

# Design and Simulation Converter with Buck-boost Converter as The Voltage Stabilizer

Aris Suryadi\*

Teknologi Listrik

Politeknik Enjinering Indorama Purwakarta,  
Indonesia  
aris.suryadi@pei.ac.id

Purwandito Tulus Asmoro

Teknologi Listrik

Politeknik Enjinering Indorama  
Purwakarta, Indonesia  
purwandito@pei.ac.id

Agus Sofwan

Teknik Elektro

Institut Sains dan Teknologi Nasional  
Jakarta, Indonesia  
asofwan8@gmail.com

\*corresponding author: aris.suryadi@pei.ac.id

**Abstract**—Buck-boost Converter is the device with the function convert dc Voltage input to the setpoint dc Voltage output. Buck-boost converter can be used for regulating unstable voltage became a stable voltage by the user's needs. The application of a Buck-boost Converter in the research is about how to apply a Buck-boost Converter in the ac to ac Converter device, ac to ac Converter is the device to convert ac voltage to ac Voltage where the voltage can be modified. In the research, the input Voltage of ac to ac Converter is unstable, so that the output Voltage is unstable too in the range of 190 V to 250 V. To solve this problem, that the Buck-boost can be installed to ac to ac Converter, it is useful to keep output Voltage stable even though the input Voltage is unstable. The ac to ac Converter device in this research consists of Rectifier, Buck-boost Converter, and Inverter. It is indicated that the unstable ac input voltage is connected to a rectifier results in the stable dc voltage by controlling a buck-boost converter. Then, this dc voltage leads to a stable ac voltage when it is connected to an inverter, corresponding with the set point. For further development, ac to ac Converter combined with Buck-boost Converter can be applied to maintain a standard of Voltage 220 V ac from the sources to keep it stable.

**Keywords**— buck-boost converter, converter, rectifier, inverter, regulator

## I. INTRODUCTION

DC to DC Converter switching type as known as dc Chopper is used to supply dc output Voltage which variable value depends on the load. The power process of dc to dc Converter comes from dc Voltage with input voltage with a fixed or variable value. To produce dc output Voltage can be done, by controlling the time between the output side and the input side in the same circuit. The component which is used to switch, for example, is Thyristor, Mosfet, IGBT, and GTO. Usually, there are two functions of dc Chopper, as the Voltage Boost, where the output voltage is higher than input Voltage, and as the Voltage Buck, where the output voltage is lower than input voltage. The buck-boost method combines between buck and boost, Fig.1, where the output Voltage can be controlled became higher or lower than the input Voltage. In the operational of Buck-boost Converter, the formula of Voltage is:

$$V_o = -\frac{D}{(1-D)} V_{in} \quad (1)$$

Output Voltage of buck-boost Converter inverts Voltage against input Voltage. So that this method is used for an application that needs a Voltage inversion without a transformer, even though it is a simple circuit, the buck-boost method had a weak, such as there is no isolation between input and output side, and a high ripple in output Voltage or output current.

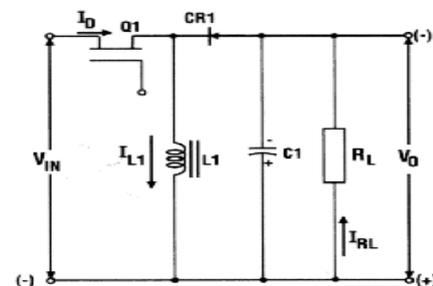


Fig. 1. Buck-boost Converter

## Buck-boost Converter Working Principle

The Buck-boost is the one switching mode regulator resulting in a higher or lower output voltage than input Voltage. The working principle of the Buck-boost Converter is shown in Fig. 2. and Fig. 3. In mode 1, shown in Fig. 2. the transistor Q<sub>1</sub> is "On" and D<sub>m</sub> Diode is in reversed bias, then the current increases to flow through the inductor L, and passing to the Capacitor C, D<sub>m</sub> diode, and finally it inflows to load. Charging energy inside the inductor L will be transferred to load. And the inductor current will be decreased until the transistor Q<sub>1</sub> is "On" again to the next cycle [7]. When the Buck-boost circuit Mosfet transistor is "On", it causes the diode in reversed bias, so that the current will flow to inductor L. When the current is flowing to the inductor, that means the inductor is recharge and the inductor current I<sub>L</sub> is increased. Fig. 3 is shown that the transistor Mosfet Q<sub>1</sub> is "Off", causes the diode forward biased, and the current is flowing to inductor L, Capacitor C, Diode D<sub>m</sub>, and to the load. The energy from the inductor is discharged [7].

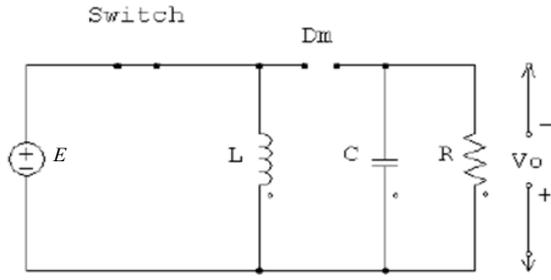


Fig. 2. The Buck-boost Converter with Close analyze [7]

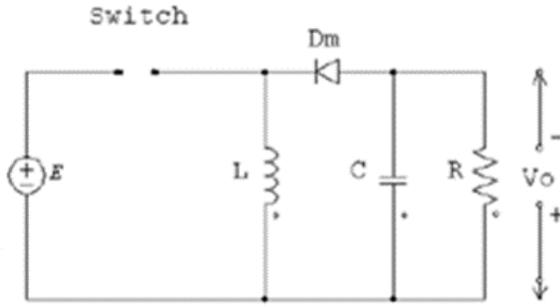


Fig. 3. The Buck-boost Converter with Close Open analyze [7]

The Buck-boost converter results in the higher or lower output voltage than input Voltage. Noted, that a PWM Duty Cycle as the switch trigger is more than 50 %, so that the output voltage is higher than the input Voltage. If a PWM Duty Cycle is less than 50 % so that the output voltage is lower than the input voltage [7].

#### Design Formulas of Buck-boost Converter

The steps of calculation and design a Buck-boost converter is:  
Step 1: Determine the Duty Cycle (D)

Duty Cycle (D) is the time comparison between output Voltage  $V_o$  with output Voltage add the input Voltage,  $V_{in}$ . The formulas to determine a minimum or maximum Duty Cycle is shown [8]:

$$D_{max} = \frac{V_o}{V_o - V_{in(max)}} \quad (9)$$

$$D_{min} = \frac{V_o}{V_o - V_{in(min)}} \quad (10)$$

where:

- D = Duty Cycle
- $V_o$  = Output Voltage (volt)
- $V_{in}$  = Input Voltage (volt)
- $V_{in(min)}$  = The minimum input Voltage (volt)
- $V_{in(max)}$  = The maximum input Voltage (volt)
- $\Delta V_o$  = Difference of output Voltage (volt)
- $I_o$  = Output current (Ampere)
- f = Frequency (Hz)

Step 2: Determine the resistance ( $R_L$ ) [8]:

$$R_L = \frac{V_o}{I_o} \quad (11)$$

Step 3: Determine the minimum inductance ( $L_{min}$ ) and maximum inductance ( $L_{max}$ ) of inductor [8]:

$$L_{min} = \frac{V_{in(min)} \cdot D_{max}}{\Delta I \cdot f} \quad (12)$$

$$L_{max} = \frac{V_{in(max)} \cdot D_{min}}{\Delta I \cdot f} \quad (13)$$

where:

- $L_{min}$  = Minimum inductance (Henry)
- $L_{max}$  = Maximum inductance (Henry)
- $V_{in(min)}$  = Minimum input Voltage (volt)
- $V_{in(max)}$  = Maximum input Voltage (volt)
- $D_{max}$  = Maximum Duty Cycle
- $D_{min}$  = Minimum Duty Cycle
- $\Delta I_o$  = Difference of output current (Ampere)
- f = Frequency (Hz)

Step 4: Determine a minimum capacitance ( $C_{min}$ ) [8]:

$$C_{min} = \frac{I_o \cdot D_{min}}{\Delta V_o \cdot f} \quad (14)$$

$$C_{max} = \frac{I_o \cdot D_{max}}{\Delta V_o \cdot f} \quad (15)$$

AC to AC Converter is the device to convert ac Voltage to ac Voltage where the Voltage can be modified. Usually, the ac to ac Converter consist of Rectifier, and Inverter.

#### Rectifier

Rectifier used to convert ac Voltage or Current became dc Voltage or Current Fig. 4. In this research, the rectifier which is used to convert ac Voltage to dc Voltage is Full Wave rectifier or Full Bridge rectifier [9].

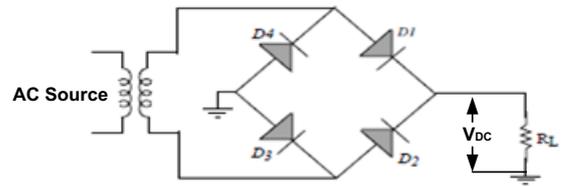


Fig. 4. Full bridge rectifier [10]

The formula to find dc Full Bridge rectifier Voltage ( $V_{dc}$ ) is shown as [10]:

$$V_{ACrms} = 0.707V_m \quad (16)$$

$$V_{DC} = \left[ \frac{2 \cdot V_m}{\pi} \right] \quad (17)$$

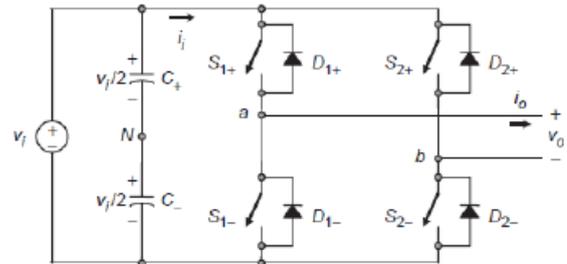


Fig. 5. Inverter circuit [11]

#### Inverter

The inverter is the dc to dc Converter, it can be used to change dc input Voltage to ac output Voltage where the frequency of ac output Voltage can be modified. Fig. 5 in the inverter circuit, a capacitor is needed to create an N point, so that the capacitor Voltage keep

constant [11]. There is 2 side of switches, S1 + and S1-, S2+, and S2-. They are not working synchronously to prevent a short circuit [11]. ON and OFF condition from both sides of switches is determined by modulation technique, that called PWM (Pulse Width Modulation) [11].

## II. RESEARCH METHODOLOGY

AC to AC Converter is the device to convert ac Voltage to ac Voltage where the Voltage can be modified. In this research, the input Voltage of ac to ac Converter is unstable, so that the output Voltage is unstable too in the range of 190 V to 250 V. To solve this problem, that the Buck-Boost can be installed to ac to ac Converter, it is useful to keep output Voltage stable even though the input voltage is unstable. The ac to ac Converter device in this research consists of Rectifier, Buck-Boost Converter, and Inverter.

### Design the Buck-Boost Converter

The first step to implement a 220 volt Buck-boost converter is determined a Buck-boost component, such a minimum and maximum inductor ( $L_{min}$ . and  $L_{max}$ ), minimum and maximum capacitor ( $C_{min}$ . and  $C_{max}$ ), and load resistance

The Buck-boost converter parameter data is given:

|                          |                           |
|--------------------------|---------------------------|
| Minimum input Voltage    | = 190 volt                |
| Maximum input Voltage    | = 250 volt                |
| Output Voltage           | = 220 volt dc             |
| Output current           | = 25 Ampere               |
| Load power ( $P_{Out}$ ) | = $220 * 25 = 5500$ Watts |
| Switching frequency      | = 40 kHz                  |
| Allowed current ripple   | = 30 %                    |
| Allowed Voltage ripple   | = 0.8 %                   |

The steps of calculation is given:

Step 1: Determined a Duty Cycle (D):

$$D_{max} = \frac{V_o}{V_o - V_{in(min)}} = \frac{220}{220 - 190} = 0.536$$

$$D_{min} = \frac{V_o}{V_o - V_{in(max)}} = \frac{220}{220 - 250} = 0.468$$

Step 2: Determined a load resistance ( $R_L$ ):

$$R_L = \frac{V_o}{I_o} = \frac{220}{25} = 8,8 \text{ Ohm} \approx 10 \text{ ohm}$$

Step 3: Determined a minimum and maximum inductor:

First, determine  $\Delta I_o$  :

$$\Delta I_{Out} = r_L \cdot I_{Out} = (30\%) * 25 = 7.5 \text{ Ampere}$$

After that, determine the minimum and maximum inductor ( $L_{min}$ . and  $L_{max}$ ):

$$L_{min} = \frac{V_{in(min)} \cdot D_{max}}{\Delta I \cdot f} = \frac{190 \cdot (0.536)}{(7.5) \cdot 40000} = 339.46 \cdot 10^{-6} \text{ H} = 339.46 \mu\text{H}$$

$$L_{max} = \frac{V_{in(max)} \cdot D_{min}}{\Delta I \cdot f} = \frac{250 \cdot (0.468)}{(2.5) \cdot 40000} = 390 \cdot 10^{-6} \text{ H} = 390 \mu\text{H}$$

Step 4: Determined a minimum and maximum capacitor ( $C_{min}$ . and  $C_{max}$ ):

First, determine  $\Delta V_o$  :

$$\Delta V_{Out} = r_v \cdot V_{Out} = (0,8\%) * 220 = 1.76 \text{ volt}$$

After that, determine a minimum and maximum capacitor ( $C_{min}$ . and  $C_{max}$ ):

$$C_{min} = \frac{I_o \cdot D_{min}}{\Delta V_o \cdot f} = \frac{25 \cdot (0.468)}{(1.76) \cdot 40000} = 166.2 \mu\text{F}$$

$$C_{max} = \frac{I_o \cdot D_{max}}{\Delta V_o \cdot f} = \frac{25 \cdot (0.536)}{(1.76) \cdot 40000} = 190.34 \mu\text{F}$$

The result of a Buck-boost converter calculation given:

Inductor :

$$L_{min} = 339.46 \mu\text{H}$$

$$L_{max} = 390 \mu\text{H}$$

Capacitor :

$$C_{min} = 166.2 \mu\text{F}$$

$$C_{max} = 190.34 \mu\text{F}$$

Load resistance ( $R_L$ ) = 10 ohm.

For the simulation, a Buck-boost converter parameter is determined, such inductor,  $L = 330 \mu\text{H}$ , capacitor,  $C = 220 \mu\text{F}$ , because both inductor and capacitor is available on the electronic store, generally used to many of the electronic circuits, the load resistance ( $R_L$ ) = 10 ohms.

### Simulation of Rectifier Voltage

The simulation of rectifier Voltage using Power Simulator (Psim) Software. The Scheme of rectifier circuit in Psim software is given by Fig. 6.

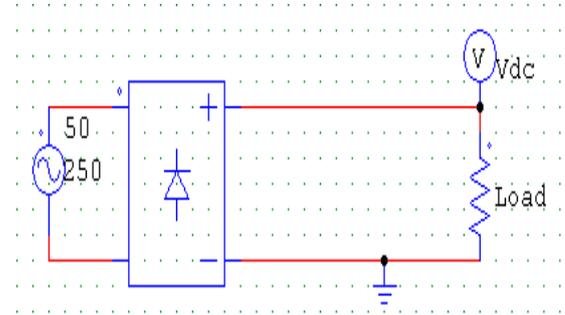


Fig. 6. Rectifier simulation

With the ac 250 volt source Voltage, the result of the simulation is given by Fig. 7.

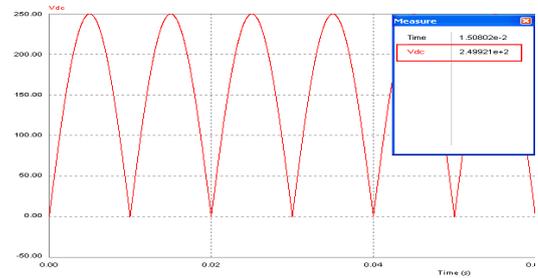


Fig. 7. Simulation result of rectifier

From the simulation, the measurement simulation table which is remarked by the red line shows that dc Voltage  $V_{dc} = 2.49921e^{+2}$ , which means  $2.49921 \times 10^2$ , or equal 249.921 volt dc, so that the output ( $V_{dc}$ ) is 249.921 V dc. With a similar method, can be determined the output Voltage ( $V_{dc}$ ) based on variable input Voltage, from 190 volt to 250 Volt. Table I. of the rectifier output voltage is shown.

It can be concluded that if the source Voltage compared to rectifier output Voltage, there is an average of difference Voltage 0.069429 volt. In this research, the simulation of ac to ac Converter which consists of a rectifier, a buck-boost converter, and an inverter. The simulation of ac to ac Converter is to analyze the characteristic of ac to ac converter design as the stabilizer in 220 Vac Voltage. The Scheme of ac to ac converter circuit in Psim software is given by Fig. 8.

TABLE I. SIMULATION RESULT OF RECTIFIER OUTPUT VOLTAGE (VDC)  
(RANGE OF VOLTAGE 190 TO 250 VAC)

| V Source                         | V <sub>DC</sub><br>(Simulation) | Voltage<br>Difference<br>(ΔV) |
|----------------------------------|---------------------------------|-------------------------------|
| (V AC)                           | (V DC)                          | Volt                          |
| 250                              | 249.921                         | 0.079                         |
| 240                              | 239.924                         | 0.076                         |
| 230                              | 229.927                         | 0.073                         |
| 220                              | 219.931                         | 0.069                         |
| 210                              | 209.934                         | 0.066                         |
| 200                              | 199.937                         | 0.063                         |
| 190                              | 189.940                         | 0.060                         |
| Average Of Difference<br>Voltage |                                 | 0.069429                      |

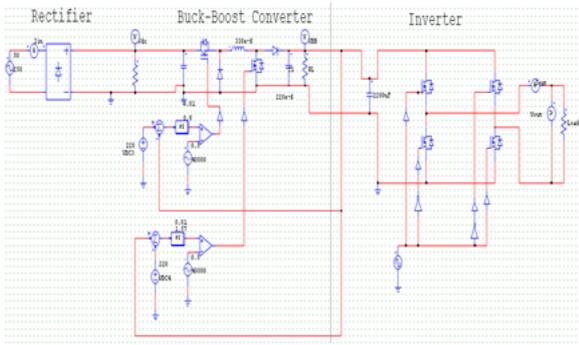


Fig. 8. Scheme of 220 V ac to ac converter

#### Simulation Of 220 V ac to ac Converter in ac 250 V Source

After design ac to ac converter parameters, the next step is to simulate ac to ac converter to analyze the characteristics when it operated in variable ac Voltage, with the ranges are 250 V, 230 V, and 220 V. The setpoint output Voltage expertly is ac 220 V. The result of simulation ac to ac converter in 250 V source is given by Fig. 9. Fig.9 shows that the simulation result of ac to ac converter in ac Voltage 250 V. Simulation “measurement” in Fig. 9 show that the measurement numbers:

V<sub>dc</sub> (Rectifier output Voltage) = 249.9 V (dc)  
 V<sub>BB</sub> (Buck-Boost Converter output Voltage) = 225.2 V (dc)  
 V<sub>out</sub> (Inverter output Voltage) = 225.2 V (ac)

The simulation result shows that from the input Voltage ac 250 V source, the output voltage from the inverter is ac 225.2 V so that ac to ac converter output Voltage is not too far from the setpoint ac 220 V.

#### Simulation of 220 V ac to ac Converter in ac 220 V Source

The result of simulation ac to ac converter in 220 V source is given by Fig. 11.

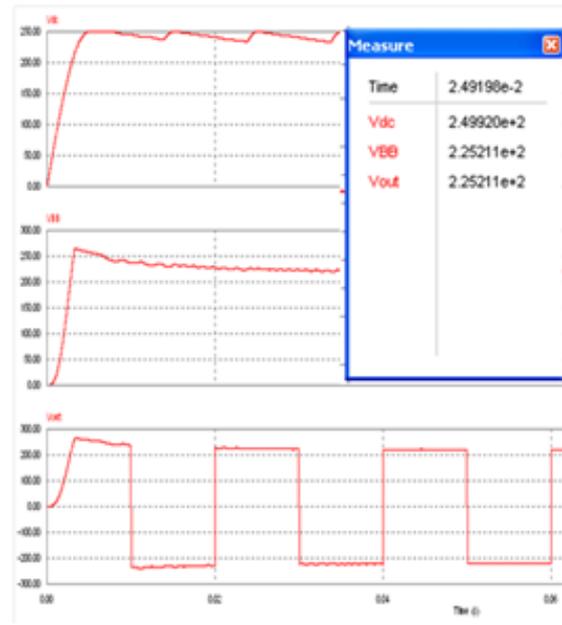


Fig. 9. Simulation result of 220 V ac to ac converter in 250 V

#### Simulation Of 220 V ac to ac Converter in ac 230 V Source

The result of simulation ac to ac converter in 230 V source is given by Fig. 10.

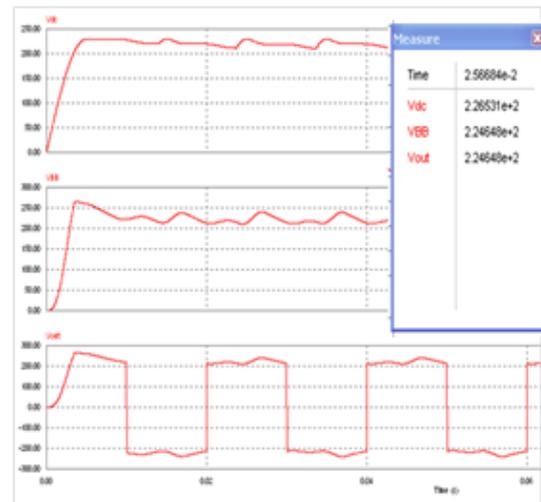


Fig. 10. Simulation result of 220 V ac to ac converter in 230 V

Simulation “measurement” in Fig. 10 show that the measurement numbers: V<sub>dc</sub> (Rectifier output Voltage) = 226.5 V (dc), V<sub>BB</sub> (Buck-Boost Converter output Voltage) = 224.6 V (dc), V<sub>out</sub> (Inverter output Voltage) = 224.6 V (ac)

The simulation result shows that from the input Voltage ac 230 V source, the output voltage from the inverter is ac 224.6 V so that ac to ac converter output Voltage is not too far from the setpoint ac 220 V. But, there is a problem that too many of Ripple in the output Voltage wave, to solve the problem, , and inverter.

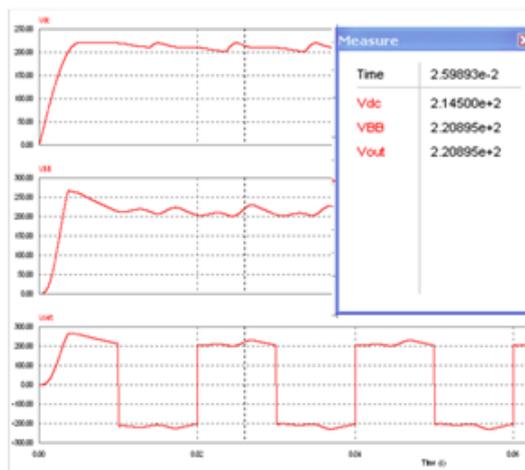


Fig. 11. Simulation result of 220 V ac to ac converter in 220 V

Simulation “measurement” in Fig. 11 show that the measurement numbers: Vdc (Rectifier output Voltage) = 214.5 V (dc), VBB (Buck-Boost Converter output Voltage) = 220.8 V (dc), V<sub>out</sub> (Inverter output Voltage) = 220.8 V (ac). The simulation result shows that from the ac input voltage of 220 V, the ac output voltage from inverter is 220.8 V, so that ac to ac converter output voltage is not too far from the setpoint of 220 V. The square wave of ac to ac converter output Voltage is caused by transistor switching so that the output Voltage wave from ac to ac converter is not a Sin wave.

#### V. CONCLUSION

The result of simulation show that 220 V ac to ac converter which consists of a rectifier, buck-boost converter, and inverter, in variable ac Voltage sources as the input Voltage with the ranges, are 250 V, 230 V, and 220 V, the ac to ac converter output Voltage is not too far from the setpoint ac 220 V. Based on simulation measurement, it is shown that the a with the ranges, are 250 V, 230 V, and 220 V, the ac to ac converter output Voltage is not too far from the setpoint ac 220 V. Based on simulation measurement, it is shown that the ac input voltage of 250 V, contributes the ac output voltage of 225.2 V. The ac input voltage of 230 V, results in the ac output voltage of 224.6 V. Furthermore, the ac input voltage of 220 V, leads to the ac output voltage of 220.8 V. The square wave of ac to ac converter output voltage is caused by transistor switching mode, so that, the output voltage wave from ac to ac converter is not a sinus wave.

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