IElectrix Project – Demand Response and Customer Engagement in Shakti Demonstration

Tanguy Choné[1], Pierre-Jacques Le Quellec[2], Abhinav Pal[3], David Pampliega[4], Christophe Dromacque[5], Lalima Goel[6]

[1]Project Manager at Odit-e, Grenoble, France
[2]Project Coordinator at Enedis, Paris, France
[3]Project Manager at Tata Power Delhi Distribution Limited, Delhi, India
[4]Project Manager at Schneider Electric, Seville, Spain
[5]Innovation Director at Geco Global, Helsinki, Finland
[6]Smart Grid Lab Manager at Tata Power Delhi Distribution Limited, Delhi, India

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Abstract

IElectrix is a response to the Horizon 2020 Call of the European Commission: "Integrated local energy systems".

Within a cooperation agreement signed by 4 European partners and TATA POWER Delhi Distribution Limited (TPDDL), Shakti demonstration is set up in Delhi to explore innovative solutions allowing the implementation of "Local Energy Communities" using local photovoltaic (PV) and storage for self-consumption approach.

By 2020, with Advanced Metering Infrastructure (AMI), TPDDL is looking to broaden DR program by extending behavioural DR (BDR) program across its residential consumers. BDR hinges on consumer participation as loads will be managed entirely by them in response to critical peak pricing. With smart phones acting as the gateway to home automation solutions, use of smart plugs to control home appliances such as air conditioners and other high-power equipment can be considered to allow functions such as "set it and forget it" mode for consumers. These DR initiatives are aligned with IElectrix objectives, and some of them will be carried out in the framework of the project.

1. Introduction

The Shakti demonstration in Delhi aims at showing how innovative solutions allow the implementation of Local Energy Communities (LEC) using local PV units and the self-consumption approach [1].

Low Voltage (LV) networks, considered uncritical, have been disregarded for the last 60 years. As a result, their characteristics, their status in terms of voltage plan and load level are poorly known. Furthermore, in most of the cases, no remote-controlled devices are available in this part of the grid neither for grid configuration nor for load management.

Consequently, its management requires new investments to monitor and control voltage and congestion aspects, especially in scenarios of PV insertion.

Two kinds of solutions will be implemented within Shakti demonstration:

- One solution uses dedicated assets like on load tap changers on distribution transformers, storage capabilities allowing large PV insertion and islanding operation during outages.
- The other solution uses DR at customer premises level combined with a grid state estimation based on data coming from currently deployed smart meters and from real-time data directly fed by Remote Terminal Units (RTU).

This paper will first explain the context of the demonstrator, its architecture and global operation. Then it will detail more in depth the technical implementation of this second solution in Shakti. Finally, it will focus on a topic that is necessary for this kind of program: customer engagement.

2. Size & Context of the Shakti Demonstrator

A DR program is being developed within the IElectrix project, this time involving not only TPDDL but also Enedis, Geco Global, Schneider Electric and Odit-e.
For this pilot, a total of 38 consumers are considered. To understand how and when the DR program operates, it is important to describe the possible modes of operation of this pilot:

- An off-grid mode (also called islanding mode) that is used when constraints on the grid are too high and to avoid outages. In this mode, the consumers are connected to a 274kWh battery.

- An on-grid mode in which all the consumers are connected to the medium voltage (MV) grid.

The DR program is run when the pilot is in this second mode: the objective is to avoid as much as possible voltage excursions and congestions, to optimize the overall operation of the grid and integrate efficiently PV production as well as the charging of the 274kWh battery that must be at all time at a sufficient level in case of sudden switch to the off-grid mode.

In the on-grid mode as well as in the off-grid mode, flexibilities (i.e. smart meters load fluctuation as described in Fig. 3) are recruited and therefore customer engagement is required to make this pilot work.

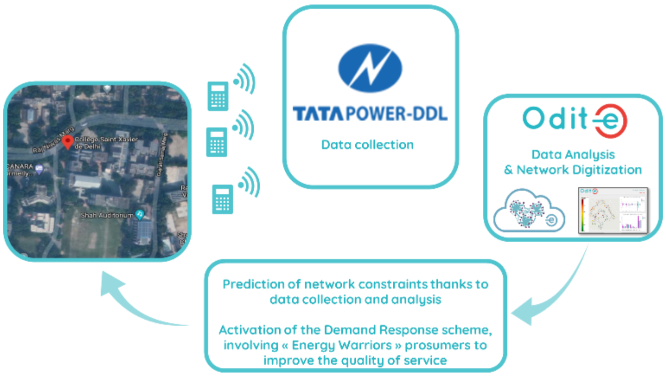

Fig. 1 Global architecture of Odit-e & TPDDL cooperation

3. Technical Implementation of the Program

3.1 Learning stage

3.3.1 Integration of smart meters data

The solutions proposed by IElectrix to implement DR program in the Shakti demonstrator relies first and foremost on a learning phase in which it is necessary to collect data.

The data required to make this phase successful is the following:

- LV Feeder data: this data is collected over at least two months with a 1-minute time stamp. In the case of the Shakti demonstrator, active energy load curves, apparent energy load curves, average current profiles and average voltage profiles will be collected for the three phases.
- Smart meters data: this data is also collected over two months but with a 30-minute time stamp. The same data than above is collected on one or three phases depending on the smart meter.

3.1.2 Computation of the influence matrix

From this data, a first model is computed and enables to understand the grid behaviour. Computation of the model f_1 with N smart meters named SM_1, SM_2, …, SM_N:

$$f_1(LVFeederData(t)) = \begin{pmatrix} U_{SM_1}(t) \\ \vdots \\ \vdots \\ U_{SM_N}(t) \end{pmatrix}$$

This first model makes possible a computation of flexibilities to be implemented when needed. It can be used with forecasted data to provide flexibility needs for the next day.

3.1.3 Integration of flexibilities data and continuous upgrade of the influence matrix

In order to have a more precise model and to optimize the flexibilities to be implemented, the influence of each flexibility on the grid is planned to be integrated through its activation schedule and the obtained results. From all this data (LV feeder, flexibilities activation schedule, smart meters data, including data showing the influence of a flexibility), two models are computed:

- The first one is a statistical state estimator: based on the parameter we know of the grid in real time (measurement from LV feeder that is sent by Schneider Electric through the Easergy T300 RTU, and the scheduled of flexibilities). It estimates the voltage level at every smart meter. This new model f_2 that integrates the activation schedule becomes more precise and optimized.

$$f_2(LVFeederData(t), ScheduledFlex(t)) = \begin{pmatrix} U_{SM_1}(t) \\ \vdots \\ \vdots \\ U_{SM_N}(t) \end{pmatrix}$$

- The second one estimates the impact of the activation of a flexibility and provides the expected variation in the voltage level at each smart meter in case of activation:

$$f_{2,m}(ScheduledFlex_m(t)) = \begin{pmatrix} \Delta U_{SM_1}(t) \\ \vdots \\ \vdots \\ \Delta U_{SM_N}(t) \end{pmatrix}$$

This way, a complete state estimation of the grid is performed. This state estimation then allows to deal with two different problems often seen on LV networks: voltage excursions and congestions.

3.2 Operation stage

3.2.1 Prediction & location of voltage excursions

The computed model allows to estimate the state of the network 24h ahead. It enables to identify which points of the grid are susceptible to face voltage excursions (which U_{SMx} will be out of the regulatory limits and at what time). A list of flexibilities to be implemented is then computed to solve this issue. This optimized list is sent to TPDDL a day ahead.

3.2.2 Prediction & location of congestions flexibilities

Regarding congestion management, the operation remains the same but is based on forecasted LV Feeder data that is sent day ahead by the EMS of Schneider Electric.

3.2.3 Sequence of operations sum up

Hereafter is a figure that sums up the basic operations of the DR program and how it runs in the Shakti pilot:

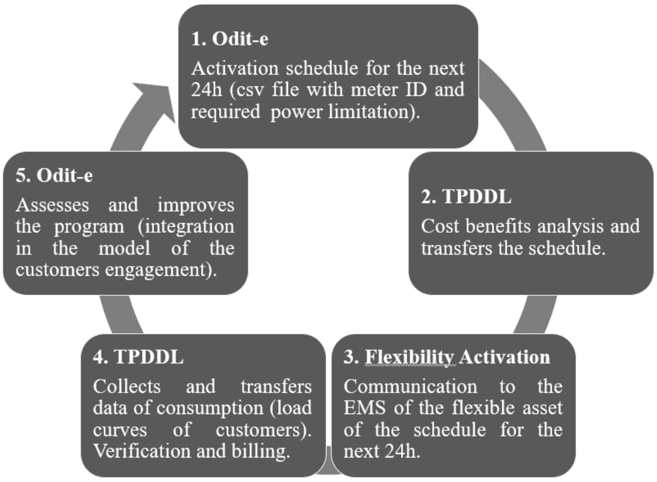

Fig. 2 Global sequence of operations

To be more precise the following figure illustrates how this program is operated from one day to another:

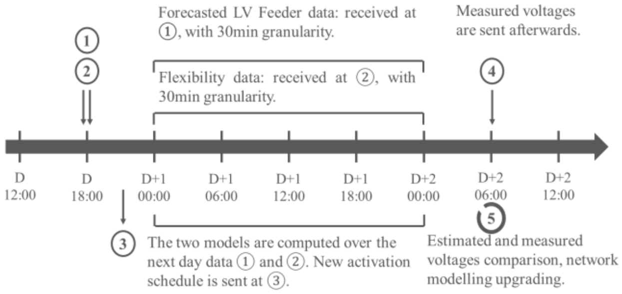

Fig. 3 Chronological operation of the program

3.3 Control and continuous upgrading stage

Once the DR program runs in the demonstrator, Odit-e ensures that the mechanism is fully optimized and efficient. To achieve that, many ways are used:

- More replicable monitoring data may be integrated like the MV feeder average current profile (primary substation)
- New flexibilities are enrolled and customer engagement for each flexibility is measured and integrated
- Estimated and measured voltages at the smart meters level are compared and the accuracy and performance of the voltage management system is calculated

In the end, the more this program runs, the more optimized and efficient it will be [2].

4. Customer Engagement & Benefits

Geco Global and TPDDL will implement a range of communication and consumer engagement activities that consider the specificities of the territory and the people living in it.

The starting point will consist in understanding the community and its members. Design personas will be specified so that differences in attitudes, perceptions, emotions, ability to make changes and behaviours around dynamic pricing and the energy transition in general are fully assessed [3][4].

This important dimension provides a lever to engage with consumers' values and attitudes in relation to topics such as environmental concern, desire to save money, desire to engage in a community project, and interest in novel technology during the ensuing communication and awareness campaigns of the pilot activities and positive local impacts through tailored (i.e., based on personas specified) messages and channels.

In addition to this deeper consumer understanding, the existing knowledge and interest gaps will also be taken into consideration. Perhaps because most consumers are not fully aware of their own energy consumption, increase in knowledge and concern from mass communication campaigns may not translate into observable change of behaviour unless the general information is combined with other more tailored and targeted techniques. In addition, dynamic prices themselves do not generate peak clipping; they generate the nudge that in turn may lead to peak time savings. It is therefore paramount to address pilot participants' expressed concerns and provide them with tips and advice on how to take advantage of the smart plugs and dynamic tariffs as well as with quick feedback on the impact of their actions during the critical peak thereby enabling them to directly identify links between activities and consumption. State-of-the-art content and interaction design techniques will be used to ensure tips and advice are relevant (i.e., personalized and based on user needs and capabilities), timely (i.e., soon before and during an event), easily accessible and written in a way that is easy to understand (i.e., using clear and non-expert language).

Since we are not our customers, an evaluation framework and a set of metrics will be designed allowing for the continuous tracking and calibration of the engagement activities (e.g., consumer satisfaction, impact of communication campaigns) therefore ensuring consumer feedback are considered and appropriate adjustment measures can be taken [5][6][7].

The benefits of the DR program for a participating customer include financial incentives for participating in the DR program, and the savings that result due to reduced energy consumption during peak hours.

DR incentives should be greater than the opportunity cost available to consumers as well as provide savings to make it lucrative for the consumers to enrol and participate. For a utility, the cost share revolves around primarily the administrative cost of the program, fixed cost of infrastructure and revenue loss if it leads to load shed vs load shift [8].

6 Conclusion

The Demand Response program implemented by TPDDL in Shakti and that runs during the on-grid mode of the pilot solve voltage constraints on the low voltage grid (voltage excursions and congestions). The technical implementation of this program is designed by Odit-e and is made of three parts: a learning phase, an operation phase and finally an upgrading phase that are all detailed in this paper.

This design relies on the possibility to recruit flexibilities quickly on the grid which is only made possible by a strong customer engagement (Geco Global).

During the islanding mode, flexibilities will also be recruited but they will not serve the same objective: the main constraint in this case is capacity of the battery and is not that much related to voltage issues. This part will be more precisely designed in the future of the IElectrix project.

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This paper reflects only the authors' view and the Agency and the Commission are not responsible for any use that may be made of the information it contains.

8 References

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