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VICINITY Platform-based Load Scheduling Method by Considering Smart Parking and Smart Appliance

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***Abstract*—A VICINITY platform-based load scheduling method by considering the smart parking and household smart appliances for renewable energy resources integrated residential microgrids is proposed in this paper. The proposed method can shift the local loads and publish the vacant number of parking slot with a real-time electric vehicle charging price to VICINITY platform according to the renewable energy generation and the usage of the parking spaces to reduce energy cost and increase resident's revenue. The experimental platform-based real-life cross domain lab testing verifies the effectiveness of the proposed control approach.**

Keywords-load scheduling, smart parking, smart appliance, residential microgrid, VICINITY.

I. Introduction

An increasing demand on parking spaces in Europe cities indicates more search traffic, which leads to higher emission of CO2, more congested traffic and severer air pollution. Industrial and academic researchers have been investigating in smart parking solutions in order to make it easier to find an available parking space [1]-[9]. Additionally, parking is one of the basic foundations of a smart city. By taking advantage of the parking data, cities will soon have the ability to achieve better parking management and to capture new types of data and multiple analyze results.

Meanwhile, as the rapid development in sensing, measuring, networking, controlling, renewable energy generation, ambient intelligent technologies, and business process optimization, smart residential microgrids (RGMs) get a lot of attention. Unlike traditional microgrids (MGs), the existence of smart sensors, smart devices and appliances, and the involved residents induces a lot of new opportunities and considerations in many aspects, such as smart appliances related-energy scheduling optimization, residents behavior-enabled energy cost reduction, smart sensors-based energy efficiency improvement, and living quality enhancement [10]-[16]. Moreover, a smart RGM works as an important entity to form a smart city by modernizing power delivery and usage patterns, improving the reliability of integration of distributed and renewable energy resources, and achieving Internet-of-Things (IoT) enabled capabilities.

The various technologies and domains for pursuing the future cities and the power grid, for instance, smart parking, upgraded water circulation system, renewable energy utilization, demand side response, ehealth and assistive living, require the interoperability to achieve the global integration of IoT ecosystems across borders of different domains, vendors and standards.

The VICINITY EU-funded project under Grant Agreement (GA) No. 688467 can connect various IoT landscapes, and allow integration of end-users and creation of new business models [17]. VICINITY paves the way for a large-scale demonstration of the applicability of the solution in different use cases that implement and demonstrate different value-added services (VAS) facilitated by VICINITY platform [18], [19].

In the development of traffic management systems, intelligent parking systems get a lot of attention in terms of sharing private and public parking space, reducing the cost of hiring people and for optimal use of resources for car-park owners. One of the actions in need of better exploiting available resources in order to reduce traffic congestion and pollution in order to improve living conditions and introduce regulations. The private and public owners of a parking facility are involved by offering their parking facility when not in use. For instance, in a residential neighborhood, the residences can share their idle parking slot and charging facilities to be involved in the parking management solutions and to increase their revenue generation.

In this paper, an effective solution is used to integrate the parking management system with RGM energy management system in order to have the overall supervision and regulation. The overall management system runs based on VICINITY platform which includes VICINITY cloud, VICINITY nodes, and VICINITY peer to peer (P2P) network. A load scheduling method by considering the smart parking and household smart appliances for renewable energy resources integrated RGMs is proposed in this paper. The proposed method can shift the local loads and publish the vacant number of parking slot with the real-time electric vehicle (EV) charging price to VICINITY platform according to the renewable energy generation and the usage of the parking spaces to reduce energy cost and increase resident's revenue. The experimental platform-based real-life

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cross domain lab testing verifies the effectiveness of the proposed control approach.

The paper is organized as follows. Section II reviews the VICINITY platform. Section III introduces a RGM IoT architecture. Section IV presents the proposed VICINITY platform-based load scheduling method with smart parking and smart appliance scenario. Real life experimental results are shown in Section V in order to evaluate the feasibility of the proposed approach. Section VI concludes the paper.

II. VICINITY Platform and Concept

VICINITY establishes and demonstrates a device and standard agnostic platform for IoT infrastructures that offers "Interoperability as a Service". It relies on a decentralised and user-centric approach that offers complete transparency across vertical domains while retaining full control of the ownership and distribution of data. It demonstrates a bottom-up ecosystem of decentralised interoperability of IoT infrastructures called virtual neighbourhood, where users can share access to their smart objects without losing control over them. The ubiquitous interoperability that is intended to be brought by VICINITY will release the vendor locks that are present in the current IoT ecosystems and open the door towards independent VASs across IoT domains taking benefits of the availability of big amounts of data in semantic formats that are generated by IoT assets.

VICINITY project aims to provide the owners of connected IoT infrastructures with a decentralized interoperability. The concept of decentralism is expressed by the fact that the platform includes neither central operator roles, nor central databases to store sensitive data about users. Instead of that, it connects different smart objects into a “social network” where infrastructure owners keep under control their shared devices and data thanks to web-based operator console called VICINITY neighbourhood manager (VNM). Guest IoT infrastructures, VICINITY enabled services, as well as the VICINITY auto-discovery space, are connected to a VICINITY interoperability gateway using the same VICINITY gateway API.

Using the VNM, the user can control which of his/her IoT asset is shared with whom and to which extent. To get connected to the VICINITY platform, the users are provided with the VICINITY open interoperability gateway. More specifically, the integration to VICINITY can happen on:

- Network/infrastructure level – to connect proprietary IoT infrastructures. In that case, the users (or their system integrators) just need to take the open VICINITY gateway API with sample implementations and can easily develop an adapter to the platform. Once an IoT infrastructure is integrated to VICINITY, its owner can simply manage the access to his/her IoT data and controls using the VNM.
- IoT device level – to connect standard IoT infrastructures. The users just need to take the open VICINITY auto discovery device and to register it with the help of VNM. The device will automatically discover the smart objects and they will appear in the user’s device catalogue on the VNM. Then the user can manage the access rules to his/her discovered smart objects using the VNM.

Once an IoT infrastructure is connected to VICINITY platform, the traditional IoT value chains become unlocked. It opens the doors toward seamless interoperability between IoT islands present in the current IoT landscape and enables the exploitation of independent VASs including various cross-domain IoT applications.

The power of cross-domain interoperability brought by VICINITY shows on a large-scale demonstration involving 8 sites in 7 countries. VICINITY connects smart transport and smart building infrastructures in Norway, a renewable site in Portugal and health-house in Greece. These real sites operation scenarios are pre-tested in laboratory environments of IoT-MG Laboratory in Denmark, M2M laboratories in Germany, intelligent building laboratories in Greece and last but not least IoE laboratories of ATOS in Spain.

The demonstrated use-cases highlight the benefits of the virtual neighbourhood of intelligent buildings cooperating with smart renewable energy sites connected to intelligent transport infrastructures. Moreover, application scenarios in the health domains are deployed where the term “virtual neighbourhood” is referred to supporting communication of personal health status data to selected participants of the network such as family members.

III. A RGM IoT Architecture

A. *Gorenje Smart Appliances*

Two Gorenje smart domestic appliances which include 1 WiFi-enabled ovens and 1 WiFi-enabled refrigerators are installed in AAU testing laboratory. 17 more Gorenje smart appliances are equipped in VICINITY pilot sites and other testing labs. Two VICINITY adapters for Gorenje oven and refrigerator have been implemented which can achieve 1. read the properties of oven and refrigerator (door status, temperature etc.); 2. control oven and refrigerator (setting temperature, start baking etc.); 3. send events from the oven and refrigerator (door status, device status etc.).

B. *PlacePod Parking Sensor*

PlacePod is an IoT-enabled smart parking sensor for on-street and off-street public and private parking management. It solves the most mission-critical aspects of parking management: accurate, real-time vehicle detection and the location of available parking spaces. The sensors communicate with a gateway to provide real-time parking data over a Low Power Wide Area Network (LPWAN). Three PlacePod smart parking sensors and a MultiTech MultiConnect conduit programmable gateway are placed in front of Aalborg University (AAU) IoT-MG Laboratory. The same parking sensor and gateway are also deployed in Tromsø Pilot site in Norway. A VICINITY adapter has been developed for the PlacePod parking sensors to send events from the parking sensors to subscribers via VICINITY P2P network (vacant/occupation status, temperature, etc.).

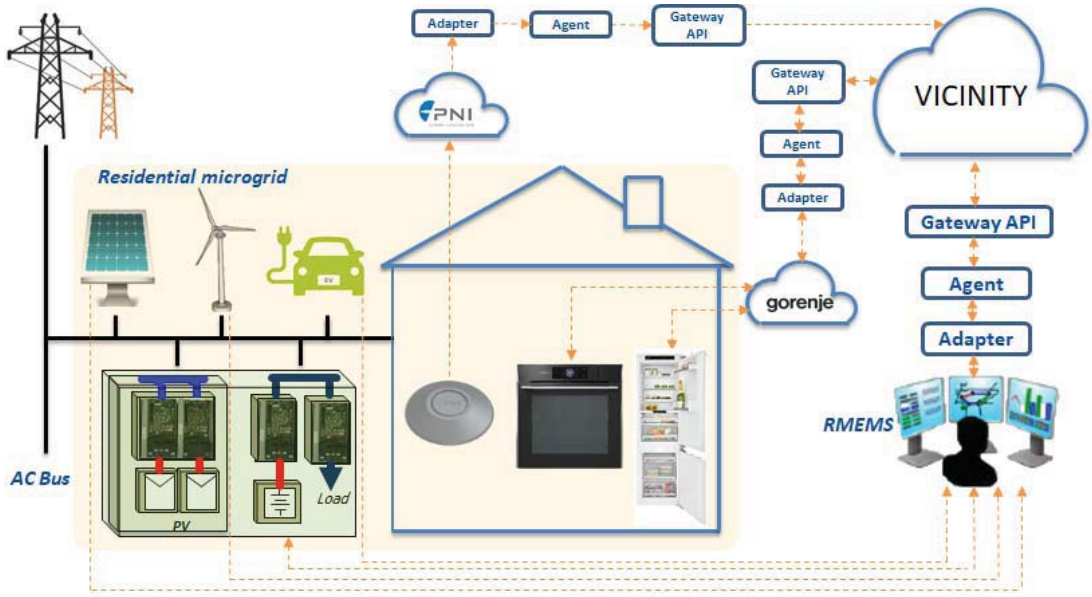


Figure 1. RGM IoT Architecture

C. RGM IoT Architecture

The AAU MG-IoT laboratory is used as a testing lab and a demonstration of an intelligent RGM with smart sensors/devices/appliances for cross-domain applications.

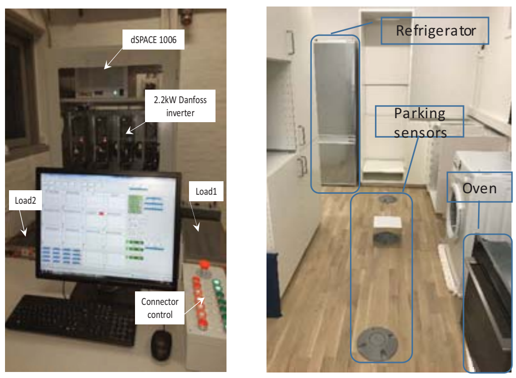
The RGM Energy Management System (RMEMS) in addition with the smart sensors, devices, and appliances allow the users to have full access to the system´s information and provide the users the option to remotely control the system. Smart sensors, devices, and appliances operate in an integrated way and provide the real-time data to the RMEMS to achieve demand side management, energy cost reduction, energy efficiency improvement, optimal energy usage, and so on.

A RGM IoT architecture has been built in order to achieve the VICINITY Platform-based optimal usage of parking slots by considering energy costs and implementing load scheduling method, as shown in Fig. 1. The parking slot usage data is collected through VICINITY by using three parking sensors to achieve monitoring function. A hybrid MG, which consists of PV, a wind turbine and batteries, is emulated based on a real-time dSPACE experimental platform. The RGM is assumed to supply power to EV chargers in the three parking slots. Gorenje smart refrigerator and oven are included in the RGM. The real-time charging price is calculated by considering the simulated real-time utility electricity price, state-of-charge (SoC) of batteries, and forecasts of the PV and wind turbine power generation. The parking slot usage and the real-time charging price will be sent automatically to users after subscribing Optimal Usage of Parking Slots by Considering Energy Costs VAS. LabVIEW- based user interfaces are developed for monitoring and notification.

The VAS adapters, PlacePod parking sensor adapter, Gorenje appliance, VICINITY Agent, Gateway API and all interaction patterns in VICINITY are tested during the VAS implementation process. Active and Passive Discovery of the Agent is used for the parking sensor adapter and the VAS respectively. The VAS can read the properties of the parking sensor through VICINITY by sending GET request. The VAS subscribes to the event published by the parking sensors and publishes an event to end-users thus testing the publish/subscribe performance of VICINITY.

IV. EXPERIMENTAL PLATFORM-BASED REAL-LIFE VALIDATION

As mentioned, in order to verify the proposed VICINITY platform-based load scheduling method, a real-life cross domain experiment platform consisted of a hybrid MG workstation, a kitchen area with a Gorenje smart oven, a Gorenje smart refrigerator, and three PlacePod parking sensors were built, as shown in Fig. 2.



(a) MG workstation (b) Kitchen area in IoT-MG Lab

Figure 2. Cross-domain RGM experiment platform

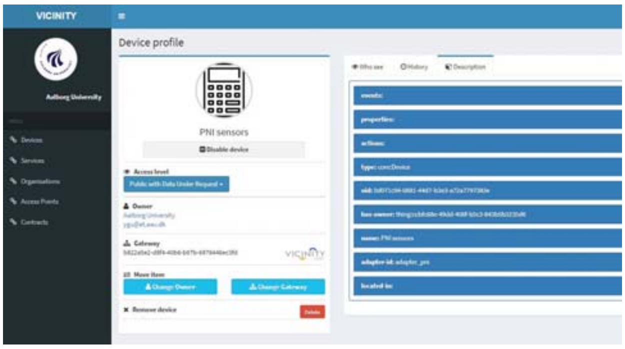


Figure 3. Parking sensors are registered as “Devices” in the VNM

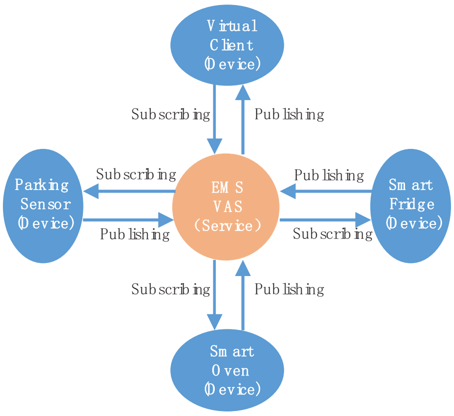


Figure 4. Relationships between VICINITY nodes.

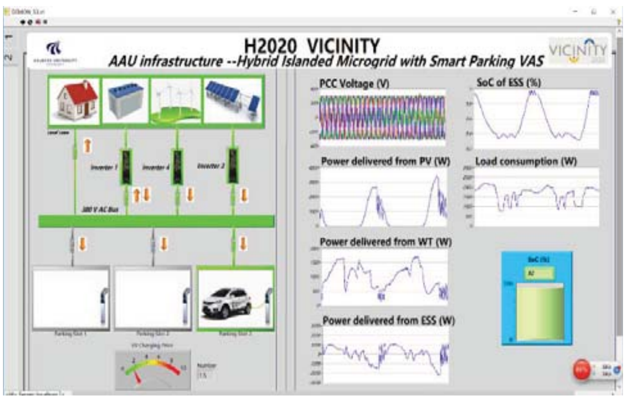


Figure 5. LabVIEW-based EMS user-interface

The MG workstation includes three 2.2 kW three-phase inverters that have been used to emulate a PV/wind turbine/energy storage system (ESS) hybrid RGM, *LCL* filters, resistance-inductive line impedance, local resistive loads. A real-time Hardware-in-the-Loop experimental platform dSPACE1006 is used as the center controller.

A. Information exchange

All information exchanges between different components in the experimental platform are established based on the

Figure 6. Simplified user interface

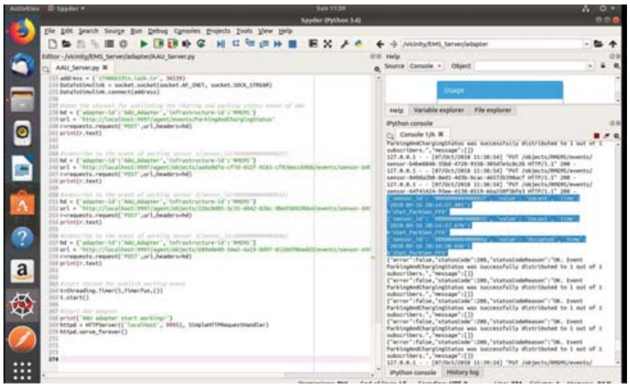


Figure 7. Event receiving of EMS VAS

VICINITY platform. Firstly, the VICINITY gateway and agent start up without failing. Then, the Optimal Usage of Parking Slots by Considering Energy Costs VAS of RMG energy management system (EMS) is registered in the “Services” catalog in the VICINITY platform by sending its Thing Description through the Restful POST request to VNM, while the three smart parking sensors and Gorenje smart appliances are registered in the VNM in the “Devices” catalog, as shown in Fig. 3.

The friendships between EMS VAS node with the parking sensors, Gorenje smart appliances, and the virtual client node are established in the VNM for enabling the communication and for granting access to the data for the EMS VAS. The EMS VAS adapter subscribes to the event of the parking sensor, the smart oven, and smart refrigerator, meanwhile, the virtual client subscribes to the event of EMS VAS, as shown in Fig. 4. In this way, the usage status of the three parking sensors is sent to the EMS VAS node automatically by RESTful PUT request, as shown in Fig. 7. By using the same method, the EMS VAS node can receive the oven and refrigerator working status as well.

Moreover, a LabVIEW-based EMS user-interface is developed to monitor the MG operation, as shown in Fig. 5. It is can be seen that the residential microgrid manager can monitor not only the hybrid microgrid operation and renewable energy resources generations, but also the working status of the smart appliances, the usage of the parking slots, and the real-time EV charging price.

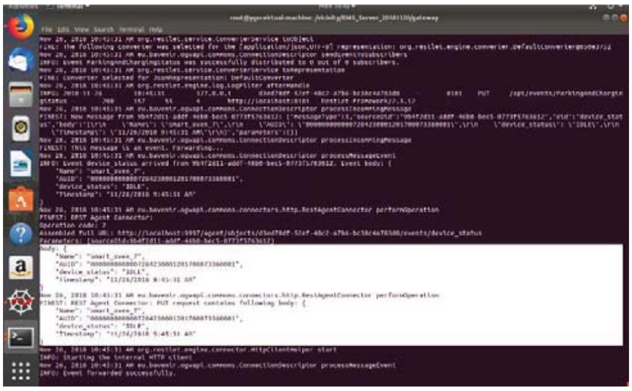


Figure 8. Load scheduling is shown in VICINITY gateway

An event which contains the number of vacant parking space, time-stamp and predicted EV charging price is published to the subscribers via VICINITY Cloud. Apart from the overall EMS user interface, a simplified user interface is also developed based on LabVIEW web publishing tool, as shown in Fig. 6. The subscribers which are emulated by a virtual client node registered in VNM, for instance, the drivers and EV owners, can visit the user interface webpage to choose the preferred parking time based on the vacant parking slot number and real-time charging price.

Besides receiving data from other nodes through VICINITY platform, the MG EMS is also in charge of calculating real-time charging price according to the operation status of the hybrid MG and the usage of parking slots. At the same time, MG EMS VAS adapter will change the working status of the smart refrigerator and oven according to the SoC of ESS and renewable energy outputs to achieve load scheduling, therefore maximising the use of resources and reducing the energy bill of the residents, as shown in Fig. 8.

B. *Operation status of the RMG*

A 48-hour scenario including the profiles of PV and wind turbine active power generations, the residential active power loads, three typical EV users with different charging plans are used to verify the effeteness of the proposed strategy, as shown in Fig. 9.

It can be seen from Fig. 9, that EV1 user emulates the residents living in the community, and the parking and charging periods are mostly in the nighttime. EV2 user is defined as a user who works nearby the community, and his parking and charging periods are mostly in the daytime. The EV3 user is a random user who is charging price sensitive and will only charge EV with low price temporarily.

The active power outputs of PV, wind turbine and ESS are shown in Fig. 10. The SoC and EV charging price are shown in Fig. 11. As observed, at the beginning of the waveforms, the ESS in the RMG is fully charged. The EV charging price is below 4.5 DKK/kWh when SoC is greater than 0.6 from the start point to 21 hours. However, during the night, only the wind turbine and the ESS supply electricity to the RMG for the peak hours. The SoC of ESS

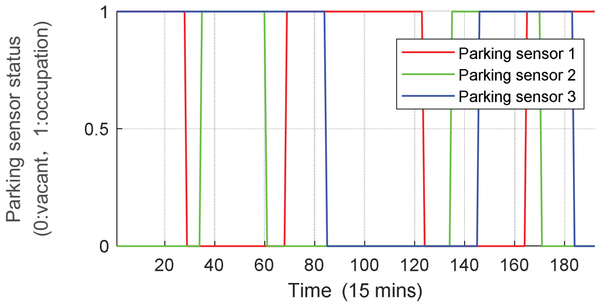


Figure 9. Charging plans of three parking users

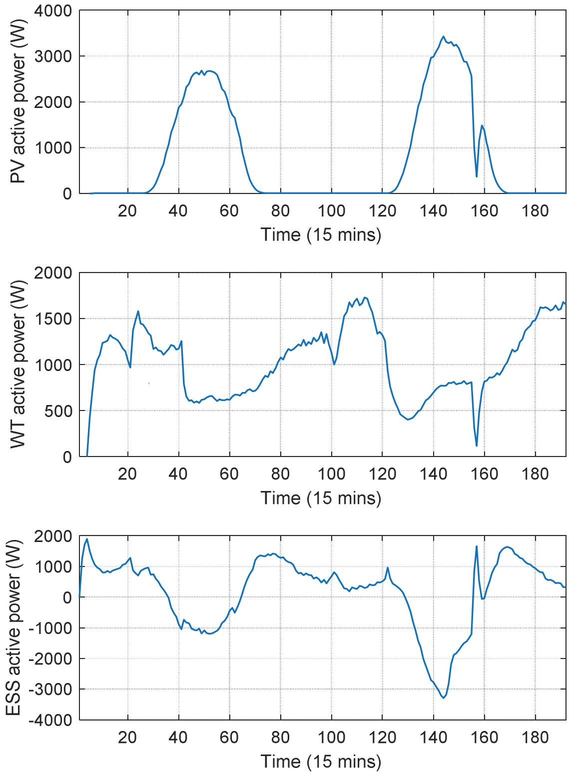


Figure 10. Active power outputs of PV/WT/ESS

continuously drops to around 0.5 from 21 hours to 28 hours 45 mins. Accordingly, the EV charging price is increased by EMS dynamically to suppress the charging requirement and maintain the power sustainable, as shown in Fig. 11.

Since EV1 user needs to charge his EV regardless of the price fluctuation in the testing scenario, SoC decreases below than 0.4. Furthermore, the EMS VAS starts to disconnect the EV charging load due to the battery discharge protection after 28 hours 45 mins, and to schedule household loads, including changing the refrigerator's working mode from fast freeze to normal mode and delaying baking at 30 hours 30 mins when SoC drops to 0.35. Later, along with the ESS charging, the household loads and EV charging load are reconnected when SoC increasing to 0.5 and 0.8 at 34 hours 30 mins and 36 hours 30 mins respectively, as shown in Figs. 12 and 13.

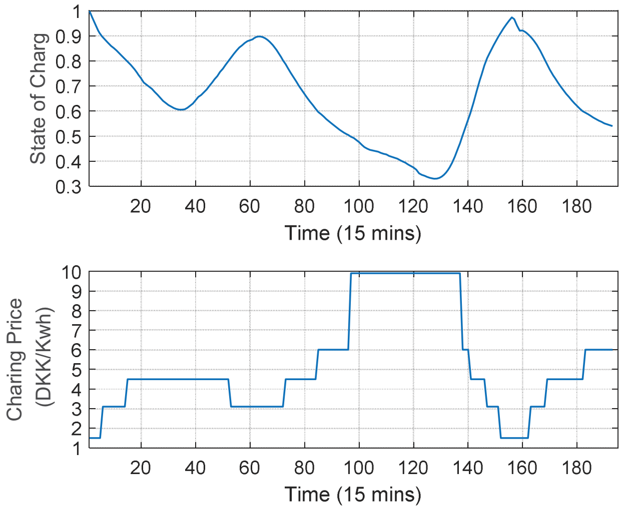


Figure 11. SoC and charging price

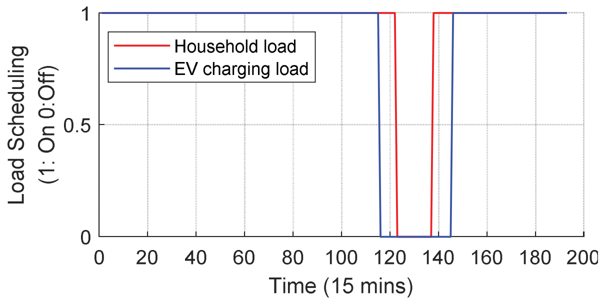


Figure 12. EMS load scheduling

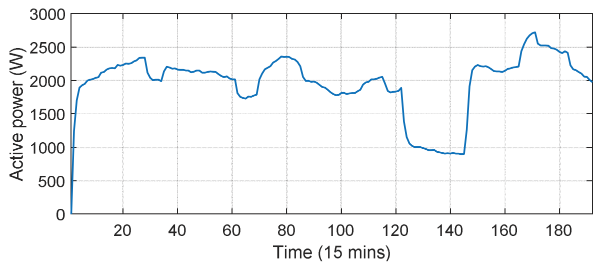


Figure 13. Active load in MG

V. Conclusion

The paper proposes a smart sensor and smart appliance involved load scheduling method based on VICINITY platform. The proposed method can deal with cross-domain load shifting issues thanks to the interoperability provided by VICINITY. It is able to predict EV parking charging price, to change the smart appliance working status to maximise the use of resources and to reduce energy cost. The experimental platform-based real-life cross domain lab testing verifies the effectiveness of the proposed control approach.

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