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Voltage Control System Using Buck-Boost Converter at Load Balancing on Grid Inverter

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Abstract— *Solar power plant is one renewable energy that is widely use. In fact, the energy that produced by solar energy cannot be used to meet all load requirements, especially during peak loads, because the power generated is relatively small. Therefore solar energy is used for additional power to electricity on electricity company (PT. PLN). The 0n-grid system is used to reduce the cost of using electricity on PT. PLN by using solar panels through an on grid system. It functions is to combine electricity from solar panels with PT. PLN's electricity. This research uses 600 WP solar panels and PLN's electricity as a source of electrical energy. Due to the output voltage from the solar panel ranging from 0-40 Volt DC, so a buck-boost converter circuit is needed as a stabilizer for the output voltage of the solar panel. The output voltage from the solar panel is controlled at 24V so that it can go through and processed by the inverter. The control of this system is using Arduino Uno.*

Keywords— *On-grid system, Grid-tie inverter, Non-Inverting Buck-Boost Converter, Arduino Uno.*

I. INTRODUCTION

Solar Power Plant is a power generation system that utilizes solar energy to become electrical energy through solar panels which are included in green energy so that it becomes a renewable, more efficient, effective, reliable generator and can supply electrical energy needs.[1] Solar Power Plant is one of the means to meet the community's need for electricity that is very environmentally friendly. [2].

Solar power generation On-Grid is a term to refer to a Solar Power Generation system which functions to convert energy from solar heat into electrical energy. [3]. This system is generally used in homes, offices, or factories. One of the most effective solutions for electricity cost efficiency because it can save significantly on monthly electricity costs. This type of solar power generation is installed on the roof or building, so that it can receive solar heat optimally.[4]. Later the heat received will be converted into DC (direct-current) and the inverter will convert it into AC (alternating-current). After that, it synchronized with the electric current from PT. PLN. [5]

There are many methods to maximize the use of solar panels, but there is an electronic circuit that is most important in maximizing the solar panels, namely a converter circuit in the form of a buck-boost converter. Buck-boost converter is an electronic circuit that can increase and decrease the output voltage, the voltage value can be adjusted by changing the duty cycle value. [6][7][8].

II. METHODOLOGY

The design of the buck-boost converter circuit with the expected output voltage of the buck-boost converter is 24V.

The specifications of the buck-boost converter are :

- The minimum input voltage of the buck-boost converter is 10 V.
- Maximum input buck-boost voltage 40.8 V
- Desired buck-boost output voltage 24 V.
- Desired output current 5 A.
- 100 Watts of buck-boost power.
- Output Voltage Ripple 1%.
- Inductor Current Ripple 10%.
- Load resistance 12.
- 40 kHz switching frequency.

After determining the specifications of the buck-boost converter, then determine the value of the components to be used in the circuit with the following equations:

1. Calculating duty cycle using input voltage 10V

   Duty cycle

   $$Vo = \frac{1}{1-D}\ x\ Vin$$

   $$24 = \frac{1}{1-D}\ x\ 10$$

   $$D = \frac{1}{1+24}\ x\ 10$$

   $$D = 0{,}4$$

   Induction value

   $$Io = Ic = 5A$$

   $$IL = Io + Ii$$

   $$IL = 5 + 5 = 10L$$

   $$L = \frac{Vi\ x\ D}{\Delta Vcpp\ x\ fsw} = \frac{10\ x\ 0{,}4}{0{,}1\ x\ 10\ x\ 40.000} = 0{,}1\ mH$$

   Capacitor value

   $$C = \frac{Io\ x\ D}{\Delta Vcpp\ x\ fsw} = \frac{5\ x\ 0{,}4}{0{,}01\ x\ 24\ x\ 40.000} = 208\ \mu F$$

2. Calculating duty cycle using input voltage 40V

   Duty cycle

   $$D = \frac{Vo}{Vin} = \frac{24}{40} = 0{,}6$$

   Induction value

   $$L = \frac{Vo\ x\ (1-D)}{\Delta ILcpp\ x\ fsw}$$

   $$L = \frac{24\ x\ (1-0{,}6)}{0{,}1\ x\ 5\ x\ 40.000} = 0{,}48\ mH$$

   Capacitor value

   $$C = \frac{\Delta ILpp}{8\ x\ \Delta Vcpp\ x\ Fsw}$$

   $$C = \frac{0{,}1\ x\ 5}{8\ x\ 24\ x\ 0{,}01\ x\ 40.000} = 6{,}51\ \mu F$$

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From the calculation of the value of the buck-boost converter component above, the lowest inductor value is 0.1 mH and the highest is 0.48 mH. Then the lowest inductor is selected multiplied by 10, so the inductor value is 1 mH.

Fig. 1. Inductor Manufacturing and Measurement

While the largest capacitor value is 208 μF, the actual capacitor selection is 470 μF in order to adjust to the availability of components sold in the market.

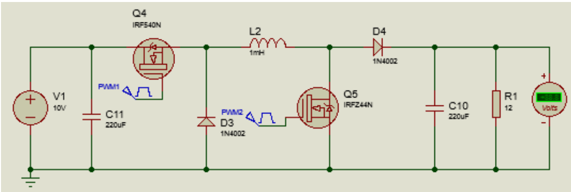

Fig. 2. Non-inverting Buck Boost Converter Design

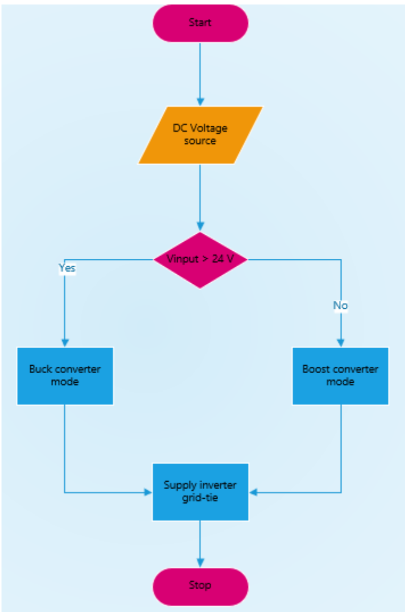

Fig. 3. Flowchart of Buck-Boost Converter

The voltage source comes from a 600 WP solar panel. The output voltage from the solar panel which ranges from 0-40 V goes to the buck boost converter circuit to be stabilized at a voltage level of 24 V. If the voltage from the solar panel is more than 24 V, the buck boost converter will work in buck mode to lower the voltage to 24 V. V. However, if the voltage from the solar panel is less than 24 V, the buck boost converter works in boost mode to increase the voltage to 24 V.

When the voltage is at the 24 V level, the voltage then enters the grid tie inverter to be further converted from 24V DC to 220 V AC by the inverter. The program is finished.

III. Result

A. *PWM Signal Testing on Arduino D9 Pin*

PWM signal is a signal that has ON and OFF periods, the amount of this period depends on the value of the duty cycle. The greater the ON period, the greater the duty cycle value. The following is the output of the PWM signal in the circuit displayed on the oscilloscope.

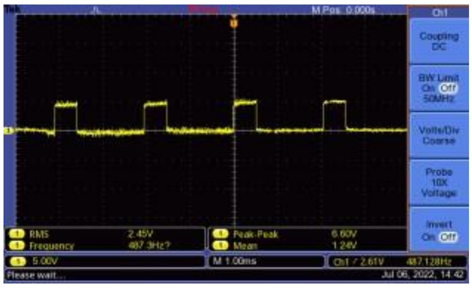

Fig. 4. PWM Signal on 25% Duty Cycle

Fig. 5. PWM Signal on 50% Duty Cycle

Fig. 6. PWM Signal on 75% Duty Cycle

When the duty cycle going to 25%, it produces 2,45V RMS voltage and a get Peak-Peak voltage of 6.6V. When the duty cycle going to 50%, it produces 3,42V RMS voltage and 6,8V Peak-Peak voltage. When the duty cycle is 75%, it produces an RMS voltage of 4.32V and a Peak-Peak voltage of 6.8V.

B. *Voltage Sensor Test*

The voltage sensor is used to determine the value of the input and output voltages of the buck boost converter circuit. The voltage sensor used is a voltage divider type.

From table 1. it can be seen that the measurement results using the voltage sensor have a small error value. The voltage sensor is in good condition to use because it has a percentage error value of less than 5%.

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TABLE 1. Voltage Sensor Test Data

No	Voltage Supply (V)	Measurement on voltmeter (V)	Measurement on LCD Display (V)
1.	18	17.97	17.9
2.	19	18.94	18.9
3.	20	19.95	19.9
4.	21	20.93	20.8
5.	22	21.94	21.8
6.	23	22.93	22.8
7.	24	23.96	23.8
8.	25	24.95	24.8
9.	26	25.93	25.7
10.	27	26.95	26.7

C. Testing the Buck-Boost Converter Circuit with Power Supply Source

The buck boost converter circuit test aims to determine whether the circuit is as desired. In testing the buck boost converter circuit, it uses an input power supply ranging from 12 volts to 31 volts.

TABLE 2. Testing the Buck-Boost Converter Circuit with a Power Supply Source

No.	Vin (V)	D Buck (%)	D Boost (%)	Vout Target (V)	Vout Test (V)	Eror (%)
1.	12	100	50	24	24.3	1.25
2.	13	100	46	24	24.4	1.67
3.	14	100	42	24	24.4	1.67
4.	15	100	38	24	24.4	1.67
5.	16	100	33	24	24.3	1.25
6.	17	100	29	24	24	0
7.	18	100	25	24	24.1	0.4
8.	19	100	21	24	24.2	0.83
9.	20	100	16	24	24.3	1.25
10.	21	100	13	24	24	0
11.	22	100	8	24	24.4	1.67
12.	23	100	4	24	24.1	0.4
13.	24	100	0	24	24.3	1.25
14.	25	96	0	24	24.4	1.67
15.	26	92	0	24	24.2	0.83
16.	27	88	0	24	24.3	1.25
17.	28	85	0	24	24.2	0.83
18.	29	82	0	24	24.3	1.25
19.	30	80	0	24	24.4	1.67
20.	31	77	0	24	24.4	1.67

From the table data, a graph is then drawn up to analyze the results of the buck boost converter test.

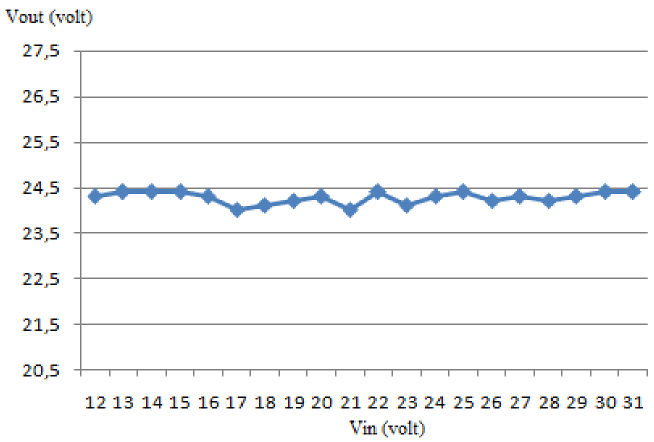

Fig. 7. Buck-Boost Converter Circuit Testing with Power Supply Source

The table and graph above shows the output voltage value of the buck boost converter circuit with varying input voltage values. From the graph, it can be seen that the output voltage of the buck boost converter has a fairly stable value at 24 volts. The test results show that the output voltage has an average error percentage of 1.12%

D. Testing The Buck-Boost Converter Circuit with a Solar Panel Source

In this measurement, this buck boost converter circuit using solar panel inputs ranging from 12 volts to 31 volts.

TABLE 3. Testing the Buck-Boost Converter Circuit with Solar Panel Source

No.	Vin PV (V)	Vin LCD (V)	Vout Voltmeter (V)	Vout LCD (V)	Iout (A)	Power (watt)
1.	12	12	25.15	24	0.29	7.29
2.	13	12.8	25.03	24	0.25	6.25
3.	14	13.7	25.14	24	0.38	9.55
4.	15	14.6	25.07	24	0.35	8.77
5.	16	15.6	25.16	24	0.22	5.53
6.	17	16.5	25.27	24	0.24	6.06
7.	18	17.5	25.17	24	0.26	6.54
8.	19	18.3	25.24	24	0.17	4.29
9.	20	19.4	25.14	24	0.50	12.57
10.	21	20.2	25.15	24	0.45	11.31
11.	22	21.2	25.25	24	0.63	15.90
12.	23	22.1	25.03	24	0.64	16.01
13.	24	23.1	25.05	24	0.77	19.28
14.	25	24.1	25.12	24	0.80	20.09
15.	26	25	25.07	24	0.85	21.30
16.	27	26	25.08	24	0.42	10.53
17.	28	26.8	25.20	24	0.47	11.84
18.	29	27.7	25.05	24	0.20	5.01
19.	30	28.8	25.11	24	0.25	6.27
20.	31	29.8	25.14	24	0.40	10.05

From the table data, a graph is then drawn up to analyze the results of the buck boost converter test.

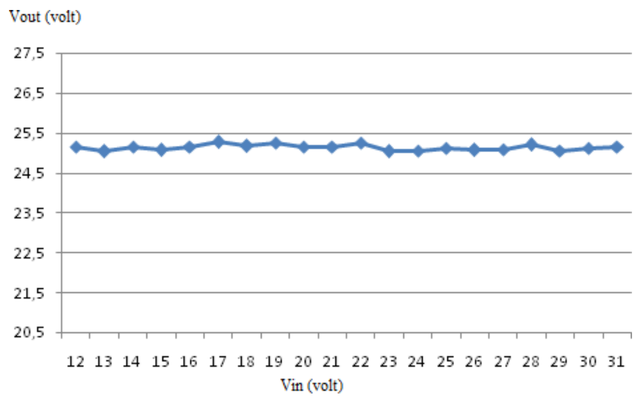

Fig. 8. Buck-Boost Converter Circuit Testing with Solar Panel Source

The table and graph above shows the output voltage value of the buck boost converter circuit with varying solar panel input voltage values. From the graph, it can be seen that the output voltage of the buck boost converter has a fairly stable value at a voltage of 25 volts. The test results show that the output voltage has an average error percentage of 4.17%.

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E. Testing The Buck-Boost Converter Circuit for Supplying the Inverter

Testing the buck boost converter circuit to supply the inverter aims to determine whether the circuit is functioning properly. In testing this buck boost converter circuit using a 600WP solar panel input with a voltage of 20 volts.

Fig. 9. Buck-Boost Converter Circuit Testing with Power Supply Source

When the buck boost converter circuit is given input from a solar panel of 20 volts, the input current is 0.04 amperes and is connected to an on-grid inverter and given a 5 watt lamp load, the voltage will decrease. The output voltage of the buck boost converter is 16.3 volts and the output current is 0.16 amperes.

IV. Conclusions

The conclusions of this study are as follows:

A. The series of Buck Boost Converter with Non Inverting type can work according to the desired specifications. When the input voltage is more than 24V, the buck mosfet will be ON and switch while the boost mosfet is OFF. When the input voltage is less than 24V, the boost mosfet will be ON and perform switching while the buck mosfet remains ON but does not switch to supply the source to the boost mosfet.

B. The circuit can stabilize the voltage to 24-24.4 volts with an input of 12-31 volts. The stabilized voltage is then used to supply the grid tie inverter.

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