StoreNet

Deliverable

StoreNet VPP Control

Consortium

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Executive Summary

This study analyses five different energy management system (EMS) approaches for the VPP aggregator and are equally important for the local energy market operator (LEMO) in future. The proposed solutions are based on the real-life demonstration project, StoreNet. The study assesses the techno and economic performances for each approach using real-life measured data and compares the proposed solutions with the StoreNet basic self-consumption (SB-SC) EMS approach that is already implemented by the aggregator in this project. For the benefits of customers, analysing one-year measured data, it is observed that the implemented SB-SC approach allows 16% - 19% electricity cost saving whereas the proposed VPP-bill minimisation (VPP-BM) approach can benefit from 37% - 42% cost saving. This is also 7% - 8% higher than the case of the single house bill minimisation (SH-BM) approach where the community does not participate in the VPP model. On the other hand, the peak shaving (PS) approach is more favourable for the network operator. It can reduce the load peak by 46.5% to 64.7% but drastically also reduces the benefits for the customers.

The comparison between different control algorithms and the deployed SB-SC has shown that an economic-based objective function-driven algorithm design (VPP-BM, PSDT, SH-BM, or the applied SC) could increase the consumption peak dramatically. Indeed, despite reducing the consumption during the daytime, this type of algorithm may shift the peak to the nighttime and also can be higher than the original peak demand. While taking into account the fast popularisation of residential PV and storage, this phenomenon can also lead, in the future, to some power quality or grid stability issues in the distribution network. In counterpart, it was also pointed out that network-oriented algorithm design (LL and PS) has a negative impact on the economic benefits and can increase electricity bills. This will discourage customers from engaging in such a concept and prevent the grid operator from benefiting from an important source of flexibility and green energy.

To alleviate the gap between the technical and economic benefits of the above-mentioned algorithms, one solution could be to develop a novel consumption tariff scheme to enhance the synergy between local energy market development and grid support. Indeed, to engage prosumers more in the future local electricity market, an attractive consumption tariff is to be applied to justify the initial prosumer investment. However, the scheme should also include a kind of network requirement compliance awards or penalties. This will hedge the grid from some kind of cobra phenomenon relating to the fast development and quick transition of the local and wholesale energy market.

1. Introduction

The evolution of the generation mix from one dominated by large, central, predictable, and inherently flexible power stations to small, distributed, and intermittent renewable generation presents significant challenges to the power system. This evolution is further complicated by developments on the demand side, where new demand, such as electrification of heat and transport, together with changing demand profiles, is altering the landscape. As a result, demand peaks and troughs are becoming more extreme, and power quality, protection, and voltage regulation are more challenging. System operators require increasingly flexible solutions to balance supply and demand and to operate the network within acceptable standards.

The roll-out of smart meters, demand response, and dynamic pricing is driving advancement in the energy system decarbonisation and market participation. The challenges faced by the utility providers include facing the demands of power production, both in monitoring and forecasting. The integration of VPP can help alleviate any potential grid volatility by providing a granular response to demand. A VPP may be able to help with the intermittency of renewables, reduce consumption at times of peak demand and provide a reserve of power.

Few VPP projects were developed all over the world to assess the techno-economic viability of this novel concept in the real case. Indeed, in the US, ConEdison VPP is managing battery and PV installed in residential houses. The Australian SA VPP project presents good learning in the VPP paradigm[1]. This ongoing effort enabled building a better understanding of the VPP and the concept they are created for and encouraged investors, financial and funding institutions to take part in the VPP future. However, there is still a lot of learnings are required to bring this technology as a mature product to the market. Many questions are still required to answer and the StoreNet is trying to answer a few of these, such as; What kind of innovative business models can be adapted for residential VPP? How a residential VPP business model can combine different revenue streams? What are the impact of the aggregator control approach and grid tariff (as TOU) on VPP operation and social welfare optimisation? What is the impact of the popularisation of residential VPP on the future operation of the electric network?

2. Controls in VPP

VPP represents an internet of energy tapping existing grid networks to tailor electricity supply and demand services for customers maximising value for both end-user and distribution utility through software innovations (attempts to create a mini-independent system operator). To develop and manage the VPP, a new player/role in the electricity industry called an aggregator is needed. This aggregator is an actor whose main role is to be the mediator between the consumers who want to trade their self-generation/demand flexibilities (modifications in consumption) and the markets where the aggregator offer (sell) these flexibilities for use by other electricity system players. In principle, a VPP is similar to a conventional power plant; it has its own operation characteristics, such as generation limits, operating cost, and bidding volumes to the markets. The VPP consisting of different distributed generators, storage and load management can be used in order to reduce generation costs as well.

[1] Wang, Z. Liu, H. Zhang, Y. Zhao, J. Shi, and H. Ding, "A Review on Virtual Power Plant Concept, Application and Challenges", in 2019 IEEE Innovative Smart Grid Technologies - Asia (ISGT Asia) (2019), pp. 4328-4333.

The concept of VPP was developed to enhance the visibility and control of DER to system operators and other market actors by providing an appropriate interface between these system components.

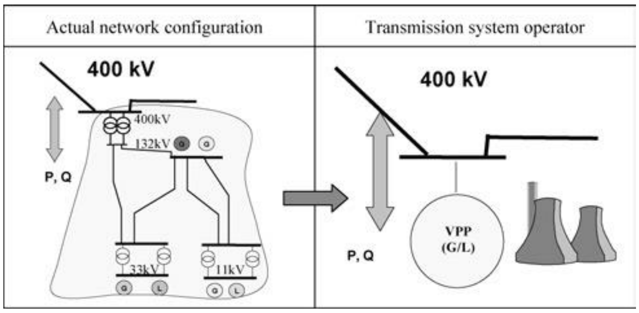


Figure 2.1

The integration of energy storage potentially enhances the VPP market uptake and grid integration scalability and sustainability. Indeed, ESS can reduce the investment needed in upgrading the network to be able to cope with the significant peaks and troughs in the flow of electricity[2],[3].

These activities of market participation and system management and support for VPP are considered respectively as commercial and technical activities, and thus the concepts appear as commercial VPP (CVPP) and technical VPP (TVPP)[4].

In CVPP, the impact of the distribution network is not considered. The functionality of CVPP mainly includes (i) trading in the wholesale energy market, (ii) balancing of trading portfolios and provision of services that are not location-specific to the system operator. On the other hand, TVPP consists of distributed energy resources/storage from the same geographic location, i.e., they are bound by the same local network constraints. Thus TVPP functionality mainly includes (i) local system management for DSOs, (ii) providing system balancing and ancillary services to TSO. There can however be a commercial value associated with the provision of such grid services. Figure 2.2 shows the CVPP and TVPP activity in the energy market and system management context.

The main goal of VPP is to contribute in the markets and act like a conventional but intelligent generator. Therefore, the VPP coordinator/operator is responsible for supervision, balancing control, ancillary services and market interface.

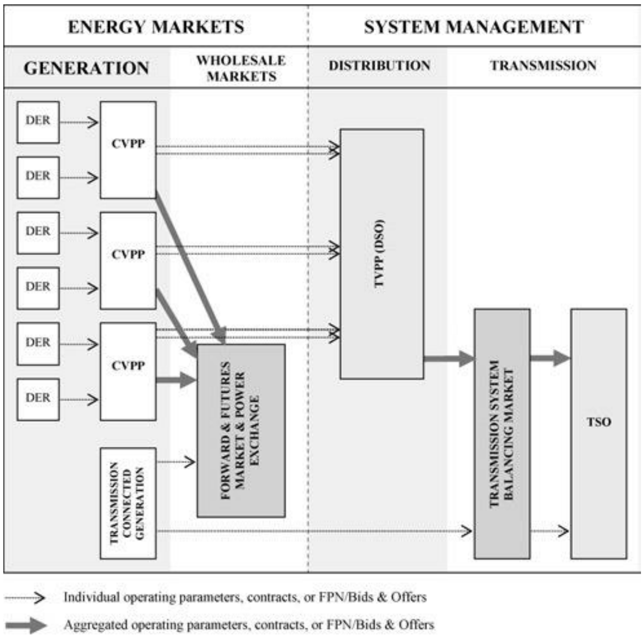


Figure 2.2

3. Improvement of StoreNet VPP Control

The energy management system (EMS) presents the core of the VPP concept. Its main functionality consists of ensuring an optimal dispatch of the

[2] 1Behnaz Behi, Ali Baniasadi, Ali Arefi, Arian Gorjy, Philip Jennings, and Almantas Pivrikas, "Cost Benefit Analysis of a Virtual Power Plant Including Solar PV, Flow Battery, Heat Pump, and Demand Management: A Western Australian Case Study", Energies 13, 10 (2020).

[3] 2C. A. Correa-Florez, A. Michiorri, and G. Kariniotakis, "Optimal Participation of Residential Aggregators in Energy and Local Flexibility Markets", IEEE Transactions on Smart Grid 11, 2 (2020), pp. 1644-1656

[4] Xu, W. Wu, Z. Wang, and T. Zhu, "Coordinated optimal dispatch of VPPs in unbalanced ADNs", *IET Generation, Transmission Distribution* 14, 8 (2020), pp. 1430-1437

VPP resources while scheduling the electricity production and consumption of different VPP resources. Indeed, it plays a key role in collecting, storing, and analysing the different forms of data from VPP resources and coordinate the control of remote monitoring devices. Usually, a certain number of sub-functionalities are implemented to ensure robust and coordinated operation of the control system such as forecasting of the DER generation and loads, SoC (state-of-charge) management of storage unit etc. The EMS dispatch concept is to accomplish certain technical and/or commercial objectives for the VPP operation such as reducing greenhouse emission, maximizing profit, minimizing network losses, reducing energy cost, etc. To this end, different approaches have been developed in the literature[5]. These approaches can be split into analytic or heuristic methods. The literature review shows that most adapted algorithms in the deterministic category are mixed-integer linear programming, dynamic programming, nonlinear programming, and to count model, measurement, or forecast uncertainties, researchers refer usually to stochastic or robust optimisation method. Heuristic methods are showing an increasing potential for VPP design and especially using the genetic algorithm and PSO method.

3.1 Existing StoreNet VPP Control

The StoreNet VPP demonstration is located in the Dingle peninsula in the southwest of Ireland and controlled by the aggregator in Cork. 20 homes currently host a 10kWhr/3.3kW peak Sonnen lithium-ion battery. Nine of those homes also have installed rooftop 2.4kW Solar Photovoltaic (PV) panels and all of the homes are on meters with day/night-time tariffs. Sonnen Energy (with the support of Sonnen) provides the control system platform with the delivered battery that gives a 17% savings to the households with the differential tariffs, showing an early advantage to homes that install local generation and storage.

3.2 VPP Control Improvement

This study proposes different control approaches for aggregator operating StoreNet VPP demo side and investigates the interaction aspect with the adopted day-night tariff in Ireland and the impact on the consumption pattern. This will give the aggregator and network operator a better idea on what type of improvements in the VPP management and operation are required. Moreover, it will provide a framework for both DSO, supplier, and market operator to develop an appropriate remuneration scheme that will shape the future of the local energy market and its contribution to distribution network stability and pathing the way to easing renewable energy integration and grid decarbonisation.

Indeed. To deal with the future local energy market concept, a VPP bill minimization control strategy is proposed. The main aim here is to optimize the demand and resources management in order to maximize the economic benefits. A zero feed in tariff is considered here to accomplish with the Irish policy. The algorithm here considers the VPP as a single entity having the privilege to exchange energy between different houses but not benefiting from any Feed-in tariff scheme. The impact of the aggregation concept is investigated through the design of a single house bill minimisation (SH-BM) control algorithm. This algorithm offers similar functionality to VPP bill minimization (VPP-BM); however, it focuses on individual houses benefits rather than considering it as a part of the community (collective).

From a network point of view, peak shaving (PS) and load leveling (LL) algorithms have been designed. The main aim is to study the impact of providing such services to the grid operator on the revenue stream. A peak shaving during day time (PSDT) algorithm is also assessed. This

[5] 5Natalia Naval, Raul SÃ¡nchez, and Jose M. Yusta, "A virtual power plant optimal dispatch model with large and small-scale distributed renewable generation", Renewable Energy 151 (2020), pp. 57 - 69.

strategy is developed to concretize the grid operator requirement of minimizing the peak during the day time to enhance the network flexibility during this period where the total consumption is usually very high and can trigger some power quality issues.

The performances of each algorithm mentioned above are described and compared with the initial StoreNet basic self-consumption (SB-SC) algorithm as developed and controlled by the Solo Energy through the StoreNet VPP cloud platform. The overall structure of the VPP control platform is shown in Figure 3.1(a). The power and energy exchange among the batteries, the houses, the PV generators and the grid depends on the control methods/algorithms. The basic power flow for a single house is illustrated in Figure 3.1(b).

A Mixed Integer Linear Programming (MILP) algorithm is used to design the reference signal for the power conversion system in order to ensure an optimal management of the system to fulfil a specified criterion or a so-called objective function. The input of the MILP algorithm are a time series data of the forecast of the PV generations, the Loads, and the actual status of the batteries. The algorithm takes into consideration the characteristics of the system components and the design objective to synthesize the optimal control scenario. The basic structure of the proposed control methods are shown in Figure 3.1(c), whereas Figure 3.1(d) shows a part of the VPP dashboard where the real-time performance and forecasting are revealed.

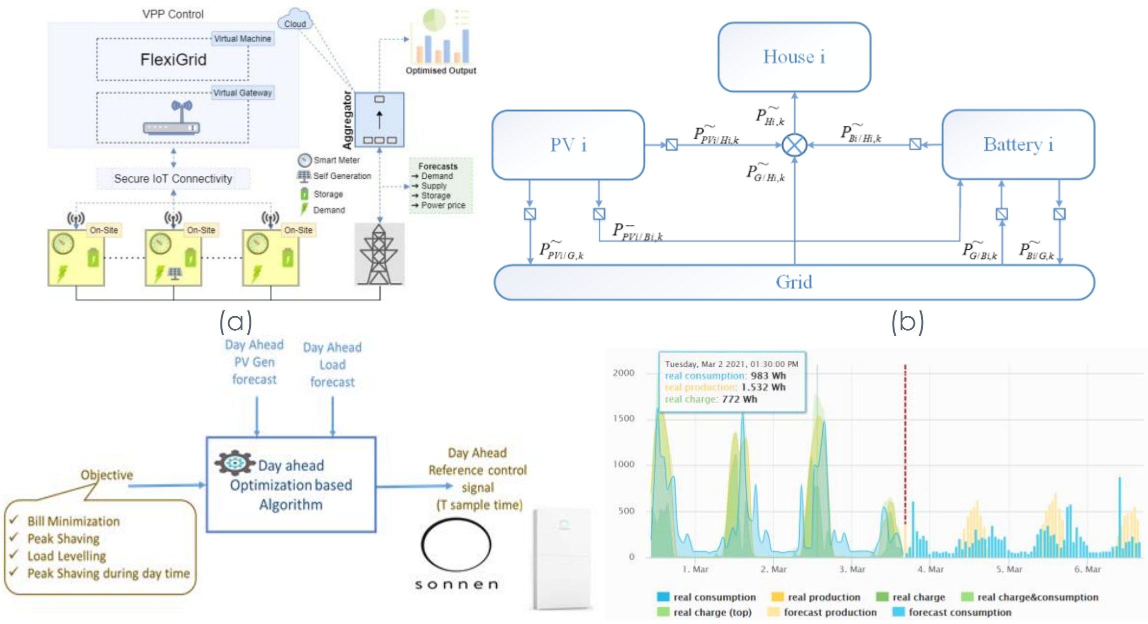


Figure 3.1 VPP Control Platform

The proposed control methods are briefly presented here. These will offer the aggregator the operational flexibility to deal with different scenarios in future and to compare their technical and economic impacts on the network and the end users.

3.2.1 Single house bill minimisation (SH-BM):

The controller considers, here, each house as a single entity. The role of the aggregator then, is to design a battery charge discharge controller that maximize the economic benefits of each single house independently. The benefits are generated through purchasing energy from the grid to charge the battery in the night-time, and then use it during the daytime to feed the load. The DERs in this case (ESS and PV) are not optimally deployed in favour of the community since they are controlled as a separate unit to maximise the individual profits without being able to share these resources with the other VPP customers.

3.2.2 VPP Bill minimisation (VPP-BM):

The control algorithm in this case optimises the DERs in favour of all the VPP customers. It enables sharing of DERs among customers and creates a collective/cooperative energy exchange framework between the households in the community. The main aim of the VPP is to generate the maximum benefits from the use of batteries and PV generators through the minimization of the total electricity bills by aggregating the loads, the PV generation and the batteries use of the different houses[6],[7].

3.2.3 Peak shaving (PS):

Peak Shaving is one of the potential VPP applications in the smart grid networks[8],[9]. It aims at reducing the peak demand value to avoid the installation of additional generation, distribution, and transmission capacities to secure the supply during the peak load period. Usually, this peak could appear either in the early morning or early evening time. This control will offer a good feature of the TSO/DSO to control their network and to minimize the future grid support investment. However, this will impact the direct economic benefits of the end users.

3.2.4 Peak shaving during day time (PS-DT):

Referring to its name, Peak shaving during the daytime is another control approach that combines peak shaving and kind of energy bill minimisation. This will specially be applicable where the day-night tariff system exists, such as in Ireland. Usually, the day time electricity tariff is much higher than that to the night time and also a peak demand appears at day-time (mostly in the late afternoon and evening time) that makes the DSO feel concerned about the ability of their facilities to respond to the peak demand. This approach is different from PS since minimising the peak during night-time (early morning) is out of the scope here.

3.2.5 Load levelling (LL):

The load levelling approach aims at reducing the fluctuation in electricity demand by minimizing the gap between the on-peak and the off-peak values. The aggregator in this case might use the batteries to store the electricity excess during low demand and use it during the high demand period so that the import electricity from the grid maintains nearly a constant level throughout the day-night period. This approach presents many advantages for TSO/DSO and system operator to manage the upstream generation and the electrical network[10].

3.2.6 StoreNet Basic Self-consumption (SB-SC):

The StoreNet basic self-consumption algorithm has been used by Solo energy to control the battery. It aims at maximising the PV generation self-consumption at the household level. The battery charging and discharging are managed based on the generation and consumption day ahead forecast, and on site conditions. Indeed, if the consumption is greater than the PV

[6] Yong-Gi Park, Jong-Bae Park, Namsu Kim, and Kwang Y. Lee, "Linear Formulation for Short-Term Operational Scheduling of Energy Storage Systems in Power Grids", Energies 10, 2 (2017)
[7] Z. Ullah, G. Mokryani, F. Campean, and Y. F. Hu, "Comprehensive review of VPPs planning, operation and scheduling considering the uncertainties related to renewable energy sources", IET Energy Systems Integration 1, 3 (2019), pp. 147-157.
[8] X. Wang, Z. Liu, H. Zhang, Y. Zhao, J. Shi, and H. Ding, "A Review on Virtual Power Plant Concept, Application and Challenges", in 2019 IEEE Innovative Smart Grid Technologies - Asia (ISGT Asia) (2019), pp. 4328-4333.
[9] T. Xu, W. Wu, Z. Wang, and T. Zhu, "Coordinated optimal dispatch of VPPs in unbalanced ADNs", IET Generation, Transmission Distribution 14, 8 (2020), pp. 1430-1437
[10] T. Xu, W. Wu, Z. Wang, and T. Zhu, "Coordinated optimal dispatch of VPPs in unbalanced ADNs", IET Generation, Transmission Distribution 14, 8 (2020), pp. 1430-1437

generation, the battery is discharged to even out as much of the deficit as possible. However, if the PV generation is greater than the load consumption, there is a surplus of electrical energy.

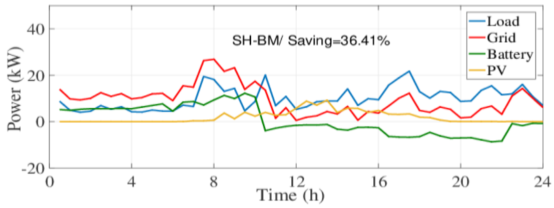
4. Case studies

It is to be noted that the smart meter data collection has been started from February 2019 and data that are more complete are available in between May 2019 to Oct 2020. For rest of the analysis, we have used the measured data from July 2019 to June 2020 to complete a cycle year. The overall case studies have been carried out in three steps. At first, the dynamic performances of the developed controllers are observed for a typical day where the full power and energy capacity of the storage units are considered.

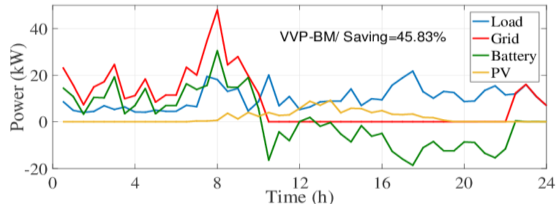
The second group presents a comparative analysis on the different control approaches in terms of savings and peak consumptions. The third group shows sensitivity analysis of the VPP-BM total saving for battery capacity and power allocation and investigates the system performances while considering 20% - 100% of the total energy and power capacities of the batteries.

4.1 Full Capacity Storage Utilisation

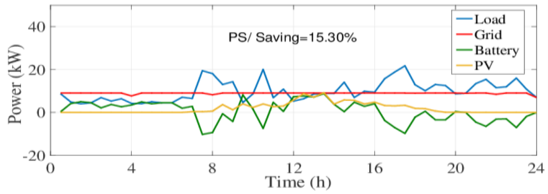
Figure 4.1 presents VPP outputs. The load (blue lines) represents the real life measured data combined for 20 customers. The obtained results show that compare to the single house optimisation, the combined/VPP optimisation allows 9.42% more return on a typical day. This preliminary result shows the advantage of aggregating DERs to generate higher revenue. Moreover, it can be observed that the VPP-BM and PSDT offer a close performances in term of saving; however the PSDT offers more peak reduction than that of the VPP-BM (grid - red lines). The applied StoreNet SB-SC is less performing in terms of saving (23.72%) compare to SH-BM (36.41%), VPP-BM (45.83%), and PSDT (43.63%). The PS and LL algorithms exhibit almost the same peak reduction (grid) for that day. Moreover, both presents a similar savings that is close to 15%. The differences between these PS and LL can be obtained more clearly in the case of annual performance. Hence, to get insights into the overall performances, a deeper analysis should be performed considering seasonal and monthly scenarios. Thus, in the next session, a second group of case study is presented. It includes extensive simulations of the different proposed control strategies implementing 1 year of real measured data.



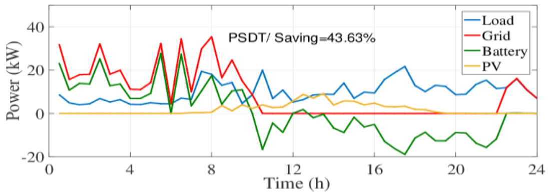
(a) SH-BM



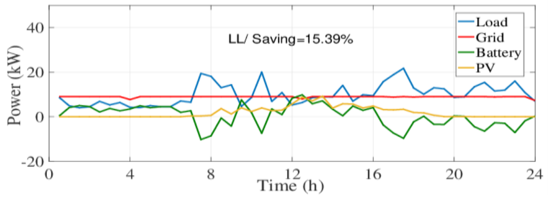
(b) VPP-BM



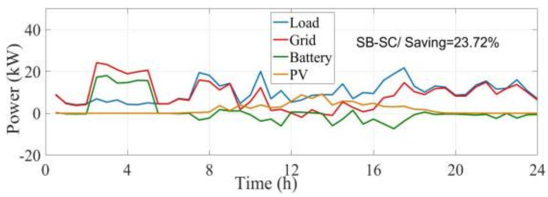
(c) PS



(d) PSDT



(e) LL



(f) SB-SC

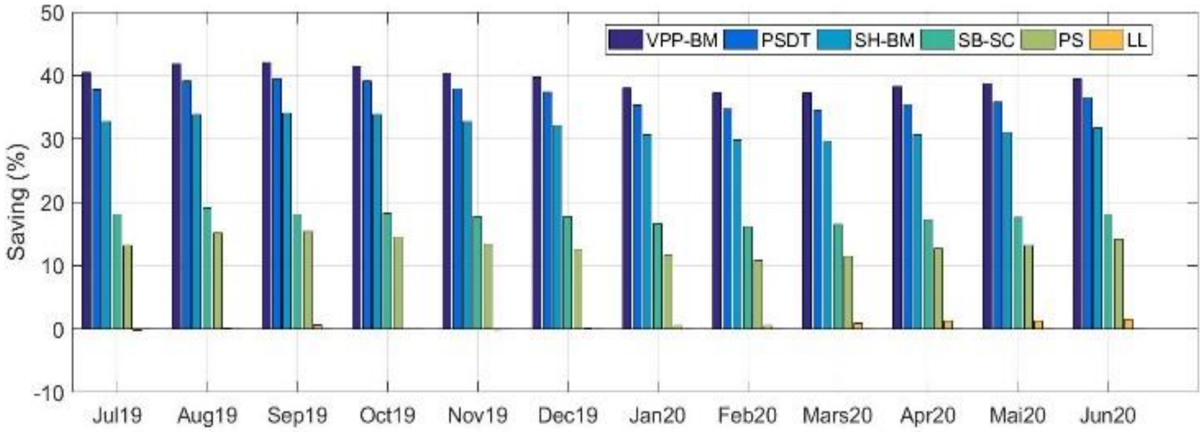
Figure 4.1 Different EMS output for a typical day (100% capacity utilisation)

4.2 Savings and Peak Consumption Study

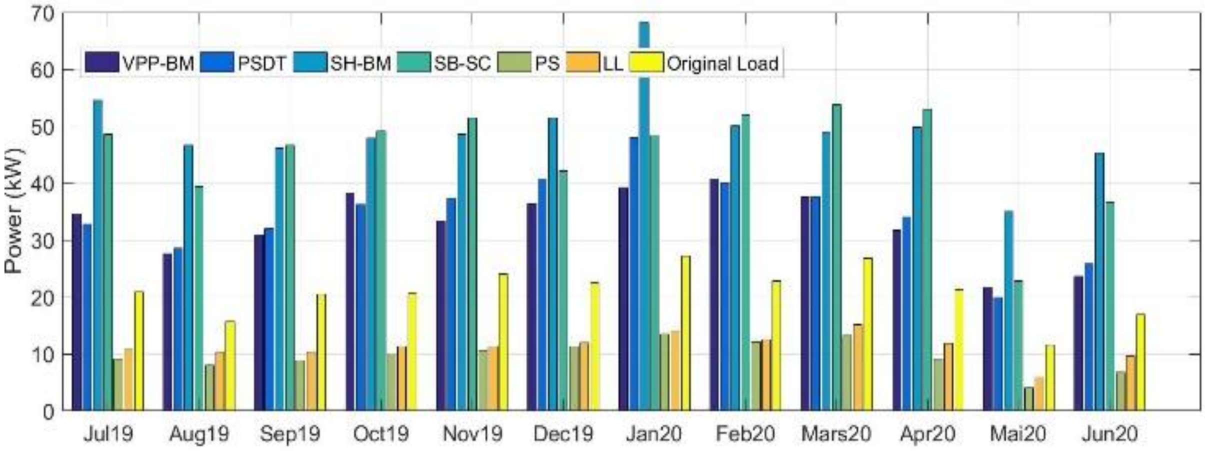
This section presents comparative studies on the performance of the newly proposed and developed EMS algorithms and SB-SC algorithms that are already implemented in the existing VPP cloud platform. The performance is evaluated in terms of monthly electricity cost savings and the peak consumption in VPP aggregation mode. Figure 4.2 (a) shows the possible monthly savings if the proposed algorithms are implemented and the existing day-night tariff scheme is considered. It is clearly observed that the VPP-BM can be the best approach in terms of saving. PSDT is in the second rank, followed by SH-BM, and SB-SC is in the fourth rank. The LL here is offering the least saving ratio and can even lead to a negative value for some periods. To assess the impact of the control algorithms on the consumption waveform, the peak values are plotted in Figure 4.2 (b). It shows that SB-SC and SH-BM exhibit the highest peak value (despite neither of the algorithms showing a considerably best saving ratio).VPP-BM and PSDT show almost the third and the fourth-highest peaks. The peak PS is the best approach here in terms of reducing the peak, followed by the LL showing almost similar peak values but the saving are comparatively very low.

The main takeaways from this case study are: 1) along with improving the economic viability of the VPP, the aggregation concept can help to reduce the peak compared to the non aggregated (single house) control concept. 2) The PSDT peak values are much higher than the original peak. Despite that this algorithm can dramatically improve the economic benefits, it can shift the peak load to the night-time, thus may impact the grid operation negatively. 3) The LL control approach can contribute to peak shaving. The grid peaks are less than the original load peaks and very close to the PS algorithm peaks; however, the economic performances by LL algorithm are very poor even compared to PS control algorithm.

In the previous first and second case studies, full batteries power and capacity budgets are considered. The nominal battery parameters, the load, and PV generation values are used. The previous case studies will answer any questions related to the aggregator control strategy for this pilot project; such as VPP-BM or PSDT can be the best choices for the aggregator and for the benefits of participating customers. On the other hand, PS can be preferred by the network operator. However, a very important question arises again here about the sensitivity of these control approaches to the load or battery capacity variation. In practice, it means will it be beneficial if the number of VPP houses increases, or/and an allocation of part of the batteries power and capacity budget to provide other services to the community or the grid?



(a)



(b)

Figure 4.2 (a) Saving (%) for different control algorithms from July 2019-June 2020; (b) Consumption peaks vs Load Peak – July 2019-June 2020

4.3 Sensitivity Analysis

In this case study, a sensitivity analysis is performed to investigate the impact of batteries power and capacity budget on the economic viability of the VPP. As the initial objective of the StoreNet VPP is to reduce the VPP community bills and previous analysis also show that VPP-BM strategy can be the best choice, this analysis is extended to study further how the battery power and capacity variation can impact other control performances and compare this with the VPP-BM algorithm outputs. Extensive simulations have been performed for VPP-BM strategy considering different power and capacity budgets variations of the batteries. The simulations have been performed using one-day 30 min time series data while considering the same simulation conditions as it is done in the first group of case study.

The main results are plotted in Figure 4.3. It can be observed that for this VPP demo site, the capacity budget has more impact on the savings rather than the increasing power ratio. For a fixed power ratio between 0.2 and 1, the saving percentage is linearly dependent on the capacity budget. The maximum saving can be achieved at around 0.7 – 0.8 capacity ratio and a power ratio of 0.2 - 0.3 (20% - 30% of the nominal power). The maximum saving value here is 45.83% (as described in the first case study), and it is higher than the mean value of the year as shown in Figure 4.2 (a) (in the second case study). The saving value is due to batteries usage. It can be concluded that the batteries utilisation factor in this case is very low. This can impact the profitability of the battery investment. A further development of the batteries budgets should be considered. Indeed, in this case study, at least 70% of the total power budget and 30% of the total capacity budget can be used to perform other VPP services without impacting the VPP-BM economic performances.

To give more insight into the impact of batteries power and capacity budget variation on the other control strategies performances, simulations have been performed considering respectively 20% of the battery capacity and 20% of the allocated battery power. Table I shows the main outputs while considering the five different proposed algorithms. The obtained results show that VPP-BM, in this case, is an energy-oriented application. The saving shows high volatility when reducing the capacity battery budget (26.45% considering 20% of the total capacity budget) compared to allocating less power budget (43.42% considering 20% of the total power budget). The SH-BM and PSDT exhibit similar high sensitivity to capacity budget; however, both algorithms are too sensitive also to power budget allocation compare to VPP-BM. The saving ratios of applying PS and LL algorithms have almost the same values. This can be justified by the large capacity and power budgets of the aggregated storage units compared to the total aggregated load.

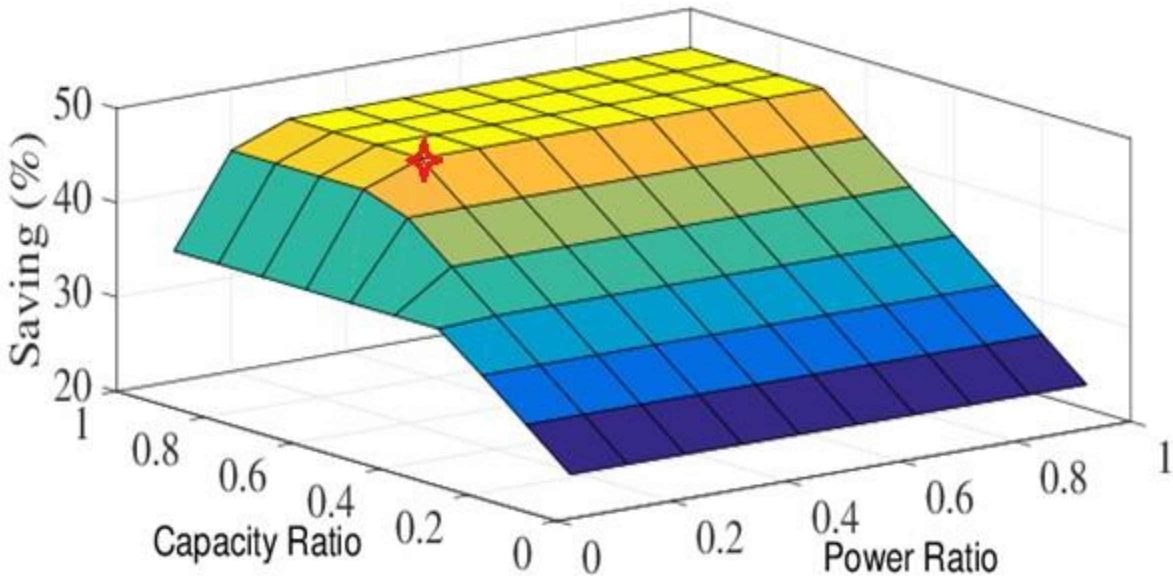


Figure 4.3 EA Saving for different capacity and power ratio.

Table 1 BILL SAVING FOR DIFFERENT BATTERIES CAPACITY AND POWER RATIOS

	SH-BL (%)	VPP-BL (%)	PS (%)	PSDT (%)	LL (%)	SB-SC (%)
20% Power	26.76	43.42	15.30	24.17	15.25	--
20% Capacity	16.18	26.45	15.33	18.04	14.86	--
Nominal	36.41	45.85	15.30	43.63	15.39	23.72
Annual Average	31.89	39.358	13.16	36.90	0.54	17.59

5. Concluding remarks and recommendations

Five different control approaches for a residential VPP platform integrating rooftop PV and energy storage systems have been analysed in this paper. The controller has been synthesized through the resolution of the MILP problem formulation for a horizon decision interval that considers the forecast of PV generation and load demand.

Extensive simulation studies have been carried out using the time series real measured data from July 2019 to June 2020. Moreover, a sensitivity analysis is also presented to assess the impact of reducing the battery power and capacity budgets on the control outputs and economic returns. The Irish day/night tariff scheme is used to evaluate the techno-economic impact of each algorithm, and a zero feed-in tariff is considered in compliance with the Irish regulation for residential PV systems.

It has been found that the VPP-BM and PSDT (respectively PS and LL) share almost the same performances for nominal cases - when the battery power and capacity budgets are large enough to reach the optimum. When the storage capacity or power is reduced to 20%, the PSDT performances were very poor compared to VPP-BM. PS and LL performance analysis exhibit very little sensitivity toward decreasing the battery power or capacity budgets.

The sensitivity analysis has also shown that the capacity of batteries mainly drives VPP-BM economic saving. An optimal financial incentive could be gained while considering only a small portion of the power budget. This will give a potential asset to the VPP to participate in other applications, mainly the power one, and create an additional revenue stream to support their business model. In this case, ancillary services markets to reserve markets could be the interesting options. A design of a sophisticated optimisation algorithm will play a key role here, and the aggregator needs to develop good flexibility to operate in both local and wholesale energy markets and coordinate its operation in both markets.

The comparison between different control algorithms and the deployed SB-SC has shown that an economic-based objective function-driven algorithm design (VPP-BM, PSDT, SH-BM, or the applied SC) could increase the consumption peak dramatically. Indeed, despite reducing the consumption during the daytime, this type of algorithm may shift the peak to the night-time and also can be higher than the original peak demand. While taking into account the fast popularisation of residential PV and storage, this phenomenon can also lead, in the future, to some power quality or grid stability issues in the distribution network. In counterpart, it was also pointed out that network-oriented algorithm design (LL and PS) has a negative impact on the economic benefits and can increase electricity bills. This will discourage customers from engaging in such a concept and prevent the grid operator from benefiting from an important source of flexibility and green energy.

To alleviate the gap between the technical and economic benefits of the above-mentioned algorithms, one solution could be to develop novel consumption tariff scheme to enhance the synergy between local energy market development and grid support. Indeed, to engage prosumers more in the future local electricity market, an attractive consumption tariff is to be applied to justify the initial prosumer investment. However, the scheme should also include a kind of network requirement compliance awards or penalties. This will hedge the grid from some kind of cobra phenomenon relating to the fast development and quick transition of the local and wholesale energy market.