REQUIREMENTS FOR COORDINATED ANCILLARY SERVICES COVERING DIFFERENT VOLTAGE LEVELS

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ABSTRACT

The massive development and implementation of small and medium scale generation units within the distribution grids result in novel needs and options for ancillary services. The project DeCAS develops solutions for the coordinated activation of ancillary cross-voltage-level services considering the different objective functions of individual voltage levels. This paper aims to analyze, define and describe common requirements focusing on a technical, stakeholder and market perspective.

INTRODUCTION

Power systems have been operated successfully as a combination of large generators, transmission and distribution grid for decades. The European legislation with the related electricity market liberalization and renewable energy support, led to the massive development and implementation of small and medium scale generation units (distributed generation, DG), which are usually connected near the consumption mainly in low (LV) and medium voltage (MV) networks. Many existing research projects in the field of smart grids focus on the DG integration in and on increasing the hosting capacity at one specific voltage level as well as on an individual market and with regard to singular stakeholder aspects. Combining smart grid control and operation algorithms across voltage levels (from LV up to the high voltage (HV) level), the project DeCAS [1] is the next step, when addressing the challenges of an increasing share of distributed generation from a technical and market perspective. DeCAS is an ERA-Net Smart Grid Plus [2] funded project (launched in February 2016) and aims for mainly two aspects:

- To research and analyze the coordination of ancillary services such as aggregated "prosumer" response control reserve, individual voltage control and reactive power management concepts over traditional boundaries from high voltage, medium voltage to low voltage
- To develop approaches and concepts for a coordinated control approach considering the different objective functions of individual voltage levels. It will include the integration related to monitoring and controls in process control systems as well as to existing and future markets for flexibility

In order to fulfil these objectives, nine partners from four countries are part of the project DeCAS (see Figure 1). The DeCAS partners are grouped in three demonstrator sites, so called innovation cells (ICs), consisting of the respective national partners of the cell (Germany, Austria or Finland). The individual solutions implemented at the three ICs aim for a prototype demonstration of selected ancillary services at different operational environments.

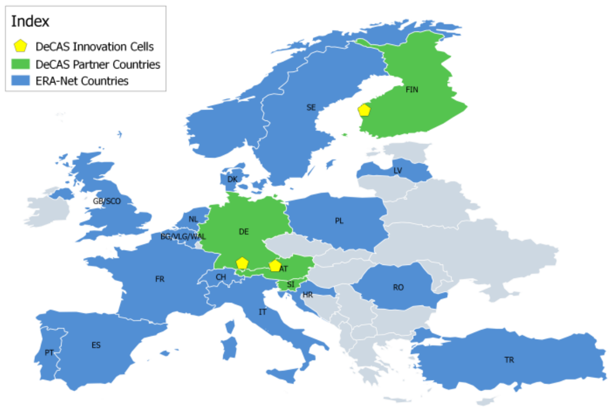

Figure 1 - Location of the DeCAS Innovation Cells

This paper aims to analyze, define and describe common requirements based on the experiences of the individual demonstrator's (innovation cells) along to the three research layers:

i. **technical requirements** for the HV/MV/LV interaction:
Investigation of solutions for the coordinated activation of ancillary cross-voltage-level services considering the different objective functions of individual voltage levels.
ii. requirements for **stakeholder integration:**
Identification and analysis of benefits and/or barriers regarding the integration of relevant stakeholders (e.g. generators or prosumers).
iii. requirements from a **market perspective** for the innovation cell (but also defining requirements for future markets):
Focus on market-based solutions as part of network control to involve stakeholders of generation and/or demand side management in future markets.

INNOVATION CELL AUSTRIA

IC Austria is focusing on coordinated voltage control based on existing research infrastructure within the distribution grid area of Salzburg Netz, which includes medium voltage as well as low voltage networks. Besides Salzburg Netz [3], the IC partners include Siemens [4], AIT [5] and TU-Vienna [6]. This IC enhances concepts and results of the prior projects ZUQDE [7] and LEAFS [8]. As one of the enhancements an intelligent substation (MV/LV Interface) will be connected to the SCADA system to control the reactive power flow over system boundaries.

Technical Requirements

Figure 2 shows the target schematics of IC Austria mapped to SGAM. The aim of this specific Innovation Cell is to establish a coordinated VAr-control (Volt-ampere reactive) between high, medium and low voltage grids taking augmented concepts for LV grid operation into consideration.

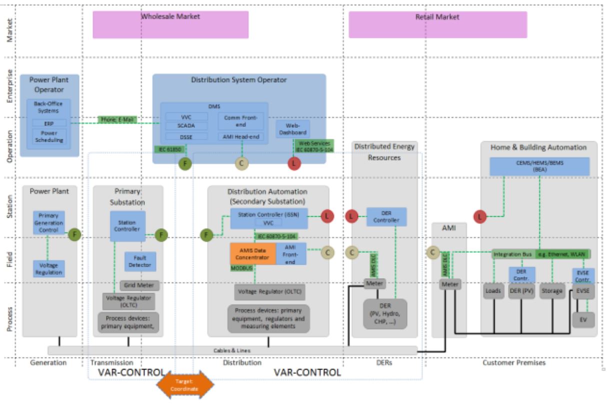

Figure 2 - SGAM mapping of IC-Austria

Traditional network operation, still dominant today, is based on three distinct and in terms of control separated levels: the HV transmission network with voltage and frequency control, the MV distribution network with basic voltage control and the LV distribution network, without observability and controllability. This topology is reflected also in most smart grid pilot projects, focusing on the three levels separately. However, with the rising share of DG the influence between the levels will become substantial, and will require addressing the interaction between HV, MV and LV networks. The coordinated network control will form the basis for the definition of new ancillary and market services, and will be tested via simulations and validated on-field. A coordinated approach is essential to analyse the interdependencies across voltage levels to guarantee overall system stability with increased hosting capacity at LV and MV level. As field trial region, the northern part of the federal state of Salzburg was chosen. This part of the grid is also modelled in an additional, project specific SCADA system. Also the intelligent substation network (iSSN) Köstendorf is included in the field trial area. Therefore it will be possible to demonstrate the interface and the interaction of the central SCADA System with a decentralized intelligent local grid.

Stakeholder Adoption

The implementation of a smart grid will impact different stakeholders such as customers (prosumers), network operators, aggregators and market actors. In future the classic consumer will be substituted by prosumers which are operating DG, flexible loads like e-cars and battery storage systems. Via demonstration activities and description of best practices the DeCAS project will reduce the barriers for engaging the prosumers, as well as technicians and other staff at DSOs in smart grid topics and how to take part in future ancillary service provision. Therefore one part of the planned project will evaluate promising concepts for low voltage grid operation e.g. transferred from the world of IoT (Internet of Things), bringing the stakeholders together. Figure 3 shows some exemplary use cases for IoT based operation of iSSNs as well as how they could interface with MV/HV SCADA DMS as described above.

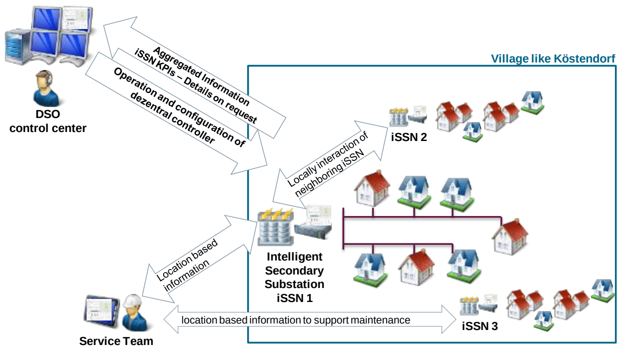

Figure 3 - Exemplary use cases for IoT based operation of iSSNs

In this project, a true interaction between the decentralized controllers (=iSSN) on the LV/MV side and the substation on the MV/HV side will be designed and implemented in a proof-of-concept/field test. To avoid flooding of the control center, the iSSNs aggregate and process the collected data from prosumer’s technical representatives (e.g. a Customer Energy Management System) and provide KPIs. If necessary, more detailed information can be requested by network operators or planers. A further important advantage gained by using IoT for the iSSN is that local information can be provided directly to service teams.

Market Requirements

Future distribution grids will include a range of flexibilities, but these are often not owned by DSOs, but rather by prosumers or independent plant operators. Inter-voltage-level ancillary services contracted bilaterally or via flexibility markets could create an incentive for aggregators and prosumers to offer their flexibility also to DSOs or attract DSOs to act as platform operator. However, markets are not in the scope of the developments around the IC Austria.

INNOVATION CELL GERMANY

The IC Germany focuses on the provision of reactive power within and across grid levels in the context of a comprehensive operational planning process for local virtual power plants (LVPP) [9]. The IC builds on the IRENE and IREN2 projects [10], [11], in which a LVPP in a local LV-grid is set up. In DeCAS, the LVPP will be scaled up by including distributed energy resources (DER) connected to the medium voltage (MV-) grid. Additionally, the IC Germany will add new DER in the LV-grid expanding the demonstrator from the projects IRENE and IREN2. Furthermore, the operational planning process will be extended by an intraday planning process to make better use of short-time generation and load forecasts. In general, virtual power plants (VPPs) are a concept to improve market participation of DER. The IC partners include Allgäu Netz GmbH [12], University of Applied Sciences Kempten [13] and RWTH Aachen [14].

Technical Requirements

The LVPP set up in the IC Germany includes various DER units, e.g. photovoltaic (PV), combined heat and power (CHP) and storage units, which are controlled according to the planned day-ahead schedule via a control system. The operational planning process uses day-ahead generation forecasts as well as real-time grid measurements. Based on this data, a reactive power demand, that represents the demand of the transmission system operator, is derived and an optimal aggregated reactive power schedule is calculated. The scale up in DeCAS requires several extensions of the technical infrastructure as well as of the operational planning software (cf. Figure 4).

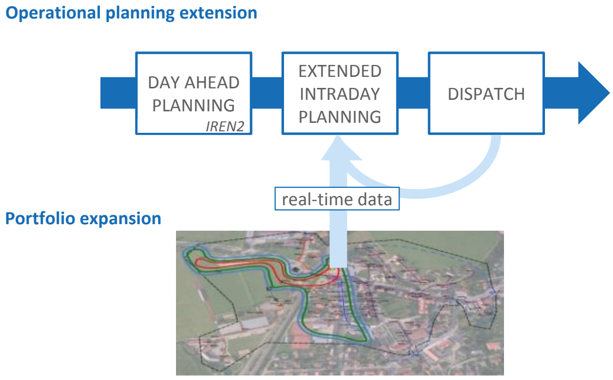

Figure 4 - Scale up of the LVPP infrastructure

The extension of the existing microgrid consists of a nanogrid and a controllable biogas combined heat and power plant (biogas-CHP). The nanogrid is implemented as a smart home including a home battery system, a controllable photovoltaic system (PV system), and a power-to-heat system (P2H). The integration of MV-units requires a communication interface to the distribution system operator's (DSO) SCADA system. Due to network security issues, a direct control of DER in the MV-grid is not possible. Therefore, an open loop control via the DSO's control system will be installed, during which the DSO tries to carry out the planned schedule. The expansion of the metering infrastructure to higher grid levels is necessary to analyse the potential of the LVPP's reactive power provision not only from the LV- to the MV-grid but also to the HV-level. Aside from measurements in the MV-feeder, the power flow across the HV/MV-transformer is an important evaluation criterion to assess the potential.

The extensions regarding the operational planning aim at complementing the day-ahead planning process (once every 24h) by an intraday planning process (hourly). Further automation of the planning process is necessary to realize the short-term planning stage. This relates mainly to the data transfer from and to the control system as well as to the planning algorithm itself. Furthermore, intraday planning requires the update of day-ahead generation forecasts to generate the required input for the planning process. For this purpose, real time data can be used to correct the day-ahead forecasts' deviations, yielding updated and more accurate intraday forecasts.

Stakeholder Adoption

The realisation of the scale up to the MV-grid level requires additional participants compared to the existing LVPP at LV-level. Therefore, the owners of generation units connected to the MV-grid, i.e. large scale PV and CHP units, willing to participate in the field test must be recruited. The participation entails allowing the remote control of reactive power feed-in during the field test as well as the installation of additional metering equipment.

Additionally, further involvement of the DSO is necessary to enable control of units at MV-grid level. The DSO has to dispatch the planned schedules to the respective generation units. Hence, a communication interface in form of an open loop control between the operational planning software and the DSO's control system is necessary.

Market Requirements

In addition to the grid-oriented provision of reactive power, the IC Germany aims to investigate the market integration of DER into the energy markets. This investigation is carried out within a simulation environment, independently from the field test. The current market framework with high requirements regarding minimum volume, block offers and the compliance with the reported schedule obstruct the market participation of VPPs including intermittent generation. Therefore, two approaches to further improve the market participation of VPPs are investigated in this project. The first approach targets the mitigation of market risks caused by intermittent generation. Possible countermeasures include the regional distribution of generation as well as the use of new developed futures products to hedge against risks [15], [9]. The second approach investigates the impact of different market frameworks on the market integration of VPPs. Therefore, frameworks from various European market areas are analysed and included in the simulation environment. The efficiency of the two approaches regarding the market participation of VPPs is analysed and compared using the simulation environment. The investigation requires an adequate data basis for:

- local forecasting errors of intermittent generation
- market data of futures products
- market data of different European market areas

INNOVATION CELL FINLAND

Sundom Smart Grid (SSG) [16] in Vaasa, Finland (Figure 5) is a smart grid pilot of ABB Oy, Vaasan Sähkö (local DSO), Elisa (telecommunication company, previously Anvia) and University of Vaasa. SSG serves as Finnish IC in the DeCAS project. IC Finland concentrates on research and development of future active network management (ANM) schemes and related technical flexibility service market structures as well as on development of future-proof islanding detection functionalities.

Technical Requirements

IC Finland, ABB in cooperation with University of Vaasa, utilizes very accurate measurement data from multiple points and control of available DG units (Wind turbine 3.6 MW, PV unit 33 kW, Figure 5) on the research and development of different new centralized/decentralized combined islanding detection schemes [17] and local (DSO) ANM schemes (Figure 6) which can fulfil multiple targets simultaneously during grid connected operation.

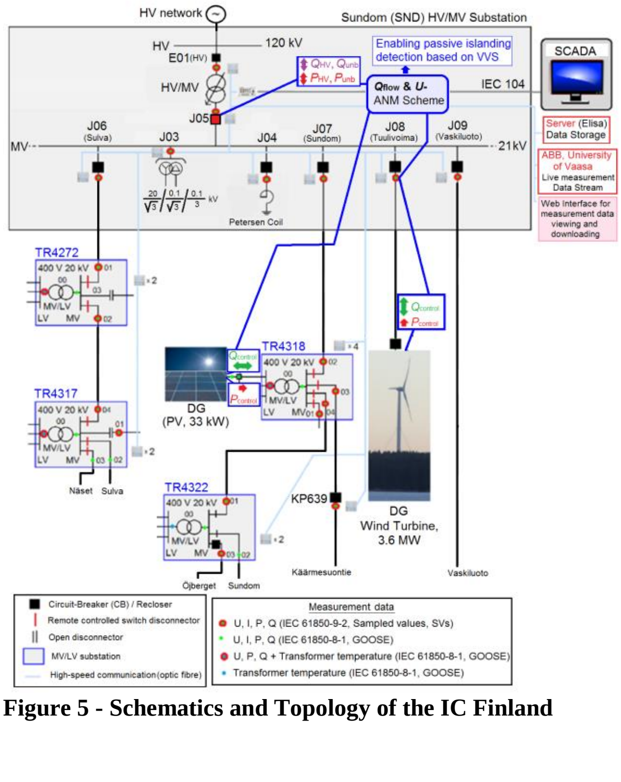

Figure 5 - Schematics and Topology of the IC Finland

1) Primary local (DSO) ANM method: Q_{flow} & U -management
- Q_{flow} & U -management tries to fulfill multiple DSO targets a)-d) simultaneously by reactive power control of available flexibilities ($Q_{control}$)

a) Control of Reactive Power Import/Export (Q_{HV}) between DSO and TSO
b) Reliable Islanding Detection
- Continuous control of Q_{unb} or Q_{HV} by $Q_{control}$ of flexibilities to enable reliable islanding detection i.e. operation outside the NDZ of used passive method
c) Coordinated MV Network Voltage Control
d) Enabling Stable Transition to Intended (Microgrid) Island Operation
- Keeping Q_{unb} or Q_{HV} under certain limits (i.e. small enough) by $Q_{control}$ of available flexibilities (depending also on P_{unb} or P_{HV} as well as on available fast $Q_{control}$ / $P_{control}$ capacity of flexibilities

- Priority ranking of a)-d)

2) Secondary local (DSO) ANM method: P_{flow} -management
- By $P_{control}$ of available flexibilities if operation within voltage and thermal limits cannot be achieved with primary ANM method or target d) in primary ANM cannot be achieved without P_{unb} or P_{HV} control

Figure 6 - ANM scheme which can fulfill multiple MV network targets simultaneously

In addition, coupling and potential mutual effects between ANM schemes / targets of different voltage levels (MV/LV) or levels of FlexZones [18] and between local (DSO) and system-wide (TSO) flexibility service schemes will be studied. Studies are expected to show, for example, a) what is the effect of LV network ANM methods on MV network ANM methods and vice versa, b) what is the effect of local (DSO) MV network ANM methods (i.e. Q_{flow} & U and P_{flow} -management, Figure 5) on available system-wide (TSO) flexibilities/flexibility forecasts (from that particular DSO network) and c) how possible system-wide (TSO) flexibility services like *P/f* -control may effect on local (DSO) level for example on congestion management (voltage and thermal limits) and on available local (DSO) flexibilities for primary and secondary local ANM schemes. Different scenarios related to above issues will be studied by simulations with larger amount of different available flexibilities connected in MV and LV network than today (Figure 5).

Stakeholder Adoption

The realisation of Q_{flow} & U- ANM scheme (Figure 6) in IC Finland (Figure 5) requires coordinated reactive power control of MV and LV network connected DG units and their owners' willingness to participate. These ANM schemes could be realized alternatively in DSO SCADA or by decentralized, hierarchical and coordinated management solutions at HV/MV, MV/LV substations with management units called FlexZone units (FZUs) [18]including also future-proof protection and islanding detection functionalities [17]. In the future, one alternative could be that some of the less critical / high-speed communication dependent DSO FZU functionalities like ANM schemes would be located in cloud servers.

Market Requirements

IC Finland studies also possible future retail and technical flexibility (ancillary) service market structures in Europe and market models for future ANM schemes (like in Figure 6) and effects to different parties considering coupling/potential challenges between local (DSO) and system-wide (TSO) needs.

CONCLUSION & OUTLOOK

The previous chapters including the descriptions of the Innovation Cells provide insight to the different thematic orientations of the national demonstrators. Overall, a variety of different approaches for ancillary services are being developed, implemented and tested at the ICs. Besides the focus on cross voltage level services, the main commonalities and challenges at the ICs based on the three layer approach are:

- technical perspective: voltage level services
- stakeholder perspective: participation of owners of DGs
- market perspective: applicability of (future) flexibility markets

Table 1 provides a summary from the approaches of different ICs:

Table 1 - Summary based on the three layer approach

Innovation Cell	Ancillary Service	Stakeholder involvement	Market
Austria	Voltage Control (HV/MV/LV)	TSO, DSO, Generators, Consumers	n.A.
Germany	Reactive Power (MV/LV)	DSO, Generators, Consumers	Day ahead
Finland	ANM & islanding detection (HV/MV/LV)	TSO, DSO, Generators, Consumers	Future markets for ANM

The three ICs are following diverse approaches. Whilst IC-Austria focusses on the technical aspect of coordinated network control over all voltage levels, the LVPP of the German IC tries to bridge the gap of centralized energy markets and local network constraints and at IC Finland also islanding detection under future conditions is investigated. Regarding the stakeholder perspective the innovation cells require a participation of the owners of DGs that take part in ancillary service provision. Project DeCAS aims to ensure replicability and scalability of the developed services. Therefore, the next steps include the development of system models of the individual ICs for simulation and analysis purposes. The exchange of knowledge and experiences will be based on this joint simulation platform. This is expected to lead to project wide technical recommendations for further developments within DeCAS.

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