Study of Microgrid Hybrid System of Photovoltaic and Diesel Engine

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Background

Indonesia has many remote areas and small islands which have yet to get access on electricity. In 2014, electrification ratio in Indonesia was at 81.70% [1]. The data show that there were 3,132 of 78,609 villages which have not been electrified yet [2]. On the other hand, Indonesia has various energy sources such as solar, water and bioenergy that can be used for generating electricity in rural area. In Indonesia, solar energy potential is about 4.8 kWh/m^2/day and wind velocity is about 3-6 m/s [3]. Whereas for bioenergy, Calophyllum inophyllum and Jatropha curcas are some of the plants in Indonesia that can be used as biofuel. The potential yield of these plants to produce bioenergy is about 4,680 and 1,900-2,500 kg of oil per hectare per year, respectively [4].

Furthermore, characteristic of renewable energy resources is intermittent in nature. So, the application of renewable energy resources should work together with energy resources that can produce more stable energy in hybrid system. Considering that there are generator sets in rural areas, the idea is to produce electricity generation using hybrid system consist of diesel engine and photovoltaic (PV). The experiment will focus on observing and analyzing the characteristics of the hybrid system which consist of 1 kWp photovoltaic and 3 kW diesel engine. Experiment was conducted in Combustion Engines and Propulsion System Laboratory, Institut Teknologi Bandung.

Aim

To probe the characteristic of hybrid system which consist of photovoltaic and diesel engine

Experiment

The whole system consist of 1 kWp photovoltaic, 3 kW diesel engine, bidirectional inverter, solar charge controller, battery, load and monitoring system. The diesel engine specification is lister type with power rating of 3000 watt and operate normally at 650 RPM. The inverter type is bidirectional inverter, it can convert current from Direct Current (DC) become Alternating Current (AC) and vice versa. The specification of inverter is Conext XW+7048 by Schneider Electric with continous power output of 5500 W. The specification of solar charge controller is Conext MPPT 60 150 from Schneider Electric. The battery capacity is 200 Ah consisting of 8 batteries in series and 2 parallels to satisfy inverter input. Monitoring system using Conext Combox from Schneider Electric. The hybrid system scheme is shown in Figure 1.

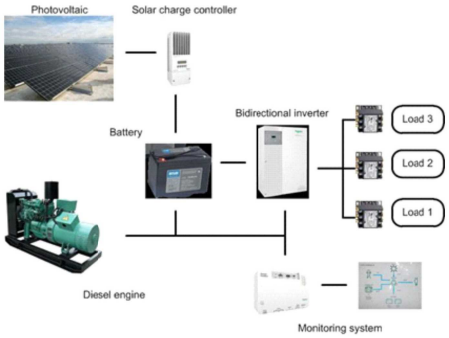

Figure 1. Scheme of smart microgrid hybrid system

Hybrid experiment started with the setting of diesel engine supply as the base load. Independent variable to be change was load power. First, load was set at 1000 watt and diesel engine supply 500 watt. The load was increased each with 500 watt after 10 minutes, but keeping diesel engine supply constant. So, it would have 4 variations of load when the diesel engine supply was 500 W, i.e. 1000 W, 1500 W, 2000 W and 2500 W. Then adding the diesel engine supply to become 1000 W with 3 variations of load, 1500 W, 2000 W and 2500 W. If the diesel engine produce 1500 W, the load variatons are 2000 W and 2500 W and the last was supply power from diesel engine was 2000 W and the load was 2500 W.

Result

Before starting the experiment, the measurement of solar radiation at the place of experiment is shown in Figure 2. Maximum solar radiation was 918.1 W/m^2, the minimum value was 88.2 W/m^2 and the average was about 683.1 W/m^2.

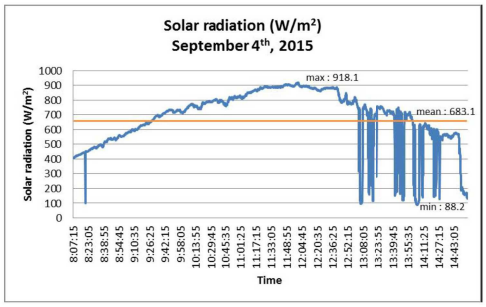

Figure 2. Measured solar radiation

Figure 3 shows the result of system consist of battery and load. There were 2 battery banks parallelly connected. The first battery banks supply power to load and second battery bank receives power from photovoltaic. Figure 3 shows that battery will supply more power when the load is higher. It means that the battery needs more power to convert from DC to AC. The trend of this result match with the convertion efficiency characteristic show in Figure 4.

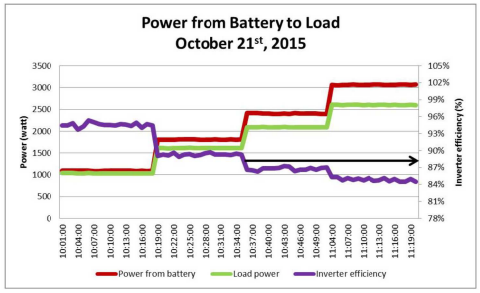

Figure 3. Power supply from battery to load

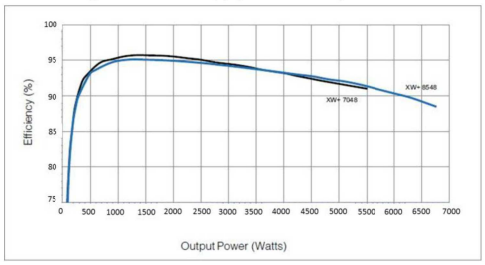

Figure 4. Convertion efficiency characteristic of inverter Conext XW+ 7048 [5]

Figure 5 shows that the power from PV was saved in battery bank 2. The power from PV pass through the solar charge controller and bidirectional inverter before it was saved in battery bank 2 in DC mode.

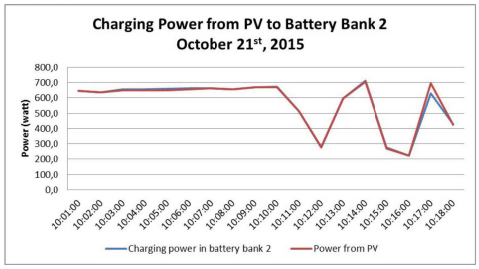

Figure 5. Power from PV charging battery bank 2

The second configuration used diesel engine to supply load. The supply from diesel engine was adjusted from inverter by defining the limit of maximum current which was allowed by inverter. Figure 6 shows the results of diesel experiments. The inverter efficiency for diesel engine was different from inverter efficiency for battery because output from generator was AC mode, the same mode with load. So basically, the power only passed through the inverter.

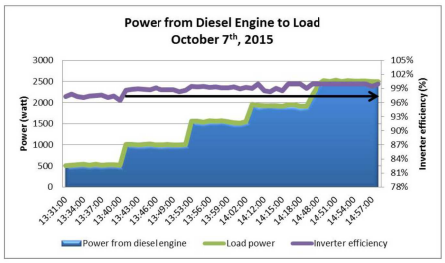

Figure 6. Power supply from diesel engine to load

The last experiment and the most important part set the system in hybrid configuration. Figure 7 and Figure 8 show the result of hybrid system. Figure 7 shows the result when diesel engine generate power from high power to low. Figure 8 shows the diesel engine generate power from low to high. Figure 8 shows that the inverter took time to synchronize with diesel engine when the supply from diesel engine was changed. When it happened, load will be automatically supplied by battery bank 1.

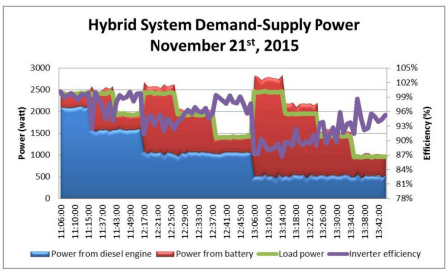

Figure 7. Hybrid power supply when diesel engine power was decrease

The inverter needs to synchronize with diesel engine because when output power from diesel engine is changed, the RPM of diesel engine will change, which means changing the frequency as well.

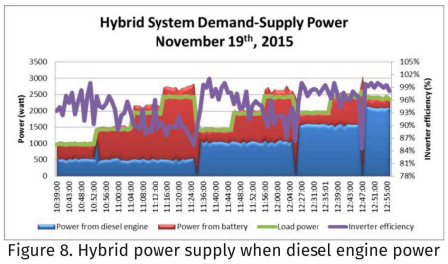

Figure 8. Hybrid power supply when diesel engine power was increase

Acknowledgements

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References

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