AUTOMATED DEMAND RESPONSE SYSTEM: LINKING CUSTOMERS AND SYSTEM OPERATORS FOR IMPROVING ENERGY EFFICIENCY AND NETWORK'S MANAGEABILITY – A DEMONSTRATION PROJECT

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ABSTRACT

This paper describes the main progresses of the LISCOOL – LISbon COOL energy project. LISCOOL aims to implement and demonstrate the technical and economic feasibility of an Automated Demand Response System (ADRS). This project presents an innovative character as it provides a suitable solution for large-scale deployment by leveraging the role of active consumers on electrical networks, who can support network operators on grid management and thus, effectively contributing to the transition towards Smart Grids paradigm. This paper includes a detailed architecture of the LISCOOL project and some of the simulated results are highlighted. LISCOOL has been designed to allow the integration of different types of assets and end-users as this solution has been endowed with the OpenADR 2.0 b protocol, enabling, among others, high standards of interoperability between systems and devices. The adequacy of this project will be assessed over a three year timespan using two demonstration sites, where it was installed both flexible resources (Air Conditioning systems with cold storage tanks) and renewable energy resources (PV panels).

INTRODUCTION

In recent years, there has been a fast deployment of Distributed Energy Resources (DER) such as Electric Vehicles (EVs) and microgeneration units (e.g. PV solar panels) in distribution networks, resulting from the growing consumer's awareness about the climate change and these solutions' increasing economic attractiveness. Hence, the demand and production patterns are becoming more volatile (e.g. due to the high variability of the renewable energy resources), leading to not only a more challenging balancing of demand and production but posing challenges to the efficient and safe operation of electrical networks, i.e., within the technical limits.

As a result, and considering the undergoing changes in electrical power systems towards the Smart Grids paradigm, this paper presents in detail a Theme constituent of the LISbon COOL energy (LISCOOL) project: Theme 1 - Fast ADR operation under Retailer's DR program. On this theme, it is intended to implement and demonstrate the technical-economic feasibility of an Automated Fast Demand Response System (AFDRS), focusing on the main following business and technical objectives:

- Demonstrate the added value of an ADR platform to end-users, grid operators and electricity retailers;
- Implementation of two fast Demand Response (DR) programs – Direct Load Control (DLC) and DER program – with the main purpose of demonstrating the role of active consumers in the network management by providing support to network operators (e.g. reduce consumption during demand surplus periods - grid stability problems) and by promoting a smoother integration of DER.

LISCOOL Theme 1, being carried out between 2017 and 2019 and sponsored by NEDO (New Energy and Industry Technology Development Organization) – a Japanese governmental agency -, encompasses two demonstration sites belonging to Lisbon City: a) Lisbon City Hall and b) Olivais Offices, where it was installed Air Conditioning (AC) systems with cold storage tanks units and PV microgeneration units. Although the AC system is already capable of providing flexibility to the electricity grid (e.g. through temperature set point variation, load factor, etc.), the introduction of storage tanks allows to expand the AC system capabilities by enabling to shift consumption, either downwards or upwards, during the AC operation. It is designed to be a more flexible resource when compared with the conventional energy storages. In addition, this project targets the development of a suitable solution of DR for rollout in worldwide markets and therefore, the system will need to be able to accommodate the future integration of different end–users and types of assets. Taking this account, it was decided to use OpenADR 2.0b as a data exchange protocol.

SYSTEM OVERVIEW AND DESCRIPTION

The AFDRS has been designed following a top down approach, according to the OpenADR 2.0 b specification [1], where a hierarchical relation is established between systems and/or devices. As a result of this hierarchical relation, two main actors are identified under the OpenADR protocol:

i) Virtual Top Node (VTN) – a server that transmits OpenADR signals to end devices or other intermediate servers;
ii) Virtual End Node (VEN) - typically represents an end device that can be seen as a client (can be a Home Energy Management System (HEMS), a thermostat or other end device) that accepts the OpenADR signal from the VTN. A VEN can be, at the same time, a VTN if it is responsible for managing other end-devices.

The overall system's architecture of AFDRS is depicted on Figure 1. The DRMS – playing the role of VTN - is the central management system, being responsible for processing all the available information, ranging from smart meters installed on site, weather forecast and information sent by all the VENs connected – in this case, the AC ADR system. The AC ADR System has two VENs associated – one for each site – and is responsible for gathering data and to control the AC system according to the DR events received from the DRMS.

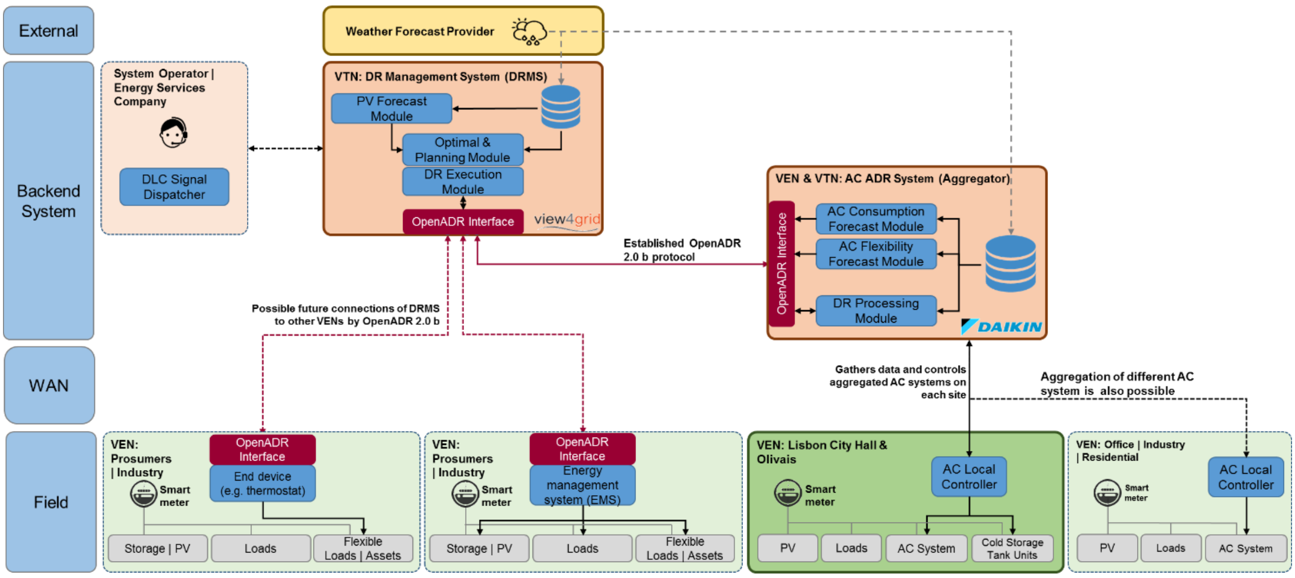

Figure 1 - Fast ADR System General Architecture

System's Operation

As mentioned above, on the scope of LISCOOL project, under the DRMS there are two VENs - one for each site - associated to the AC ADR System, which then communicates with the VTN (DRMS) through the OpenADR 2.0b signals detailed in the protocol [1]. The interactions between VTN and VEN (AC ADR server) can be aggregated in three main stages:

1) Registration Phase (One time interaction)

In Figure 2 are depicted all the interactions during the registration of a VEN into a VTN server. Only after the registration phase, a VEN can be considered eligible for participating in DR programs/events.

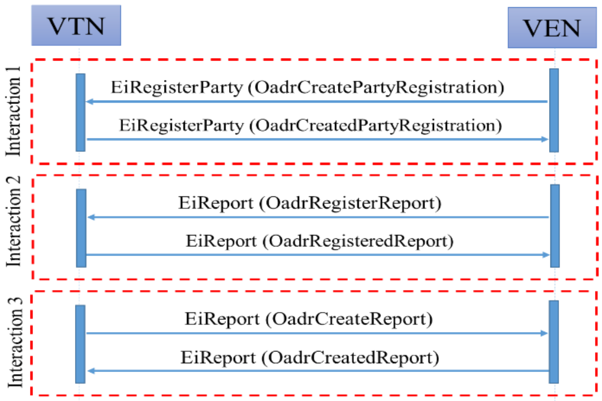

Figure 2 - OpenADR sequence: registration phase

Interaction 1: first interaction in which a VEN registers at the VTN server to enable to start the process of DR programs between these two entities.
Interaction 2: interaction in which the reporting capabilities of the VEN are sent to the VTN. Based on this information the VTN can identify which information shall be sent by the VEN for participating in DR programs (e.g. type of data and frequency);
Interaction 3: interaction in which the VEN sends a confirmation about the reports specification of the VTN;

2) Cyclical Operation – DER Program

After the initial registration phase, there will be a continuously and cyclical communication between both servers concerning the planning and execution of the DER program. This program is focused on the consumer side management, by coordinating the microgeneration resources and the AC system with cold storage tank units of each site. Therefore, the goal is to increase the self-consumption of the building, thus, reducing the energy needs from the network. This coordination also brings benefits to the network operators as it smooths the integration of DER into the network, increasing load profiles predictability and reducing its variability. Under the scope of this project's component, the optimization carried out by the DRMS is performed with the objective of minimizing each building's consumption on a daily basis.

The Figure 3 represents the respective interactions scheme between the VTN (DRMS) and the AC ADR System (VEN) for each site.

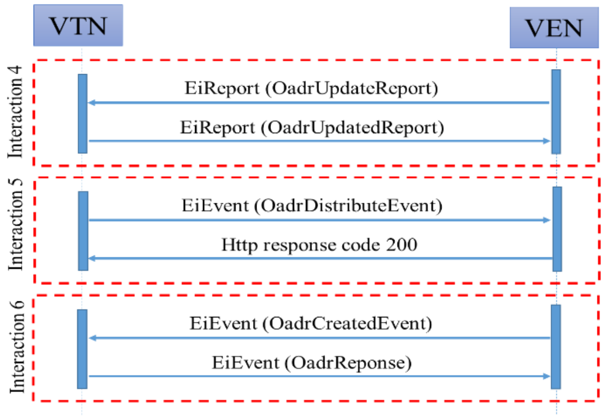

Figure 3 - Cyclical operation.

Interaction 4: represents the process used by the VEN to send updated information (reports) to VTN according to what was specified in interaction 2.
Interaction 5: used to notify a VEN about a DR event, where is included the operation schedule to be followed during its duration (e.g. set points).
Interaction 6: based on the event sent on the previous interaction, each VEN sends a response to the VTN, informing about its availability to participate in the event with: i) optIn – VEN accepts to participate in the event; b) optOut – the VEN is not able to participate in the DR event.
In the specific case of this demonstration project, the AC ADR server, as a VEN, will be responsible for sending reports to the DRMS (Interaction 4) on a day-ahead basis, divided into 30min periods, containing the information about the power consumption and flexibility forecasts of the AC system on each site:

1. Reference AC Consumption (kW) – AC_{Ref};
2. AC's flexibility Upper Limit (kW) – AC_{Ref_upp};
3. AC's flexibility Lower Limit (kW) – AC_{Ref_low};

These values represent the flexibility range for the following day, in which the AC system will be capable of changing its reference power consumption until the lower or upper flexibility limit as requested by the DRMS. All values are sent in kW. Notwithstanding, the VEN (AC ADR Server) is also capable to send an updated report on the above-mentioned forecasts to the DRMS, during an intraday operation mode.
Besides the information of the AC power consumption forecasts, the DRMS also gathers information based on weather forecasts and receives the power consumption/production through the smart meters installed on each site. This information is used to produce the respective forecast for PV generation for each site and verify the compliance of the AC system on the DR events. After processing both forecasts, the VTN can send an optimized planning consumption for each site by providing an optimal AC power consumption schedule to the AC ADR server—AC_{SP} — for each 30min period (Interaction 5). After receiving these values, the AC ADR server will process the requests of DR and respond to the DRMS with Opt-In or Opt-Out to each requested change (Interaction 6). For the DR events created (Opt-In), the required commands to each building's AC system will be sent by the AC server to the AC units.

3) Emergency Operation - DLC Program

On top of the DER program, the DRMS also supports a DLC (Direct Load Control) program, which aims at providing support to the DSO on grid management by leading consumers to change their consumptions in response to an event that may require:

- Increase consumption, typically during over supply periods
- Reduce consumption, typically during demand surplus periods

This event is typically generated until 15 minutes before the start time, as it is used to tackle operation problems that were not predicted and thus, require fast action controls. For this reason, it implies a direct coordination between the network operator and the available VENs to participate in this type of events. Under the scope of LISCOOL project, the role of the network operator will be simulated. In such a way the DLC events are manually triggered through the Human Machine Interface (HMI) of DRMS, as show in Figure 4.

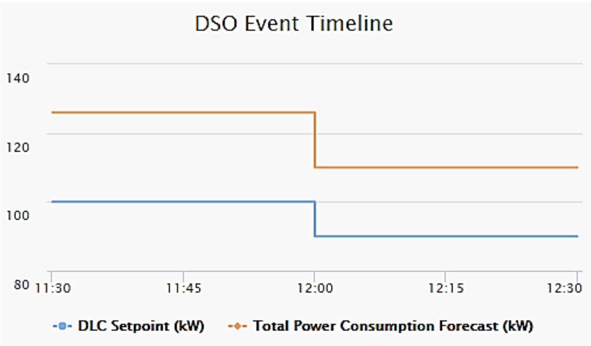

Figure 4 – Generation of a DLC event.

On this interface, it is also available a prediction of the total power consumption during the DLC event duration, to be used as reference for the load shedding control (e.g. amount of power consumption reduction) carried out during the DLC event. Once this event has been submitted, the DRMS starts an optimization process in order to identify the operation schedule that shall be sent to each VEN. This optimization is performed with the following objective functions:

i) maximize the fulfilment of the load shedding requested by the system's operator;

ii) maximize fair assignment - participation effort of each VEN in the DLC event – by minimizing the variance of the ratio between the AC_{SP} and the AC_{Ref} for all VENs while guaranteeing that the limits of the flexibility range sent by the VENs are not surpassed.

After this optimization is processed, a DR signal is sent to the AC ADR System (Interaction 5), to which it will reply to DRMS with an Opt-In/Opt-Out (Interaction 6).

Coordination between DER and DLC programs

Since the scope of each DR program to be implemented and tested on the demonstration sites is different, they have to be coordinated in order to not overlap the controls execution and to distinguish the response of each one as well. Consequently, and considering that the DLC events only happen during contingencies situations, the DRMS is continuously operating the DER program until there is a notice regarding the need to respond to a DLC program event.

RESULTS

Since the system's operation is still on a preliminary phase - testing phase -, some of the results obtained in laboratory environment are presented below. As previously explained, smart meters were installed at the demonstration sites in order to evaluate the real response of the system during DR programs.

DLC Program Results

In Figure 5 is depicted a DLC event with 30 minutes of duration.

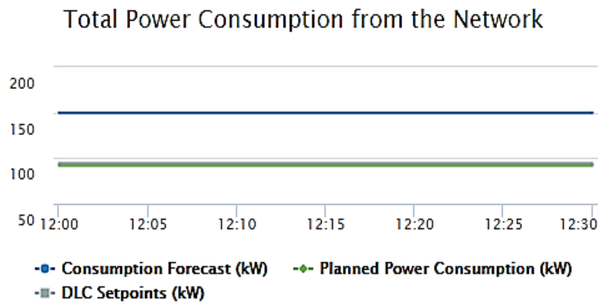

Figure 5 - Example of DLC Event – Results.

The power consumption forecast for this period was 150 kW, and with the flexibility provided it was possible to reduce the power consumption around 50 kW, accomplishing the request of the system's operator. For this reason the planned power consumption line is superposing the DLC set points line.

DER Program Results

For the DER program, in Figure 6 is exemplified the simulated system's actuation (Lisbon City Hall VEN) for the period between the 12:00h pm. and 18:00 h pm. The blue line represents the power consumption that has been predicted by the AC system. The green line represents the optimal power consumption that should be followed in order to minimize the energy needs from the network.

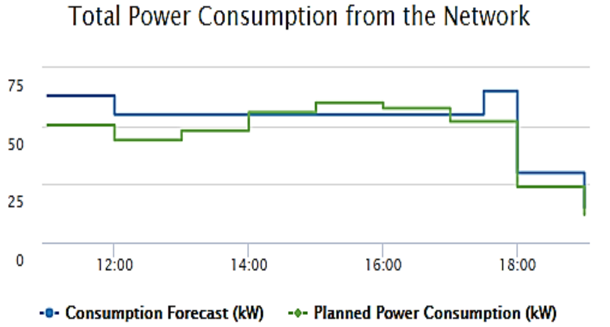

Figure 6 – Example of DER Program – Results.

These power consumption variations in the AC system are supported by the cold storage tank units.

CONCLUSIONS

In this paper an overview of the LISCOOL project – Theme 1: Fast Dr Operation - is presented, where the main information flows and interactions between systems are detailed.

More than a system with DR capabilities, LISCOOL also entails the development and assessment of alternative solutions as flexibility sources. Under LISCOOL scope, the flexibility is provided by the AC system interconnected with cold storage tank units, which can be seen as an alternative to conventional energy storage systems.

The main differentiating aspect of LISCOOL refers to its capability for introducing consumers as a flexible and active participant in the network management, enabling among others, the increasing of the networks capacity to host new DER, to increase the penetration levels of renewable energy in the energy mix and the improvement of the quality of service and energy. It addition, it leverages the reduction of the greenhouse gas emissions and promotes better standards of energy efficiency. Moreover, it presents high scalability leveraged by the use of the OpenADR 2.0b standard protocol, and thus, allowing the integration of other consumers/resources in the DRMS.

ACKNOWLEDGMENT

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REFERENCES

[1] OpenADR Alliance, OpenADR 2.0a and the OpenADR 2.0b Profile Specification and schema. Available at: http://www.openadr.org/specification.