FLEXIBILITY PLATFORM AND ASSOCIATED ROLE OF FUTURE DSO WITHIN IELECTRIX SHAKTI PILOT PROJECT

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Keywords: ENERGY COMMUNITY, MICROGRID, FLEXIBILITY, DIGITIZATION, ISLANDING

Abstract

Energy decentralization is encouraged through customer empowerment within the formation of Energy Communities. The key enabling role of DSO to support Energy Communities is however hampered by a lack of LV grid digitization and flexibility. The H2020 IElectrix project (2019-2022), co-funded by the European Commission, is devoted to solving this issue. Five DSOs (E.DIS, Enedis, Energie Güssing, E.ON EED, Tata Power Delhi Distribution Limited) have joined with innovative solution providers and research centres, to demonstrate the combined roles of distribution grid innovations in different regulatory systems (Austria, Germany, Hungary and India). This paper focuses on innovative solutions for the Indian system, with a power sector sustenance majorly dependent on the cash-flow coming from its distribution sector. Nevertheless, this is the weakest link of the power sector and faces major challenges such as the increase in the power purchase cost, high Aggregate Technical and Commercial (AT&C) losses, lack of cost-reflective tariffs and the energy transition. With the government's impetus towards promoting clean energy and the intermittent nature of the renewables and the variability of charging electric vehicles, this requires real-time demand supply management and network flexibility. The Indian SHAKTI pilot, located in Delhi, aims to demonstrate relevant technologies involving prosumer support.

1 Introduction

IElectrix project gathers partners from Europe and India to implement several Smart Grid demonstrators with the aim of keeping up with the energy sector transformation (renewable intermittent energies, digitization, decentralization, and consumer's implication) [1].

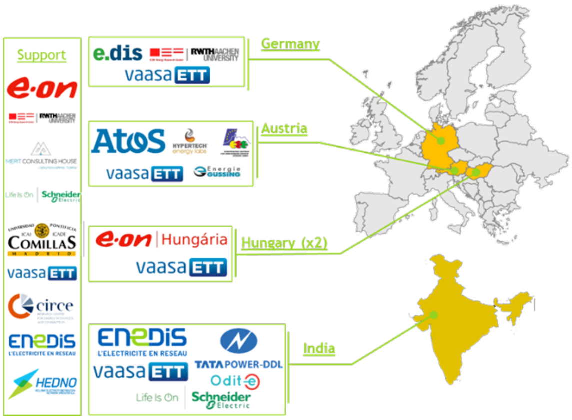

Figure 1 IElectrix demonstration map [2].

The main challenges the project is facing is to test innovative solutions in various regulatory regimes, with diverse geographical, technical and economic situation, and at different stages of Energy Communities development.

This paper will focus on the regulatory regime of India. In India, the power sector sustenance is majorly dependent on the cash flow coming from its distribution sector. Nevertheless, this is the weakest link of the power sector and it faces major challenges such as the increase in the power purchase cost, high Aggregate Technical and Commercial (AT&C) losses, lack of cost-reflective tariffs and the recent being energy transition. Due to the intermittent nature of the renewables and the variability of charging electric vehicles, this requires real-time demand supply management and network flexibility.

In that context, the pilot in India, also called as SHAKTI demonstrator, aims to showcase innovative solutions addressing the following goals:

- Maximize the penetration of local energy in the Low Voltage (LV) grid.
- Increase the local consumption of renewable energy.

- Improve the resilience of the local energy system.

The paper will describe the technical solution that will be deployed in SHAKTI demonstrator and will present the different use cases that will be implemented.

2. The SHAKTI Indian pilot architecture and use cases

The Indian SHAKTI demonstration, located in Delhi, will demonstrate various Smart Grid Technologies, including microgrid solutions, Remote Terminal Units (RTU), self-regulated transformer and grid digitization techniques to experiment use cases on the LV grid with prosumer support. Those Smart Grid technologies will be deployed on the St. Xavier's secondary substation and its associated LV grid. The energy community is made of a large school with 3,000 students, a community centre and several households and buildings, with 120 kVA provided by photovoltaic (PV) panels installed on the roofs of the school. Up to 200 kVA of additional PV panels should be installed during the duration of the demonstration.

Figure 2: Shakti Indian pilot located in New Delhi.

The architecture of the system is represented below according to the SGAM [3] mapping.

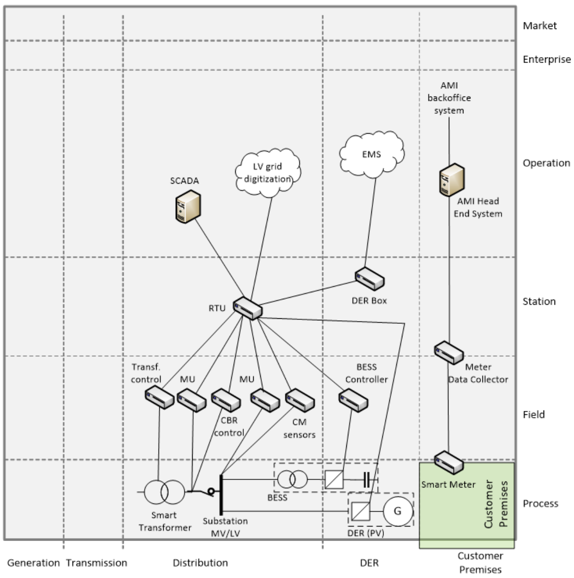

Figure 3 SHAKTI pilot architecture.

Main elements of the architecture are the following ones:

- Battery Energy Storage System (BESS): A battery of close to 400 kVA will help improving network stability, by providing a power backup in situations of outages affecting the upstream Medium Voltage (MV) grid.
- Smart transformer: A self-regulated transformer, able to automatically adjust the LV voltage to ensure it remains within the defined limits.
- Energy Management System (EMS): The EMS will allow to dynamically control on-site energy resources and optimize their performance, by connecting to PV panels and BESS to forecast and optimize how and when to consume, produce, and store energy.
- Remote Terminal Unit: The RTU will monitor and control the LV grid and will be the central hub interconnecting all the elements involved in SHAKTI demonstrator.
- LV Grid Digitization system: This system will process data coming from the smart meters at customer premises and the data monitored by the RTU, in order to obtain the state estimation which will regulate the smart transformer and to provide ad-hoc services adapted to the real conditions of the Energy Community through the Digital Twin of the LV grid.

The whole system is currently under development and is planned to be commissioned in autumn 2020.

A combination of the described elements will allow to address 3 functional use cases, which are detailed in the following sections.

2.1 Forecasting/scheduling Distributed Energy Resources

The objective is to balance and optimize the electricity supply (rooftop PV units and BESS) and loads by managing the power flows. To achieve this, the EMS will allow maximizing self-consumption as well as participating to grid frequency support.

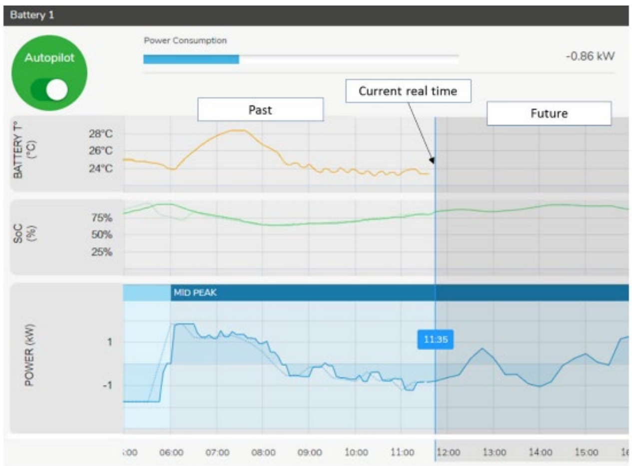

Figure 4 Example of real-time battery monitoring in the EMS.

Figure 4 shows some parameters of the battery that are being monitored in real-time. It's possible to check historical and forecasted data. The figure shows how the State of Charge (SoC) of the battery changes according to the positive or negative power output.

Regarding frequency support activities, frequency would be monitored in real-time at the substation. When frequency is detected to be outside of the accepted limits, a regulation mechanism would be activated. In case the frequency needs to be reduced, the BESS would need to be charged at a higher rate until the frequency is again under the accepted limits. On the opposite scenario, the BESS would reduce its consumption, to allow frequency increasing. This operating procedure is depicted in Figure 5.

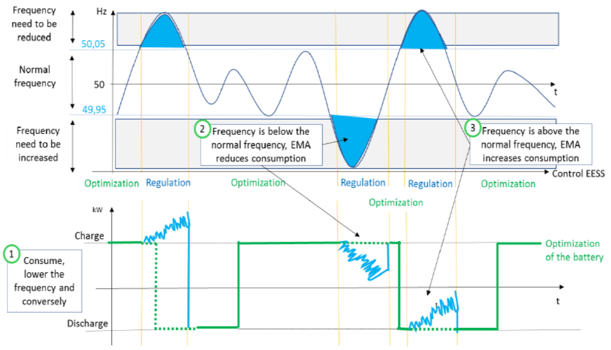

Figure 5 Frequency regulation using BESS.

This use case will also address the management of voltage levels, by using a self-regulated transformer. This transformer will adjust the output voltage of the LV grid after an estimation of its real-time state provided by the LV grid digitization system, to ensure the right level of voltage at the customer level.

The transformer will combine a conventional transformer with a booster transformer in series to decrease or increase the voltage. The on-load regulation is able to control 5 taps of 2% of the voltage (or 9 taps with up to +/-10%) and is completed with a de-energized tap changer to adjust the nominal voltage as usual in a traditional transformer.

2.2 Customized, human-centric prosumer participation in Demand Response (DR) programs

The scope is the participation of local final customers in innovative DR models involving the demo infrastructure and smart meters.

Tata Power Delhi Distribution Limited (Tata Power DDL), the Indian DSO, will be able to analyse the outcomes of such DR programs applied to Shakti demonstrator, in order to define the most suitable DR programs to be offered to their customers. The demonstration will focus on benefits for both DSO and final customers.

2.3 Ensured energy system resilience

This use case aims to ensure the resilience of the microgrid, achieved through three levels:

2.3.1 Islanding to recover from outages on the upstream grid: In order to withstand outages of the upstream grid, the substation will be able to operate in the following modes:

- Grid-connected mode: The BESS would be a grid-tied asset and could be charged or discharged depending on the defined EMS functions. Microgrid frequency and stability would be ensured by the network.
- Islanded mode: The BESS would be the anchoring resource (grid-forming mode) and the EMS would stop sending charging/discharging commands. Microgrid frequency and stability would be ensured by the BESS.

The deployed solution at SHAKTI demonstrator would allow detecting power outage conditions and would manage the transitions between grid-connected and islanded modes.

2.3.2 Condition monitoring: Condition monitoring technologies in the MV/LV substation will allow notifying an indication of early failure conditions that may occur.

The RTU will be able to concentrate the condition information of the substation (like environment, cubicle or transformer) and apply algorithms on them. The main goal of those algorithms is to provide substation condition information and alarms, to ease remote service or any local maintenance operation.

It allows also collecting alarming information from existing equipment or devices to complete the substation condition information.

2.3.3 Digital services: A deeper knowledge of the condition under which the LV grid operates is made possible through the analysis of smart meters data by the LV grid digitization system. It creates a digital twin of the network which is used for four different digital services:

- The identification of the grid topology which provides the smart meter – phase – feeder – MV/LV transformer connexion [7].
- An impact prediction tool which assess the capacity to insert new facilities such as PV panel or Electric Vehicle (EV) charging infrastructure [8].
- The estimation of the state of the low voltage network in real-time.
- An estimation and location of non-metered energy.

3. Grid protection and Cybersecurity

Grid protection and cybersecurity are paramount aspects that have been considered in the design of the architecture, as the deployed solution needs to be safe for the citizens and operators, as well as resilient against possible cyber-attacks.

3.1 Grid protection

Protection systems for SHAKTI have been carefully studied due to the high penetration rate of inverter-based generators (PV panels and BESS).

Firstly, the microgrid shall be operated with many operating modes, involving the main grid, the BESS and the PV sources. To meet the safety requirements, the protection system must be ensured in all possible operating modes, to facilitate the fault location and reduce the repairing time [5].

Secondly, short-circuit currents will have low magnitudes. The inverter-based generators are producing short-circuit currents between one to twice the rated current, according to the withstanding of power electronic components inside inverters. According to the operating mode, minimum short-circuit currents in some feeders could be close to the maximum load/rated currents [4], [6].

Finally, the short-circuit currents will have bi-directional flows inside main feeders, due to Distributed Generation (DG) sources.

All these constraints have been taken into account in a dedicated protection and discrimination study in order to ensure protection and discrimination among the energy community.

3.2 Cybersecurity

The adopted cybersecurity strategy is in-line with IEC 62443 requirements for an industrial system. Risk analysis is being modelled with Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service, and Elevation of Privileges (STRIDE) methodology.

The risk analysis begins by establishing the context: devices inventory and cartography to have a clear technical scope and communication flows with other systems. Criterions to be used need to be defined with metrics for risk appreciation.

The risk analysis of the system identifies feared events, main threats and potential attack paths, as well as which security measures could provide protection.

The system architecture that has been designed for SHAKTI incorporates security functionalities, like availability, integrity, as well as authenticity and confidentiality.

Security features follow a layered defence in-depth approach to ensure the right level of protection is achieved depending on the identified risk.

4. Conclusion

The paper has provided a short overview about IElectrix project, and has focused on the Indian demonstrator, called SHAKTI. The innovative architecture design has been presented, as well as the use cases that it will support, with the aim of minimizing issues related to congestion and voltage management at the same time they increase network stability of the Tata Power DDL grid.

5. Acknowledgements

The activities described in the paper are part of IElectrix project. IElectrix project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824392.

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.

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