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Inverter Development as A Boost Converter for DC Microgrid

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Abstrak

Konverter penaik tegangan (Boost Converter) merupakan peralatan yang penting dalam sistem jaringan listrik mikro arus searah (DC microgrid) yang berfungsi sebagai penaik tegangan. Dalam pembuatan boost converter peralatan pembangkit daya sering mengalami persoalan tersendiri terutama dalam perancangan transformator switching sehingga membutuhkan waktu yang lama dan biaya yang mahal. Untuk mengatasi persoalan tersebut dalam penelitian ini telah dibuat pengembangan inverter sebagai boost converter yang dilakukan secara simulasi dan experimen. Hasil simulasi menunjukan bahwa untuk tegangan masukan 10-14 Vdc mengasilkan tegangan 254 Vdc, sedangkan melalui pengukuran untuk tegangan masukan 10-14 Vdc menghasilkan tegangan 253 Vdc. Baik hasil simulasi maupun hasil pengukuran menunjukan bahwa tegangan tersebut dapat diterapkan dalam sistim jaringan listrik mikro arus searah untuk keperluan beban berbasic adaptor swiching (switch mode power supply/SMPS).

Kata kunci: *jaringan listrik, jaringan listrik mikro arus searah, inverter, penaik tegangan*

Abstract

DC boost converter is an essensial equipment in the system of DC microgrid which has a function as step up voltage. In making a boost converter equipment of power generation, it often encounters a problem within especially in designing of switching transformer, so that it is need a long development time and high development cost. In order to solve this problem, in this research it has been made a inverter development as boost converter which has been done by simulation and experiment. The simulation results show that for an input voltage 10-14 Vdc yields voltage 254 Vdc, while by testing for an input voltage 10-14 Vdc yields voltage 253 Vdc. Either simulation or test result show that voltage can be applied in the system of dc micro grid for the need of load based switch mode power supply /SMPS.

Keywords*: microgrid, dc microgrid, converter, inverter, boost converter*

1. Introduction

The concept of microgrid network is first developed by RH. Lassete in 2002, that is a pattern of distributed generation covering variety of energy sources from fossil energy sources to renewable energy sources (solar, wind and biogas). Microgrid is a network system interconnected from variety of distributed energy sources into a little network which can be operated independently or connected to utility grid [1][2]. Figure 1 shows the concept of microgrid supplied by some renewable energy sources and connected to utility grid.

The research of ac microgrid have been carried out but there are still many problems that should be solved reated to stability of operation of inverter, like parallel mechanism, stability of frequency and power supply. In addition, the price of inverter is relatively expensive, especially for household application. Method of inverter parallel has been done, such as use of *phase look loop* (PLL) method and Droop Voltage [4][5]. However, another problem still appears too, such as change of frequency and reactive power due to change and type of used load. It will become its own problem in the microgrid system. Several researhes associated with direct current have been developed to overcome problems occured in the alternating curent such as calculation of losses in the network and ratio of effeciency of alternating current and direct current [6].

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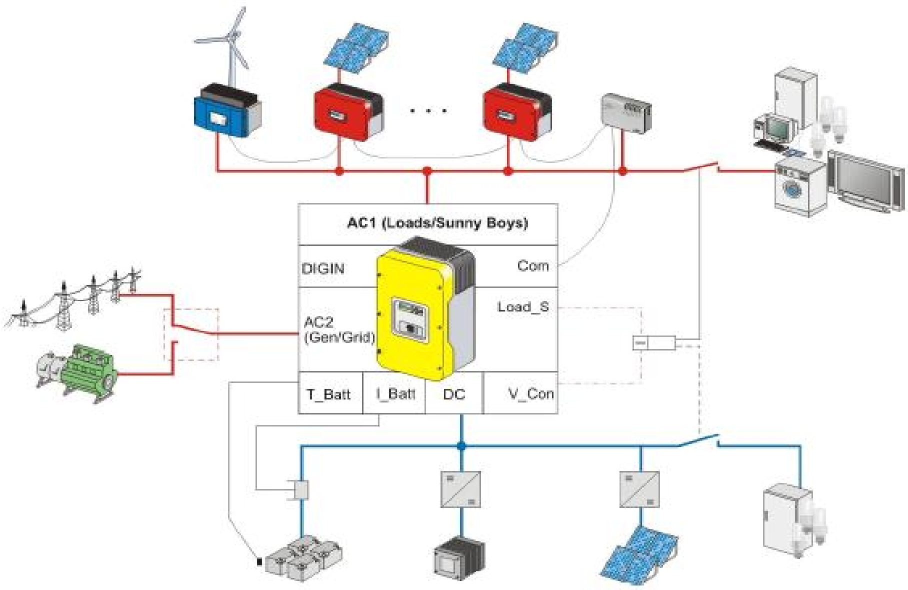

Figure 1. Concept of Microgrid [3]

Research about DC microgrid started developing by Youichi Ito in 2004 [7]. The DC microgrid is developed to meet the need of increased electric power coincides with developing microgrid system. The microgrid is economic if it is used for supplying electric power in an isolated region such as mountainous areas and remote areas. The DC microgrid can eliminate DC-AC converter or AC to DC converter, so that it will get high efficiency with low cost and short length of line. The dc microgrid can supply a load switch mode power supply/SMPS which can operate at the voltage of 100-240 Vac or 141-340 Vdc [8]. Most of environmental friendly generators use dc sources. It is eminently suitable and electronic and digital equipments using direct current. The network system of dc microgrid is built as well as the existing electric power system.

The microgrid system consists of [9]:

a. Power generation or distributed generation
b. Converter
c. Load
d. Energy storage unit
e. Transmission / distribution line
f. Control system and communication line

The dc microgrid diagram can be seen in Figure 2.

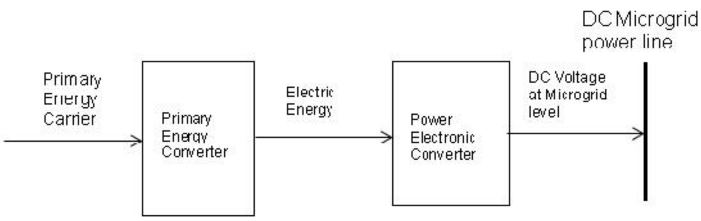

Figure 2. DC Microgrid Diagram [9]

The use of conventer in the dc mirogrid system is main component in the energy conversion technique. The dc converter is divided into three clasifications [10] :

a. *Buck converter*
b. *Boost converter*
c. *Buck-boost converter*

The boost converter serves a function to step up voltage from one level to another level. The diagram circuit of boost converter can be seen in Figure 3.

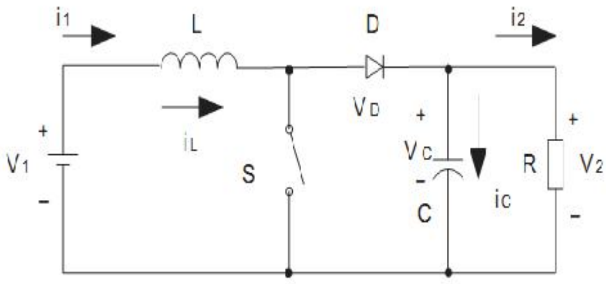

Figure 3. Circuit diagram of boost converter

The output voltage of boost converter can be calculated using equation below:

$$V_0 = \frac{T}{T-t_{on}} V_{in} = \frac{1}{1-k} V_{in} \quad (1)$$

Where:
T = periode of wave, T = $\frac{1}{f}$
f = chopping frequency
t_{on} = time of switch on
k = repeatedly conduction cycle, k = $\frac{\text{ton}}{\text{T}}$

Piotr Biezel explains using boost converter in the dc requires criterion as follows [11] :
a. Ripple current at low input and output
b. Having high abilities to switching over voltage
c. Controllable from external
d. High efficiency
e. Low cost

Research about conventer in the dc microgrid has been carried out by P. Biczel,. 2007. This research explains a role of dc converter in the dc microgrid to change from one level voltage to another level voltage. This equipment is needed in order to voltage suplying the microgrid meets the voltage needed. Several development methods DC-DC converter have been done in order to get higher efficiency using swicthed-capacitor circuit or the other [12]. In 2010 Yi-Ping also performed a research about increasing the efficiency in dc converter with electronic circuit variations such as capacitor, diode and inductor by performing installation configurations in order to get higher efficiency [13]. Felinto S.F,Silva, Antonio A.A., et al., have developed high gain DC-DC boost converter with a coupling inductor in a solar cell. This research explains about a model of step up voltage from 24 V dc to 311 V [14].

The use of dc converter in this research is not the same as before done by researchers [12][13][14]. In this research, the converter used is inverter as a DC boost converter. It is intended to the need of DC boost converter made easily. In the boost conveter the equipment of power generation often has its own problems, especially in the design of the switching transformer, so that it takes a long time and complicated [15], finally it becomes expensive. From the simulation and experimental results show that the inverter as DC boost converter shows good performance, so that it can be applied in renewable energy systems.

2. Research Method
Performed research method uses simulation and experiment.

2.1. Simulation Method
In the simulation method, test circuit is taken from circuit of Matlab Simulink DC boost converter by determining initially input parameters needed:

Parameter.1.

Input voltage (Vs)	: 10-15 volt
Output voltage (Vo)	: 254 volt
Switching periode (T_s)	: 20 µs
Frequency (fs)	: 50 kHz
Output voltage ripple	: 0,1 %

Determining Duty cycle *value* (D)

$$D = 1 - \frac{Vi}{Vo} \quad (1)$$

Determining average output current at the edge of continuous conduction in boost converter is given by equation : [16]

$$Iob = \frac{Ts.Vs}{2L} + D\,(1 - D) \quad (2)$$

For determining inductance using equation

$$L = \frac{Ts.Vo}{Iob} + D\,(1 - D)^2 \quad (3)$$

Where :

Iob	= Average output current	(Amperre)
Vs	= Input voltage	(Volt)
Ts	= Switching periode	(µs)
D	= Duty cycle	(0,75)
L	= Inductance	(Hendry)

After determining parameter 1, obtained values of
1. Calculation of *duty cycle* (D)
2. Calculation of inductance
3. Calculation of capacitance

From those results than are entered to Matlab Simulink in order to know the output voltage obtained. Simulation circuit for DC boost converter can be seen in Figure 4.

2.2. Experiment Method
In order to know the ability of inverter as DC boost converter in the dc microgrid, than it is made a change in the existing circuit in the inverter. The change is performed by varying the circuit in the generation transformer side on high frequency rectified. The result of this voltage will be returned in order to generate ac voltage. For determining this circuit is usually signed by rectifier circuit equipped with diode and capacitor which have high capacity and high voltage. The quantity of voltage resulted from DC boost conveter is determined by the value of capacitance (C) and inductance (L) existed in the voltage generation circuit. It can be calculated using equations (1), (2), and (3) above. The scheme of development of inverter as DC boost converter can be seen in Figure 5.

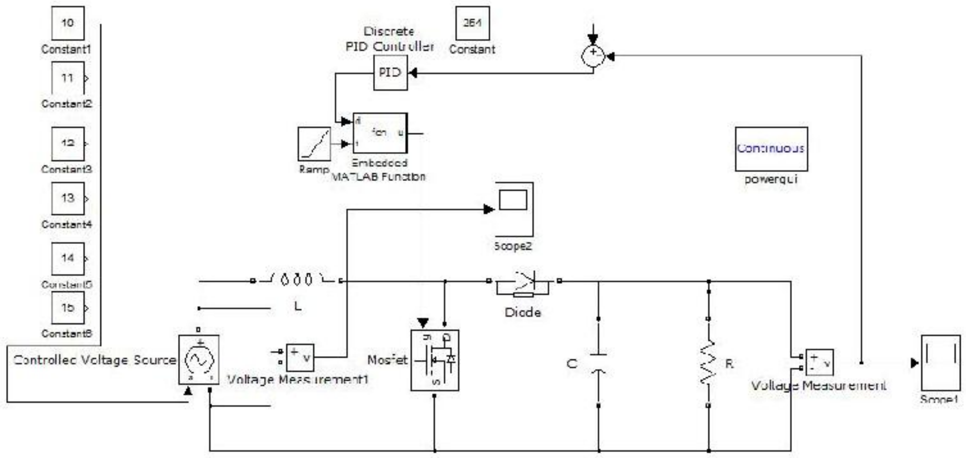

Figure 4. Simulation of DC Boost Converter with PID

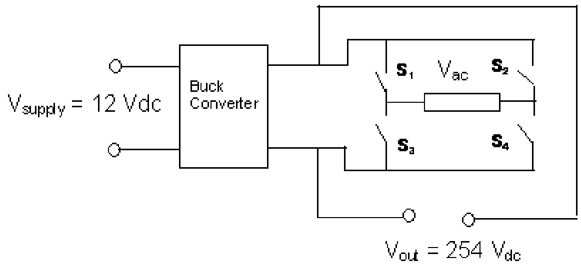

Figure 5. The Scheme of Development of Inverter as DC Boost Converter.

Test of inverter as DC boost Converter is performed by feeding input voltage (Vs) from a variable power supply 3 A, Varying the supply voltage from 10 Volt to 14 Volt, the output voltage from DC boost converter resulted is compared with simulation results. Figure 6 shows the experiment of inverter as DC boost converter. The implementation of development of inverter as DC boost converter in the DC microgrid can be seen in Figure 7.

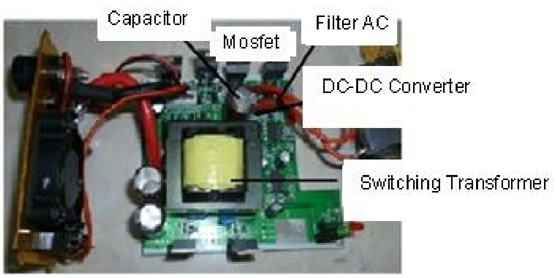

Figure 6 . Development of Inverter as DC Boost Converter

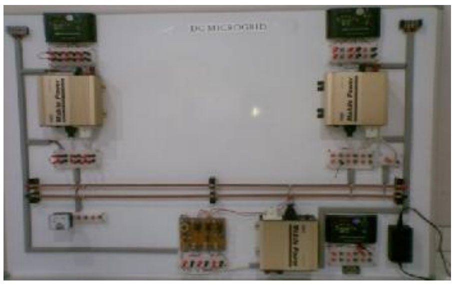

Figure 7. Implementation of Boost Converter in DC Microgrid

3. Results and Analysis

The result of development of inverter as DC boost conveter shows that supply voltage from 10 – 14 Volt can be increased to 254 Vdc. The result of test of dc voltage profile in DC boost converter shows operating voltage of 254 Vdc, so that this voltage can operate in house appliances with a model of *switch mode power supplay* /SMPS operating in the range of voltage 100 – 240 Vac [17]

3.1. Simulation Results

Using simulation of Matlab Simulink by input parameter data 1 and equation (2) and (3), than the results can be obtained in Figure 8.

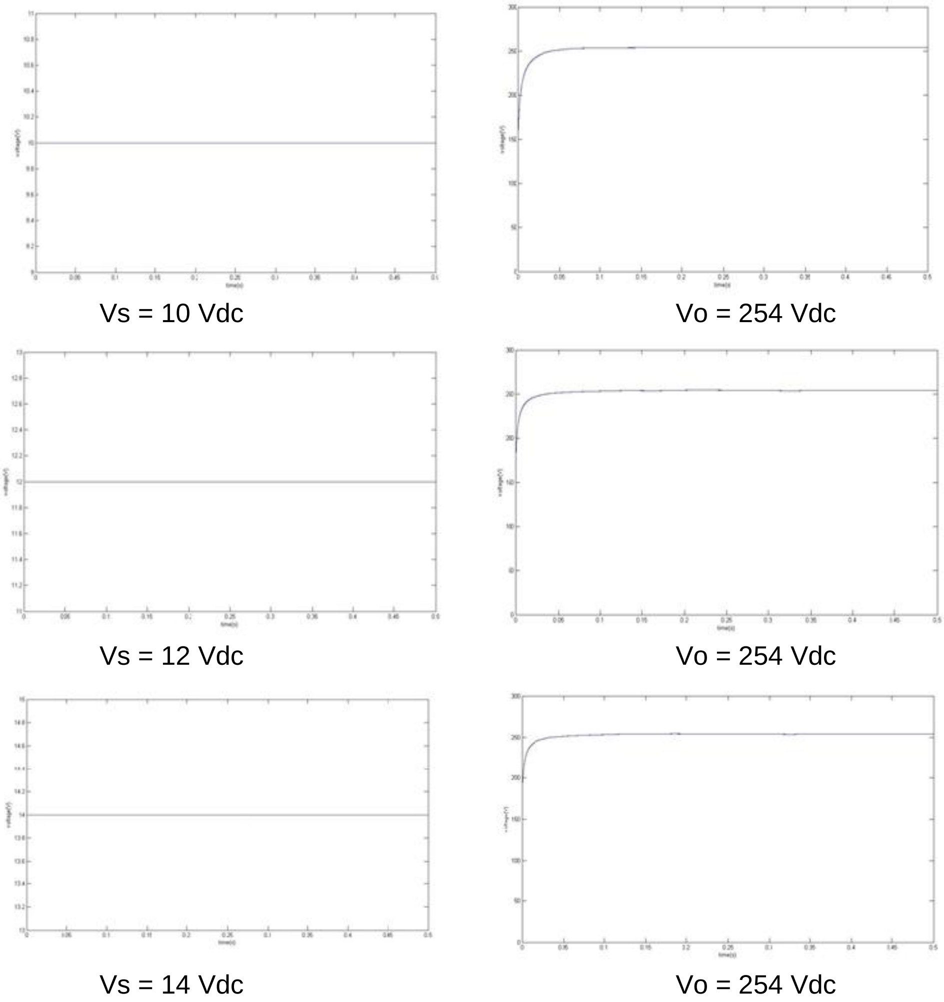

Figure 8. The graph of input voltage (Vs) vs output voltage (Vo) in the development of Inverter as DC Boost Converter.

From the graph of simulation result in that figure can be seen that while input voltage 10-14 Volt, DC boost converter produce constant output voltage of 254 volt. The increase of input voltage value will influence duty cycle (D), so that *steady state* velocity of output voltage is obtained rapidly.

3.1. Experiment Results

Test of inverter developed to become DC boost converter is tested in no load and under load. No load test of DC converter can be seen in Table 1, while test of DC boost converter under load with 20 W can be seen in Table 2.

By experiment, no load test of DC boost converter with supply voltage 10 – 14 V, yields output voltage of 253 V, while from simulation yields 254 V. From the two results show there are no significant different. While under load test, by experiment the output voltage decreases at the time of voltage 10 – 11 V. Since the ability of power supply is limited, so that when the current increases, the voltage decreases. The decrease of voltage is also caused by losses in the installed component.

Table 1. No Load Test

Vsupply (Volt)	Vout (Volt) Experiment	Vout (Volt) Simulation
10.5	253	254
11	253	254
11.5	253	254
12	253	254
12.5	253	254
13	254	254
13.5	254	254
14	254	254

Table 2. Under Load Test

Vsupply (Volt)	Vout (Volt)	Vout (Volt) simulation
10.5	241	254
11	242	254
11.5	253	254
12	253	254
12.5	253	254
13	253	254
13.5	253	254
14	253	254

In the simulation result, the output voltage is constant 254 V, it is not decreased. It is assumed that DC boost converter is ideal, so that there is no losses in the component. As the criterion of DC boost converter required by Piotr Biezel that ripple current in the input and output is low [9], so that ripple voltage yielded is 787 mV, and wave defective yielded is very low and ripple current is low**.** The results ripple voltage of DC boost converter can be obtained in Figure 10.

Figure10 . Ripple Voltage of DC Boost Converter.

4. Conclusion

According to the simulation and test results, the development of inverter as DC boost converter yields voltage of 253 – 254 Vdc. This voltage is still in the limit of operating voltage requirement of equipment, there are minimum of 141 Vdc and maximum of 340 Vdc. From the voltage test of ripple is 787mV, so that the use of inverter as DC boost converter can be applied as DC converter. The result of the development and the experiment show that inverter as DC boost converter will make easy to use renewable energy sources in the future.

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