Smart TSO-DSO interaction schemes, market architectures and ICT Solutions for the integration of ancillary services from demand side management and distributed generation

Final project exploitation plan

D7.6

Authors:
D. Bernardo (EUI), C. Canestrini (EUI), G. Migliavacca (RSE), L. Ortolano (TERNA), M. Palleschi (TERNA), H. Madsen (DTU), M. Pardo (ENDESA), S. Horsmanheimo (VTT), R. Ebrahimy (DTU), E. Estrade (Vodafone), H. Gerard (Vito), G. d. Croce (SELTA), M. Marroquin (ONE), M. Erba (Siemens), S. H. Sørensen (Energinet), C. A. Andersen (Eurisco)

Distribution Level	Public
Responsible Partner	Daniela Bernardo - EUI
Checked by WP leader **Daniela Bernardo**	Date: 18/06/2019
Approved by Project Coordinator **Gianluigi Migliavacca**	Date: 21/06/2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691405

Issue Record

Planned delivery date	18th June 2019
Actual date of delivery	21th June 2019
Status and version	V1.0

Version	Date	Author(s)	Notes
1.0	18.06.2019		

About SmartNet

The project SmartNet (http://smartnet-project.eu) aims at providing architectures for optimized interaction between TSOs and DSOs in managing the exchange of information for monitoring, acquiring and operating ancillary services (frequency control, frequency restoration, congestion management and voltage regulation) both at local and national level, taking into account the European context. Local needs for ancillary services in distribution systems should be able to co-exist with system needs for balancing and congestion management. Resources located in distribution systems, like demand side management and distributed generation, are supposed to participate to the provision of ancillary services both locally and for the entire power system in the context of competitive ancillary services markets.

Within SmartNet, answers are sought for to the following questions:

- Which ancillary services could be provided from distribution grid level to the whole power system?
- How should the coordination between TSOs and DSOs be organized to optimize the processes of procurement and activation of flexibility by system operators?
- How should the architectures of the real time markets (in particular the markets for frequency restoration and congestion management) be consequently revised?
- What information has to be exchanged between system operators and how should the communication (ICT) be organized to guarantee observability and control of distributed generation, flexible demand and storage systems?

The objective is to develop an ad hoc simulation platform able to model physical network, market and ICT in order to analyse three national cases (Italy, Denmark, Spain). Different TSO-DSO coordination schemes are compared with reference to three selected national cases (Italian, Danish, Spanish).

The simulation platform is then scaled up to a full replica lab, where the performance of real controller devices is tested.

In addition, three physical pilots are developed for the same national cases testing specific technological solutions regarding:

- monitoring of generators in distribution networks while enabling them to participate to frequency and voltage regulation,
- capability of flexible demand to provide ancillary services for the system (thermal inertia of indoor swimming pools, distributed storage of base stations for telecommunication).

Partners

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Executive Summary

The big novelty of the SmartNet Project approach is related to the fact that the domain under investigation spans over both transmission and distribution networks, which have both to be simulated in great detail in order to simulate the outcome of nodal tertiary markets and the complexity of the management of real T&D network in order to purchase ancillary services from distributed resources.

The resulting implementation of the three national scenarios into the SmartNet simulation platform is characterized by an impressive number of data feeding a huge relational database, which constitutes the linkage between the three layers of the simulation platform.

The additional features of the new platform realized for the SmartNet project could make it suitable to be both reused as such or improved/customized for further scenario simulations aiming at investigating balancing and congestion management market architectures in a regulatory framework allowing subject connected to distribution grids to bid in such market. TSOs and DSOs could be interested to perform studies both on isolated countries or in the framework of the implementation of the ENTSO-E platforms for trans-national coupling of ancillary services markets. Regulators wanting to set up new modalities for services provision and enlarge the bidding subjects to distribution grids could profitably make use of the SmartNet simulation platform and (in case pertinent) of the three national scenarios at 2030 in order to perform impact analysis.

Also after the end of the project, the SmartNet platform could still be available in order to enable testing of new technically optimized and cost-effective modalities to employ local resources for the support of balancing and congestion management.

In addition to the simulation platform, the three physical pilots realized within the SmartNet project constitute a very valuable asset at the disposal for further work and assessments, also after the end of the project. And in particular, the legacy of what obtained in these three Pilots will be of great impoirtantce for the National Regulators.

Finally, the ICT platform studied in the SmartNet project promises to be an interesting subject of further investigation for analysing the requirements of future TSO-DSO platforms for the purchase of ancillary services from distribution networks.

Introduction

In the last years, the quickly increasing amount of variable RES is requesting the availability of an ever growing amount of reserve in order to operate the system in security and, at the same time, is shifting the focus of the investigations from energy markets towards real time services markets.

In this context, the aim of the SmartNet has been assessing in simulation the techno-economic performance of different TSO-DSO coordination schemes for the acquisition in real time of ancillary services (in particular: system balancing and congestion resolution) from distributed resources (generation and load) connected to distribution grids.

After more than three years of research, simulation and testing solutions on three pilot projects, the progress made by the project open interesting scenarios and opportunities for further exploitation after the end of the project itself, which will be analysed in the current document.

1 Macro product 1: SmartNet simulation platform and scenarios

1.1 Pre-existing industrial situation and drivers to implementation

Simulation platforms to simulate energy markets are quite common and a lot of studies have been already carried out by a manifold of subjects (spanning from the European Commission to several European and national stakeholders, universities and research centres) in order to assess market architectures able to perform an optimal allocation of the resources. Some of such models also implement a zonal market structure and are, thus, able to account for the constrained capacity of some interconnecting lines, so as to highlight some important bottlenecks of the transmission network and provide better price signals to the market participants. More rarely such models push the level of details to the single nodes of the transmission network (nodal energy markets are currently implemented only in the US, nowhere in Europe). More recently, a few simulators were built in order to investigate the advantages of market coupling among the European energy markets, considering transit constraints between countries and, maybe, also implementing a zonal structure for some "bigger" country where the national regulation foresees such kind of architecture. In any case, implementation needed to analyse constraints in distribution networks, typically modelled as "bus-bar" regions in virtue of the fit-and-forget philosophy, for which DSOs ware typically prone to oversize their systems in order to prevent congestion.

In the last years, the quickly increasing amount of variable RES is requesting the availability of an ever growing amount of reserve in order to operate the system in security and, at the same time, is shifting the focus of the investigations from energy markets towards real time services markets. For this reason, some simulators are currently being built in order to study how to improve allocation efficiency in real time services markets and, in particular, balancing markets. However, few of these markets are nodal in Europe (the Italian balancing market being one of the few exceptions). Additionally, the fact that the purchase of services was so far limited to resources (typically big thermal generators) characterized by high rated power and always connected to transmission networks made it so far useless to enlarge the simulation domain up to embrace the structure and the topological details of distribution grids.

1.2 Progress realized by SmartNet over status quo

The SmartNet project aims at assessing in simulation the techno-economic performance of different TSO-DSO coordination schemes for the acquisition in real time of ancillary services (in particular: system balancing and congestion resolution) from distributed resources (generation and load) connected to distribution grids. Four different TSO-DSO coordination schemes have been fully simulated in order to perform a cost-benefit analysis and understand which is the most efficient one. This for three national

cases (Italy, Denmark and Spain) on very detailed scenarios at the 2030 target year. The big novelty of this approach is related to the fact that the domain under investigation spans over both transmission and distribution networks, which have both to be simulated in great detail in order to simulate the outcome of nodal tertiary markets and the complexity of the management of real T&D network in order to purchase aFRR service. Whereas system services are traditionally purchased from subject connected to transmission networks, SmartNet puts such subjects in competition with distributed resources connected to distribution grids. Such competition can't overlook transit limitations on both transmission and distribution networks (which are very likely to abandon the fit-and-forget approach in the future). As potential services providers connected to distribution networks are typically small and can bid very limited chunks of power each, they mightn't be admitted to bid singularly in the services market, hence the additional need to simulate typical aggregation and disaggregation processes.

For these reasons, the simulation platform set-up for the SmartNet project is made up of three levels (layers) respectively modelling:

- the allocation mechanism of a nodal tertiary market purchasing mFRR resources to balance the system and solve congestion from resources connected to both transmission and distribution grids while maintaining reasonable conditions on voltage regulation. Potential congestion is considered on both networks (however, network transit constraints in distribution networks are implemented only in some coordination schemes according to their definition).
- the real low level management of the physical network, applies to the bidding resources the set-points implementing the outcome of the tertiary market sessions. This simulation requires details on the structure of the distribution network itself, but also a detailed simulation of the bidding resources, which are classified in eight categories: electric energy storage units (stationary and electric vehicles), distributed generation (variable renewable energy sources, combined heat and power units and conventional generators) and demand response (shiftable and curtailable loads, as well as thermostatically controlled loads).
- The need to interface the resources connected to distribution grids bidding in the tertiary market with the market itself has requested to analyse and model in detail the aggregation and disaggregation process, for which different aggregation modalities were selected in dependency from the characteristics of the aggregated resource.

The resulting implementation of the three national scenarios into the SmartNet simulation platform is characterized by an impressive number of data feeding a huge relational database, which constitutes the linkage between the three layers. As an example, the Italian 2030 scenario includes 655,323 photovoltaic panels, 31 wind farms, 20 large CHP plants, 1,833 run-of-river hydropower plants, 308 conventional fuel-based generators, 13 pumped hydro stations, 212,704 electrical cars, 1,489,193 residential wet appliances (washing machines, dishwashers, tumble dryers), 68,481 residential heat pumps, 33,783

dimmable street-lights, as well as non-controllable loads in all distribution grids and some transmission nodes. In this way, not only the simulation platform, but also the three national scenarios at 2030 constitute an important product of the project that could be re-utilized for further future studies.

Finally, it has to be noted that some modelling aspects were not implemented as out of scope for the SmartNet investigation. The most important one is the aspect of bidding strategies. All resources bid at their costs (which can include also sophisticated aspects like discomfort costs and opportunity costs, arbitrage between different markets) which could seem a non-realistic modelling decision. However, considering the opportune modelling approach to tackle bidding strategies would have implied to use game theory strategies which are out-of-scope for models of the size of those SmartNet is considering. Additionally, results of the application of game theory models bring to extreme solution highlighting levels in the exercise of market power which are not realistic (regulators would not allow to put in place such bidding behaviours). So, a pert a small check on game theory models made in the framework of the SmartNet deliverable D2.2, this aspect was disregarded. This is also reflected by the aggregation strategy, which is carried out on a nodal basis by different algorithms, one for each kind of resources and doesn't account for a possible "portfolio" management of the resources by means of a subject owning a mix of generators, storage and flexible load in one node and aiming to bid them altogether as a virtual power plant.

1.3 Opportunities created by the new platform

The additional features of the new platform realized for the SmartNet project could make it suitable to be both reused as such or improved/customized for further scenario simulations aiming at investigating balancing and congestion management market architectures in a regulatory framework allowing subject connected to distribution grids to bid in such market.

1.4 Potentially interested stakeholders

TSOs and DSOs could be interested to perform studies both on isolated countries or in the framework of the implementation of the ENTSO-E platforms for trans-national coupling of ancillary services markets. For this latter, a SW development would be needed in order to implement trans-national services market coupling.

Regulators wanting to set up new modalities for services provision and enlarge the bidding subjects to distribution grids could profitably make use of the SmartNet simulation platform and (in case pertinent) of the three national scenarios at 2030 in order to perform impact analysis. Such impact analysis could also concern how new rules to manage the tertiary markets could affect its allocation efficiency, impact on social welfare and the like.

In general, all the scientific community can take profit of the modelling hypotheses of the SmartNet simulation platform, documented in detail into the modelling deliverables (D2.1 and D2.2) and in the implementation deliverable D4.1 (contractually classified as confidential but nonetheless made partly public and downloadable, as all the other deliverables, from the SmartNet web site) and the scenario deliverable D4.2. Additionally, the cost-benefit analysis approach implemented by the SmartNet project and described in detail in the deliverable D4.3 could be replicated in any other case when DSO-TSO coordination schemes have to be compared.

1.5 Scenario for future exploitations

Also after the end of the project, the SmartNet platform could still be available in order to enable testing of new technically optimized and cost-effective modalities to employ local resources for the support of balancing and congestion management. The SmartNet simulation platform could be put available, behind commercial agreement, to all those actors, most notably the DSOs and the TSOs and/or possible subjects deputed to manage future ancillary services markets both at local and at system level, that will be interested to a further exploitation. TSOs, DSOs and other actors (like Regulators for impact assessment of new regulations) could be interested in an application for analysing the operation in their own markets.

1.6 Barriers to future exploitation and ways to remove them

Contractually speaking, the SmartNet simulation platform tool remains property of those entities which have developed it, each one for the portion of their competence. Some implementation parts could contain optimized code which some beneficiary could not be wanting to distribute to external subjects.

Consequently, two scenarios could be possible in order to allow future exploitation of the SmartNet simulation platform (the final choice being tied to the details of the study to be realized, to the level of potential engagement foreseen by the stakeholder interested to develop further studies and other factors:

- SCENARIO 1 – The simulation platform is adapted by the SmartNet platform developers on the basis of some contractual agreement, then the package is delivered in machine format not allowing to read the source code, so that the external stakeholder can create the scenario and run it in full autonomy (about the scenario, an agreement could also be reached on the SmartNet consortium building and delivering an ad hoc scenario for the studies to be led)
- SCENARIO 2 – The SmartNet platform developers adapt the platform, create the scenario and run the platform on behalf of the interested stakeholder and then deliver the results in form of a study report.

2 Macro product 2: SmartNet Pilot A

2.1 Pre-existing industrial situation and drivers to implementation

In the Italian energy context, in recent years, there has been a rapid spread of the installation of renewable energy power plants, also due to the European policy that aims to encourage the development of new and renewable forms of energy and the fossil fuel replacement. In Italy, the wind power capacity installed by the end of the 2018 is about 10GW and the solar power capacity installed by the same date is about 20GW.

The binding targets set for cutting greenhouse gas emissions and increasing the share of renewable energy and energy efficiency by 2030 and the purpose to reach the complete dismissing of coal plants by 2025 will lead to further increase the renewable capacity.

An important consequence is the growth of embedded generation composed by small-sized renewable plants connected to the distribution network, especially photovoltaic panels and hydro power plants.

The safe, efficient and reliable management of the transmission grid has to face with typical characteristics of this new energy framework; first at all the unpredictable nature of the aleatory energy sources (solar, hydro and wind) increase the need to improve the infrastructure for the monitoring and the control of MV and LV levels. This aspect becomes crucial for the TSO considering that the growing production of renewable connected at MV and LV grid levels often lead to reverse flow power because in case of local oversupply the active power rises from distribution grid to upper grid level.

Furthermore, the possibility to monitor the distribution generation allows to include the embedded generation in the ancillary services. Currently Italian NRA has incentivized pilot project in order to involve aggregations of DG and mixed sites in the RR service. In order to ease the involvement of this types of flexibility sources it is necessary increase the observability and the control of them, also in view of a replace of the contribution of big traditional plants that currently provide grid services with very high performance.

Regarding the observability of the distribution grid, at the moment the control system of Terna receives the electrical measurements at the HV side of the transformer of the substation (net value of load and generation). The Italian NRA's resolution 646/2015/R/eel aimed to incentivize an innovative functionality in order to obtain the observability of power flows and status of the embedded resources in grid characterized by high renewable distributed generation. The resolution entrusted to the DSO the task of develop architecture in order to estimate and provide to Terna real time data representative of the distribution level through aggregations differentiated by source. The project gave useful elements for the understanding of the topic but didn't success in achieving the desired results; in particular the required accuracy has been reached only in the parts of the grid where there were almost the complete

measurement and no adapt solution for the estimation algorithm has been found. The Smartnet project confirmed the need of a high *coverage rate*[1] of direct measurement for the estimation of power generation characterized by high unpredictability (in the specific case, hydro generation); on the other hand, it is clear that, from TSO perspective, the increase of coverage rate itself is a necessary but not sufficient precondition to guarantee an adequate level of observability of the grid. The pilot showed that, with high coverage rate, decent results can be achieved at substation level, but also it is clear that to achieve a wider observability the architecture needs to be enforced with a more advanced and complete estimation algorithm, that can be managed at TSO central level that ensures the coherency of the measures, managing stochastic aspects giving a realistic estimation suitable for operation by combining information from different points of measurement with different levels of aggregation (electrical, regional, weather, etc.), in order to optimize the whole process. As example the Italian pilot project showed that for hydro power plant it is essential to choose the right measurements to represent the whole chain of hydro power plant related to a specific hydraulic flow; this is obviously not related to the electrical topology of the grid and benefits from a centralized wider view.

Regarding the ancillary services here follows a brief introduction of the current situation in Italy. The relevant programmable power plants, i.e. thermic and programmable hydro power units which have nominal power greater or equal than 10 MVA, are required to provide local voltage regulation (called primary voltage regulation). The service is mandatory and non-remunerated. On the other hand, the coordinated voltage regulation is provided only by large power plants equipped with specific devices to participate in the hierarchical control voltage. In particular it is an obligation for traditional plants with a generator with a size of more than 100MW. ARERA resolution 300/2017/r/eel proposes to realize pilot projects about modalities for the remuneration of ancillary services currently non-remunerated as the voltage regulation, in order to collect useful elements on the subject.

The active power dispatching market (MSD – Mercato dei Servizi di Dispacciamento) it's not open to embedded generation. The Authority, within the resolution 300/2017/R/eel, has open to the possibility of access to the market also to non-programmable resources and embedded generation. At the moment only pilot project for the dispatching market (mFRR and RR) to aggregation of non-relevant units and of loads has been opened.

Regarding the current approach adopted by DSOs for the distribution grid operation, among the different DSOs there isn't a standard for the automatic voltage regulation and active power management in real time. In the past years, in the framework of some Italian and European pilot projects, the technology providers experimented decentralized Smart Grid solutions focusing on how DER Active

[1] Coverage rate: for a determined type of generation (hydro, PV, etc.) the coverage rate is number of directly measured power plants against total number of power plant

Control can increase the MV network hosting capacity of renewable energy resources; these projects had both a laboratory test phase and a real field installation and operation.

In brief in the above-mentioned projects the DSO Control System has the following functionalities:

- it communicates with the Substation Control System located in the HV/MV Substation sharing the relevant static data
- it sends and receives information to/from the devices located in the HV/MV and MV/LV Substations via/sharing them with the Substation Control System

The Substation Control System has the following main functionalities:

- Local Supervisory Control & Data Acquisition (SCADA) able to manage the Database representing the Primary Substation and the of the connected MV network
- State Estimation and Voltage Regulation algorithms for local regulation
- Communication with DSO Control Center

The HV/MV Transformer Smart Protection Panels are able to manage the tap changers in order to implement the setpoints calculated by the Voltage Regulation algorithms for local regulation.

Within this actual status, the innovative aspect introduced with the SmartNet pilot project, as better explained in the next paragraphs, is the investigation of the technical feasibility and the evaluation of the advantages of the centralized approach where the embedded generation can participate in market service, coordinated DSO-TSO voltage regulation (DCC EU Regulation puts obligation on DSO toward TSO network in terms of reactive power exchange) and full observability to the TSO.

2.2 Progress realized by SmartNet over status quo

The Italian pilot is a technological project that aims to investigate the feasibility to integrate renewable energy sources in smart grid systems in order to deal with the future challenges mentioned above about the management of a constantly evolving grid.

On a practical level, the objective of this project is to realize, implement in field and test two devices developed by the technological partners of the consortium (Siemens and Selta) to monitor in real time the distribution sources and to use these plants to provide the voltage and the f/P regulation, controlled in a centralized scheme by TSO.

The first device, called HVRS (High Voltage Regulation System) has been installed in HV TSO substation in order to control in a coordinated way the reactive power consumption/production of two hydro power plants connected at subtransmission grid (132kV), that currently don’t participate in the hierarchical control of the voltage.

The device is able to receive by the TSO control center both a reactive power setpoint, defined as a percentage value of the capability calculated at the operating point, and a voltage value target of the busbar expressed in kV. In this second case, the HVRS converts the setpoint in a reactive power command based on the voltage error and split the requirement among the four synchronous generators in such a way that the percentage contribution is the same.

The second device, called MVRS (Medium Voltage Regulation System), has been installed in the DSO (Edyna) control room in order to monitor and control the embedded generation. The main functionalities of the algorithms developed are:

- Aggregation function that allow to exchange with the TSO SCADA the real time data of the active and reactive power at the distribution level with a nodal representation of the equivalents of solar resources, hydro resources and load connected at the HV/MV substation
- The voltage regulation of the HV busbar of the Primary Substation through the distributed generators connected at the transformers
- The power/frequency regulation (aFRR) through the modulation of the active generation of the plants connected at the distribution grid involved in the project
- The estimation algorithm to calculate the estimated generation of some plants should they be unmonitored

From the TSO point of view, this device allows to have the real time data, and in case of unmonitored power plants their estimation, of generation and consumption connected to the distribution grid, every 20 seconds, and to know the availability of the flexibility resources connected to the MV grid on the basis of the aggregated capability of embedded generation calculated by MVRS.

Secondly MVRS is able to receive a voltage setpoint and an active power level from the TSO and to forward to the signal split among the controllable plants, taking into account the constraint of the distribution grid. In fact, the algorithms are developed in order to work in security avoiding violation in the distribution grid, as demonstrated during the tests carried out within the project.

2.3 Opportunities created by the new platform

The pilot has been the first Italian test of the involvement of the embedded generation in the ancillary services controlled by TSO, in terms of coordinated TSO-DSO voltage regulation and aFRR regulation.

It represents the first step to allow the use of the DG in the management of the transmission grid, through a centralized scheme that considers the constraints of the whole grid, including the distribution grid.

To summarize, the functionalities implemented that represent future opportunities are:

- Coordinated voltage regulation in HV grid by small-size generators;

- Activation of active and reactive resource of embedded generation by the TSO in real time, considering the DSO grid constraints.

2.4 Potentially interested stakeholders

The results of the pilot A have clearly an important impact on numerous stakeholders. First at all, it represents the possibility for the European TSOs to technically deepen the possibility to use the embedded generation to provide ancillary services.

Secondly the tests have shown the feasibility to take into account, in real time, the constraints of DSO grid, guaranteeing a safe operation of the grid, with a direct activation of the services by the TSO.

The project is defining attractive business models for the small and medium-size power plant owners and for third parties, as aggregators, because it highlighted the opportunities of new future involvement in new services for the TSO in order to manage the grid with a reducing number of big traditional plants. The project has experienced the typical challenges of a service provided by new active players of future scenarios from a technical point of view.

Finally, the innovative experimentation showed interesting lessons, that can be an opportunity for other manufactures interested in investigating new devices and functionalities to comply with TSO needs regarding the provision of services, particularly regarding the performance necessary in the provision of aFRR. The project has highlighted new opportunities also for ICT developments in order to improve the technology in terms, for instance, of costs, availability, response time and security of the communication always complying with TSO requirements.

2.5 Scenario for future exploitations

The lessons learnt from the experimentation helped the TSO on addressing the choices regarding the data exchange among producers, DSO and TSO for the implementation of the European Regulations (both the connection codes and system operation guideline) that requires the TSO to define a data exchange proposal, in terms also of real time data exchange (experimented in the SmartNet project pilot A). The results of the project, considering also the future growth of renewable and embedded generation, address to the necessity of improving the observability and the control of DER by the TSO and the pilot represents one of the first application in this direction, proving that a direct activation of the resources by the TSO respecting DSO grid constraints in real time is possible. It also highlighted how a good cooperation in terms of reactive power management can be found between TSO and DSO: reactive power management is used along the feeders as also in coordination with the HV network needs together with the TSO, even if in the latter case the benefits to the HV network are limited due to the (obviously) limited amount of reactive power available.

The tests regarding the provision of ancillary services by RES connected at the subtransmission grid and distributed generation revealed important points for future considerations. In fact, it is clear the necessity to improve the performance of the response, considering that:

- The reactive power regulation of the embedded generation brings improvements for the voltage profiles along MV feeders, but marginal benefits at the HV busbar of the substation
- The active power regulation, for an aFRR service, shows good results in terms of amount of MW activated but, at the moment, the performance is not compatible with the technical requirement of this type of service. Furthermore, it shows that opening to aFRR service to DER would need good observability of the DSO grid with a sampling rate aligned with the other resources providing the services, in order to properly monitor the impact on the power exchange between DSO and TSO grid.

Moreover, an important opportunity is represented by the HVRS, that allow to obtain coordinated voltage regulation by small-size HV connected power plants, also of different technology (power parks and traditional generators), and also, if necessary, with the opportunity to coordinate the voltage with the primary substation of the DSO.

2.6 Barriers to future exploitation and ways to remove them

The technological nature of the pilot has shown mainly technical barriers in the integration of embedded generation.

Firstly, it appeared clearly necessary the continuous and accurate monitoring and the transparent access to the MV and LV levels of the grid in order to ensure a safe and reliable management of distributed resources, particularly to handle non-programmable sources.

In fact, the observability is a pre-requisite to gives TSO a better perception of the energy mix underlying the primary substation and, in particular, of the geographic allocation of the generation and the actual energy consumption of the load. It allows improving the grid calculation, where currently a gross estimate based on the installation is used, i.e. for state estimation and for static and dynamic simulation online and offline to individuate also critical constrains. It could enhance the Defense System, adapting the protection scheme of the system, and it could increase the adequacy of the Load Shedding Plan, providing the awareness of the real presumption disconnection. Moreover, it could support the TSO during the Restoration of the service after a disconnection. All these aspects are necessary in order to ensure a safe and reliable activation of distributed generation for grid services. As previously explained, the feasibility of a technological increase of coverage rate in only one part of the observability problem that needs a strong coordination by the TSO, defining and managing the estimation algorithms and performances/availability required to the system. For sure a 100 % coverage rate cannot obtained with a deterministic approach; proper estimation algorithms must be developed at TSO level.

Pilot project showed the necessity to improve the technical performance and the capabilities of the power plant in terms of regulation. The tests carried out confirmed the possibility to modulate the active and reactive power of each plant involved in the project; on the other hand, the contribution of this type of the resources at the moment has performance not in compliance to the services requirements, in terms both of accuracy and response time. Such results can't lead to a replacement of provision of traditional plants, for the safe operation of the grid, even if it gave promising results.

In the communication chain, there are also several critical components: for instance, the interposition of numerous devices leads to delay in the data flow, the telecommunication performance has a crucial role and, besides, the phone network coverage is necessary and it is a critical aspect especially in remote location.

Regulatory framework shall be properly addressed to allow participation of embedded generation in the energy market always keeping into account the technical needs of the ancillary services provided.

3 Macro product 3: SmartNet Pilot B

3.1 Pre-existing industrial situation and drivers to implementation

The Danish power system is characterized by high penetration of Renewable Energy Sources (RES), wind, but, increasingly, also solar Photovoltaic (PV) systems. Other highly flexible DERs, such as Combined Heat and Power (CHP), waste treatment plants, as well as Electric Vehicle (EV) and heat pumps are also expected to have a significant role in the mid-term. Denmark has the world highest share of renewable energy in the power system wherein 2018 wind contributed to 44% of electricity consumption. Currently, the primary sources of the flexibility in Denmark are extensive use of the interconnectors to the neighbouring power systems and the flexible displaceable thermal power plants. This means that based on the current situation usually there is great amount of flexibility available on the supply side and the transmission that is available from a technical standpoint to harvest but not exploitable in reality due to lack of price signals and economic incentives. This is due to the existing regulations, the market design as a whole and the contractual arrangements among the involved parties.

In the Danish pilot, the aim has been to provide a degree of flexibility to T-D using predictable consumer demand and to shift the load to the times that the consumers can reduce their CO2 emission and buy electricity when the prices are lower. To achieve this, several summer houses with sizeable thermal capacity in different areas of Denmark with a weak voltage control have been chosen for this study. These houses have an annual electricity consumption of around 30,000 kWh per house. These house have provided a great overview of experimenting successfully providing flexibility and cost saving to the hose owners.

3.2 Progress realized by SmartNet over status quo

While the physical power system includes components such as interconnectors, transmission grid etc. allowing the electricity to flow across national and international borders, there is also a power market which is a software to ensure the economic efficient allocation of resources based on supply and demand. The market heavily relies on the availability of diverse set of data to set the market prices and when considering adding flexibility of the lower level with smaller aggregators participating in biddings the complexity for the market increase significantly. Therefore, when including the smaller actor into the market it is essential to have a robust digitalization and data processing hub in place to aid the smooth functionality of the market. The Danish pilot, achieved this by dividing the process of providng flexibility into three categories to implement;

- Hardware installation in the swimming pool that include IoT devices and a specially designed Gateway for the communication.
- Cloud based services to collect data from the sensors installed in the swimming pools, hosting the market simulator, gathering weather forecast data and provide a web interface for daily operation and monitoring.
- Develop control algorithms to provide set points to the hardware installed in the swimming pool derived from the input data of the cloud service developed earlier.

Figure 1. Danish pilot set upsummarizes how the devices are used in the Danish pilot and how they are connected to the cloud services hosted at ENFOR's servers.

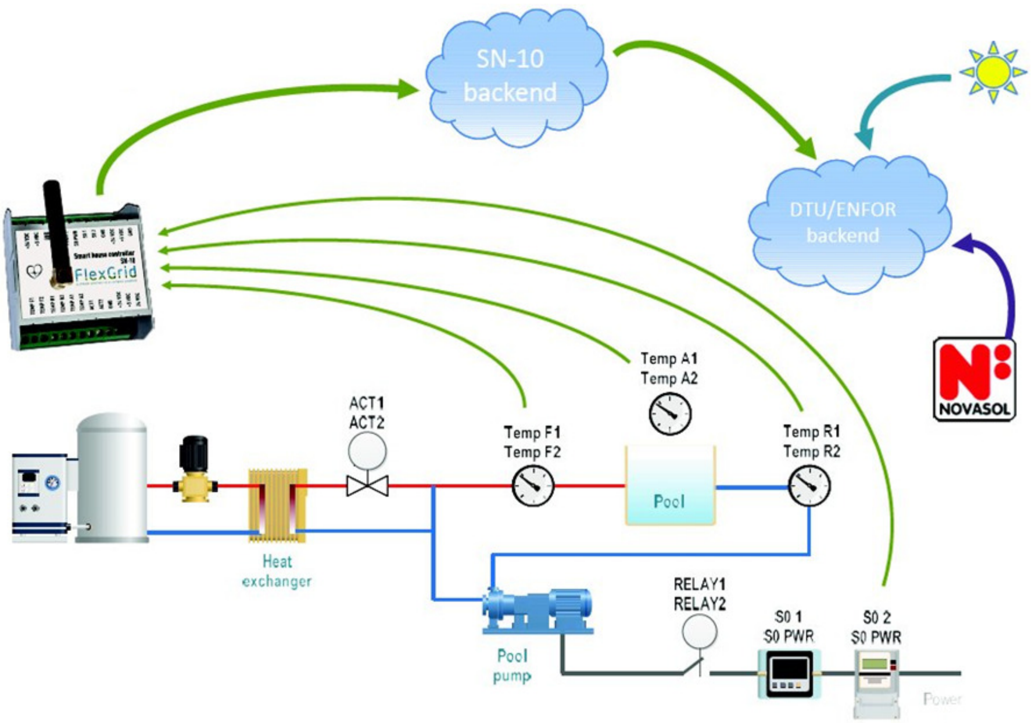

Figure 1. Danish pilot set up

3.3 Opportunities created by the new platform

The methodologies and technologies used in the Danish pilot paved the way for more significant interaction and joint industrial and academic collaborations in designing the new control algorithms during the execution of the pilot. In light of the close partnership and the unique insight from the pilot, the partners were also able to gain unforeseen benefits and opportunities created by the pilot. For

instance, ability to remotely control and monitor the swimming pool was not one the objectives of the pilot at the start; nonetheless the design of the set up and technologies in the pilot accommodated such benefits. Similarly, the prospect of using some of the algorithms and hardware designed for the pilot in future scenarios has created further opportunities to explore.

3.4 Potentially interested stakeholders

The Danish pilot set up includes a set of methodologies, technologies and hardware that has been explicitly designed to facilitate and provide flexibility at the consumer levels. Danish pilot has been heavily dependent on the forecast data for the optimization models to provide accurate control signals for the controllers. The pilot has been successful in adopting and co-creating a set up and an infrastructure where by maximizing the use of data it would provide available flexibility of the swimming pools. Therefore, it is not surprising to see that the physical set up, methodologies and algorithms developed are attractive to various stakeholders. Among those are IT companies that deal with forecasting data and artificial intelligence, and product manufactures that design heat pumps and cooling services. In addition, the research community can also gain insight by further developing the optimization, control, and forecast models to provide outputs that are more accurate by including uncertainties in the models.

3.5 Scenario for future exploitations

The Danish pilot experiments have provided suitable solutions for deploying the set up in the district heating systems (DHS). In general, DHS and swimming pools in the summer houses have similar characteristics. For instance, both could provide thermal capacity as a way to give flexibility to the grid. Although quantity wise, DSH can provide much larger flexibility than the swimming pools, and that makes it a great candidate to adapt the Danish pilot set up. The Danish pilot has already shown a 10% reduction in CO2 emission and achieving similar numbers in DHS means maximizing the carbon reduction based on the existing technologies with less needed investment.

3.6 Barriers to future exploitation and ways to remove them

Some of the main challenges for adopting solutions such as the Danish pilot depend on the existing regulations, taxation and incentivisation, availability of data and preserving privacy and security. The amount of flexibility a swimming pool provides may not fulfil the minimum bidding requirement to participate in the electricity market, therefore for such solution to work, the market regulations should accommodate smaller bids amounts and allow smaller aggregators to participate.

Taxations also play an essential role in adopting such solutions by consumers with a lower amount of flexibility. The taxation scheme could be used as an incentivisation method for motivating consumers to

engage in such solutions, considering that for some smaller participant the financial gains might not be adequate to reward them in adopting the solution if there is no incentivisation available to them.

For such a solution to be viable and worthy of installing, it is also important to point out that there is a high dependency on the availability of data from various sources to be shared to provide such flexibility. There is a need for robust and secure communication links and software integration services to facilitate the provision of available flexibility. When considering consumer's data, which includes a usage pattern, privacy should become an integral part of the solutions to ensure the consumer's privacy is preserved.

4 Macro product 4: SmartNet Pilot C

4.1 Pre-existing industrial situation and drivers to implementation

The status of the actual energy generation model is taking a replacement of fossil-fuel-based generation by renewable generation. These movements are facing important challenges in terms of frequency stability, congestion management, voltage regulation and power quality, due to its variable behavior. Simultaneously there is a growing penetration of medium and small-scale, flexible demand and storage systems in distribution networks. These resources could potentially be available to provide network services if they are aggregated effectively and there is an appropriate coordination between transmission systems operators (TSOs), distribution systems operators (DSOs) and aggregators.

The share of highly-variable production from renewable energy sources increase the complexity activities in the Iberian market. Balancing and associated ancillary services become important methods to solve this uncertainty of generation. Under such scenario the use of any controllable device that may allow the regulation of power consumption is required and an asset with flexibility to be exploited.

The Vodafone Bases station network is equipped with passive back up scaled to ensure the security of service to mobile voice and data customers across Europe and in particular in Spain. This passive backup is dimensioned upon the grid quality and supplied by 48V Valve Regulated Lead Acid batteries of different capacities to support 1 to 4 h of service out of grid, site location, radio transmission equipment load, and local security of service regulatory requirements depending.

The driver to participate and implement the Pilot C is straight forward:

- DER economical interest: These batteries represent an unused available power asset and unexploited flexibility around 100 MW that could be used to supply services, provided their original back up mission is still available. This service, remunerated in return by the DSO, are representing an energy cost off setting opportunity for the future, contributing positively to the DER balance sheet.
- On the congestion management point of view the scattered, small-scale flexibility that can be aggregated on demand on random territories could be very useful to solve small/medium scale issues in a flexible and simple way.

4.2 Progress realized by SmartNet over status quo

The DSO in pilot C develop a new role with the local market operator, demonstrating the proposed scheme of coordination with a shared responsibility on the balancing. This new role give to the DSO the possibility to balance the interconnection points and also the possibility to solve distribution grid

problems such as the congestions. This new responsibility force to have more power flexibility services in case of there is not enough offered flexibility in the market to get the balance.

During this pilot appeared the necessity to get the information of the DSO monitoring system at consumer level in low voltage close to real time. Nowadays, this monitoring system is used for biding and these devices are configured to communicate the data once a day. The installed smart meters are capable to perform these measurements but are not configured to do that. The DSO did the necessary actions to get the measures in a 5 minutes resolution to adapt to the pilot.

The market running with the aggregators has been performed and the flexibility activated. This pilot has demonstrated that the balancing at distribution level is possible with the aggregations of the flexible resources. Also, it has been demonstrated that, at the same time, possible congestions can be resolved. At the end, the conclusion of these results are that with the sufficient flexibility the DSO is capable to be a balancing responsible, or sharing the responsibility with the TSO.

From the Telecom Business / DER/ Customer view the essential was to understand the synchronized activation impact on the customer service delivery , and if there are the right existing BTS software rules & parametering set up to ensure there are no deviation possible.

The flexibility tests activated randomly on the different period of the pilot could demonstrate the absence of impact even in case of full discharge of the batteries thanks to automatic switch back to the Grid. In the preparation phase, it could also be demonstrated the variability between different generation of DC power controllers Hardware and software version, leading to several discussion with each provider to operate upgrade and harmonize the information availability for a secure and synchronized activation.

4.3 Opportunities created by the new platform

The new platform developed and validated within Pilot C of SmartNet has created new opportunities for the future of distribution networks. The release of flexibility of controllable assets (in this case communication base stations) allows to ensure the stability of the distribution network as well as the security of supply, under future cases of high penetration of renewable energies as well as reduce the investment on grid reinforcement to cope with large load conditions. Being more specific, such platform unveils the following opportunities:

- change from passive distributors to active Distribution System Operators: Such platform may allow the evolution of the distribution system operation, modifying the old behavior of "fit and forget", (i.e. make the matching from transmission to consumption without any specific control; other than ensure stability, security and quality of service) to "Active Neutral Market Facilitator" which acts as the technical validator of the required resources to actively ensure the proper fitting of all existing electricity assets

- TSO/DSO interaction: Such platform creates the appropriate framework for interaction between TSO and DSO on power balancing achievement.
- Local markets for distribution network support: Such platform allows the integration of different local markets that may co-exist within the distribution network to offer services to the grid.
- Consumers' flexibility activation: The platform (although the pilot was focused on base station energy storage) may allow the integration of consumers' flexibility and participation to flexibility markets in twofold: prosumers and consumers with controllable loads (Demand Side Management).
- Use of unexploited flexibility by aggregators: Such platform allows the integration of different aggregator services to operate in a single flexibility market.
- Scattered, small-scale flexibility that can be very useful to solve these issues.

In addition, other benefits may relate to:

DER owners:

- As owning more than 100 000 base stations across Europe, representing ~250MW, Vodafone could transform a passive equipment into an active power asset, creating an opportunity for Energy cost offsetting meanwhile supporting the grid operators.
- The DSR activation/ or site availability to do so, and the associated remuneration, once known, will certainly support the business case for an accelerated transition to different battery technologies, such as Lithium ion cyclic kind , which at this stage still over budget vs.standard back up.
- On the DSR operational stand point, it has been demonstrated the possibility to control availability and activate the base station back up in using only the existing BTS's 48V DC Power Supply SW, out of the communication and control devices set up for the need of the pilot management. This is a unique opportunity for future implementation cost management for both Telecom DER and Aggregators, in accelerating the time to market for mass introduction of the DSR principles into Bases stations, upon strict communication and security agreement between the parties.

4.4 Potentially interested stakeholders

The results of the pilot C have led to a definition of different stakeholders. As the main beneficiary, the DSO could technically deepen the possibility to use the embedded generation to provide ancillary services. Therefore, the DSO has more options to solve grid congestions on the Distribution Network, beyond traditional options such as grid reconfiguration.

The project is also defining attractive opportunities for entities like ONE, than can act as aggregators, to propose aggregation of flexibility as a service to third parties. The project has experienced the typical challenges of a service provided by new active players of future scenarios from a technical point of view.

The project has highlighted new opportunities also for ICT developments in order to improve the technology in terms, for instance, of costs, availability, response time and security of the communication always complying with DSO requirements.

Further stakeholders are all EU Telecom Operators or Services companies, such as Tower Companies, which are managing thousands of sites across Europe with Power solutions today dedicated to supply backup to the radio and transmission equipment for voice and data. The necessary investment for power and backup upgrade in relation to the 5G deployment could be enabled, provided the DSR scheme is ready and offered in time as to be integrated into the site batteries infrastructure design right from the beginning- meaning from now on and within the next 2 years.

Not only EU Telecom Operators could be interested in this scheme, but also any other DER owner with the capability of providing flexibility.

4.5 Scenario for future exploitations

The short-term exploitation of the platform is related to a further validation into a larger scenario case as well as the improvement of the platform to a commercial one. Such further validation is expected in the recently funded COORDINET project.

In addition, further developments to integrate other active assets is required to maximize the platform potential impact.

The potential mid-term exploitation of the platform innovation is related to the current market share of Enel's groups. ENDESA as part of ENEL's group aims to transfer such platform into all the countries where they are operating the grid.

Update of battery technologies: Transforming backup equipment in Power asset needs a design change for the supported infrastructure (e.g. Base stations DC Power) and a dimensioning based on future cyclic usage. The cycling frequency will affect the lifetime of the batteries, leading to use the appropriate technologies (e.g. Lithium ion industrial batteries instead of Valve Regulated Lead Acid). Purpose will be to limit the time for recharge to ensure availability consistency meanwhile reducing the maintenance/ replacement operation and associated costs.

4.6 Barriers to future exploitation and ways to remove them

To further exploit such platform development, there are certain barriers to overcome in Europe but especially in certain countries where Enel Group operate.

- Regulation: In certain countries as Spain or Italy, the aggregator cannot operate yet, which is a clear barrier; however, the experience in other countries, technology readiness and the results of such projects may help politics to move forward. TSO/DSO agreements: There is the need to change the current information flow among TSO/DSO in order to ensure proper services provision, especially in common interconnection points as Substations. In addition, there is the requirement of proper coordination and responsibility definition.

From the DER standpoint, 3 barriers to overcome:

- Regulatory possibility to aggregate short load together
- DER remuneration plan to make the DSR business case positive in a very short period. This element was not part of the Pilot and will require a right dimensioning to be enough attractive.
- Cost of DSR implementation on a multi-thousand-infrastructure base, simultaneously. Means explore further the way to operate remote secure activation and control by SW only -as partly demonstrated in Pilot C, without intrusive additional HW on site. Purpose will be to avoid additional costly sites access and operation for the set-up, which is a main barrier for a mass deployment. This remote activation by third parties will need in return the set-up of the appropriate secured routes.

5 Macro product 5: SmartNet ICT Platform

5.1 Pre-existing industrial situation and drivers to implementation

Energy systems are moving from static and centralized architectures towards more flexible and distributed structures as the share of distributed energy resources (DER) gets larger. As the energy flow becomes more and more bidirectional and systems more dynamic, the amount of exchanged information increases and demands for ICT become more versatile. Improved communication solutions are needed to increase controllability and to ensure high quality and flexibility of distributed energy systems. This poses challenges for today's smart grid communication systems, because the communication cost, flexibility, quality of service, availability, response time, and security, do not always meet all of the expectations. Moreover, grid communications solutions are developed on the top of the data communication standards targeted to human users, which have required tailoring and retrofitting work to adapt them to energy systems. This has lengthened the time-to-market time of the grid communication devices and services. The challenge is to define and identify ICT requirements adequately of the future energy systems and include them to parallel development of communication and grid system components.

As a starting point, the Smart Grid Architecture Model (SGAM) has been a good tool in energy domain, since it offers a framework for the validation of smart grid use cases and their support by standards. However, the handling of ICT requirements and market designs is not included in the SGAM model, which may result in inadequate system designs. There is a need for an enhanced SGAM model also to include communication requirements to help interaction between energy and communications domains to detect and resolve potential bottlenecks in the future energy systems. The exploitation of new wireless technologies e.g. 5G is anticipated as the smart remote monitoring and control are extended to distant entities in the power grid. The fifth generation (5G) cellular technology is making a significant advance in the combination of latency reduction and reliability enhancement. This makes 5G an option for a replacement of fixed cable connections. Since the beginning of 5G, electricity distribution has been one of the major use cases for ultra-reliable low-latency communications (URLLC). Mobile devices have offered high quality connectivity over several generations, but 5G is aiming to make a big difference in offering better connectivity between machines. Especially 5G URLLC is targeted to low-latency with high-reliability communications. This addresses the demand from many vertical sectors for mission-critical machine-type communications (MTC), which are essential for new use cases and applications, such as smart grids, industrial automation, and intelligent transportation.

Currently, effects of wireless communication have been modelled with computer simulations and their effect is included in lab experimentations with simplified terms. Adequate calibration and verification of the simulations with the real wireless networks is still missing. The conventional way is to use wired

connections without characteristics of the wireless networks. Consequently, SW simulations of wireless systems can be rather far from real operational situations. There is a need for a tool that enables bringing wireless communications measurements from real operational environment to a smart energy lab or system simulators. Testing communication and smart energy components already in the prototype stage would help reduce time-to-market, time-to-revenue, and deployment costs of future grid components and services.

5.2 Progress realized by SmartNet over status quo

SmartNet ICT platform consists of extended Smart Grid Architecture Model (SGAM) with ICT requirement capturing process, and a process to generate QoS profiles from field measurements to include effects of wireless communication to the lab simulations.

5.2.1 SmartNet's ICT requirements capturing process

SmartNet's ICT requirements capturing process is an extension to the SGAM approach. The developed analysis process enhances the SGAM approach by embedding communication and security requirements in each SGAM layer. As a result, ICT requirements are specified in business, function, information, communications, and component layers. To make the process well adoptable, IEC 62559's design template and ELECTRA project's use case design methodologies were utilised. They provided structured guidelines for preparing use case descriptions as well as mapping business and system functionalities into SGAM layers. The developed process is incremental to enforce close interaction between energy and communications system providers and developers. Requirements for communications tend to change, so parametrised architecture model was implemented with Architect Enterprise with SGAM toolbox that offers a practical tool to validate architecture design and assess effects of changing ICT requirements in cases of centralised, local, shared, common TSO-DSO, and integrated market models. To support the process, a conceptual model depicted in Figure 4.1 is used for the dialogue between ICT and energy personnel to capture the main data exchange operations and their requirements in different TSO-DSO coordination schemes.

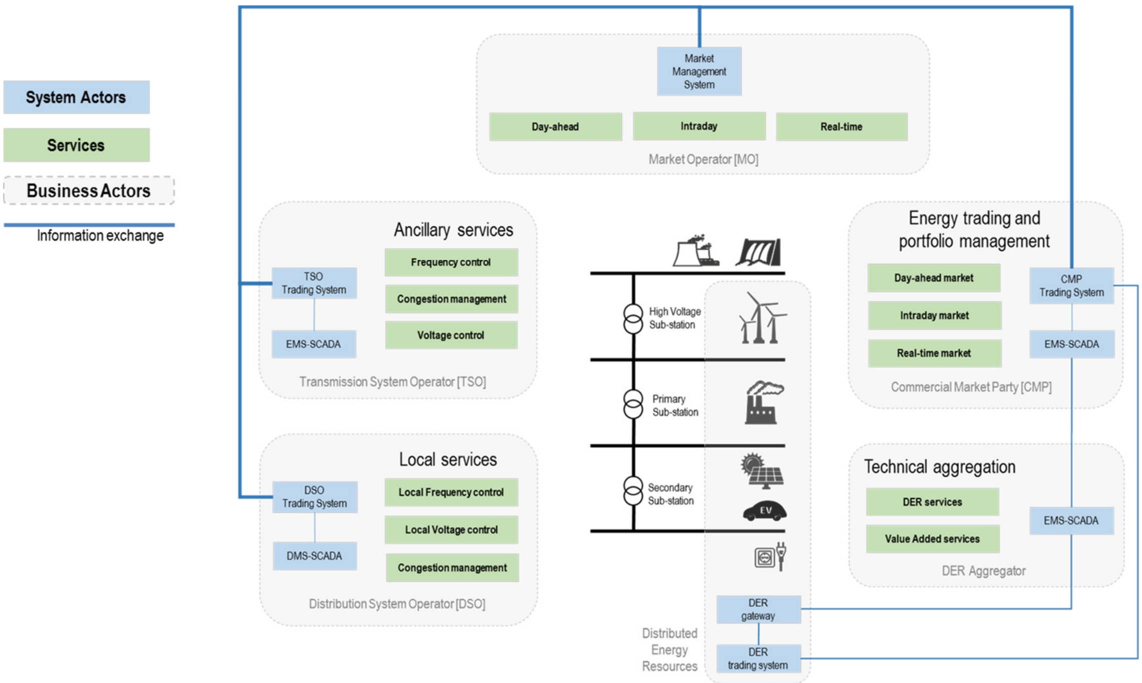

Figure 2. A concept model for identifying communication links and their requirements.

The model presents actors, system components, and services. In the figure, grey rounded boxes present core business actors/roles in different coordination schemes. The stakeholders can play multiple business actor roles. For example, an aggregator can do both technical aggregation and energy trading. The Market Operator (MO) role can be played by various stakeholders depending on the market scenario: central TSO (market), DSO (local), TSO-DSO (shared), or IMO (independent).

Blue boxes represent the main system components a.k.a. system actors or entities used by business actors. Trading system (TS) is devoted to exchange information with the market management system, e.g. schedules for prequalification, procurement, or activation of ancillary services. DMS/EMS-SCADA is considered here as the system used for network monitoring and control operations. Respectively, Market management system (MMS) is dedicated for running market processes (by the TSO, DSO, or IMO) and to establish a link between the market operator and stakeholders. Connecting blue lines represent external data exchange links between system components. Thinner lines in the figure are presenting internal communication links. The model was used for analysing the system operations from an energy market point of view, but it can be extended to remote metering and protection. Green boxes represent core ancillary services including e.g. frequency and voltage control, and congestion management. The pictures in the middle represent the grid infrastructure and distributed energy resources, from high-voltage down to low-voltage grid, which help mapping the energy market events to the physical grid entities.

5.2.2 Conversion of communication measurements to QoS profiles

The process to generate QoS (Quality of Service) profiles from field measurements was a new approach to include effects of wireless communication to the lab simulations. This process offered a way to mimic real-life or statistical latency profiles in e.g. commercial 3G/4G/5G mobile networks and to analyse the effects of different communication network parameters on the interaction of the distributed energy system components. For this, a wireless QoS measurement setup depicted in Figure 3 and a dedicated communication emulator were implemented. The former one gives an opportunity to create profile data that can be used directly on an emulator or used for generating synthetic QoS profiles for lab systems and simulators. The QoS profile mimics network effects by changing e.g. delays, packet losses, and corrupted packet rates.

Figure 3. A wireless QoS measurement setup.

There are many possibilities where the emulator can be installed in the lab environment. In the SmartNet trials, the emulator was placed between Supervisory Control and Data Acquisition / Distribution Management System (SCADA/DMS) and the Power Plant Controller (PPC), and between the SCADA/DMS and power system simulator. In the first case, the SCADA/DMS and the PPC are communicating frequently with each other and the physical distance between the two components in real operational environment is long enough to make sense to deploy wireless communications. For the second case, the SCADA/DMS needs to continuously collect measurements from the grid and thus emulating the changes in communication conditions allows to investigate performance boundaries of the interconnected components. The communication emulator can also be used to experiment different communication technologies, such as fixed, GPRS, 3G, 4G, Wi-Fi, etc.

Figure 4. SmartEST Laboratory at AIT used for emulated communications tests.

Figure 5 illustrates the connections between SmartNet Simulator, Laboratory equipment, and Communication Emulator. In this example, the emulator allows to test the communication link between SCADA/DMS and PPC with different communication technologies and in different radio propagation conditions.

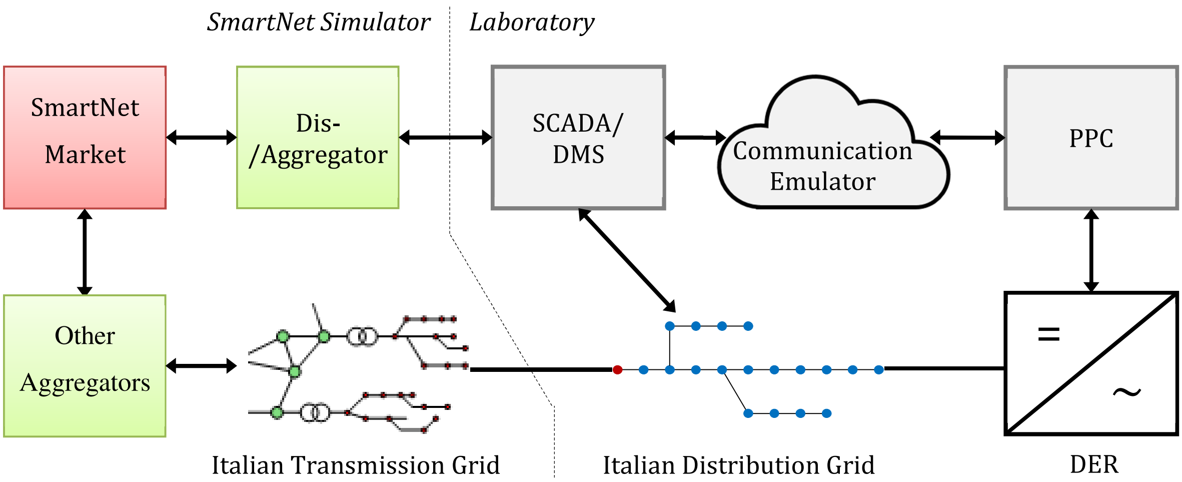

Figure 5. Communication Network Effects on the Interactions of the SCADA/DMS and the PPC.

5.3 Opportunities created by the new platform

The trend is towards more intelligent distributed energy systems exploiting ICT for flexibility. New market models and smartness of the energy system require tighter coupling between energy and ICT communication system components. The challenge is to capture ICT requirements affecting the overall

system performance. The second challenge is how to increase dialogue between energy and communication system developers and providers. The developed extended SGAM process offers a tool to overcome these challenges and to support the design of energy systems of different sizes with regional characteristics. As an example, two large national research projects under 5GTNF (5G test network Finland) have already used the process for designing and implementing smart energy monitoring and protection pilots.

The trend of research and development is toward more realistic lab simulations where SW simulators and HW components are interconnected. As larger parts of the grid are included to the simulations, the modelling of communication links becomes more important. The process of converting field measurements into QoS profiles is compelling for both lab environments and simulation tools. They give an opportunity to test communication and smart energy components already in the prototype stage, which helps to reduce components and services' time-to-market, time-to-revenue, and deployment costs. Device and system manufacturers can test their equipment or simulator components in the same lab environment using data from different parts of Europe without the need for performing full field tests in different locations.

Reduced time-to-market and development costs improve European manufacturers' competitiveness in international markets. According to "*Europe 5G Readiness Index: Assessing Europe's readiness to deploy 5G*", Denmark, Finland, Iceland, Norway, and Sweden are ranked among the top 10 countries, and three of them are in the top 5. The Nordic countries have traditionally been at the forefront of communication technology development, whereas Central and Southern Europe are leading the way in smart energy systems. Combining communication measurements from the Nordic countries with a lab environment modelling Southern Europe energy systems opens new business and R&D opportunities for a variety of companies.

5.4 Potentially interested stakeholders

For SmartNet's ICT requirements capturing process, the potentially interested users are ICT vendors and solution providers that offer new services and devices for Smart Grid. In fact, the process has already been exploited in two Finnish 5G research projects offering wireless services for verticals including the energy sector. A joint 5G and smart grid pilot has been one of the main drivers for the 5G ecosystem. Another target group is TSOs, DSOs, and large aggregators that design communication solutions for future distributed energy generation, transmission, and storage systems. National regulators from energy and communication domains have also shown increased interest on the outcome of the process.

Stakeholders interested in the conversion of communication measurements into QoS profiles are all companies that are involved in smart grid communications. However, these companies need direct or indirect access (via universities and research institutes) to lab environments or simulation platforms that can exploit measured QoS measurements. Another group of interested end-users are TSOs and DSOs. In

the future, the simulation platform could be customized upon request in order to experiment a specific application case. In addition to national regulators, also European regulators and the Agency for the Cooperation of Energy Regulators (ACER) could be interested in results of extensive testing of TSO-DSO interaction schemes with selected national cases.

Smart energy has become one of the main drivers for 5G ecosystem projects. In addition to energy and communications companies and research institutes, national regulators from energy and communication sectors have been interested in the results obtained from the pilots and complementary simulations performed in a controlled environment.

5.5 Scenario for future exploitations

The scenario for future exploitation for SmartNet's ICT requirements capturing process is to promote the process and the specification templates as well as electrical design tools e.g. Architect Enterprise with SGAM toolbox to industrial parties operating in energy and telecom domains to enforce their collaboration already in design phase. The process has been exploited in national pilot projects that have proven its applicability to support the design of smaller systems and system parts targeted to e.g. remote monitoring, control, or protection in medium voltage networks. The scenarios for future exploitation of communication measurements as QoS profiles in lab and simulation environments (Macro product 1: SmartNet simulation platform) are diverse. They can be exploited by TSO and DSO companies to test or evaluate new communication technologies between new energy system components or to retrofit new technologies to existing ones. This gives an opportunity to test communication and smart energy components already in the prototype stage. This helps to reduce components and services' time-to-market, time-to-revenue, and deployment costs. By linking measurements from real operational environment with the lab platform, larger scenarios can be created to support also regulation and standardisation activities. Additionally, full testing including real devices and a "lab" environment mimicking the real energy system components paves the way for a faster transition of the SmartNet simulator platform from a demo setup to a fully operational system.

In particular, DSOs and TSOs, as well as stakeholders responsible for managing future ancillary services markets at both local and system levels, would be interested in further exploitation. On one hand, TSOs and DSOs will be interested in analysing operations in their own markets, and on the other hand, ICT vendors are keen on assisting them by further customizing and developing services for real-size system implementations taking into account the complexity of the real world. This opens new market perspectives for a product helping local DSOs to cope with the optimization of their local dispatch while interacting with all the entities connected at distribution level able to provide ancillary services. The presence of international ICT vendors such as VODAFONE, SIEMENS, SELTA and EURISCO within our consortium ensures the passage from the project stage to the post-project exploitation.

5.6 Barriers to future exploitation and ways to remove them

The barriers for more extensive exploitation of the ICT platform can be considered from the perspective of the small DER owners and aggregators, DSOs, TSOs, Mobile Network Operators (MNO)s, and other ICT service providers, and regulation and standardisation.

Small owners and aggregators: At the moment, lack of remote controllability of small distributed DERs is a barrier for engaging small DER owners and aggregators to energy markets. The last km communication costs and other aggregation costs are much higher than the ICT costs that stem from the SmartNet market designs and depend on the coordination schemes. It is important to consider whether ICT solutions may have a negative effect on competitiveness of some DER technologies. Finally, any solution that depends on reliable communication and data from a large number of devices, has to consider cyber security issues. It can be argued that end-users/terminals are the weakest point, because they may update equipment infrequently and their software is less up-to-date. One of the main challenges is to define who should be responsible and how to enforce adequate measures.

DSOs, TSOs, MNOs and other ICT service providers: Legislation adequately defines the ownership and responsibilities of data. However, when information is aggregated by multiple stakeholders then the ownership of data becomes more unclear. The same happens in the service level when different types of market models are introduced with changing business roles and responsibilities. The recast electricity Directive states that "eligible parties" (defined as customers, suppliers, TSOs and DSOs, aggregators, energy service companies, etc.) may have access to data of the final customer with their explicit consent. This does not clearly identify the ownership of data or system components.

Regulation and standardisation: Prioritisation of control traffic is needed for new energy system to ensure that transmission of control signal to a DER is always reliable. There is no regulation ensuring this. The regulation is the other way around: traffic management need to allow low latency transmission of small real time control signals will be allowed as long as it does not reduce the quality of normal internet access of the end users. Another barrier is conflicting telecom and energy regulations and standards that forces vendors to support large number of different interfaces and thus makes the equipment more expensive and less interoperable.

6 Conclusions

The progress realized by SmartNet over the status quo, as well as the many opportunities created by the project have been disseminated to the potential stakeholders in dedicated events across Europe, open access publications and online, together with the main recommendations in light of the current results.

The scenario for future exploitation of the project outlined in this document takes into account the different stakeholders' perspective and needs, facilitating the passage from the project stage to the post-project exploitation.

It must also be highlighted that two new Horizon2020 projects, both started in January 2019 will take an important heritage of the SmartNet project: INTERRFACE and CoordiNet

INTERRFACE (http://www.interrface.eu/) is a 48 month long Horizon2020 project counting 42 partners and coordinated by European Dynamics (software developer). Among the partners in is worth mentioning ENTSO-E, many European TSOs and DSOs, one National Regulator (Romania) and one Market Operator (Bulgaria).

INTERFACE aims at demonstrating the added value of sharing data among all participants in the electricity system value chain (customers, grids, market), from local, regional to EU level. It will also enable TSOs, DSOs and customers to coordinate their efforts to maximise the potential of distributed energy resources (DERs), demand aggregators and grid assets, so as to procure energy services in a cost-efficient way and create consumer benefits. This is carried out by designing, developing and exploiting an Interoperable pan-European Grid Services Architecture to act as an interface between the power system (TSO and DSO) and the customers and allow the seamless and coordinated operation of all stakeholders to use and procure common services. State-of-the art digital tools based on blockchain and big data management will provide new opportunities for electricity market participation and thus enlarge customers into the INTERRFACE proposed market structures that will be designed in order to exploit Distributed Energy Sources.

Consequently, specific objectives are:

- to design an Interoperable pan-European Grid Services Architecture (IEGSA) that will connect market platforms in a transparent, non-discriminatory manner and will allow a pan-European electricity exchange that will link wholesale and retail markets and will enable the trading of energy services.
- to demonstrate the IEGSA components and architecture and the relevant IT infrastructure; IEGSA will be deployed in seven Demonstrations which will take place in nine countries (Greece, Bulgaria, Slovenia, Romania, Hungary, Italy, Finland, Estonia, Latvia), focusing on illustrating specific functions and serving real need and existing challenges, engaging different actors of the energy value chain.

RSE and Florence School of Regulation are the only SmartNet partners being present in the INTERFACE consortium. RSE, in particular, leads task 3.1, defining the services to be implemented into the IEGSA platform and will be involved in task 3.2, defining services market architectures. In doing that,

the experience of the SmartNet project will be taken in full account along with specificities bound to the demos to be developed.

CoordiNet (https://coordinet-project.eu/) is a 42 month long Horizon2020 project counting 33 partners (among which many in common with the SmartNet consortium) coordinated by the Spanish DSO ENDESA and aimed at assessing different coordination schemes between transmission system operators (TSOs), distribution system operators (DSOs) and consumers in order to contribute to the development of a smart, secure and more resilient energy system. Special emphasis is given to the analysis and definition of flexibility in the grid at every voltage level ranging from the TSO and DSO domain to consumer participation. The coordination schemes proposed by CoordiNet are strongly derived from the ones analyzed by SmartNet. They will be tested in three large-scale demonstration projects across 10 different locations in Spain, Sweden and Greece. Such demos will apply different coordination schemes and test the complete set of products for grid services defined within the project.

Finally, the newly awarded Horizon2020 project **FlexPlan,** availing itself of the same coordinating person as SmartNet project (as well as many partners in common), will still tackle the topic of “flexibility” and “TSO-DSO cooperation”, yet from a different angle point. Aim of FlexPlan will be to set up a new advanced grid planning methodology considering storage units and flexibility as an alternative to building new lines. This methodology will be applied to a domain including both transmission and distribution grids supposing that important flexibility contributions will come from distribution. Here, again, the experience derived from the SmartNet project will be fully valorized.

This paper reflects only the author's view and the Innovation and Networks Executive Agency (INEA) is not responsible for any use that may be made of the information it contains.