CIRED 2020 Berlin Workshop (CIRED 2020)

22-23 September 2020

Theme 3: Flexibility Platforms and the Role of future DSO's

Journals
The Institution of Engineering and Technology

ISSN 2515-0855
doi: 10.1049/oap-cired.2021.0215
www.ietdl.org

Energy flexibility harvesting from data analytics – integration of building energy resources into energy markets

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Abstract: The study seeks to explore how building automation resources could integrate into energy markets and also to give insights into how flexibility resources could be harvested from large building complexes. This study describes four data-driven building automation use cases for the campus building in the Nordic climate environment. The focus is on the use case defining the integration of the building automation resources into energy markets. In addition to the first use case, the paper also describes three other use cases as follows: first, the data platform enabling easy access to data, second, the integration of real-time data analysis on the data platform, and third, the data platform providing real-time carbon emission balance reading for public. As the main result, the paper seeks to define the use case describing the integration of building automation resources into energy markets in detail to enable implementation in later phases of the project. In addition, the paper gives insights on how flexibility resources could be harvested from large building complexes and what are the requirements for such a resource to enter flexibility markets.

1 Introduction

In the Nordic, a variety of demand response markets exist nowadays, but only a handful of resources can participate in flexibility markets due to the lack of qualifying control systems or communication architectures. The topic is well covered in the research, for instance [1] reviews some approaches to tackle the issue. Also, to be noted, in many cases, the sole purpose of these automation devices is to operate on flexibility markets, while the very same devices could be applied for other purposes simultaneously. The discussion about small-scale flexible energy resources has been active for many years to date. However not that many concrete actions have been taken so far [2].

The paper describes four data-driven building automation use cases for the campus building in the Nordic climate environment. The focus is on the use case defining the integration of building automation resources into energy markets. The paper also describes three other use cases as follows: first, the data platform enabling easy access to data; second, the integration of real-time data analysis on the data platform; and third, the data platform providing real-time carbon emission balance reading for public. The paper aims to advance our understanding of how building automation can aid the entry of the small resources that could provide market flexibility only as of the secondary or the tertiary task into market. In addition, the use case definition aims to set minimum functionality requirements to building automation and integration data platforms to facilitate its operation as a flexible resource in energy markets. The results of the use case definition can be further applied to give a better understanding of the indexes defined by the utilisation of the Smart Readiness Indicator (SRI) for buildings [3].

Multiple studies propose that there are efficiency gains to achieve by utilising more sophisticated control strategies. For instance, Thieblemont et al. [4] proposed that weather forecast could aid in the predictive control of the building automation incorporated with energy storages. Also, in [5] promising efficiency gains were demonstrated by utilisation of predictive control in the building automation system. Kumar et al. [6] proposed a more sophisticated utilisation of AI models in building automation control. The previous articles rely strongly on the data availability and interoperability of the IT systems. In practice, there might be a huge amount of data available via various IT systems. However, if those systems are not truly interoperable, the full potential of the sophisticated analysis tools and control algorithms cannot be exploited. One has to bear in mind that also sensors and the controllability of the building resources play an essential role in the process. In the traditional systems, many control methods can cope with a minimal amount of actual sensor data but as the control systems complexity increases, the need to increase the amount of monitored variables may arise in order to gain benefits from more sophisticated control methods. To understand fully how buildings are operating there is a need to have better access to data while also data quality must be ensured.

Fig. 1 shows the general backbone of the study. There is potential to emerge new business if suitable expertise and enabling technologies can be incorporated with the data analysis process.

As the main result, this paper seeks to define the use case describing the integration of the building automation resources to energy markets in detail in order to enable implementation in the later phase of the project (see acknowledgement). In addition, the paper gives insights on how flexibility resources could be harvested from large building complexes and what are requirements for such a resource to enter the flexibility markets.

2 Background

The test platform focuses on the resources that are available in the campus building of LUT University, in Lappeenranta, Finland. The campus consists of seven building phases with a total area of 61 392 m^2. The annual energy consumption of the buildings is 7 350 MWh in heat and 6 640 MWh in electricity. The campus

Fig. 1 *Data cycle from raw data to knowledge and business opportunities*

has in total of 508.5 kWp solar PV installed. The majority of the buildings are owned by the University Properties of Finland Ltd. The energy manager's responsibilities and burden of maintaining energy-efficient operations still lie on the building user. This creates additional motivation for the LUT University to look for more efficient ways of controlling building automation and improving energy efficiency.

The issue with the existing system is that building automation data and other supporting data streams are distributed in different IT systems. Systems are often seen as separate systems and thus also lacking sufficient integration interfaces that would enable coordinated operation. For instance, weather forecasts are not typically integrated with building automation control. By integration of weather forecast to the building automation control, there could be noteworthy benefits available with more advanced control [4].

The other prospect in building automation control may arise from the benefits of integration into energy markets. By offering some flexibility to energy markets there is an opportunity to decrease campus buildings' operational cost by earnings gained from the electricity markets. It is shown by Aduda et al. [7] that there are several resources in the building that could provide flexibility resources cost-efficiently to the energy markets. In order to get all flexibility resources utilised, it would require more knowledge and better analysis of the resources. In the present system, analysing the data is not the most fluent process, as the system holding data resources lacks integration of analysis tools. In practice, the data needs manual export from the building automation system at regular intervals and manual pre-processing for analysis purposes.

3 Use cases

This chapter describes four use cases that are defined from the basis of the development needs of the City of Lappeenranta building management. The development needs are defined hand in hand with the LUT University building's development needs and use cases will be demonstrated in the campus buildings in the first demonstration stage. The use cases aim to find an answer to the increasing demand for data-driven data analysis that is often seen as a way to decrease building operational costs and to integrate more flexibility resources into energy markets. The first two use cases mainly serve as the supporting or enabling use cases for the latter two use cases, but still, the role of the two first use cases is crucial in the process.

The use case 'Data platform enabling easy access to data' sets the requirements for the automation system and data platform integration. The second use case 'Integration of real-time data analysis to data platform' focuses on defining the Application Programming Interface (API) that interacts with the data analysis tools. The third use case 'Data platform enabling energy market integration' defines requirements to operate as part of energy markets. The fourth use case 'Data platform providing real-time carbon emission balance' utilises data available from the data platform to demonstrate the versatility of the data platform. The use descriptions follow loosely Cockburn's [8] use case description style. As the main idea here is to deliver a clear look into use cases rather than dive into a highly detailed level, use cases are described at a rather general level.

3.1 Data platform enabling easy access to data

The main goal of the use case is enabling data access to a user to easily fetch, browse and explore building automation data. In addition, the platform should enable incorporating other data sources in data exploration. The platform should provide a basis for the visual analysis of the data streams available to study.

- *Primary actor* of the use case is the user who uses or explores data, such as building maintenance responsible person, researcher or data analyst.
- *Goal of the primary* actor is to easily access data streams and to conduct fast visual analysis on the data available. In addition, the data should be easily exportable from the user interface.
- *Participants* of the use case are building management organisations who hold access to building data automation resources, other data stream sources such as weather observation and forecast institutes or organisations.
- *Preconditions* of the use case are that all the participants have sufficient data management contracts settled and IT systems are interoperable.

3.2 Integration of real-time data analysis to data platform

The main goal of the use case is to enable analysis tool integration to data platform and integration of available data streams that may be streaming from building automation systems or external sources such as energy markets. The deployment of analysis tools should not require highly skilled IT engineers to execute the deployment process, but instead, data analysts or building maintenance personnel should be able to handle prebuild analysis tool deployment.

- *Primary actor* of the use case is the user who wishes to conduct an analysis of the available data. A person may be building maintenance responsible person, researcher or data analyst.
- *Goal of the primary* actor is to easily conduct complex analysis on the data available. In addition, the user interface should provide prebuild analysis tools that can be executed at the request of the user.
- *Participants* of the use case are building management organisations who hold access to building data automation resources, other data stream sources such as weather observation and forecast institutes or organisations.
- *Preconditions* of the use case are that all the participants have sufficient data management contracts settled and IT systems are interoperable. In addition, the backend system needs sufficient hardware resources to meet the requirements of the analysis tools used.

3.3 Data platform enabling energy market integration

The main goal of the use case is to offer buildings' flexibility resources to energy markets. The use case relies strongly on the previously described use cases and knowledge gained by the analysis tools. The data platform supported by the analysis tools should be able to distinguish flexibility volumes of the available resources in order to provide bid or availability information to markets.

- *Primary actor* of the use case is the building energy manager.
- *Goal of the primary* actor is to minimise the operational cost of the building. The primary actor gathers flexibility volumes and provides resource availability information to the aggregator.
- *Participants* of the use case are energy market actors such as aggregator who receives flexibility information from building management and further bids resources to energy markets. In addition, there may be service providers providing supporting data streams to be incorporated with the available flexibility volume definition process.
- *Preconditions* of the use case are that all the participants have sufficient data management contracts settled and IT systems are interoperable. Also, it is required that building management has a contract with aggregator and IT systems and data structures are interoperable.

3.4 Data platform providing real-time carbon emission balance

The main goal of the use case is to make building users more aware of the building carbon emission balance. The data platform can provide a detailed estimation of the real-time carbon emission balance divided into various energy consumption sectors.

- *Primary actor* of the use case is an individual who visually inspects data and premade analysis results on the kiosk screens in public spaces.
- *Goal of the primary* actor is to easily interpret results shown on the kiosk screens in public spaces.
- *Participants* of the use case are building management organisation who holds access to building data automation resources, other data stream sources such as weather observation and forecast institutes or organisations.
- *Preconditions* of the use case are that all the participants have sufficient data management contracts settled and IT systems are interoperable.

4 Insights of technical properties

To fulfil the requirements, imposed by the use cases the system should be able to provide the following services: ingest of data, long-term data storage, rapid bulk data export during initial data exploration and finally easy and reliable interface, that can be used to deploy microservices, that enable individual parts of functionality or use cases. Fig. 2 shows data streams in the system.

Data platform consists of four main components: Data storage, frontend server, docker swarm microservice platform and automated machine learning platform.

4.1 Data storage component

The data storage component consists of three InfluxDB [9] time-series database instances and additional scripts, that enable data replication and cluster resilience. Each instance runs on an independent server and includes NGINX web server service and Python data replication scripts that allow load balancing and data synchronisation between instances.

4.2 Frontend server

The frontend server runs an instance of Grafana [10] web user interface, that can be used to access data that are available in InfluxDB in a convenient and fast manner. The interface enables rapid generation of queries, while InfluxDB provides tools for data interpolation, imputing and resampling. Finally, some basic computations can be performed on displayed data to improve exploration quality.

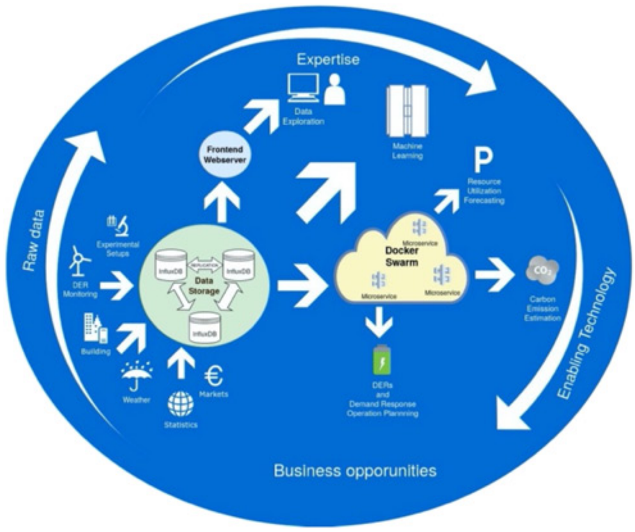

Fig. 2 *Data development to knowledge via series of analysis processes and steps*

4.3 Automated machine learning platform

The machine learning platform will include an interface to configure automatic data pre-processing, selection of training and test sets and hyperparameters of models, trained to predict the data. The aim of this platform is to allow automatic generation of up-to-date models as raw data accumulates and enable automatic update of live models, used by microservices.

4.4 Docker swarm microservice platform

Parallel to InfluxDB instances same servers also run Docker Swarm [11] scalable containerised cloud service for microservices. Each microservice is intended to either provide data integration with existing data sources or is used to provide service and business integration. An example of such integration is demand response capacity planning. Such planning might include a list of available demand response actions (I.e. by reduction of heating or ventilation in unused spaces), that can be utilised by supervising market aggregators and sold in flexibility markets. Another option is forecasting the number of electric vehicles (EVs), that are parked on university premises and using these vehicles as a platform for peak shaving by controlling them via smart charging protocols.

5 Conclusion

As the main result, the paper described four data-driven building automation use cases for the campus building in the Nordic climate environment. The general use cases defined in the paper will be further utilised to develop implementation use cases in detail. The general use case approach used in the paper gives broader look into the topic but already supports in defining the system requirements. The general use cases give insight what are the essential interfaces between the various IT systems involved in the process. Presented use cases will enable the integration of the building flexibility potential into electricity markets and promote the carbon neutrality of the buildings. Further development of the implementation use case is the question in the further studies.

6 Acknowledgments

This study was carried out within the European Union Regional development fund project Integrated Building Automation Data Platform project, funded by European Union Regional developed funds managed nationally by the Helsinki-Uusimaa Regional Council, funding decision EURA 2014/8264/09.

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