Optimal storage operation with flexible tariff under consideration of sector coupling and renewable energy sources in a new settlement area

Muhammad Tayyab
Chair Electric Power Networks and Renewable Energy (LENA)
Otto-von-Guericke-Universität Magdeburg (OvGU)
Magdeburg, Germany
Muhammad.tayyab@ovgu.de

Jun.-Prof. Dr.-Ing. Ines Hauer
Chair Electric Power Networks and Renewable Energy (LENA)
Otto-von-Guericke-Universität Magdeburg (OvGU)
Magdeburg, Germany

Christian Klabunde
Chair Electric Power Networks and Renewable Energy (LENA)
Otto-von-Guericke-Universität Magdeburg (OvGU)
Magdeburg, Germany

Prof. Dr.-Ing. habil. Martin Wolter
Chair Electric Power Networks and Renewable Energy (LENA)
Otto-von-Guericke-Universität Magdeburg (OvGU)
Magdeburg, Germany

***Abstract*— Energy storages are important to manage the high amount of electricity generation from renewable energy sources in microgrids. Furthermore, the economic benefits of battery energy storage (BESS) such as self-consumption maximization have proven its feasibility. In the present paper, a settlement area with photovoltaic and storage systems is investigated, where electrical loads including the heating load profile by using a heat pump. Different battery operation strategies have been analyzed and compared under consideration of the Brazilian white tariffs with the goal to decrease the grid supply. For this purpose, linear programming has been used. The results have been compared with the flat electricity tariffs to analyze the white tariffs effect on these types of systems. The result shows a significant increase in profit using white tariff. However, considering the investment cost of the battery, 5 years of payback time is required.**

Keywords—Microgrid, battery energy storage, direct usage, optimal storage operation, white tariff

I. Introduction

The application of battery storage systems in a microgrid application poses several advantages. Since the high amount of intermittent generation of renewable energy sources can be managed using battery storage systems. However, the cost of a battery increases with each kWh. Therefore, the analysis of their profitability and their potential in a microgrid application are necessary. The analysis should be performed under different conditions such as the use of different energy tariffs since the smart meters allow the application of flexible energy prices [1]. Such flexible tariffs are often referred to as off-peak and on-peak price levels, where the battery charges at off-peak price times and discharges at on peak times. The white tariff, introduced in Brazil, realizes this principle [2]. It is an hourly tariff and can be applied to use storage and other distributed energy resources in an efficient way. The introduction of the white tariff in Germany with different production and load profiles can be beneficial. White tariff has been introduced in Brazil where the low voltage consumers can choose between this type of tariff and other tariffs. A detailed discussion can be found in [2], due to which it will not be explained in this paper.

The maximization of self-consumption is another factor of interest in a microgrid application. The local consumption of the energy from the renewable energy sources is recommended which enables the reduction of the grid supply. The incentives such as feed-in tariff and energy tariffs are important input terms for the maximization of self-consumption [1].

Grid-connected microgrids have been studied excessively. The use of the battery energy storage system for efficient use of energy such as peak shaving, voltage support, reliability, and integration of renewable energy sources has been studied in [3]. The studies show the usage of storage management for power balancing by storing energy at off-peak hours and distribute it at on-peak hours. Furthermore, the energy storage systems to support the distribution grid has been widely studied [4]. Grid-connected microgrids with BESS in a different configuration and under consideration of time-of-use tariffs got more attention [5,6]. The BESS studies in terms of self-consumption based on demand forecasting have been studied in [7- 12,13]. Similarly, self-consumption with different electricity prices has been analyzed in [14]. A combination of the different distributed energy resources (DER) with respect to BESS to gain technical and economic benefits are still to be analyzed [15]. Investigation of BESS coupled with PV to facilitate the consumer to get the benefit of feed-in tariffs incentive has been done in [16]. The study uses mixed integer linear programming (MILP) to solve the optimization problem. The studies [17,18] considered the optimization for different tariff structures. Furthermore, BESS with PV and time-varying tariffs to decrease the operational cost has been studied in [19,20,21,22,23]. However, a study on the comparison of battery charging with PV and grid usage, along with PV under white tariffs to decrease the grid usage ultimately at the peak price time is lacking.

The study in the present paper investigates a settlement area with photovoltaic and storage systems. The electrical loads of the settlement houses include the electrical profile of heat pumps. Different battery operation strategies have been analysed and compared under consideration of the white tariffs with the optimization goal to decrease the grid supply.

The results have been compared with the flat electricity tariffs to analyze the white tariffs effect on these types of systems.

The paper is organized as follows. Firstly, the settlement area is defined. Secondly, a methodology is presented and finally, the results followed by discussion and conclusion based on the comparison of different scenarios are presented.

II. Methodology

A. Description of the settlement area

The investigated settlement area is located in Magdeburg, Germany. It has been assumed that the settlement consists of five single-family houses (SFH) and six multi-family houses (MFH). The single-family houses occupied by one to five persons while two MFH consist of 12 dwellings and four MFH consist of 16 dwellings. The area of the SFH is assumed to be 140 m² and the area of the MFH with 12 dwellings and 16 dwellings are 950 m² and 1170 m², respectively [24]. The houses in the settlement are assumed to be passive houses which have an annual space heating demand of 15 kWh/m2 and are equipped with PV systems [27,30].

B. Load profiles

The heating demand (water and space heating) has been computed considering the number of persons and area of the houses in the settlement. A heat pump has been used to cover the heat load of the houses in the settlement. The electrical energy required for the heat pump has been computed based on the settlement heating requirement [26,27]. The seasonal coefficient of performance (SCOP) is needed for this purpose which has been calculated by using VDI4655.

The electrical loads for the settlement area have been chosen from HTW Berlin University of Applied Sciences [25]. The load profiles exist for a range from 1.4 MWh to 8.6 MWh. The electrical load with an annual electricity consumption of 1.4 MWh is assumed for a one-person household. The number of persons and their electricity consumptions are given in Table 1.

TABLE I. Annual electricity consumption [27,28,29]

Household size (Number of persons)	1	2	3	4	5
Annual electricity consumption in MWh	1.20-1.97	2.70-3.33	3.00-4.50	3.60-5.50	4.90-6.00

C. PV production profile

The rated PV production is calculated in (1) [31],

$$PV_{\mathrm{PV,inst}} = G \cdot \eta_{\mathrm{M}} \cdot PR \cdot A_{\mathrm{PV}} \quad (1)$$

where G represents the irradiance, which is assumed to be 1000 W/m^2, η_M refers to the solar module efficiency, PR shows the complete system performance ratio and A_{PV} is the total PV area. Module efficiency of 19.1 % and a performance ratio of 85 % is assumed [32]. The total PV area (A_{PV}) is given in (2) [33],

$$A_{\mathrm{PV}} = A_{\mathrm{R}} \cdot GCR \quad (2)$$

where AR is the total roof's area and GCR is the ground coverage ratio assumed to be 75 %. Different tilting mechanisms increase PV production by 15 % compared to the horizontal surface [34]. The PV details are shown in Table 2. The total rated PV capacity installed in the settlement is 224 kW. The roof's area of the SFH and MFH has been assumed to be 70 m^2 and 250 m^2, respectively.

TABLE II. Total PV area and installed capacity

House type	Number of Houses	Total Roof's area	Total PV area	PV Production capacity in kW
SFH	5	350	262.5	42
MFH	6	1500	1125	182

D. Storage and Converter rated capacity

The capacity of the storage refers to the settlement PV production. According to the storage monitoring carried out by the Institute of Power Electronics and Electric Drives (ISEA) at the RWTH Aachen, the rated storage capacity has approximately a 1:1 ratio as compared to the rated PV production as shown in Fig. 1.

The capacity of the converter is selected based on the rated capacity of the battery. In the present study, it is assumed with 50 % of the rated capacity of battery [35]. A district quarter storage system is in the present paper because the centralized storage system has more potential to be used [27]. From the study, a storage capacity equal to PV production will decrease the curtailments. The district quarter storage with a capacity equal to PV will ensure greater self-sufficiency as well as a reduced grid usage as compared to distributed energy storage [27].

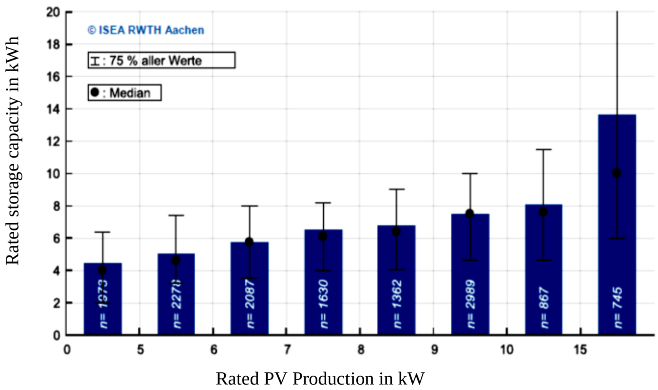

FIG. 1. Rated storage capacity versus rated PV production [41]

E. Tariffs

The white tariff has been implemented in Brazil for low voltage consumers and is shown in Fig 2.

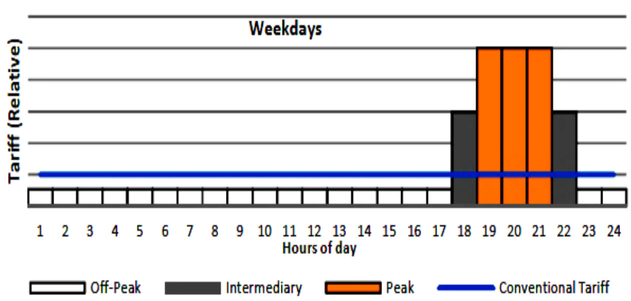

Fig. 2. White tariff [2]

The tariffs have different values in the weekdays as well as on weekends. The cost of electricity for off-peak, mid-peak and on-peak time is assumed to be 20 Cents, 50 Cents and 90 Cents per kWh for weekdays and a flat value of 30 Cents on the weekend and on holidays. For comparison, the system is also analyzed with a flat rate as implemented in Germany. A flat rate of 30 Cents/kWh has been assumed [2].

III. PROBLEM FORMULATION

The objective for the optimization is to increase the battery discharge at the time of peak price and decrease grid usage. For this purpose, linear programming is used for the implementation. The objective function to increase the profits is shown in (3)

$$\max \sum_{t=1}^{h} (P_{GF}C_{GF} - P_{CT}C_{GF} - P_{GS}C_{GS} + P_{BD}C_{GS}) \quad (3)$$

Where, h is the hours, C_{GF} is the cost of selling energy and C_{GS} is the cost of electricity purchased from the grid. P_{GF} is the grid feed-in, P_{GS} is the grid supply, P_{BD} is the battery discharge and P_{CT} is the curtailment. Extra costs related to the operation of district storage systems (EEG-levy) is not considered.

The load should be always covered by PV direct usage, battery discharge, and grid supply. Similarly, PV production should be totally utilized in direct usage, battery charge, grid feed-in, and curtailment. The constraint is shown are given in (4,5).

$$P_{Load}(t) = P_{DU}(t) + P_{BD}(t) + P_{GS}(t) \quad (4)$$

$$PV_{PV,inst}(t) = P_{DU}(t) + P_{BC}(t) + P_{GF}(t) + P_{CT}(t) \quad (5)$$

Here, P_{DU} is direct usage and P_{BC} is the battery charge. The battery charge and discharge are bounded by the capacity of the battery. The battery discharge energy cannot exceed the battery charge. Furthermore, the battery discharge has to be less than the battery charge given as follows.

$$0 \le P_{BD}(t) \le P_{max,CON} \quad (6)$$

$$0 \le P_{BC}(t) \le P_{max,CON} \quad (7)$$

$$\sum P_{BD} - P_{BC} \le 0 \quad (8)$$

Here, $P_{max,CON}$ is the converter capacity. In the scenario where the battery will be charged from PV and from the grid, P_{BC} will be the accumulated value for the day. The grid feed-in limitation is assumed to be 50 % of the installed PV capacity [36,37,38]. The constraint for the grid feed-in, grid supply, and curtailment are given in (9).

$$\begin{cases} 0 \le P_{GF}(t) \le 0.5 \cdot PV_{PV,inst} \\ 0 \le P_{GS}(t) \le P_{Load} \\ 0 \le P_{CT}(t) \le PV_{PV,inst} \end{cases} \quad (9)$$

Here, the $PV_{PV,inst}$ is the rated capacity of the PV system installed.

IV. RESULTS AND DISCUSSION

The grid-connected microgrid scenario with the settlement described in section (II, A) has been analyzed. Three cases have been considered for the evaluation based on white and flat tariffs. In the present paper, a one-hour resolution is used for one year in simulating the results. The configuration for the cases is as follows,

Case 1: PV without battery storage as a reference case

Case 2: PV with battery storage and the battery will be charged only from PV

Case 3: PV with battery storage and the battery will be charged from PV as well as the power system

A. *Case 1*

Since there is no battery energy storage, direct usage and grid feed-in are the parameters of interest. When the PV production starts, the load is fulfilled by PV and the electricity imported from the grid has been gradually decreased to zero. If the PV production is higher than the direct usage, the remaining power is fed into the grid or curtailed. The curtailed energy is 305 kWh on this day and the energy purchased from the grid are 237.5 kWh. The grid feed-in is 588.2 kWh. The power balance at summer and winter is shown in Fig 3 and Fig 4 respectively.

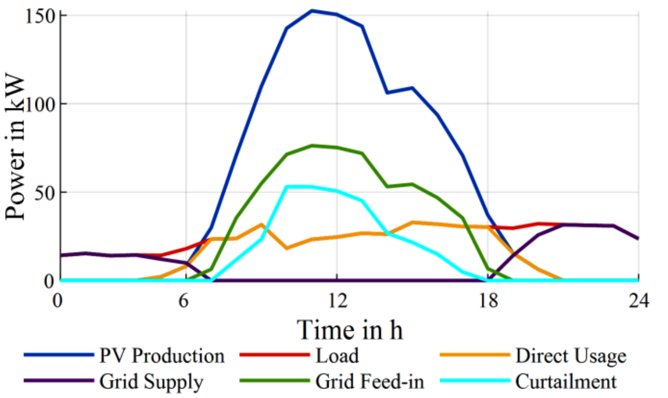

Fig. 3. Power balance summer day (July, 19th)

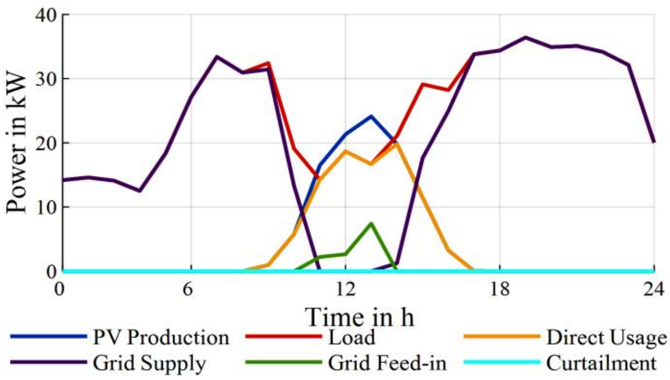

Fig. 4. Power balance for winter case 1 (January, 15th)

As in winter, the PV production is low, there is only a small amount of grid feed-in around 12 PM without curtailment. Most of the produced energy has been self-consumed by direct usage. The grid supply is 514 kWh for the day which means that an average of 154 € of electricity should be purchased from the grid to fulfill the load of the settlement considering a flat rate of 30 Cents/kWh. The grid feed-in on the day is 12 kWh.

B. *Case 2*

In this scenario, the battery capacity is 224 kWh. In a winter day such as January, 15th, the PV production is low and is not enough to charge the battery. However, the battery has covered a part of the load at the peak price. Due to which, a high amount of grid supply is needed to cover the load. The power balance for a winter day is shown in Fig 5.

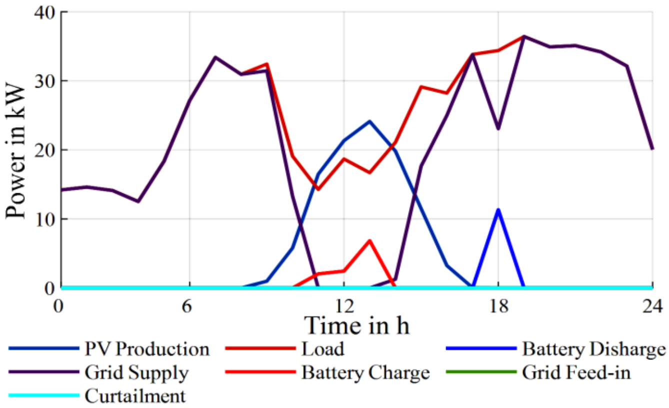

Fig. 5. Optimal power balance for case 2 in winter (January, 15th)

On a summer day, to cover the total load by the battery. discharge, an increase in battery capacity is recommended. Furthermore, charging from the grid should be included to use the total capacity, which will be discussed in the next section. The grid feed-in, grid supply, and curtailment on 19th July are 588 kWh, 80 kWh, and 81 kWh respectively. The curtailments and grid usage have been decreased as compared to case 1. The grid feed-in is same, because of high PV production and the energy needed to charge the battery is taken from the curtailment

C. *Case 3*

A battery with a capacity of 224 kWh is placed and the battery is also charged from the grid. In the context of reducing the grid import at the peak price, this type of system will be useful as shown in Fig 6.

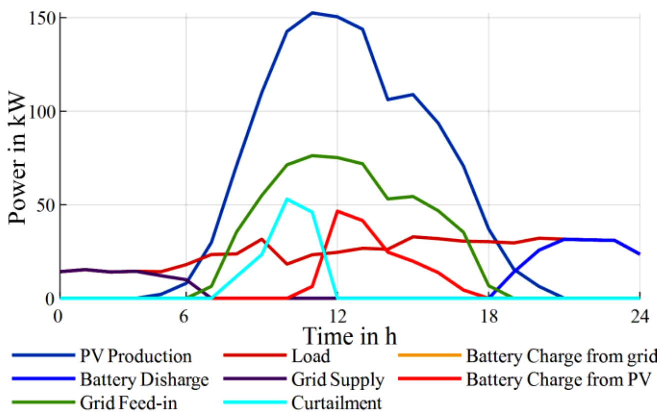

Fig. 6. Optimal power balance for case 3 in summer (July, 19th)

It has been assumed that the battery is empty at the start of the day. The PV production is high, and it can charge the battery completely. The purchased energy from the grid on this particular day is 80 kWh, 85 % less compared to case 1. The grid feed-in and curtailment on this day are 588 kWh and 137 kWh, respectively. Power balance on a winter day is shown in Fig 7.

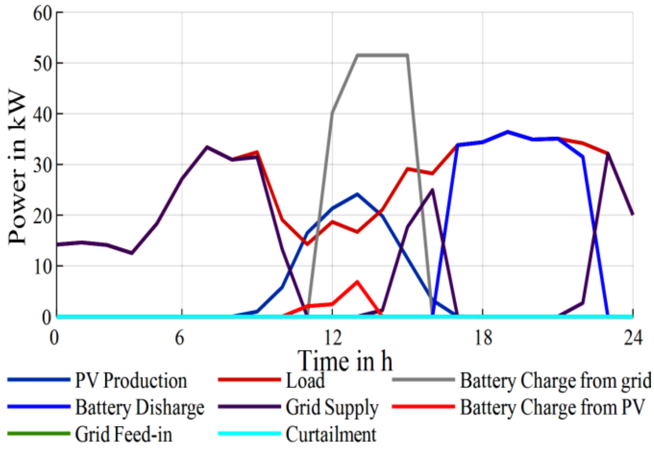

Fig. 7. Power balance for winter (January, 15th)

On a winter day, the grid will be used to charge the battery completely as shown in Fig 7. The battery is empty at the start of the day. The battery is slightly charged from PV production. Most of the PV production has been used as direct usage. Using the grid and PV, the battery has been fully charged and the load at peak price time has been covered by the battery discharged as shown in Fig 7. The purchased energy to cover the load is 308 kWh and 194 kWh is needed from the grid to charge the battery. The curtailment and grid feed-in are 0 at the day.

D. *Comparison*

Fig 8 shows, that the grid supply and grid feed-in are much more in case 1. Furthermore, case 3 provides more flexibility in term of battery full capacity usage. The average state of charge is 33 %for case 3 while it is 20 % for case 2. Which means that the battery in case 3 has utilized its capacity more times compared to case 2. Technically, case 3 has more potential to decrease grid stress. The curtailment is also low in case 3 compared to another case. The energy balance of the three cases is presented in Fig 8.

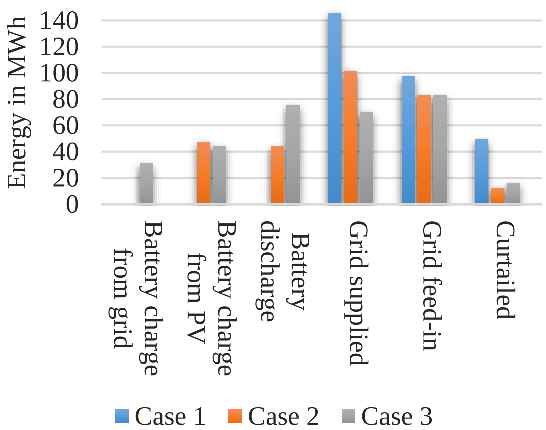

Fig. 8. Yearly energy balance

The objective function value for one year considering the white tariff (see section IV) and a selling price of 11 Cents/kWh for the energy fed into the grid is shown in Table 3. The flat rate as implemented in Germany with 0.30 €/kWh assumption is also considered and compared with white tariff is Table 3.

TABLE III. OBJECTIVE FUNCTION VALUE

Cases	Objective function value using white tariff (€)	Objective function value € using flat rate (€)
Case 1	-48 933	-37 874
Case 2	2916	-8893
Case 3	27 243	-9390

According to Table 3, Case 2 and Case 3 has a positive value when white tariffs have been used. The positive values mean that the revenue from grid feed-in and battery discharged is greater than the cost of energy amount from grid supply and curtailment. In Case 3 the integration of the grid to charge the batteries at a low price time will enable the system to use the full capacity every day. The objective function value for Case 3 under flat tariff is higher than in Case 2. Due to charging from the grid, the curtailment is higher (see Fig 8) because sometimes the battery reaches its capacity and still there is PV production. The revenue and cost of the amount of energy purchased, sold and curtailed is shown in Table 4

TABLE IV. PURCHASED, SOLD AND CURTAILED ENERGY REVENUE/COST UNDER WHITE TARIFFS

Cases	Energy purchased (€)	Energy sold (€)	Cost of the Curtailed amount (€)
Case 1	54 687	11 572	5818
Case 2	30 051	9802	1471
Case 3	20 301	9812	1926

It will bring revenue from better utilization of energy using a bigger storage capacity and the usage of the grid to charge it as shown in Table 4. In Case 3, the cost of the energy has been decreased because the battery will discharge at peak price time almost every day due to its full capacity ensured by grid charging. The cost of the curtailed amount is higher in Case 3 as compared to Case 2 because the battery is charged from the grid and the PV production needs to be curtailed after grid feed-in. However, by assuming an annual fixed cost of the battery system of 66 €/kWh and a battery life of 10 years [39]. For the battery storage in Case 2 and Case 3, the investment costs of 135520 € are required and the payback time for Case 3 is 5 years. It means that after 5 years of profit, the battery would be amortized. By assuming an annual fixed cost of 40 €/kW for PV systems, the payback time will increase to 8 years [40]. It can be seen that the implementation of the battery in Case 2 is not feasible, because the savings are low per year and the battery is expensive. With a flat rate, in all Cases, the cost of purchased and curtailed energy is greater than the sell or self-consumption as shown in Table 5. Due to a flat rate of energy purchased, Case 3 and Case 2 has identical values

TABLE V. PURCHASED, SOLD AND CURTAILED ENERGY REVENUE/COST UNDER FLAT TARIFFS

Cases	Energy purchased (€)	Energy sold (€)	Cost of the Curtailed amount (€)
Case 1	43 627	11 572	5818
Case 2	30 426	9802	1471
Case 3	30 452	9812	1926

V. CONCLUSION

The present study is a Case study for a new settlement area where the load is considered in the form of the electrical load alongside thermal load by using a heat pump. The settlement area has been analyzed in term of time-varying electricity prices specifically white tariffs. Three different scenarios have been implemented using linear programming to find the optimal storage operation to decrease the grid usage at the time of peak price of electricity. Firstly, the scenario without battery storage has been analyzed. Secondly, energy storage with half of the maximum PV production has been studied. Furthermore, the capacity equal to PV to utilize maximum PV production has been implemented in the third scenario and the battery will also charge from the grid. After comparison, keeping in mind the battery life and cost, the implementation of white tariff alongside with grid charging is beneficial when operated as Case 3.

VI. REFERENCES

[1] G. Subramani, V. K. Ramachandaramurthy, S. Padmanaban, L. Mihet-Popa, F. Blaabjerg, and J. M. Guerrero, "Grid-tied photovoltaic and battery storage systems with Malaysian electricity tariff - A review on maximum demand shaving," Energies, vol. 10, no. 11, 2017.

[2] D. De Campos, E. A. C. A. Neto, R. C. Fernandes, I. Hauer, and A. Richter, "Optimal tariff system for integration of distributed resources based on a comparison of Brazil's and Germany's system," 2016 IEEE Symp. Ser. Comput. Intell. SSCI 2016, pp. 0–7, 2017.

[3] Muhammad Faisal et al, "Review of energy storage system technologies in microgrid applications: Issues and challenges," SPECIAL SECTION ON ADVANCED ENERGY STORAGE TECHNOLOGIES AND THEIR APPLICATIONS,IEE,2018

[4] J. Tant, F. Geth, D. Six, P. Tant, and J. Driesen, "Multiobjective battery storage to improve PV integration in residential distribution grids," IEEE Trans. Sustain. Energy, vol. 4, no. 1, pp. 182–191, 2013.

[5] F. A. Inthamoussou, J. Pegueroles-Queralt, and F. D. Bianchi, ''Control of a supercapacitor energy storage system for microgrid applications,'' IEEE Trans. Energy Convers., vol. 28, no. 3, pp. 690–697, Sep. 2013.

[6] Teng F, Miles J, Thomson A, Strbac G, Brandon N, Pudjianto D. Potential value of energy storage in the UK electricity system. Proc ICE - Energy 2015; 168:107–17. http://dx.doi.org/10.1680/ener.14.00033.

[7] Bertsch V, Geldermann J, Lühn T. What drives the profitability of household PV investments, self-consumption and self-sufficiency?; 2017.

[8] Weniger J, Tjaden T, Quaschning V. Sizing of residential PV battery systems. Energy Procedia 2014;46:78–87. http://dx.doi.org/10.1016/j.egypro.2014.01.160.

[9] Brusco G, Burgio A, Menniti D, Pinnarelli A, Sorrentino N. The economic viability of a feed-in tariff scheme that solely rewards self-consumption to promote the use of integrated photovoltaic battery systems. Appl Energy 2016;183:1075–85. http://dx.doi.org/10.1016/j.apenergy.2016.09.004.

[10] Castillo-Cagigal M, Caamaño-Martín E, Matallanas E, Masa-Bote D, Gutiérrez A, Monasterio-Huelin F, et al. PV self-consumption optimization with storage and Active DSM for the residential sector. Sol Energy 2011;85:2338–48. http://dx. doi.org/10.1016/j.solener.2011.06.028.

[11] Linssen J, Stenzel P, Fleer J. Techno-economic analysis of photovoltaic battery systems and the influence of different consumer load profiles. Appl Energy 2017;185:2019–25. http://dx.doi.org/10.1016/j.apenergy.2015.11.088.

[12] Ratnam EL, Weller SR, Kellett CM. Scheduling residential battery storage with solar PV: Assessing the benefits of net metering. Appl Energy 2015;155:881–91. http://dx.doi.org/10.1016/j.apenergy.2015.06.061.

[13] Pyrgou A, Kylili A, Fokaides PA. The future of the Feed-in Tariff (FiT) scheme inEurope: The case of photovoltaics. Energy Policy 2016; 95. doi:10.1016/j.enpol.2016.04.048.

[14] Quoilin S, Kavvadias K, Mercier A, Pappone I, Zucker A. Quantifying selfconsumption linked to solar home battery systems: Statistical analysis and economic assessment. Appl Energy 2016;182:58–67. http://dx.doi.org/ 10.1016/j.apenergy.2016.08.077.

[15] Ruth M, Pratt A, Lunacek M, Mittal S, Wu H, Jones W. Effects of home energy management systems on distribution utilities and feeders under various market structures 2015;15(18).

[16] Ratnam EL, Weller SR, Kellett CM. An optimization-based approach to scheduling residential battery storage with solar PV: Assessing customer benefit. Renew Energy 2015;75:123–34. http://dx.doi.org/10.1016/j.renene.2014.09.008.

[17] Jayawardana HPAP, Agalgaonkar AP, Robinson DA. Novel control strategy for operation of energy storage in a renewable energy-based microgrid. In: 2015 Australasian Universities Power Engineering Conference (AUPEC), IEEE; 2015, p. 1–6. doi:10.1109/AUPEC.2015.7324891.

[18] Ratnam EL, Weller SR, Kellett CM. An optimization-based approach for assessing the benefits of residential battery storage in conjunction with solar PV. In: 2013 IREP symposium bulk power system dynamics and control - IX optimization, security and control of the emerging power grid, IEEE; 2013, p. 1–8. doi:10.1109/IREP.2013.6629420.

[19] Tazvinga H, Xia X, Zhang J. Minimum cost solution of photovoltaic–diesel–battery hybrid power systems for remote consumers. Sol Energy 2013;96:292–9. http://dx.doi.org/10.1016/j.solener.2013.07.030.

[20] Tazvinga H, Xia X, Zhu B. Optimal energy management strategy for distributed energy resources. Energy Procedia 2014;61:1331–4. http://dx.doi.org/10.1016/j.egypro.2014.11.1093.

[21] Tazvinga H, Zhu B, Xia X. Optimal power flow management for distributed energy resources with batteries. Energy Convers Manage 2015;102:104–10. http://dx.doi.org/10.1016/j.enconman.2015.01.015.

[22] Hove T, Tazvinga H. A techno-economic model for optimising component sizing and energy dispatch strategy for PV-diesel-battery hybrid power systems. J Energy Southern Africa n.d.; 23: p. 18–28.

[23] Wu Z, Tazvinga H, Xia X. Demand side management of photovoltaic-battery hybrid system. Appl Energy 2015; 148:294–304. http://dx.doi.org/10.1016/j.apenergy.2015.03.109. ´

[24] M. Fernandez and B. Cener, “Heating and cooling energy demand and loads for building types in different countries of the EU,” ENTRANZE project, March 2014.

[25] T. Tjaden, J. Bergner, J. Weniger, and V. Quaschning,“Represen tative electrical load profiles of residential buildings in Germany with a temporal resolution of one second,” Work. Pap. HTW Berlin -HTW Berlin - Univ. Appl. Sci. Res., pp. 1–7, 2015.

[26] Association of German Engineers VDI, "progress report VDI - No. 560 Refernezlastprofile of single and multi-family dwellings for the use of CHP plants," VDI Verlag, Düsseldorf 2007.

[27] Muhammad Tayyab, Ines Hauer,Christian Klabunde and M. Wolter,’’Optimal storage design and operation in a new settlement area under consideration of sector coupling and renewable energy generation,2018,Glasgow, Schottland, September

[28] Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit,“Stromspiegel für Deutschland 2014 - Vergleichswerte für Ihren Stromverbrauch“,Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 2014.

[29] M. Bost, B. Hirschl, and A. Aretz, “Effekte von Eigenverbrauch und Netzparität bei der Photovoltaik,” Berlin, Hamburg, pp. 1– 96, 2011.

[30] B.Environmental, “Energy consumption and Passive Houses.” 2014 [online] Available:http://passipedia.passiv.de/passipedia_en/start [Accessed Dec 2017].

[31] T. Lang, D. Ammann, and B. Girod, “Profitability in absence of subsidies: A techno-economic analysis of rooftop photovoltaic self-consumption in residential and commercial buildings,” Renew. Energy, vol. 87, pp. 77–87, 2016.

[32] Energysage, “What are the most efficient solar panels on the market?.”2017 [online] Available:"https://news.energysage.com/what-are-the-most-efficient-solar-panels-on-the-market" [Accessed Nov,2017]

[33] M. Culligan and J. Botkin, “Impact of Tilt Angle on System Economics for Area Constrained Rooftops,” 22nd Eur. Photovolt. Sol. Energy Conf. Exhib., p. 3278, 2007.

[34] H. Wirth, “Recent facts about photovoltaics in Germany,” Fraunhofer ISE, Berlin, Hamburg p. 92, 2015.

[35] J. Weniger, T. Tjaden, J. Bergner, and V. Quaschning, “Sizing of Battery Converters for Residential PV Storage Systems,”Energy Procedia, vol. 99, pp. 3–10, 2016.

[36] J. Bergner, J. Weniger, T. Tjaden, “Algorithmus zur Umsetzung der prognosebasierten Batterieladung für PV-Speichersysteme mit messewertbasierten PV-und Lastprognosen (Version 1.1) Berlin Forschungsgruppe Hochschule für Technik und Wirtschaft HTW Berlin 2016

[37] J. Bergner et al.,“Verbesserte Netzintegration von PVSpeichersystemen durch Einbindung lokal erstellter PV- und Lastprognosen,” Symposium Photovoltaische Solarenergie, Kloster Banz, Bad Staffelstein vol. 1, 2015.

[38] J. Bergner, J. Weniger, T. Tjaden, and V. Quaschning, “ Feed-in Power Limitation of Grid-Connected PV Battery Systems with Autonomous Forecast-Based Operation Strategies,” 29th European PV Solar Energy Conference and Exhibition Amsterdam, 2014.

[39] J. Dancker, M. Wolter, J. Rosberg, and E. Tsotsas, “Increasing self-sufficiency in a micro grid: Integrated vs. non-integrated energy system approach,” Proc. - 2018 53rd Int. Univ. Power Eng. Conf. UPEC 2018, pp. 1–6, 2018.

[40] Christian Ziegler, André Richter, Ines Hauer, Martin Wolter, “Technical Integration of Virtual Power Plants enhanced by Energy Storages into German System, Operation with regard to Following the Schedule in Intra-Day” Proc. - 2018 53rd Int. Univ. Power Eng. Conf. UPEC 2018, pp. 1–6, 2018.