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Real-time demand response and intelligent direct load control

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From Empirical to Intelligent Load Management in a Banking Energy Performance Contract

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Abstract

As stated in the H2020 Work Programme of the societal challenge, moderating energy demand will be crucial in the current energy transition. Demand Response (DR) strategies represent an appealing value proposition to end-users, as it enables them to monetise the flexibility embedded in their peak demand through the minimisation of unnecessary or excessive electricity usage. This market opportunity sets the base for the Virtual Power Solutions (VPS)' Kisense platform, which is an Active Energy Management System that delivers state-of-the-art DR technology for distributed blocks of buildings, providing new energy flexibility services as part of energy contracts and enabling micro-grid environments in liberalised energy market contexts. With that said, VPS engaged in an Energy Performance Contracting (EPC) with a major Spanish bank with activities across Portugal from 2013 to 2020. VPS equipped more than 100 bank branches with the Kisense platform, which enables the implementation of DR strategies, namely load shedding, load shifting and optimization of the energy contract towards RTP of electricity, which in approximately 15% annual energy saving (KWh) in 2016, when compared to the baseline year (2013). As for what VPS envisions for the future, the evolution of energy markets is accelerating in the direction of a greater reliance on Distributed Energy Resources, and the most promising strategy to address this trend is Virtual Power Plants (VPPs). In short, VPP creates better conditions for the introduction of new renewable energy sources and that is why VPS developed Kiplo, the first in the VPP platform market, designed to scale-up the Kisense platform. In conclusion, Kiplo will be in line with the growing European interest in open energy markets and Kiplo is expected to be a key tool in the future in this market segment.

Keywords: automated demand response, energy performance contracts, load management, virtual power plants

1. Introduction

As stated in the H2020 Work Programme of the societal challenge entitled 'Secure, Clean and Efficient Energy', moderating energy demand will be crucial in the current energy transition. A high level of energy efficiency is beneficial for security of supply, sustainability, affordability for households, SMEs and industry and competitiveness of the EU economy.

By seeking a solution to this challenge, Small and Medium Enterprises (SMEs) are identifying comprehensive market opportunities to deliver energy efficiency measures whilst ensuring high levels of indoor environment quality (thermal comfort, air quality, etc.) through Demand Response (DR) programmes.

In general terms, DR mainly refers to programmes that communicate to consumers the changes in energy market prices or in their overall energy consumption patterns, whilst encouraging them to alter their energy consumption behaviour and habits to reduce peak loads and save energy [1] [2].

In this sense, DR combines significant scientific fields such as energy efficiency, energy storage, distributed electricity production from renewable sources integration as well as Energy Management with valuable active end-user engagement to achieve the desired shifting of peak loads [1] [3].

DR offers several benefits to the energy systems, including increased efficiency of asset utilization, supporting greater penetration of renewables on the grid without decreasing stability, easing capacity issues on distribution networks to facilitate further uptake of distributed generation on congested local networks, reducing the required generator margin and costs of calling on traditional reserve, and including the associated environmental benefits through reduced emissions [2]. This represents an appealing value proposition to end-users, as it enables them to monetise the flexibility embedded in their peak demand through the minimisation of unnecessary or excessive electricity usage.

Banks represent a well-fitted addressable market for these solutions as it often has large-scale, diverse facilities with significant utility costs, complex operational requirements and increasing regulation requiring proof of effective energy and carbon management.

Currently, most of the DR tools available in the market provide only rather static and coarse means to control, monitor and estimate energy consumption at the consumption sites, which leads to energy wasting in buildings - e.g. non-optimal heating/cooling. Despite the many advantages of DR applications, there are still very few examples of the successful deployment of DR technologies in distributed blocks of buildings in the real world [6], achieving a reduction in peak grid demand and real savings for consumers.

This market opportunity sets the base for the Virtual Power Solutions' Kisense platform, which is an Active Energy Management System that delivers state-of-the-art DR technology for distributed blocks of buildings, providing new energy flexibility services as part of energy contracts and enabling micro-grid environments in liberalised energy market contexts.

2. Context

Virtual Power Solutions (VPS) is a technology company that addresses important market needs arisen from the current energy transition, thus targeting: i) energy consumers that want to minimise, optimise and monetise their energy demand, to be adapted to the future introduction of innovative dynamic tariffs in European markets, and to increase their energy independence and sustainability through low carbon buildings; and ii) energy suppliers, DSOs and aggregators who need to balance their grid, assure a secure operation and minimise the deviations to the forecasted demand by introducing automated DR capabilities in their customer base.

Accomplishing these huge market needs, VPS provides Energy Savings as a Service (ESaaS) to all sectors – i.e. industrial and commercial, SME and domestic - across Europe, contributing to a low carbon economy and the balancing of the electric grid. VPS has been strongly involved in European research collaborative projects to address such challenges in Europe, and has developed strong knowledge and experience in Internet of Things (IoT), developing highly scalable business supported on hardware and software solutions, M2M communication platforms based on cloud and mobile applications for Smart Homes and Smart Cities, acquiring and processing a grand portion of granular data to provide valuable information from its data centre to all-over the world.

With that said, VPS engaged in an Energy Performance Contracting (EPC), entitled Strategic Program on Energy Efficiency, with a major Spanish bank with activities across Portugal from 2013 to 2020. An EPC is an agreement between contracting parties where the contractor is engaged in the design, delivery, validation of comprehensive energy efficiency programs in customers´ buildings, often accompanied by a guarantee that it will be self-financed through savings produced through the life of the project [7] [8]. In light of this, VPS carries all the risks inherent to this EPC project and thus must act proactively and propose practical measures in order to deliver the promised energy savings to the bank.

For the purposes of the EPC, more than 100 bank branches spread across mainland Portugal were encompassed in the Strategic Program on Energy Efficiency proposed by VPS. It was agreed a priori that the active consumption of energy in 2013 would be used as baseline in the process of measuring energy savings. Then, an annual comparison analysis between active energy consumption before and after the implementation of the comprehensive energy efficiency measures is carried out to uncover energy saving results, with the appropriated adjustments that take into consideration potential changes in the baseline conditions.

3. Application scenario

On average, the bank branch dimension is 182 m2. Work time ranges from 8:30am to 05:30pm. Nonetheless, the bank branches encompassed in the scope of this project differs in several variables that have strong correlation with the baseline conditions, such as type of electricity contracts - e.g. fixed rates, Time-Of-Use (TOU) rates, etc. -, facility size, location and bioclimatic zone, number of facility´s users, type and number of electric equipment installed, etc. Therefore, all these factors were considered for the saving analysis.

VPS equipped each bank branch with the abovementioned Kisense platform, which enables the implementation of DR strategies, namely the remote on-off control of the outdoor advertising lighting sign, indoor lighting, HVAC system and ventilation. Data collected includes total active electricity consumption, partial HVAC electricity consumption, and in some cases, the temperature near the air duct and at user level.

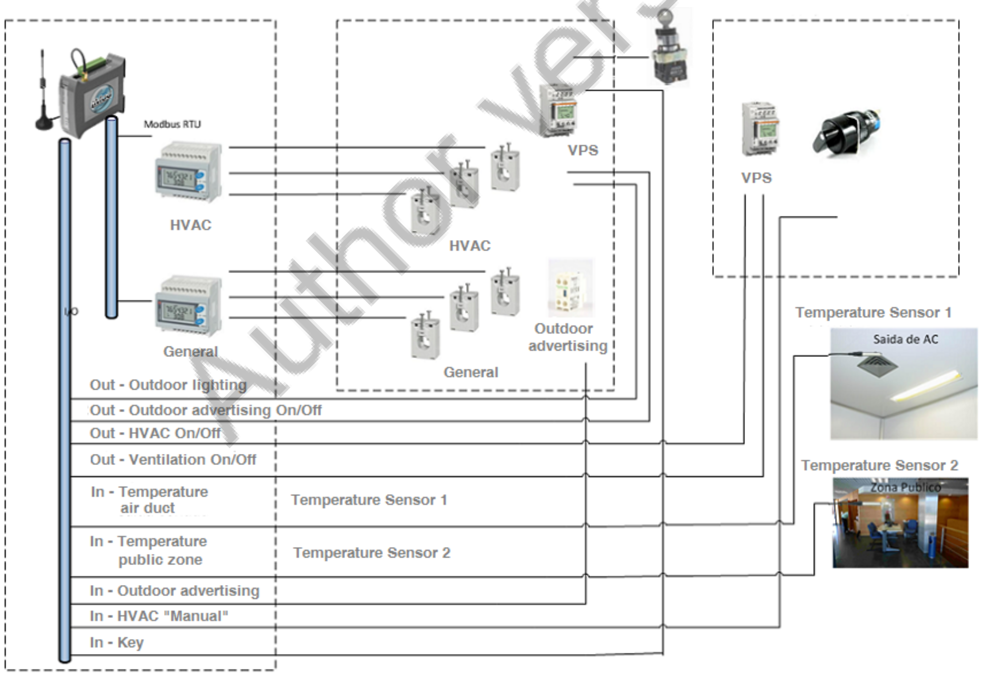

Fig. 1: Typical branch setup.

Kisense is composed by the following elements:

- Sensors & Actuators: smart meters, sensors and actuators;
- Communication Module (CM): responsible for retrieving data from the field with several communication protocols. After acquisition, raw data from sensors are stored in a database. This module implements a number of standards and protocols that goes beyond VPS´s protocols, thus assuring the openness of the solution;
- API - Web Service: this module allows the remote access and data delivery from sensors. It is based on RESTful Web Services, also known as REST APIs. This API is a default door to web applications

data, providing a powerful yet simple tool to integrate different systems. This approach allows quick prototyping and interoperability capabilities between web applications and other systems in the physical world and its integration potential is enabled by the existing web infrastructure;

- Data Processing Module (DPM): this module receives data from CM or Web Service as well as processed and aggregated data, performing operations such as unit conversion, format adaptation, tariff calculation, and distributing hourly and daily values. This data treatment layer offers a unified interface for other applications (UI, advanced analysis, forecasts) through another API – Web Service. Additionally, CM and DPM, working as back office applications, may be installed on the same physical machine (server) of each site;
- User Interfaces: a set of visual modules that provide access to end-users to several features, such as historic data visualization, consumptions normalization and benchmarking, alarm definition and visualization as well as remote real-time monitoring and control, as illustrated in Figure 2.

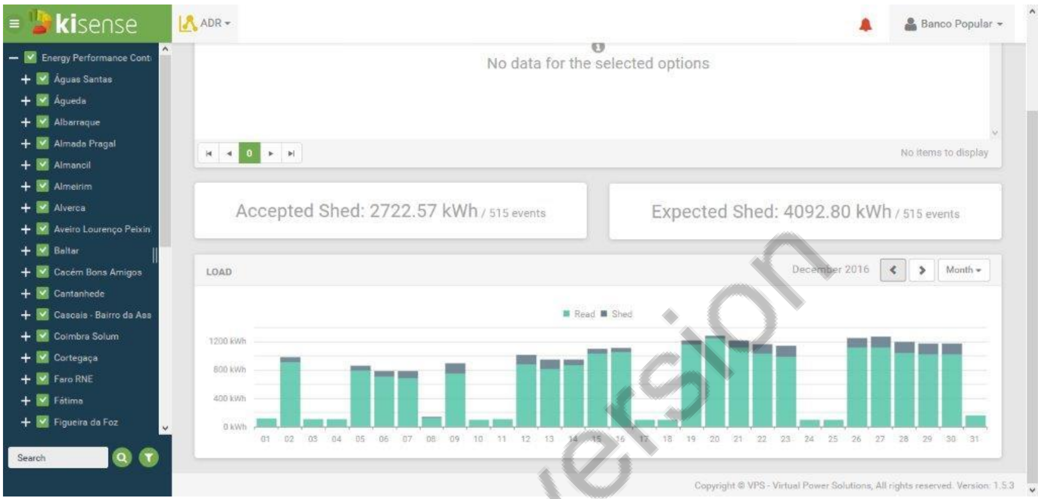

Fig. 2: Kisense´s DR user interface.

The implementation of the Kisense platform brings the following benefits to the bank:

- Minimisation of consumption, by permanently eliminating wasted consumption through the incorporation of energy efficient assets and the elimination of 'wasted' energy – i.e. standby consumption;
- Optimisation of consumption, through real-time management of non-essential consumption away from peak times and optimization of embedded generation and storage.
- Monetisation of consumption: revenue earning by allowing end-users consumption profiles to be used to help balance the grid. This dynamic platform manages the optimisation of consumption with revenue available from grid based DR programmes.
- Energy sharing initiatives between bank branches have also been simulated. Although impending deregulation is still to be overcome in this matter, the technology already allows to monitoring surplus of energy generation and the use of shared energy with predefined end-users.

4. Simulations

In terms of the proposed energy efficiency measures that were implemented in the initial stages of the project, it includes load shedding and load shifting of HVAC loads. A survey concluded that the HVAC system alone corresponds to approximately 39% of the annual active electricity consumption in the bank branches. In light of this, during winter, the HVAC systems were remotely turned off in predetermined times.

The same rationale applies to load shifting. During periods of mild climatic conditions, for bank branches with 3- or 4-period TOU rates in certain bioclimatic zones, automated DR strategies were implemented to shift HVAC load to off-peak periods – i.e. when electricity tariff is the cheapest.

Additionally to these two energy efficiency measures, Real- Time Pricing (RTP) of electricity appears to be very promising in such application scenarios, according to a number of meta-analysis collating findings [3] [4] [5] from many DR trials that indicate that economic and other incentives are effective in changing consumer behaviour, offering new opportunities and challenges in the energy performance of buildings [9]. Therefore, the electricity tariff optimization – i.e. energy contract renegotiation, shift in electricity provider, reduction of contracted power, etc. – towards RTP is a potential future energy efficiency measure to be implemented when proper conditions and regulations in the Portuguese liberalised energy market are set in place. In such cases, the reduction of the electricity bill is not necessarily associated with a reduction in energy consumption, but to the adjustment in tariff options to fit customers´ energy consumption profiles better and to reflect more appropriately the fluctuation of the electricity price in the wholesale market. The combination of a real-time monitoring and management system with access to the electricity consumption history, as well as with the possibility to remotely operate sub circuits such as the HVAC system, makes RTP of electricity an even more appealing energy efficiency measure. That is because such DR systems are able to schedule action orders that allow the HVAC system to be remotely switched on and off in periods when the electricity presents the most advantageous prices, based on cost fluctuation signals in the wholesale market. As illustration, Figure 3 presents a comparison analysis that uncovered how much electricity would had been saved during the first semester of 2016 if the bank branches encompassed in the data sample had adhered to RTP of electricity.

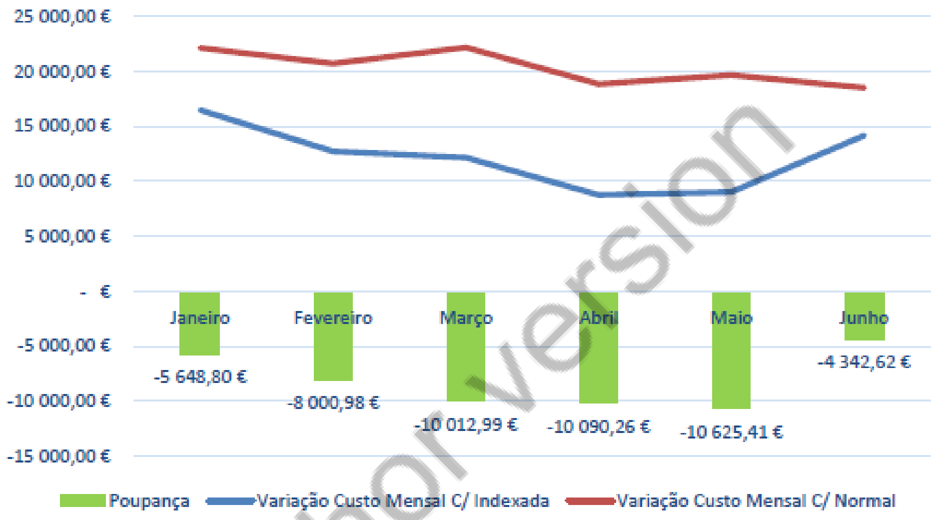

Fig. 3: Monthly electricity cost fluctuation of a TOU rate versus RTP of electricity for the data sample (2016).

The analysis of the graph allows to infer that, with the current tariff structures in place, the bank branches spent approximate 122,054€ with active electricity consumption in the first half of 2016 (distribution costs were neglected in this analysis). The introduction of RTP would have represented electricity savings in the order of 48,721€, with corresponds to approximately 40% of the semiannual electricity costs. Globally, with the implementation of all the energy efficiency measures abovementioned, a 15.4% annual energy saving (KWh) was achieved for the data sample in 2016, as seen in Table 1:

Table 1: Energy savings between 2013 and 2016 with the implementation of energy efficiency measures.

	Peak	Mid-Peak	Hollow	Off-Peak	Without cycle	Very Hollow	TOTAL
2013 (kWh)	753 349	2 090 313	1 021 721	183 127	380 791	24 363	4 453 663
2016 (kWh)	665 686	1 903 261	682 149	160 588	337 581	16 430	3 765 696
Savings (kWh)	87 662	187 052	339 572	22 538	43 210	7 933	687 967

5. Future applications

As for what is envisioned for the future, the evolution of energy markets is accelerating in the direction of a greater reliance on Distributed Energy Resources, and the most promising strategy to address this trend is Virtual Power Plants (VPPs). A VPP is a cluster of energy producers and energy consumers, creating a new large virtual entity [10]. VPPs act as a single operating entity towards the power market, which may contain storage devices and is internally controllable due to a balanced portfolio of generators and consumers [10]. Within VPP, balance can be reached in different ways; for instance, aggregators – i.e. those who operate VPPs - can decide to switch off a number of electricity consuming installations or to switch on big power consuming units – e.g. electrical cars that have to be charged or charge batteries - in moments when production in the system is at its peak. By doing so, it increases the flexibility of the electric grid, thus decreasing the risk of destabilisation of the grid associated with the incorporation of decentralised renewable energy generators. Therefore, the core of VPP consist of a coordinating mechanisms resulting in a predictable and stable outcome. Aggregators can negotiate much more favourable contracts with electricity companies in this way. In short, VPP creates better conditions for the introduction of new renewable energy sources and that is why Virtual Power Solutions (VPS) developed Kiplo.

Kiplo was designed to scale-up the Kisense platform, by including a series of novel tools within it, such as: i) a multi-level DR forecasting engine to satisfy conflicting real-time demand and supply of electricity, enabling automatic and dynamic pricing and incentive-based DR for distributed blocks of buildings; ii) consumption matchmaking engine to provide optimal mapping among DR programs/strategies and available elasticity/flexibility of consumption to facilitate the integration of local energy generation into the power grid, iii) a sharing tool to support small and medium energy communities to manage and share the lack and/or surplus of renewable local generation – i.e. the creation of Nearly-Zero Energy Communities; and iv) context-aware HMIs to provide easy-to-use and intuitive user interfaces supported by visualisation techniques, alarms and recommendation.

In this sense, Kiplo represents the opportunity to shift from local management – i.e. end-user level - to aggregated – i.e. community-level - flexible management. By aggregating end-user's individual flexibilities, the product allows flexible consumption, solar-PV generation and electricity storage to be managed at the local community level by the aggregator. The platform will collect community user's electricity consumption, generation, and storage in real-time and, considering each consumer individual contract. In this way, the energy trading shifts away from a centralised structure – e.g. exchanges, trading platforms, energy companies - towards a decentralised system – e.g. end customers, energy consumers. Therefore, third-parties are no longer required, cutting costs and speeding up processes. As a result, the entire energy system becomes more flexible, as many previously manual work tasks are carried out automatically through smart contracts.

In conclusion, Kiplo will be in line with the growing European interest in open energy markets. In 2016, the European Parliament and the Council presented a proposal on common rules for the internal market in electricity. With that, Kiplo is expected be a key tool in the future.

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