BASELINES COMPARISON PROCESS FOR DEMAND RESPONSE

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ABSTRACT

Developments made on the electrical system in order to optimize its operation were first made on the production side. Nowaday within the context of energy transition more and more studies are dealing with demand response (DR). The aim is to see to what extent customer load can adapt to new situation such as massive integration of intermittent power sources or new market prices. The consolidated partnership between ERDF and Schneider Electric allows working on this topic from site equipment and management to DR control. Beyond the fact that technological solution need to be set up, DR need to be valued on markets for example. In order to value this service it is necessary to assess how a load curves is modified with less consumption at certain point but may be higher at some others. The idea is to compare a "normal situation" to a situation with DR. Several methods already exist to determine load modification during DR event. These methods are more or less efficient depending on which consumer segment they are applied on. Nevertheless there are few processes that allow comparing these methods according to several key indicators. This paper presents a comparison process for DR control methods and some results within the context of French Smart Grid projects.

I. INTRODUCTION

At the beginning of 2013, the CRE (French Energy Regulation commission) published its deliberation regarding the rules for Demand Response (DR) introduction in French energy markets [1]. Many issues regarding DR are still to be solved. Several issues are at stake: An unexpected change in the load curve can have an impact on the network and balance responsible entity. It is therefore necessary to find efficient methods to quantify DR. Indeed, measuring or estimating non-consumed energy is very complex. Depending on the customer segment, the adapted methodology to control DR can be very different. The outcomes of DR control are very important for aggregators in order to build their business model. As mentioned earlier before, regarding DR control discussions continue in order to compare and study several DR control methods and how to implement these methods. In this context, having experimenting fields is a great opportunity to test solutions at a limited scale and draw some conclusions. Smart grid projects are a part of that process.

II. SMART GRID PROJECTS

These projects gather a wide variety of energy sector's actors (TSO, DSO, pool aggregators, equipment manufacturers and universities…). Smart Grid projects give the opportunity to test several solutions and compare them in a favorable environment. Among many projects, Schneider Electric and ERDF (main French DSO) are working together on DR experimentation in the smart grid project GreenLys.

GreenLys is a smart grid development project which was selected as part of the first investment program for the future, following a call for interest by the French Environment and Energy Management Agency (ADEME) in 2009. GreenLys was set up by a consortium of partners from the French electricity supply chain all offering complementary expertise - ERDF, GEG, GDF Suez, Schneider Electric and Grenoble INP – and brings together a number of specialists from the field of smart grids - Atos Worldgrid, Cnrs EDDEN , Hespul, CEA-LITEN , AlstomGrid, RAEE and RTE. GreenLys is the first demonstrator to test the operation of a Smart Grid as a whole, involving all stakeholders in the electricity market from the producer to the end consumer, including the distributor and the supplier.

Within this context, the aim for Schneider Electric, ERDF and their partners is to study the value chain from the equipment and site management to DR event control. In this case the customer segment assessed is mainly tertiary buildings or tertiary uses (heat pump, air conditioning ...). In this testing ground it was possible to recruit beta-customers, to equip buildings with Schneider Electric prosumer solution and ERDF was able to analyse the data from the meters.

III. PROSUMER SOLUTION FOR COMMERCIAL AND INDUSTRIAL ENERGY END USERS

The new Smart Grid paradigm requires changes in the way end-consumers use energy. While keeping full control of their energies, end-users can adjust some of their behaviors to participate in the smart grid services and to become proactive consumers or "Prosumers". In order to enable these behaviors, state of the art technologies are needed. Thus, a set of tools and services dedicated to the commercial &/or industrial prosumer has been developed. It is from now available under SaaS

(Software as a Service) and enables a strategy of energy management, flexible and connected to the Grid.
First the solution is able to suggest control resource strategies to minimize end-user energy bill. The algorithm includes energy pricing, weather conditions, and the predicted load profile for every connected building. For example, reduce cooling load and use stored energy to respond to load curtailment requests when energy prices are higher, or avoid a peak demand penalty by rescheduling a non-critical process.
These actions are part of tariff optimization initiatives but the solution can be used to control building resources for DR. In this case the algorithm can include real time pricing in order to spot the best possible valuation for DR on energy markets. The two aspects of this solution allow the prosumer to better manage energy consumption and to value flexibility.

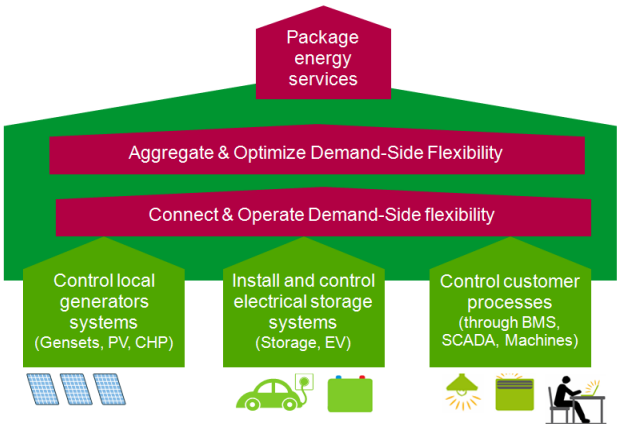

Figure 1: Prosumer architecture at a glance

A. Architecture

A cloud platform is connected to the onsite energy resources through the internet network. This solution is composed of two distinct layers: a remote Smart Grid services platform and a local onsite energy management system (cf. **Figure 2**).

1. Remote Smart Grid services platform

The SaaS platform is provided with an OpenADR web service (WS) connector that connects the flexibility of energy resources to the aggregator. This service is able:

- to activate the flexibility of a Demand-Response request,
- to cancel a load curtailment request before and during the load curtailment,
- to control the resource before, during and after the load curtailment to monitor the right execution of the load curtailment,
- to forecast & propose available flexibility to the aggregator.

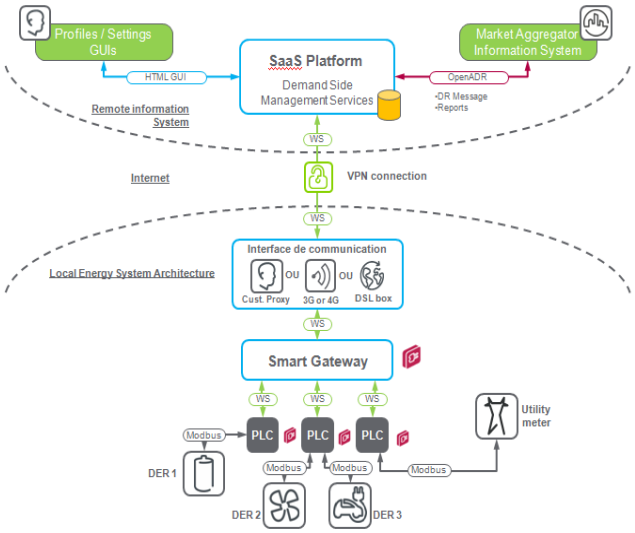

Figure 2: Prosumer architecture

OpenADR is a protocol used to exchange information with market aggregator information system. OpenADR is recognized and already widely used standard in North America and begin to be deployed in Europe.
It is important to give to end-user the right needed information with a friendly interface (Graphical User Interface) that allow them to understand how the system works and engage them to become active actors of their consumption. Energy of every controlled component is displayed on the interface. In the following screen shot (cf. **Figure** 4), we can identify a Demand Response event, realized on a real commercial building located in Grenoble FRANCE, equipped with Prosumer solution (cf. **Figure** 3).

Figure 3: Commercial building equipped with Prosumer solution

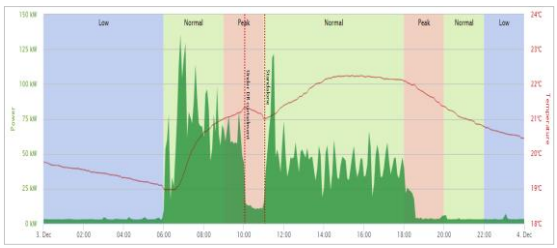

Figure 4: Graphical User Interface

2. Local onsite energy management system

It is composed of different bricks (cf. **Figure 2**):

- A communication interface: a Virtual Private Network (VPN) is set up between the site and the SaaS platform for secure communication.
- A Smart Gateway: it allows the communication between networks that use different communication protocols.
- Power Logic Controllers (PLC): it controls Distributed Energy Resources (DER) according to SaaS platform orders
- Distributed Energy Resources (DER) divided in three types: flexible loads, distributed generators and distributed energy storage systems.

B. Scalable for several markets and uses

The technical solution allows addressing different types of Demand Response programs. In fact, for each of them a specific performance evaluation methodology is used.

More precisely, earnings optimization is possible thanks to advanced analytics adapted for every baseline consumption methodology (baseline or non baseline methodology). Indeed, the system has the ability to meet certain technical requirements such as rapid speed of response to load control signaling (lower than 5 minutes), and thus allows DER to be eligible to provide energy, capacity, and/or an ancillary service in wholesale markets. In this way, all the Demand Response baseline consumption methodology can be implemented on the platform.

Furthermore, the system offers the capacity for aggregator to check the curtailment (in relation to applied baseline method) and to forecast its future cash flows. The system is able to collect and to send in real time utility meter and DER energy data with the debit period required by the aggregator. The same data can be used to shed light on an improper operation.

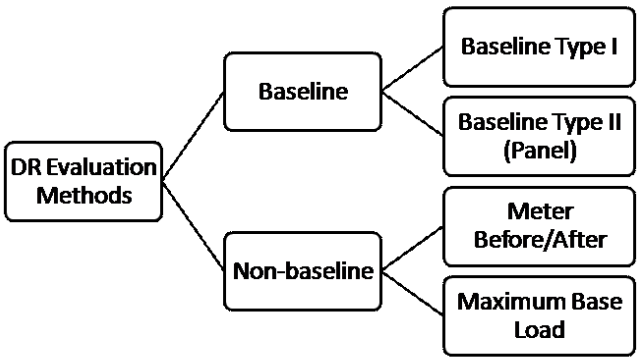

Figure 5: Demand Response evaluation methods [3]

IV. DR CONTROL

Once the potential for flexibility is identified and equipped, then comes the issue of DR control for markets purposes. Flexibility can be valued on several markets or mechanism and in some cases for ancillary services. But DR control will be needed to settle properly these valuations. In this experiment Schneider Electric equipped several tertiary buildings with a prosumer solution allowing them to participate to DR. Then, using the meters load curves, ERDF studied several methods for DR control.

A. Definitions

First of all let's start with some definitions. Indeed, to control DR it is therefore necessary to define a DR event. DR is one part of Demand Side Management (DSM), it represents the capacity of demand (in this paper we will only deal with demand but this can also be adapted to generation) to be modified according to a direct signal linked to energy markets or eventually grid safety reasons. It is very important to distinguish DR from energy efficiency actions or tariff optimization. Indeed, energy efficiency actions or tariff optimization are permanents or regulars and allow reducing energy consumption or energy bill. DR events are punctual in the way that the occurrence of DR events must create a difference with the standard situation. If a DR event is too often repeated it then becomes part of the standard situation and does not create the expected difference in the load curve.

B. DR control methods

Monitoring and controlling DR then requires comparing DR events with standard situation. To do so, there are several methods. They are sorted into two categories [2]: "non-baseline" and "baseline" as illustrated in Figure 5 The commonly used criterion to compare DR control methods are illustrated in Figure 6. The simplicity criterion represents the complexity of the method. This complexity in terms of calculations and data needed for these calculations. The integrity criterion depicts method's robustness under atypical behavior such as DR anticipation through an increased consumption. This criterion allows testing method's ability to remain unbiased and reliable. A baseline with a high level of integrity will protect against irregular consumption and attempts to alter the measurements [4].Concerning the accuracy criterion it simply illustrates method's precision."Non-baseline" methodologies rely on the load curve containing DR event to create linear extrapolations in order to model the consumption during the DR event. These methods are easy to set up but scarcely take into account side effects and then can be biased by these side effects. These methods are usually used for DR events occurring on the transmission network considering the event generally consists in stopping one industrial process.

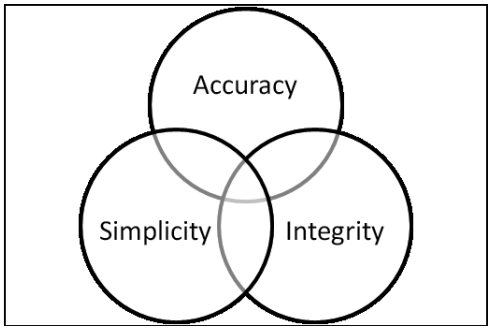

Figure 6 : Demand response measurement criteria [5]

"Baseline" methods require extra data in order to build a dynamic baseline. "Baseline Type I" methods are using the individual load curve history from the DR facility to create the baseline. The baseline can be built from a selection of previous eligible days load curves. It can then be adjusted if needed. "Baseline Type II" methods generate a baseline from a panel of customers through statistical sampling. This type of methodology is more commonly applied on the residential segment because it requires a wide panel for the statistical sampling.

C. Comparison process

As mentioned before it is complex to control DR and to model consumption during DR events. In the set of criteria presented before, the comparison process focuses on the accuracy criterion. Indeed, this criterion is key to evaluate DR control methods. To measure the performance of DR methods it is then necessary to implement key indicators.

Concerning Non-baseline methods, the reference curve is built only during the DR event. It is then difficult to calculate a precision indicator. Nevertheless by comparing baselines methods with known precision indicators can give a good idea on non baseline methods precision. Several key indicators are necessary to conclude on the precision criterion. Our methodology includes four key indicators: Mean Absolute Percentage Error (MAPE expressed in percentage), Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and Estimated Gap (EG expressed in percentage). A convergence of these key indicators toward one DR control methods gives a better overview of accuracy performance than only one and allows a more efficient comparison. These indicators are calculated over 24h containing a DR event. The DR event itself and the side effects were excluded from the computations. The aim is to calculate the indicators during a "normal" situation and to assume the precision rate is the same during DR event and side effects. The MAPE allows us estimating how close is the reference from the real curve, the EG or bias gives the tendency to overestimate or underestimate. The RMSE can highlights punctual deviation between baseline and real curve. The MAE is complementary to the MAPE. The computation of these four indicators gives a good opinion regarding DR control methods precision. It is then possible to compare baseline methods and also to give elements to compare with non baseline methods.

Then comes the issue of DR event qualification. Indeed, we are able to quantify baseline DR control methods and to give a level of accuracy in percentage. If the percentage of load shed during the DR event is inferior to this percentage it will then not be consider as a DR event because it will be in margin of error. Considering the purpose of DR it does make sense because if the DR event is not "seen" from the meter, and thus the network, it won't create the expected difference within the context of a market. Consequently, it is very important to focus on general meters and not on sub meters. For example in terms of absolute value a DR event of 100kW for one site is very important (in comparison with residential it is around 1kW per site). But if the average consumption of the site is 2MW it only represents 5% in relative and then becomes difficult to qualify as a DR event.

V. RESULTS

In this section we will present some results on the tertiary segment gather within the context of smart grid projects. The bottom line is to give some practical examples of the comparison methodology and to highlight is these case the differences between "Non-baseline" and "Baseline Type I" methodologies.

The applied methods for this study were three baselines methods and two non baselines. The first ones are using historical load curves with the previous eligible day for baseline 1, the average of the two eligible previous days for baseline 2 and the average of the three eligible days for baseline 3. An eligible day is a working DR event free day. For the non baseline 1 the reference level is the load immediately before DR event. For non baseline 2 it is the lowest reference between an average of 30 minutes before DR event and an average of 30 minutes after DR event. Figure 7 gives two examples with the DR load curve and the five references.

On the first graph, two DR event occurred during the day. We can see that the gap between baselines reference is quite small. Nevertheless the baseline 3 fits better the DR load curve. Table 1 sums up the accuracy criteria for each baseline methods. The MAPE is a little higher and the method tends to underestimate the load curve but the Baseline 3 still is better than Non baseline 1 and slightly better than non baseline 2.

On the second graph of figure 7 we can see one particular DR event load curve because there is an anticipation thanks to an earlier heater starting. Indeed, on this day, the heater started at 4:00am instead of 5:00am. "Baseline" methodologies allow catching this kind of phenomenon. In this case it is interesting to note that despite the anticipation, post DR rebound is still present.

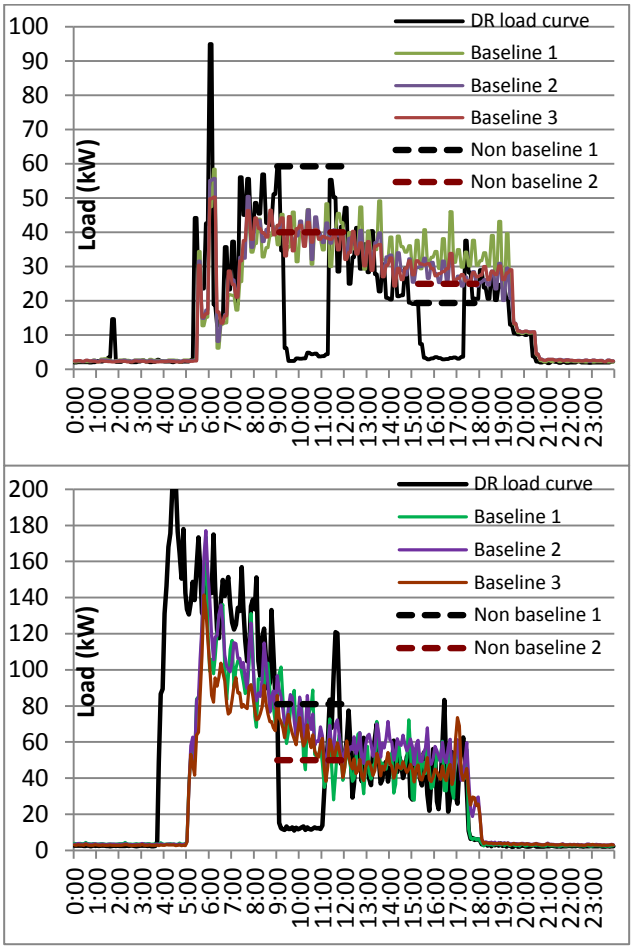

Figure 7: Example of DR control methods comparison on tertiary building

Graph 1	MAPE	EG	MAE	RMSE
Baseline 1	29%	-3%	5,8	10,6
Baseline 2	27%	-6%	4,6	8,4
Baseline 3	26%	-4%	4,6	8,3
Graph 2	**MAPE**	**EG**	**MAE**	**RMSE**
Baseline 1	28%	-3%	9,2	301,8
Baseline 2	44%	-17%	9,6	267,7
Baseline 3	38%	-3%	11,7	450,8

Table 1 : Results accuracy criteria

It is then necessary to analyse this on the energy point of view to see if it is profitable. In this case anticipation is excluded from indicator's calculations. The results are summed up in table 1 : Baseline 1 fits the best the load curve. Nevertheless it is difficult to conclude because anticipation modified the load curve for a long time (for example around 6:00am 7:00am the DR load curve is very different from the baselines). Hence the negative EG for all the methods.

In conclusion about these results, over all the cases of the study, it is the baseline 1 that fits the best the load curve. With an average MAPE of 30% and an EG of 1% it is the best reference of all three. It was predictable due to the fact that the buildings concerned were tertiary buildings and thus very sensitive to temperature. The best reference is then the closest in time to the DR event. Concerning the comparison between baseline and non baseline methods, it is hard to give numbers due to the very different nature of these references (one exist only during the DR event and the other all over the day with measurable precision indicators). Nevertheless in this case, baseline methods have proven their accuracy and better integrity compared to non baseline.

CONCLUSION

The study presented in this paper gives a glimpse into the complexity of the topic. From site analyse in order to find source of flexibility to DR control methods this article gives an overview of the global chain of value but many issues are still to be solved. Indeed, The CRE (French Energy Regulation commission) published a new set of rules for DR rules at the fall of 2014. Thanks to smart grid projects it was possible to test DR solutions and to draw some conclusion. Regarding the equipment a more exhaustive feedback is expected by the end of smart grid projects. Concerning DR control methods more complex "baseline type I" methods are under study in order to take into account weather adjustments. One purpose of this study was to highlight the assets of "baseline" methods regarding the assessment of side effects and their better accuracy and integrity.

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[1] This paper is submitted within the context of Smart Grids projects, the developments and findings expressed in this paper may be modified in another context (more general context).