Synchronization Testing of Hybrid Generators (Solar and Wind) Based on DC - AC Inverters

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Abstract

Hybrid electricity generation is a combination or integration of several types of renewable energy based power plants. Generating systems typically used are solar power plants and wind power plants. The two types of power plants are operated together on one rail/busbar to serve the maximum load. This study will test the synchronization system of hybrid power plants (solar and wind) based on a DC-AC inverter using a buck-boost converter. The input voltage on the inverter remains constant at 12 volts and loads 220 watts. The test is carried out on the Alternating Current load and Direct Current load.

Keywords
Renewable energy, Converter, Inverter, Hybrid

1. Introduction

Based on data from the Ministry of Energy and Mineral Resources that the potential of solar energy in Indonesia is 0.87 GW in 2024 and wind energy is 0.97 GW in 2025. To support this potential, the government issues regulations on national energy policies (Kemenkumham 2006). North Sumatera, has a topology with an altitude of 0-1400 m above sea level, causing many remote areas that are not reached by on-grid electricity. It is very important that energy experts find solutions to solve these problems. Therefore research on the availability of renewable energy sources continues to be carried out by combining several renewable energy sources (Zhou et al. 2010). Hybrid power plants are a combination or integration of several types of renewable energy-based power plants (Hayu and Siregar 2018). Both types of power plants are operated simultaneously on one rail / busbar to service loads. Independent hybrid renewable energy systems usually incur lower costs and show higher reliability than photovoltaic (PV) or wind systems (Bhandari et al. 2014) and (Bhandari *et al.*, 2015).

Hybrid power systems can range from small systems that are able to provide electrical energy for one house to a large system that can drain electricity for a village or island. Hybrid electric power systems have a large impact on remote areas, especially developing countries where national electricity networks are not technically and economically feasible (Bhandari *et al.*, 2015) and (Nehrir et al. 2011).

The potential for solar power in Indonesia in general is at a sufficient level (Nurliyanti and Pandin 2014). The supply of solar energy received by the earth's surface is reaching 3x1024 joules per year, this energy is equivalent to 2x1017 Watts. That amount of energy is equivalent to 10,000 times the energy consumption in the world today. Indonesia also has sufficient wind capacity, because the average wind speed in Indonesia ranges from 3-6 m/s. Higher speeds can be obtained in the Nusa Tenggara region. While islands such as Sumatra, Java, Kalimantan, Sulawesi and Papua only have wind speeds of 2.7– 4.5 m/s . Turbines used in general use designs from Europe and America which are continents with the greatest wind potential with speeds of around 9-12 m/s (Wuriyandani 2015) so it is necessary to do research related to the design of suitable turbines in Indonesia. use of CAD / CAA Tools to analyze hybrid systems through linear programming techniques with the aim of minimizing average electricity production costs and to achieve a reliable system taking into account environmental factors both in design and operation (Chedid 1997).

The undirectional electrical energy produced by hybrid plants is stored in the battery, transformed into alternating electrical energy. This is caused by electrical loads that require alternating current such as television, lights and others, there are still many who use alternating electricity supply. To convert electrical energy in a direction to alternating use an inverter (DC-AC converter) (Hamzah and Hendri 2016).

Research on "Multi-Control Design DC-DC Converter Inputs of Wind Turbine and Solar Cell Hybrid Systems Using Fuzzy Logic Controls" is carried out using DC/DC input which is controlled using fuzzy logic controller which can produce maximum power from the maximum solar cell power and wind turbines so that losses to solar cells and wind turbines can be minimized (Pamuji, 2015) and (Dileep and Singh 2017) and (Hossain and Rahim 2018).

The inverter is used to convert DC - AC voltage. The output of the inverter can be a regulated voltage and a fixed voltage. The input voltage source of the inverter can use batteries, fuel cells, solar power, or other DC voltage sources. The output voltage that is usually produced is 120 V 60 Hz, 220 V 50 Hz, 115 V 400 Hz, while the boost converter serves to regulate the wind turbine voltage to the load voltage, so that the output power is always at maximum power point (Hidayatullah and Ningrum 2016).

Buck Converter is a circuit where the output voltage value is lower than the input voltage value, buck converter circuit consists of an inductor, capacitor, and a switch in the form of a MOSFET. The working principle of the buck converter circuit is divided into two conditions, namely the condition of the switch on and the switch condition off. When the switch is on, current flows from the source to the inductor so that there is a process of storing the current in the inductor. At the same time the capacitor will store energy in the form of voltage. The second condition is when the switch is off and there is no voltage source, the current stored in the inductor is released towards the load. In this process, the inductor empties energy stored in the entire series. If the switch is on again before the inductor runs out completely, the voltage at the load will always be greater than zero (Shiau and Cheng 2010)(Saharia 2016).

This study will conduct synchronization experiments of hybrid (solar and wind) generators based on DC-AC inverters using buck-boost converters to determine the performance of hybrid generator systems in North Sumatera. Experiments are carried out on 3 character loads, namely: resistive, inductive and capacitive loads to obtain accurate test results in serving household loads.

2. Methodology

2.1 Hybrid Power Generation System

Hybrid Electric Power Station consists of: (1) Energy generating sources in the form of: hydropower, wind, solar and others (2) converter (3) inverter (4) battery (5) automatic control for monitoring the system (Sopian et al. 2005). Various components of the hybrid system are arranged in several configurations, namely: (1) series, (2) parallel and (3) hybrid system (Nayar et al. 1993). Optimization of hybrid plants was also carried (Protogeropoulos and Marshall 1997), while the economic calculation of the utilization of hybrid plants for remote areas was carried out (Petrakopoulou 2016). Then for the storage technique carried out (Alotto and Moro 2014), the design of hybrid plants using the Arota hybrid model (Arota and Lumi 2013), hybrid PV and wind (Badwawi et al. 2016) and (Bailera et al. 2017).Then an accurate measurement method of the hybrid Photovoltaic-Wind system using Object-Oriented Programming. This computer program was built based on the photovoltaic model, wind generator, battery, Power Supply Probability (LPSP) algorithm and techno-economic algorithm to determine the system with the lowest investment (Belmili et al. 2014). Research on the use of hybrid systems to supply electricity continuously at load to produce maximum power, using a DC-DC multiple-input buck-boost converter to regulate the flow of power to obtain MPP (Maximum Power Point), so that the efficiency of the wind turbine and photovoltaic can be improved (Pamuji 2015).

Parallel hybrid systems usually use bidirectional inverters to change DC-AC/AC-DC power. In conditions where the battery power is higher than the load, the load will be supplied by the battery through an inverter, while the diesel generator is turned off. if the battery power is less than the load on the diesel engine, then the diesel generator will turn on to serve the load and charge the battery. In this condition the bi-directional inverter as a regulator and battery charger. when the load power is greater than the output power of the diesel engine, the inverter and generator in parallel serve the load. Some of the advantages of doing a parallel combination on a hybrid system are: (1) the load can be served optimally, (2) the high efficiency of the generator, and (3) low investment costs (Nayar et al. 1993).

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2.2 Buck-Boost Converter

At present, DC-DC power converters have become very interesting subjects because of their increased utilization in a wide variety of applications. In general, Photovoltaic (PV) and Wind as a renewable energy resource experiences system instability. Therefore, a DC-DC converter with the Maximum Power Point Tracking (MPPT) algorithm is very important to ensure the maximum available power from PV can be fully utilized (Pamuji 2015).

DC-DC converters are an integral part of the PV system as an impedance adjustment unit between the load and the PV panel. A converter is also needed to adjust the output voltage to the planned requirements. The DC-DC converter consists of several configurations: the buck type as a voltage reducer, the Boost as a voltage booster, while the buck-boost, cuk, single ended primary inductor converter (SEPIC) and Zeta converter to reduce or increase the voltage that is always used with MPPT controller for maximum power tracking (Dileep and Singh 2017). Of the four types of converters, only the buck-boost converter is capable of producing an output voltage smaller than the input voltage (Kok Soon, Mekhilef, and Safari 2013). Then states that the connection can improve PV performance (Enrique and Dura 2007)

2.3 Design System

In this experiment using 100 WP solar modules with the following specifications: panel dimension 117 cm long, 30 cm wide and 82 cm high, the base of the solar panel has a length of 110.5 cm and a width of 68 cm. while the components of wind power plants are designed using 40 mm angled iron as a turbine buffer tower, tower height 215 cm, ½ inch galvanized pipe as a rotor drive on the turbine, 8 inch blade, bearing plate, DC electrical energy generator using a permanent DC magnet type GR53X58 and gear as a turbine connecting device to the generator. For synchronization components, batteries, solar charger control, buck-boost converter, ATMEGA32 microcontroller and power inverter are used.

The experimental series of hybrid power plant synchronization systems carried out in this study, first used the buck-boost converter and the second without using a buck-boost converter. There is a system that uses the buck-boots converter as shown in Figure 1. below.

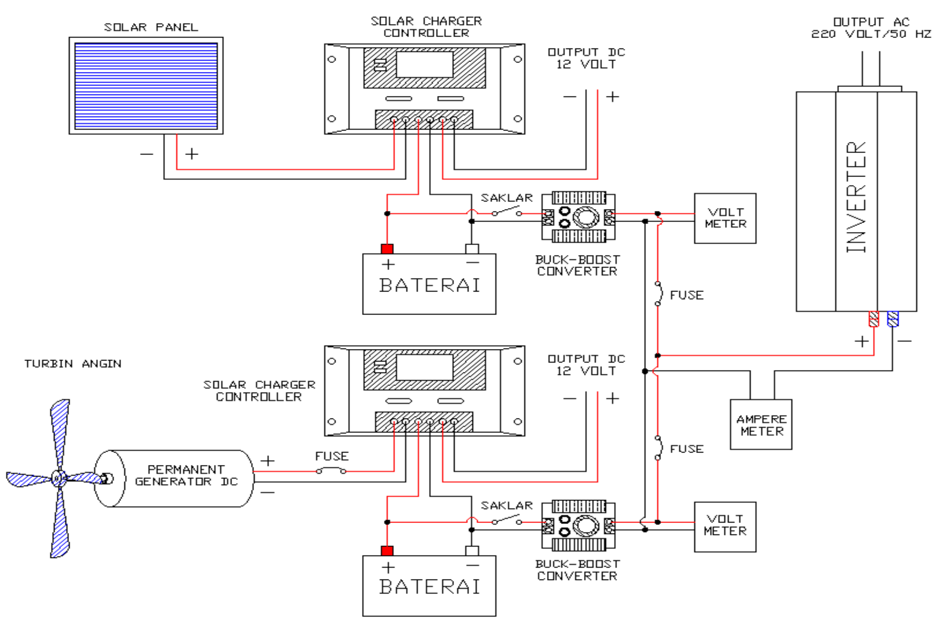

Figure 1. Hybrid generator synchronization series using buck-boost converter

Figure 1 shows a circuit that uses a buck-boost converter, where the battery can be used in the buck boost converter input for voltage assistance to be more stable.

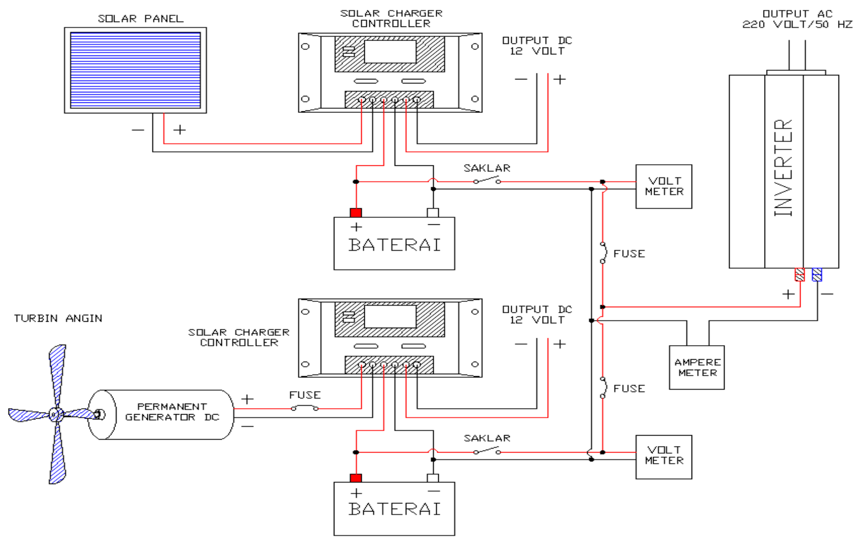

Figure 2. Synchronization circuit without buck converter

Show in figure 2 a synchronization circuit that does not use a buck-boost converter where the two batteries are connected in parallel and also connected directly to the inverter input.

3. Results and Discussion

3.1 Load of Incandescent Lamps, Motors and Capacitors With the Buck-Boost Converter

This test is carried out to determine the maximum loading using a buck-boost converter on the load of lights, motors, and capacitors. Data testing using buck-boost converters can be seen in table.1 below.

Table 1. Experimental data for loading the maximum synchronization of hybrid power plants using the Buck-Boost converter

Load	Voltage Inverter (V)	Current Inverter (I)	Buck-Boost Converter Voltage1	Buck-Boost Converter Voltage 2	Battery Voltage1 (B1)	Battery Voltage 2 (B2)	Current B1+B2
Lamp 6 W	202	0,225	11,925	12,1	12,625	12,65	16,6
Lamp11 W	201,75	0,0525	11,925	12,1	12,625	12,65	16,6
Lamp26 W	202	0,1225	11,925	12,1	12,625	12,65	16,6
Motor 50 W	201,75	0,155	11,925	12,1	12,625	12,65	16,6
Capasitor 3.5 µf	201,75	0,2175	11,925	12,1	12,625	12,65	16,6
Capsitor 4 µf	202	0,2625	11,925	12,1	12,625	12,65	16,6
Beban Total	201,25	1,115	11,925	12,1	12,625	12,65	16,6

Shown in table 3 a testing using light loads, capacitors and motors, the maximum power that can be served using buck-boost converter is 223 watts, 201.25 volt inverter voltage and 1.11 ampere current. The load served is 3 lights, 2 motors and 2 capacitors. This shows the output voltage of the two buck-boost converters drops to 11 volts and the current at B1 + B2 is 16 amperes, which has reached the maximum current limit from the two buck-boost converters which each have a maximum current of 8 amperes. This shows that the entire system and Maximum Power Point Tracking are operating properly. Graph showing the ratio between current and voltage to load seen in the figure 3.

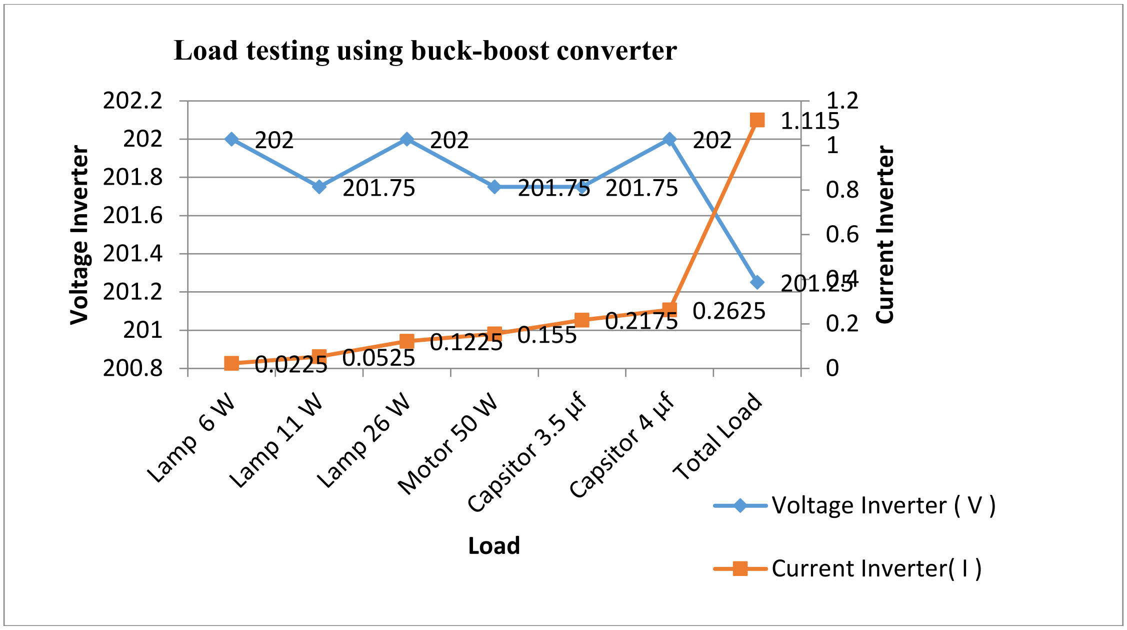

Figure 3. Graph of voltage and current inverter comparison to combined load using buck-boost converter

In Figure 3 shows analysis of overall load data using a buck-boost converter, where each load has a different power, the lowest voltage at the total load is 201.25 volts with a current of 1.115 amperes which is the maximum burden of testing using a buck-boost converter. This shows that the greater the power used, the current and voltage will follow linearly.

3.2 Load of Incandescent Lamps, Motor And Capacitor Loads Without Using The Buck-Boost Converter

Test data without using buck-boost converter power which can be produced can be seen in table 2 below.

Table 2. Test data for hybrid synchronization using a combined load without buck-boost converter

Jenis beban	Inverter Voltage (V)	Inverter Current (I)	Baterai Voltage 1 (V)	Baterai Voltage 1 (V)	Curret B1+B2 (A)
Lamp 6 W	226,5	0,225	12,225	12,425	17,2
Lamp 11 W	225	0,0525	12,225	12,425	17,2
Lamp 26 W	224,75	0,1225	12,225	12,425	17,2
Motor 50 W	202,25	0,15	12,225	12,425	17,2
Motor 75 W	202	0,23	12,225	12,425	17,2
Capsitor 3.5 µf	201	0,215	12,225	12,425	17,2
Capsitor 4 µf	201,5	0,26	12,225	12,425	17,2
Total Load	202	1,175	12,225	12,425	17,2

Table 2 shows in testing using a combined load without using the maximum power buck-boost converter that can be served is 236 watts with an inverter voltage of 202 volts and 1.17 amps, as much as 14 watts more than the one using buck-boost converter and still able to service 2 motors with 50 watts and 75 watts of power, that's because the power inverter is taken directly from the battery without passing any circuit.

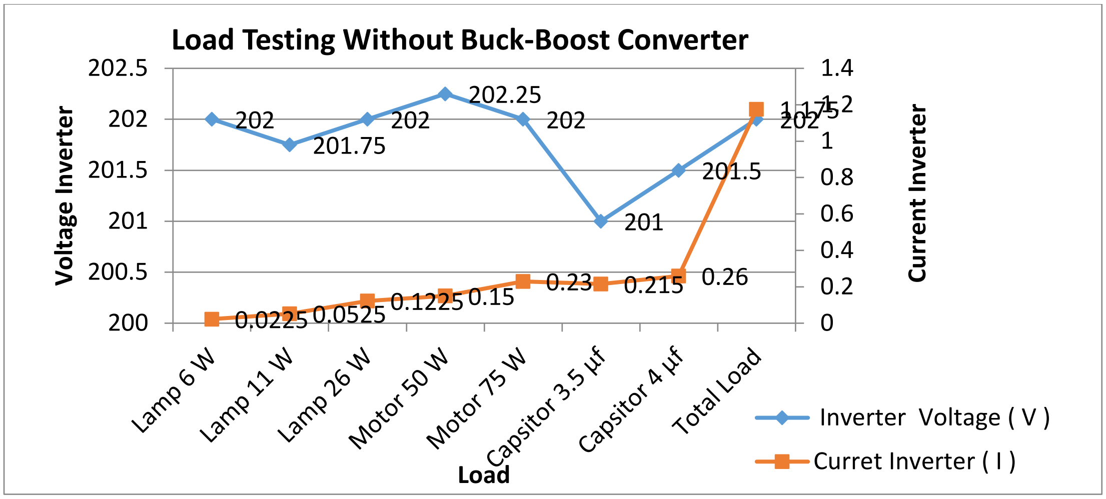

Figure 4. Graph of voltage and current inverter comparison to combined load without using buck-boost converter.

In figure 4 shows a joint test without buck-boost converter is carried out at 202 volts and 1.175 amperes current which is also the maximum load from testing without using buck-boost converters.

4. Conclusion

The conclusions that can be drawn from this test are as follows:

1. The synchronization circuit of a hybrid power plant can be done by equalizing the voltage of the two generating units into one, the solar charger controller multiplies the energy generated from the two generators and flows it to the battery. this tool is capable of serving household electrical loads up to 230 watts. The Buck-boost converter works well to regulate the voltage of the solar charger controller to be more constant and flow to the inverter to be converted into AC voltage.
2. When using the buck-boost converter the input voltage on the inverter remains constant 12 volts and is able to serve loading with a power below 220 watts on AC load or 192 watts on DC loading. When buck-boost converters are not used, the power generated is greater, but the voltage generated from the controller solar charger changes which affects the battery voltage.

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Biography /Biographies

Rimbawati, completed her undergraduate study in 1998 in the electrical engineering department at Universitas Muhammadiyah Sumatera Utara, then completed her master's degree in electrical engineering at Gadjah Mada University in 2007 with renewable energy science field. Because of his love for the research world, in 2009 he decided to serve at the Universitas Muhammadiyah Sumatera Utara. Various grants were obtained, in the development renewable energy system in Indonesia.

Mohammad Yusri, a lecturer at Universitas Muhammadiyah Sumatera Utara with an education in regional planning. He completed his undergraduate study in 1998, a master's program in 2005 and a doctoral program at the University of North Sumatra in 2016. The focus of his field was on planning the layout of rural areas by utilizing renewable energy sources to support green energy with the regional government of North Sumatra. He is also active in motivating senators to carry out their duties as people's representatives.

Zulkifli Siregar, a lecturer at Universitas Muhammadiyah Sumatera Utara in the field of architectural and landscape engineering, he has been designing landscape systems based on renewable energy for 10 years. So, currently active in conducting tourism designs for remote villages throughout Indonesia

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