INTEGRATED SMART GRID CROSS-FUNCTIONAL SOLUTIONS FOR OPTIMIZED SYNERGETIC ENERGY DISTRIBUTION, UTILIZATION STORAGE TECHNOLOGIES

Whitepapers

INTEGRIDY INTEGRATES CUTTING-EDGE TECHNOLOGIES,

SOLUTIONS AND MECHANIMS IN A SCALABLE CROSS-FUNCTIONAL

FRAMEWORK OF REPLICABLE SOLUTIONS TO CONNECT EXISTING

ENERGY NETWORKS WITH DIVERSE STAKEHOLDERS.

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Contents

Editorial

inteGRIDy aims at integrating cutting-edge technologies, solutions and mechanisms in a scalable Cross-Functional Framework of replicable solutions. This framework connects existing energy networks to diverse stakeholders, with enhanced observability of both generation and consumption profiles. inteGRIDy pursues facilitating the optimal and dynamic operation of the Distribution Grid, fostering the stability of the electricity grid and coordination of distributed energy resources, Virtual Power Plants and innovative collaborative storage schemes within a continuously increased share of renewable energy.Integration of existing smart-metering/automation systems, with IoT infrastructure, enabling interoperability through standard APIs and efficient data collection and monitoring of grid assets.

- ☑ Novel modelling and profiling mechanisms allowing the creation of network topology and Demand Response models, together with battery cycling and charging profiles.
- ☑ Predictive algorithms enabling dynamic scenario-based simulation and multi-level forecasting for managing real-time demand and supply of energy and optimised decision making.
- ☑ Powerful and efficient visual analytics and end-user applications, using novel human machine interaction techniques.
- ☑ A security access control framework, built upon the standardization, regulatory environment for privacy and data protection.
- ☑ Innovative business models providing important tools to the energy market for dynamically involving Demand Response strategies and allowing new energy market entrants.

inteGRIDy envisions the realisation and demonstration of a solution covering the aforementioned innovations under a variety of environmental, market and societal conditions at 10 pilot and demonstration sites throughout EU.

In summary, inteGRIDy produced a number of relevant outcomes and key exploitable results, as detailed in the previous sections. If we were to select the most relevant ones, the following list summarizes the outcomes inteGRIDy is proudest of:

- ☑ The **inteGRIDy Cross-Functional Modular Platform**, which was conceived in WP1, developed (of their individual modues) in WP4 and integrated in WP5. This was a huge piece of effort, mostly delivered in the first half of the project.
A full architecture definition together with the development of around 30 different software tools (some of them covering multiple layers) was performed. As a result, the project achieved a wide set of key exploitable results:
  - * inteGRIDy framework definition, including a paper publication for dissemination, outlining the usage of state of the art software references for energy systems[1].
  - * Specific partner's exploitable tools, enhancing the initial TRL from which they started in inteGRIDy (some of them even developing the tools from scratch) and achieving in most cases pre-commercial or even fully commercial solutions.
- ☑ The **inteGRIDy solution space**, as a way to demonstrate tool interoperability and the way forward for the project towards an integrated approach. This solution space validated the integrability of inteGRIDy solutions from multiple perspectives:
  - * Individual tools were tested so that they were all compliant with the reference architecture and the interoperability requirements set by the project.
  - * The framework was instantiated in all 10 inteGRIDy pilot sites, with just the functionalities needed for the particular case. For those modules included in each pilot site, full tool interoperability and seamless communication was required, outputting the relevant KPIs and information for managers to test the propers pilot implementation.
  - * As having 10 different instances of the framework does not prove full inteGRIDy interoperability, the solution space offered this proof of concept of an integrated system where:
    - All inteGRIDy tools (apart from those which where static and/or just for modelling) are included, with a unified Reference Knowledge Warehouse (RKW) where all inteGRIDy tools posted relevant data. This is, therefore, a fully integrated framework at data level.
    - Definition of standardized APIs for tool communication, allowing the interaction

1 A. Perez, G. Paterno, M. Lazzaro, J. Landeck, J. Valiño, O. Càmara, D. Gómez, P. Gkaidatzis, A. Tryferidis, "Smart ICT Framework for the intelligent management of different modern energy systems." 10.1109/EEEIC.2019.8783709, 2019/06/13

directly between tools for high level signalling and/or control. This is done also for all inteGRIDy tools.

- A unified visualization center, aggregating the information from all inteGRIDy pilots, where relevant KPIs were identified as information to be shown (as a subset of the ones detailed in WP8). This is also incorporated for all tools and all pilot sites.

- A full automated space for advance integration. This is achieved using a micro-service oriented architecture and a dockerized approach for tool integration, as suggested in WP4. Pilots opting in (it was demonstrated in at least 3 inteGRIDy pilot sites so far) can use a Common Integration and Common Deployment (CI/CD) environment fully automated and interoperable.

☑ The **inteGRIDy Business Modelling and Replicability tool**, which was developed under WP3 and validated in WP8. The online tool, which is open to third party usage and also showcased through an online webinar and presented as part of BRIDGE Scalability and Replicability task force, provides an easy to use business modelling canvas for energy solutions, with a lot of pre-existing templates and suggestions, paving the way for an automated identification of the best modelling for a given innovative idea.
As an added feature, the tool incorporated the replicability analysis, which uses BRIDGE methodology for scalability and replicability analysis, and complements it with a database of replicability items and scoring for different technologies and their readiness in different EU countries. This database started with just inteGRIDy pilot countries, but it is currently enhanced with most EU countries.
The tool is available at Business Model Replication Tool.

☑ **inteGRIDy stakeholder engagement** activities. Even with the inconvenience of the COVID-19 restrictions and the need to move to a fully online or, at least, hybrid approach for stakeholder engagement activities, inteGRIDy delivered a high quality and high impact campaign of workshops, with the aim of spreading the word locally regarding inteGRIDy pilot activities, trying to enlarge the current set of end users for the project solutions and also fostering the inter-pilot and inter-tool synergies, inviting other pilot/tool owners to present their solution in different countries, so they can explore potential new exploitation opportunities.
This included 8 Pilot workshops, aggregating 604 visitors.

All in all, even with all the obstacles and setbacks inteGRIDy faced along the 54 months in which it was active, the quality of results and final impact has been proven to be not just in line with the requirements set in the DoA, but, in some case, expanding the initial expectations.

This book aggregates the collection of whitepapers that have been produced as a way to disseminate inteGRIDy outcomes. They are presented in chronological order, so the first ones record the preliminary studies and definition of requirements and use cases, while the last ones are devoted to present the pilot implementations and also the overall techno-economic evaluation.

Business model innovation for energy services and solutions

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ARTICLE INFORMATION

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Tags: *energy industry*, *business model*, *business model development*, *business model innovation*

ABSTRACT

Technological developments, being an important enabler, are crucial to make the envisioned concepts like microgrid or advanced DER aggregation become reality. However, successful commercialization and end user acceptance require from technological innovations to be coupled with a well-defined business model.

In the inteGRIDy project, UCP-SCIL is developing a business modeling methodology that will help pilot leaders to unlock the value of technological solutions being developed across ten pilot sites.

Introduction

The energy industry is in constant reshape due to policy shifts, technological advancements and changing consumer demands. These trends have led to the emergence of new areas for business opportunities and new market actors with their distinct novel offerings.

There is no doubt that these transformational shifts are highly dependent on technological advancements, which open up in front of incumbents and new market entrants various new possibilities for shaping their business.

However, how to ensure that market players make the most out of this? How to make novel solutions affordable, adaptable and commercially viable? Or how to make new offerings appealing to the end user? Technology on its own is not enough to realise the opportunities that novel solutions can offer to market players. To bring a novel solution to the market successfully, technological innovation must be coupled with a well-defined business model (Teece, 2010). Therefore, finding the answer to the question of how to help market players to develop viable business models becomes very topical and rather urgent.

In the inteGRIDy project, UCP works on developing a business modeling methodology that will help pilot leaders to unlock the value of technological solutions being developed across ten pilot sites.

A holistic approach to business modeling

While conducting research activities and consulting companies on the topic of business modeling, the team of UCP-SCIL came across a fundamental problem – unavailability of a practical methodological approach to help the energy industry in its transformation towards more sustainable business models. An additional challenge concerns the fact that there is often a lack of expert guidance in the industry on how to create a real economic value with highly technology-driven innovations.

In inteGRIDy project, UCP-SCIL is developing a methodology that will provide a consistent guidance through the business modeling process and help pilot leaders overcome these challenges. This methodology is based on a notion of “blended” approach, which combines online coaching on business modeling with on-site workshops. The ambition is to go even further and develop an online platform that will allow new industry actors, as well as established players, engage in an interactive, easy-to-follow and action-oriented process of business model development for their novel business ideas or existing products/services/solutions.

The methodology that is at the heart of this platform allows the business modeling process to be the way to explore various business model options at hand. It also allows engagement in this process to be the moment when companies seek and find answers to vital questions that must be answered to discover which one of the available

business model options is the winning one. Examples of such questions include: what the most attractive market segment is and how big it is, or what the “job to be done” for the customer is, and what the ways to create a real value with the product/service/solution are. Hence, the business modeling methodology will allow not only opening up the opportunity space with various business model paths available to the company to take, but also closing it by guiding toward the most suitable business model options based on the way the business idea evolves.

Business model prototyping with business model patterns

Finding and exploring various available business model options has traditionally been a very challenging activity. One of the key developments that the work of UCP-SCIL within the inteGRIDy project brings about is making the process of business model ideation simple and easy to perform. The key to understanding the approach lies in so-called business model patterns, which a business model of any company consists of.

A business model pattern can be defined as a proven solution to reoccurring problems in a business model context. Examples of some of the most popular business model patterns include “Razor & Blade” (e.g. Gillette), “Freemium” (e.g. Skype), or “Peer to peer” (e.g. Ebay). Patterns vary in their types from being rather generic, and thus applicable to almost any industry, to more specific ones that make sense only in certain industries. Trying out different pattern combinations help spark creativity, identify blind spots, and most importantly, come up with new configurations that can unlock latent value.

In inteGRIDy, UCP-SCIL is developing a unique pattern library designed to support the business modeling process in the energy industry.

Already now, the pattern library includes 250+ time-tested patterns, which help industry players consider multiple business model options, particularly the ones that are not traditionally associated with the energy industry. For example, a digital transformation pattern pack allows exploring different ways of building digital into a business model and creating value for customer by focusing on digital capabilities.

Currently, business model patterns are organized in seven pattern packs. The UCP-SCIL team is further developing and enhancing a pattern pack specifically tailored to the energy industry, which in combination with other available pattern packs will open up various novel ways of creating and capturing value with the product/service or solution.

In combination with the Business Model Canvas, business model patterns become a powerful way of structuring the newly developed ways of creating and capturing value.

These developments will make business model innovation an accessible and easy to perform an activity for both novel and established players in the energy industry.

Conclusions

The goal of UCP-SCIL is to develop a business modeling methodology that will allow pilot leaders, and potentially the whole energy community, look at business ideas in novel ways, unlock hidden potential with technological innovations and configure viable business models. This methodology is now in its testing phase, where UCP-SCIL applies it to develop business models for ten pilots together with the pilot leaders.

Figure 1. Business model pattern packs on the Business Modeling Platform

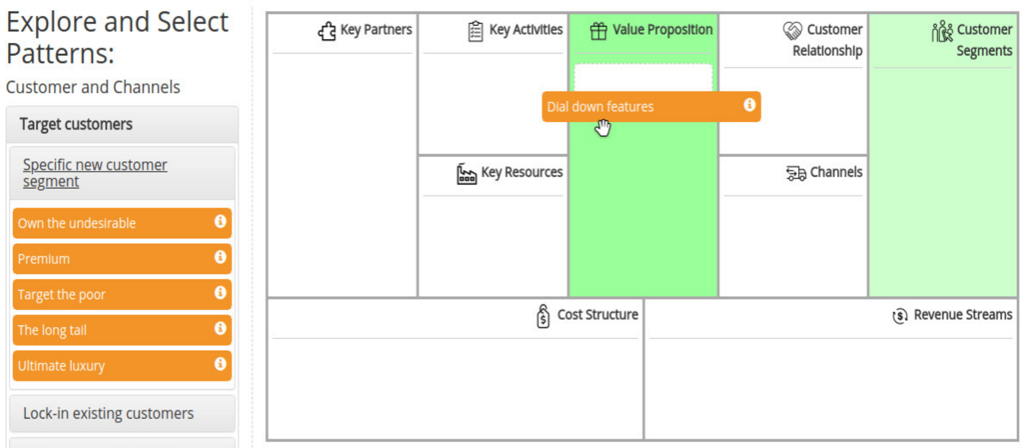

Figure 2. Business model configuration using the Business Model Canvas and business model patterns on the Business Modeling Platform

The inteGRIDy Reference Architecture: functional and technical specification

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ARTICLE INFORMATION

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Key words: *inteGRIDy Reference Architecture, 4+1 View Mode, Logical View, inteGRIDy tools, Pilots*.

ABSTRACT

This white paper is about the functional and technical specification of the inteGRIDy Reference Architecture.

The methodology for designing the inteGRIDy architecture is based on the 4+1 View Model. Indeed, the inteGRIDy software architecture is designed using five concurrent views: Logical View, Implementation View, Process View, Deployment View and Use Cases View.

This document focuses on the inteGRIDy Logical View, providing an overview of the macro functionalities offered by each architectural layer and the main interaction between them.

An important piece of the inteGRIDy Reference architecture is the Cross- functional Modular Platform (CMP), an integrated framework of different tools, models and mechanism envisioned to support the smartening distribution services.

The inteGRIDy Reference Architecture will be demonstrated in the ten Pilot sites, in which the innovative technologies and solution will be exploited to address the specific Project pillar: Demand Response, Smartening the Distribution Grid, Energy Storage, and Smart Integration of grid users from Transport.

In the inteGRIDy project, ENG is mainly responsible for designing the inteGRIDy Reference architecture and for leading the development activities of the inteGRIDy framework.

Introduction

This paper aims at providing an overview of the inteGRIDy Reference Architecture. The inteGRIDy architecture represents the knowledge base for the implementation of the inteGRIDy Distribution Grid Optimization Framework, a set of innovative technologies and solutions addressing the four Project pillars: Demand-response, Smartening the distribution grid, Demonstration of energy storage technologies and Smart integration of grid users from transport.

This document addresses the following aspects:

- the applied methodology for the provision of the functional and technical specification of the inteGRIDy architecture;
- the architectural design model adopted to describe the inteGRIDy software architecture;
- the functionalities offered by each architectural layer and exploited in the inteGRIDy pilots.

Methodology for designing the inteGRIDy architecture

The design of the inteGRIDy Reference architecture has been performed following a specific methodology: the starting point is the represented by the information provided in the task titled Elicitation of Stakeholders, Market Needs & Implementation Priorities and the task called Pilot Sites Surveys, Use Case Requirements & Business Scenarios;

then the Requirement Elicitation process is performed through the support of surveys and conference call involving both inteGRIDy technology providers and pilot leaders. The main outcome of this process is the definition of scenarios and use cases for each inteGRIDy pilot. Finally, a deep analysis determines the design of inteGRIDy architecture based the '4+1' view model of architecture[1]. The latter has been selected as architectural design model since this involves all necessary views to cover the functional and technical specification of the inteGRIDy reference architecture. Moreover, the 4+1 architectural model involves an iterative approach in the views specification helping to refine and better understand the requirements; this is compliant with the organization of the Project since expecting to deliver an updated version of the inteGRIDy Architecture at the end of this year. The architectural design represents the starting point for the development activities of WP4 inteGRIDy Distribution Grid Optimization Framework. This WP is organised in six tasks and each task is responsible for handling the implementation of Tools offering features related to the main research aspects addressed in the Project. This reflects the inteGRIDy approach of having macro- functionalities horizontally distributed into a layered architecture.

Figure 1 provides a graphical representation of the methodology for designing the inteGRIDy architecture.

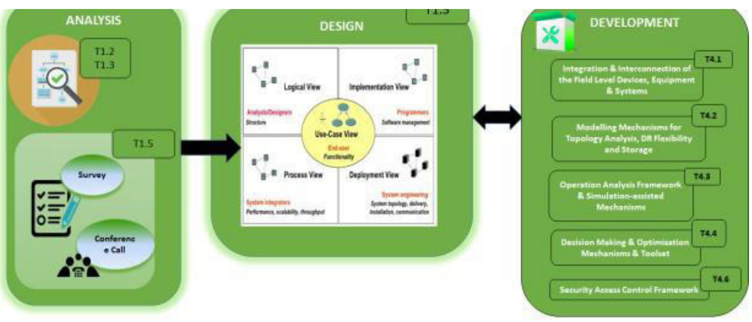

Figure 1. Methodology for designing the inteGRIDy Reference architecture

The inteGRIDy software architecture

As anticipated, the "The '4+1' view model of architecture" is adopted to describe the inteGRIDy software architecture. There are 5 concurrent views, each of which addresses a specific set of concerns allowing various stakeholders to find what they need in the software architecture:

- Logical view: involves a static approach of the system describing the architectural elements that deliver the system functionalities to end-users; this view is used to describe the macro-functionalities offered by each architectural layer and in particular by the inteGRIDy Cross-functional Modular Platform.
- Process view: deals with the dynamic aspects of the system; it is used to describe the main inteGRIDy process and the dynamic interaction of inteGRIDy tools.
- Implementation view: shows the system from the programmers' point of view; this view drives the development in relation to tools' features extension and development from scratch.
- Deployment view: depicts the mapping of the software onto the HW describing the physical environment, where the system is intended to run; this view is provided for all ten inteGRIDy pilots.
- Scenario view: describes the main functionalities of the system and works also as validation of the architecture after that the design is complete; it is useful since the information gathered in the elicitation phase are formalized in terms of use cases and functional requirements.

Moreover, the inteGRIDy Data View is explicitly added to the other five architectural views with the aim of describing the inteGRIDy Reference Knowledge Warehouse (RKW). The RKW refers to all information that is managed, stored, maintained or exchanged in the architecture. The Non-Functional Requirements that the inteGRIDy system should meet are described with the related implementation priority.

Focusing on the inteGRIDy Logical View, Figure 2 provides an overview of the macro functionalities offered by each layer and the main interaction between them. Starting from the button, the Field Middleware relying on physical equipment like sensors and meters collecting energy data to be processed by the upper levels. This layer is also composed of actuators connected to controllers handling the set points provided by the upper levels of the inteGRIDy architecture. Indeed, the communication interfaces and protocols are taken in account. One important piece of this architecture is the inteGRIDy Cross-functional Modular Platform (CMP), an integrated framework of different tools, models and mechanism envisioned to support the smartening distribution services. The CMP is organises in three layers:

- the Modelling and Profiling of Grid, DR/DSM & Storage systems Layer deals with the most suitable mathematical representation and modelling of both energy devices and energy actors behavioural profiling;
- the Operation Analysis Framework/Simulation Layer focuses on the implementation of analysis, simulation and forecasting techniques that are crucial for the analysis of the behavioural of all energy systems involved in moderns power system;
- the Decision Making & Optimization Mechanisms/Toolset Layer provides a set of tools able to perform optimisation and decisionmaking processes in smart energy scenarios.

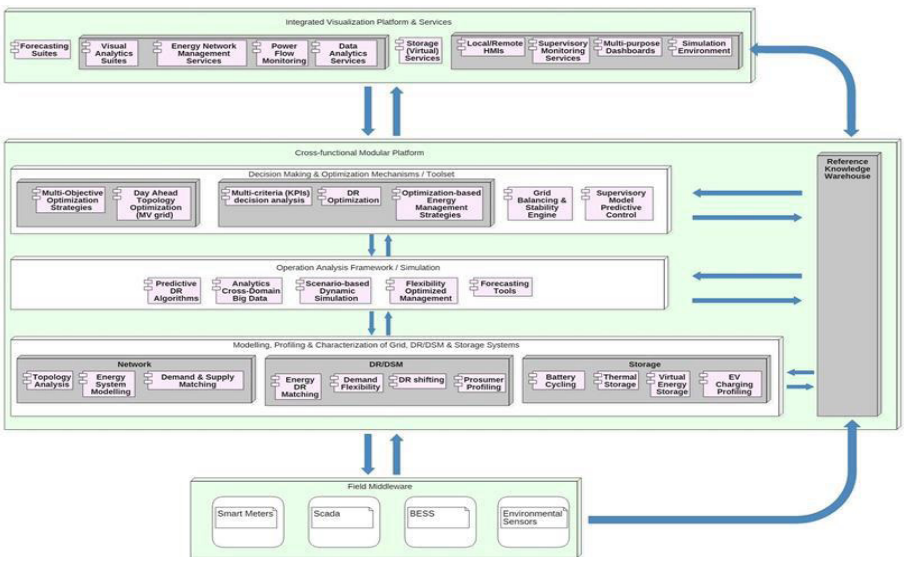

Figure 2. inteGRIDy Reference Architecture – Logical View

The top level of the inteGRIDy architecture represents the Integrated Visualization Platform (IVP) Layer that is related to the inteGRIDy tools providing interfaces, dashboard and service in order to exploit data processed inside the CMP. These data can be additionally analysed and interpreted; the main goal of this analysis is to enable all of the stakeholders like DSOs and final users to access to this data and to exploit and manage the functionalities provided by the CMP.

The interconnection between the CMP and both the upper layer and the top layer is covered by the Cross-functional

Standardized Interface API Layer; the latter plays an important role in this architecture since allowing and formalising this bidirectional data flow.

The Security Access Control Framework deals with all security aspects of the inteGRIDy Reference Architecture. It is applied both in the communication between the top and bottom layer with the CMP components, as well as in the handling of sensitive data stored in the Reference Knowledge Warehouse. The inteGRIDy tools will be developed with security-by-design.

The inteGRIDy Reference Architecture will be instantiated in the ten inteGRIDy Pilots. Indeed, during the development phase, the inteGRIDy tools will be enhances and extended in order to be compliant with the inteGRIDy Reference Architecture and the particular needs and objectives of the pilot(s) where they will be integrated. And in addition, each Pilot site will make the required adjustments to their already deployed infrastructures, so that the inteGRIDy technologies could be properly integrated and deployed.

The functionalities that each inteGRIDy tool provides over the inteGRIDy architectural layers are therefore exploited in the specific pilot site for addressing the four pillars on which the inteGRIDy project is based.

Conclusions

This document provides to the Reader an overview of the overall architecture of the inteGRIDy Framework focusing on the Logical architectural view. In the Project, this view is designed in order to capture the functionalities offered by the inteGRIDy Reference Architecture and in particular by the CMP. The Logical View is useful for Analysts and Software Designer but can be also exploited by Project's stakeholders.

The functional and technical specification of the inteGRIDy architecture, drives the development of inteGRIDy tools that will be exploited in the ten Project pilots.

The design of the inteGRIDy software architecture summaries the fruitful collaboration that has been established between ENG and all partners involved in the project with the role of technology providers and pilot leaders.

References

[1]. Philippe Kruchten (1995). Architectural Blueprints—The "4+1" View Model of Software Architecture. Paper published in IEEE Software 12 (6) November 1995, pp. 42-50

About Engineering Ingegneria Informatica S.p.a

Engineering Ingegneria Informatica S.p.a (ENG) is a leading provider of advanced Information Technology systems and services to diverse commercial and governmental customers, with a particular attention to the Energy and Smart Grid sector. Engineering Group is currently the first IT group in Italy has 40 branch offices in different countries. The Engineering Group operates through 7 business units; its innovation capability is supported by the Central Unit of Research & Development, with around 250 researchers currently involved in over 50 research projects co-funded by national and international authorities.

In the inteGRIDy project, ENG works on the definition of the functional and technical specification of the inteGRIDy software architecture and it is also in charge of leading the design and development activities of the inteGRIDy framework. Moreover, a strong participation is foreseen in tasks related to the optimization of energy flows, and, as large enterprise and IT company, also contributes to the definition of business models for the InteGRIDy future sustainability. ENG is the technology provider offering the inteGRIDy solution for the pilot demonstration of Terni (Italy).

Information about the authors

Since 2007, Marilena Lazzaro works as a researcher in Engineering's Research and Development Laboratory. She got his University Degree in Computer Science in 2004 from Palermo University. She got Master of Science in Computer Engineering in 2010 from Torino Politecnico.

In the inteGRIDy project, she leads the task responsible for the functional and technical specification of the inteGRIDy Architecture. Moreover, she leads the WP titled inteGRIDy Distribution Grid Optimization Framework by coordinating all the tasks assigned.

Demand Side Management Tools for Optimal Exploitation of Distributed Energy Resources Flexibility

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ARTICLE INFORMATION

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Key words: *Demand Side Management, Demand response, smart home, flexibility, DER modeling, Prosumer Profiling*.

ABSTRACT

InteGRIDy is a EU funded H2020 project that reflects, promotes and aims to push further the challenges and opportunities of the Smart Grid era with the implementation of modern technologies in ten different pilot projects across Europe.

TREK Development, being the technology provider for the pilot case of St-Jean in France, and in close collaboration with the local DSO and InteGRIDy partner, SOREA, has set the goal to design, develop and provide to the latter a set of tools for the realization of Human-centric Explicit Demand Response operations in a number of residential and commercial buildings in the area. The solution provided incorporates the concepts of DER modelling, participants' Comfort Profiling, Virtual Energy Storage and Demand Flexibility Profiling.

Introduction

For the past few decades, the electricity energy sector has met tremendous development with the implementation and exploitation of Smart Grids which have become the main enabler for the adoption of new concepts that empower technology providers and business model experts to push their limits towards achieving the envisioned "Smart Cities", while curving their way into the Energy Market.

Such groups have put forward the realization of ambitious concepts that create added-value for the already existing stakeholders of the energy market but most importantly extend the value chain by creating and including new participants, eventually reaching to the simple end-user. Probably, one of the most important evolvements of the Smart Grid era is the numerous emerging incentives that urge simple consumers to transform into active prosumers.

Among various concepts, Demand Response, in conjunction with "Smart Home" technology, seems to be the concept that is likely to succeed significant levels of customer engagement, achieving remarkable, both qualitative and quantitative benefits to the parties involved as well as the power grids per se. Moreover, Demand Response is expected to be mostly channelled into the energy market through quite recently introduced market players such as Aggregators, Energy Communities and VPPs, thus enriching their activities and establishing their role in the market.

Demand Side Management through "Smart Home" Innovation

Among InteGRIDy's main technical objectives is to demonstrate Distributed Energy Resource (DER) modelling, user profiling extraction and flexibility management techniques for the implementation of innovative DR mechanisms, in order to support optimized decision making in everyday distribution system operations. Such functionalities are being delivered to the stakeholders and/or end-users through user-friendly HMIs and Services, allowing optimal monitoring and control of the infrastructure while providing integrated Visual Analytics tools.

Demand Response in Residential and Commercial Users of St-Jean, FR

St-Jean de Maurienne in France, is the set where one of the numerous pilot- projects of InteGRIDy takes place. In this pilot project, "Novel Demand Response & Virtual Energy Storage Schemes" are being developed and showcased through the close collaboration of the Greek technology provider "TREK Development" and the local DSO "SOREA Energies & Communications", the latter acting also as an Aggregator. In the framework of this project, a portfolio of assets, deprived of residential and commercial buildings, has been selected to participate in the implementation of explicit Demand Response operations through the exploitation of DER modelling, Consumer Potential Flexibility Profiling and Virtual Energy Storage techniques. Lighting, HVAC and Water Heating devices are the types of loads included in the use cases of this pilot project to be monitored, profiled and controlled through DR signals.

Field Middleware Management Layer

The solution comprises of both dedicated field equipment (mostly off-the-shelf products) and software tools developed by TREK. The field equipment constitutes a mesh network of wireless sensors, actuators and meters, all coordinated by a local hub (gateway) which aggregates and feeds all field data to the application and storage layer and also communicates control signals to the devices. The data extracted from the field deprive of indoor environmental measurements (luminance, air temperature, humidity and water temperature) and other contextual data such as device operating status/mode, energy consumption and occupancy.

This data flow is then fed into the application server which is located in TREK's premises and hosts the two main applications of the platform, namely the *Demand Side Energy Profiling Engine (DSEP) and the Visualization Analytics Engine (VAE)*.

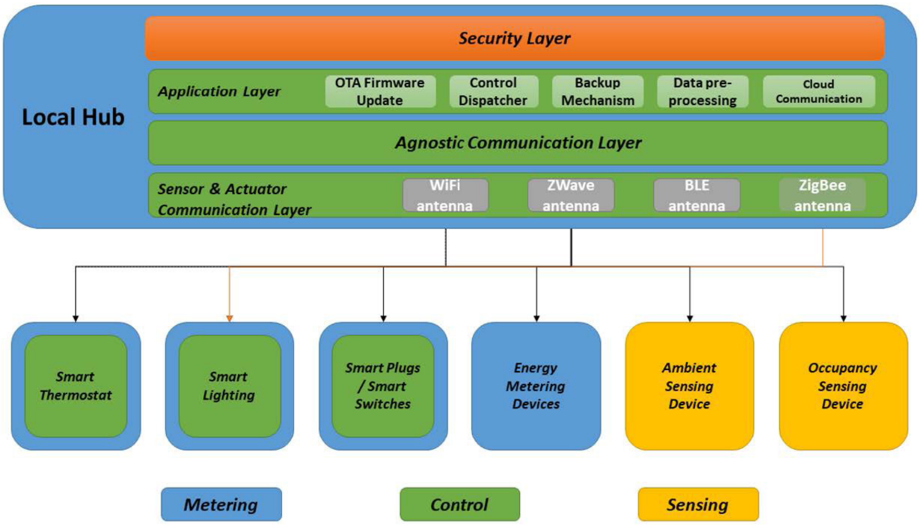


Figure 1. Field-Middleware Management Layer

Demand Side Energy Profiling Engine

The DSEP lays at the core of the platform and is in charge of processing field data in order to derive comfort and DER flexibility profiles, which enable the accurate decision making within the building environment according to different business scenarios.

Sensorial, operational and consumption conditions are the information that the DSEP Engine requires for the extraction of comfort profiles, further correlated with device profiles to enable the accurate decision making in building environment. The main objective of the tool is to enable the establishment of an automated framework in a non-intrusive way, in order

to facilitate the performance of explicit DR campaigns by the aggregator/DSO while maintaining the acceptable level of comfort for the participants.

Visual and thermal comfort boundaries are derived and continuously updated through the observation and recording of user relevant preferences. Subsequently, a discomfort utility function is incorporated to quantify and assess the impact of demand response operation on consumer's comfort, thus revealing the potential flexibility factor which is critical for the realization of an automated demand control and optimization strategy.

Along with the derivation of user profiling the realization of a consumer-centric demand flexibility framework, requires also DER modelling which stands for mathematical formulations for the calculation of electricity consumption of each device type as a function of dynamic input data and static parameters that affect DER operation. In addition to this purpose, the enhanced DER modelling offers impact evaluation of each DER operation on indoor environmental conditions.

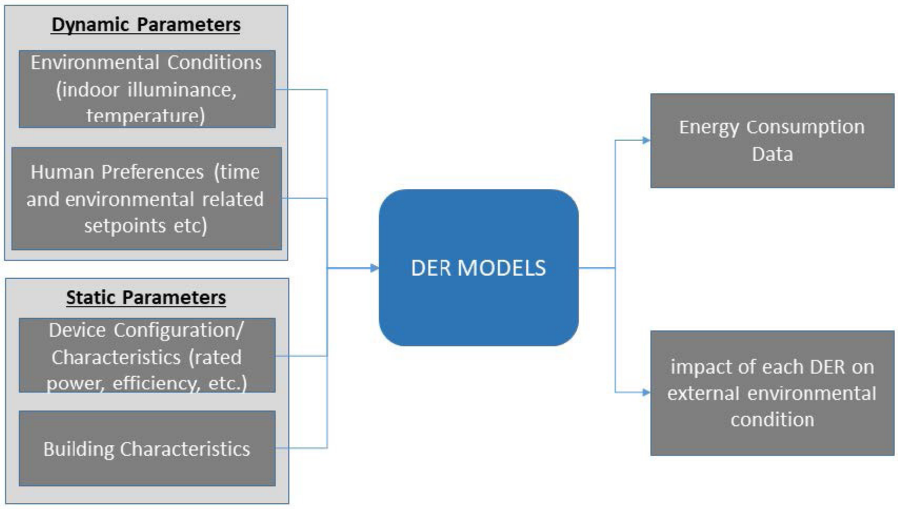


Figure 2. Prerequisites and outcomes of DER Modelling

Context Based Demand Flexibility Profiling is further enhanced by incorporating the **Virtual Energy Storage** concept, examined also in InteGRIDy project. Therefore, a combined building mass and thermal load modelling is required to act as the simulation engine that will facilitate the real-time analysis of building thermal conditions, enabling the accurate forecasting of thermal losses/gains of the building and subsequently (by combining device operational characteristics) Demand Flexibility potential calculation. A high overview block diagram of the DSEP Engine incorporating the aforementioned components is illustrated in Figure 3

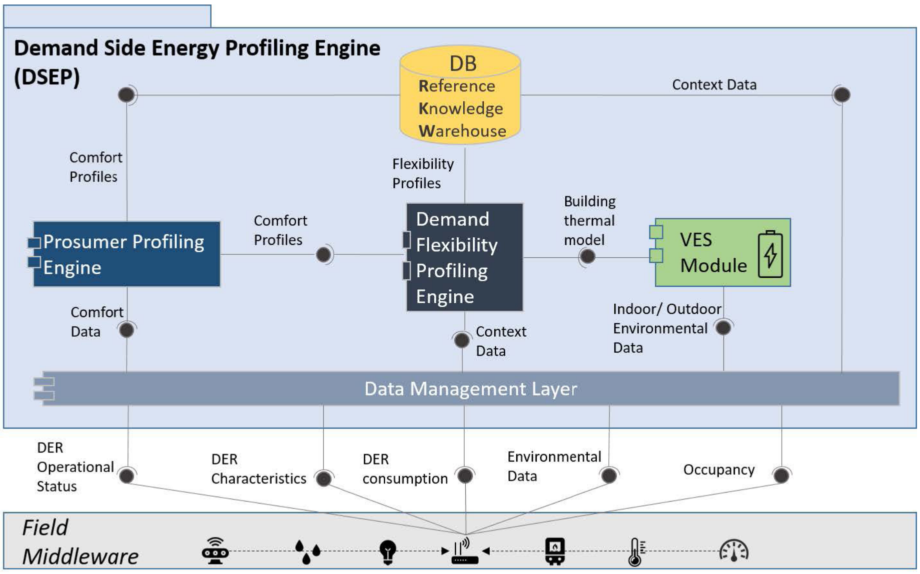


Figure 3. DSEP Engine component overview

Visualization Analytics Engine

The VAE is the interface with the beneficiary of this platform, namely the DSO/Aggregator, towards asset monitoring, analytics, decision making and dispatch control. As illustrated in figure 4, a number of modules are available to provide full functionality to the stakeholder.

Complementary to real time decision making, data analytics are performed over raw data streams flowing from DERs as well as processed data (e.g. demand flexibility). Enriched visualization techniques present the outcomes of the analytics process in a visually appealing way towards facilitating quick and accurate decision making. To this direction, portfolio analysis is available incorporating functionalities such as portfolio clustering/classification depending also on the selection among different business objectives. In addition, “Trend Analysis” functionality is supported by the tool. The main objective of this feature is to correlate heterogeneous data attributes and KPIs in order to extract trends and subsequently outliers in portfolio performance.

Moreover the “What if Analysis” module of the VAE is the interface of the user with the optimization layer of the platform as well as the dispatching functionality. Specifically, this module offers the optimization of asset selection and DR signals distribution in respect to a certain Demand Side Management campaign as well as the ability to actually trigger the DR signal towards the associated assets.

Finally, the evaluation of assets’ performance in respect to certain DR campaigns (achieved vs requested) and the implementation of possible remuneration schemes by the DSO/Aggregator are available.

The aforementioned tools are offered to the stakeholder (DSO) through a proper user-friendly, web-based UI. The user applies filters to achieve different levels of system detail targeting on the performance evaluation of a) the whole portfolio b) a subsection of the portfolio depending on the type of assets (commercial/residential) or geographical position and c) a specific asset (drill-in functionality). A comparative view is always available to evaluate the performance of a specific asset versus the normalized aggregated performance of the whole portfolio.

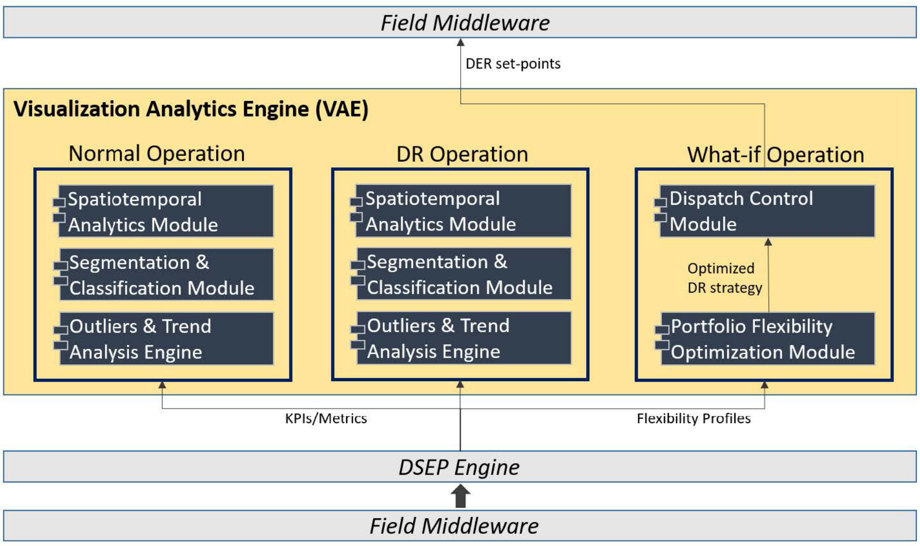
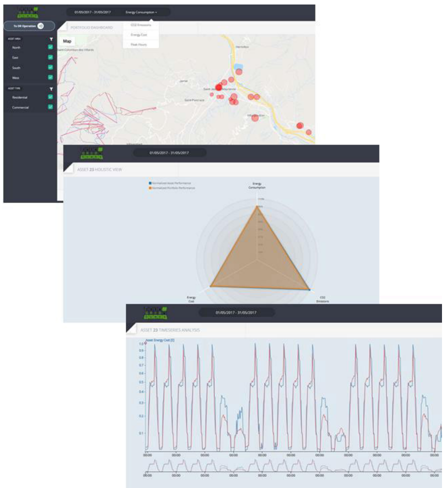


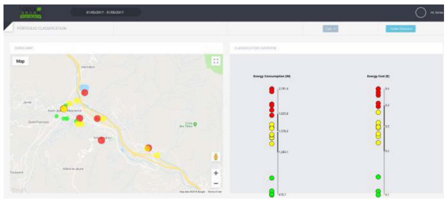
Figure 4. VAE Engine component overview

Table 1 illustrates a summary of the VAE's main functionalities along with indicative snapshots of the corresponding Dashboards.

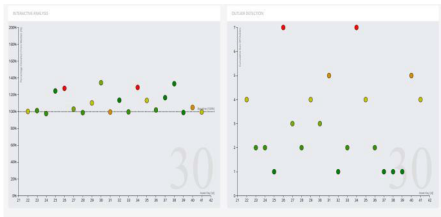
VAE Modules	Functionality GUI/Dashboard
Normal Operations	Assets geographical representation, visual on analytics on KPIs (e.g. Energy Consumption, Energy Cost, CO2 Emissions), drill-in functionality
DR Operation	Asset geographical representation, visual analytics on KPIs (e.g. Potential Flexibility, DR Performance)
Portfolio Analysis	Portfolio Classification over different business scenarios (eg.consumption minimization, CO2 reduction, costminimization)
Trend Analysis	Correlation of heterogeneous data attributes and KPIs in order to extract trends and subsequently outliers in portfolio performance.
What-if on/Dispatch Control	DR campaign Operati optimization and dispatch signal



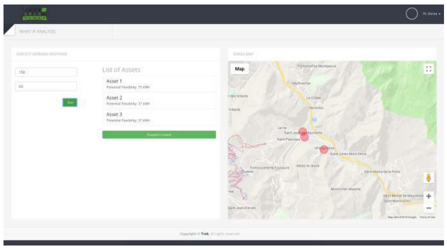
Normal Operations



DR Operation



Portfolio Analysis



Trend Analysis

Conclusions

User energy preferences profiling, DER modeling and DER Demand Flexibility evaluation are proven to be fundamental elements towards reaching successful human-centric Demand Side Management especially when dealing with residential assets. Trek Development has developed a complete platform based on those elements in order to offer Demand Response operation for the DSO SOREA, acting also as an aggregator within InteGRIDy project. Both hardware and software infrastructure are currently being commissioned to the associated assets and the first results will be soon available.

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About TREK Development

TREK Development is a consultancy and technology development services firm, providing Information Technology (IT) services to small, medium and large Organizations all across Europe, North Africa and the Middle East. TREK aims at providing flexible solutions for small and medium-sized electricity consumers and integrated solutions for electric utilities and service providers in the field of demand management (Aggregators).The business strategy of TREK (deployed also through the subsidiary companies belonging to the TREK Group of Companies) includes research and development of advanced technologies, to create a full suite of solutions and products appealing to everyone involved in the electricity market.

Information about the authors

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Challenges and opportunities to inteGRIDy innovations

Otilia Bularca, Ana-Maria Dumitrescu

SIVECO Romania SA

ARTICLE INFORMATION

Published 18 January 2019

Key words: *Energy sector, R&D drivers, obstacles and barriers, inteGRIDy innovations*.

ABSTRACT

This document offers an insight into the estimated effects of key external factors (political, economic, social, legal, technological and environmental) to the proposed inteGRIDy challenges (Demand Response, Smartening the distribution grid, Energy Storage Technologies, Smart Integration of grid users from Transport) starting from the pilot's deployment activities. The main drivers of R&D investment and obstacles to innovation in the energy industry in general and related to inteGRIDy are approached. The content presents the results of an in-depth analysis conducted by all involved partners.

Introduction

This document summarizes the impact of main drivers and obstacles to R&D investment in energy sector and external factors influencing inteGRIDy proposed innovations: Demand Response, smartening the distribution grid, energy storage technologies and electric vehicles.

An extensive analysis has been undertaken in order to provide valuable information for the Consortium in the implementation of cutting-edge technologies, solutions and mechanisms in a scalable Cross-Functional Platform, connecting energy networks with diverse stakeholders. Within inteGRIDy project SIVECO coordinated this effort.

The outcomes presented in this document are based on two public reports on Obstacles & Barriers related to inteGRIDy Framework [1] and Smart Grid Deployment, Infrastructures & Industrial Policy applicable to the inteGRIDy pilot cases [2].

Challenges and opportunities

inteGRIDy H2020 project is an Innovation Action aiming at demonstrating demand response, smartening the distribution grid, energy storage distribution and Smart Grid transport integration in 10 pilot sites across Europe (UK, Spain, France, Greece, Cyprus, Italy, Romania and Portugal).

To assess the relevant aspects regarding the investment in innovation in the energy industry and also the major obstacles to innovation the strategies, policies, market demands, existing technologies each pilot country provided information about:

- ☑ Energy market structure and R&D investment
- ☑ Smart Grid relevance in partner countries
- ☑ Emergent structures sustaining energy innovative investment

Early assessment of drivers and obstacles sets the baseline for an appropriate planning and management of innovation expectations.

Even though the most important driver to innovation in energy industry is the common EU development strategy in energy for a long term each member state faces a different set of macro-environmental factors.

Innovation challenges in energy sector are country-dependent as the technological advancement sets a coherent framework for the communication between the R&D and public/business sectors.

With Demand Response the consumer itself seems to be the key factor for a successful implementation and the focus should be on awareness, engagement and identifying the possibilities of incentivizing the consumer.

The endeavour of smartening the distribution grid is supported by long term strategies because the costs with the infrastructure are high and the results are not visible immediately.

Looking into energy storage technologies and electric vehicles integration in smart grid regulation represents the main factor

limiting the innovation investments. On the one hand DSOs are not allowed to own and operate storage devices due to policies. On the other hand storage devices are very expensive and the viability of the investment on the long run is yet to be demonstrated.

Mainly, the efforts of EU and governments converge in an attempt to link business – academic – public – private institutions. An interesting example is provided by France with The Internet of Electricity which promotes a new business model via including Telecom operators in the deployment of Smart Grids; the role of Telecom being to provide the technologies needed to make the electrical system smarter.

As drivers, inteGRIDy partners have mentioned the importance of supporting with regulations the energy communities like aggregators, renewable energy cooperative and the regulation of such structures like feed-in tariff/green certificates and time of use.

EU-28 governments are committed to reducing carbon emissions and they make efforts to stimulate innovation but only partially support market access, i.e. the focus should be on deploying new technologies while also helping to make them part of the mainstream.

Going further with the identified obstacles to energy sector – the different price structures and inconsistent regulations are among the most mentioned by inteGRIDy partners. Beyond this there are some peculiarities that are worth mentioning.

Spain is the only country in the world to tax home renewable energy generation.

UK is the first country to claim the importance of interoperability of smart meters. Going large scale with SMETS 1, UK government faced the reality of meters reverting to classical meters when changing suppliers. It lead to a second deployment with meters that can be used in 'smart mode' if suppliers are switched (SMETS 2).

Italy completed a full roll-out in 2011 and is now working on replacing the smart meters with new generation ones that comply with the new set of functionalities and communication protocols.

Greece runs many demonstrators within R&D projects based on renewable energy sources while still using coal technologies on a large scale.

Cyprus, Portugal and Romania are among the countries that try to catch up with national strategies and cross-sector communication.

Macro-environmental analysis

The results of the macro-environmental analysis show on the one hand that the political, social and environmental factors support inteGRIDy-like innovations. On the other hand the economic, technological and legal factors vary from one country to another. For instance, the level of consumer engagement is affected by country specific indicators like gross domestic product, investment priorities and DSO particularities.

The economic factor may be a barrier considering the prioritization of investment and budget allocation.

An applied example for technological factor is the importance of the maturity level of smart metering solutions which reflects in the success rate of deployment.

But there are also exceptional cases. For instance, the smart metering architecture in place in Italy does not (yet) meet the minimum requirement considering 15' readings resolution even if Italy was one of Europe's forerunners in implementing smart metering systems (with 95% coverage in 2011) and is now deploying 2nd generation smart meters.

Alongside all mentioned macro-environmental factors the DSOs seem to set the trend in the energy market. From monopolistic to competitive markets, ancillary services are not easily promoted and integrated in the energy market due to inconsistent regulations.

Conclusions

Considering R&D impact inteGRIDy partners have scanned for existing or emergent structures supporting R&D investments in terms of contributing to research, disseminating results, making recommendations, accelerating business models or mandating for large demonstrations.

The issues faced to innovate in energy sector are similar for European member states with particularities based on smart metering roll-out status, renewable energy sources penetration, available infrastructure and political will.

The emergence of new business model and structures increases the importance of the active consumer in the value chain and the economical factor needs to consider how to motivate consumer behaviour to create the desired trends.

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About SIVECO Romania

SIVECO Romania SA is a private shareholder company, established in 1992, located in Bucharest, Romania. During its twenty-five years of existence, SIVECO has become one of the most important Romanian providers and software integrators of Cybersecurity &Big Data, ERP, eLearning, eGovernment, eHealth, eBusiness, eAgriculture, eCustoms solutions and turnkey projects acting both on the internal and international markets. Moreover, SIVECO has gained a solid reputation on international markets by developing successful projects together with several international companies, collaboration that has blossomed into genuine partnership over the years. SIVECO can provide all services on the whole life cycle of the information projects: analysis of users' requirements, design, development, testing, implementation, end-users training and technical assistance, system maintenance. SIVECO has significant experience and an exceptional track record in R&D and R&I projects, having been involved as technological provider and as coordinator in many European and national research projects. In particular, SIVECO has established considerable experience and expertise in the implementation of large-scale user-centred systems at national level.

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A White Paper on Standardisation Analysis, Regulations & Privacy Policy for the EU Smart Grid

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ARTICLE INFORMATION

Published 01/03/2019

Key words: Standards, regulations, privacy, interoperability, compliance, impact, technical and commercial arrangements, data protection, data management, smart meters.

ABSTRACT

A close look at the EU standards, regulations and privacy policy is necessary to identify how legislation influences smart grid transformation. The EU Directives are accepted, translated and implemented by the EU-28 countries. This whitepaper addresses the following aspects of EU legislation on smart grids:

- Interoperability
- Compliance and Impact
- Data protection and management
- Smart meters

The paper summarises WP2 findings, written in a way to encourage readers to familiarise themselves with the legal aspects of the EU Smart Grid, with examples from inteGRIDy research findings.

Introduction

The H2020 inteGRIDy project is based on four aspects (pillars) to modernise the legacy EU energy grid:

- ☑ Enable the grid to store energy
- ☑ Enable access for electric vehicles to connect to the grid
- ☑ Interact with consumers to shift energy usage when necessary (Demand Response)
- ☑ Introduce technologies, architectures and engineering practices to smarten the grid to make it more reliable and resilient.

In order to achieve these goals, a regulatory framework is needed. Standards set out rules (protocols) for the development and adoption of products, allow compatibility, interoperability, interconnectivity and have an impact on market development. In order to understand how legislation impacts Smart Grid transformation, it is necessary to consider the EU standards, regulations and privacy policy.

Regulating the EU Smart Grid

The EU directives have been accepted by the EU-28 countries, translated and implemented into the national legislation of each member country. This paper addresses the following questions regarding EU legislation on smartening the grid:

- ☑ Interoperability: What are the main EU standards for interoperability?
- ☑ Compliance and Impact: What is the impact of legal policies and market design on the smart grid transformation?
- ☑ Smart Meters: What determines the interoperability and adoption of smart meters in the EU?
- ☑ Data protection: What regulations are there for privacy & cybersecurity; and how is data handled?

The establishment of a regulatory framework, and the compliance with standards and EU/national regulations, are essential for ensuring interoperability. In addition, the impact of legislation and market design on technical and commercial arrangements that enable smart grid transformation needs to be considered. For example, Smart Meter is the main enabling technology for Demand Response, at least for domestic users. Consumers may participate in Demand Response events, which could shift peak energy usage to provide financial and environmental benefits. What makes a Smart Meter interoperable will depend on its capability for two-way communication between the DSO and third party devices using a high level, semantic communication protocol. Smart Meters reveal vital information on the energy consumption behaviour of consumers; therefore they need to comply with data protection and privacy standards. The adoption of Smart Meter technology may vary by member country, despite compliance with the EU directives.

Interoperability

In order to describe the regulatory framework that leads to interoperability, a list of standards and EU/national regulations are presented in Table 1. Within the inteGRIDY consortium, all eight members (UK, Italy, Spain, France, Portugal, Greece, Cyprus, and Romania) have transposed the main EU Directives that cover market liberalisation, regulations, safe supply of energy, price transparency and regulation, reduction of energy consumption and renewable energy.

EU Legislation
Market Liberalization IME3
Regulation (EC) No 713/2009
Safe Supply 2005/89/EC
Directive 2008/92/EC on Price Transparency & Regulation (EU) No 1227/2011
Reduction of Energy Consumption 2012/27/EU 2010/31/EU
Renewable Energy 2009/28/EC

Table 1. Energy Directives transposed by the EU countries

However not all countries have implemented them. For instance, new standards that guarantee interoperability with third party devices are required in Italy. Interoperability is embedded in new developments or planned infrastructures in Greece and Cyprus; no compliance issues were found in Portugal; and in Romania interoperability was assured by Smart Meters.

Compliance and market impact

In order to gauge legislation and market impact, there is a need to understand how the EU member countries comply with the key standards and their effect on some of the key technical and commercial arrangements that are of major significance to the DSOs.

A list of standards (core, demand response, storage and electrical vehicles) below shows the regulations compliance by the partner countries.

Core standards	
Generation Management Systems; EMS, DMS; DA; SA; DER; AMI; DR; E-Storage	EN 61970 EN 61968
Energy Market Information Exchange	EN 62325
DER; AMI; DR; Smart Home; E-Storage; E-mobility; Data Exchange for SM Reading, Tariff and Load Control	EN 62056
Security for All Systems	EN 62351
Functional Safety of Electrical/ Electronic/Programmable Electronic Safety Related Systems	EN 61508
Generation Management Systems;EMS, DMS; DA; SA;DER; AMI; DR; E-Storage	EN 61970 EN 61968

Table 2. Core standards

Demand Response Standards	
DR Adoption: Smart Grid - Application Specification	EN 50491-12
System Interfaces & Communication Protocol	EN 62196

Table 3. Demand Response standard

Energy Storage Standards	
Core Information Model and Language for the IEC/EN 61850 Series	61850-7-2
DER	IEC 61850-7-420
Batteries	IEC 61850-90-9
Distributed Control and Automation	EN 61499

Table 4. Energy Storage standards

E-mobility Standards	
EV-Communication E-mobility; Home & Building Management Systems	EN 61851
Industrial Communication Networks	IEC 62443
Conductive Charging of Electric vehicles	IEC 61850-90-9
Distributed Control and Automation	EN 62196

Table 5. E-mobility standards

Findings from the inteGRIDY research show that:

- The impact of legal, regulatory & market design varies across the eight inteGRIDy countries. It is evident that even if the relevant directives are translated, it does not necessarily lead to implementation.
- Within the eight inteGRIDY member countries, the most important smart grid legislation issues are related to the physical and the communication infrastructure and their operation.
- UK, France, Spain and Italy are leading countries in terms of maturity in the legislative framework and in the implementation of EU rules.
- UK and Italy are leading in terms of Demand Response market regulations.
- There is a lack of national regulations regarding energy storage in Cyprus, Portugal, Greece, and Romania.
- Italy, UK and France implement a Smart Meter rollout strategy, whereas rollout is managed by DSO initiatives in Spain, Portugal, Greece, Cyprus and Romania.

Compliance and market impact on some of the most important technical and commercial arrangements are shown in Figure 1. These arrangements include Demand Side Response, Smart Meters, electrical energy storage and other forms of balancing such as electric vehicles.

For example, Figure 1 shows that legislation is consistently present for Smart Meter roll-out implementation among the inteGRIDy member countries

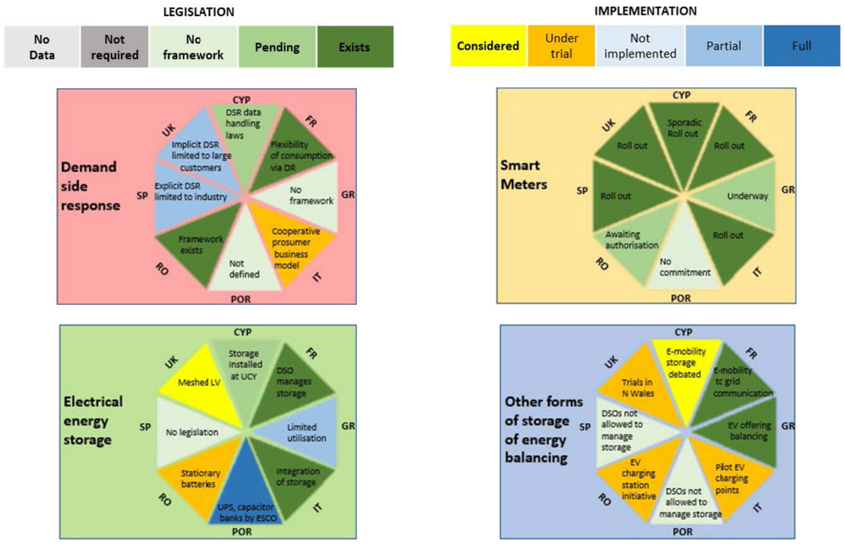

Figure 1. Impact of legislation on technical arrangements, by inteGRIDY partner country, on Demand Side Response, Smart Meters, electrical energy storage, other forms of balancing (electric vehicles).

Conclusions

H2020 inteGRIDy research is focused on energy storage, electric vehicle integration, Demand Response and technologies for smartening the grid. The EU Smart Grid legislation corresponding to these pillars sets rules for the development and adoption of technology. The legislation framework, standards and regulations for smart grids provide compatibility, interoperability and interconnectivity in grid components. One such example is the legislation for Smart Meters, which is the enabling technology for domestic Demand Response. The Smart Meter rollout within the inteGRIDY countries shows commitment for roll out in countries where the legislation is in place. Legislations on smart grid aspects such as Demand Side Response, storage and other forms of energy balancing, such as electric vehicles, show variations by country. Although the EU Energy Directives are translated, the implementation may not take place. Missing regulations especially in the case of energy storage may hinder development.

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About Teesside University

Teesside University Centre for Construction Innovation of Research (CCIR) is a research centre with a focus on building integrated management and energy Demand Response tools. FP7 (SIVECO, IDEAS), H2020 (DrBoB, inteGRIDy, E-DREAMS and REACT) are

some of the EU funded past and present projects participated by the CCIR group.

Information about the author

Hatice M. Tuncer is a Research Associate at Teesside University Smart Systems and Energy Informatics Research Group. She has a background on electronics and communications engineering, MEMS and nanotechnology. She is involved in the adaptation of Energy Management tool NEMO, into the inteGRIDY Barcelona pilot, where photovoltaic energy generation, battery storage and Demand Response functionalities are incorporated into the building management system of a sports complex.

Special thanks to Prof. Prof Delfanti for his peer review of this whitepaper.

Dynamic energy pricing in combination with demand side management

Aleksandra Krivoglazova
PH Energia Lda

ARTICLE INFORMATION
Published March 2019
Key words: *indexed tariffs, demand side management, wholesale electricity market.*

ABSTRACT

In recent times, the implementation of the dynamic pricing in the electricity supply is getting more and more attention. The dynamic (= indexed to the wholesale electricity price) tariffs are characterized by its changeable nature on the hourly basis, depending on the price at which there is being sold the electricity in the wholesale market. The implementation of the Indexed Tariffs works well in combination with Demand Side Management resulting in the significant savings in the electricity bill when the major part of loads are shifted from the peak hours to off-peak hours.

Thus, in the inteGRIDy project, one of the global goals of PH Energia is to analyse the impact of electricity cost variations on the capability of Demand Response implementation. More specifically, it would be tested in the Lisbon Pilot Project in order to provide energy demand flexibility (the change of EVs and ice tanks charging profile) and the subsequent savings in the electricity bill.

Introduction

In recent times, the implementation of the dynamic pricing in the electricity supply is getting more and more attention. With the evolution of the energy sector, the dynamic (indexed to the wholesale electricity price) tariffs appeared in order to bring monetary value for the final energy consumer as well to achieve the objectives stipulated by policies such as increase of the reliability of the electrical system and promotion of energy production from the renewable energy sources.

It is also expected that the final consumers would be more encouraged to reduce the energy consumption as peak hours or to adjust its consumption profile in accordance with the energy costs, meaning to transfer the loads to the more profitable periods when the energy prices are lower.

It is also expected that the final consumers would be more encouraged to reduce the energy consumption as peak hours or to adjust its consumption profile in accordance with the energy costs, meaning to transfer the loads to the more profitable periods when the energy prices are lower.

Indexed Energy Tariff implementation

The indexed tariffs are characterized by its changeable nature on the hourly basis, depending on the price at which there is being sold the electricity in the wholesale market. Thus, the final energy customer would have hourly different price for the energy he consumes. As a result, it may happen that in some months he would pay less for each kWh of the consumed energy when compared to the fixed tariffs. However, it may also happen that in a determined month, when the electricity price in the wholesale market rises significantly, the customer would be obliged to pay more.

PH Energia has developed a formula for the indexed energy tariff calculation:

$$PE_{(h)} = P\ NAT_{(h)} + (P_{OMIE(h)} + CGS_{(h)}) \times (1 + Losses_{(h)}) + K$$

Where:

- **PE(h)** = Energy price for a certain hour (€/kWh);
- **P NAT(h)** = Hourly Network Access Tariff published by ERSE (€/kWh);
- $P_{OMIE(h)}$ = Hourly electricity cost in the OMIE daily market – Portugal (in €/kWh);
- $CGS_{(h)}$ = Hourly Cost of the Management System (0.0028 €/kWh);
- $Losses_{(h)}$ = Hourly losses coefficients for the corresponding time period published by ERSE (in %);
- **K** = Fixed value corresponding to the spread of the energy trader (in €/kWh).

It is important to bear in mind that in the wholesale market, there may be wide variations in the electricity price, as it happened for example in September 2018, when the electricity price on 17th of September at 21:00 was 81,82 €/MWh and on 24th of September at 06:00 it decreased until 50,42 €/MWh. This instability in the electricity price may happen due to several reasons, including climate. For example, in Abril 2018 the major part of the energy was produced from renewable energy sources, with hydro and wind energy among the main ones, contributing for a low energy cost (42 EUR/MWh) [1]. Therefore, the lack of abundant precipitation and wind, coupled with the high energy demand may result in the significant increase of the electricity wholesale price. From the perspective of the indexed tariffs implementation, it is possible to group the years in "good" year and a "bad" year. A good year is characterized by medium temperatures and high precipitation, resulting in dams

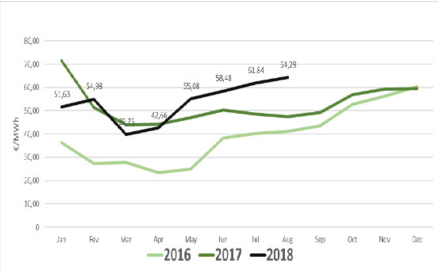

Figure 1. OMIE wholesale electricity prices evolution in 2016, 2017 & 2018 (Source: OMIE)

being filled with water, whereas the bad year is characterized by high temperatures and low precipitation, resulting in the dams being empty.

As it is possible to observe from the Fig. 1, the year 2016 that was characterized by high renewable energy production (hydro energy and wind energy) could be the most profitable, when compared to 2017 and 2018, since the market electricity price was low. The year 2018 can be characterized as a "bad year", since the wholesale electricity prices reached shocking values.

In order to make the implementation of the indexed tariffs economically feasible at any time, PH Energia is going to combine the Indexed tariffs with Demand Response through the Electrical Vehicles and Ice tanques charging profile management.

Indexed Tariff in combination with Demand Side Management

The implementation of the Indexed Energy Tariff (Real-Time Pricing) is very interesting for studying the loads flexibility and Demand Side Management [2]. With the application of these tariffs, it is expected that the energy customers would be informed about the electricity prices, and would be encouraged to reduce their energy consumption at peak hours or to shift the biggest loads to the off-peak hours, in order to reduce their electricity bill.

According to our analysis of the electricity wholesale prices in 2018, due to the high wholesale electricity prices, there was no advantageous environment for the Indexed Tariff implementation. For this reason, PH Energia proposes the idea to implement the indexed tariffs in combination with Demand Side Management to attribute the bigger loads to the low prices tariff times. It would be achieved by using the ice tanks to store cold and scheduling the EV charging periods to match low price periods of the dynamic tariff in order to reduce the charging in peak hours and increase its charging in off-peak hours, replacing the existing fixed-tariff system.

Conclusions

According to the preliminary simulations realized by PH Energia, the implementation of the Indexed Tariffs would work well in combination with Demand Response techniques.

The goal of PH Energia is to give a significant contribution to the business model development for the Portuguese Pilot which would permit to lower the electricity costs of the Lisbon Municipality Building using our knowledge and experience in Indexed Tariff Implementation and study the possibility of its combination with loads shifting.

About PH Energia Lda.

S'mples energia

PH Energia, Lda is an electricity retailer company that is aimed to provide market energy solutions to consumer, commercial and industrial applications. It makes use of the experienced and

knowledgeable team in the energy sector, in both business and academic field, to develop and integrate both services and products that present a valuable proposal. Through brand Energia Simples, PH Energia sells energy in the Portuguese market, residential, business and industrial sectors. With an innovative, digital and straightforward approach to the customer service, based on openness and trust, the company offers one-to-one advice and support to every customer. PH Energia also introduced market indexed tariffs, charging over the daily energy market price a transparent spread, in each month, to the domestic segment. Fully committed to the environment and efficiency PH Energia invests in a push market strategy that looks forward to market micro-production centres using solar energy and technology that monitors and processes information, providing efficient, economically and environmentally, in all segments.

Since the beginning of its commercial activity, Energia Simples has grown significantly from 11,8 GWh of the sold energy and 94 customers in May 2015 to 1012 GWh and 15 000 clients in December 2018, holding the 7th place both in sold energy and number of customers.

Information about the authors

Aleksandra Krivoglazova is a Project Manager working in PH Energia specialized in Smart Grids, Energy Efficiency & Environmental Sustainability

1 www.omel.es/pt/inicio
2 www.sciencedirect.com/science/article/abs/pii/0031320 39400154E

Building Transformation – From standard to smart. A demand-side response (DSR) solution demonstration.

Justice Agbo / Tom O'Reilly

Siemens Plc.

ARTICLE INFORMATION

Published: 17th April 2019

Key words: *Smart, Energy, demand- side management, efficient solution, cloud-based platform*.

ABSTRACT

In recent years, the Isle of Wight council building managers has been thriving to ensure energy is used in a more sustainable way within their estate through their building management system (BMS). The challenge was to establish if there were any loads that could be affected within the Isle of Wight's commercial and industrial buildings, by reducing demand and using less energy to achieve a better economic and more efficient solution. The Heights Leisure Centre was selected as the pilot building.

Siemens integrated the existing building control and energy infrastructure with a smart building management system, turning a conventional building into a connected building.

This meant occupants can experience more comfortable temperatures, the Council can lower their energy spend and the planet can benefit from reduced carbon emissions.

Introduction

Siemens and Isle of Wight Council's buildings project were developed in relation to the 'InteGRIDy' programme's demand-side response (DSR) pillar. The overall purpose of the project was to establish if there were any loads that could be affected within the Isle of Wight's commercial and industrial buildings, by reducing demand and using less energy to achieve a better economic and more efficient solution. For this project, The Heights Leisure Centre was selected as the pilot building.

Siemens recognised that in order to design the optimum solution, there needed to be improved understanding of how the building operated and a clearer picture as to where and how energy was being used. Although the majority of the building's assets were controlled by a building management system (BMS), there was no visibility of the detailed operation of equipment and what was happening in the centre's spaces.

The challenge for Siemens was to deliver a solution that greatly improved the existing data logging system. It had to be a flexible platform with remote capabilities to allow information to be shared easily and provide the project's stakeholders - located at various locations across the UK and Europe - with the ability to easily visualise vast amounts of data.

Introduction Solution implementation

The first step we took to delivering an effective solution was to install the Siemens Navigator platform. This allowed immediate access to the building's data by the various project stakeholders. Navigator is a proven, integrated, cloud- based platform, that is used to collect and store data for detailed reporting and advanced analytics. In this instance, it provided visibility of the building's performance and its energy use."

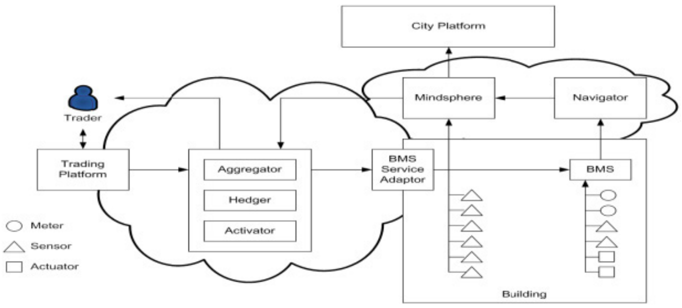

Figure 1. Navigator Platform Integration with BMS

The platform allowed users to easily evaluate the Leisure Centre's data - through either manual or automated fault detection - to identify potential energy waste and building improvements. In a leisure Centre environment, this could range from lights being left on when exercise spaces are not being used, to the continued operation of ventilation systems when the building is closed.

As part of the installation, the Siemens team decided to leverage the existing building management system's infrastructure and the leisure centre's utility metering to trend over data points, which automatically sent update information to the Siemens Navigator servers as part of daily reporting. In addition to providing a technically sound system, the solution also required close collaboration between the site's BMS contractor, the council's IT department and technical experts from Siemens to collect the data and export it successfully outside of the council's IT network. The result was web-based access to, new data values every day for ad hoc reporting and easy-to-interpret data visuals from the Navigator dashboard.

Outcome

The initial objective of the project to provide programme stakeholders with access to building data was successfully achieved. Building operations, meaning what was running, when, and how efficiently, were given a greater level of transparency, and a potential for DSR control was exposed. The Navigator platform solution provided both Siemens engineers and council staff the data necessary to identify opportunities for increased energy efficiency, lower operating costs and improved comfort for the leisure centre's visitors.

Siemens was also able to deliver added value by leveraging its own cross-divisional relationships and exploiting the knowledge of its experts in energy solutions and building technologies in the design of the solution. The Navigator solution, combined with the Building Performance and Sustainability engineers behind it, and with support from the Isle of Wight council and the site's BMS contractor, meant any technical hurdles were easily overcome without risk of compromising the quality of the solution.

Other areas that would improve the leisure centre's energy efficiency or comfort where identified and discussed with the Isle of Wight council. Analysis of space temperatures against outside air temperatures and time of day indicated that control of the ventilation and temperature control system could be adjusted for improved efficiency and comfort throughout the day." "We also found that the swimming pool hall air temperature was set based on the main pool's water temperature. The smaller teaching pool was kept at a higher temperature which meant the air surrounding it was colder than the water, this increased evaporation and heat loss and made swimmers feel cold when exiting the pool. These problems could be mitigated by installing a pool cover overnight and making changes to building control.

This is a demonstration of how a conventional building can become a smart building. The integration of existing data into a modern, cloud-based platform can provide a clear insight into what is happening inside and proves that a building does not have to be new to be connected.

Conclusions

This project demonstrates how a conventional building can become a smart building and proves that existing buildings can become easily connected with the right know-how.

The Siemens Navigator platform allowed immediate access to the building's data by the various project stakeholders.

About Siemens Plc

Siemens is involved in more than 200 countries globally focusing in the areas of electrification, automation and digitalisation. One of the world's largest producers of energy–efficient, resource-saving technologies, Siemens is No. 1 in offshore wind turbine construction, a leading supplier of combined cycle turbines for power generation, a major provider of power transmission solutions and a pioneer in infrastructure and energy solutions as well as automation and drive and software solutions for industry.

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A Demonstration of an integrated Battery Energy Storage System in Residential and Commercial buildings

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CERTH/ITI.

ARTICLE INFORMATION

Published: May 2019.

Key words: *Battery Energy Storage System, BESS, Demand-Side Management, Active consumer/s.*

ABSTRACT

Recent technological advancements have made it possible for even small stakeholders, or consumers to participate in the electricity energy market, not as passive consumers, but as active stakeholders. In that regard, and within the framework of inteGRIDy project, in Thessaloniki, Greece one such aspect will be examined; the implementation and integration of a Battery Energy Storage Systems (BESSs) in residential and commercial buildings. CERTH will be responsible for providing the state-of-the-art solution and its specifications for that case study, with the collaboration of Sunlight and Watt+Volt.

Introduction

The last few decades a shift has taken place in the electricity sector, where the traditional structure is challenged by the introduction of new technologies, bearing with them new advancements in the field, such as Distributed Generation, Renewable Energy, Battery Energy Storage Systems (BESSs) etc. [1].

These technologies have made it possible for even small parties to enter the electricity market and the previously passive consumer to actively participate in it, as well, namely Demand-Side Management. This aim at leading to a smarter and more efficient collaboration between the existing infrastructure such as the electricity grid and new technologies and a better integration of the latter.

In that context, within the inteGRIDy framework, BESSs will be installed in both residential and commercial buildings in the Thessaloniki Pilot case and their setup will be tested and configured for an optimal deployment and operation, for both the end-user/ consumer and the aggregator, in that case the utility provider.

The integration of a Battery Energy Storage System following inteGRIDy reference architecture

Following the inteGRIDy reference architecture [2], the proposed BESS setup, for both residential and commercial cases, will be integrated in the different corresponding inteGRIDy layers, as detailed in the following paragraphs, namely:

1. Field middleware equipment,
2. BESS model and consumer profiling,
3. Operation Analysis,
4. Optimization and Decision Making methods,
5. Integrated Visualization tools.

Field middleware equipment Layer

For extracting load measurement from field devices or points of aggregated load that the BESS serves and the BESS itself. The BESS and its accompanying equipment will be provided by Sunlight batteries system manufacturer in Greece. Additionally, control devices will be needed.

Moreover, all the data are assembled and stored in secured databases, depicted as the Reference Knowledge Warehouse in the diagram below. This concerns not only the data from the measurement points, but also all the data generated from all the tools and components performing various tasks, described below.

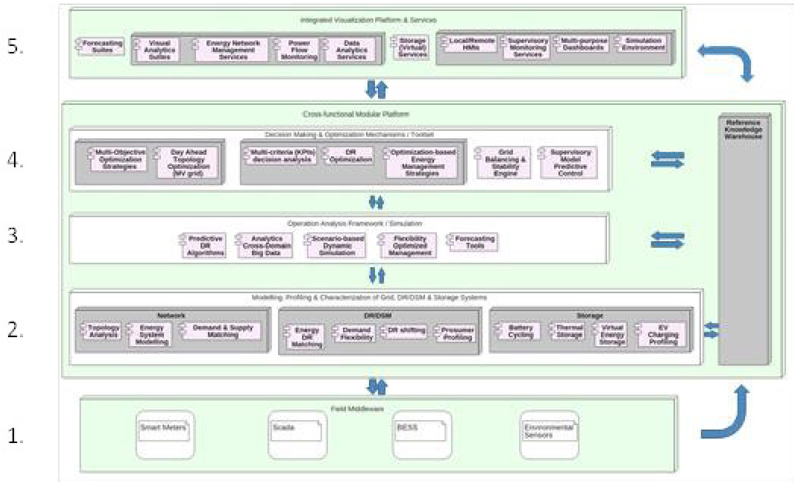

Figure 1: inteGRIDy Reference Architecture diagram.

Bess model and Consumer Profiling Layer

Model information of the BESS, such as maximum capacity, technology used etc. is necessary to specify its capabilities that is its maximum available Depth of Discharge, rate of charge/discharge for better exploiting it and avoiding its degradation. In addition, the load profile of the building, where the BESS would be installed, is also necessary. These would be mostly historical data of consumption.

Since access to more detailed information further requires more measuring equipment to be installed locally, usually leading to end-user/ consumer discomfort, a more minimalistic approach has been decided and implemented. That is trying to exploit the least and fundamental information possible, leading to least possible equipment to be installed, and thus minimizing equipment cost and end-user/ consumer discomfort, leading to the simplest setup possible, and therefore adding to its ease of use, replicability and scalability as a service

Operation Analysis Layer

For this section, load forecast of at least a day-ahead is needed for the setup to determine the usage of BESS. Innovative techniques are used, such as Machine Learning, for generating the appropriate load forecasting, using historical data of load consumption [3].

The load forecast is generated for an entire day and it is being compared constantly with the current real-time load. If any deviation between them above a certain threshold has been detected and for a certain amount of time, then the load forecast is triggered again to recalculate and provide a more accurate forecast.

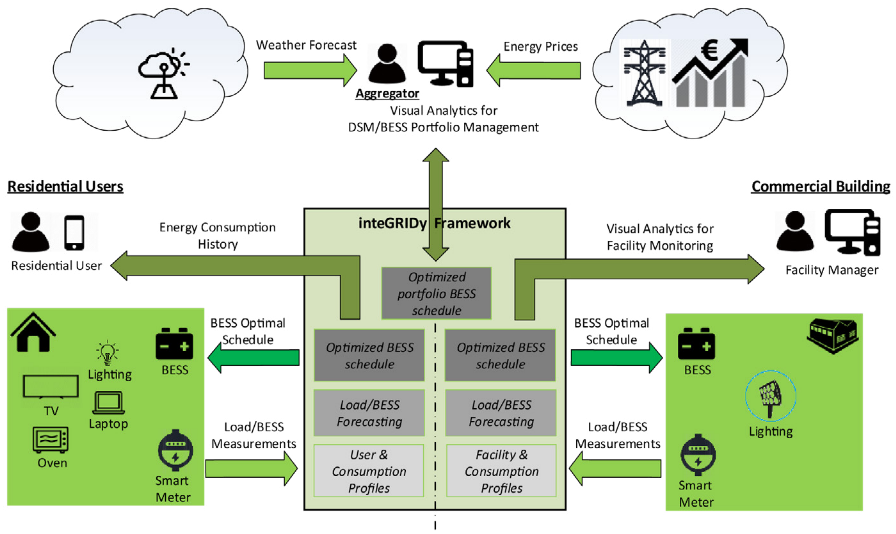

Figure 2: inteGRIDy Framework regarding BESS implementation in Thessaloniki Pilot.

Optimization and Decision- Making Layer

Based upon the load forecast, the optimal BESS schedule will be generated. The objective would be the minimization of cost of the electricity bill for the consumer, either commercial or residential. This can also be combined with the provision of Demand Response flexibility towards the aggregator, in that case the utility provider,

i.e. Watt+Volt, or, if scaled up, by the aggregator towards the Distribution System Operator, leading to smarter and innovative grid solutions.

Integrated Visualization Layer

In order for the end-users/consumers, a visualization platform will be developed, offering both a mobile and a web user interface, in order for them to have access to operational and historical values, and further be able to provide configuration setup.

For example, the end-users will be able to monitor the current status of the Setup, the current forecasted BESS schedule and the load forecast and the savings that have been made, either current or of previous days.

A visualization platform will further be created for the aggregator, allowing him to monitor the whole BESS portfolio, current status of the BESS installed and savings, and further provide configuration setup as desired.

Conclusions

An integration of Battery Energy Storage System in residential and commercial consumers has been presented. It has also been presented that through the exploitation of innovative technology and services this solution aims at leading to smarter grid solutions.

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About CERTH

Founded in 2000, the Centre for Research and Technology-Hellas (CERTH) has important scientific and technological achievements in many areas including: Energy, Environment, Industry, among others, as well as several cross-disciplinary scientific areas. Two different CERTH institutes participate in order to fulfil the objectives of inteGRIDy project: CERTH/ITI exhibits substantial research activity as well as technology transfer actions, and employs a high quality scientific group in the area of multi-sensorial and energy related systems, the development of simulation platforms and visual analytics for highly complex systems; CERTH/CPERI has a wide background on the study and construction of process systems and integrated systems used for energy production, management and storage and has unique knowledge in system design, engineering and industrial automation.

Information about the authors

Paschalis Gkaidatzis is a Research Associate at CERTH/ITI specializing in Distributed Energy Resource and their impact on the Distribution Network, involved in the inteGRIDy project on design and modelling of innovative Energy and Battery Solutions on top of the inteGRIDy Reference Architecture.

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Becoming energy self-sufficient using sustainable energy sources

Dr Venizelos Efthymiou / George E. Georgiou

University of Cyprus.

ARTICLE INFORMATION

Published 5th July 2019.

Keywords: *Smart, Energy, demand-side management, efficient solution, efficiency, BEMS..*

ABSTRACT

The University of Cyprus (UCY) has set the goal of becoming energy self-sufficient using energy produced from sustainable energy sources. To achieve that 10 MWp of PV, 7.5 MWhr of electrochemical storage, solar thermal units and heat pumps will be engaged (own funding). An energy management system will evaluate and demand-side management strategies, such as peak load shifting and shedding of non-critical loads, to reduce energy cost. This energy management system will be capable of identifying costly variations in electrical load profiles by determining if and when peak demand usage occurs in the facility, while the optimum use of resources all year-round will be offered through a planned micro-grid architecture.

UCY as a pioneer in the research field will utilize the cross-functional platform provided within inteGRIDy to increase the energy efficiency within the university campus.

Introduction

The Cyprus pilot tests two different use cases. The first use case is related to the operation of a grid-connected microgrid within the campus of University of Cyprus (UCY) in Nicosia city, while the second one is focused on dispersed prosumers within Cyprus island, enabling the DSO of Cyprus to harness the benefits of demand-side flexibility. The selected prosumers have a photovoltaic (PV) installation with two separate smart metering infrastructures, to have access both to production and consumption data. These prosumers are dispersed within Nicosia and Larnaca regions. These two different sites have been proposed for reasons of having different weather conditions, while being located near UCY. Furthermore, the selected prosumers are not supplied by the same distribution feeder. The impact of the proposed solutions to a single feeder of the electrical grid will be examined within the university microgrid test case.

The University of Cyprus is selected as a pilot site, since it is in the transformation phase to become a “living lab”. Currently, more than 400 kWp PV are installed both on rooftops and in terrain. Furthermore, many buildings within the university campus have Building Energy Management Systems (BEMS) for controlling the heating/cooling needs. A large PV park (10 MWp) and a battery storage bank (7.5 MWh) are in the design stage to be installed within the university campus, enabling the microgrid operation. The monitoring of the microgrid will be carried out through sensors and advanced smart metering infrastructure, placed in several nodes within the campus. A single point of collecting the measurements and take the respective control decisions is included in the solution.

In short, the challenge is the optimal use of local resources, leading to the minimization of energy cost. Both use cases of the Cyprus pilot address problems of energy communities. The planned solutions maximise the use of local resources and allow sharing between the members of community, through the best utilisation of the embedded synergies.

Solution implementation

The Energy Community Build & Operate Solution is being implemented in the university campus and distributed through aggregated practices that can be extended to flexible portfolio for managing the flexibilities of Demand Response.

The solution includes the Central Energy Management System within the university campus linked with the storage management system, both interfaced via open protocols with the Demand Response Optimization Engine. The final solution also incorporates all the required components: smart sensors, real-time communications and PV forecasting tool.

The Energy Community Build & Operate Solution helps energy communities (i.e. commercial entities, industrial zones, local communities) to minimize energy costs by utilizing local energy resources & benefits of synergies. Furthermore, it can generate flexibility as an add on trading commodity.

UCY as a pioneer in the research field will utilize the cross-functional platform provided within inteGRIDy to increase the energy efficiency within the university campus. By activating the identified control points within the campus, the microgrid concept will be implemented. The target is to transform the University of Cyprus into a “living laboratory”, which will use its own RES production to cover the electricity needs. The architecture so developed is applicable as an Energy Community in all commercial and industrial controlled areas.

DSO can take advantage of the controllable microgrid and the controllable prosumers within Cyprus to solve grid issues (such as violations of the voltage profile, grid congestion issues, power quality deterioration, etc.).

The cross-functional platform of inteGRIDy will be utilized to combine all the information provided by the smart metering infrastructure (for RES production, energy storage and energy consumption) and installed sensor systems within the university campus microgrid with the forecasted energy. The target is to increase the controllability and energy flow efficiency of the microgrid.

The platform provided by inteGRIDy will be utilized by the dispersed prosumers to offer ancillary services to the DSO through controllable demand response. The DSO will use the controllability of both the microgrid and the dispersed prosumers to resolve the above referred grid issues.

As a result, the highly valuable benefits can be summed up as follows:

1. World-class learning environment from teaching and research
2. Deep sustainable energy expertise and capabilities
3. Dedicated facility for energy research and development

Conclusions

Cyprus' pilot cases demonstrate how the Energy Community Build & Operate Solution helps energy communities (i.e. commercial entities, industrial zones, local communities) to minimize energy costs by utilizing local energy resources & the benefits of synergies, which will bring the following benefits:

- ☑ Sustainable Energy research and development
- ☑ Cultural, social and economic development to Cyprus
- ☑ Establishment of facilities for transforming the university into a green campus with microgrid controls for generating flexibilities for use by the grid operators, effective energy and demand side management.

About the University of Cyprus

The University of Cyprus, established in 1989, aims to establish itself as a Pioneer Research Institution achieving International Scientific Recognition in European Higher Education, offering Competitive Programmes and to become a Centre of Excellence in the wider Euro - Mediterranean Region. More specifically, the Research Centre for Sustainable Energy (FOSS) was created in order to play a key role in research and technological development activities in the field of sustainable energy within Cyprus and at international level with the aim of contributing to the achievement of the relevant energy and environment objectives set out by Europe.

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St. Jean: how to implement Demand-Response campaigns based on the consumer's comfort and flexibility potential

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ARTICLE INFORMATION

Published 31th July 2019.

Keywords: *Smart, Energy, demand- side management, efficient solution, efficiency.*

ABSTRACT

Following a strategy to operate a fully decarbonized grid in 2030, the main aim of the pilot activities in the French pilot site spins around the integration of increasing volumes of distributed renewables into the distribution grid without threating its stability and reliability. To this end the pilot activities focuses on the introduction of novel technologies and business models for Human-Centric Demand Response (DR) in Buildings (control of Heating, Ventilation & Air Condition and lighting loads without compromising building occupants' comfort and health) and Virtual Energy storage (through the application of Power-to-Heat solutions).

Introduction

In the recent years, SOREA, among other DSOs, has observed a number of significant changes in its electrical grid; such as increased electricity consumption, increasing number of producers connected to the network due to liberalization of the electricity market, and integration of intermittent renewable energy sources due to the new objectives in the greenhouse gases emissions. Despite these changes, it is essential that the electricity network meets the consumer requirements and at the same time maintain a high quality of service, balance of supply and demand, and safety of the system.

In this context, three levels of the electricity distribution system architecture need to be addressed in order to update the network services and meet the requirements of safety, quality and stability: the transmission and distribution network, the communication and data collection, and the level of applications and services. The application of smart grid technologies is expected to promote the network modernization on these three levels in order to keep up with the ongoing changes.

Solution implementation

To address the aforementioned points, TREK in co-operation with SOREA has designed and developed the St.Jean Pilot Scheme in regards to three of the InteGRIDy project pillars: Demand response, Smartening the distribution grid, and Energy storage. The purpose of

this pilot scheme is to implement and test an innovative portfolio management system that allows ESCOs/Aggregators to optimize and implement DR campaigns taking into account the consumer comfort and flexibility potential. To achieve this, a user profile framework has been developed based on real-time energy demand data and ambient information from the consumers' premises in order to define continuously calibrated, personalized visual and thermal comfort profiles, dynamic consumer flexibility profiles and assess the assets' capabilities to virtual energy storage. Both commercial and residential buildings have been selected as pilots.

As the proposed system relies on the continuous flow of monitoring and metering data streams from the participating buildings, the establishment of a non-intrusive and flexible IoT system is necessary to allow the DSOs/Aggregators to have real-time access to their consumers' data. Additionally, an intuitive and easy-to-use tool that provides visual analytics for the comparison of the received data is necessary to facilitate the portfolio management, the evaluation of the proposed DR strategies and the actualization of the available dispatch control actions.

For these purposes, TREK has designed a complete solution including the design of a sensor network based on off-the- shelf meters and sensors to be installed at the consumers' premises, a reliable and robust data management system, and two tools: the Demand Side Energy Profiling (DSEP) tool and the Visual Analytics Engine (VAE) tool.

The designed sensor network allows the collection of information at the consumer premises in a non-intrusive way as it is based on wireless protocols, eliminating the use of cables. The data management system collects real time data from the installed devices, additionally offering a back-up mechanism to avoid the loss of information in cases of connectivity disruptions. The data streams are uploaded to TREK's cloud server where they were processed and stored in a dedicated data base.

The DSEP tool deployed in the cloud server uses the collected data streams in order to derive personalized visual and thermal profiles of the consumers and DER profiles of the available devices. By correlating these profiles, the available flexibility is assessed in order to allow the generation of optimized DR scenarios that also preserve the indoor conditions within the acceptable comfort conditions of the users. Last but not least, the VAE tool provides a visualization and interaction mechanism that provides the DSOs/Aggregators with different metrics and KPIs which facilitate the analysis and management of their asset portfolio through a web application. Functionalities such as "what-if" scenarios to allow the optimization of the DR campaigns and dispatch control signals to implement them are also included in the web application.

Conclusions

continuous data flow of indoor conditions and energy consumption information has been established. The bilateral communication of the developed system with the actuators installed at the pilot buildings allows not only the collection of information regarding the operational status of the electrical equipment at the consumer premises but also their remote control within the scope of the proposed context aware DR strategies. In this way, the conventional energy transmission grid becomes smart and enables the optimization of the DR campaigns in a human-centric way, using accurate and personalized flexibility profiles of the consumers.

The developed tools offer a number of innovative functionalities to the involved business stakeholders, who can adjust their business strategies based on a human-oriented philosophy to improve the effectiveness of their offered services and increase user acceptance. In this way, the competitiveness of the DSO in the electricity market is increased as the quality of services provided is improved. Finally, the visualization tool developed within the scope of InteGRIDy provides to the DSO a user friendly and intuitive way of monitoring and managing the assets composing their portfolio through a wide list of metrics and KPIs.

The installations of the non-intrusive wireless sensor network have been successfully carried out at the pilot buildings at the St. Jean area, and a

About TREK and SOREA

TREK Development is a consultancy and technology development services firm, providing Information Technology (IT) services to small, medium and large Organizations all across Europe, North Africa and the Middle East. TREK aims at providing flexible solutions for small and medium-sized electricity consumers and integrated solutions for electric utilities and service providers in the field of demand management (Aggregators).The business strategy of TREK (deployed also through the subsidiary companies belonging to the TREK Group of Companies) includes research and development of advanced technologies, to create a full suite of solutions and products appealing to everyone involved in the electricity market.

SOREA is a local Energy Utility/ Retailer and DSO operating in the Maurienne Valley area in France. SOREA is active in electricity production and distribution and operates its own grid with hydropower and photovoltaic production. The grid supplies 15,000 customers (counters), private people and industry in the Maurienne Valley in France, near the Italian border. SOREA distributes over 140 GWh of electricity every year, with peak demand of 42 MW (peak power period). 35% of the total annual electricity is produced by renewables, namely PVs and small hydro plants, with the aim to reach 60% in 2020 and 100% in 2030. SOREA supplies more than 14,000 private people (houses and buildings).

Information about the authors

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Romain Chomaz is an R&D engineer at SOREA, where he is involved in various European projects.

Integrating a building energy management system with solar pv production, electric vehicles and energy storage

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Lisboa E-Nova

ARTICLE INFORMATION

Published August 2019.

Keywords: *Energy consumption, savings, CO2, billing, smart buildings, dynamic tariffs.*

ABSTRACT

The Lisbon Municipality holds a large stock of administrative buildings under its responsibility. Campo Grande 25 is a five-block building, that comprises most part of the municipality's public services, with around 2000 workers and an average yearly consumption of 3,2 GWh. In both -1 and -2 floors it is possible to find 45 charging stations, with different charging velocities, from normal and semi-fast options to fast ones, in order to ensure the supply of a fleet of around 100 electric vehicles. Due to the fact that this is one of the city's buildings with the highest consumption there is a need to integrate the available resources and technologies to modernize it. The development of the Lisbon pilot leads to a reduction in the energy consumption and in the CO2 emissions to the atmosphere, as well as a decrease in the energy bill.

Introduction

The Lisbon Pilot consists in the development of a building energy management system (BEMS), integrating innovative technologies in the energy storage area, mobility sector and renewable energy production.

The Solution

The presented pilot lays in 3 of the 4 inteGRIDy project pillars: Demand response, Energy Storage Technologies and Smart Integration of grid users from Transport. In the Demand response area, the inclusion of dynamic tariffs with the demand side management, aiming to associate bigger loads to low priced tariff times will enable savings. The proposed load shifting will take place with the help of the ice banks to produce ice, storing energy during the off-peak hours to use it during the day. Regarding the EV charging, it must be scheduled to match low price periods of the dynamic tariffs. The EV batteries may also be used to store energy during the night in off-peak hours. Moreover, the pilot also includes a small photovoltaic (PV) system, to be installed at the rooftop, with an installed capacity of 16 kWp, that will also enable to reduce the grid load, leading to savings. In fact, the renewable energy production will be integrated with the EV fleet management.

To sum up, the Lisbon pilot will integrate numerous sustainable measures, backed up by energy storage, load shifting criteria and renewable energy production in a twofold aim: to contribute to a greener electric vehicle supply and to reduce the grid load requirements. Bearing this in mind, the Lisbon pilot will certainly manage to help Campo Grande 25 reach its objectives and reducing their energy consumption.

Conclusions

Managing an administrative building in a traditional way is already gone! Nowadays, it is crucial to be connected to the grid and take advantage of the numerous available technologies, getting to know our needs in a shorter time frame and choosing the best option to suit them, either consuming from the grid, through the PV system or resorting to the stored energy in the ice banks. Thanks to the BEMS and the different technologies integrated in the Lisbon pilot it is possible to aim for a decrease in energy consumption and a reduction in energy bills, increasing energy efficiency. Not all the buildings have space in the roof to install PV or have EV chargers and specially don't have ice banks, like in the pilot site. However, the demand and response principles for the use of electric energy may be replicated in other buildings reaching positive results with energy consumption savings. The Lisbon Pilot results may encourage the implementation of a BEMS in other Municipality buildings, adapting for the type of equipment existing in each site.

About LISBOA E-NOVA

LISBOA E-NOVA is a non-profit association operating under private law that seeks to contribute to the sustainable development of the city of Lisbon through mainstreaming good practices in urban planning, construction, urban management and mobility, involving all the city's key stakeholders, among political decision makers, all major urban stakeholders and the citizens of Lisbon. LISBOA E-NOVA is composed by a General Assembly, a Board of Administrators, a Consultancy Committee and a Supervisory Board. The General Assembly comprises 26 affiliates who are active in very distinct sectors, including local administration, education, water and energy utilities, transport, among others. LISBOA E-NOVA is responsible for the development and monitoring of Lisbon's Energy-Environment Strategy, signed by the Lisbon Municipality in 2008, setting targets in the field of energy, water and materials resources, for the period from 2009 to 2013. LISBOA E-NOVA also coordinates Lisbon's participation in the Covenant of Mayors assuring the communication with the European Commission and the status of results. Within this context LISBOA E-NOVA coordinates several projects, both in the technical and communication fields, with which it addresses the sustainability challenges that the Lisbon city faces, raising the awareness of all key stakeholders and motivating their participation in the systematic and continuous improvement of the city's energy and environmental performance.

Information about the authors

António Sequeira, Vasco Abreu, Nuno Limas, Carlos Raposo are Project Managers working in the technical department of LISBOA E-NOVA.

Il Moggio farm: increasing efficiency and sustainability from an environmental point of view

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ARTICLE INFORMATION

Published August 2019.

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ABSTRACT

The Lisbon Municipality holds a large stock of administrative buildings under its responsibility. Campo Grande 25 is a five-block building, that comprises most part of the municipality's public services, with around 2000 workers and an average yearly consumption of 3,2 GWh. In both -1 and -2 floors it is possible to find 45 charging stations, with different charging velocities, from normal and semi-fast options to fast ones, in order to ensure the supply of a fleet of around 100 electric vehicles. Due to the fact that this is one of the city's buildings with the highest consumption there is a need to integrate the available resources and technologies to modernize it. The development of the Lisbon pilot leads to a reduction in the energy consumption and in the CO2 emissions to the atmosphere, as well as a decrease in the energy bill.

Introduction

ASM TERNI will take care of the setup of the pilot that will allow to test the collaboration between the microgrid and TERNI's Smart Grid. This pilot site is a farm called "Il Moggio" located in Terni municipality; it is at present a stand-alone grid already in operation. "Il Moggio" microgrid comprises a significant amount of distributed generation: a 30 kWp rated PV plant, two 31 kVA – 25 kWt biomass Combined Heat Power (CHP) generators; in addition, electric storage consists of 50 lead batteries responsible for managing distributed generators without curtailments.

The CHP generators are a pillar of this pilot since they enable stand alone operation. They are produced and managed by All Power Labs, which is a global leader in small-scale gasification. The company produces biomass gasifier generators that are ready for everyday work, to serve real world distributed energy needs. They combine the best usability features of diesel generators, with the clean running of typical renewables, with the potential for a

carbon negative impact. With CHP generators, it is possible to generate on-demand power for 1/4 the operating cost of diesel, at 1/2 the capital cost of solar. Moreover, it is possible to shrink your carbon footprint and contribute positively to global efforts against climate change.

In this pilot, the Energy Storage pillar is focused on the optimisation of the microgrid distributed generation (PV and CHP) by means of a battery storage system. The optimisation aims both at maximising microgrid self-consumption during normal operation of the distribution grid and at supporting the grid in case of surplus of power or local congestions.

From an environmental point of view, it will be evaluated how a proper energy management can increase green energy consumption. From an economic point of view, an improvement of savings due to flexibility's supply is expected. At this level, a proper flexibility assessment will be established.

Solution implementation

ASM TERNI as a smart DSO will use its own distributed automation unit, installed in the distribution substation, to test what partially controllable energy resources of a microgrid can provide as services to the DSO. It has already been deployed a tool to monitor and control the microgrid and all the sensors necessary to monitor the cowsheds and greenhouses. This sensing, monitoring and controlling equipment is the pre-requisite to deploy an optimisation tool able to evaluate the dynamic flexibility of the microgrid and to offer proper services to the Smart Grid.

The flexibility of the microgrid will be exploited with the aim to find a trade-off between the DSO needs and the rural microgrid economic and technical constraints. By means of hardware equipment and software tools that the inteGRIDy technology providers will make available in the pilot site, it will be possible to demonstrate the application of a hybrid cooperative business model between the DSO and the microgrid's actors. Indeed, the DSO will be able to exploit the microgrid flexibility to improve stability and reliability of the distribution network without ignoring the needs of microgrid owner in terms of business operation and energy requirements (electric and thermal needs). The pilot will demonstrate that the integrated tools will estimate both energy production and energy consumption, in compliance with local constraints imposed by production processes, a "flexibility as a service" business model will be put in place and validated.

The visualisation and optimization tool provided for the Terni pilot is the Multi-carrier hub Optimisation Engine tool that puts at disposal of the microgrid manager a GUI showing the most relevant power profiles, price trends and process parameters. This tool provides optimisation functionalities able to deal simultaneously with different objectives in order to provide optimal solutions in terms of economics and technical operations. Moreover, there is one tool puts at disposal of the DSO that is the Flexibility Optimised Management tool; this tool provides a dashboard aimed at displaying microgrid data, both historical as well as real-time ones, to the DSO. In particular, the DSO can create a power profile request at the MV connection point. The Power profile request is created selecting the KPI related to the desired grid service inside the flexibility range, which is indeed the flexibility capability of the microgrid.

Conclusions

Main savings concern microgrid resources optimisation (e.g. increasing of self-consumption, internal losses reduction), green energy consumption maximisation, network reliability and resilience improvement. Furthermore, on the distribution network, loss reduction is expected, as well as power quality improvement. ASM Terni aims at reducing SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index), reducing voltage fluctuations.

Regarding the pilot site, ASM Terni aims at increasing both efficiency and sustainability, from an environmental point of view. Environmental improvement involves CO2 emission reduction and self-consumption increase. From an economic point of view, these improvements can be considered as revenues. In actual fact, green certificates can be obtained by GSE (the energy services manager).

The pilot exploits a rural microgrid and represents a good opportunity in providing improved electric service reliability and better power quality to the end customers. Microgrid can also furnish the local utility with additional benefits by providing dispatchable power to be used in peak load conditions; moreover, there is a benefit also for the DSO related to the possibility to alleviating or postponing distribution system upgrades. Due to the increasing amount of distributed generation, many independent and private microgrids similar to the one involved in this Pilot are envisaged in the near future. Therefore, the Terni Pilot may be taken as a benchmark for the management of similar DER clusters connected to the distribution network.

About ASM TERNI, ENGINEERING and La Sapienza

ASM TERNI is Public Company fully owned by the local municipality (City of Terni). The activity of the company is related to very essential public services in the City of Terni area as: i) Production and distribution of Electric Energy, ii) Management of public street lighting, iii) Environmental Health, iv) Drinkable water distribution and water treatment plant, v) Gas distribution . As DSO, ASM Terni directly owns and operates the power distribution grid and distributes electricity from the MV-LV and HV-MV substations to the end consumers' (65.000 Smart Meters)..

ENGINEERING Engineering Ingegneria Informatica S.p.a. is a leading provider of advanced Information Technology systems and services to diverse commercial and governmental customers, with a particular attention to the Energy and Smart Grid sector.

"Sapienza" University (UNIROMA1) participates in inteGRIDy through its Dept of Astronautics, Electrical and Energetics Engineering of the Civil and Industrial Engineering Faculty. The members of this research unit have an extensive experience in network studies related to planning, design, operation and protection of transmission and distribution networks; as well as in developing of simulation models for static and dynamic studies related to the integration of distributed generation, demand response, storage systems and EV charge systems in smart and micro grids during normal operation or fault conditions

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Managing energy in islanded multi-node microgrids involving hybrid storage technologies: Xhanti pilot

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ARTICLE INFORMATION

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Keywords: *microgrid, RES, EMS, PEM.*

ABSTRACT

Xanthi pilot demonstrates the operation of an islanded microgrid network, owned by Sunlight, that fulfils local load demand with RES sources and energy storage using advanced control technology. Xanthi microgrid incorporates advanced technologies that smarten the grid and makes it an example among low voltage, smart autonomous microgrids.

These technologies are incorporated in three tools developed by CERTH/CPERI-PSDI: the Data Exchange Tool, the Integrated Decision Support & Supervisory EMS and the Supervisory Model Predictive Control technologies for Energy Systems tool.

Introduction

Xanthi pilot demonstrates the operation of an islanded microgrid network that fulfils local load demand with RES sources and energy storage using advanced control technology. Microgrids, according to CIGRE, are electricity distribution systems containing loads and distributed energy resources that can be operated in a controlled, coordinated way either while connected to the main power network or while is islanded.

The microgrid, which consists three portable nodes, is owned by Sunlight and located in its premises and is used to power auxiliary equipment and charge the factory electro-vehicles (forklifts). The nodes are set up in such way that different power production and storage dynamics are met in order to cover different set up topologies depending on user needs.

The microgrid is powered by photovoltaics and wind generators. Lead-acid battery arrays are utilized to store energy and to provide the necessary power to the systems when needed. As a backup option each system has a diesel generator. A Polymer Electrolyte Membrane (PEM) electrolyzer produces and stores hydrogen and a PEM Fuel Cell system produces power when required using the stored hydrogen. The energy exchange within each standalone node where DC and AC busses exist, is established through power converters. A high voltage DC bus bar is used to exchange energy between the nodes using DC/DC Bidirectional converters.

The operational objectives of the microgrid are to exchange power based on demand-response strategies, to maximize the usage of available stored power at network level and to utilize the total amount of available renewable energy. The desired features for the overall behaviour of the network is to ensure the security of supply, to reroute the energy based on dynamically evolving conditions and to provide an automatic decision support mechanism based on available network resources.

Solution implementation

Xanthi pilot addresses all four of the InteGRIDy's project pillars. Demand Response, Smartening the Distribution Grid, Energy Storage Technologies and Smart Integration of grid users from Transport.

In the Xanthi pilot, the concept of demand response is viewed from a broader perspective. Being an isolated microgrid, an internal energy management is being prioritized. This means that apart from controlling the internal auxiliary loads, upper level DR mechanisms among the distributed microgrids are implemented in order for the entire grid to be able to fulfil the individual loads. This is achieved by interconnecting the microgrids, enabling the ability of energy exchange.

To achieve nodes cooperation and improve the energy exchange at the distribution level, smart and adaptable energy management strategies are used. Advanced Model Predictive Control using system/network models is applied in order to achieve optimum power distribution in the grid. Furthermore, supervisory monitoring options and services provide to the grid operator knowledgeable actions using multi-criteria decision analysis and capitalizing on the historical data of the network behavior. The information/notification and status metrics are included in the multipurpose dashboards for visual analytics of the distribution domain status, in local and remote HMIs.

Concerning the Energy Storage Technologies, and optimization of the energy storage usage within each station is performed. The field trial, is carried out on the 3 nodes with active serving to storage and load demand, utilizing flexible storage management algorithms for charging/discharging. The formulation of a Virtual Central Storage from aggregated distributed storage systems offers balancing solutions among hybrid storage options (electricity, hydrogen) utilizing Smart Energy management tools with RES-enabled storage systems.

The last aspect involves smart Integration of grid users from Transport. The energy management methods are being evaluated considering the forklift charging at dynamically changing schedules using RES, batteries or stored hydrogen options on demand. The integration of EVs offers grid balancing solutions through the ability to provide flexibility in demand side management and, in the case of the EV charging unit, returning power to the grid at peak network demand.

Three tools, developed by CERTH/CPERI-PSDI, implement the above-mentioned functionalities. Data Exchange Tool, as the name indicates, is a tool that manages transmission of selected data from the SCADA system to the other tools using IoT technologies.

The Integrated Decision Support & Supervisory EMS tool targets the Integrated Optimum Operation, Advanced Control, Energy Monitoring & Energy Management Strategies for autonomous energy networks. The tool is designed to assist the end-users to gain the most out of their available resources. The resulting automation and control systems are monitored with data and network security considerations. The main functions of the tool are the collection, processing and visualization of real-time data, the implementation of automated algorithms and the implementation of Energy Management Strategies.

The Supervisory Model Predictive Control technologies for Energy Systems tool is developed to give the ability of the unattended operation and supervision of an isolated power grid consisted of multiple microgrids. Its purpose is to be used in RES microgrids where latest power systems technologies are installed, with the objective of smartening the grid. The tool is based on the model-based control concept.

Using model predictive methods and appropriate setpoints of operation, future control actions are provided in order to guide the operation to the desired levels. Energy that should be exchanged is calculated and control actions are sent to the field devices for energy storage balance assuring the energy integrity of the grid.

Conclusions

Within InteGRIDy project, the focus is towards isolated smart-grid networks and more specifically to their operations domain in terms of information exchange and distribution of energy. The deployed tools provide online information about the grid operation both to the user and between the microgrid nodes. The integrated solutions offer online optimum decision making for the distribution of energy for isolated smart grids with an option of charging batteries for EVs. In short, the benefits of applying the deployed technology are:

- ☑ Microgrid autonomous operation relying on RES and energy storage that serves varying load profiles in areas where the transportation of fuel is difficult.
- ☑ Formulation of a Virtual Central Storage from aggregated distributed storage systems delivered from the smart energy management.
- ☑ Grid balancing through the ability of flexible energy distribution and, in the case of the EV charging unit, returning power to the grid at peak network demand.
- ☑ Emission reduction. The usage of RES combined with the stored energy at batteries or hydrogen will minimize the use of a diesel generator which is installed to operate in case of emergence or critical energy deficiency.
- ☑ Energy consumption savings derived by the optimum operation of the subsystems and the maximum utilization of available RES.

Overall, Xanthi microgrid incorporates advanced technologies that smarten the grid and makes it an example among low voltage, smart autonomous microgrids.

About CERTH-CPERI and Sunlight

CERTH-CPERI (CERTH Chemical Process Engineering Research Institute) is a non-profit research and technological development (RTD) organization founded in 1985 in Thessaloniki, Greece. CPERI's mission is to conduct high caliber basic and applied research, to develop novel technologies and products and to pursue scientific and technological excellence in selected advanced areas of Chemical Engineering, including Energy, Environment, Materials and Process Technologies, in response to the needs of the Greek and European industrial and productive sector.

SYSTEMS SUNLIGHT S.A. operates in the energy market for three decades and ranks among the world's top manufacturers of energy products and systems, being specialized in design, production and distribution of: (1) Energy Storage Systems for industrial, consumer and advanced applications, (2) Energy Power Systems, (3) Green Energy Systems, (4) Energy-related services. SUNLIGHT contributes with its integrated energy storage systems to the use case of «UC-10: Flexible DR at Residential and Tertiary Building with Local Storage (Thessaloniki, GR)».

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Network reconfiguration and energy storage systems real-time dispatching for a more sustainable power system operation

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ARTICLE INFORMATION
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Keywords: *renewable energy sources, DSO, RES, grids, energy storage*.

ABSTRACT
Renewable Energy Sources (RES) are the main driver of the ongoing energy revolution all over the world. In order to manage RES, electric networks infrastructure and the relevant regulatory/market frameworks need to be properly updated. Within the project, the San Severino Pilot involves the medium voltage distribution grid of San Severino Marche, a small town in the centre of Italy, managed by the local Distribution System Operator.

Introduction

The pilot is based on three InteGRIDy pillars (Demand Side Management, Energy Storage and Smart Grid).
In the demonstrator, an already existing Smart Grid architecture is exploited, which has been displaced on the distribution network by a past experimentation promoted by the Italian Energy Authority. Thanks to this architecture, the DSO's control centre has been equipped with a SCADA able to manage innovative functions, such as the real-time monitoring of grid parameters, the active and reactive power control of dispersed generation, generators remote disconnection, advanced protection techniques (logical selectivity), etc. Moreover, a communication system based on different TLC vectors (fibre optic, Wi-Fi and LTE technologies) has been deployed and is used to enable the real-time communication between the DSO, electrical substations and customers, required to implement the features envisaged by the InteGRIDy project.

Solution implementation

The San Severino Marche pilot has been designed in order to achieve benefits both in the DSO's perspective and in the customer's one. It focuses on two main sets of functionalities:

- the management of the topology of the medium voltage grid (by delivering suitable information to the DSO, in real-time and in advance) to improve the network's operational efficiency (e.g., reducing energy losses, maximizing the grid's hosting capacity for RES);
- the collection of ancillary services (frequency regulation, congestions mitigation, etc.) on active and passive users, by means of Energy Storage Systems.

The pilot foresees the installation of new equipment in the ASSEM control centre and on the distribution network, and the development of some software tools.

Some residential users are equipped with Energy Storage Systems able to adjust their working point according to remote setpoint signals sent by the core unit developed in the project and installed in the DSO's control centre. Moreover, the project enables the real-time monitoring of the storage devices, in the perspective to allow Aggregators to manage and take advantage of these new control resources within the Ancillary Services Market. In addition, to support the DSO in adopting an optimal network configuration, some secondary substations are equipped with monitoring devices devoted to collecting grid measurements and with remote- controlled switching devices.

A set of software tools is deployed on a workstation in the ASSEM control centre. A first tool is designed to compute a forecast of RES production and load over the network. Predictions are evaluated also with the support of weather forecast collected from an external web service provider. The optimization of the network topology is performed by another tool, which models the medium voltage distribution network from a mathematical point of view.

With the purpose to implement the algorithms required to optimze the grid configuration, based on power flow calculations, the tool needs in input the forecast profiles of generation and load, and the monitoring data collected over the network. The tool identifies the optimal grid topology considering as fitness function energy losses on grid's conductors or other operating indexes (quality of service, hosting capacity, etc.). As a main output of the optimization process, the tool provides suggestions regarding which switching devices over the network should be opened/closed by the facility manager in the DSO's control centre to adopt the configuration considered the optimal one.

Further tools perform a simulation of the Ancillary Services Market and define the optimal strategy to charge/ discharge Energy Storage Systems at the residential users' premises. This is carried out by considering different working parameters such as the batteries' state of charge, the local production and actual rate of self-consumption of users and the requirements in terms of provision of ancillary services to the electricity market

Conclusions

The first benefit expected from the pilot is an improvement of the distribution grid efficiency and quality of supply; such goals drive to economic income to the DSO thanks to an optimal management of the distribution grid.

Also, the grid's Hosting Capacity (capability to connect new generators) will benefit of the solutions designed in the project, thanks to the minimization of grid congestions obtained by the adoption of energy storage solutions and Demand Response strategies. These aspects will allow the DSO to avoid/postpone some structural investments in the distribution network.

Benefits on energy losses reduction are also of great interest for the DSO, because according to the reward/ penalty mechanism enforced by the Italian Energy Authority, if the actual losses on the network are lower than the conventional ones (value defined according to a national average), this originates an income for the DSO.

In the other side, the final user will have an economic gain thanks to an effective participation to the Demand Response logics, providing services to the local grid or to the market. These functions are nowadays under evaluation in the Italian framework. Nevertheless, the regulatory framework is not yet completely defined, consequently the project results particularly on-time to provide useful on field results. Eventually, thanks to the ESS apparatuses, the active users will be able to better manage the energy needs in their houses (increasing the self-consumption), minimizing the energy bill.

Finally, the better energy efficiency of network operation, the increase in hosting capacity and users' self-consumption are expected to bring to a reduction in carbon dioxide emissions. The opening of the Ancillary Services Market to distributed generation would lead to a greater and better exploitation of renewable energy resources, with economic and environmental advantages in the management of the power system.

About ASSEM SpA, Politecnico di Milano, UNE Srl and E@W

ASSEM SPA is be involved as Distributor System Operator (DSO) in all the project tasks regarding the grid improvement and its analysis, considering the previous experience of ASSEM SPA about smart grid development and the effort and the strategic importance of the topic for the company. The main roles are the deployment of inteGRIDy framework at San Severino Marche pilot area, its monitoring and topology optimization.

POLIMI, the main role of Politecnico di Milano within the project regards with the deployment of the distribution grid optimization framework, by assisting the other partners during the integration of the available tools in the experimental architecture taking care suitably of the electrical grid needs and constraints, and in the following coordination of the large scale pilot use cases realisation.

UNE is an Italian SME created in 2011. The company provides services and competences in the field of renewable energy and environmental sustainability. UNE supplies hybrid thermal and PV plants as well as micro-wind turbines. UNE is a high innovative company with strong collaboration with Universities and Research Centres. The main mission since 2013 is the development of an innovative Renewable Energy Storage System (RESS) designed and optimized for residential buildings.

E@W is an innovative non-profit start-up organisation founded in 2014 thanks to a funding of 1.250.000,00 € under the Italian PON cooperative society. The main goals for Energy@Work are the exploitation of researchers' activities, protecting national young excellences in research, promoting on its own territory and abroad technological research and innovation.

Information about the authors

Dr. Massimo Fiori who is leading the San Severino pilot works like ingenieer in ASSEM SpA. **Prof. Marco Merlo** and **Dr. Davide Falabretti** are professors and researchers of the Department of Energy in the Politecnico di Milano. **Dr. Lorenzo Corghi** got a degree in Electronic Engineering currently and currently works like a R&D manager UNE Srl. **Dr. Luigi D'Oriano**, with strong background in ICT solution for energy efficiency works like Project Manager and Researcher at Energy@Work.

Enhancement of the smart grid infrastructure in Romania by implementing the innovative solution EIIS (Energy Integrated Information System)

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ELECTRICA SA Romania

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SIVECO Romania SA

ARTICLE INFORMATION

Published 31th December, 2019.

Keywords: *demand-response, smart grid, algorithms*.

ABSTRACT

Pilot Ploiesti is implemented in relation to the 'InteGRIDy' project's Demand Response pillar. The purpose of implementing the EIIS (Energy Integrated Information System) within the Ploiesti Pilot is to ensure a Demand Response (DR) Smart Grid for a residential area, where buildings' energy management and control systems will operate based on critical peak pricing and intelligent DR programs/algorithms..

Introduction

The challenge of implementing the Ploiesti Pilot is to deliver an innovative

solution which provides specific functionalities such as monitoring and control of the operation of DR programmes in order to decrease the peak of power consumption, engaging

consumers in DR, testing and validating the concept of a DSO (Distribu tion System Operator) as user of demand- side flexibility. Moreover, the consumer behaviour has to be analyzed to increase flexibility of energy consumption using specific DR intelligent algorithms with the final goal of providing trade flexibility solutions.

ELECTRICA SA, as a large Romanian DSO, will use the results of Ploiesti Pilot implementation to improve the offered services and to provide innovative energy distribution services packages.

Solution implementation

The Ploiesti Pilot is based on electric energy consumption data for residential users. Particularly for the Romanian Pilot, the energy demand and supply are matched by means of an intelligent solution, the EIIS (Energy Integrated Information System), aiming at delivering a direct impact on overall energy consumption. The Ploiesti Pilot is a solution developed from the scratch. The economical objective of the Pilot is to analyse the effect of the proposed automated DR solution, based on smart meters infrastructure, on the energy consumption in targeted/specific areas and the positive outcomes of implementing this type of solutions for the DSO and consumers.

ELECTRICA SA will develop within the Pilot an innovative infrastructure with energy consumers and energy providers whose demand and supply of energy will be monitored. Dedicated smart meters installed on site (smart metering infrastructure) provide data about consumption (using specific communication lines and software) which are used together with historical data to implement and validate DR algorithms.

The core integration platform of EIIS developed by SIVECO will handle several DR profiles, which could then be tested. The resulted web-based solution will provide relevant information about the power demand and evolution of consumption and also easy-to-interpret data visual representations and reports.

Such an implementation could then serve as a main starting point for latter more complex DR profiles, like Demand Side Management (DSM) and bring elements of automated decision-making, based on various profiles or criteria.

Ploiesti Pilot is based on four major data exchange flows:

- ☑ Data collection / simulation (Load measurements, Environmental measurements)
- ☑ Data analysis (based on facility & user consumption profiles)
- ☑ Data processing based on DR programs and algorithms (modelling, optimization, forecasting)
- ☑ Outputs: Alerts and notifications.

Conclusions

The Ploiesti Pilot is a complex system developed from the scratch, being the first implementation of this type of DR solution in Romania, offering a good opportunity not only for implementing a such innovative DR solution in the energy domain, but also the opportunity of implementing and validating domain specific smart algorithms and intelligent domain specific business models.

The EIIS (Energy Integrated Information System) solution will provide both consumers and Distribution System Operators the relevant data necessary to identify opportunities for consumption optimization and increased energy efficiency, ensuring the following benefits:

- ☑ Optimizing the energy consumption
- ☑ Costs reduction, energy savings
- ☑ Consumers can track and manage their consumption
- ☑ Consumers can make informed decisions
- ☑ Empowering the staff of the DSOs, Public Utility companies, electricity suppliers
- ☑ Ensuring a better forecast of the energy consumption and energy losses
- ☑ Ensuring the process transparency and the clarity of roles and responsibilities (DSO)
- ☑ Validating various business models, compliant with the specific of the targeted market.

About ELECTRICA SA and SIVECO

Electrica (SDFEE Electrica S.A) is a Romanian joint stock company focused on power distribution (DSO) and supply, providing communications infrastructure / information and energy services. In inteGRIDy, Electrica develop san innovative infrastructure with energy consumers and energy providers whose demand and supply of energy is being monitored.

SIVECO (SIVECO Romania S.A) is a private shareholder company located in Bucharest, Romania, that participates in all inteGRIDy stages of the solution development, starting with the analysis of use case requirements, the definition of the conceptual architecture, functional & technical specifications, and is the main technical partner leading the integration of the sub-components, and will also take part in the Back-end Platform demonstration and evaluation activities.

Integrated Simulation Environment for Analysing Smartening Scenarios of Distribution Grids

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ARTICLE INFORMATION

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Keywords: *Smart Distribution Grid, Renewable Energy Sources (RESs), Energy Storage Systems (ESSs), Demand Side Response (DSR), Distributed Energy Resources (DERs), Optimal Power Flow, Integration.*

ABSTRACT

Due to the proliferation of the distributed energy resources (DERs) including renewable and non-renewable types,

(re-)thinking on the way of planning and operation in electricity systems necessitated. Therefore, to decide on the best strategies for future growth in this evolution and to be able to host new DERs and to smarten operation and planning strategies a simulation environment is an essential tool. This paper presents the main characteristics of an integrated simulation environment (ISE) that can provide a multi-level analysis of the distribution level for scenario-based analysis of different distribution networks to support the smartening goals. It can help the decision-makers to decide on the best possible planning and operation strategies and in parallel help them to analyse future development scenarios. Indeed, the ISE can be applied in the design, optimization and re-adaptation of the energy networks using grid models of different smart grid pilots and different systems for various kind of studies to improve the energy potential and optimize the distribution and storage of the network at all levels.

Introduction

Due to the changing industry landscape, utilities all around the world are currently (re-) thinking the way of planning and operation to decide on the best strategies for future growth and to be able to host new distributed energy resources (DERs) and smartening strategies. So, they need to enhance their operations and planning and should become proactive enablers of integrating the new technologies.

Designing an integrated simulation environment (ISE) as a platform and decision tool for analysing different scenarios and implementing different protocols forms the basis for this paper. The ISE is a necessary tool for providing a multi-level analysis on the distribution level for scenario-based analysis of different networks to support the smartening goals [INT20-2]. It can help the decision-makers to decide on the best possible planning and operation strategies and in parallel help them to analyse future development scenarios. The ISE is able to be used to analyse both short-term and long-term effects of smartening scenarios in the distribution grids, using the forecasting tools along with the experimentally tested and validated models, behaviour profiling as well as data from the characterization of responses from the grid.

The ISE Concept

The conceptual design of the integrated simulation environment is illustrated in Figure 1. As it can be seen, there is a power system simulation tool as a core tool (here, it can be the integration test environment (ITE) of the Newcastle University [JIA20-2] or in the simplest form the MATPOWER [MAT19]) that integrates different simulation tools according to the designed scenarios.

The integration of intermittent DERs including demand side responses (DSRs) energy storage systems (ESSs), renewable energy resources (RESs), and energy management is a challenge that calls for smarter modelling and simulation analysis of the electrical networks.

The ISE is a solution to provide an interface among the model of the grid in a power systems simulation tool and different modelling, forecasting, planning and operation tools. The ISE is able to model different types of power grids in steady-state and perform the control and optimisation tasks using different algorithms. The main aims for the development of an ISE are depicted in Figure 2.

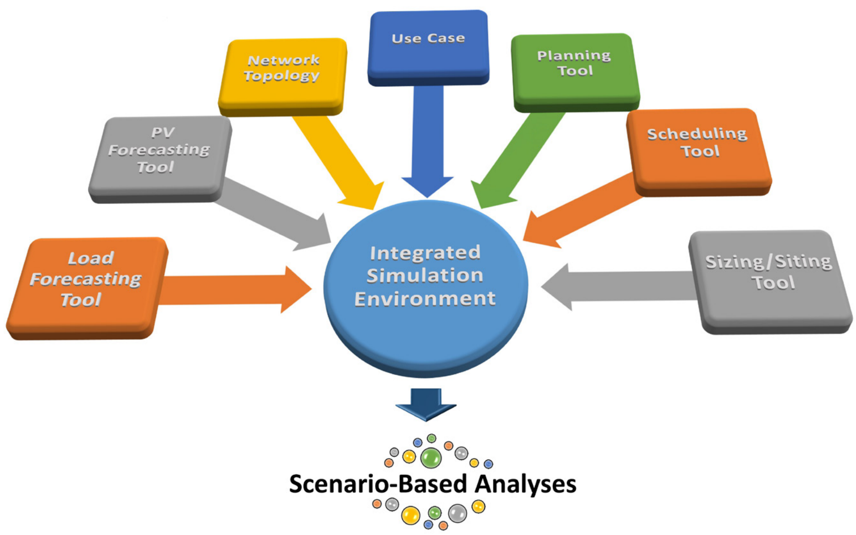

Figure 1. Conceptual Design of an Integrated Simulation Environment

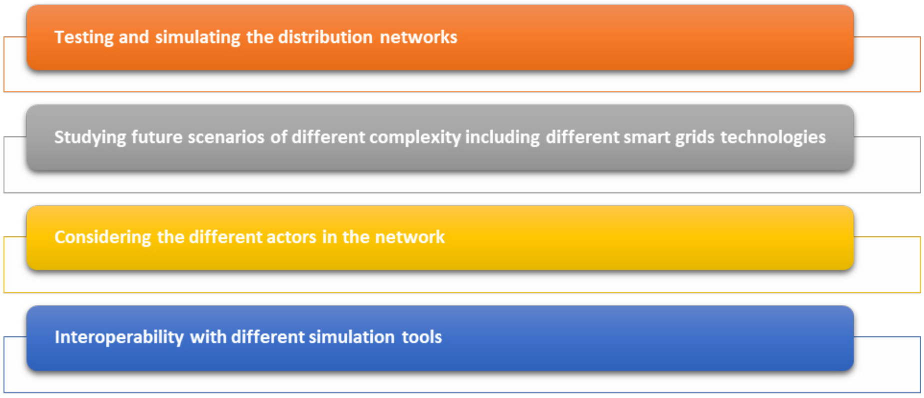

Figure 2. The main aims of the Integrated Simulation Environment development

The ISE Design

The ISE is able to be applied in the design, optimization and re-adaptation of the energy networks using grid models of different pilots and different systems for various kind of studies to improve the energy potential and optimize the distribution and storage of the network at all levels. Here, it includes three analytical layers as revealed in Figure 3, and these layers are described in the following.

3.1. Data Layer

The accuracy of every study depends not only on the efficiency of the employed model and algorithms but also on both the quality and quantity of available data. For simulation purposes, according to the cases, a variant range of data is needed. Fortunately, with the deployment of the smart grid, an avalanche of metered data

has become accessible that would be able to introduce a fresh perspective on the analysis of the systems. In the inteGRIDy pilots [INT17-1], we have extensive use of AMI and metering infrastructure that play a vital role in enriching simulation studies through the provision of a wide range of data.

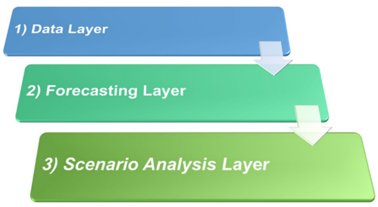

Figure 3. Analytical Layer of the Simulation Environment

3.2. Forecasting Layer

Forecasting is an essential and vital function in almost any industry. In the power and energy industry, forecasting enables the effective planning operation of the systems. It is the foundation for operation and planning studies, and it is a fundamental business problem in the industry. Particularly with the significant change in the energy resources basket and an increasing amount of renewable energy resources which brings unusual risks to the electric power industry, it is crucial to have accurate load and renewable generation forecasts for optimal operation and planning.

In the inteGRIDy project, there are various forecasting tools developed in different pilots [INT20-1] that can make a building block of the data-enriched analysis layer of the proposed simulation environment. The forecasting tools can be used to predict short-term, mid-term, and long-term time series of load and PV generation and other influential data.

In the forecasting layer, we would be able to use different available tools to forecast the profile of load, PV, etc. to have the first step to analyse future scenarios.

3.3. Scenario Analysis Layer

The objective of this layer includes the determination of the siting of new distribution generations, taking into account the flow limits of the distribution lines, voltage constraints, and meeting the required demands in different parts of the network.

In this layer, a power system simulation environment such as ITE [JIA20-2] or MATPOWER [MAT19] are able to act as the core tool. Other developed simulation tools in the inteGRIDy project, including Integrated Decision Support & Supervisory EMS (IDS&SEMS) and Supervisory Model Predictive Control for Energy Systems (SMPC) [INT20-1], can integrate with the core tool and can be used to perform a specific study or analyse an alternative scenario.

The ISE Capabilities

Alternatives simulation scenarios that can be examined by decision-makers using the ISE include, but are not limited to, the followings:

- Analysis of the impacts of adding new distributed generating capacity (different non-renewable DGs, renewable generations, customer-owned generations) in different locations of the IoW (i.e. electric busbars at 11kV and 33kV level) on the technical parameters of the network (voltage, line flows and power losses);
- Analysis of the impacts of the change of the loads in different locations of the IoW (i.e. electric busbars at 11kV and 33kV level) on the technical parameters of the network (voltage, line flows and power losses);
- Analysis of technical parameters due to the change in distribution topology (but limited) by adding new distribution lines or switches;
- Impact analysis for implementing energy efficiency and DSR programs;
- Analysis of the impacts of adding new electricity storage devices in different locations of the IoW (i.e. electric busbars) (at 11kV and 33kV level) on the technical parameters of the network (voltage, line flows and power losses);
- Analysis of the effects of EV penetration in different locations of the IoW (i.e. electric busbars at 11kV and 33kV level) on the technical parameters of the network (voltage, line flows and power losses);
- Analysis of the effects of DSR programs in different locations of the IoW (i.e. electric busbars at 11kV and 33kV level) on the technical parameters of the network (voltage, line flows and power losses).

A summary of the aforementioned possible studies using the ISE is illustrated in Figure 4.

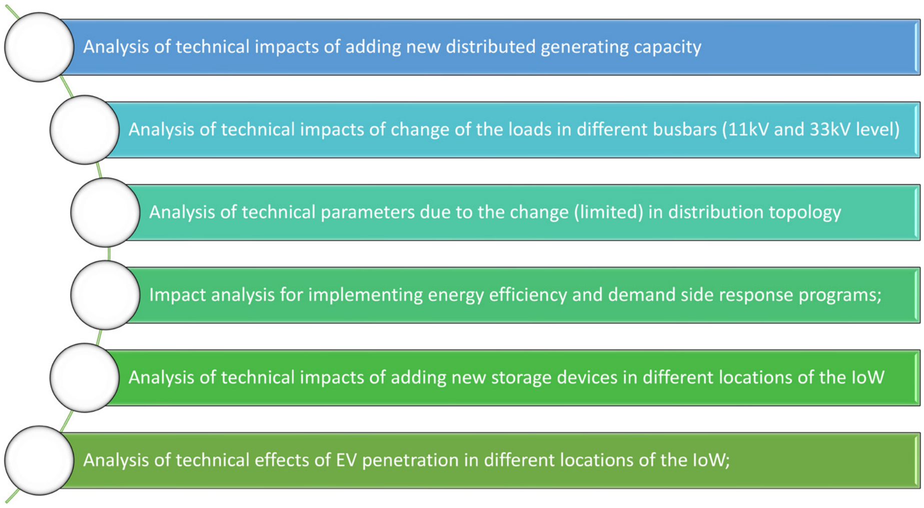

Figure 4. Different possible studies using the proposed simulation environment

Scenario Assessment

Three main steps needed to perform a scenario assessment using an ISE which are depicted in Figure 5 and explained in the following:

- Data gathering and system identification;
- Forecasting the future values of loads, PV generations, and so forth;
- Identification of the model of the system to study alternative scenarios (e.g. potential energy resources for meeting the future loads considering the predicted future generation potentials of PVs) [IPS20], [JIA20], [VAH19];
- Executing the simulation tools for analysing alternative scenarios;
- Creation and implementation of the future operational plans.

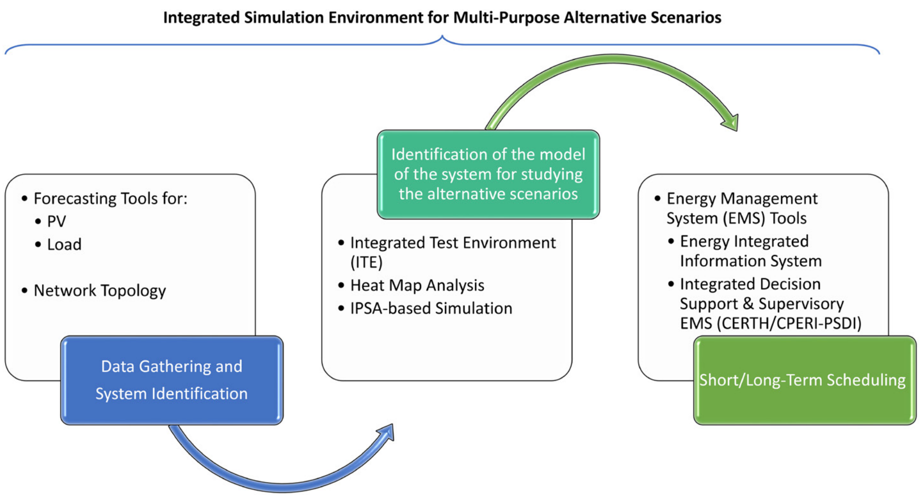

Figure 5. The main steps need to be taken in the creation of a scenario analysis

Conclusions

The ISE provides a comprehensive simulation environment for scenario-based analysis of different pilot distribution networks to support the smartening goals. It is based on a set of the state-of-the-art tools provided in different inteGRIDy pilot areas and can be applied as a useful means for analysing various scenarios in any distribution systems. It can help the decision-makers to decide on the best possible planning and operation strategies and in parallel help them to analyse future development scenarios. Indeed, the presented ISE can be applied in the design, optimization and re-adaptation of the energy networks using grid models of different pilots and different systems for various kind of studies to improve the energy potential and optimize the distribution and storage of the network at all levels. A demonstrator based on the ISE for the Isle of Wight [INT20-2], as one of the large pilots in the inteGRIDy project, showed the potential of the ISE for analysing a wide range of scenarios.

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About Newcastle University

Newcastle University is among the top 20 higher education institutions in the UK in terms of research power, according to the influential professional publication, Research Fortnight. The group of Electrical Power at Newcastle University is also one of the strongest research groups in the UK and it covers all areas of electrical power, ranging from power systems to electrical drives/machines and power electronics. More specifically in the area of electrical power, the group is considered to be one of the world’s leading research teams with international collaboration, large research funding from EU/UK, multiple esteemed publications and a very strong collaboration with industry. The infrastructure regarding power systems has been recently further strengthened with 2 newly built research facilities (The Smart Grid Lab and Energy Storage Test Bed) funded with £2m from the Engineering and Physical Sciences Research Council (EPSRC), Newcastle University and industrial partners Northern Powergrid and Siemens. These key facilities part of Newcastle’s £200 million flagship project Science Central bring together academia, the public sector, communities, business and industry to create a global centre for urban innovation and sustainability.

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Dr Damian Giaouris has received his PhD & MSc in the area of Control of Electrical Systems from Newcastle University (UK), Postgraduate Certificate & BSc in Mathematics from Open University (UK), and BEng in Automation Engineering from Technological Educational Institute of Thessaloniki (Greece). He was a Lecturer in Control Systems at Newcastle University since 2004, before moving to the Centre for Research and Technology Hellas (Greece) in 2011. He is a Reader in Control of Energy Systems at Newcastle University. His research interests include power systems, smart grids, electric vehicles, and nonlinear dynamics of electrical systems. He has more than 110 publications (with more than 2700 citations). He was an associate editor of IET Power Electronics, and he has been a Guest Associate Editor of IEEE Journal on Emerging and Selected Topics in Circuits and Systems. He has been involved with many research projects (EU or EPSRC) and currently, he works in one of the leading UK Universities in the area of Energy Systems.

Smart grid integration, self-consumption strategies & enlarged RES penetration factor

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ARTICLE INFORMATION

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Keywords: *energy consumption, savings, RES, smart buildings, Building Energy Management System*.

ABSTRACT

The pilot site for the Barcelona demonstration is the Rambla del Celler sports, located in Sant Cugat. This centre is currently consuming electricity and gas from the grid as well as producing its own energy through a hybrid solar-thermal system.

Smart tools will be developed on the specific site of high energy demand, in order to carry out DR optimisation. Alongside, additional storage solutions (thermal) or (electrical) the use of distributed Li-Ion batteries will be addressed along with the analysis of the capability of distributed end-user energy storage facilities to help the grid penetration of RES.

Introduction

The European guidelines are aiming to unify all countries' legislations and energy operating systems and, moreover, it is expected that a higher RES penetration will be highly encouraged through different strategies during the upcoming years. In addition, the demand aggregator figure is already starting to appear in the Spanish legislation, which will make the energy market to operate under different conditions and will open the door to Demand Response (DR) strategies to be applied.

This expected high RES penetration will imply a challenge in terms of operating and managing the distribution grid, which will require the implementation of DR strategies offering the end-users to be able to manage they assets (consuming elements, batteries, PV systems, etc) in order to obtain significant savings. Having said that, it is far from trivial to identify the optimum conditions and actions that would derive in an economical saving. Therefore, the technology developed within the inteGRIDy project will be demonstrated in the Barcelona pilot in order to handle the aforementioned challenges.

The pilot site for the Barcelona demonstration is the Rambla del Celler sports, located in Sant Cugat (20km from Barcelona city centre and being one of the city owned sports centres managed by the Eurofitness foundation. The sports centre has approximately 6200 members and consists of a main swimming pool next to a smaller pool, a spa area as well as several rooms dedicated to guided sessions, cycling and other fitness activities. This centre is currently consuming electricity and gas from the grid as well as producing its own energy through a hybrid solar-thermal system with a power of approximately 25kWp. In addition, ten other tertiary municipality buildings will be monitored and analysed in order to potentially increase the flexibility of the grid.

The scope of the inteGRIDy project is the main swimming pool since it has been identified as the major consumer, which requires from different elements to operate; an Air-Handling Unit (AHU) and a combination of a Seasonal Thermal Energy Storage (STES) and a heat pump in order to maintain the swimming pool under comfortable conditions. The STES was implemented in the center as part of the CHESS SETUP project, a Horizon 2020 project under grant agreement No 680556.

Several interesting energy saving measures will be implemented in this centre, including monitoring equipment and a Building Energy Management System (BEMS).

The Solution

Smart tools will be developed on the specific site of high energy demand, in order to carry out DR optimization. Alongside, additional storage solutions (thermal) or (electrical) the use of distributed Li-Ion batteries will be addressed along with the analysis of the capability of distributed end-user energy storage facilities to help the grid penetration of RES.

These tools will give solution to the following project use cases:

- ☑ Optimization of swimming pool control. A numerical model coupled with an optimiser will replicate the behaviour of the pool hall area and optimise the control parameters. Optimised control parameters of the swimming pool will be obtained based on the weather forecast, electricity pricing and swimming pool schedule.
- ☑ Usage of the swimming pool as a thermal storage system: The high inertia of the swimming pool provides certain degree of energy consumption flexibility which is exploited to provide virtual energy storage capabilities to the grid.
- ☑ Smartening the distribution grid: stacking battery functionalities. The charge and discharge of the battery system connected to a solar PV system can be controlled via a number of strategies: arbitrage; peak shaving; maximize self-consumption of solar PV production; and provide grid services.
- ☑ Smartening the distribution grid: service to the grid: Aggregation of tertiary consumers as well as prosumers, to provide grid flexibility, grid congestion management and increase the penetration of renewable energy. This service is triggered by generation schedule or DR events and requires information of the flexibility of battery and swimming pool systems, as well as forecast of energy demand and generation of site solar PV system.
- ☑ Usage of battery system in case of grid outages. Use the battery system to feed a critical demand at the sport centre in case of grid outage.

Conclusions

The implementation of the cross-functional platform provided within inteGRIDy to the Rambla del Celler sports centre aims to increase the energy efficiency of the sports centre and, thus, to offer an associated economic savings to the end-user.

Moreover, this technology can also be used by ESCOs/demand aggregators in order to increase the grid flexibility, manage DR events and improve the distribution grid management. This technology is expected to have a high relevance in the upcoming years with the consolidation of the demand aggregator figure.

The solution proposed by the inteGRIDy project has been designed such as it can be replicated for any high energy consuming building with potential large inertias, being able to offer cutting-edge technologies within a replicable and scalable cross-functional platform.

The resulting main benefits of the solutions proposed in the Barcelona pilot are:

- Improve the energy efficiency of the system considered.
- DR strategies to end-users to obtain economic savings as well as improving the grid management performed by ESCOs/demand aggregators.
- Energy storage: optimisation of battery operation and offering a backup system for grid outages.

About AIGUASOL

AIGUASOL provides engineering and research services, promoting innovative solutions to reduce the impact associated with energy consumption (experience in urban planning, construction, industrial processes and power generation, with a focus on energy planning, savings measures, energy efficiency, process integration and renewable energy implementation).

In inteGRIDy, AIGUASOL leads the Modelling Mechanisms for Topology Analysis, DR Flexibility and Storage and uses individual tools developed by CERTH and POLIMNI for the development of a consolidated tool capable of optimizing the commitment and dispatch of an electric power system, including as well aspects of sub-hourly production cost estimates. Moreover, they support the demo activities in the Sport Centre of Barcelona, under the supervision of GNF, undertaking the roles of engineering and commissioning of the specific demo activity.

Information about the author

Òscar Càmara, Mechanical Engineer, senior expert - Since 2008 he is a project manager at AIGUASOL focusing on energy modelling, renewable energy and energy efficiency. He has been involved in TASK 44 IEA Solar and Heat Pump Systems. He is AIGUASOL’s team leader in the EU project InteGRIDy and has contributed technically to the EU Projects RenewIT, PITAGORAS, INDUS3ES and CHESTER.

From inteGRIDy to INTERPRETER: a framework for added value energy services

A white paper by the inteGRIDy and INTERPRETER teams:

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ATOS SPAIN

ARTICLE INFORMATION

Published: 2020.

Keywords: *Distribution Grid, efficiency, smart grid, microgrid, DSO*.

ABSTRACT

The European strategy and its latest key targets for 2030 focuses on sustainability and energy efficiency. Reducing CO2 emissions has become the highest environmental priority, which is a cooperative work of all social agents. “Smartening” of the Distribution Grid (DG) will increase the efficiency, reliability, flexibility and adaptability of the power system and will reduce the overall expenditure of electricity generation and distribution. Research projects such inteGRIDy and INTERPRETER offer innovative solutions supporting smart grids in the effective management of the energy supply and demand.

Introduction

The European strategy, and its latest key targets for 2030, focus on sustainability and energy efficiency. Reducing CO2 emissions has become the highest environmental priority, which is a cooperative work of all social agents. From policy makers, to electricity companies or individual users, improving energy efficiency implies a change in perspective, law and consumption habits, which must go hand in hand with technological and infrastructure development.

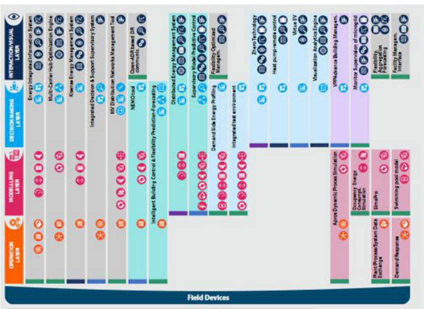
The Challenges

The electricity grid has a fundamental role in achieving the objectives set by the European Union. Hence, “smartening” the Distribution Grid (DG) will improve control and automation systems. Moreover, precise monitoring tools and the integration of micro-grids and virtual power plants will increase efficiency, reliability, flexibility and adaptability of the power system and will reduce the overall expenditure of electricity generation and distribution.

To address these challenges, innovation is needed in system integration, interoperable technologies, services, tools, business processes and regulatory regimes. Different research projects in the field of smart grids focus on validation, upscaling and replication, integrating the layers “technology”, “marketplace” and “adoption”. inteGRIDy and INTERPRETER are among these initiatives.

Solution implementation

On the one hand, inteGRIDy offers a framework of interoperable tools, oriented to different stakeholders and with special emphasis on the Distribution Grid. The ~30 inteGRIDy tools work at different layers (field, model, decision and visualization) addressing different needs and requirements in the form of macro-functionalities, facilitating optimal and dynamic operation of the Distribution Grid (DG), fostering the stability and coordination of distributed energy resources and enabling collaborative storage schemes within an increasing share of renewables. All inteGRIDy tools are developed to be compliant with a comprehensive and interoperable-by-design reference architecture.



These tools are currently being tested through 10 pilots in 8 different European countries (Spain, UK, France, Portugal, Greece, Romania, Italy, Cyprus) for validation in real-life conditions and under different market regulations.

Moreover, the inteGRIDy business model & replicability tool analyses the context and provides an assessment on how to address this replication in different markets, taking into consideration both economic and regulatory factors, and supporting, thus, industry practitioners in developing novel business models.

On the other hand, INTERPRETER offers a modular grid management solution consisting of a grid modelling tool together with a set of 10 software applications (interoperable off-line and on-line software tools) for an optimal design, planning, operation and maintenance of the electricity grid – with a special focus on the distribution network – that will be offered to grid operators through an open-source interoperable platform. These tools will support DSOs and TSOs to move from a traditional grid management approach to an active system management approach, addressing the whole power system (i.e. both distribution and transmission level) and considering the rapid deployment of distributed energy resources (variable renewables and storage) as well as growing environmental concerns.

The overall solution and each of INTERPRETER modules will be developed, tested and validated in close collaboration with 2 DSOs and partners from 6 different EU countries, providing a set of representative use cases, thus ensuring the replicability and uptake of INTERPRETER solutions across Europe.

The Use Cases are:

- Electricity grid in rural areas, characterized by long power lines with stability and power quality problems;
- Congested grids in urban areas due to a massive penetration of distributed generation (PV) and/or excessive demand (new loads);
- Old electricity grids with frequent

power outages;

- Electricity grid extension in new urban and rural areas;
- Connection of new large industrial loads to the grid;
- Connection of new large variable generation units (PV or wind) to the grid.

Conclusions

Following a pilot-driven approach that ensures the replicability and uptake of the inteGRIDy framework and the INTERPRETER solution across Europe, both projects offer a set of interoperable tools and services incorporating trending technologies with the objective of enhancing the capability of the grids, moving from a traditional grid management to an active system management approach and leading to a more dynamic smart electricity network.

The grids will benefit from the innovations developed in these projects including:

- Decarbonization of the electricity grid by the integration of large shares of renewables.
- Increased local energy self-consumption, self-sufficiency, new service provision, energy cost savings or increased energy efficiency and compensation through the integration of innovative smart grid technologies (e.g. IoT, predictive algorithms, forecasting engines, visual analytics).
- Full compliance with the European directives and regulatory framework.

Visibility of H2020 project solutions is key to guarantee reusability and best practice transfer. The EC is currently fostering this through BRIDGE cluster of projects, where common interest topics are analysed from the perspective of all involved projects (currently over 60 projects, including inteGRIDy)

Atos will keep working across the different active projects in its portfolio and in close collaboration with BRIDGE so that the outcomes of each project can benefit from the feedback and agreements (especially on the data management, architectural and harmonization topics) extracted from multiple sources. This way, the overall proposed framework of solutions would be scalable, interoperable and reusable.

About Atos Spain

Atos Spain (ATOS) is a global leader in digital transformation with over 110,000 employees in 73 countries and annual revenue of over € 11 billion. European number one in Cloud, Cybersecurity and High-Performance Computing, the Group provides end-to-end Orchestrated Hybrid Cloud, Big Data, Business Applications and Digital Workplace solutions. The group is the Worldwide Information Technology Partner for the Olympic & Paralympic Games and operates under the brands Atos, Atos Syntel, and Unify. Atos is a SE (Societas Europaea), listed on the CAC40 Paris stock index. The purpose of Atos is to help design the future of the information technology space. Its expertise and services support the development of knowledge, education as well as multicultural and pluralistic approaches to research that contribute to scientific and technological excellence. Across the world, the group enables its customers, employees and collaborators, and members of societies at large to live, work and develop sustainably and confidently in the information technology space.

Atos Research & Innovation (ARI) is the R&D hub for emerging technologies and a key reference for the whole Atos group. With almost 30 years of experience in running Research, Development and Innovation projects, ARI has become a well-known player in the EU context.

As industrial strategic partner, Atos is the inteGRIDy project coordinator and in INTERPRETER Atos is leading the Integration of the grid modelling tool and SW applications in a common framework and existing platforms facilitated through the FUSE platform.

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Javier Valiño is the Head of the Energy, Climate and Decarbonization Unit in ARI. In his role of Head of Unit, Javier is managing a portfolio of ~10 research projects and is responsible for FUSE, an open-source framework that enables the integration of devices at the edge by fully exploiting the available data from local and distributed energy resources to build value-added services for several user profiles. With a wide experience in European projects, he is the project coordinator of inteGRIDy.

Nuria Rodríguez is the Head of the Communications and Marketing group within ARI Innovation Hub team, aiming at maximizing the impact of the research projects and promoting their value to addressed targets by standardizing and professionalizing the communication processes, methodology and guidelines in the team. In parallel, she is also leading the communication tasks in various H2020 projects, and more specifically in inteGRIDy.

María M. Carbonell has a degree in Marketing from University of Murcia with a Master Degree in Neuromarketing and Customer Behavior from Complutense University of Madrid. She has been working in Atos as a Marcomm expert in charge of communication, market research and event organization and collaboration activities for different projects (among others SODALITE, INTERPRETER, MERLON, ASSET).

Malena Donato is a Business Consultant and working for business development in the Atos Research & Innovation group. Her expertise focuses on business planning, market analysis, and exploitation for IT research projects. She has more than 12 years of experience. Malena holds a degree in International Relations at The American University, Washington DC, USA and a master's degree in International Economics & Cooperation, at Complutense University of Madrid in Spain. She is the Innovation Manager in INTERPRETER and business consultant in MERLON and ASSET.

InteGRIDy Business Models: Validation Highlights

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ARTICLE INFORMATION

Published: May 2021

Keywords: *Business model development, business model validation, financial analysis, cash-flow analysis, business model replicability, inteGRIDy Business Modelling Tool, inteGRIDy Business Model Replicability Tool.*

ABSTRACT

In this whitepaper, we present a summary of the results of business model validation and business model replicability analysis conducted for inteGRIDy business models.

Overall, depending on an inteGRIDy solution and its business model, the financial analysis performed to validate the developed business models showed that the cash flow would be likely positive in the range between the first 6 months to the first 1,5 year of operations.

Furthermore, we investigated the replicability potential of the developed business models across Europe. The analysis helped assess the market readiness for inteGRIDy solutions and their business models across 17 European countries..

Introduction

During the last three years, our team at SCIL has been working closely with partners across all 10 inteGRIDy pilot sites to develop and validate business models for solutions enabled by inteGRIDy tools.

The objective of the activity was two-fold. First of all, to understand how (potential) providers of technological solutions developed by inteGRIDy pilots can create, deliver and capture value in the market. And secondly, to investigate the replicability potential of the developed business models across Europe. For this second objective, dedicated modules – Feasibility Check and Business Model Replication Tool – were developed as part of the inteGRIDy Business Modelling Platform. These tools help identify the market readiness for innovative solutions in the home country, and in other European countries. Some examples of such technological solutions would include the ones that enable the implementation of energy communities, DER and DR aggregation, local flexibility markets, and local microgrids. With support of the tool, together with pilot partners, we analysed what is the replicability potential of inteGRIDy business models across 17 European countries.

InteGRIDy Business Mode l Validation Results

In inteGRIDy, the objective of business model validation activities was to analyse how financially viable the developed business models are from the perspective of potential solution providers. Business models developed for inteGRIDy solutions all represent some variation of a Product-Service System, where the focus is on delivering a combination of products and services. To analyse their viability, we performed a cash flow analysis per business model taking into account such aspects as a potential number of customers that can be served in the first several years, costs associated with product and service provision per customer, and expected revenue streams. Each cash flow analysis was further supported by a number of solution-specific assumptions, which were validated by inteGRIDy technology providers.

Overall, depending on an inteGRIDy solution and its business model, the cash flow analysis turned out to be likely positive in the range between the first 6 months to the first 1,5 year of operations.

However, some interesting challenges and insights came up in the validation process. One of the most common challenges was high upfront equipment costs per customer. These costs are usually associated with obtaining and installing the required physical infrastructure, such as sensors, meters, or heat pumps.

Let`s take an example of the solution developed by the St Jean pilot, to see how such a challenge can be addressed. The St Jean pilot has been exploring the use of DR with commercial and residential customers and researching on its benefits for both the grid and the customer.

The solution that is proposed and partially demonstrated by the pilot is the Smart Home Service Platform. It enables residential consumers and commercial building operators to participate in DR programs and take advantage of the related financial benefits without compromising their level of comfort. Moreover, additional functionalities are offered to allow customers to understand their energy consumption through detailed analytics. The solution is enabled by necessary IoT devices (gateways, sensors, meters, actuators etc.), which must be installed onsite, as well as software applications developed by TREK (Demand Side Energy Profiling & Visual Analytics Engine).

From a service perspective, the customer can choose between a Basic and Premium package. The Basic package would include such functionalities as generation of the consumption profile; real time consumption monitoring (weekly, monthly); visual analytics; smart control of HVAC, water heater, lighting, plugged devices; several modes; and eligibility to participate in DR schemes (flat discount/discount linked to DR signals). In addition to these, the Premium package enables consumption optimization towards different scenarios, such as comfort and savings, based on profiles; and suggestions on what to do with achieved savings (i.e. offering ticket discounts linked to hobbies and favourite recreational activities). All in all, customers would be able to optimize their consumption while also enjoy smart home services.

In this scheme, SOREA would offer the Smart Home Service Platform to its residential and commercial clients and play the role of an aggregator. TREK would be their technology provider performing all necessary software updates.

In the process of validating the above described business model together with partners from SOREA and TREK, high upfront equipment costs (sensors, meters, actuators) per customer was identified as a key challenge. On average, the cost amounts to 450€ per residential customer and 1800€ per commercial customer. As benefits for customers (i.e. savings) become evident only as they are accumulated over time, such upfront costs are considered to be too high for local customers, and thus can affect the overall attractiveness of the offer. After trying different approaches, partners came up with the following scheme that tries to address this challenge. To support customers, it was suggested to offer all IoT equipment (sensors, meters, actuators) under a rent-to-own agreement. The contract would be offered in consent with the IoT equipment supplier and would be offered for 1,5 years with a 3% interest rate. Payments to the IoT supplier would be done by SOREA every 6 months. It is assumed here that the equipment provider would consider the offer attractive, as it would allow them to have a) a long-term contract with SOREA as their key provider of IoT equipment, and b) a new income stream. The exact contract conditions would of course need to be negotiated with the supplier. Under this scheme, SOREA would also contribute to The solution that is proposed and partially demonstrated by the pilot is the Smart Home Service Platform. It enables residential consumers and commercial building operators to participate in DR programs and take advantage of the related financial benefits without compromising their level of comfort. Moreover, additional functionalities are offered to allow customers to understand their energy consumption through detailed analytics. The solution is enabled by necessary IoT devices (gateways, sensors, meters, actuators etc.), which must be installed onsite, as well as software applications developed by TREK (Demand Side

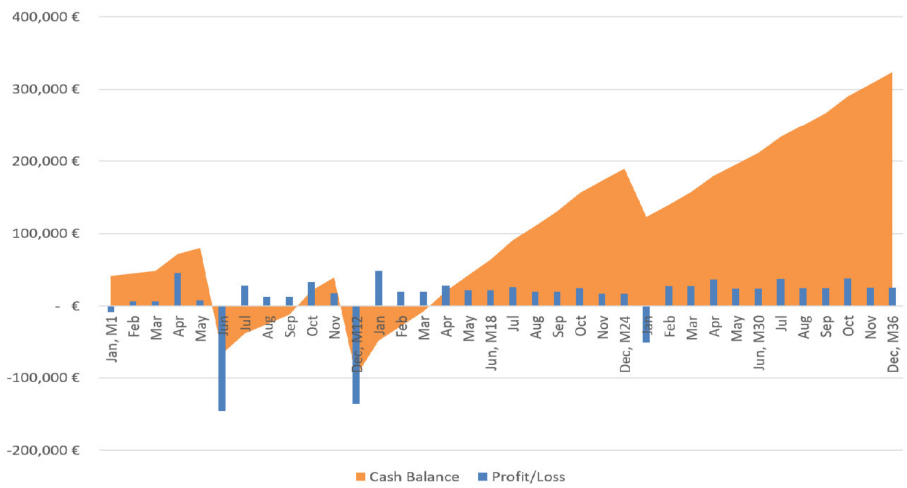

Figure 1. Projected profit & cash balance (first 3 years of operations)

Energy Profiling & Visual Analytics Engine).

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inteGRIDy Bus inessModel Replicability Analysis Results

In inteGRIDy, beyond financial viability of the developed business models, we also aimed at identifying to what extent the European countries are ready for their implementation in the market. To achieve this objective, together with project partners, we investigated the replicability potential of the developed business models across eight pilot countries (Cyprus, France, Greece, Italy, Portugal, Romania, Spain, the UK) and nine additional European countries (Belgium, Denmark, Germany, Ireland, Latvia, the Netherlands, Norway, Slovenia, Switzerland). This analysis was performed with support of the Business Model Replication Tool developed for this purpose within the project. For each country, we considered the latest status of the regulatory and legal conditions, relevant economic conditions (incl. available support schemes), current user practices (i.e. available energy community projects, V2G projects), and technology enablers. These helped us to make conclusions on the current market readiness for inteGRIDy solutions and their business models across 17 European countries (see Figure 2 for an example).

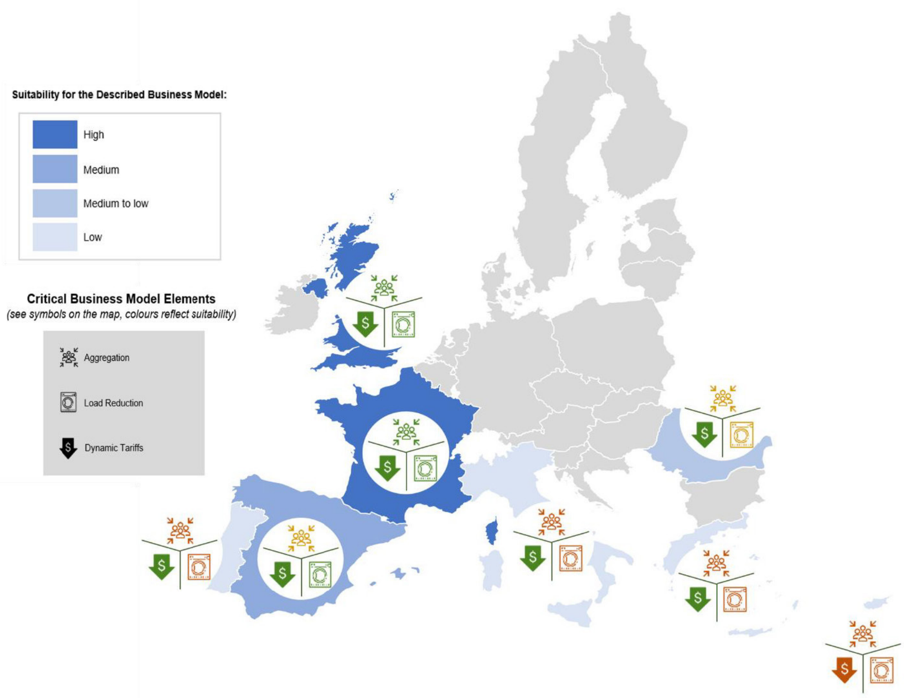

Figure 2. Results of the Business Model Replicability Analysis for the Smart Home Service Platform and its business model across pilot countries (original country of the analysed business model is France)

Figure 2. Results of the Business Model Replicability Analysis for the Smart Home Service Platform and its business model across pilot countries (original country of the analysed business model is France)

Overall, the analysis revealed that among inteGRIDy pilot countries the UK and France have the most favourable regulatory and market conditions for the implementation of the developed business models. In both countries, aggregation is legalised, and independent service providers (not involved in energy supply) are permitted, although the UK has some restrictions in place regarding the latter. In the UK, independent providers may access only some parts of the market, while some markets are closed to participation except via a supplier. In France, independent aggregators do not need to obtain a consent from the retailer/BRP to access the markets. In both countries, balancing market is open to Demand Response and Distributed Energy Resources in a range of products, and independent aggregators have access to these markets. 22 different independent aggregators are currently offering their balancing services in the UK, and around 10 independent DR aggregators are participating in the French balancing market. Explicit demand response is also practised in both countries. For example, in the UK, major participants in demand response programmes are industrial and commercial sites. The UK and France seem also to have the most favourable regulatory and market conditions for implementation of microgrid projects, particularly when it comes to interaction with the grid and the markets.

It is important to note that relevant developments are happening at their own pace in all inteGRIDy pilot countries. For example, in terms of the overall market readiness, the UK and France are closely followed by Spain. There, the regulatory framework for aggregation is currently under development, which allows to expect that the implementation of DR-related solutions will become possible in the very near future (as soon as the market rules, including DR-sensible tariffication systems, are further detailed and clarified).

Among other considered European countries, Switzerland, Germany and Ireland also seem to have rather favourable regulatory and market conditions for implementation of inteGRIDy business models.

Conclusions

The developed business models for inteGRIDy tools and components demonstrate how they can enable a variety of valuable solutions in the market while creating value for the grid, potential providers, customers, and a wide range of other stakeholders. This includes enabling benefits for local energy communities (see business model approaches for inteGRIDy technologies developed by the Nicosia and Isle of Wight pilots), local microgrids (see business model approaches developed for Terni and Xanthi pilots), commercial building operators and residential consumers (see business model approaches developed for St Jean, Ploiesti, Thessaloniki, Barcelona and Lisbon pilots).

More details on the developed business models and the business model replicability analysis will be available in D8.5 «Business Models Assessment and Replication Feasibility Analysis», which is to be published later this year.

In meantime, we invite everyone to check the inteGRIDy Business Modelling Tool for a set of useful business modelling tools designed to support researchers and practitioners in the electricity industry with developing business models for innovative solutions.

AboutUCP SCIL

Universidade Católica Portuguesa (UCP) is among the best universities in Portugal and the business school is the number one business school in Portugal according to the Financial Times Ranking (ranked 26 in Europe). Its MBA programme is ranked 36th in the world. The business school has strong ties to Portuguese businesses, the national government and the city administration of Lisbon. UCP has a tradition of national and internationally funded research projects within innovation, strategy and organizational fields.

The Smart City Innovation Lab (SCIL) is a multi-disciplinary research group at Católica Lisbon School of Business and Economics. SCIL's mission is to empower businesses to create well-being in urban areas via digital technologies, novel business models and sustainable values. The research of the group focuses on business models, entrepreneurial strategy, internationalisation and digital innovation.

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A KPI-Based Evaluation for InteGRIDy Project Framework and tools performance

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Keywords: *Key Performance Indicator, Evaluation methodology, Baseline assessment, Smart grid*.

ABSTRACT

The overall impacts and success of the different tools implemented within the inteGRIDy project were assessed through the analysis of Key Performance Indicators (KPIs) that appropriately reflect the technical, economic, environmental, and social domains of the respective inteGRIDy thematic pillars.

Teesside University led the evaluation of the overall inteGRIDy framework and tools performance, considering the evaluation of improvements brought by individual components of inteGRIDy-enabled smart solution implementations and user experience across the ten pilot sites. The analysis and interpretation of findings for the pilot use case evaluation, future development, and potential exploitation of the partner tool were ascertained.

Overall, the smart solution implementation across the ten pilot sites resulted to achieving the inteGRIDy set objectives with regards to energy consumption reduction & cost optimization (Isle of Wight, Terni, Barcelona, and Xanthi); DR flexibility / stability (Isle of Wight, San Severino, St Jean, Nicosia, Barcelona, Lisbon, and Thessaloniki) and carbon dioxide emission reduction (Isle of Wight, Lisbon, Ploiesti, and Thessaloniki).

Introduction

The overall impacts and success of the different inteGRIDy framework and tools implemented within the respective pilot sites was led by Teesside university in collaboration with partners from the pilot sites. The evaluation of pilot use cases was assessed through the analysis of KPIs reflecting the technical, economic, environmental, and social domains of the respective inteGRIDy thematic pillars, following the methodology and best practices proposed in D1.4 [1].

This white paper takes into consideration the related inteGRIDy project work packages since the information they provide defines the inteGRIDy KPIs, metrics, framework, and methodology, resulting to the overall improvement of inteGRIDy-enabled solutions and grid performance.

The analysis, interpretation of findings and a conclusive remark on the pilot use cases is provided, upon the completion of individual pilot use case evaluation.

Data collection

Data collection methods (both qualitative and quantitative) have been established and used for baseline assessment and smart solution scenarios. Data used in the KPI evaluation was obtained from different sources such as data from Building Management System (BMS) and Building Automation System (BAS), conventional and smart meters, utility bills, battery management systems and Electric Vehicle (EV) charging platforms, smart sensors, online web services and questionnaires.

Evaluation Methodology

The first list of KPIs was reported in D1.4 at the beginning of the project and later updated in D8.1 [2]. During the evaluation, it became imperative to review and validate the KPIs with respect to the pilots' needs, considering the changing effects (amendments) on some pilot sites. In some cases, new set of KPIs that show significance to the use case objectives were selected for evaluation as local KPIs (specific to the pilot site). The validation of KPI evaluation parameters and the objectives of the pilot site use-cases naturally evolve after closer interaction with the pilot partners.

For the KPI evaluation, the baseline scenario was compared against the smart solution implementation in the pilot sites. KPIs related to Demand flexibility were evaluated considering the requested and potential energy demand flexibility (increase or decrease in certain percentage of energy demand) based on the contractual framework applicable to the pilot sites.

Outcome

The KPI evaluation results are presented for the respective performance domains (Technical, Economic, Environmental and Social) across pilots. KPI results for the Isle of Wight pilot M7 Energy storage use case are presented in Table 1 to 3 below. For Technical KPI evaluation, Energy consumption, peak to average ratio, Energy consumption reduction, demand flexibility ratio and peak load reduction are presented in Table 1.

For the economic KPIs, percentage difference of 68% was obtained in the retailer cost of energy between the baseline and smart solution costs. Whereas there is a significant reduction of 982.87kg CO_2 emission due to smart implementation as shown in Table 3.

For some pilot sites, the results and analysis of the energy consumption reduction (as shown in Figure 1) are presented to show the visual difference between the baseline energy consumption and the consumption after smart solution implementation.

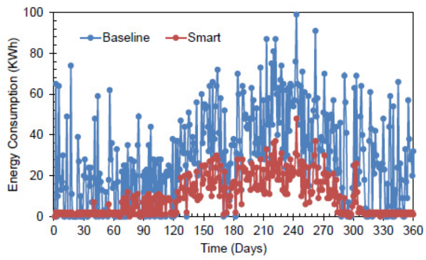

Figure 1. Minus7 Energy Storage System Energy Consumption

KPI Data	Unit	Baseline	Smart
Energy Consumption	kWh	691	48
Peak to Average Ratio	%	296	129
Energy Consumption Reduction	kWh	643	
Demand Flexibility Ratio		0.930535456	
Peak Load Reduction	%	64	

Table 1.Technical KPI Results for Isle of Wight M7 Energy storage use case

KPI Data	Unit	Baseline	Smart
Retailer Cost of Energy	£	1443.69	468.04
Avg cost of Energy Consumption	£/kWh	3.97	1.29

Table 2. Economic KPI Results for Isle of Wight use M7 Energy storage use case

KPI Data	Unit	Baseline	Smart
CO2 Emission	Kg	1454.38	471.51
CO2 Emission Reduction	kg	982.87	

Table 3. Environmental KPI Results for Isle of Wight M7 energy storage use case.

The outcome from the overall inteGRIDy framework and tools performance are summarised below:

Isle of Wight

- Virtual Power Plant (VPP) for Advance Building Management System Control (ABMSC) has been delivered.
- Demand Side Management (DSM) services have also been delivered with energy supplier input.

Terni

- Evaluation of Terni plot use cases has shown that collaboration mechanism between the DSO and Microgrid strongly enhances energy efficiency of the grid, which can be replicated in other microgrids when a proper regulatory framework is put in place.

San Severino

- A state-of-the-art forecast of renewable productions and load needs has been put in place and can provide a short-term forecast of the power injections and estimating long term (up to one year) prediction.
- Small scale batteries have been deployed in final user premises, exploiting them for improving self-consumption and testing an innovative service stacking approach.

Barcelona

- Smart solution implementation resulted in a reduction of 10% of the primary energy consumptions and a reduction of 42 tons of CO2 emissions.
- Through maximising self-consumption from battery storage systems and PV generation, a significant decrease of 15% in energy cost and a carbon emission reduction of 255.96 kg was achieved.

St Jean

- The tools deployed at the St Jean pilot focused on the accurate, human-centric demand flexibility definition and DR control implementation. The implemented strategies yielded very promising results in relation to the flexibility potential of the pilot users.
- The validation results reveal a tool of high potential and forecasting capabilities providing discrete and well accepted control automation to the end-users.

Nicosia

- Flexibility readiness of the users through ad-hoc tests and regular operation was performed.
- Despite multiple challenges faced, mostly on the user side, the Nicosia-Cyprus demo site managed to effectively test and prove the use cases, fulfilling the objectives of the project and verifying performance through platform-trackable and other derived metrics.

Lisbon

- Results of tests demonstrated in Lisbon indicated that measures in practice allow the reduction of consumption in periods of higher tariffs, due to the pivotal action of the photovoltaic generation.
- Energy stored thermally in the ice tanks is used whenever the generation is not enough to supply the building loads. Calculated KPIs demonstrate cost saving actions, enabling a downward trend of the energetic consumption as a peak load reduction.

Xanthi

- The virtual storage system implemented in Xanthi pilot site resulted to at least 45% less usage of the backup and less operating costs for the evaluation period.
- The amount of energy consumed from the microgrid (DG production) shows a reduction of 410.334 kWh in the evaluation period of (March and April). This results to a reduced Retailer cost of 329.50 € from a baseline retailer cost of 637.25 €.

Ploiesti

- The results obtained at the demonstration site show the feasibility of implementing an Energy

Integration Information System (EIIS) such as application for monitoring, forecasting and optimisation of consumption at end user and DSO level.

- Optimization and forecasting were implemented using historical data from first generation smart meters and machine learning. Energy consumption reduction of 27030 kWh was observed.

Thessaloniki

- DR schedules were generated daily via Implicit DR events for each residence. The results indicate a reduction in both the peak to average ration (PAR) and the peak reduction. In addition, a slight decrease in CO2 emission is evident, mainly due to the decreased energy consumption, both in office level and building level.
- The effect of using BESS instead of DR, when installed within the premises of commercial buildings, is also considered, where the PAR was reduced from 2.36 to 2.34% due to inteGRIDy solution.

Conclusion

The goals and objectives of KPIs and use cases, as established within the activities of WP1 and WP8, have been evaluated, following the adopted methodology for the evaluation process.

Despite the changes that occurred in some pilots due to several reasons, such as the COVID-19 pandemic restrictions, leading to procedures taking longer than originally expected, the evaluation of use case objectives has not been significantly affected. However, there have been some minor changes in the KPIs across pilot sites to adapt and reflect the objective of smart solution implementations across board. Following the KPI evaluation of pilot use cases, the overall impacts and success of the different partner tools implemented within the respective pilot sites have been ascertained.

Overall, the implementation of smart solution technologies within the inteGRIDy project has significantly achieved the set objectives such as demand flexibility/Grid optimisation; reduction in energy consumption, cost optimisation, retailers' costs, and energy storage/EV, CO2 emission reduction related to pilot site use cases.

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About Teesside University

TEES are involved in the inteGRIDy project and provides the Neighbourhood Energy Management and Optimization (NEMO) tool for the Barcelona pilot use case. NEMO has an extended functionality of communication modules and optimisation and builds upon energy management technology developed and demonstrated as part of the DR-BOB and IDEAS project1. More specifically, for inteGRIDy, NEMO optimization and decision-making functionality was implemented to optimize the self-consumption of PV generation via charging and discharging of the Battery energy management system (BEMS) in the Barcelona pilot site.

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A Cost Benefit Analysis of the Implementation of Renewable Energy Technologies and Smart Technologies Solutions to an Exisiting Energy System

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ABSTRACT

The Costs Benefits Analysis focusing on three pilot sites within the inteGRIDy project: St-Jean, Nicosia and Barcelona, was carried out. For all three pilot sites, the analysis considered two scenarios; the first scenario was a baseline scenario where no smart and/or renewable energy technologies had been implemented, and the second scenario that include the respective smart and/or renewable technologies for each pilot site. The analysis focused on examining the monetised costs and economic benefits for each pilot site to highlight the economic benefits obtained from implementing smart and renewable energy technologies.

The analysis included a set of predetermining technical, social, environmental, and economic indicators defined by previous inteGRIDy Deliverables which defines Key Performance indicators (KPI) and metrics as well as benefits categories for CBA/CEA and overall evaluation and impact assessments. Most of these predefined indicators were adopted for the CBA Analysis. However, in some cases, pilot specific and suitable indicators needed to be defined through discussion with the pilot partner and used in analysis due to various changes and technical issues that occurred over a work period. Relevant indicators such as Capital Investment, Operating and maintenance costs, and the Revenue generated from the incorporation of smart solution technologies that cover the energy storage, demand response, and smartening of the distribution grid were included in the analysis.

Results from the analysis indicated that the implementation of smart and renewable energy solution technologies proved to be economically viable for all the three pilot sites, with return on investment of 50%, 90% and 41% and payback time of 2.86, 8.2 and 12.4 years for the St Jean, Barcelona and Nicosia Pilots respectively. Furthermore, the results also highlight that implementation of a smart and renewable energy technology solution provide positive environmental gains and societal impact, since the technological implementation decreases the greenhouse gas emission for the energy system, and enhance the energy system stability, thereby improving the energy security for the consumer.

Introduction

The overall cost benefits assessment to identify and assess the economic benefits and success of the technological implementation for three different inteGRIDy pilot sites was led and carried out by Teesside University in collaboration with partners from the pilot sites. The cost-benefits analysis of the three pilot sites was structured around focusing the analysis on assessing the economic gains of integration of renewable energy, energy storage, optimization, and distribution technology to an already exciting energy system within three inteGRIDy pilot sites St-Jean, Barcelona, and Nicosia. The methodological selection, justification and underpinning of the cost benefits analysis and identification of key relevant economic, social, and environmental KPIs were proposed in D1.4 and D3.2. [1,2]

This white paper focuses on presenting the key results from the cost benefits analysis for the three identified pilot sites and provide a policy recommendation based on the results. The work presented in this white paper takes into consideration related inteGRIDy project works carried out in other work packages

since the previous work defines the selection of the three pilot sites, identified some of relevant KPIs for the cost-benefits analysis, framework structure and methodological settings and justification, which provide the basis for the cost benefits analysis carried out in T8.4.

Data collection

Data collection for the cost benefits analysis required a collection of quantitative data sets regarding i) the energy system such as energy consumption, energy supplied, energy production capacity, investment cost for energy system expansions, energy technologies within the system, and operation and maintenance cost of the energy system and ii) the energy market, such as energy price, market size, the share of renewable energy technology in the market, shares of convectional fuel energy technologies in the market. The required data collected was based around 2019 and was used to establish a baseline at the first year of analysis for both the baseline scenario and technology implementation scenario, which differentiate between each pilot based on their specific technologies and characteristics. The data were obtained through collaboration with relevant partners at each respective pilot site.

Evaluation Methodology

The selection and justification of the cost benefits analyses method were stated in D3.2, which provide the justification of selecting and applying the cost-benefit analysis methodology to assess the economic gains. As highlighted, the analysis focused on the economic benefits of the implementation of renewable energy technologies and smart technological solutions to existing energy systems for the three pilots [2].

The initial list of KPIs reports in D1.4 at the beginning of the project and later updated in D3.2 and D8.1 provide a good list of relevant economic, environmental, and social variables to be included in the cost-benefit analysis [1-3]. Nevertheless, during the work, it becomes evident that more KPIs needed to be reviewed and updated to include local and specific KPIs relevant to each pilot site's needs and the characteristic of their use cases and energy system. These predefined KPIs and, along with review added KPIs are present in Table 1

KPI	Domain	Units
Average Cost of Energy	Economic	(€ / year)
Average cost of Energy Consumption	Economic	(€ / year)
Cost of Energy Consumption	Economic	(€ / year)
Energy Payback Time (EPBT)	Environmental	(€ / year)
Cumulative Energy Demand	Environmental	(€ / year)
RES Generation	Technical	(MWh / year)
Energy Consumption (Yearly, Monthly, Daily)	Technical	(MWh / year)
Energy Imports	Technical	(€ / year)
Energy Consumption Reduction (Demand Flexibility)	Technical	(MWh / year)
Demand Flexibility Ratio	Technical	(MWh / year)
Energy Mismatch	Technical	(MWh / year) (€ / year)
Energy Mismatch Ratio	Technical	(MWh / year) (€ / year)
Share of RES	Technical	(MWh / year)
Cost of Flexibility	Economic	€
Cost of Production One unit of Energy (MW)	Economic	€
Investment Costs	Economic	€
Operation and Maintenance Costs	Economic	€
Total Income (Revenue)	Economic	€
Energy Price per MW	Economic	€
Savings gained from Flexibility	Technical	€
Benefit gains from 1 Euro Invested	Economic	€

Table 1: KPIs used for Cost Benefit Analysis

The cost-benefits analysis for this study is constructed around applying the KPIs present in Table 1, which are relevant costs indicators to the capital costs, operation and maintenance costs, energy market costs variables, and KPIs relevant to benefits costs such as revenue from energy sale, saving gains, and cost of flexibility in the energy production,

Moreover, the evaluation methodology requires a set of general assumptions applied across all three pilot sites, which is present in the Table 2 below.

Beside the general assumption, a pilot site-specific unique set of assumptions were required to ensure that calculation capture and illustrate close as possible the real-world scenario and dynamics of each pilot site, these assumptions are present in Table 3

General Assumption	Description/Value
Discount Rate	3.5%
Time Period	2020-2039
Base Year	2020

Table 2: General Assumption for CBA

Description	Values / Units	Comments
St Jean Pilot Site		
Energy Price per MW (PV)	€ 380.00	At the first year
Energy Price per MW (National Grid)	€ 110.74	At the first year without taxes
Centrale des Clapeys	€ 70.00	At the first year
Centrale de Saint Julien Montdenis	€ 75.70	At the first year
Centrale de la Neuvachette	€ 83.20	At the first year
The three plants that come online between 2023 and 2027	€ 80	At the first year of operation
Energy Imports Growth	1.20%	per year
Growth in RE Generation	5%	36% - until 2028
O&M cost annual increase (Hydro)	3%	of total investment
Energy Consumption growth rate	-1.50%	per year
Annual Price Decrease (PV)	6.30%	per year
Avg Annual Price increase	5%	per year
Other Growth Rate	3%	
Discount Rate set by France Authorities	2.8%	
Energy index tariff evolution	1.12%	
PV - Annual Investment from 2020 to 2023	€ 464,600.00	
PV - Annual Investment from 2023 to 2028	€ 920,000.00	
Hydro - Annual Investment to 2023	€ 965,333.33	
Hydro - Annual Investment to 2028	€ 2,606,400.00	
Hydropower plant Centrale Valloirette (3 MW) - 2023 O&M costs	€ 55,000.00	Per year
Hydropower Plant 1MW - 2026 O&M costs	€ 35,000.00	Pear year
Hydropower Plant 1MW - 2027 O&M costs	€ 35,000.00	
Barcelona Pilot Site		
Energy Price (€/MWh) Conventional	68.45	At the first year
Energy Price (€/MWh) PV	68.45	At the first year
Gas Price (€/MWh)	45.85	At the first year
Increase in energy price (Conventional)	2.5%	Per year
Increase in energy price (PV)	3.5%	Per year
Energy Consumption Growth Rate	-0.5%	Per year
Carbon Dioxide Emission Ratio	0.331	Per kWh
Exchange rate	1.16	Pounds to Euros
Nicosia Pilot		
KPI Peak Demand Reduction	15%.	during operational period
labour cost	€40,000.00	For the labour cost, 4 operators with an average annual wage
wage increase rate	1%	wage increase rate for 20 years was assumed

Table 3: Pilot Specific Assumptions

Pilot Site Scenario Description

St Jean

The cost-benefits analysis for the St-Jean pilot site also consists of and considered two scenarios.

- Scenario A – Conventional Energy System grid with no Renewable Energy Technology implementation.
- Scenario B – Renewable Energy Technology Integration, Energy Flexibility and Storage capabilities.

The key difference between these two scenarios that are considered in the cost-benefit analysis is that Scenario A is based on the assumption that the energy supply from pre-existing energy systems only comes from conventional fossil energy resources without any localized energy technologies. In comparison, Scenario B is based around the introduction and implementation of renewable energy technologies and smart technology solutions to the pre-existing energy system from scenario A. The main characteristics for both Scenarios based on the simulation results over the period from 2019 to 2039 can be seen in Table 4 and Table 5.

Average (Supply)	111705.48	MWh
Peak (Supply)	124813.76	MWh
PAR (Supply)	112%	%
Average (Demand)	110954.60	MWh
Peak (Demand)	127600.72	MWh
PAR (Demand)	115%	%
% of Res	0%	
% of Imports	100%	

Table 4: Key Characteristics for Scenario A

Average (Supply)	133231.85	MWh
Peak (Supply)	140237.65	MWh
PAR (Supply)	105	%
Average (Demand)	110954.60	MWh
Peak (Demand)	127600.72	MWh
PAR (Demand)	115	%

Table 5: Key Characteristics for Scenario B

Barcelona

The cost-benefits analysis for the Barcelona pilot site consists of and considered two scenarios.

- Scenario A – Conventional energy system without the implementation of any smart solution technology.
- Scenario B – Smart solution implementation in addition to the conventional energy system.

The implementation of renewable and smart technologies consider for cost benefits evaluation of the Barcelona Pilot site can be characterised into two groups; the PV system with battery storage technology classified as Technology A, and then the Integrated Energy Platform classified as Technology B. Associated costs with Technology A and Technology B are summarised in Table 6 and Table 7.

CAPEX	€54,359.57
OPEX (maintenance)	€50.25
Total Cost	€49,318.82

Table 6: Costs specific of Technology A

CAPEX	€5,100.00
OPEX (periodic fee)	€3,200.00

Table 7: Integrated Energy Platform Costs

Nicosia

The cost-benefits analysis for the Nicosia pilot site similarly consists of and considers two scenarios.

- Scenario A – Business as Usual, the current energy system which applies conventional grid upgrade and reinforcement solution and has minimum flexibility within the system
- Scenario B – Integration of a Flexibility Platform to the current energy system for congestion avoidance to replace the usual conventional grid upgrades and reinforcement.

The associated costs for the flexibility platform are presented in Table 8.

	DR= None	DR=1.5%	DR=3.5%
CAPEX	5000000	5000000	5000000
OPEX Personnel	3523041	3009440	2475354
Market Reimbursements	21229831	16692492	12223836
Total Cost	29752871	24701931	19699190

Table 8: Flexibility Platform Costs

Outcome

The overall results from the cost-benefits analysis of the three pilot sites highlight that implementation and integration of renewable energy technologies to pre-existing conventional energy systems provide positive impacts and gains across the economic, social, and environmental spheres. The implementation and integration of renewable energy technologies provide economic gains for the stakeholders involved in the energy system by increased flexibility, possibility to increase revenue through the sale of excess energy, economic cost savings gains associated with lower CAPEX and OPEX associated costs and more effective utilization of energy resources and lower costs regarding grid upgrades and reinforcements once the integration of technology solution is completed. Secondly, the positive environmental gains in terms of decrease in greenhouse gas emission. Thirdly the positive societal impacts related to reductions in emissions from the energy system and improved energy security gained from increased flexibility capacity of the system and enhanced supply stability in the system.

Figure 1 below shows the flexibility changes and gains between the two St-Jean scenarios, with orange colour bars representing Scenario B, and blue colour bars representing Scenario A.

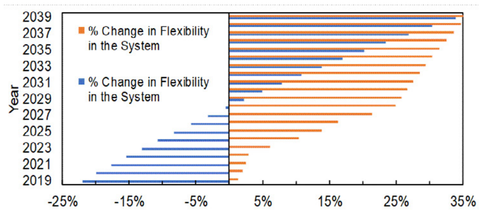

Figure 1: Flexibility for St Jean Pilot

St Jean

- The transition towards an energy system where the energy generation is entirely based on renewable energy technology appears to be economically viable for DSO stakeholders within the St-Jean energy system, with DSO obtaining a total economic gain of € 1,127,344.46 (NPV) over the whole simulation period from 2019 to 2039, Table 9 illustrates results from the economic assessment concerning the investments, income, and economic benefits gained from flexibility for both scenarios.

Variables (€)	2.80% (€)	3.50%
Total Energy System Investment (Scenario A)	29,681,906	29,481,159
Total Investment (Scenario B)	63,883,765	63,451,701
Economic benefits from the Flexibility (Scenario A)	5,127,606	5,092,92
Economic benefits from the Flexibility (Scenario B)	65,058,511	64,618,502
Total Income (Scenario A)	552,954,300	549,214,512

Table 9: Sensitivity Analysis for St Jean Pilot

- The transition towards and implementation of renewable energy generation to St Jean pilot also has a social impact since the transiting to a fully renewable-based energy system enables a shift towards greener energy consumption.
- The analysis carried out also presents that shifting towards renewable energy-based energy systems improves the system's energy security and stability, with a higher degree of flexibility to meet demands within the system.
- The renewable energy system provides support for the implementation of smart technology solutions such as VES, which will enable a better utilization rate of energy flexibility capacity within the system.

Barcelona

- Over the 20-year period considered for this evaluation, for scenario A with no smart solution implementation (baseline), a total 47 MWh of electricity and 24 MWh of gas are required which amounts to € 5,731,156.
- The incorporation of the technologies will require a capital investment (CAPEX) of € 80,709 an operating cost of € 65,000, electricity demand of 47 MWh and a gas demand of 20 MWh making a reduction of 4 MWh of gas. The overall cost of the smart solution technologies implemented in the Barcelona pilot adds up to € 5,662,921.
- Table 10 illustrates the economic assessment results concerning the OPEX, CAPEX, Total Costs, and Revenue through the whole simulation period from 2019 to 2039.
- Overall, the analysis indicated that implementation of smart solution tools for the Barcelona Pilot are economically viable with a payback time of 8.2 years. The technologies were also able to save over 53 tonnes of carbon dioxide emission just within the first year.

Discount Rates	2%	3.5%
Total Energy Costs Scenario A	€ 5,618,780.00	€ 5,537,348.41
CAPEX Scenario B	€ 79,126.05	€ 77,979.29
OPEX Scenario B	€ 5,472,757.24	€ 5,393,441.92
Total Cost Scenario B	€ 5,551,883.29	€ 5,471,421.21
Revenue Scenario B	€ 314,259.30	€ 309,704.82
NPV Scenario B	€ 32,839.10	€ 32,363.17

Table 10: Sensitivity Analysis for Barcelona Pilot

Nicosia

- Investment and implementation in flexibility platform technology that is used to congestion avoidance within Nicosia Pilot energy system provide economic savings for the DSO in terms of costs associated with CAPEX and OPEX costs and overall costs compared to the DSO investing in conventional gird and reinforcements upgrades. Table 11 above illustrates results from the economic assessment and presents DSO economic savings concerning the CAPEX, OPEX, and total costs.
- The implementation of flexible platform technology to the Nicosia pilot site energy system has a positive societal impact since the implementation of the technology enhances the energy system, which improves energy utilization rate within the system, decreases energy waste in the system, and enhances the stability of the system. Thereby providing increase energy security to the consumers.

Variables (€)	2.50%	5%
Market Reimbursement (Increase)	9,059,215.55	8,641,903.25
Grid CAPEX Savings (Decrease)	8,622,066.36	7,767,604.88
Flexibility platform CAPEX (Increase)	9,351,527.84	9,226,527.84
Flexibility platform OPEX (Increase)	9,401,291.85	9,326,055.85
Flexibility Prices (Increase)	9,059,215.55	8,641,903.25

Table 11: Sensitivity Analysis for Nicosia Pilot Conclusion

Conclusion

The economic analysis of the three pilot sites (St. Jean, Nicosia, Barcelona) that was carried out in T8.4, focused on understanding the economic viability and highlighting any positive and negative economic impacts regarding the technological investment and implementation of renewable energy technologies and smart solutions technology to respective energy systems.

The economic analysis highlights that across all three pilot sites, the investment and implementation of the proposed technology solution prove to be economically viable over the 20-year evaluation simulation period. Provide low to high marginal profit to the DSO either through increase revenue gain from the flexibility and better energy utilisation or cost avoidance related to lower costs associated with grid upgrades.

Besides, the economic gains achieved from implementing smart and renewable energy technology to pre-existing energy systems result in positive societal impacts through increasing energy security and stability of the energy system. In addition, the mitigation of greenhouse gas emissions is achieved by increasing the shares of renewable energy generation within the systems and greener energy consumption.

Overall, the results from the economic analysis of the implementation of smart solution technologies within the three inteGRIDy pilot sites (St Jean, Nicosia, Barcelona) highlights that the implementation enhances the demand flexibility/Grid optimisation; reduction in energy consumption, cost optimisation, retailers' costs, and energy storage/EV, CO2 emission reduction.

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About Teesside University

TEES are involved in the inteGRIDy project and provides the Neighbourhood Energy Management and Optimization (NEMO) tool for the Barcelona pilot use case. NEMO has an extended functionality of communication modules and optimisation and builds upon energy management technology developed and demonstrated as part of the DR-BOB and IDEAS project1. More specifically, for inteGRIDy, NEMO optimization and decision-making functionality was implemented to optimize the self-consumption of PV generation via charging and discharging of the Battery energy management system (BEMS) in the Barcelona pilot site.

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