USE OF RADIO BASE STATIONS TO PROVIDE ANCILLARY SERVICES TO THE DSO THROUGH LOCAL FLEXIBILITY MARKETS

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ABSTRACT

The changes in the energy sector require an appropriate coordination between transmission systems operators (TSOs), distribution systems operators (DSOs) and aggregators. The project SmartNet aims at defining and comparing different TSO-DSO coordination schemes, by implementing dedicated analyses in Italy, Denmark and Spain. This paper describes the pilot project implemented in Spain and presents its main outcomes.

INTRODUCTION

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

The project SmartNet [1] compares five different TSO-DSO interaction schemes and different real-time market architectures [2], [3] with the aim of finding out which one could deliver the best compromise between costs and benefits for the system. For that purpose, an ad-hoc platform has been developed to carry out simulations, and a cost-benefit analysis (CBA) has been implemented to compare the costs needed to implement the five TSO-DSO coordination schemes with the benefits drawn by the system [4]. In parallel, three demonstration projects (pilots) for testing specific technological solutions are implemented to enable monitoring, control and participation in ancillary services provision from flexible entities located in distribution. Moreover, these pilots are aimed at uncovering regulatory, operational or implementation barriers.

Both the long-term (2030) analysis related to the CBA and the short-term analysis performed in the pilots are focused on the three countries selected in the project: Italy, Denmark and Spain.

PILOT SCOPE

The objective of the pilot is to demonstrate the technical feasibility of using urban, distributed GSM radio base stations to provide ancillary services for the DSO through demand side management. Each base station is equipped with back-up batteries which ensure the continuity of communications service in the (rare) event of a blackout in the distribution grid. By using these back-up batteries, radio base stations can be disconnected from the grid on purpose.

A second objective of the pilot is to identify implementation barriers, including regulatory issues, administrative processes and other practical barriers.

For that purpose, the "Shared balancing responsibility model" coordination scheme is implemented [3]. In this coordination scheme, the balancing responsibility is divided between the TSO and the DSO, so that each of them is responsible to maintain a predefined exchange schedule in the common border.

In order to maintain the predefined exchange schedule and solve congestions in the distribution grid, the DSO opens a local flexibility market to allocate flexibility from distributed energy resources (DER) connected to medium- and low-voltage grid. Therefore, the DSO takes on a new role, called Local Market Operator (LMO). The scheduled profile, which has a 24-hour horizon and a 15-minute resolution, is generated on a day-ahead basis.

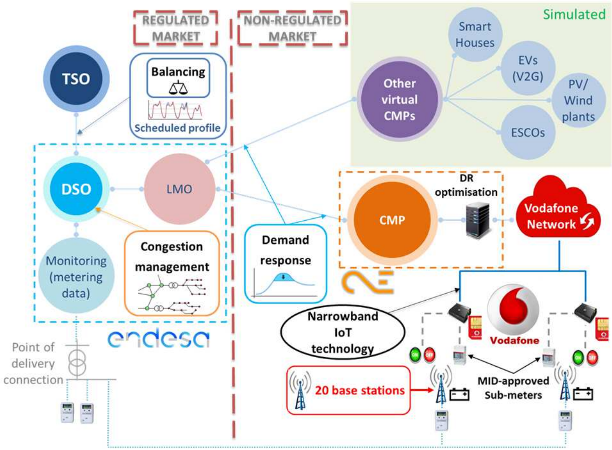

Figure 1. General architecture of the pilot project

As displayed in Figure 1, different commercial market parties (CMPs) offer the flexibility of the DER in their portfolio to the LMO, which clears the market by selecting the most efficient ones and communicates market results to CMPs. Once they receive market results, CMPs dispatch the most appropriate DER within their portfolio to provide the required flexibility. With a view to be able to create the bids to be sent to the market and to check the actual activation of the required DER, CMPs monitor the status of the batteries and receive real-time consumption measurements from the different assets. In addition to this real equipment, some virtual units are also included in the pilot, to simulate the competition among real units and other types of DER.

Endesa Distribución is leading the pilot, performs the roles of DSO and LMO and simulates both the TSO-DSO coordination by defining the exchange profile and the offers sent by other flexibility aggregators to compete with the batteries in radio base stations. Tecnalia is the technological advisor to support Endesa in leading the pilot. Our New Energy (ONE) is the CMP calculating the flexibility available in base stations, creating the bids to be sent to the local flexibility market and sending the activation signals once the market is cleared. Vodafone is the owner of radio base stations and the provider of communication services between the sites and ONE to monitor and control remotely the DER flexibility.

The pilot involves 6 primary substations and 19 radio base stations in the city of Barcelona, as Figure 2 shows.

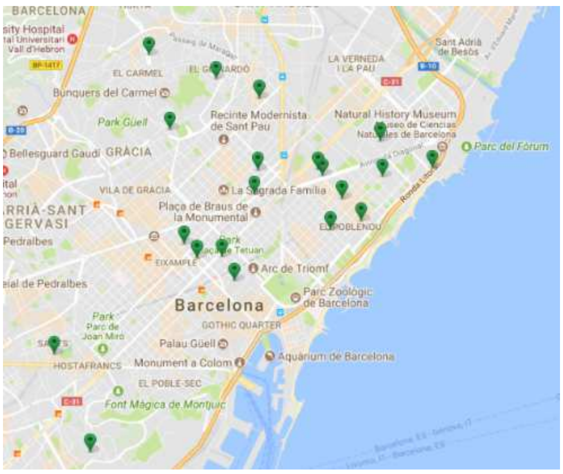

Figure 2. Location of base stations involved in the pilot project

Base stations use electricity to provide communications services to Vodafone's clients and for some ancillary systems within the base station (lighting, cooling of the enclosure for communication systems…). The critical load is the one for communication systems, so some back up batteries are included in the base station to be able to keep supplying such load in case there is a black out in the main grid.

The nominal capacity of the battery, which determines the duration of the back-up energy, depends on the relative importance of the radio site. The capacity of the base stations included in the pilot ranges between 3 and 17 kW.

IMPLEMENTATION

The pilot is organised around the local flexibility market, which, as usual, obtains the optimised bid dispatch to cover certain needs. In this case, the needs are provided by the DSO, as the operator required to maintain the exchange profile at the TSO-DSO interconnection point and to avoid congestions in the distribution grid:

1. Endesa, as the DSO, acquires real data from the distribution grid but, since there are very few local congestions in real operation at the moment, those data are combined with some simulated data which allow creating virtual congestion problems in the grid for the purpose of the pilot. This way, the simulated situation is close to real life (as real data have been used), but it also allows simulating a likely situation in the future when more congestions will appear in the distribution grid and a local flexibility market may be required.
2. The output of this virtual case is compared to the power of the scheduled profile at the TSO-DSO interconnection point to assess existing deviations from the schedule. Moreover, the DSO also forecasts the status of the grid for the subsequent time steps and sends all this information to the LMO.

In parallel, CMPs must define the bidding strategy to create their bids to be sent to the LMO. With the purpose of fulfilling these duties, ONE communicates with the base stations, via Vodafone's Energy Data Management (EDM) systems, to acquire real-time status of the batteries. In addition, real-time information from the wholesale market operator and the system operator is also gathered to select the most interesting bidding strategy.

When the LMO receives flexibility bids from the different CMPs, all the information available is used to perform an Optimal Power Flow (OPF) calculation, which ensures the fulfilment of all DSO requirements (compliance with the scheduled profile, while avoiding congestions in the distribution grid). The result of the OPF provides the market clearing result, which is communicated to CMPs, so that they can appropriately dispatch the DER units. Then, both CMPs and the DSO monitor the behaviour of DERs to check whether they really provide the required flexibility.

Figure 3 summarises the communication flows and processes, which are described below:

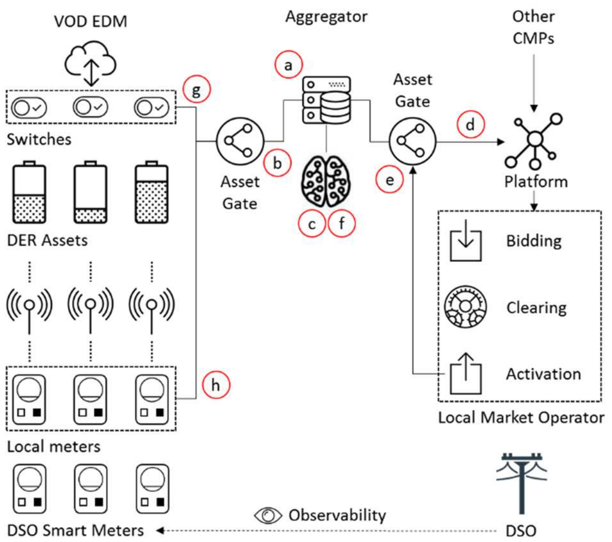

Figure 3. Process flow to create the flexibility bids

a) Battery aggregation models developed within the project SmartNet [5] are the basis for aggregation the flexibility of radio base stations.
b) Those models are fed with the status of the batteries from radio base-stations. The CMP receives updated information from several parameters in real-time, to understand battery status and availability for activation.
c) Based on such information, the CMP assesses the potential gains to bid upward and/or downward flexibility and compares them to the arbitrage opportunities in intraday wholesale markets.
d) Once the bidding strategy is selected, a bid is sent to the market platform in due format and timing.
e) If the bid is accepted, the market platform sends a message to the CMP, including the volume to be activated and the market clearing price.
f) The CMP performs the disaggregation of the accepted bid, i.e. assigns individual activations to each DER unit, so that the total aggregated flexibility is the volume cleared in the market. The CMP uses direct control of the batteries, which makes the disaggregation process rather trivial, as every bid in process d) represents a cluster of individual activations, thereby rendering the simplest form of disaggregation. In order to avoid issues if any of the batteries that must be activated changes its availability, a risk-neutral cost minimisation approach is taken.
g) Once the disaggregation process is finished, the CMP uses Vodafone's EDM to send an activation message to the relevant assets.
h) Then, the CMP can check the reaction of the activated assets by means of the real-time battery status update described in b), whereas the DSO uses the observability provided by smart meters to monitor the performance of each unit.

The DSO's monitoring system takes measures are at the head of each medium voltage feeder to calculate the status of the network, the line congestion and the voltage. In addition, it also receives measurements at the connection points of 10 radio base station to improve observability. With all this information, the DSO can monitor the provision of the balancing service at the TSO-DSO interconnection point and whether any congestion appears in the distribution grid.

Figure 4 shows a screenshot of the DSO's monitoring system for the balancing service, where the baseline load (yellow), the new schedule after clearing the local market (green) and the real-time consumption (red) are depicted.

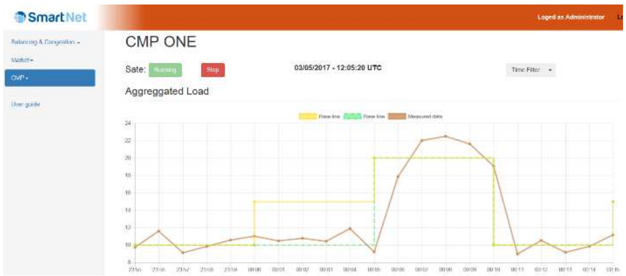

Figure 4. Monitoring system for the balancing service

For monitoring the congestions, a different representation is used. Figure 5 shows the diagram of one primary substation involved in the pilot, where the network has been simplified for a better visualization and the lines are depicted with different colours to represent the congestion.

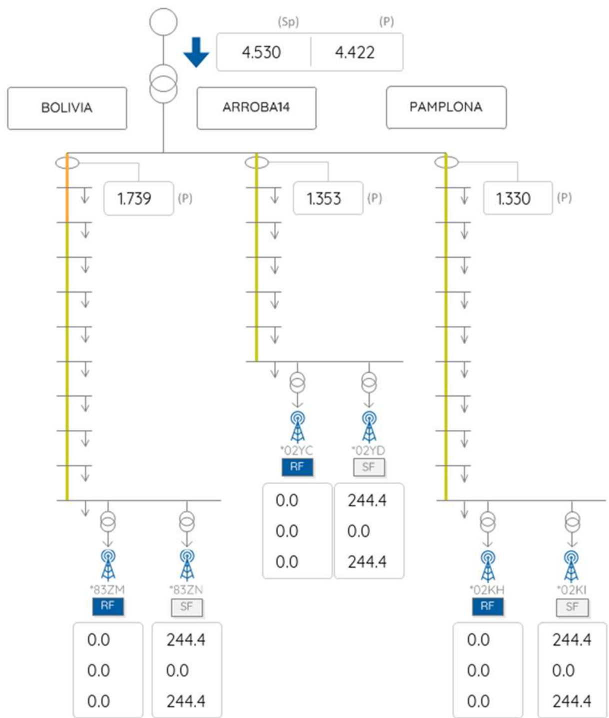

Figure 5. Network diagram, primary substation of Tanger

C2 General

TESTS

Before starting the execution of the pilot, two rounds of tests have been performed. During the first round (in June 2018), the communications were tested, to ensure a smooth data transfer from one base station to CMP and from the CMP to the DSO. The test was successful and, thus, the remaining base stations were provided with the required equipment. However, having two different providers for the controllers of base stations created some issues which delayed the replication of the test. Finally, all the issues were solved, and a second round of tests was performed to the whole group of the base stations in November 2018. During this second round, the following functionalities were tested:

- The virtual private network (VPN) connection between the DSO and the CMP, to encrypt the communications.
- The CMPS' real-time data acquisition system.
- The time server to synchronize the messages between the CMP and the market clearing system.

During the test, the market clearing process has been deactivated to test all the equipment and the message with market results has been advanced 5 seconds due to the lag of the messages in the communications channel.

Due to the strict working requirements for the base stations, since Vodafone's customers must keep on receiving a non-stop communication service, the tests are not tailored to assessing the impact on batteries, but to demonstrate that they can provide the flexibility when requested by the CMP or the DSO. Therefore, each base station needs to retain a certain level of battery autonomy in order to maintain mobile based services in the (rare) event of the local grid outage.

During testing this was limited to 5 minutes in every hour, but once live this restriction can be removed with base station able to participate in an event once the battery charge is 95% or greater. However, an error in interpreting the test deactivation from one particular battery manufacturer resulted in a 70-minutes activation of a base station during the testing phase, until the safeguard from Vodafone controls kicked-in, with the resulting discharging of the battery (as shown in Figure 6), but the communication service was not affected at all.

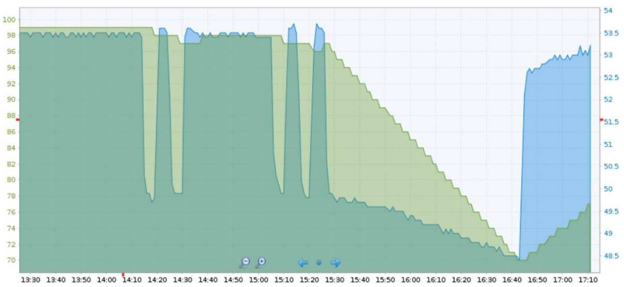

Figure 6. Long disconnection test of one base station

As a result, several firewalls and exception-based controls were implemented by the CMP to ensure the correct operation of the batteries.

RESULTS

After the successful test rounds, the experimentation of the pilot was carried out during the second week of December 2018 (from December 10 to 18) and additional weeks of experimentations will be carried out in January and February 2019). Main results are summarised below:

- On the balancing side, the times when the system had enough flexibility to meet the balancing requirements, the system achieved the desired value with only a small error. However, there were also periods in which there was not enough flexibility to meet the objective of the energy balance, which means that there is not enough flexibility available to meet the requirements of the scheduled profile.
- The congestion system also worked properly, and the market requested demand reductions in case there were line overloads.
- Regarding the market clearing, it was demonstrated that the two different CMPs could compete at the same electrical point, so that, due to the difference in the availability and price of the flexibility traded by each of them, in some cases the real CMP was dispatched, in some others, it was the virtual aggregator and in some other the two of them.
- The system for sending offers was able to send them in a stable way, correctly participating in the market, even if the flexibility offered was not enough for the system in some cases, as mentioned above.
- The real CMP obtained market results in a continuous way, which demonstrated that the communications between the CMP and the LMO worked properly.
- In the activation process, activation and deactivation connections of the batteries have been established for each market in a stable manner, so communication systems between the real CMP and DER units were also successfully demonstrated.

RETURN OF EXPERIENCE

In addition to the results of the pilot itself, some lessons have been learnt from the implementation of the project.

First, the market clearing frequency established in the pilot (to be in line with the proposals of the SmartNet project) is much higher than that of existing markets. As a result, some adaptations have been required to have the pilot running. For example, the DSO must install smart meters in the sites of a contracted power of up to 15 kW, so some sites have been downsized to go beyond that threshold; however, the change of contracted power can only be requested once every 12 months and some sites had to be downsized at later stages because they have changed their contracted power before this issue was identified.

Moreover, the operation of smart meters is tailored to regulatory requirements, which establish that they must register consumption on an hourly basis and send the data to the DSO every day. This frequency is much lower than what is required in the pilot, but Endesa has been able to adapt its systems to receive the data in the required frequency. For the sites where smart meters could not be installed (capacity above 15 kW) or where they could not be adapted, Vodafone's on-site meters are used and the information is sent to Endesa through the communication infrastructure set-up between ONE and Vodafone. In the status files received by ONE we have the voltage, intensity data which is made available via an XML message with the aggregated information from available base-stations.

Second, access to the sites is not a trivial issue. Base stations are facilities used by Vodafone to provide a real commercial service. Consequently, all the activities related to the pilot must take into account the limitations of such commercial service. First, physical access to the DER sites for operations has strict security rules, since base stations are located in residential building blocks, so the transit of people must be minimised to avoid complaints by residents. Moreover, the existence of multiple proprietary software systems in the 48V controllers created challenges to ensure full interoperability of the EDM platform and to obtain a smooth communication with the aggregator's platform. Last, all the activities in the pilot must be consistent with Vodafone's commercial activity and, hence, certain periods of the year (Christmas, big events such as the Mobile World Congress, etc.) cannot be used for testing or on-site operations.

CONCLUSIONS

The required decarbonisation of power systems will require a closer cooperation between TSOs and DSOs. The project SmartNet is analysing different alternatives for such cooperation, both in long-term simulations and in real-life demonstration projects.

Despite some practical difficulties found during the implementation phase, the pilot demonstrated that the unused available capacity back-up from radio base stations, if properly aggregated, can be very useful for the DSO for congestion management and for supporting the TSO under the "Shared balancing responsibility" coordination scheme. Eventually, it can also avoid the costly ignition of thermal power plants.

The pilot has high replicability and scalability (Vodafone alone has more than 250 MW of available flexibility in its base stations across Europe) and the difficulties described above will be very useful for the replication phase.

Besides, it allowed the DSO to test innovative ways of integrating battery systems into the power grid, to avoid or delay grid reinforcements, to help decreasing grid tariffs by procuring more efficient balancing services, to envision new potential coordination schemes with the TSO, to push new technologies and grid digitalisation and to contribute to the social welfare of European citizens by activating the circular economy.

If the additional experimentations are in line with the results obtained so far and they demonstrate the end-to-end process feasibility and replicability, switch activation frequency and duration growth will allow an increased usage, which will create benefits for all parties (DSO, CMP and DER). However, the lifetime of the energy storage equipment already included in base stations (valve-regulated lead-acid batteries) would be strongly affected by such enhanced usage and their replacement by lithium-ion technologies to ensure the durability of the equipment should be assessed, both in technical and economic terms.

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