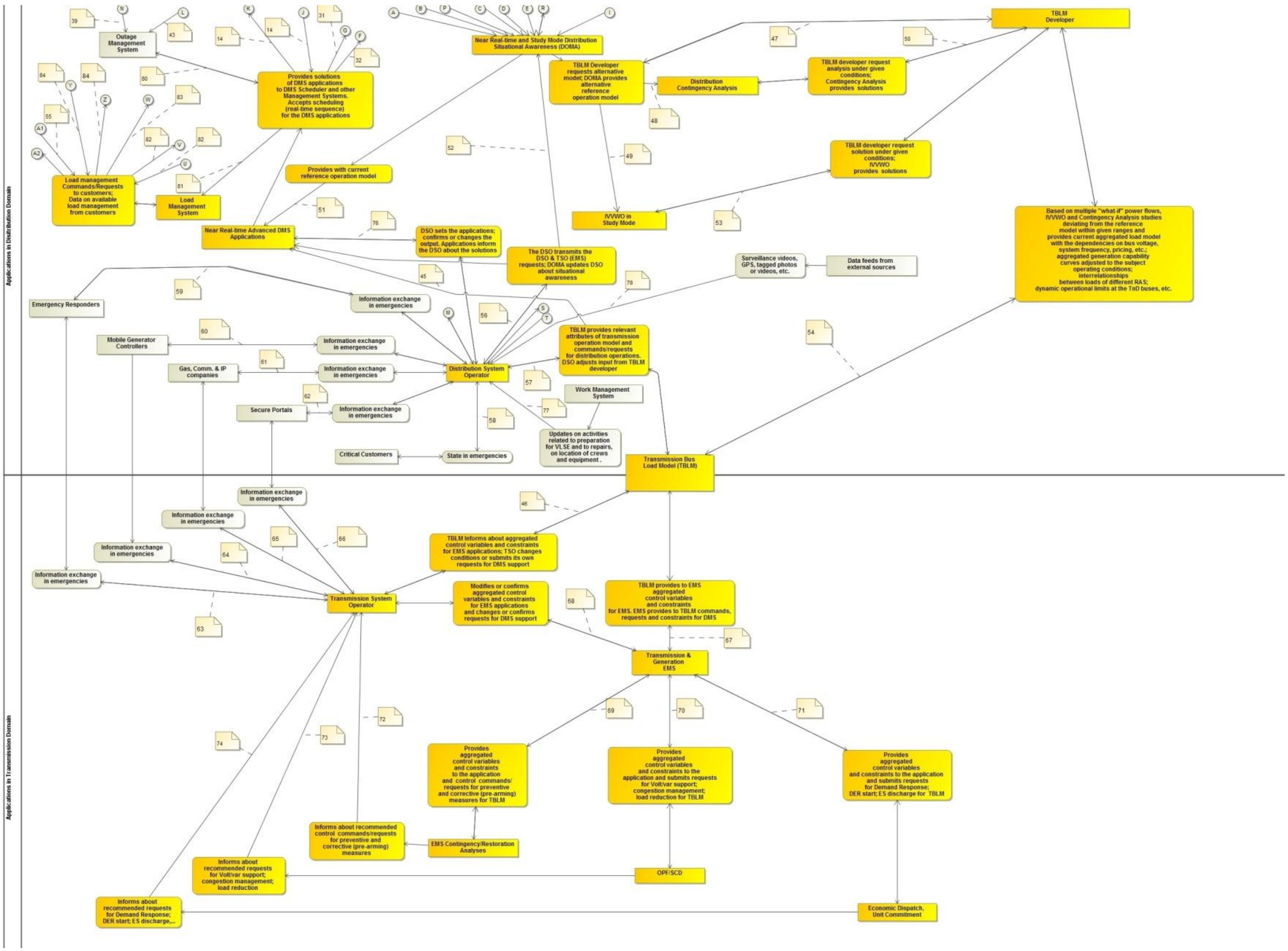


Figure 2-4. Portion of activity diagram for DMS and EMS applications and TBLM

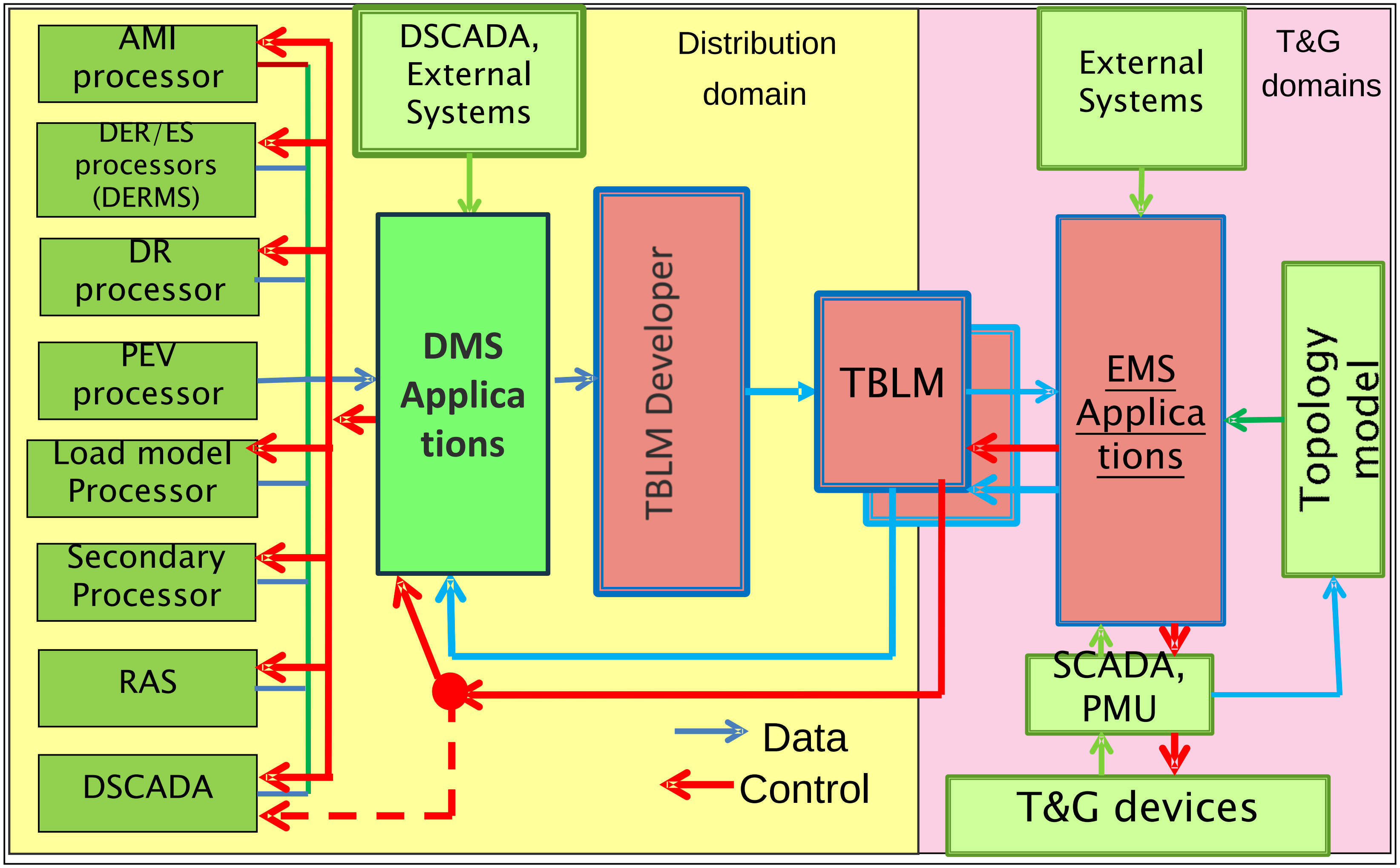


Figure 2-5. Conceptual information exchange between the DMS and EMS through TBLM

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), including OMS or Customer Information System (CIS) for outage	Additional functionalities: Communicates with large DER systems, µEMS, and other collective EMS receiving aggregated data and issuing commands/requests. A wider use of DSCADA for communications with smaller DERs, microgrid and other customer EMSes can be expected

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
			scenarios.	with the implementation of new interoperability standards (e.g., IEC 61850), which support more types of data and provide higher security.
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.	Transmission SCADA/EMS collects data through the TBLM. EMS contains the transmission power system model on its side of the TBLM. 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/μG 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, defines the conditions under which the DERs/μG will operate during pre-defined times, and the operational tolerances for control of these devices, if any. These agreements may include a number of clauses regarding volt/var functions., e.g., provision to support a particular power factor under given conditions; or some ancillary services, etc. The agreements may also include the clauses on when, how and why to utilize the advanced functions.
5	Large Customer EMS	System of a large	A customer EMS in typically implemented for large customers, such as large industrial or commercial	Customer EMS can provide DMS with an aggregated model of the

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
		customer	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 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, if needed or mutually agreed by the EPS and the customer, e.g., for transition state from island to connected mode or for unintentional islanding detection • Weather data • Attributes of load shedding schemes • Attributes of Demand Response aggregated at the PCC, like near-real time or short-term look-ahead available amount and duration of DER, price-level tolerance, etc. (see UC #7) • Attributes of dispatchable load • Aggregated load-to-voltage dependences in the normal and emergency ranges (Separately for load and generation) • Aggregated at the PCC load-to-frequency dependences in the normal and emergency ranges (Separately for load and generation) Customer EMS can provide the following services under

#	Actor	Actor Type	Actor Description	Further information specific to this use case. New functionalities
				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 (new actor)	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	Communicates with Data Management Systems of DMS or other systems dedicated to manage aggregated generation and loads. This communication is for the coordination of the EPS operations with the operations of the composite customer. It may be executed through the aggregator, if

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
			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. .	it meets the scope and timing requirements of the information exchange. Supports control of frequency and voltages either in autonomous mode, or controlled by the DMS. The EMS also calculates, stores, and communicates to the DMS aggregated net load and generation, Demand Response, generation capability data for the community, summarized at the PCC ride-through and RAS 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
8	Campus EMS (new actor)	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.	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. The EMS also calculates, stores, and communicates to the DMS aggregated net load and generation, Demand Response, generation capability data for the campus, summarized at the PCC ride-through and RAS settings and

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
				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 (see Use Cases #1, 2, 4,and 7)
9	DER controller	Device/sub-system	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.	Some (under mutual agreement) DER controllers communicates through the DSCADA with DMS Scheduler and back-office systems, like DER Data Management System, DER Model Processor or other back-office systems dedicated to manage DER. 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.
10	Microgrid EMS (new actor)	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	µEMS communicates with µG Data Management System and µG model processor of the DMS, with the DMS scheduler or other systems dedicated to manage microgrids, including market systems,

#	Actor	Actor Type	Actor Description	Further information specific to this use case. New functionalities
			information with the EPS DMS. . 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) 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.	The aggregated models of the microgrid contain measurements of current generation, generation schedules, DER capability curves, load-to-voltage and frequency dependences and generation-to-voltage and frequency dependences 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, dependences of model components on external signals, degree of uncertainty and validity of the model components and other data needed for current and predictive model of microgrid operations.
11	VPP Management system (new actor)	System	VPP Management system performs planning and trading an aggregation of generation and load within one control area.	The participation of a microgrid in a VPP should be governed under conditions of the agreements between the microgrid, VPP, and EPS. VPP management system 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

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
				with the market domain. 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, based on predefined templates.
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. This may include profiles of real and reactive power injections and

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
				charges, modes of operations and settings.
16	Smart customer appliances	Devices	Equipment and systems at the customer site that could be controllable and can participate in demand response and other programs. Includes lights, pool pumps, air conditioners, electric air and water heaters, refrigerators, washers, electric dryers, dishwashers, etc.	The characteristics of the smart customer appliances can be used in the load management applications and to derive components of adaptive load models that can be used for the aggregated models.
17	External Systems (e.g. Weather)	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.	The information obtained from these may contain the following: (see also the requirements developed by PAP 21). • Temperature • Wind parameters at given height • Speed • Direction • Solar irradiance (near-real time and short-term forecast), W/sq.m • Cloudiness cover (near-real time and short-term forecast), % • Cloud velocity (near-real time and short-term forecast), m/sec • Cloud direction (near-real time and short-term forecast) • Cloud height • Cloud shadow patterns (near-real time and short-term

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
				forecast)
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	MOS deals with energy products, including products of the bulk generation, distributed generation, electric storage, electric transportation, and demand response, and composite participants, such as large microgrids and other customer EMS. It also deals with the products of the ancillary services.
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/GIS database should be interfaced with the Outage Management System (OMS), Customer Information System (CIS) 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	AM/FM/GIS 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

#	Actor	Actor Type	Actor Description	Further information specific to this use case. New functionalities
			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.	AM/FM/GIS database can contain transmission connectivity and facility data and relevant to distribution operations customer-related data. GIS should also contain data aggregated at the PCCs of composite prosumers (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 systems providing customer information including billing data, customer types, and numbers of customers connected 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	The DA applications are the central component of the EPS' DMS,

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
			of the electric distribution system	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 EMSes of large and composite consumers and prosumers, including µEMS. (Microgrids' EMS will have similar although scaled-down applications)DMS displays the summary results to the DSO via a GUI and issues commands and requests to monitored and controlled components of the Active Distribution Network either directly, or through the DMS scheduler.
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, DSO 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. It transmits the commands and requests to monitored and controlled components of the Active Distribution Network issued by the DMS applications.
24	DMS conversion and validation function (processor) - (C&V)	Application	The C&V function uses standard interface between	With the high penetration of DER

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
			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 expectations (e.g., if the utility expects that it can to back up 50% of maximum load of any faulted feeder, and the contingency analysis shows that it cannot be done, then it is likely, with a certain degree of uncertainty that the input data is wrong and need double-checking). .	and micrograds, and other composite DER categories, the C&V function should integrate the specifics of these categories and new Smart Grid technologies. One significant aspect of these categories is the uncertainty of the components of the aggregated models at the PCC. Major causes of the uncertainty are the intermittency of renewables, the autonomous not monitored operations of the DERs, and the performance of the enabled demand response. These uncertainties are propagated to the uncertainty of the overall validation in level 2. Also, if significant inconsistencies are determined within the sub-system of the composite prosumer, the validity of the aggregated models is compromised, and a corresponding message should be delivered to the C&V processor. The C&V processor submits its results to the personnel in charge for the GIS and relevant data management systems.
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	AMI Data Management System derives aggregated at the distribution transformer load profiles based on the link between

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
			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.	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/µG 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	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

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
			external data.	provided by the DER, current protection settings, etc.
28	Microgrid Data Management System		µG 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 µG 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 µG 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

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
				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, µG Model Processor and Data Management System, µEMS, AMI Data Management System, and DMS applications.
31	Load Model Processor	Application	The Load Model Processor develops daily load models based on information available from CIS and GIS (currently – typical load profiles and typical load-to-voltage dependences)) and engineering input. interfaces with AMI Data Management System, DER and µG Data Management Systems and Model processors, customer and µG 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	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 dependences 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 dependences of the load on the changes of these conditions.

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
32	PEV data management system and model processor	Application	PEV data management system is 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	The secondary equivalent processor provides DMS with equivalents of the voltage drops and power loses in the secondary circuits fed from distribution transformers It 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	The topology processor provides DMS with near-real time connectivity model. It 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	ESI is a 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	May be a part of µEMS, and other EMS of composite prosumers, or may interface with these EMSes.

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
			specialized class of services potentially included in HAN gateways. Also commonly referred to as a Home-Area Network Gateway.	
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 μG 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	The Distribution Situational Awareness utilizes adaptive nodal load, DER/Micro-grid, and PV models and secondary equivalents. It communicates with AMI,

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
			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.	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

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
				•
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. The application issues advice to the DSO and/or commands to switching devices in the EPS circuits, to Demand Response installations, to µGrid EMS, and to other relevant components of the Active Distribution Network.
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. The application issues advice to the DSO and/or commands to switching devices in the EPS circuits, to Demand Response installations, to µGrid EMS, and to other relevant components of the Active Distribution Network
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	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

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
			Response/Load Management System, field IEDs and adjusts voltages and vars during and after the operations of FLISR.	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	The application should include the modeling and control of the

#	*Actor*	*Actor Type*	*Actor Description*	*Further information specific to this use case. New functionalities*
			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.	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 dependences, the generation-to-voltage/frequency dependences, 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	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

#	Actor	Actor Type	Actor Description	Further information specific to this use case. New functionalities
			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 dependences 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.	

3.2 Information exchange

The list of interfaces presented in **Error! Reference source not found.** is consistent with the activity diagram presented in **Error! Reference source not found.** through **Error! Reference source not found.**

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	Medium to	Minimum	According to

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
			status information from the observable portions of the distribution power system Protection and Remedial Action Schemes data	Large	exchange times	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 Data requests	Small to average	Immediately after change	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
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

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
			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	Small to average	Immediately after change	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
			Data requests			
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	Small to average	Immediately after change	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
			increase, or both) Data requests			
18	Customer EMS	AMI Data Management System	Aggregated from Smart 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	Small to average	Once a day	Revenue 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	Generation kW and kvar	Small to average	Once a day	Revenue

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
		System	Generation kWh Generation profiles Interval average voltages Weather data. Generation change triggers received with timestamps; 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			accuracy for kW and kvar; 0.5%-0.2% accuracy for Voltages
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	Small	Immediately after change	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
			operation and setpoints Desired ride-through settings Data requests Synchronization commands			
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	Load Model Processor	Load impacting factors with	Large	Once a day	Verified

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
	Management System		time stamps, e.g., local weather data, Demand Response requests with start and stop times, other related events with timestamps			historic data
28	AMI Data Management System	Secondary Equivalent processor	Daily kW and kvar load profiles from individual Smart meters and aggregated at the distribution transformer load profiles Daily profiles of interval-average voltages	Large	Once a day	
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	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
					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	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
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	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
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 Awareness (DOMA)	Distribution System Operator	DOMA updates DSO about situational awareness	Small	Periodically and by event	
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	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
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 limits at the TnD buses, etc.	Large	Every update of the State Estimation, e.g., every 5-10 min and by events, for multiple scenarios	Verified information
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	Transmission Bus Load	Authorizes and/or changes the components in the TBLM	Small	By event	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
	Operator	Model `				
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 Controllers	Distribution System Operator	Information exchange in emergencies	Small	By event	
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	Transmission System	Information exchange in	Small	By event	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
	Controllers	Operator	emergencies			
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 Load Model	Transmission & Generation EMS	Provides aggregated control variables and constraints for EMS	Small	After every update of TBLM	Verified information
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	Transmission & Generation EMS	Submits control commands/ requests for preventive and	Small	When preventive and corrective	Verified information

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
	Contingency Analyses		corrective (pre-arming) measures		measures in distribution are needed	
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 equivalent)	Transmission & Generation EMS	Submits requests for Demand Response; DER start; ES discharge, etc.	Small	When Demand Response; DER start; ES discharge in distribution are needed	Verified information
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	Verified information

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
					needed	
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 repairs, on location of crews and equipment.	Small	As needed	
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	Data on outage and restoration management	Small to medium	By events	

# in AD	Source	Recipient	Contents of information	Volume	Timing	Accuracy
		applications				
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) Update the short-term load-and-generation to voltage dependencies at the µGrid's PCC within normal voltage ranges
2) Update the long-term load-and-generation to voltage dependencies at the µGrid's PCC within normal voltage ranges

3.4 Step-by-step actions

The step-by-step actions presented in

Table 3-3 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	DMS provides µEMs with the expected range of voltage in the PCC for the short-term look-ahead time interval	DMS applications	Update of voltage range at PCC	DMS runs IVVO for the next short-term interval and informs the µEMS about the expected voltages at the µGrid PCC and desirable range of voltage at the PCC for further network analyses.	DMS applications, DSO	µEMS	Update of voltage range at PCC	In each cycle of the DMS applications, the applications run "what-if" studies, exploring different voltages within an expected range. In each step of these studies, the appropriate load/generation dependencies on voltage should be used. Therefore, the µEMs should provide with the dependencies for the expected range of PCC voltages that will be used by the DMS applications.
2	µEMS provides DMS with the adjusted load and generation dependencies for the provided range of	µEMS	Update of µGrid load and generation dependencies on voltage	µEMS provides DMS with load/generation dependencies adjusted for the requested PCC voltage range	µEMS	DMS	Update of µGrid load and generation dependencies on voltage	

	PCC voltages.							
3	DSO changes the IVVO objective to load reduction	DMS	Request for the µGrid load-reducing dependencies on the voltage	In case the µGrid load does not reduce with PCC voltage reduction in the expected range of PCC voltages, DMS/DSO may request to change the dependencies to load-reducing ones	DMS, DSO	µEMS	Request for the µGrid load-reducing dependencies on the voltage	
3.1	µEMS is able to change its VVO setup and provide load-reducing dependencies	µEMS	Information about adjusted µGrid load/generation dependencies on voltage	µEMS informs DMS about adjusted µGrid load/generation dependencies on voltage and about associated consequences for the µGrid in accordance with the agreements between the µGrid and EPS	µEMS	DMS	Information about adjusted µGrid load/generati on dependencies on voltage	For instance, µEMS runs the super-quality objective, and the load does not change within the subject voltage range. Based on the DMS request, the µEMS either changes the setup of its VVO so that the reactive power sources do not compensate for voltage reduction at the customer terminals, or switches the VVO to the CVR objective, which reduces the load. These changes result in some drawbacks for the µGrid, which should be dealt with in accordance with the agreements between the EPS and µGrid
3.2	µEMS is unable to change its VVO setup to provide load-reducing dependencies	µEMS	Information about inability of providing load-reducing dependencies of the µGrid	µEMS informs DMS about its inability of providing load-reducing dependencies of the µGrid and about the reasons why	µEMS	DMS	Information about inability of providing load-reducing dependencies of the µGrid	For instance, the load cannot be reduced because the µEMS already runs the CVR objective, or because the CVR-factors for the µGrid are negative (or close to zero) due to a high level electric heating.

4	The real power generation by the µGrid DERs significantly changed	µEMS	Information about significant change of the load/generation dependencies on voltage	µEMS informs DMS about a significant change of the load/generation dependencies on voltage due to the change of contribution of real and reactive power generation	µEMS	DMS	Information about significant change of the load/generati on dependencies on voltage	For instance, a change from a sunny to a cloudy sky may significantly reduce the real power generation by PV DERs and increase the available reactive power generation. This, in turn, may increase the range of the PCC voltage, under which the voltages at the service terminals in the µGrid are kept constant.
5	DMS runs the next iteration of DMS applications and returns to i.1							

4 Version Management

Version	*Date*	*Author*	*Changes*	*Comments*
1	07/02/2014	Nokhum Markushevich	Draft 1 Narrative of Use Case	
2	09/07/2014	Nokhum Markushevich	Development of the illustrative model	
3	09/26/2014	Nokhum Markushevich	Modification of the use case based on the new model	

4	09/27/2014	Nokhum Markushevich	Added long-term dependencies scenario	
5	10/08/2014	Nokhum Markushevich	Updated the narrative based on the updated illustrative model	
6	01/26/2015	Nokhum Markushevich	Revised the use case based on reviews: narrative and list of actors	
7	03/23/2015	Nokhum Markushevich	Updated to Version 2	
8	03/27/2015	Nokhum Markushevich	Added the step-by-step action table	
9	07/07/2015	Jim Reilly and Nokhum Markushevich	Formatting for posting	

5 References and further readings.

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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.