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Modeling and Simulation of a PV-Diesel-Battery System for a Standalone Microgrid

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***Abstract*—This paper presents a standalone Photovoltaic (PV)-diesel-battery system for a resort island. The system is designed to meet the demand for a typical load for islands in the South China Sea. The location selected is Tioman Island as it represents typical resort island within the South China Sea. The populations in these areas depends on diesel generations for electricity that have unpredictable prices, high operation costs, and high amount of greenhouse gasses such as CO_2. However, these islands have potential for installation of PV and other renewable energy (RE) generations due to the land sizes and abundance of renewable resources. Hence, this study aims to develop a PV model to simulate the performance of an actual system deployed on the island. The system comprises of a 1 MW PV array, Maximum Power Point Tracking (MPPT) based on incremental conductance method that are connected to 11 kV distribution network. The model utilizes actual renewable resource input such as irradiance and temperature to simulate the potential PV system generation. Moreover, actual load profile used to demonstrate the capability of a PV system to satisfy the island's load demand. This model is highly customizable where PV model, MPPT algorithm can be varied to simulate performance of other configurations.**

Keywords*—PV system; microgrid; MATLAB; MPPT; Renewable Energy

I. INTRODUCTION

According to REN21, the share of renewable energy has increased to 21.5 % with 402 GW of PV system is running in the year 2017 [1]. The PV system installation roses 33% from previous year. The drops of PV prices due to new business models, effective government policies and changes in markets has contributed to higher PV system installation globally.

Most of the populations in an island relies on diesel fuel for energy consumption. Therefore, many researches have been found to design renewable energy system to meet the load demand in an island. Most of the researchers focuses on hybrid RE system where the solar PV combined with other renewable sources such as small hydro and wind alongside diesel generator. For example, Saban Yilmaz et al. proposed hybrid PV-Diesel-Battery system for an island in Kilis, Turkey [2]. The research highlights the optimal RE configurations in the island based on hybrid optimization software such as HOMER. Moreover, Khan et al. focuses on optimal sizing of PV-wind-diesel-hydro-battery for a resort island in South China Sea. The author also proposes a new controller to optimize the energy management for the microgrid system on the island [3], [4]. Ihsan Ali et al. provides preliminary analysis for rooftop solar PV installation at Maldives [5]. The installation of PV system would reduce the diesel fuel dependency since the island depends on imported fossil fuel with high cost. Additionally, Prachuab Peerapong et al. proposed integration of solar PV system into existing diesel generation for an island in Thailand [6]. The study utilizes HOMER to identify the optimal PV size according to Net Present Value (NPC). Similarly, Garima Singh et al. presents an optimal sizing for PV-wind-battery system for island Kavaratti, India, where most of the island in the country electrified by diesel generator. Other examples of hybrid RE system for an island in India includes the development of standalone PV-battery system for Andaman and Nicobar island [7]. The authors proposed 12 kW PV system for electrification of those islands where grid connection is not possible. P. Blechinger et al. presents analysis for potential RE system for 1800 small island [8]. The analysis comprises of the island's current power generation system, population, energy demand and economic activity. Pedro Cabrera et al. also presents a framework for increasing the renewable energy share such as PV system for Gran Canaria island in Spain [9].

Not limited to modeling and techno-economic analysis of a PV system. There were also works that concentrates in improving the performance of the RE system through implementation of advanced controller such as Artificial Neural Network [10], Fuzzy [11], [12], and Particle Swarm Optimization [13]. The improvement for the PV system were made through implementation of the advance control methods in the MPPT and also through predictions.

This study will present modeling and simulation of a standalone PV system. The physical system was modeled in Simulink SimPowerSystems. Unlike other works that focuses on technical-economic analysis using hybrid energy software such HOMER. This study demonstrates the physical system performance deployed at the selected location. Variation of components can be used to monitor system performance through customizable models.

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This paper structured as follows: Section II presents the PV system model that includes inputs and model components. Meanwhile, Section III discusses on the simulation results. Finally, Section IV summarizes this paper and discusses on the future works.

II. PV System Model

A. Input

The model utilizes inputs from renewable resources such as irradiance and temperature. Both were collected from Malaysian Meteorological Department at the selected site. The temperature data is used to simulate the effect of temperature variation toward PV module performance. Moreover, actual load profile data was collected from the location. The irradiance and load profile input are shown in Figure 1 and Figure 2 respectively.

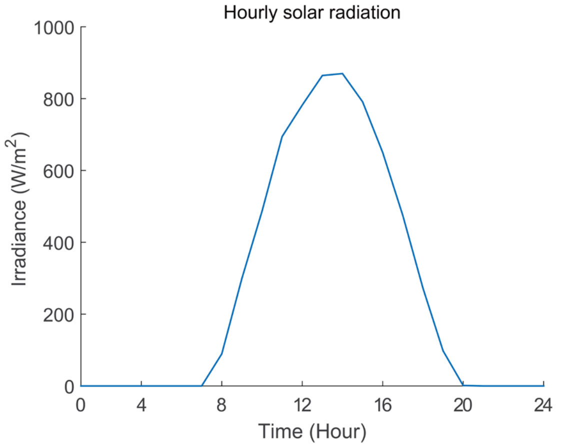

Figure 1. Load profile

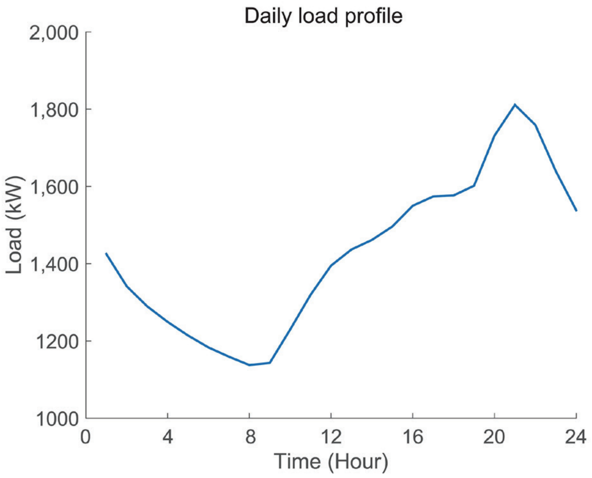

Figure 2. Solar radiation

B. MPPT

The MPPT is a typical controller that is used to maximize the power output from a solar PV panel under all load conditions. There are several MPPT algorithm available. However, in this study Incremental Conductance method was used. This scheme adjusts the PV array terminal voltage to match maximum power point based on incremental

conductance of the modules. Figure 3 shows the MPPT control scheme of incremental conductance method.

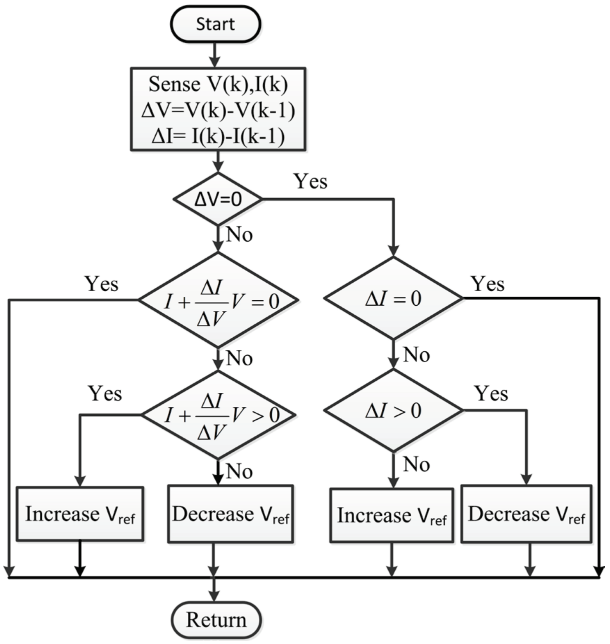

Figure 3. Incremental conductance MPPT method

C. Model

The Simulink SimPowerSystems schematic is shown in Figure 4. The microgrid consists of two 500 kW PV array with a total combined capacity of 1 MW. The battery storage system has a capacity of 10,800 Ah. The system will be integrated with a 2.5 MW diesel generator that is currently operation on the island.

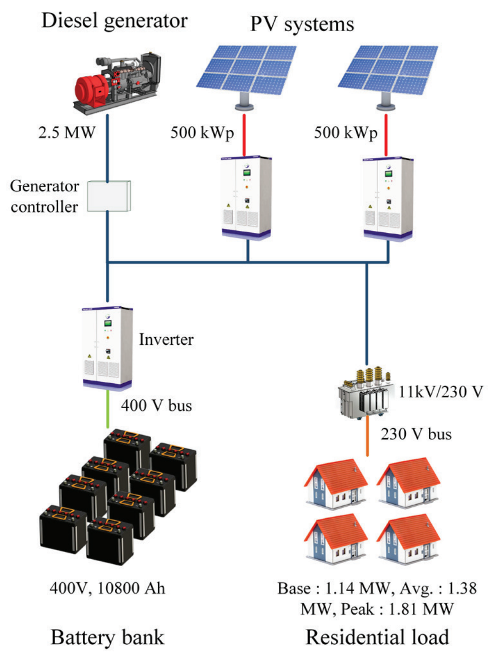

Figure 4. Microgrid system

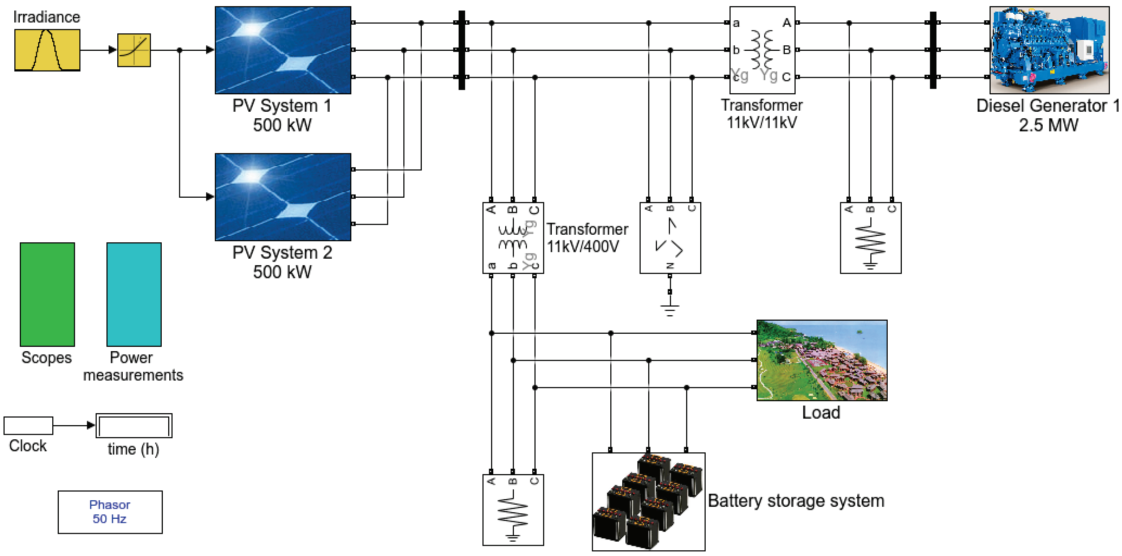

Figure 5. PV system microgrid Simulink model

The load following strategy being used for battery charging where only excess PV generation will charge the battery. During the day, the load demand will be supplied by using PV system. Diesel generator will be turned on if PV system unable to meet the demand. During night, battery storage system will be discharged to supply the load alongside diesel generator. The microgrid model is shown in Figure 5. The simulation time is 24 hours to simulate system performance daily.

III. Simulation Results

The simulation results of the system power outputs are illustrated in Figure 6 . The simulation shows most of the loads were meet by the diesel generator throughout the day. During the day, the PV system able to deliver power up to 0.5 MW. Meanwhile, the battery storage was used when PV system unable to deliver power due to no solar radiation. The load profile presented in this work follows typical demand for a

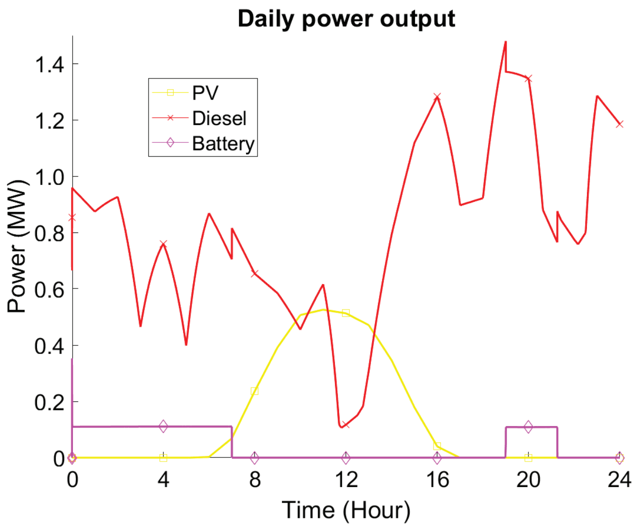

Figure 6. Daily power output of PV-diesel-battery system

resort island in South China Sea. The energy management strategy for the microgrid system is shown in Figure 7.

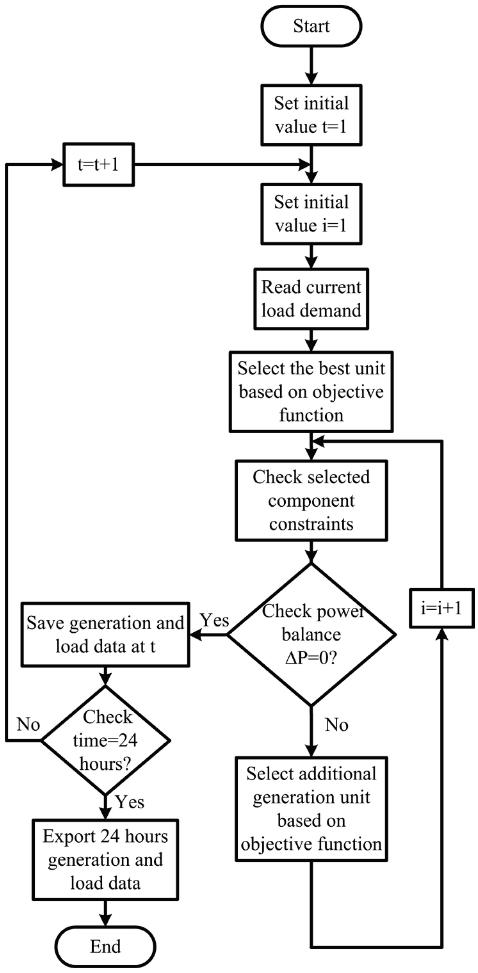

Figure 7. Energy management strategy for power dispatch in microgrid.

The PV system able to reduce diesel generations from 11:00 to 13:00 because of peak solar time. In this scenario, the battery storage has initial 80% state-of-charge (SOC). At end of the day, the battery SOC dropped to 20% capacity.

IV. Conclusion

The microgrid comprises of PV-diesel-battery presented in this study shows promising results in showcasing actual performance on site. The model capable to simulate PV system with input such as irradiance while meeting the actual load demand. Not limited to location presented in this study, the model can be used to simulate performance of PV-diesel-battery at any other locations. More advanced controller can be used to develop high performance hybrid generation system.

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References

[1] E. Martinot, *Renewables 2017: Global status report (REN21)*. Worldwatch Institute Washington, DC, 2018.

[2] S. Yilmaz and F. Dincer, "Optimal design of hybrid PV-Diesel-Battery systems for isolated lands: A case study for Kilis, Turkey," *Renew. Sustain. Energy Rev.*, vol. 77, pp. 344–352, 2017.

[3] M. R. Basir Khan, R. Jidin, J. Pasupuleti, and S. A. Shaaya, "Optimal combination of solar, wind, micro-hydro and diesel systems based on actual seasonal load profiles for a resort island in the South China Sea," *Energy*, no. 0.

[4] M. R. B. Khan, R. Jidin, and J. Pasupuleti, "Multi-agent based distributed control architecture for microgrid energy management and optimization," *Energy Convers. Manag.*, vol. 112, pp. 288–307, 2016.

[5] I. Ali, G. M. Shafiullah, and T. Urmee, "A preliminary feasibility of roof-mounted solar PV systems in the Maldives," *Renew. Sustain. Energy Rev.*, vol. 83, pp. 18–32, 2018.

[6] P. Peerapong and B. Limmeechokchai, "Optimal electricity development by increasing solar resources in diesel-based micro grid of island society in Thailand," *Energy Reports*, vol. 3, pp. 1–13, 2017.

[7] S. Bhakta and V. Mukherjee, "Performance indices evaluation and techno economic analysis of photovoltaic power plant for the application of isolated India's island," *Sustain. Energy Technol. Assessments*, vol. 20, pp. 9–24, 2017.

[8] P. Blechinger, C. Cader, P. Bertheau, H. Huyskens, R. Seguin, and C. Breyer, "Global analysis of the techno-economic potential of renewable energy hybrid systems on small islands," *Energy Policy*, vol. 98, pp. 674–687, 2016.

[9] P. Cabrera, H. Lund, and J. A. Carta, "Smart renewable energy penetration strategies on islands: The case of Gran Canaria," *Energy*, vol. 162, pp. 421–443, 2018.

[10] M. Y. Zhai *et al.*, "Adaptation of Cascade Hydropower Station Scheduling on A Headwater Stream of the Yangtze River under Changing Climate Conditions," *Water*, vol. 9, no. 4, p. 293, 2017.

[11] A. Ali and A. N. Hasan, "Optimization of PV model using fuzzy-neural network for DC-DC converter systems," in *2018 9th International Renewable Energy Congress (IREC)*, 2018, pp. 1–6.

[12] S. Samal, P. K. Barik, and S. K. Sahu, "Extraction of maximum power from a solar PV system using fuzzy controller based MPPT technique," in *2018 Technologies for Smart-City Energy Security and Power (ICSESP)*, 2018, pp. 1–6.

[13] L. Gong, W. Cao, and J. Zhao, "An improved PSO algorithm for high accurate parameter identification of PV model," in *2017 IEEE International Conference on Environment and Electrical Engineering and 2017 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I CPS Europe)*, 2017, pp. 1–5.