Ideal grid for all - IDE4L

2016

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Description of the project

The IDE4L project is a 3 year demonstration project (September 2013 – October 2016) with a total budget of 8 M€. The research leading to these results has received funding from the European Union seventh framework program FP7-SMARTCITIES-2013 under grant agreement 608860 IDE4L – Ideal grid for all. The coordinator of the project is Professor Sami Repo (sami.repo@tut.fi) from TUT.

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- 1 energy association: Danish Energy, Denmark
- 1 research institute: Catalonia Institute for Renewable Energy (IREC), Spain
- 3 distribution system operators: Unareti Spa, Italy; Union Fenosa Distribution SA, Spain; Østkraft A/S, Denmark
- 1 manufacturer: Schneider Electric SA, Spain

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Project summary

The main aim of the IDE4L project is to define, design and demonstrate "ideal grid for all", an active distribution network which integrates Renewable Energy Sources (RESs) and new loads, and guarantees the reliability of classical distribution networks. The scope of the project is within medium and low voltage networks. Enhanced solutions to be applied therein are distribution automation and planning of active network. Novelties of the project are Active Network Management (ANM) based on Distributed Energy Resource (DER) and flexibility service, distributed automation to monitor and control a complete distribution grid, new roles of DSO and aggregators, interactions of Distribution System Operator (DSO) / Transmission System Operator (TSO) and DSO/market actors and decentralized FLISR Solution based on IEC 61850 GOOSE.

Motivation

- RES, active consumers, prosumers and commercial third parties increase the complexity of network planning and operation. Real time monitoring needs to be improved to supervise fast changing conditions and to be aware of new phenomena in complete system.
- Advanced distribution automation and flexible DERs like distributed generation and demand response enable active network management to integrate more RES and new loads into distribution grids, i.e. increase the hosting capacity. Improved controllability of distribution grid enables completely new ways to design and operate distribution grids.
- Existing and new networks and resources should be fully utilized to avoid over-dimensioning of grids due to quality of supply obligations and missing possibility to control DERs
- Guaranteeing continuity and quality of electricity supply by distributed real time fault location, isolation and supply restoration solution cooperating with microgrids

To realize the project, project partners have designed, developed and field-tested the next generation hierarchical and distributed architecture for distribution automation, based on international standards, in particular IEC 61850, DLMS/COSEM (IEC 62056) and CIM (IEC 61970, IEC 61968). This automation enables real time monitoring and control of the medium and low voltage grids, and trading of flexibility services offered by DERs through aggregators. Aggregators will offer flexibility services for a flexibility market and grid companies may validate submitted offers and purchase flexibility services to avoid network constraints.

The architecture has been designed based on the Smart Grid Architecture Model (SGAM) and semantic models of the components. About 30 use cases of active network management have been utilized to define it. As a result, the description of architecture is reusable to include additional use cases for the model or to implement it in the form of alternative components, communication media or protocols, and information exchange methods and protocols. The proposed architecture also reuses existing automation solutions by integrating them like control centre IT systems (SCADA, Distribution Management System (DMS), etc.) into proposed architecture. Therefore, the proposed solution may easily be expanded from the existing systems when needed.

New functionalities for the active grid, fit for the automation solution, have been developed and demonstrated in laboratories and real field conditions of three DSOs Unareti, Union Fenosa Distribution and Østkraft.

- Distributed Fault Location Isolation and Supply Restoration (FLISR)
- Microgrid integration
- Real time monitoring
- State estimation and forecasting
- Real time and day-ahead congestion management
- Phasor Measurement Unit (PMU) information synthesis for TSO
- Scheduling of DERs based on flexibility demand

In future network planning, trade-offs between investments in primary equipment and control strategies of DERs must be considered. For this purpose, the project has developed new planning algorithms for operational, expansion and target network planning. The economic verification of developed automation solutions is proved by planning tools which are developed to evaluate the costs and the benefits of active network management like the increment of distribution grid hosting capacity for RES or cost savings due to postponed infrastructure investments. The aim of the tools is to find out if active network management may replace passive network enforcement actions in future distribution networks, instead of a business as usual evolution.

Working methodologies

The IDE4L project has defined three concepts:

- **The ANM concept** to design and operate future distribution grids and to define roles and responsibilities of stakeholders,
- **The distributed automation concept** for ANM, and
- **The aggregator concept** for validating and purchasing flexibility services for ANM from DERs and offered to flexibility service market.

Developing

- Use case definition
- Implementation of functionalities, interfaces and database of Substation Automation Unit (SAU)
- Planning tools
- Laboratory testing facilities

Demonstrating

- 3 demonstration sites of DSOs utilizing the proposed automation solutions and validating 10 use cases
- 6 laboratory demonstration sites utilizing hardware and software-in-the-loop real time digital simulation

Demonstration sites

Installing a complex automation system in a real operating environment is a non-trivial task, especially if the target environment provides a public service as the electricity distribution grid.

From the design and development stage of individual "bricks" of the architecture to the real testing of subset of the overall system, the leap needed to run a use case is quite big.

For this reason, IDE4L has devised an intermediate step where pairs of components of the system are tested together to validate their interaction, before stacking many of them together. This intermediate step is called Integration Lab, because its main focus is on the integration.

The result of adding the integration lab is the testing approach becoming a three-step procedure, as depicted in Figure 1.

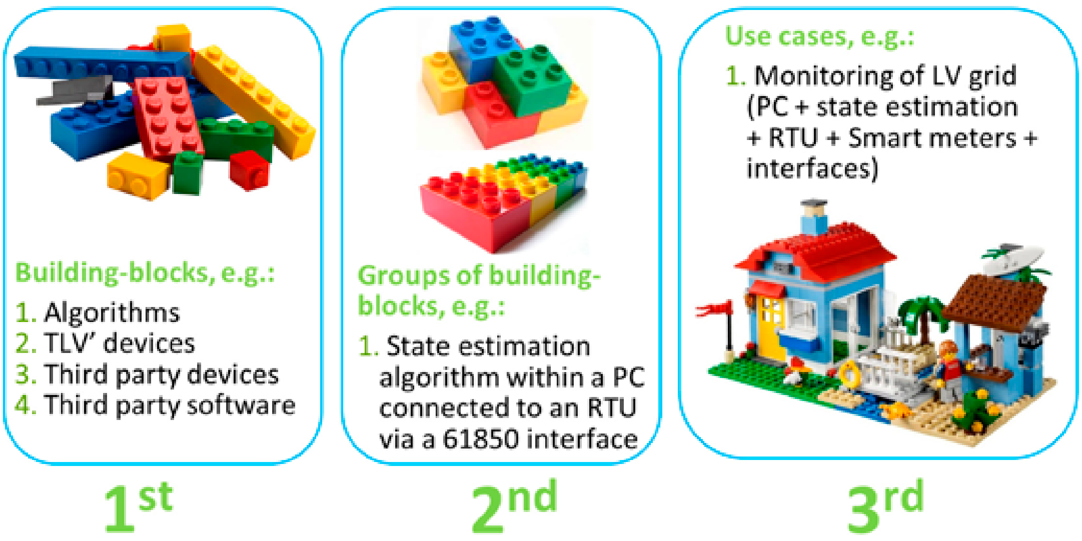


Figure 1. The testing approach.

Figure 2. Development, integration and demonstration sites.

The first step is the testing of individual components of the overall architecture. The place where this test is performed is called "Development Laboratory" by project partners. These tests, executed in simulated/emulated environments, were carried out for each automation module and algorithm to validate them before the integration phase.

The second step is the integration, carried out during "the Integration phase". These tests were executed in simulated/prototype environments integrating architectures, algorithms and tools provided by development laboratories. The integration phase validated the overall integrated IDE4L architecture and technologies that were later applied in the real demonstration scenarios.

The demonstration phase is the final assessment phase, which is carried out by demonstrations owners and supported by integration laboratory group. These tests were executed in real and simulated scenarios. They validated the IDE4L architecture in real applications.

According to the classification reported in Figure 1, Figure reports the list of Development sites, Integration labs, lab. and field demonstrators.

Active network management concept

ANM concept is the basis for the whole project and includes the following key ideas and methods:

1. Enhanced utilization of DERs for ANM

a. Connection requirements of DERs technically enable the control of DERs

b. DSO's own resources are controlled directly by advanced distribution automation

c. Control of contracted DERs of non-market based DERs (e.g. reactive power of DERs)

d. Flexibility services from commercial aggregators through flexibility market

2. Advanced distribution automation is the key for ANM

a. Automation of medium and low voltage distribution grids to monitor and control DSO's resources and DERs in real time

b. Hierarchical and distributed automation to easily enlarge existing automation and control centre systems and to provide necessary scalability

c. Integrated with national HUBs, flexibility market, and automation of aggregators.

3. Aggregator interacts with DSO to meet technical constraints in its operation, but it may also provide flexibility services to DSO and ancillary services to TSO through flexibility market.

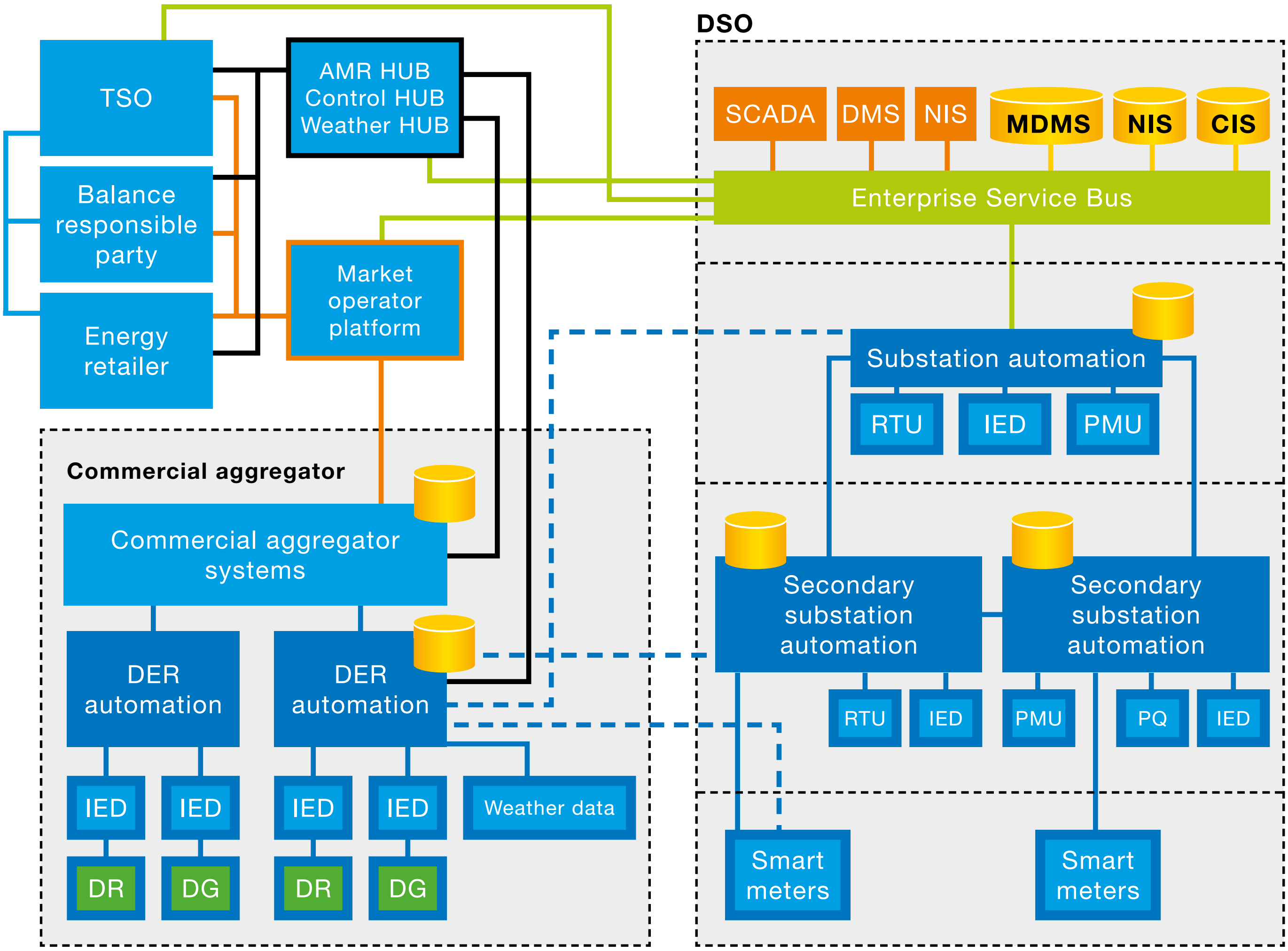


Figure 3. Active network management concept of IDE4L.

The central part of the automation solution is the Substation Automation Unit (SAU) located at primary substations and selected secondary substations. The SAU merges real time data from IEDs and smart meters. It includes a database where all information is stored to be used by functionalities or to be reported to other SAUs or control centre. Automated functions send control commands to IEDs.

By partly vertically and horizontally distributing the decision making, the problem solving and communication requirements may be relaxed, the scalability of automation system may be guaranteed, the reaction time to varying network conditions, disturbances, outages, etc. may be decreased and the workload of control centre systems and operators may also be decreased which might otherwise become very demanding.

More information

D2.1 Specification of active distribution network concept

D2.2 Final vision and roadmap of active distribution network concept

Automation concept

The IDE4L project has designed an architecture based on monitoring, control and business use cases, which effectively coordinates DER and power and voltage control actuators to resolve congestions and power quality issues. The SGAM formulation of this architecture is derived and explained in details in the IDE4L reports. Selected implementation instances are presented, and the performance of the architecture is assessed based on indexes such as communication traffic and level of distribution of automation functions.

The IDE4L architecture is technology neutral as far as standards are used; hence, it can be implemented with heterogeneous types of measurement devices, controllers and computation units. All data exchange and data modelling are based on international standards IEC 61850, DLMS/COSEM and CIM to enable interoperability, modularity, reuse of existing automation components and faster integration and configuration of new automation components.

However, implementation instances are also proposed for the sake of the demonstration and as such are easily reproducible.

The development methodology is complete: it starts with use case definition (monitoring, control and business), followed by SGAM layers definition and eventually implementation of software and hardware in the field. Operatively, we have proceeded systematically, specifying the requirements for information exchange following the parameters of IEC 61850-5 standard; the actors have been defined in terms of interfaces, databases and functions, and the information exchanges have been clustered in data objects of IEC 61850 and CIM data models.

More information

D3.1 Distribution automation concept

D3.2 Architecture design and implementation and Annexes

D3.3 Laboratory test report

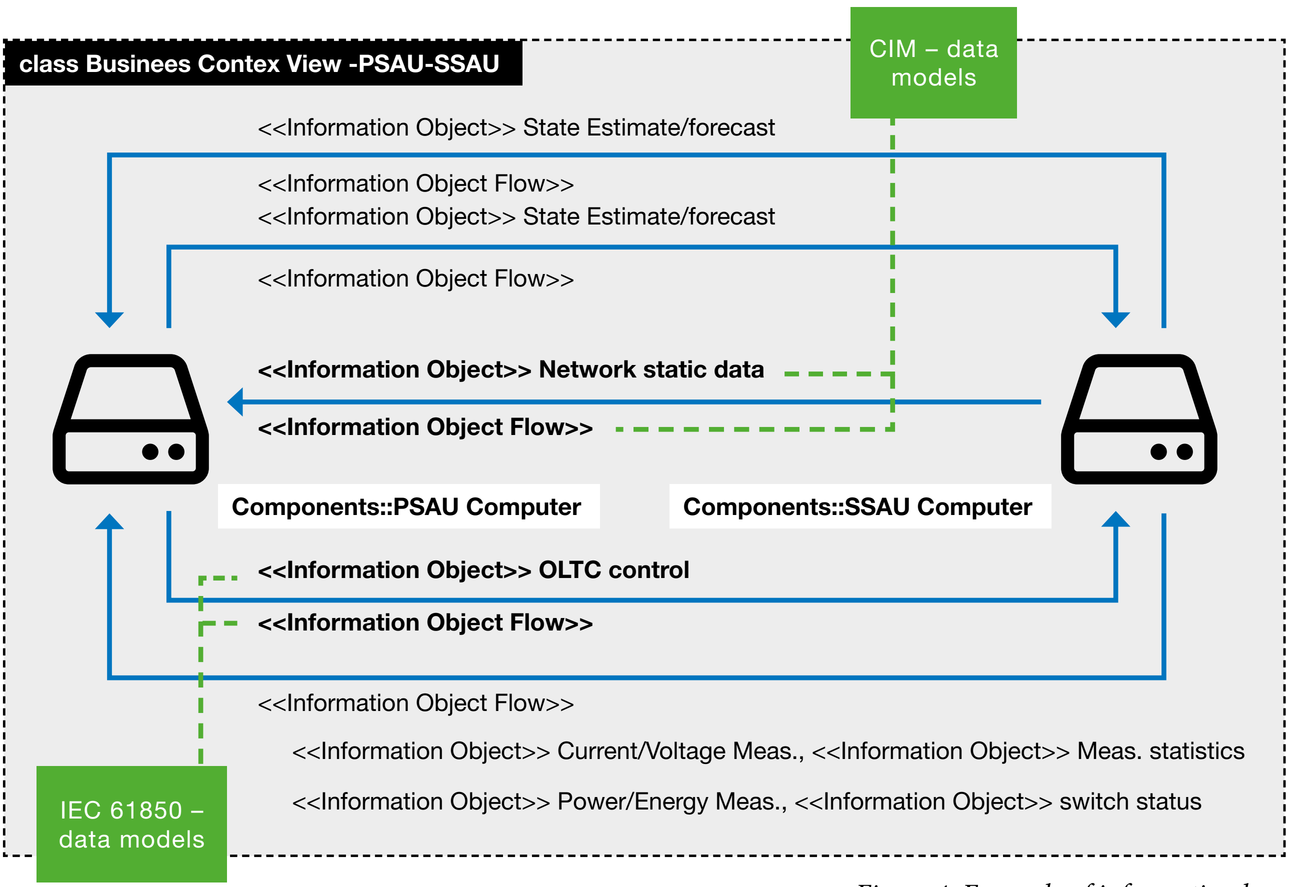


Figure 4. Example of information layer.

Commercial Aggregator concept

The Commercial Aggregator is defined as the player who buys and sells energy and controllable power (flexibility) in the electricity markets or via other forms of trading (bilateral contracts, call for tenders, etc.), by shaping the consumption of their customers. This is achieved by either sending incentives to the consumers or by "directly" controlling the consumer's consumption via active power set points. The Scheduled Re-Profilings (SRPs) are formed by means of price incentives, triggering the load re-profiling of the prosumers. The Conditional Re-Profilings (CRPs) requires a more immediate control by means of direct control signals. The commercial aggregator does not sell a specific level of demand but a deviation from the forecasted level.

Commercial aggregators interact with DSOs in different time horizons (day-ahead, intra-day, real-time) for two main purposes. On one hand, commercial aggregators need network acceptance from DSOs for demand response actions that have been previously traded in the market. In fact, the activation of a flexibility product must not cause new violations of constraints. This is the reason why they must be checked and validated before their activation. On the other hand, commercial aggregators sell flexibility services (SRPs, CRPs) to DSOs in flexibility markets.

CRPs are procured for defined time periods by DSOs, i.e. the capacity for a specified generation/demand modification for a defined period of time is procured. Optionally, such CRPs are activated by tertiary controllers when grid congestion cannot be solved only with more cost-efficient tools, such as the operation of DSO distribution assets. Commercial aggregators participating

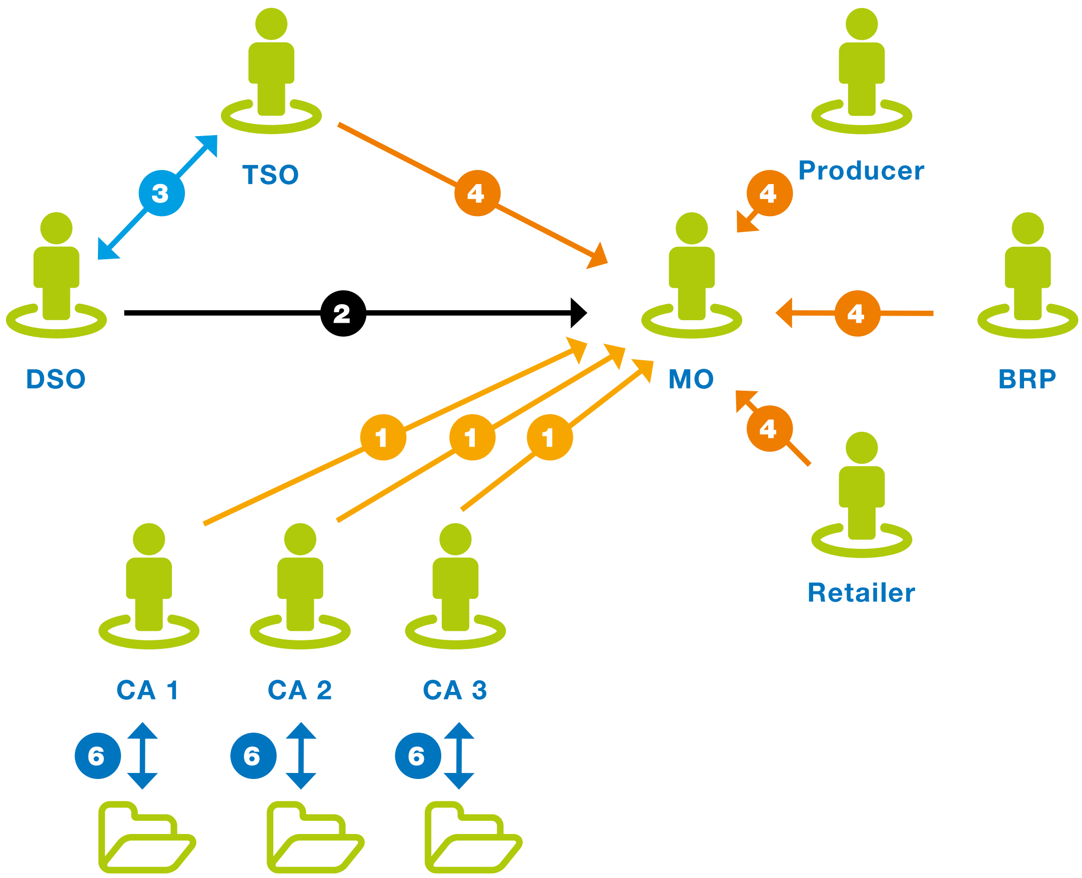


Figure 5. Interactions of flexibility market participants.

in flexibility markets/platforms are able to bid/tender their CRPs in a transparent, non-discriminatory and competitive manner (supervision of competent power system regulator needed).

The commercial aggregator will communicate with the customers thanks to a communication device, which becomes the gateway between them. This device acts as a DER automation, which is in charge of the coordination of load, generation and storage at prosumers' premises to reschedule the consumption profile by running a specific optimization algorithm.

More information

D6.1 Optimal scheduling tools for day-ahead operation and intraday adjustment - Part II: Commercial Aggregator concept

Main exploitable results

Decentralized IEC 61850 FLISR Solution

Design and **proof of concept** of a decentralized Fault Location Isolation and Supply Restoration (FLISR) solution fully based on the IEC 61850 standard. GOOSE interlocking messages are used for the implementation of the two-step logic and chronometric selectivity schemas, and for the integration of the control functions for DER connected to the medium voltage grid.

Benefits

- **Minimize impact of DER connection:**

GOOSE interaction with FLISR IEDs allows the DER controller to manage connection or disconnection from the grid. Interlocking messages to be exchanged depends on fault locations and actions being performed on circuit breakers or switches. Microgrids with DER are integrated with remote or local control based on interconnection switch, with appropriate fast and soft switching conditions according to interconnection switch requirements and, providing IEC 61850 connectivity with SAU. Local monitoring is included at the PCC. In such points, power quality issues have been also implemented (power smoothing by storage elements due to i.e. flicker noise).

- **EU Market exploitability and reduction of Integration Efforts:**

The use of IEC 61850, the global standard for communication in substations, applied to protection functions in medium voltage networks together with logic selectivity functionalities are far from a real deployment. Unareti's medium voltage demonstration site is one of the first operating environment where the concept is tested.

Real demonstration has allowed us to corroborate that the adoption of the IEC 61850 for IDE4L FLISR makes it easy to integrate into existing solutions in EU networks and to operate together with other third-parties IEC 61850 IEDs and functionalities.

- **Fast response to changeable conditions**

The main limitation of FLISR solutions is that every time the grid changes, protection settings and logics are no longer valid. IDE4L proposes an adaptive FLISR solution where settings and communication schemas can be adjusted to the network configuration and load currents, without interrupting operation. Solution is based on MMS communication with an IEC 61850 client.

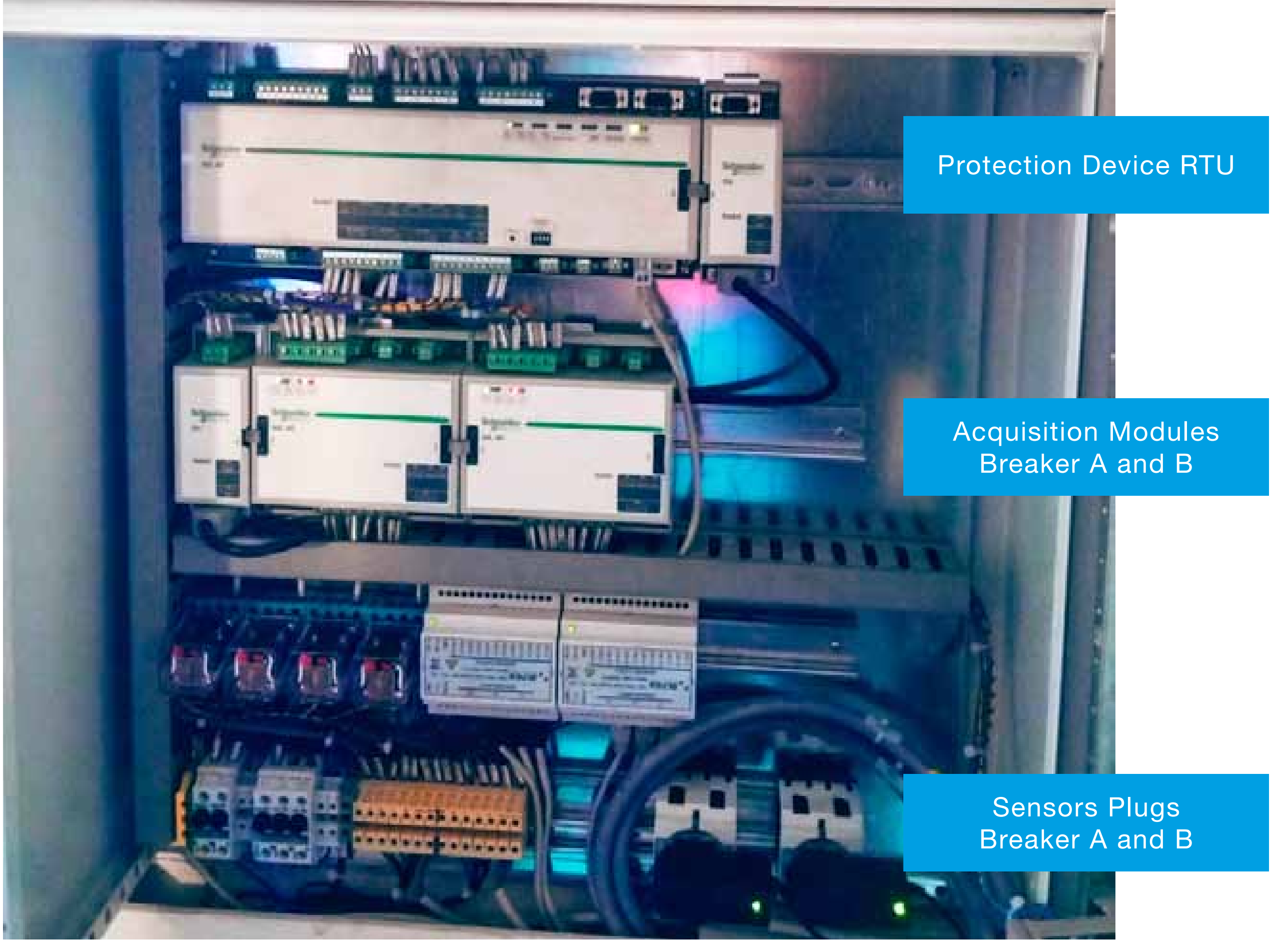


Figure 6. Schneider Electric validation cabinet of FLISR IED installed in Unareti site.

- **Reliability index improvement**

IDE4L FLISR solution allows reducing the number of customers that experience power outages in the event of a fault and the isolation of the outage area in few seconds, thus reducing the duration of loss of load in comparison with traditional schemas where protection functions are only applied at primary substation and with logic selectivity where decisions are taken at control centre level.

Limitations

Feeder automation functionalities are not currently included in the approved parts of the IEC 61850 standard, although some efforts are being performed.

Missing functionalities have been identified and proposed through the National Standardization Committee for IEC TR 62689-100: Requirements and proposals for IEC 61850 data model extensions to support Fault Passage Indicators applications.

More information

D. Della Giustina, A. Dedè, A. Alvarez de Sotomayor, F. Ramos, Toward and Adaptive Protection System for the Distribution Grid by using the IEC 61850, IEEE Industrial Electronics Society Industry Forum ICIT 2015, Sevilla, March 2015.

L. Peretto, R. Tinarelli, D. Della Giustina, A. Dedè, A. Alvarez De Sotomayor, R. Perez Romero, Study for Assessing the Conformity of a Commercial Measurement System for Smart Grid Application, IEEE International Workshop on Applied Measurements for Power Systems AMPS 2015. Aachen, September 2015.

D4.3 Preliminary assessments of the algorithms for network reliability improvement: Laboratory verification of algorithms for network reliability enhancement by FLISR

SAU device

The Substation Automation Unit (SAU) is the core of the hierarchical/distributed IDE4L architecture. The SAU, installed in the substations, conceptually identical in primary and secondary substations, realizes the local and remote monitoring and coordination of resources. Its definition in terms of interfaces, functions and database makes the SAU adaptable, it can be implemented with a subset of features, which are easy to extract from the general model, and as such it can be supported by hardware with very different performance characteristics.

Benefits

The SAU was designed for substation automation for distribution, and was not adapted from hardware and software solutions developed for the much more automated transmission networks. As such it is naturally slim, and scalable. Its computation and communication requirements can be modulated to meet specific needs, thus avoiding over-design.

The SAU may reduce the burden for computation, data storage and information exchange of the Distribution Management System (DMS), thanks to the local data processing and control. It may also speed up coordination/optimization of control actions and extend the monitoring and control of distribution network to every corner of medium and low voltage networks when compared to traditional control centre solutions.

The SAU can be exploited for measurement and control devices that are already installed in the field, thus reducing the investment for automation upgrade.

Limitations

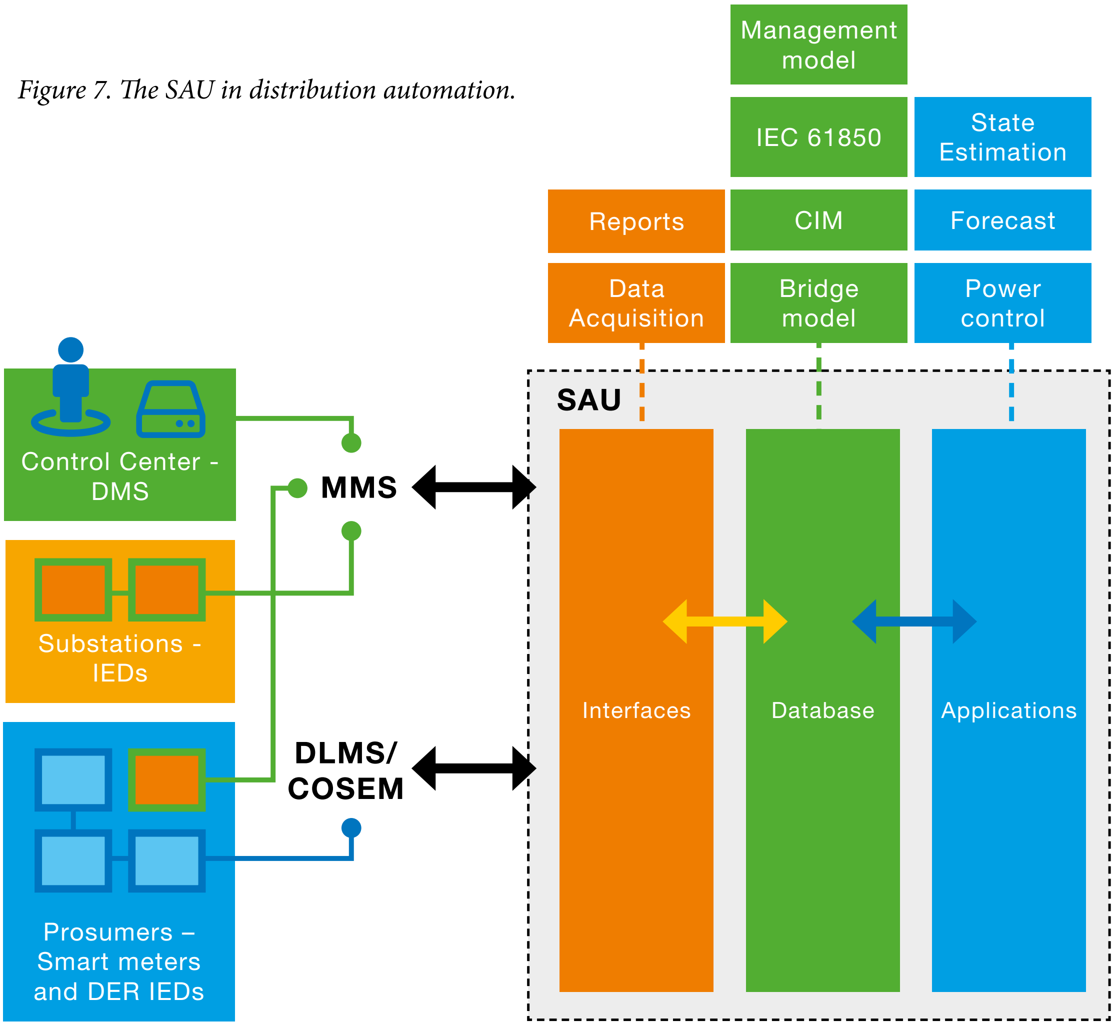
The hardware and software requirements are dependent on the size of the grid. Algorithms of state estimation, and similarly optimal power flow algorithms, may perform differently with networks of 10 or 100 nodes.

The communication requirements with remote units and customer smart meters have to be specified with regards to the requirements of the power control and fault location algorithms.

More information

D3.2 Architecture design and implementation and Annexes

Figure 7. The SAU in distribution automation.



Database (CIM/61850)

The database component of the SAU is the core of the data storage related to the field measurements, network models, business models and SAU algorithms execution. The same database is used to exchange information among algorithms and interfaces implemented in the SAU and used for the state estimation/forecast, for the control and monitoring of the grid connected to the SAU.

The two most important schemas of the database are the Measures and Commands and the Network Models, designed to be compliant with the main standards of the automation area: the IEC 61850 and the CIM.

The **Measure & Control** schema has been defined starting from IEC 61850 data model. The model, structured in physical device, logical device, logical node, data object and data attribute, has been expanded with a set of entities used to collect real time and historical data retrieved from the field and with a set of information to parameterize the communications interface to any other physical device (such as IP addresses, TCP ports, users and passwords, etc.). A group of tables has been defined specifically to model forecast profiles.

The **Network Model** schema has been designed starting from the Common Information Model (CIM). It contains a set of table per each of the most relevant CIM classes. For example the 'ConductingEquipment' table is used to model the parts of the AC power system that are designed to carry current or that are conductively connected through terminals.

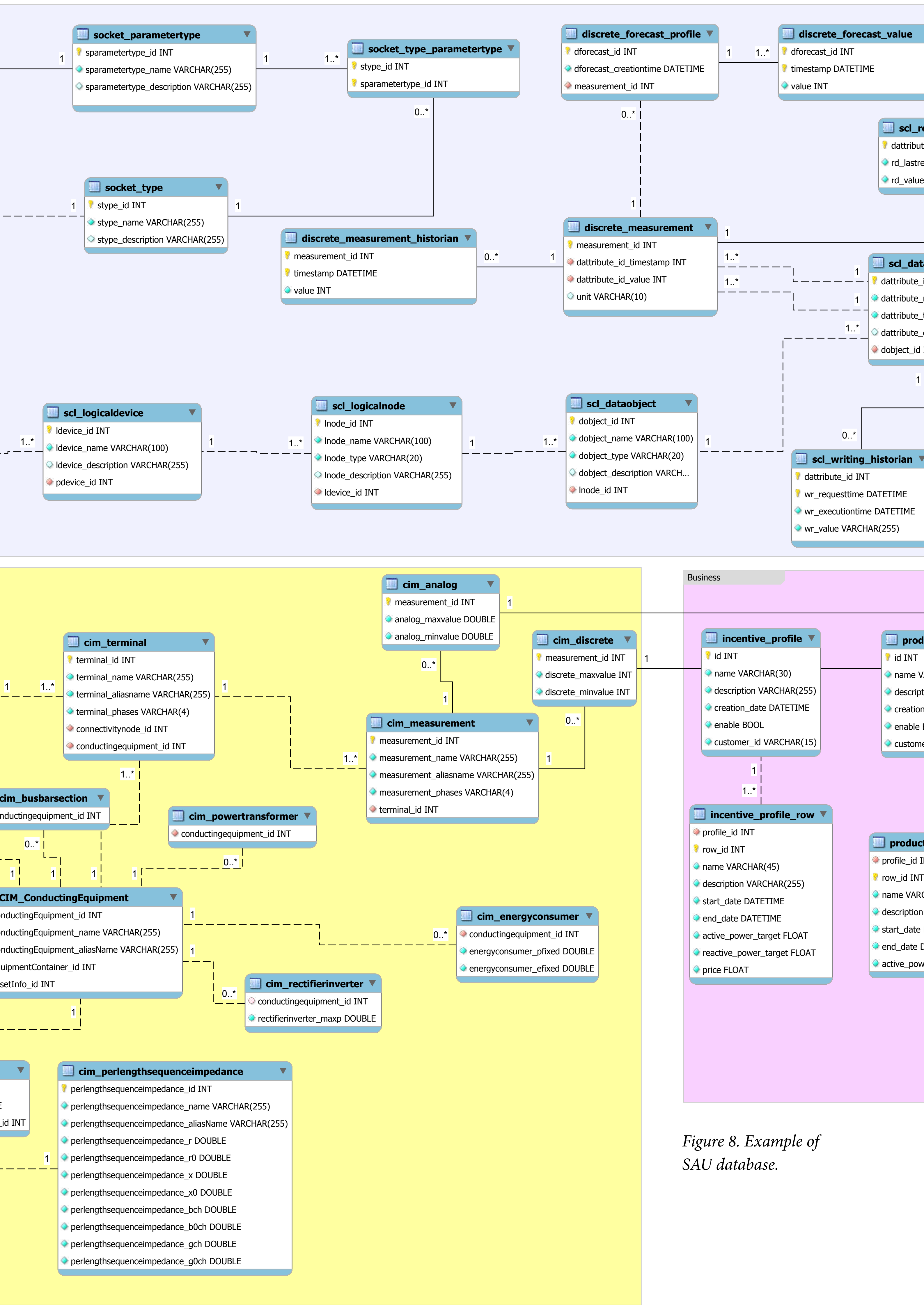


Figure 8. Example of SAU database.

SAU applications: Real time monitoring and control

The decentralized applications are executed in the SAU device. The Real time monitoring application collects data from IEDs in the monitoring and control zone of SAU, stores the data in a local database for further use and for reporting of data, events and alarms to higher layers of distribution automation architecture.

The load and production forecasting utilizing real time monitoring and weather data, provides a short-term view of loading and production condition for state estimation. State estimation computes the grid quantities based on monitoring and forecasted data and grid model.

IDE4L has delivered feasible and proven technical solutions for real time congestion management in medium and low voltage grids. It is realized by primary and secondary control schemes. Primary control like voltage control of tap changer is based on local measurements and may operate extremely fast, but it is lacking information about the complete system. The objective of secondary control is to coordinate primary controllers (including DER controls like load shedding, production curtailment or utilization of energy storage) in the network area to minimize operational costs within technical constraints. The secondary controller is located in SAU.

Benefits

The distribution of applications to primary and secondary SAUs allows utilization of real time data from a complete grid. This will enhance distribution grid observability and controllability compared to existing centralized systems. Scalability of applications is also enhanced because single application is responsible for a rather small grid area and therefore the computation performance of algorithms is not a limiting factor. Applications may also be re-used in all layers: DMS, primary SAU and secondary SAU. The modular structure of SAU allows replacing applications when needed because they are completely independent of the implementation of SAU interfaces.

Real time monitoring is a basis for the rest of applications and it extends real time monitoring to the complete grid without overloading centralized SCADA/DMS systems. It does not need to have IEDs in all grid nodes because state estimation is able to provide accurate enough data when real time measurements are correctly selected and reading frequency and data resolution are high enough. State estimation is also enhancing the accuracy of monitoring by correcting erroneous and missing data.

The aim of the secondary controller is to enhance the hosting capacity of distribution grid for DERs. Case studies have shown that the hosting capacity for distributed generation connected into a weak medium voltage grid may increase three times compared to a passive network solution and more than two times compared to a primary control scheme.

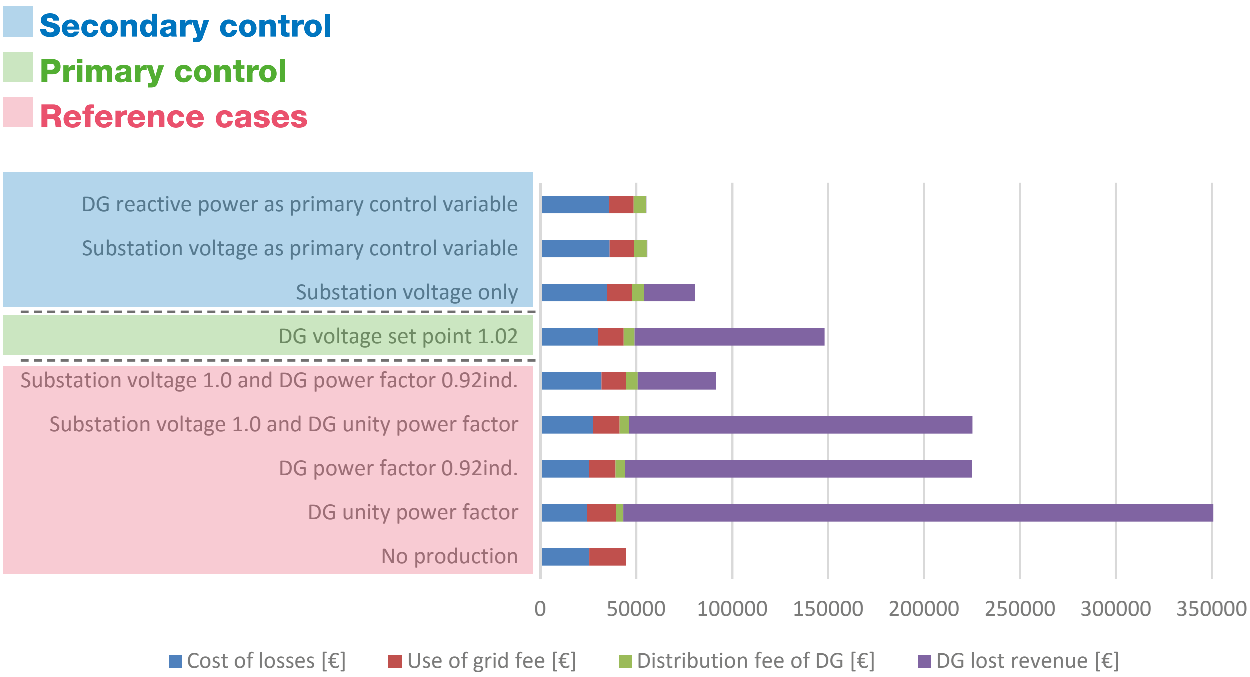


Figure 9. Costs comparison of congestion management in weak medium voltage grid [*].

Limitations

The proposed solution will not be implemented as a standard or an alternative solution to passive network reinforcement unless grid regulation allows DSOs to include congestion management investments as part of grid assets or service quality which define how much profit the DSO may make. The value of congestion management from the grid regulation perspective should be somehow comparable to passive network reinforcement, or otherwise profit maximizing DSOs will always invest in passive solutions. Similarly, the increased operational cost of congestion management compared to passive solution should not penalize DSOs in grid regulation if the lifecycle costs of congestion management are cheaper than the total costs of the passive solution.

More information

D5.1 State estimation algorithm

D5.2/3 Congestion Management in Distribution Networks

D2.3 Simulated benefits of active distribution network concept and applications

[*] A. Kulmala, S. Repo, P. Järventausta, Using statistical distribution network planning for voltage control method selection, IET conference on Renewable Power Generation, UK, September, 2011.

DMS applications: Tertiary controller of congestion management

One major result of IDE4L is the improved network management through the use of control system designed to operate with high penetration of DER and capable of using market based flexibility services. Tertiary control of congestion management is located in the control centre (DMS) and its main tasks are to verify the state of the medium voltage network, set the topology of the entire network, coordinate secondary controllers and order flexibility services from

Aggregator to minimize operational costs within a given voltage range and component ratings. The tertiary control will evaluate the current and future states of the network by using the data series provided by the state estimator/forecaster. Day-ahead rescheduling of controllable loads (demand response), production units and storage devices by technical aggregator may be realized by utilizing smart metering infrastructure, home and building automation systems or micro-grid management system.

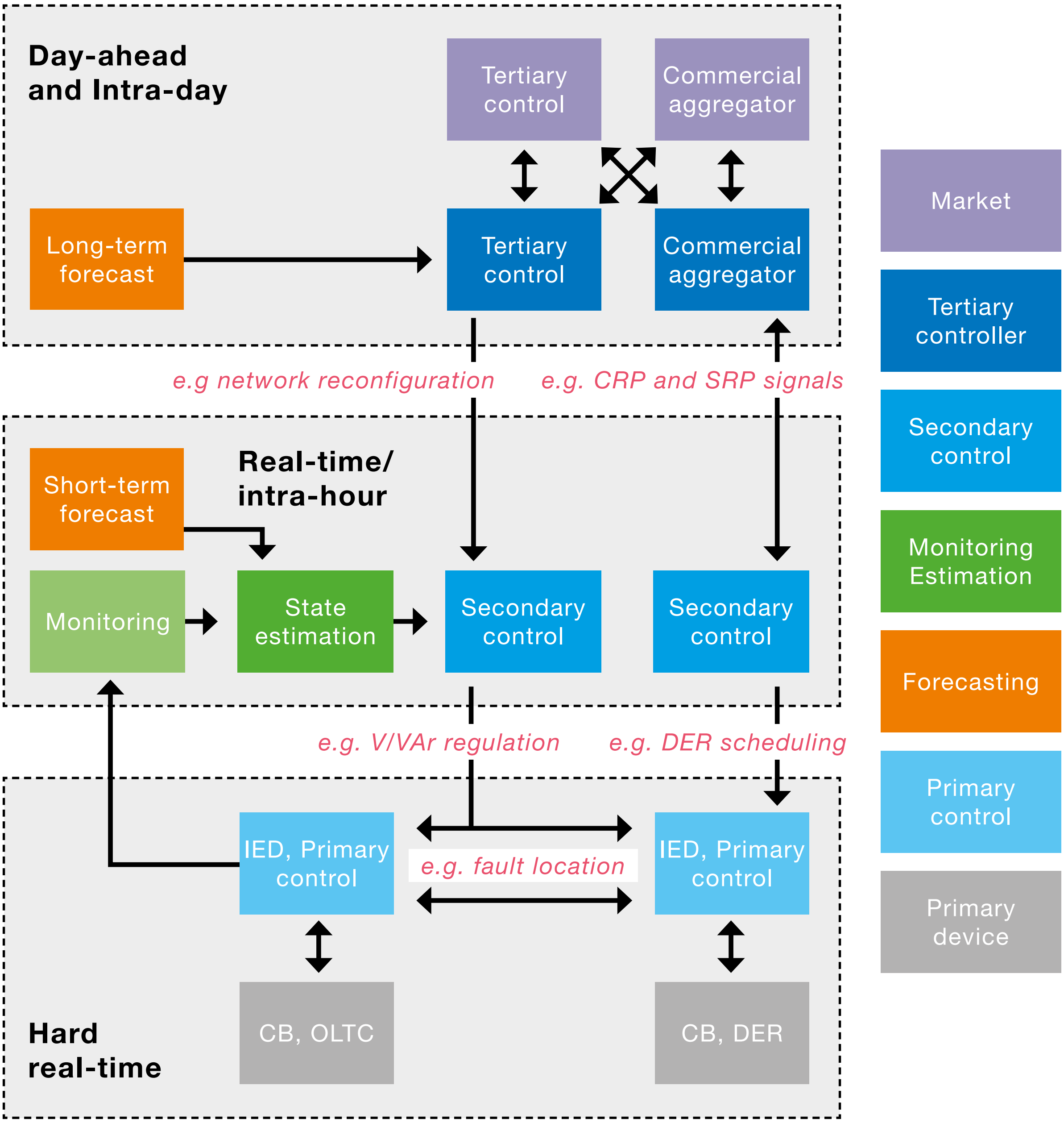


Figure 10. Interactions of hierarchical and distributed congestion management.

Benefits

Coordination of controllers provides significant enhancement for distribution network hosting capacity compared to passive network and primary control and operates in different time frames. Passive approaches can lead to high connection cost of DERs.

Congestion management scheme developed in the IDE4L project will allow the DSO to manage congestion and control voltage at minimum costs (reduced losses, production curtailment and outage times) by allowing a higher penetration of distributed generation with less network investments. Moreover, using system flexibility services for voltage control and congestion management could further enhance the benefits for the DSOs.

Limitations

New regulatory frameworks should include mechanisms that both allow DSOs to procure system flexibility services and to recover their cost. European Network Codes, such as Demand Connection, Operational Security and Electricity Balancing should not hinder the use of system flexibility services at distribution level.

More information

D5.2/3 Congestion Management in Distribution Networks

D5.4 Report on congestion management in distribution networks with day-ahead dynamic grid tariffs

M. Alonso, H.Amarís, B. Rojas, D. Della Giustina, A. Dedè, Z. Al-Jassim, Optimal network reconfiguration for congestion management optimization in active distribution networks, International Conference on Renewable Energies and Power Quality – ICREPQ, 2016.

PMU Applications

The increase of renewable generation sources in distribution grids creates more interactions between TSOs and DSOs. These interactions need to be monitored with measurement-based applications, and analyzed with models of the joint transmission and distribution system model.

The use of dynamic measurements (time series) from PMUs can be applied systematically to extract key information to be used in DMS functions and also to be sent to TSOs to be used in their operational functions. One crucial piece of information, which can be of immediate interest to exchange between DSOs and TSOs, is the equivalents of distribution network models. Using time-series from PMUs, equivalent models can be computed in near-real time which helps in understanding the strength and state of the distribution grid and consider the impact of these changes at TSO level.

More information

D6.2 Distribution Network Dynamics Monitoring, Control, and Protection Solutions including their Interface to TSOs

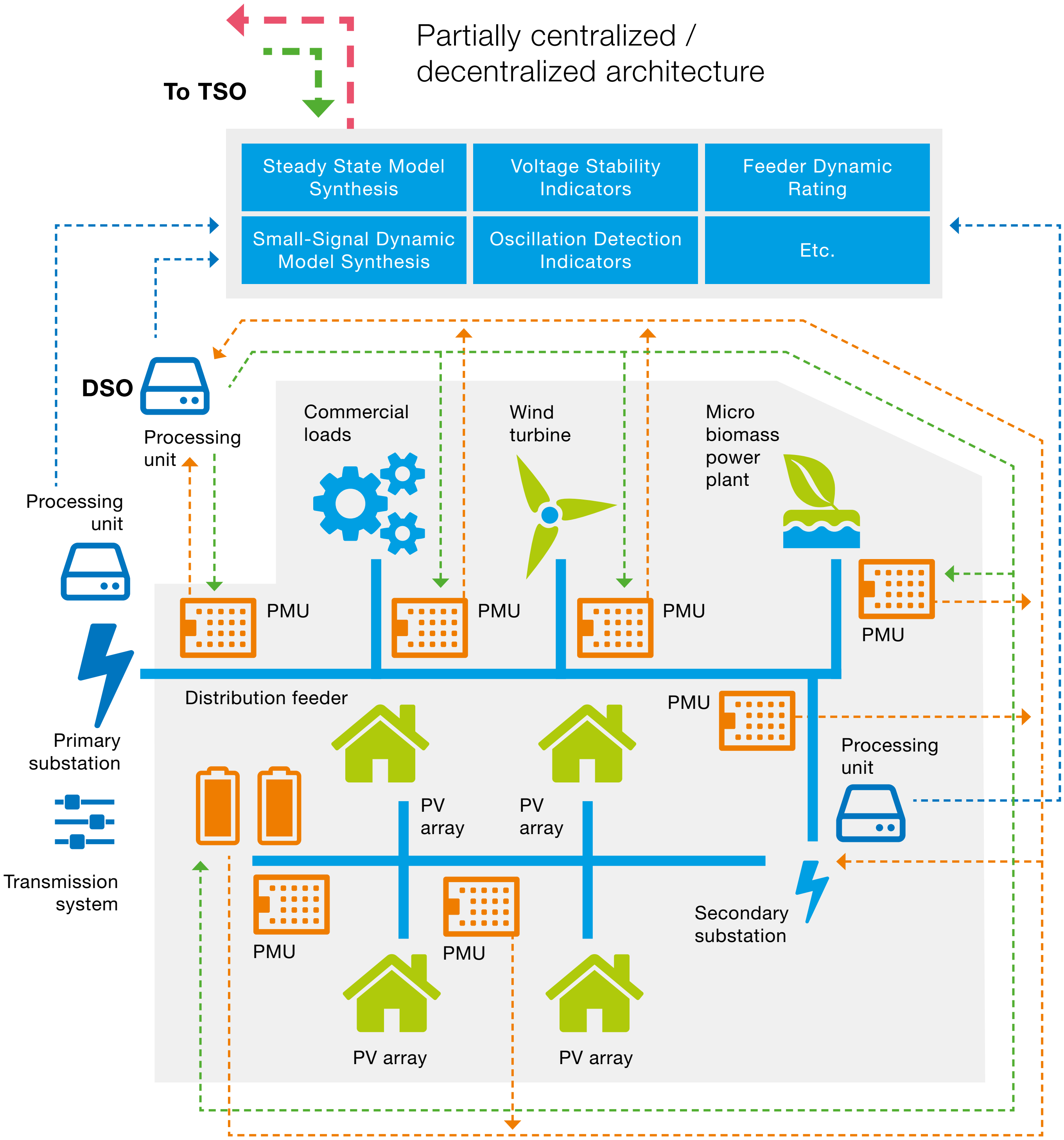


Figure 11. PMUs in distribution domain.

Commercial aggregator interactions

The aggregator interacts with other modules in two different time scales:
day-ahead and real time:

- In the day-ahead time scale, the Commercial Aggregator interacts with the wholesale energy market to use demand and price-related data as input for its Optimal Planning Tool and trades SRP and CRP products in flexibility markets accordingly. Furthermore, the commercial aggregator provides the DER controls of its customers' portfolio with the SRP incentives needed by their automation systems (Energy Management Systems) to comply with the SRP product specifications.

- In the real time scale, the commercial aggregator receives CRP activation requests from DSO (the Market Agent of the Tertiary Control) or any other qualified third party and sends CRP control set-points to the DER controls of the customers.

Benefits

Day-ahead and real time optimization and adjustments are incremental. The benefits of integrating these time scales according to the operation of commercial aggregator, DSO and TSO are:

- Real time optimisation is employed mainly for adjustments connected to truly unforeseeable occurrences. This reduces the need of real time decisions and operations, which are the most demanding.
- Foreseeable occurrences are anticipated and corrected based on historic knowledge and longer term forecasting through the day-ahead optimisation.
- Finally, the proposed operation merges technical and business knowledge and decisions, while maintaining the interests and competences well separated.

Limitations

DSOs will have to modify the way they operate by becoming more proactive. However, the implementation of technical solutions that permit this way of operation is limited by the lack of technical, economical and regulatory framework in several aspects, such as:

- Rules forbidding RES energy curtailment except for security issues so that the flexibility that these kinds of assets can provide is not utilized. DSOs should be capable of controlling the production, either by themselves or through third entities such as aggregators.
- Little/no incentives for smart grid solutions: DSOs are currently remunerated for reinforcing the network, so there is no immediate need for finding different solutions apart from reinforcements (i.e., smart grid solutions). In this sense, regulation linked to performance is a key element for the evolution of the smart grids.

It is required that regulatory authorities define a clear model which implements roles, rules, incentives and unbundling requirements for DSO and other stakeholders.

More information

D6.1 – Optimal scheduling tools for day-ahead operation and intraday adjustment, Part II: Commercial Aggregator concept

D6.1 Optimal scheduling tools for day-ahead operation and intraday adjustment - Part III: Commercial Aggregator tools and test results

D6.3 Emulation of the aggregator management and its interaction with the TSO-DSO

Demonstrations

Field demonstrators mainly focused on some specific use cases. The reason for this is that together they constitute two very important business cases:

- Congestion management business case, where:
    - a portion of the network is monitored by collecting data from smart meters and IEDs (monitoring use case),
    - its status is determined through a state estimation algorithm (state estimation use case),
    - pseudo-measurements are sent to the state estimator based on a forecast of load and production profiles (load and production forecast use case),
    - in case that a forecast is missing, fixed profiles are used as a back-up input (not a use case),
    - eventually, the network performance is optimized by the secondary (power) controller, issuing set point to IEDs.
- The Fault Location Isolation and Service Restoration, where IEDs are communicating based on a peer-to-peer paradigm in order to clear faults in the network and restore power to as many customers and as quickly as possible.

Examples of field and laboratory demonstrations

The following figures are examples of field and laboratory demonstration results in the form of selected graphs. More detailed and complete results are available in the deliverable of the overall final demonstration report.

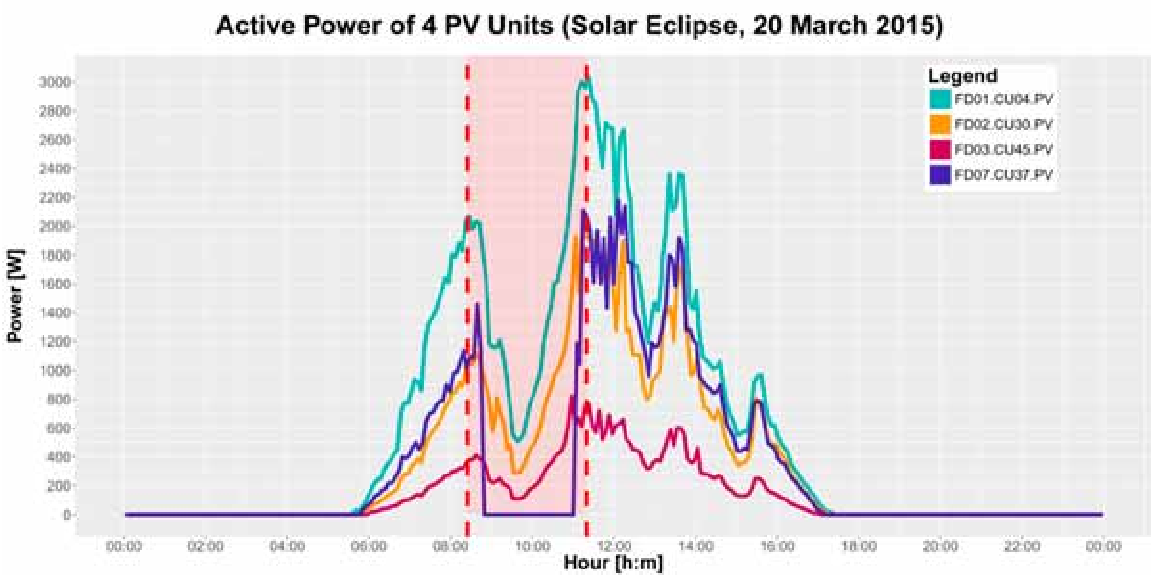


Figure 12. PV output monitoring in low voltage grid in Unareti demonstration site.

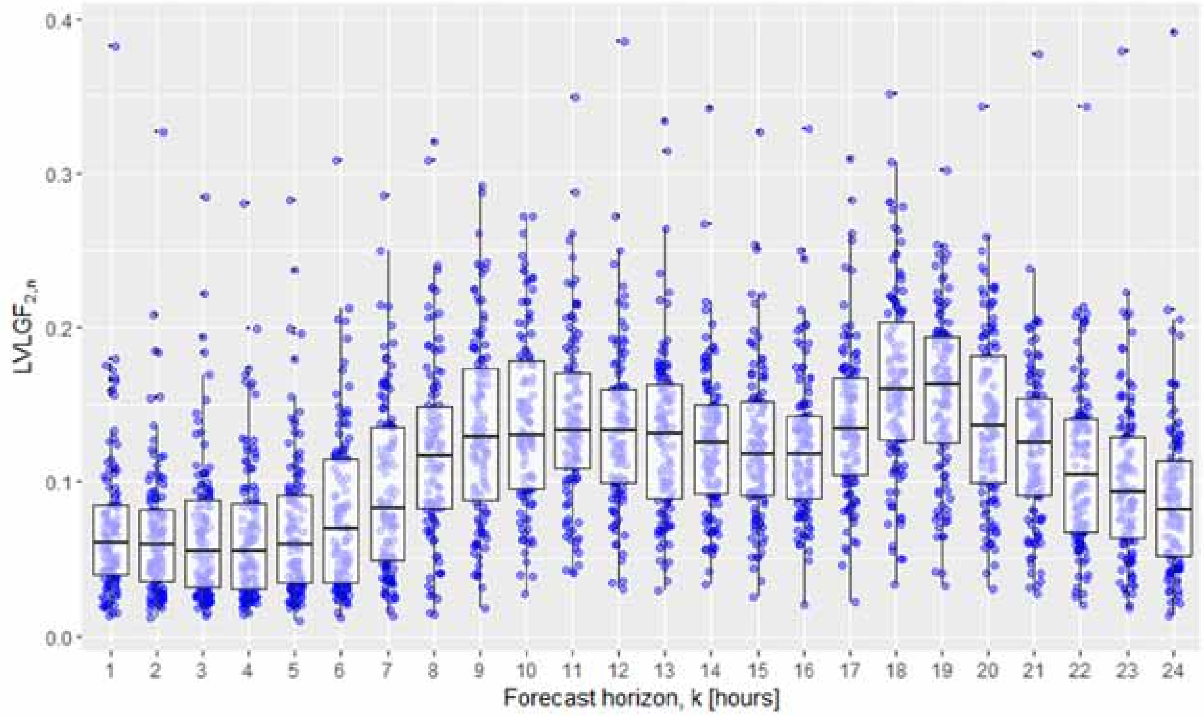


Figure 13. Net load forecasting of prosumers in Ostkraft demonstration. Low Voltage Load and Generation Forecaster (LVLGF).

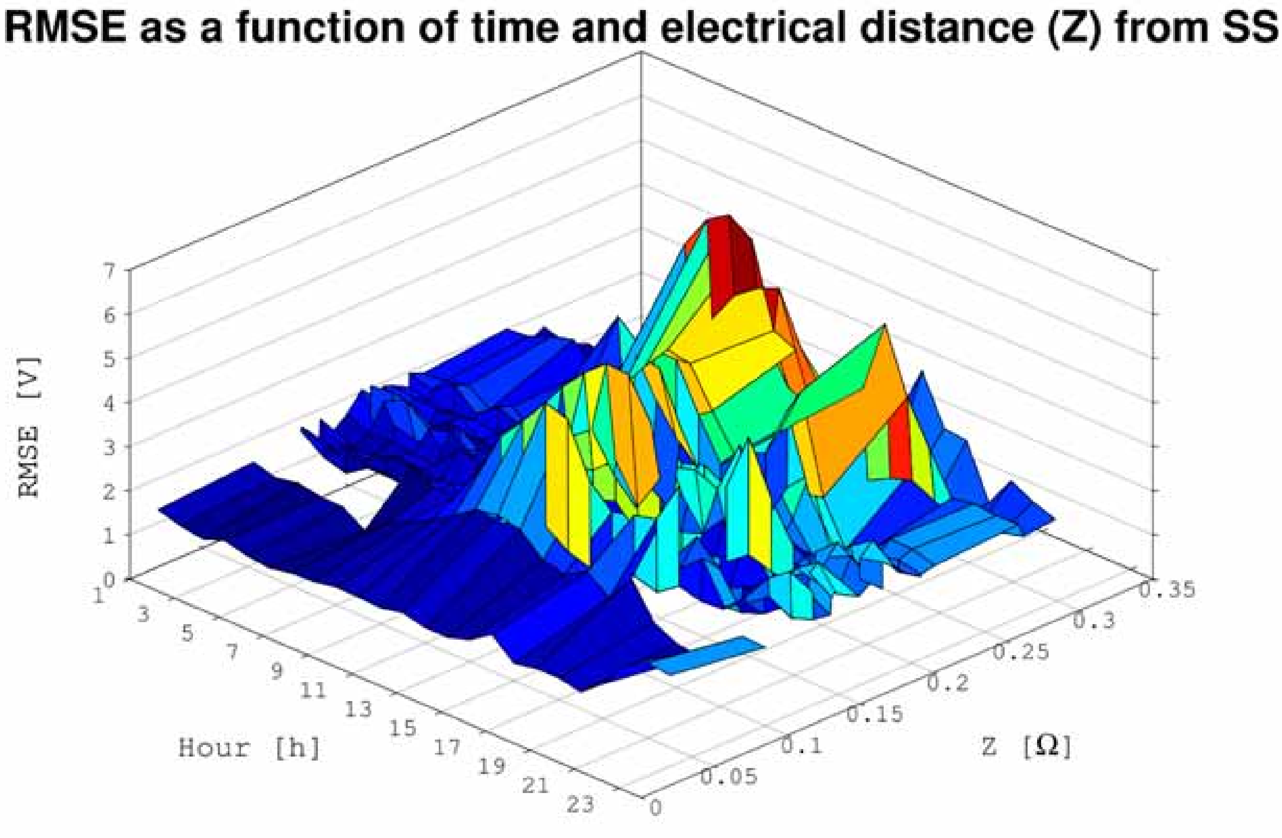


Figure 14. State estimation of low voltage grids in Unareti demonstration.

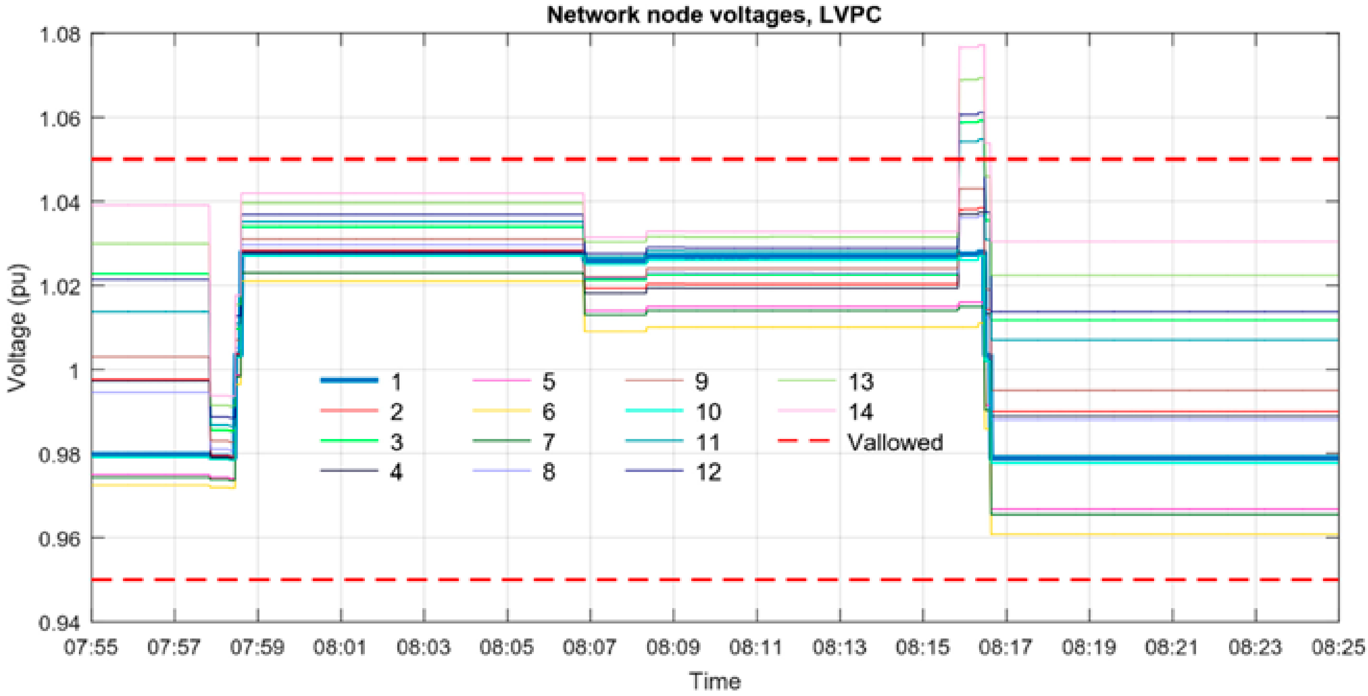


Figure 15. Congestion management of low voltage grids in TUT laboratory demonstration.

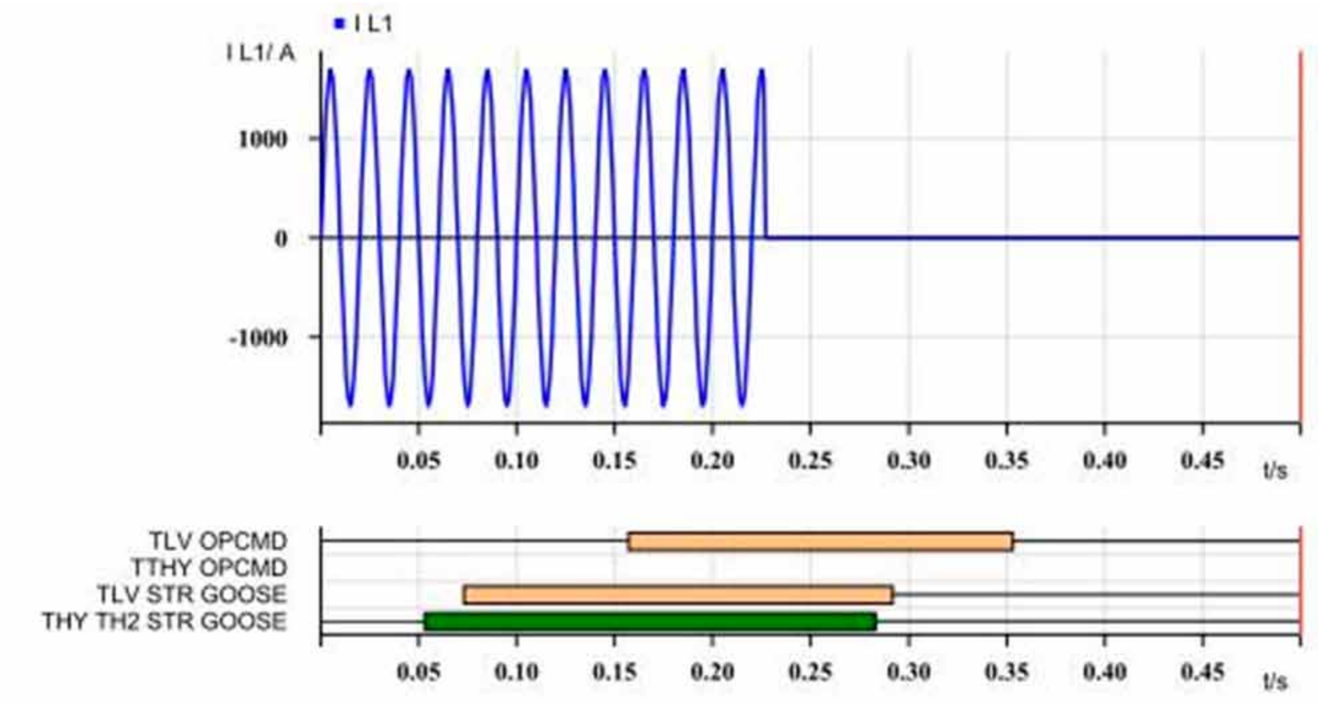


Figure 16. Distributed FLISR. The picture shows GOOSE messages and operation commands that were registered in Unareti demonstration site.

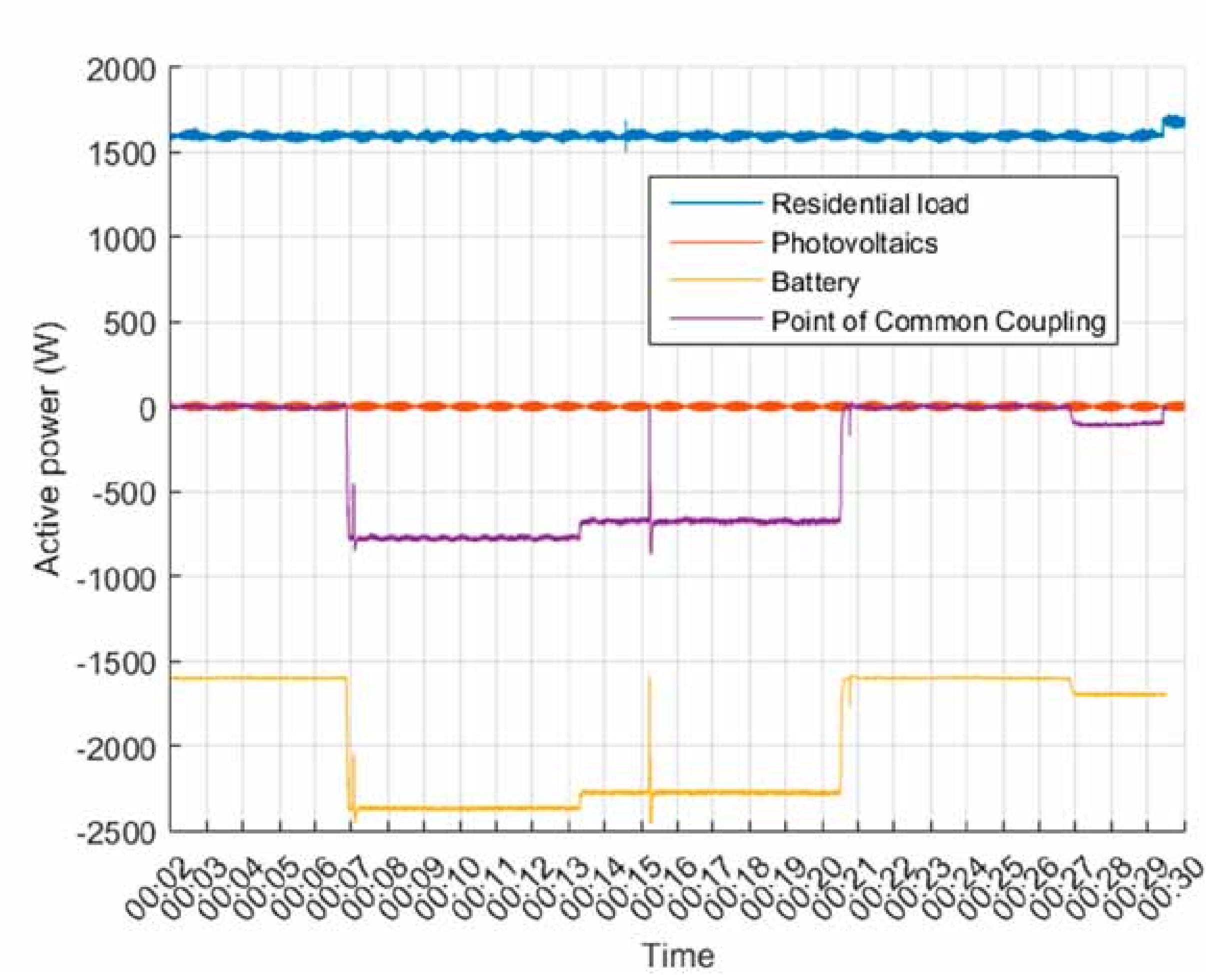


Figure 17. Active power profiles measured at microgrid's devices during flexibility activation (IREC laboratory demonstration).

Laboratory demonstrations

Demonstrations in IDE4L are shared among field and laboratory demonstrators. The latter exploit the Real Time Digital Simulators (RTDSs) to represent realistic testing condition and feed measurement devices and computation units with information of the power systems. The real time testing infrastructure allows you to understand how prompt the architecture in responding to line congestions or over/under voltages is. The monitoring chain, based on virtual and real IEDs connected to RTDS produces the necessary input for the control algorithm whose output is applied to the network simulation.

Benefits

Laboratory demonstrators enrich the field demonstration in the most powerful way, because the grid data and power profiles are exactly as the one in the fields. In addition, interesting scenarios, disturbances and congestions may be created in order to test the complete automation system and algorithms for power control and monitoring.

The RTDS laboratory creates an integration laboratory where individual developments are integrated and proved before field demonstrations. The aim of the simulations is to test interoperability of distribution automation and functionalities. This significantly reduces the time needed for setting up field demonstrations and provides necessary references for the results of field demonstrations. The integration laboratory tests have been essential to the development of interfaces and debugging of the algorithms to be deployed in the field. Without laboratory simulation in hardware and software-in-the-loop set up, it is not thinkable to thoroughly test devices, algorithms, applications and systems as was done in IDE4L.

Limitations

Virtual IEDs, based on standard computers and database and interface software, may work together or as alternatives to commercial IEDs to furnish SAUs with network information and to apply control actions on simulation environments in real time. The only components needed to apply the same approach to the field are sensors and transducers. In this way, advanced smart grid functionalities become more accessible for DSOs, and the same approach could be extended migrating the functionalities of the virtual IEDs to cloud services.

More information

D7.2 Overall Final Demonstration Report

Conclusions and roadmap

Conclusions

Based on three successful field and six laboratory demonstrations we may conclude that the proposed concepts, automation architecture and functionalities work as expected. The following paragraphs highlight the general conclusions of IDE4L project demonstrations.

Basis for distributed grid management and interaction of business players

The IDE4L project has successfully designed, implemented and demonstrated concepts of active network management, hierarchical and distributed automation architecture and commercial aggregator to provide flexibility services for grid management. Implementations of concepts have been validated by successful demonstrations in integration laboratories and field.

Efficient utilization of grid assets

The IDE4L concepts and technical solutions extend the monitoring and control of the distribution grid to all voltage levels, increase the distribution grid hosting capacity for RESs and DERs, and enhance the reliability of power supply. The improvement of the quality of supply and the management of network outages are based on distributed FLISR, which significantly reduces the number of customers experiencing an outage and speed up supply restoration to other customers compared to traditional manual or partly automated solutions. Both the hosting capacity increment and the quality of supply enhancement will have a positive effect on social acceptance of the network infrastructure and the RESs.

More hosting capacity will help the integration of a larger share of RESs into medium and low voltage distribution grids, thus supporting Europe's 20-20-20 targets. Also, it may enable postponing new network reinforcements. Secondary and tertiary controllers of congestion management are the key components for the increment of distribution grid hosting capacity. The increment depends on the grid itself and the control possibilities of DERs and flexibility services. Planning tools developed in the project are able to estimate the hosting capacity increment in different conditions.

Scalability of automation solution

The hierarchical and distributed automation architecture designed and validated in the IDE4L project is based on existing devices, protocols and interfaces, which will allow DSOs to gradually deploy the new solutions. Furthermore, the same architecture and cores of the automation are suitable for both primary and secondary substations. Monitoring, control and protection functions can be deployed locally in the substations, and can operate in a coordinated manner thanks to the IDE4L architecture. This fine granularity makes the individual local functions light, and the design of the architecture makes their integration highly scalable. Vertical and horizontal integration provides a complete view of the distribution network status. This yields business benefits in the short run, without demanding a total replacement of the existing infrastructure, which would not be feasible.

Data exchange between DSO and aggregator, merging information about DERs (validating flexibility actions) and controlling them (purchasing and activating flexibilities), will further extend ANM capabilities of DSO from distribution network to DERs and flexibility services provided by aggregators.

Replicability of solutions in other EU member states

The three DSOs partners of IDE4L represent urban and rural networks in different parts and countries of Europe. Demonstration grids also include relatively high penetration of RESs connected to low voltage grid. The same IDE4L automation system was implemented in all field demonstration sites. Results prove it effective in the different configurations (functionalities chosen by the DSO) and hardware implementations that were tested. Because the IDE4L solutions work in this variety of conditions, they are expected to be suitable for most of the EU.

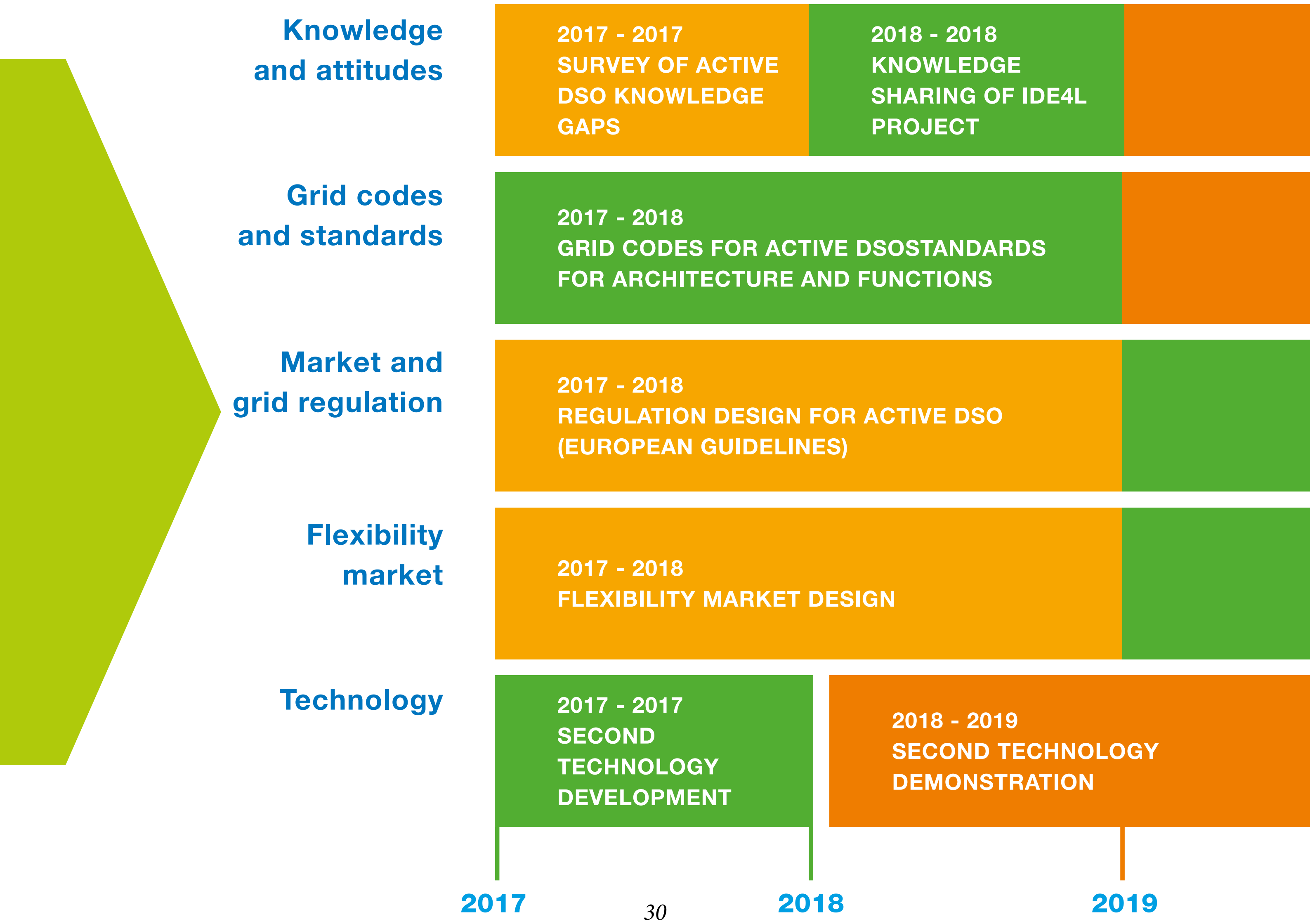
However, network regulation and energy market rules are also different in each country. Whereas not all the developments may currently be deployed everywhere, the IDE4L demonstrations are not tailored to individual DSOs but rather represent general solutions, i.e. replication is already considered in the solutions.

Finally, the IDE4L concepts of active network management, automation and commercial aggregator have been influenced by all project partners and members of the advisory board, spanning all in all 12 EU member countries.

Benefits of proposed solutions

The solutions of IDE4L empower the DSOs to undertake the modernization of distribution grids based on proven technologies. They don't have to devise themselves the right framework that is suitable for initial small scale deployment and that supports future expansions. IDE4L provides this framework, and the means to implement it, down to the individual algorithms and communications. In particular, IDE4L's benefits include:

- The support to realizing the automation and modernization of distribution grids, thanks to a reference, validated concepts, architecture and functionalities
- The availability of a solid base of critical monitoring and control algorithms, readily available and validated to work with the architecture, on top of which more can be built
- Planning tools that include the automation as an asset and a way to evaluate technical and economical benefits of proposed automation solutions in addition to traditional grid reinforcement actions
- The detailed schema to interface the commercial aggregator to validate market based flexibility services and to purchase flexibility services for active network management



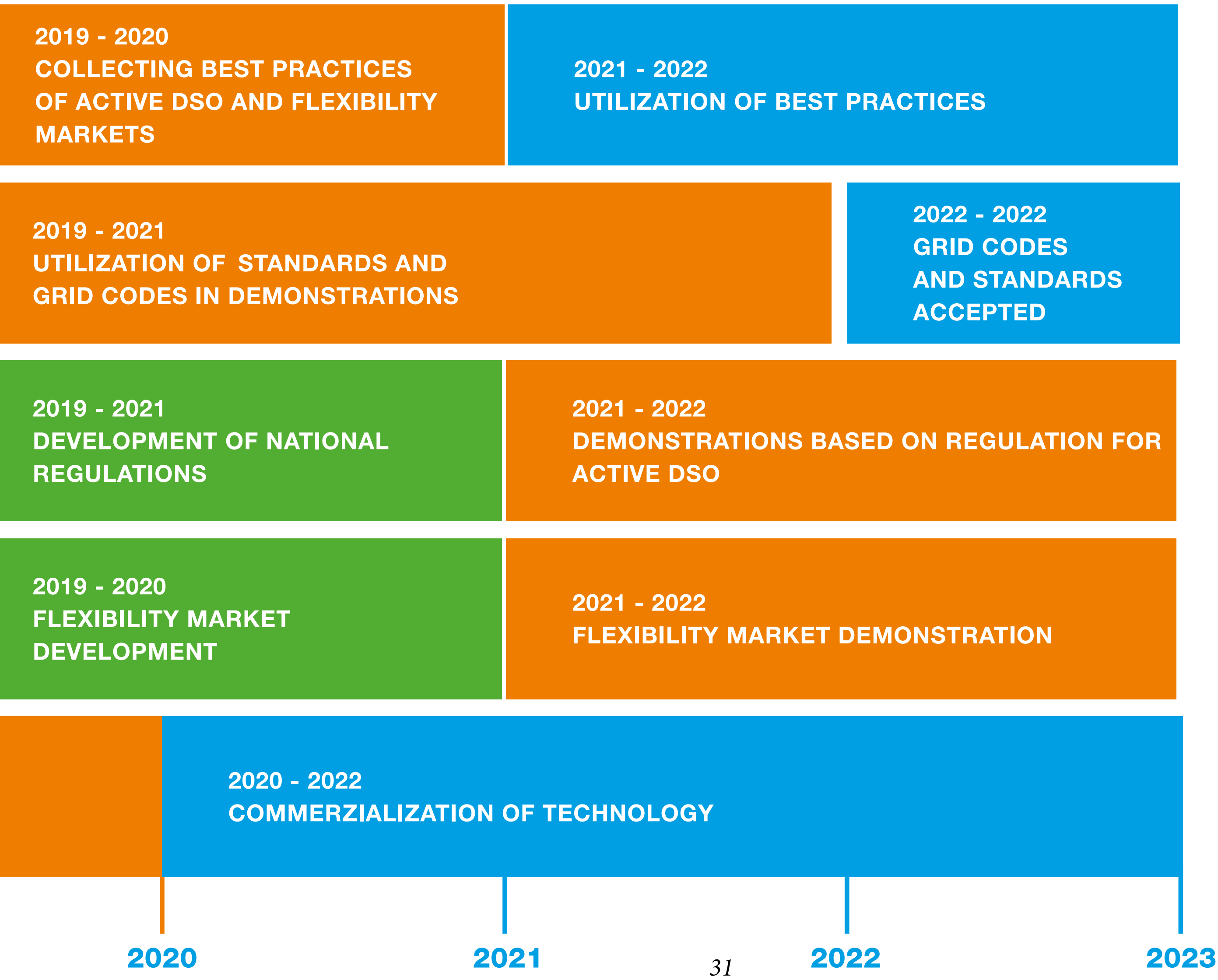
Utilization and development of standards

The IDE4L project has utilized international information model and interface standards (IEC61850, DLMS/COSEM (IEC 62056) and CIM (IEC 61970/61968)) for the design of the automation architecture and the implementation of devices and interfaces (FLISR IED, SAU and PMU) and all demonstrations. Most of the implementations are based on existing standards, only the implementation of distributed FLISR have required utilization of draft standards and have also provided feedback for the standardization working group. Concepts and implementations have been proved to be interoperable and scalable.

The interoperability has been achieved in IDE4L through:

1. Identification of interfaces and information exchange synthesized from the IDE4L use cases of advanced distribution automation concept for active distribution networks. The automation architecture was hence derived and defined based on the SGAM framework.
2. Implementation of interfaces and messaging has been realized based on above standards and off-the-shelf products. Pre-deployment interoperability of the automation system has been validated with hardware- and software-in-the-loop simulations and integration laboratory tests. Different installations of real time simulator RTDS, grid and DER emulators, real and

Figure 18. Roadmap to exploit IDE4L outcomes.



emulated IEDs, prototype implementations of the IDE4L SAU have been used for the purpose. The same testing set ups, augmented to integrate full IDE4L functionalities, have been used to investigate scenarios which cannot be realize in the demonstrations.

The applications of active network management and the implementations of the IDE4L automation system have been demonstrated in three demonstration sites in Denmark (Ostkraft), Italy (Unareti) and Spain (Unión Fenosa Distribución). The automation system in the field demonstrations has been exactly the same as the one validated in the interoperability testing.

Roadmap

The roadmap to exploit IDE4L project outcomes has been divided into five viewpoints named knowledge and attitudes, grid codes and standards, market and grid regulation, flexibility market, and technology. Figure 18 represents how these viewpoints have been scheduled for design, development, demonstration and commercialization phases.

The IDE4L project has a strong focus on technology development and therefore this aspect is probably the most advanced one of the selected viewpoints. However, the experiences collected from demonstrations should be utilized to further improve and extend the technology and therefore the second technology development and demonstration phases are required before commercializing the developed technology. Also the design and development of other viewpoints are also required before a market for all technologies developed in IDE4L project really exists.

Flexibility market for flexibility services, which are validated and purchased by DSOs, does not exists yet anywhere in Europe. Therefore, the flexibility market has to be designed first in EU member countries and harmonized on the European level, which might in practice take much more time than the scheduled two years. In addition to market design common agreement on transactions and contracts are needed to really create a well-functioning flexibility market, which should be followed by a demonstration phase of several commercial aggregators operating at DSO domain. The most important issue is to create continuity for profitable business and trust between market players, as otherwise the flexibility market will not have enough players.

Very important aspect for the success of active network management in distribution grids is the modification of grid regulation to allow efficient utilization of DERs for grid management and to enable existence of flexibility market for DSO use. Otherwise DSOs continue developing their grids as passive infrastructure. The design, development and demonstration of regulation goes hand in hand with the schedule of flexibility market.

Modification of grid codes and standards is a long process. Therefore, the objective of grid code and standard development should also focus on the future requirements of active network management in addition to the urgent needs of existing systems. The IDE4L project has utilized SGAM for automation architecture development and also provided the description of use cases to be used in the standardization work. Active participation of research and demonstration projects is required to understand future needs for the development of grid codes and standards, and to create a European vision of future active distribution grid.

Probably the most challenging aspect of the viewpoints is the knowledge and attitude. The research and development persons of DSOs are very enthusiastic to develop and demonstrate new solutions, but the challenge is to implement the new ideas as a standard practice in a DSO. For this effort it is proposed that more information about real knowledge gaps in business and engineering tasks while DSOs are making investment decisions needs to be collected. In addition to this, sharing IDE4L outcomes and collecting the best practices from other demonstration projects is needed before utilizing new ideas as the best practice in a DSO.

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