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Optimal power scheduling of renewable energy sources in micro-grid via distributed energy storage system

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ABSTRACT

This research is mainly focusing on the optimal power management by controlling the charging and discharging modes of the battery storage of the micro-grid (MG). A droop-based controller or battery controller is proposed for this work in order to optimize the power management of the battery. Charging and discharging modes are controlled by the droop-based characteristic where it will perform as a battery controller for the battery storage. Furthermore, the charging and discharging rates will depend on the signal from the MG at power secondary and its signal will be read by the battery controller and choose either to charge or discharge the battery storage where it will suffice the energy demand by loads in the micro-grid. The simulation results show the effectiveness of the controller to control sharing the power based on the desired energy from the battery storage to the loads at the MG. Moreover, all the critical cases have been advised, such as sudden decrease or disturbance of any generating unit. The result has been observed that due to sudden decrease or disturbance of any generating unit, the battery controller manages to control the charging and discharging rate based on the insufficient energy caused by the disturbance to fulfil the demand at MG.

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1. INTRODUCTION

In this world, there are two types of resource energies that are being used as power resources for electricity which are non-renewable energy and renewable energy. The non-renewable energy and also known as the finite resource, where the resource cannot be recreated by itself at a sufficient rate that follows the rate of the consumer for the acceptable economic extraction where some of the non-renewable resources cannot be replaced as fast as they are being consumed. In addition, it needs thousands of years to be formed naturally so that it can be consumed again. There are few examples of non-renewable energy such as coal, petroleum and natural gas. Renewable energy is an energy extracted from the natural resources where it exists without actions of humankind. This includes all the valued characteristics, for example, magnetic, electrical properties, gravitational and forces. On earth, it includes the sunlight, atmosphere, water and wind. These natural resources are being created by the process of nature and forces that are created from the natural event in the natural environment. There are renewable resources that are intermittent and reoccurring, and materials that can be recycled where these resources and materials can be created based on a certain period time and it can be consumed for any number of cycles. Moreover, Ribeiro et al. [1] planned an islanded MG, which was based on hybrid micro-grid where the MG consists of integration between the wind turbine generation, solar panel generation and batteries in order to meet the power demand of an island MG that is situated in Brazil. Control strategy and operation developed on a DC micro-grid, consisting of a battery energy storage system, a wind turbine generation, and DC load Xu and Chen [2]. Olivares et al. [3]designed a three-phase MG based on the mathematical model of an isolated MG by using reactive support in order to address the voltage swings. A fuzzy controller is used to control the battery storage performance for storing energy and supply energy in an isolated hybrid AC/DC micro-grid is being proposed by Hosseinzadeh and Salmasi [4]. For an islanded MG case, the large battery storage is used to supply the stored electricity back to the micro-grid (MG) and store the surplus energy from the MG.

The battery storage with a high reaction is needed to manage the power supply because of the intermittent nature of RESs. In order to achieve this, a new type of storage device is being introduced which is the ultra-capacitors along with a battery bank. In [5, 6] suggested that the character of the intermittent nature of RESs and load that causing the power supply swings could be compensated by using the ultra-capacitor in decentralized generation system where the system is based on renewable energy. Soon, there will be millions of distributed energy storage system DESS that can be used and integrated into the present power system Kempton et al. [7]. The integration between the RESs and DESS will give a secure solution, energy efficient and cost-effective to the micro-grid (MG). Discharging and charging modes of DESS have a crucial role in power system management. On the other hand, the uncoordinated discharging and charging modes of battery storage can develop some real problems for example increased fault levels, high power energy losses, voltage deviation and some other power quality problems Pahasa et al. [8-10]. Allowing the battery storage to discharge and charge without any control strategy may lead to power energy swings in the micro-grid (MG). Therefore, a better structure for power energy control is needed to organize the discharging and charging modes of battery in the micro-grid (MG). By achieving that, micro-grid can be employed and leveraged in different operation conditions to serve as an independent as well as grid connected source [11, 12].

The aforesaid discussions deduce that they are considerable work has been done where the work is focused on the optimal power management of batteries storage in MGs coordinated with RESs. Nevertheless, the researches have not gained much interest in conducting research based on the integration of DESS for MG stabilisation. In this literature, power scheduling of RESs using the battery storage for reliable operation of MGs with respect to the voltage of the system is not discussed. Also, most of the work found in this literature has not considered individual needs of DESS although the power flow management is through the DESS in MGs, for example, SOC limits [13-17].

A complete schematic diagram of the proposed MG system integrates with the RESs, DESS and loads is demonstrated in Figure 1. The micro-grid is connected to the utility grid but the system will not depend on the utility grid as its power source. Two types of power generation of renewable energy sources RESs in the MG. There are three loads where it is named as the house for the residential load. To increased reliability on supplying energy at the loads according to their demands, the battery is installed in the suggested MG where it will integrate with droop controller, in another name is battery controller where it will control the discharging and charging modes of the battery storage [18, 19].

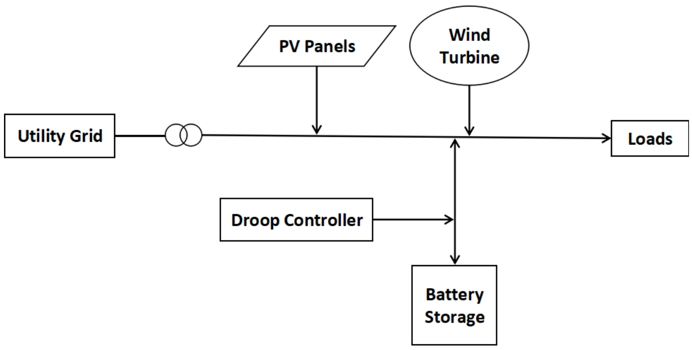

Figure 1. The schematic diagram for the proposed system for the MG.

Furthermore, the efficiency of the battery storage when it is in charging or discharging modes is assumed the same for varying charging or discharging rates for the battery storage. From the above-mentioned problems, this research proposes a power scheduling control strategy in order to secure and sustain the operation of MG integrated with DESS and RESs. Two different RESs, i.e. solar, and wind have been introduced in an isolated MG. To control the power management for the DESS, Power or voltage droop controller has been used in the MG system where it will manage the charging and discharging modes of DESS and control the power distribution between the RESs, DESS and loads in MG. The sharing power among the battery and loads is based on power droop [20, 21].

The proposed research follows the objectives which are the research focused on energy management between the RESs, DESS and loads integrated with the network of the islanded micro-grid by designing it in MATLAB Simulink software. Next, the research also focused on determining the effectiveness on employing the battery controller for optimal distribution of power among loads and DESS in MG where the DESS act as load and an energy source, depending to the power demands by the micro-grid (MG). Finally, the research also considered on ensuring a lasting operation of the proposed framework during emergency cases for example failure or disturbance of any renewable generation sources through the regulation of discharging and charging modes of the battery [22, 23]. This work is arranged as follows. Section 2 discusses modelling of different components of the planned MG. Section 3 presents the problem formulation. While section 4 shows the results and their analysis. Finally, conclusion is drawn in section 5.

2. RESEARCH METHOD

In this work, the designed MG will consist of two different RESs (solar and wind), DG, electrical loads and battery controller where it will integrate between the DESS and the MG. The proposed system will not depend on the utility grid.

2.1. Wind power generation model

Where **r** is the radius of the wind turbine, **v** is the wind speed, **ρ** is the air density and **η** is the efficiency of the wind turbine. The power that is generated (Pwtg) by a wind turbine can be calculated as:

$$Pwtg = \pi/2r^2v^3\rho\eta \quad (1)$$

2.2. Solar panel generation model

The solar panel output power mostly relies on geographical locations and atmospheric conditions. The output power of a particular solar PV panel, (Ppv), at any time, **t**, is a function of atmospheric temperature and solar radiation, which can be expressed as:

$$Ppv(t) = Pratfloss\ [Gh/Gs][1 + \alpha p(Tc - Ts)] \quad (2)$$

where Prat is the power rated for the output capacity of the solar PV panel, floss is the loss factor of the solar panel due to shadow, dirt and temperature. Gh is the hourly solar radiation that interacts in between the sun and the solar PV panel (W/m^2), Gs is the standard optical phenomenon radiation (1000W/m^2), αp is the coefficient of the temperature for the power based on the types of PV cell used, Tc is the solar PV panel cell temperature in the current time step and Ts is the solar PV panel cell temperature under standard test conditions which are 27℃ and 25℃ respectively.

2.3. Distributed energy storage system

For the case of DESS, the main component is the storage battery where its type is lead acid and the battery controller. The surplus energy in the micro-grid MG is absorbed in the DESS and DESS will provide energy when the MG is in low power generation. The charging and discharging modes are being maintained and monitored within the specified limits.

State of charge (SOC) of the battery storage can be calculated as:

$$\mathrm{SOC}(t) = \mathrm{SOC}(\text{t-1}) + \int_0^t \mathrm{I}/\mathrm{Cbat.dt} \quad (3)$$

where the SOC(t-1) is the initial state of charge (%) for the battery, I is the charge or discharge current (A) and Cbat is the capacity for the battery (AH)

2.4. Distributed generators in micro-grid network

Distributed generators in the micro-grid are usually using renewable energy as their resources in order to produce electricity and supply it to the local loads. The use of the renewable energy as the resources for the power supply gives many benefits especially involving the environment, where the system of the micro-grid uses renewable resources that have low emission of greenhouse gasses that could lead to global warming. In this research, the distributed generators will be focused on the renewable energies, mainly on the wind power and solar power involving the micro-grid network.

The micro-grid will use only islanded mode where the micro-grid will be standalone without connecting it to the grid, in order to provide electricity for the loads where this is involving of the reliability of the micro-grid system as well as its security. The micro-grid should be able to supply specific voltage for the electricity by using the distributed generators that will follow the needs of the users with the aid of some auxiliary devices [10, 13].

The total power generated by RESs at any time t is defined as Pre(t) and it can be given as:

$$Pre(t) = \{Ppv(t) + Pwtg(t)\} \quad (4)$$

where Ppv(t) is the total power generated by solar PV panels and Pwtg(t) is the total power generated by wind turbines. The total electrical load demand at any time t is defined as Pload(t) and it is presented as:

$$Pload(t) =\{Pload1(t) + Pload2(t) + Pload3(t) \quad (5)$$

where Pload1(t) is the house 1 load, Pload2(t) is the house 2 load and Pload3(t) is the house 3 load.

2.5. Power control by droop characteristics

In this research, the battery controller or power droop controller is responsible for controlling the voltage of the MG as well as the responsibility of controlling the discharging and charging modes of the DESS in the MG. Initially, the battery controller will receive the signal from power secondary from MG. The power secondary, Psec, can be given as

$$Psec(t) = Pre(t) - Pload(t) \quad (6)$$

The battery controller also depends on the SOC limit, where the SOCmin is 0% and SOCmax is 100%. If the power generated is satisfactory and greater than load needs {Pre(t)} >= {Pload(t)}, then the load demand can be fulfilled directly by the RESs and the extra power from the generation can be provided to the battery storage through the battery controller, where the Power secondary will signal the battery controller to charge the battery storage when it is in positive value. If the {Pre(t)} <= {Pload(t)}, the Psec will signal the battery controller to discharge the battery storage when it is in negative value, in order to supply the remaining power to the load demand.

When {SOC(t)} > {SOCmin(t)}, the battery storage will be in charging mode when there is excess energy in the MG and discharging mode when the RESs cannot satisfy the load demand. If the {SOC(t)} < {SOCmin(t)}, the battery will be charging when there is surplus energy in the MG and will not charge when there is no excess energy in the system. Moreover, when the {SOC(t)} = {SOCmax(t)}, the battery storage will not charge or discharge because it is not being performed by the battery controller and if there is an excess energy, the energy will be stored in the MG system and it will be provided to the load demand if the RESs power is not enough. The battery controller will perform again when the RESs cannot satisfy the load demand and will discharge to serve the load.

The battery storage energy flow is controlled by a battery controller for charging and discharging modes. The battery storage will store the excess power in the micro-grid where this process is known as charging. The process of discharging occurs when there is power shortage in the micro-grid system. The microarray is connected to the step-down transformer where it lowers the voltage from 6.6kV to 200V and connected to the power network. The renewable energy sources which are the wind turbine generation and the solar power generation are direct power power sources and the battery storage is also one of the direct current sources. The control strategy assumes that the power supplied from the wind turbine generation, solar power generation and storage is always enough where the system will not depend on the power that will be supplied from the power grid as in [24, 25].

The simulation results have been obtained according to a daily load profile (24 hours) and the time interval is 60 seconds. Figure 2 shows that when state of charge (SOC) for the battery reaches 0% which is the minimum, the battery storage will be charged when the renewable energy sources produce more than the energy of load demand but it will not do anything when the load demand is higher than the renewable energy sources. Figure 2 also showed that when the state of charge reaches 100%, which is the maximum value for state of charge, that will keep the battery energy remain at zero, since the charging and discharging is not being controlled by the battery controller. When the renewable energy from the wind turbine generation and solar panel PV generation is not enough to support the load demand energy, the battery discharging will be controlled by the battery controller as in [26].

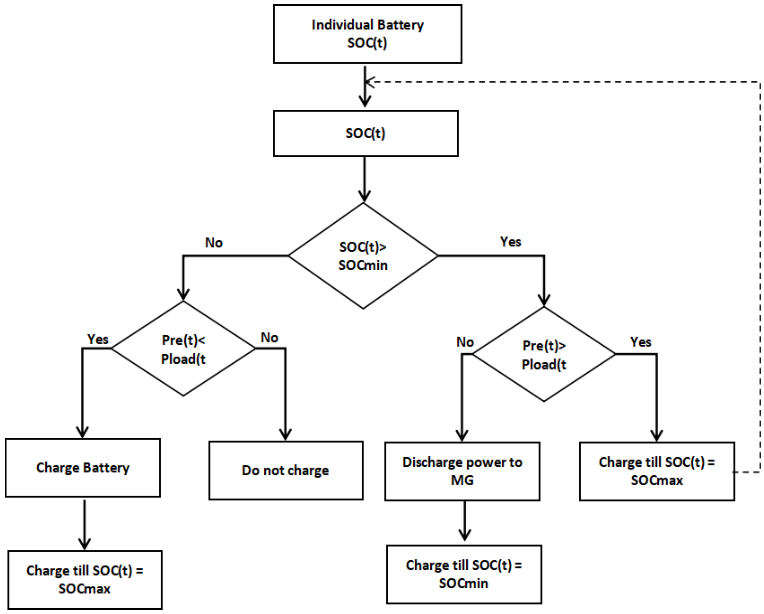

Figure 2. Flowchart of the Proposed M-G

3. SIMULATIONS AND RESULTS

Table 1 shows the parameters values for the wind turbine, solar panel PV, load residential which are 4.238kW, 5kW and 2.5kW on each load. The peak value for the load is 7.5kW in total for three loads. The minimum state of charge (SOCmin) is 0% and the maximum state of charge is 100% for the battery storage and the initial state of charge for the battery storage is 80%. The battery AH is 1000 used for the micro-grid system with nominal voltage 12V.

Table 1. Simulation Parameters

Parameters	Value
Wind turbine generation	0-4.238 kW
Solar PV panel generation	0-5 kW
Load (residential)	0–2.5 kW in each load
Peak load	7.5 kW
SOCmin	0%
SOCmax	100%
Initial SOC	80%
Nominal voltage for battery	12V
Battery AH	1000

The proposed of the research is to show the power energy sharing among the battery, renewable energies and loads. The battery controller act as a controller for the battery control to help the energy distribution from renewable energy into the battery storage for charging purpose when there is an extra energy from the system and it will discharge the energy from the battery storage into the system when the load cannot get enough power supply from the renewable energy. The storage battery will supply energy when there is insufficient power from the microgrid and absorbs the excess energy from the microgrid when its power exceeds the load energy.

The solar, wind and load resources data is taken from the NASA surface weather forecasting website. By using the resources data, the solar power PV is calculated using in (1). Figure 3 demonstrates the power generated by solar PV on a day. The solar panel power is based on the data of the irradiance and based on the solar panel in (1) where the power rating for the solar panel is 5kW and the temperature coefficient is 0.5% where the material for the solar panel used is a monocrystalline solar cell.

Based on the resources data, the output power of the wind turbine generators is calculated using in (2). Figure 4 shows the power generated by the wind turbine generation on the same day. Next, the wind turbine power is constructed based on the data of the wind and based on the wind turbine in (2), where the constants of the wind turbine are the radius which is equal to 2.618m, air density, $\rho = 1.2 kg/m^3$, efficiency, η = 40% and it will produce a constant with value of 278, in order to get the power of the wind turbine, the constant, 278 is multiplied with the wind according to the formula of the wind turbine generation. Figure 5 shows the resources data of the load demand for a typical resident load, where all three loads will receive the same data and the power demand of the load is the total of the three loads demand.

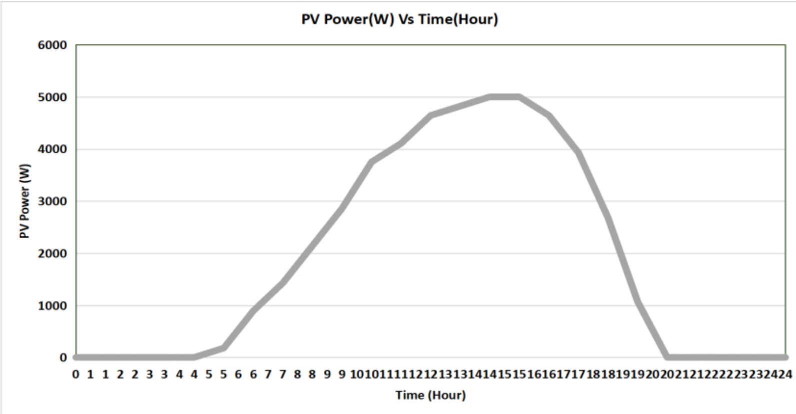

Figure 3. Power generation by Solar PV generator at the micro-grid

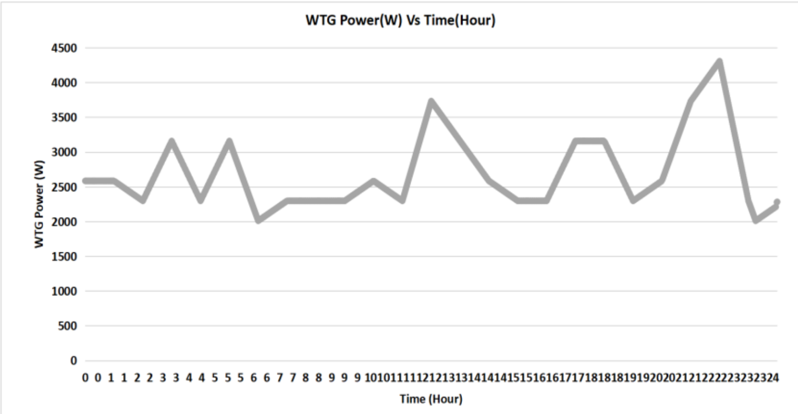

Figure 4. Power generation by wind turbine

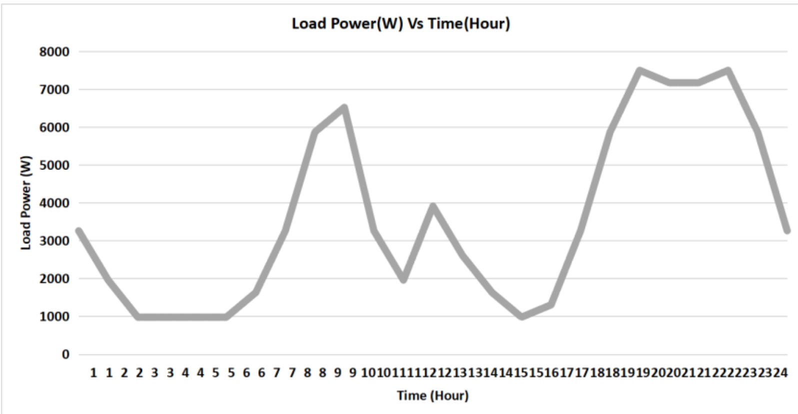

Figure 5. Load demand at micro-grid

Figure 6 shows the power that has been generated by different sources, the wind, solar PV, battery, secondary and load demand on the same day. The capacity of the battery in both modes (charging and discharging) within 24 hours is shown Figure 7. Where state of charge of the battery throughout the 24 hours which is dependent on the weather conditions is illustrated in Figure 8. The scheduling between the renewable energy sources and the battery where micro-grid would be supplied is shown in Figure 9.

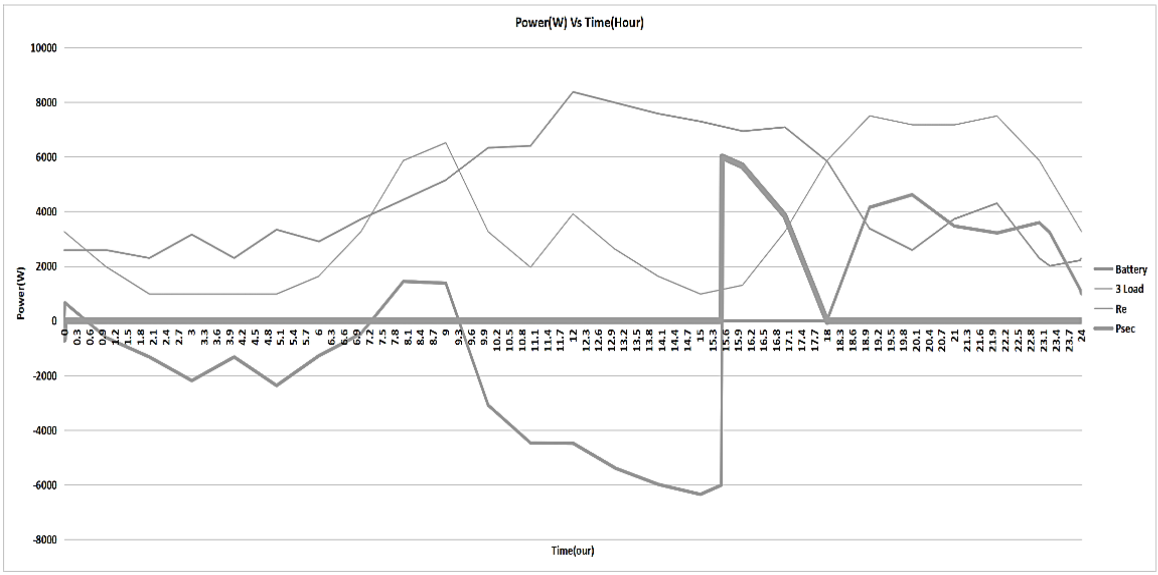

Figure 6. Total power generation by RESs, load demand, surplus power (Psec) and battery power requirement (charging and discharging modes) at MG

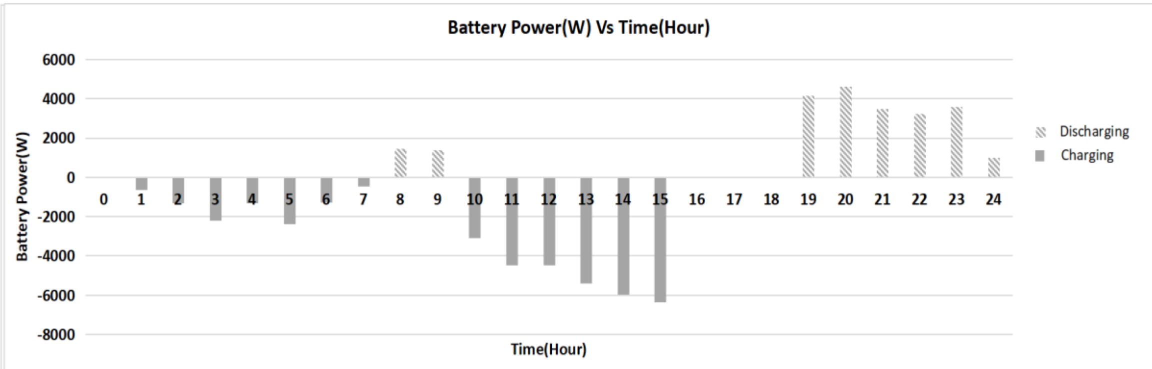

Figure 7. Battery Power on charging and discharging modes at the micro-grid

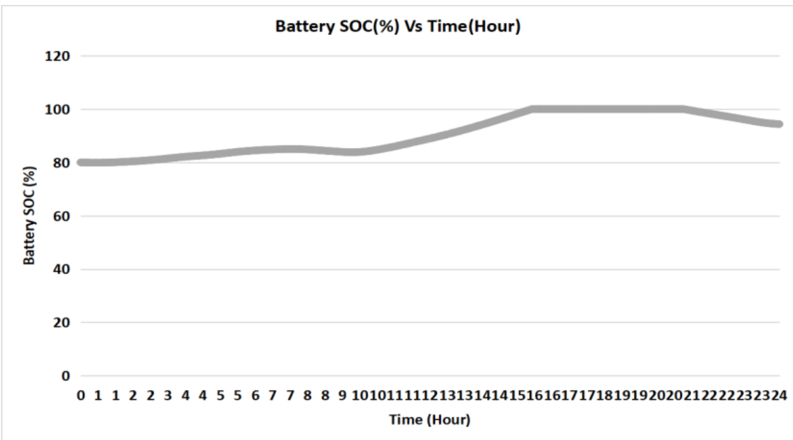

Figure 8. State of charge of the battery at the micro-grid

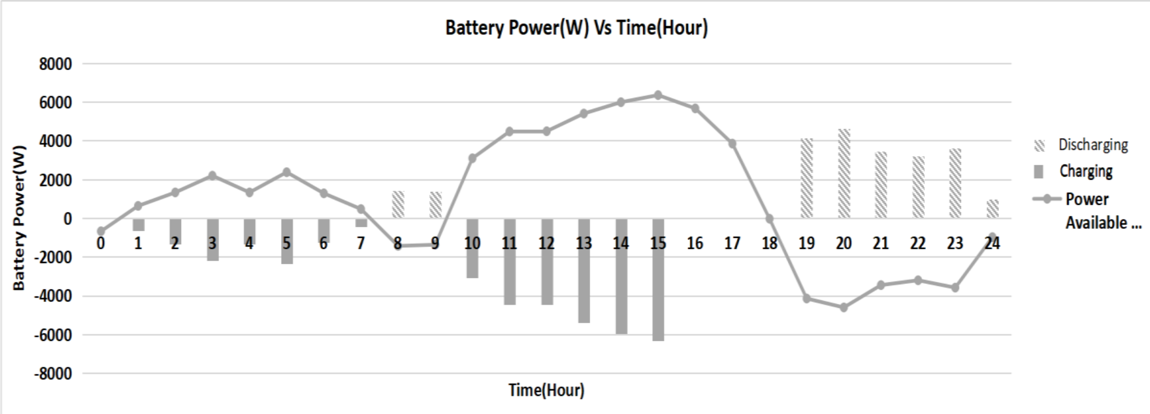

Figure 9. Power distribution and battery power on charging and discharging at the microgrid

From the Figure 10, the surplus and shortage energy can be found by having a total in between the differences on total of renewable energy from solar PV panel generation, wind turbine generation and load demand where if the value is in positive, it means that it is an excess energy at MG and can be used for charging the battery storage. When the value is in negative, it showed that the MG is in shortage of energy and need to extract energy from battery storage by discharging it accordingly on load demand energy.

There is surplus power secondary (Psec) in the system at 17 hours until 2000 hours because the state of charge for the battery reached 100% where the charging and discharging is not being controlled by the battery controller and when the system has a shortage energy, the surplus energy from Psec will be supplied to the load demand. When the system still has a shortage of energy, the battery storage will discharge its energy where it is being performed by the battery controller to supply the load demand.

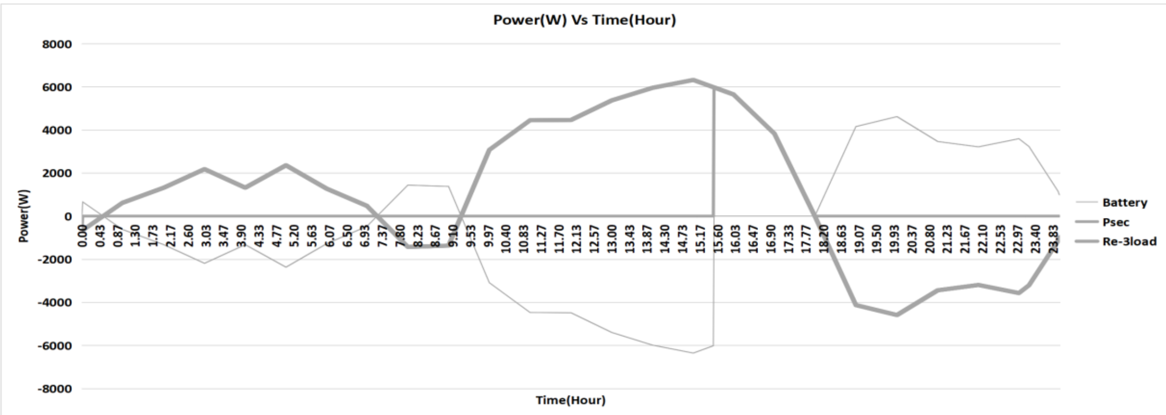

Figure 10. Total power generation by RES and load demand, surplus power (Psec) and battery power at MG

Figure 11 shows the power secondary where it can be calculated based on the (6), where it signals the MG and the signal will be read by the battery controller in order to perform the charging or discharging mode for the battery storage. At 1500 hours until 1800 hours, the value is at zero because the battery controller is not performed for the charging and discharging modes for the battery storage. At 1800 hours, the battery controller is performed because of the signal from the power secondary where the value of the signal is in a negative value, the battery storage will discharge its power to satisfy the loads' demand.

3.1. Case study: solar PV power generation sudden decrease

In this segment, a case study where a sudden decrease in the solar power has been considered in between 0900 and 1000 hours. This situation usually caused by the environment or natural phenomenon. For example, cloudy environment where this will affect the output energy from the solar power, where it depends on the irradiation from sunlight. From 0900 hours until 1000 hours, as shown in Figure 12, where a sudden decrease in solar power caused the demand load of 6559W which exceeds the generation capacity by 3171W. This caused the system at power secondary to generate a signal of -1378W, which is required from the battery energy storage to discharge into the system to fulfil the load demand as in [27]. At 1000 hours, the power plant energy operation as usual and supplies the generated power to the micro-grid, where the generation capacity is 6369W, which exceeds the load demand which is 3257W. The power secondary produces a signal of 3112W causing the battery storage to charge because of the excess energy in the micro-grid MG system.

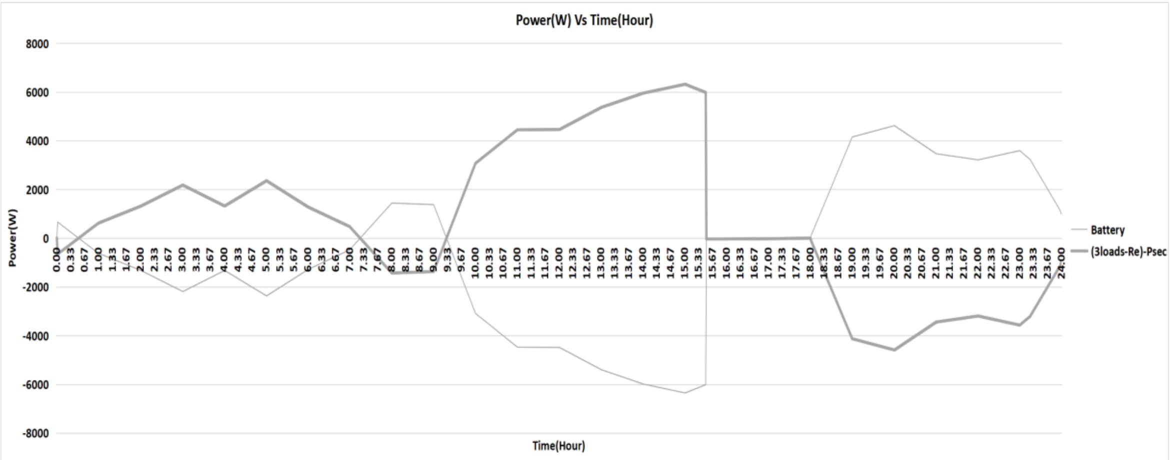

Figure 11. Total power generation by RES and load demand and surplus power (Psec) and battery power at MG

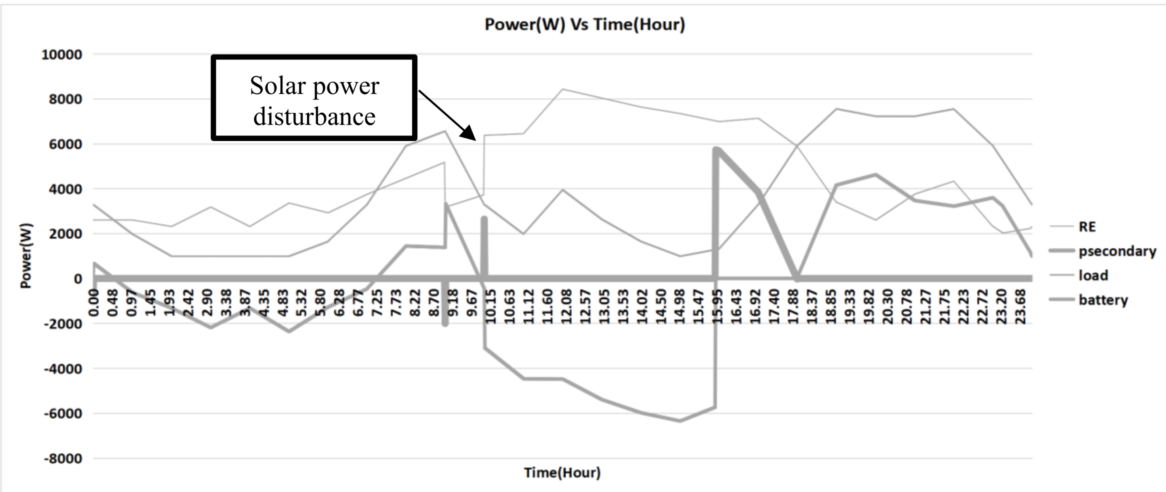

Figure 12. RESs and DESs power after a sudden decrease in solar power plant

From Figure 13, it's shown that the state of charge for the battery storage decrease from 83.54% to 82.97% where discharging mode occurs at 0900 hours because it receives a signal from the secondary power for -1378W. At 1000 hours, the state of charge for the battery increases because it receives a signal from secondary power (Psec) with a value of 3112W, which is causing the battery storage to be in charging mode and causing the increase on state of charge of the battery storage from 82.97% to 84.85% at 1100 hours. The results showed that, the proposed scheme manages to solve the sudden decrease of any energy source especially, in this case involving the solar power plant where the energy produced varies according to the irradiance that being provided by the sunlight and could be disturbed if the weather is cloudy or any event that could disturb the process of receiving sunlight by the solar power plant generation [28].

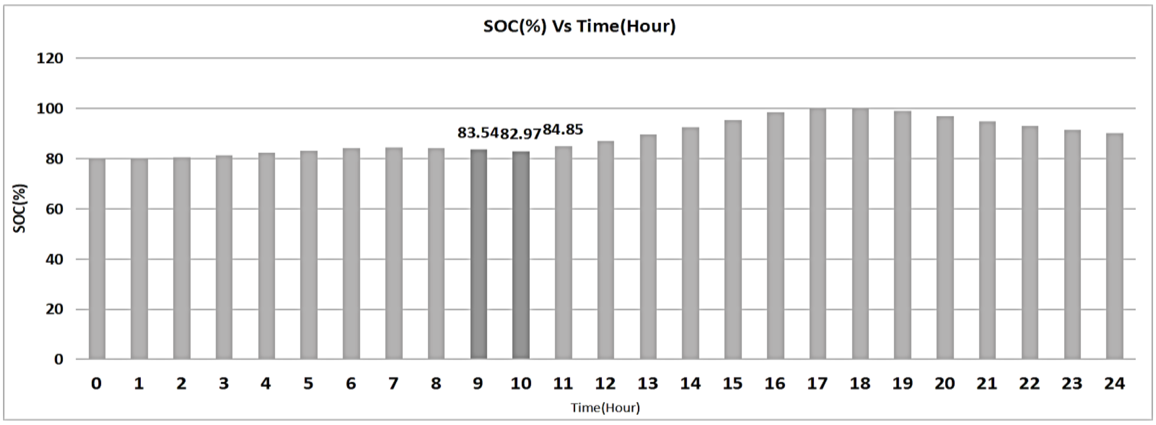

Figure 13. SOC after a sudden decrease in solar power plant

3.2. Analysis and discussion

The charging and discharging modes of the battery storage are being performed by the battery controller where in this study the power droop controller is being used. The battery storage is in charging mode when there is surplus energy generation from the renewable energy sources. Also, the battery storage is in discharging modes in order to serve the loads when the generated energy cannot satisfy the load demand and using the secondary power, Psec as power signal that will be read by the battery controller as in Figure 9. The results show the coordinated charging and discharging of the DESS where this can avoid a lot of power quality issues, where it is being determined by Pahasa et al. 2015 that uncoordinated charging and discharging can cause serious issues in power system such as high power losses, increased faults levels, and voltage deviations.

The state of charge of the battery storage is one of the main focuses which is being considered in this study, where the state of charge is limited in between the minimum and maximum which are 0% and 100% respectively. When there is surplus energy in the micro-grid, the battery storage charging is not being performed by the battery controller. On the other hand, when the state of charge of the battery reached 100% where the battery energy will remain zero and the excess energy will be supplied to the loads when there is insufficient energy generation from RESs to serve the loads as in Figure 10. The discharging mode of the battery storage will be performed by the battery controller when the power generation from RESs and surplus energy in MG cannot satisfy the loads demand as in Figure 11. From the case study, the charging and discharging modes of the battery storage are being performed by the battery controller accordingly, where it shows the effectiveness even if there is power disturbance from renewable energy sources generation as in Figure 12.

4. CONCLUSION

In this research, the interactions between the proposed DESS, proposed RESs and proposed micro-grid MG has been examined. The main focus for this research is on examining the charging and discharging modes of the battery between the DESS and the MG in order to solve the irregularity issues occurred in the MG system related to the RESs power generation. Power sharing system of the micro-grid has been successfully achieved by using the battery controller based on the droop characteristics techniques, where the DESS is controlled by the battery controller for the charging and discharging modes in the micro-grid system. The simulation results verified the efficiency on the DESS on handling the power distribution in the typical MG by using the battery controller. Impact of the DESS has been discussed in case of sudden decreasing of any one of the renewable energy resources. The proposed system has been executed satisfactorily and has obtained promising results.

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REFERENCES

[1] L. A. de Souza Ribeiro, *et al*., "Isolated micro-grids with renewable hybrid generation: The case of Lençóis island," *IEEE Transactions on sustainable energy,* vol. 2, no. 1, pp. 1-11, September 2010.
[2] L. Xu and D. Chen, "Control and operation of a DC microgrid with variable generation and energy storage," *IEEE transactions on power delivery,* vol. 26, no. 4, pp. 2513-2522, July 2011.
[3] D. E. Olivares, C. A. Cañizares, and M. Kazerani, "A centralized energy management system for isolated microgrids," *IEEE Transactions on smart grid,* vol. 5, no. 4, pp. 1864-1875, April 2014.
[4] M. Hosseinzadeh and F. R. Salmasi, "Power management of an isolated hybrid AC/DC micro-grid with fuzzy control of battery banks," *IET Renewable Power Generation,* vol. 9, no. 5, pp. 484-493, June 2015.
[5] A. Tani, *et al*., "Energy management in the decentralized generation systems based on renewable energy-Ultracapacitors and battery to compensate the wind/load power fluctuations," *IEEE Transactions on Industry Applications,* vol. 51, no, 2, pp. 1817-1827, September 2014.
[6] I. Alhamrouni, *et al*., "AC-based differential evolution algorithm for dynamic transmission expansion planning," *Telkomnika,* vol. 16, no. 5, pp. 2316-2330, October 2018.
[7] W. Kempton, J. Tomić, "Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy," *Journal of power sources,* vol. 144, no. 1, pp. 280-294, June 2005.
[8] J. Pahasa and I. Ngamroo, "PHEVs bidirectional charging/discharging and SoC control for microgrid frequency stabilization using multiple MPC," *IEEE Transactions on Smart Grid,* vol. 6, no. 2, pp. 526-533, December 2014.
[9] M. A. A. Ibrahim Alhamrouni, *et al*., "Load flow based voltage stability indices for voltage stability and contingency analysis for optimal location of statcom in distribution network with integrated distributed generation unit," *TELKOMNIKA,* vol. 16, no. 5, pp. 2302-2315, October 2018.
[10] I. Alhamrouni, *et al*., "Design and development of SEPIC DC-DC boost converter for photovoltaic application," *Int J Pow Elec & Dri Syst ISSN,* vol. 2088, no. 1, pp. 406-413, March 2019.
[11] I. Alhamrouni, *et al*., "Modeling of micro-grid with the consideration of total harmonic distortion analysis," *Indonesian Journal of Electrical Engineering and Computer Science* vol. 15, no. 2, pp. 581-592, August 2019.
[12] I. Alhamrouni, *et al*., "Modelling and design of PID controller for voltage control of AC hybrid micro-grid," *Int J Pow Elec & Dri Syst,* vol. 10, pp. 151-159, 2019.
[13] I. Alhamrouni, *et al*., "Design of single phase inverter for photovoltaic application controlled with sinusoidal pulse width modulation," *Indonesian Journal of Electrical Engineering and Computer Science,* vol. 15, no.2, pp. 620-630, August 2019.
[14] Shahnia F, *et al*., "Coupling Neighboring Microgrids for Overload Management Based on Dynamic Multicriteria Decision-Making". *IEEE Transactions on Smart Grid*, vol. 8, no. 2, pp. 969-983, March 2017.
[15] Emily W. Prehoda, *et al*., "U.S. strategic solar photovoltaic-powered microgrid deployment for enhanced national security". Renewable and sustainable Energy Reviews, vol. 78, pp. 167-175, Oct 2017.
[16] Fernando Cardoso Melo, Robson Ruiz Spaduto ; Luiz Carlos Gomes de Freitas ; Carlos Eduardo Tavares; Jose Rubens Macedo Jr ; Paulo Henrique Oliveria Rezende. "Harmonic Distortion Analysis in a Low Voltage Grid-Connected Photovoltaic System". *IEEE Latin America Transactions*, vol.13, no. 1, pp.136 – 142, 2015.
[17] Peças Lopes, *et al*., "Control Strategies for microgrids black start and islanded operation," Porto: INESC, 2005.
[18] Morris G, *et al*., "A Framework for the evaluation of the Cost and Benefit of Microgrids," *CIGRÉ International Symposium*, 2011.
[19] Chittum, A, "Valuing Resiliency: How Should We Measure Risk Reduction? ACEEE Summer Study on Energy Efficiency in Buildings. American Council for an Energy-Efficient Economy," *2016 ACEEE Summer Study on Energy Efficiency in Buildings,* 2016.
[20] Iman Askarian, Suzan Eren, Majid Pahlevani, Andy M. Knight. "Digital Real-Time Harmonic Estimator for Power Converters in Future Micro-Grids". *IEEE Transactions on Smart Grid,* vol.9, no. 6, pp.6398–6407, 2018.
[21] European Commission, "Best Practices on Renewable Energy Self-Consumption," *Brussels: European Commission*, 2015.
[22] Parisio, Alessandra, and Luigi Glielmo. "Energy efficient microgrid management using model predictive control." *In 2011 50th IEEE Conference on Decision and Control and European Control Conference*, pp. 5449-5454, 2011.
[23] Luna, A. C, *et al*., "Cooperative energy management for a cluster of household prosumers. *IEEE Transactions on Consumer Elecrics*, vol. 62, no. 3, August 2016.
[24] Grainger, John J, "Power System Analysis," *Tata McGraw-Hill*, 2003.
[25] Arefi, *et al*., "Tertiary Controller-based Optimal Voltage and Frequency Management Technique for Multi-Microgrid Systems of Large Remote Towns". *IEEE Transactions on Smart Grid*, vol. 9, no. 6, pp. 5962-5974, May 2017.
[26] Pashajavid, *et al*., "Provisional internal and external power exchange to support remote sustainable microgrids in the course of power deficiency". *IET Generation, Transmission & Distribution*, vol. 11, no. 1, pp. 246-260, January 2017.
[27] Pashajavid , *et al*., "Overload management of autonomous microgrids", *IEEE 11th International Conference on Power Electronics and Drive Systems*, 73–78, June 2015.
[28] Pashajavid E, *et al*., "Overloading conditions management in remote networks by coupling neighboring microgrids". *2015 50th International Universities Power Engineering Conference (UPEC)*, pp. 1–6, Sept 2015.