UNIversity Campus Operating as a self-Regulated Network

Project Summary

Reason

As a special consideration in the recent EU Winter Package, local energy communities (LECs) open up a possibility to tackle the complexity of energy system integration (ESI) across multiple pathways and geographical scales to deliver reliable, cost-effective energy services. In order to adapt with the appearance of LECs, the smart energy infrastructure needs to evolve by developing self-management schemes for exploiting completely their flexibility potential to decrease peak-load consumption while improving energy efficiency and resiliency. On the one hand, flexibility values from LECs have been investigated and tried out in several research and pilot demand response (DR) oriented projects. Those projects, however, address normally a single dimension of energy vector, i.e. electricity, thus lacking an ESI design view at the LEC level to explore completely flexibility value in which the thermal energy flexibility plays a predominant role.

Goal

UNICORN aims to strengthen the positions of local energy communities, particularly the TU/e campus network as a self-regulated microgrid. This project focuses on improving the monitoring of such campus microgrid by an end-to-end modular sensor solution with a high sampling rate for (real-time) control purposes embedded together with topology identification and state estimation features. Based on such an advanced monitoring platform, UNICORN develops data-driven models with deep and reinforcement learning for self-management and optimization processes. This will lay a foundation to explore flexibility potential to improve the resilience and efficiency of the campus microgrid as well as the whole integrated system. Tangible achievements for energy-saving target up to 40% and peak-load reduction up to 20% are expected from UNICORN.

Project Background

In the Netherlands, LECs can be considered as an emerging building block in the whole smart energy development where it might integrate various smart grid technologies, including demand-side participation, integrated communication, and decision support units to supply energy to its customers in an economical and reliable manner. The implementation of LECs creates various opportunities for green energy communities with participants simulated by technology, economic, and environmental benefits. Development of interfaces LECs and the surrounding system and market creates a close ecosystem to integrate renewable sources, exploit distributed resources, and provide services towards involved stakeholders. By demonstrating the ability of such an ecosystem environment, this project would increase the potential benefits from the micro-grid technology as an affordable solution to obtain low greenhouse gas emissions in the Netherlands.

Future energy systems integrated by multi-energy carriers (i.e. electricity and heat) is highly desirable and beneficial to the entire energy sector to smoothen the energy transition. The flexibility values from LECs have been investigated and tried out in several research and pilot DR oriented projects. However, due to insufficient measurement at these low voltage (LV) networks, distribution system operators (DSOs) are often blinded to incidents occurring in real-time but also missing information to prepare for necessary flexibility procurement in advance. There is a gap in monitoring and control properly the network parts between the distribution substation and the connection points of the customer. It is expected also LECs play an important role here in this network segment due to decreasing levelized costs of storage technologies. With monitoring and self-regulated capability, LECs can bridge the gap in between grid operation and the customers. Among other emerging technology trends, massive rolling-out of sensors and smart meters under the fast evolvement of the Internet of Things (IoT) opens the possibility to improve (real-time) monitoring capabilities for both grid operators and customers, not only to take control actions timely but also to schedule optimally their resources in advanced via data analytics.

The UNICORN project aims to contribute towards the energy transition going on in the Netherlands that generates considerable knowledge in the domains of renewable integration and smart energy systems. It strengthens the position of LECs, particularly the TU/e campus network as a self-regulated microgrid. In this project, innovative monitoring and control algorithms for the seamless coordination of the university campus network operation within the distribution networks have been developed. This will push forward for the advancement in technologies, both in ICT and in power system technologies.

The main goals and tangible results of UNICORN are as follows:

- Improving monitoring capability: Various data resources from smart meters and new sensor technologies would enrich the monitoring capability of LECs as well as the neighbourhood network. UNICORN will synergy such resources together with state estimation and prediction tools to indicate possible risks of outages or power quality (PQ) issues.

- Enhancing resiliency of self-regulated campus networks: UNICORN will introduce an advanced overlaying control solution to coordinate DERs including solar PV, thermal storage, and batteries within the campus premise. These solutions will be validated in a Power Hardware-in-the-Loop (HIL) testbed to show capabilities of riding through intermittency and stochasticity from DERs as well as optimal reconfiguration strategies.
- Exploring flexibility values for LECs via viable business models: While demand flexibility value is widely adopted via independent aggregators in various emerging market models, DSOs are still sceptical about the possibility of exploring this commodity in grid operation perspective. UNICORN will lay a foundation for further adoption of PQ services giving priority to secure grid operation.
- Improving the efficiency of self-regulated campus networks: A comprehensive ESI model allows UNICORN to exploit flexibility values in a multi-dimensional energy vector to achieve energy saving target up to 40%. Various thermal storage and battery technologies will be considered to address the ambition of reducing the peak load to 20%.

Short description

The UNICORN project will be coordinated by TU/e with active contributions from the consultancy company (DNV GL) and a start-up (digiEMS) partner. Besides the management and dissemination WP led by TU/e, three main WPs are dedicated for each partner. digiEMS will take charge of WP2 (Data acquisition and analysis) to develop a monitoring solution including affordable modular sensors and I/O interfaces suitable for not only data analytic but also “real-time” control functionalities. TU/e will lead WP3 on the efficient and resilient operation of a self-regulated campus network in which a set of a control algorithm for resource scheduling and real-time dispatching will be developed and validated. Last but not least, DNV GL will provide an insight in viable business models to exploit flexibility values for LECs, especially for the case study of the campus microgrid.

The WP2 encompasses the initial work of the project data gathering from the whole campus as well as relevant data sources from some relevant buildings. A cross-platform data sharing mechanism has been developed for analytics in both planning and real-time applications. WP2 determines the existing metering, control, building automation systems, DER controllers, and other objects that will be part of such demonstration sites. It will specify the technical requirements for sensors, including locations, sampling rate, time synchronization, accuracy, and bandwidth for communication. The work will also propose technical communication solutions and systems that fulfil those requirements. This WP includes methods to collect, store, and retrieve data (cloud-based vs. distributed). WP2 incudes development of the methods to ensure that energy usage and distribution pattern predictions are delivered on time. The WP provides a flexible data processing controller which allows real-time decisions on whether the data processing should happen locally (e.g. close to LECs) or remotely (e.g. on a Cloud) given time criticality, data volume, and prediction granularity required.

The WP3 aims to explore flexibility potentials from a self-regulated campus network which includes both electrical and heating/cooling systems in an integrated way. Specifically, optimal flexibility scheduling for the whole campus has been realized by data-driven models of each building as well as interdependencies among them. Based on the real-time monitoring capability, the distributed EMS of the university campus has been enhanced by corrective coordinated corrective controls of their DERs in the real-time manners to improve their resiliency. The real-time (in seconds) and near real-time (in minutes) dispatching mechanism proposed in this WP has resulted from the insights in predictive system states based on developed models in WP2. This scheduling plan is continuously compared to the real-time hybrid model and the adjustment/update is immediately performed once the error/ tolerance is higher than desirable criteria. The resiliency of the integrated system is ensured by developing real-time control strategies for LECs to autonomous operation in a self-management manner.

Further, in WP3 scheduling for flexibility usage is proposed with the support of a predictive data-driven model in WP2. In this scheduling approach, the uncertainty/assumptions in the short-term planning is step-by-step replaced once the operational data become available and the time horizon of the plan is then expanded to the next period. Furthermore, since the planning task is repeated, the planning method is designed to be self-learning for given network topology and consumption patterns based on historical data and similar network. Subsequently, short-term planning becomes more mature, and accurate solutions for that area/location/network with the models are gradually refined, extended, and/or combined. By closed-loop iterations of this planning process in this WP, operational scheduling, and data-driven model in WP2, the approach expects to reduce the overall runtimes and improve the quality of final solutions.

WP4 aims to realize business models for the self-regulated campus to offer flexibility values in both in-direct and direct control manners. Regarding an in-direct setting, flexibility resources will be based on the potential of shifting and curtailing energy consumption and production of the campus according to requests from market actors involved. Especially, it opens up a possibility to investigate peer-to-peer trading mechanisms at the local market levels. Meanwhile, the direct control setting lays a foundation for realizing the benefits of large end-users (prosumers) in taking their control actions to support and secure grid operation.

This project focuses on improving the monitoring of a microgrid by an end-to-end modular sensor solution with a high sampling rate for (real-time) control purposes embedded together with topology identification and state estimation features. Based on such an advanced monitoring platform, UNICORN will develop unique data-driven models with deep and reinforcement learning for self-management and optimization processes.

UNICORN explores the flexibility values within the context of a local energy community, i.e. the university campus network in which multi-dimensional energy vector plays an important role. In addition, UNICORN will bring in together direct and indirect mechanisms to explore the flexibility resources, not only from the demand response units but also from control actions over DER inverters and storage systems. UNICORN also investigates the role of LECs in the whole energy flexibility supply chain and come up with applicable solutions, especially for coupled grid operators.

Results

- Real-time measurement solutions are applicable for the LV network that can integrate end-users' (IoT based) data in a reliable and secure manner.
- A novel method of building energy data analysis using the technique of collaborative learning model in machine learning is developed. The prediction and the classification of the building energy consumption ahead in time are performed using several algorithms such as Fully Connected Neural Network (FCNN), Long Short Term Memory (LSTM) model, Decision Tree (DT) model for prediction, and the Support Vector Machine (SVM) model for the classification of building energy consumption. The prediction and the classification of the data is performed on data of 1 minute 5 minute and the 15-minute resolution. An attempt is made to evaluate the most suitable method out of the three methods of prediction and classification for the analysis of the building energy data ahead in time. Prediction of data using the LSTM model and classification of data using SVM model was found to be most suitable and accurate with the data resolution of 1 min.
- To explore the flexibility potentials from self-regulated campus network which includes both electrical and heating/cooling systems in an integrated way, a data-driven flexibility optimizer model for day-ahead scheduling of energy profiles for LECs, considering photovoltaic (PV) generations, heat pumps (HPs), and cooling loads have been developed under this project.
- Business models for the self-regulated campus to offer flexibility values in both in-direct and direct control manners have been developed. In principle the 'fasted' flexibility offers the most revenue, however, requires the flexibility to meet specific conditions regarding availability, automation, and prequalification. It is unclear if the flexibility on the campus can meet these. However, saving on the grid connection (and possibly energy tax by self-consumption) offers the most feasible revenues. Further, the potential to sell the flexibility to the balancing and energy markets (for example through an

aggregator or with a market-based energy tariff from an energy supplier) is limited and requires specific arrangements with an energy supplier/BRP.