MPPT Control System Based on Incremental Conductance and Constant Voltage using Coupled Inductor-Capacitor Zeta Converter in hybrid PV-Wind Turbine System

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***Abstract*—This paper proposes a method of maximum power point tracking control using Incremental Conductance employed in hybrid photovoltaic-wind turbine for DC micro-grid system. The rapid growth of renewable energy using photovoltaic (PV) and wind turbine due to low operational cost and easy to implementation. Improvement of the efficiency of PV and wind turbine based on incremental conductance is the solution to get maximum power in PV and Wind Turbine. The proposed method uses variable step to achieve maximum power with high speed tracking, high efficiency and low steady state error calculation. The performance of the MPPT technique has been applied in dc-dc boost converter. Moreover, Zeta Converter using Coupled Inductor-Capacitor is added for maintain constant voltage in passive load. This high gain converter can reach 311 Volt DC with 1000 W output power and high efficiency up to 90%. The effectiveness of proposed method is implemented in two hybrid system using PV and wind turbine source.**

Keywords—incremental conductance technique; maximum power point tracking; Zeta Converter using Coupled Inductor-Capacitor.

I. Introduction

In recent years, demand of electrical energy has been increased dramatically due to rapid growth of population, building construction and factory development. However, the availability of fossil fuels such as gasoline, natural gas and coal are limited to the next few years [1]. Renewable energy has important role for reducing fossil fuel and environmental issues about green energy. Another advantages of renewable energy is not only as clean energy, but also as power generation with high reliability, energy efficiency and lower cost [2]. Renewable energy has been promising solution for alternative power generation which available by natural process such as sunlight, wind, wave power, hydrogen, geothermal heat and fuel cells [3].

The renewable energy sources have been developed in recent years. Solar energy and wind power energy have become most attention renewable energy. Utilization of solar energy become electrical energy can be used in two methods. First, heat of solar can be employed as solar thermal energy. Second, solar irradiation can be converted become electrical energy using Photovoltaic (PV) device. Several advantages of PV is noiseless, clean, low operational and maintenance cost. However, PV still has drawbacks especially low energy conversion efficiency [4, 5]. Its need Maximum Power Point Tracking (MPPT) for kept at maximum power to get high efficiency conversion. Furthermore, wind power as attractive renewable energy source produces electrical energy by using wind turbine and Permanent Magnet Synchronous Generator (PMSG). In its implementation, wind turbine received differences wind speed condition. Its make wind turbine has different power curves characteristic. The MPPT is needed for getting maximum power in each characteristic and achieved high efficiency [5].

Several researches of MPPT has been reviewed in [6]. MPPT using fixed duty cycle method can achieved MPPT with inherit simplicity and use of a pulse width modulator to drive the dc-dc converter. In terms of extracted power, fixed duty cycle has low efficiency [6]. MPPT using constant voltage is easy implementation and use only single voltage sensor. However constant voltage has appreciable steady state error due to the difference between V_{PV} and V_{OC} [7]. Another method of MPPT is Perturb and Observe (PnO). Operation of this method is close to the maximum power point (MPP). Implementation of PnO has complex component due to use two sensors (voltage and current). Moreover PnO has low speed to achieve MPP and high error calculation [8]. The voltage range output of MPP is from 15 V to 40 V with various irradiance. When the PV used for micro inverter application with 220 V_{AC}, output voltage must be kept in 311 V_{DC} [9]. It is need high gain converter with minimum losses and high efficiency for boost the output voltage of MPP [10].

This research proposed MPPT technique based on incremental conductance (INC) method used for hybrid PV-wind turbine system using coupled inductor-capacitor zeta converter. Incremental conductance is method of MPPT technique using variable steps to achieve maximum power. This technique has fast response and precise technique. Furthermore, Zeta converter with coupled inductor-capacitor is used for boost the output voltage of MPPT converter.

II. Modeling of Hibrid PV and Wind Generation System

The proposed system in this case is to design control maximum power point of hibrid PV – Wind generation and apply constant voltage control as proposed system shown in figure 1.

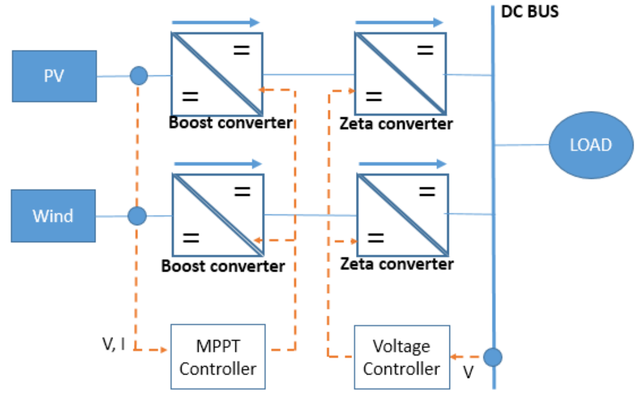


Fig 1. Proposed hybrid PV-Wind generator system

A. *Modeling of PV system*

PV module is described as current source and parallel with single diode, shunt resistance R_{SH} and in series resistance R_S [12]. The efficiency of photovoltaic module depends on many factors, such as the temperature, the solar irradiation, shaded condition and the output voltage of PV module. To increase power output of photovoltaic, PV can connected in series/parallel. If some PV modules are connected in series, the output voltage of the system is higher than parallel scheme. In the parallel scheme, current output of PV modules is high.

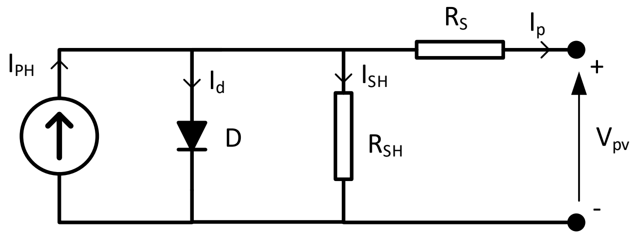


Fig 2. Equivalent circuit of a photovoltaic module [11]

The output current of a photovoltaic module is shown in Fig 2. The equation of current generated by photovoltaic module is formulated by :

$$I_o = I_{ph} - I_d - I_{sh} \quad (1)$$

$$I = I_{pv} - I_0\left[exp\left(\frac{qv + qR_a I}{N_s k_s \tau_a}\right) - 1\right] - \frac{V + R_a I}{R_p} \quad (2)$$

I_O is represented for saturation current in a solar panel, Iph is represented current generated by the incident light, I_d is the current through diode I_{sh} is the current through the parallel resistor R_{sh} .

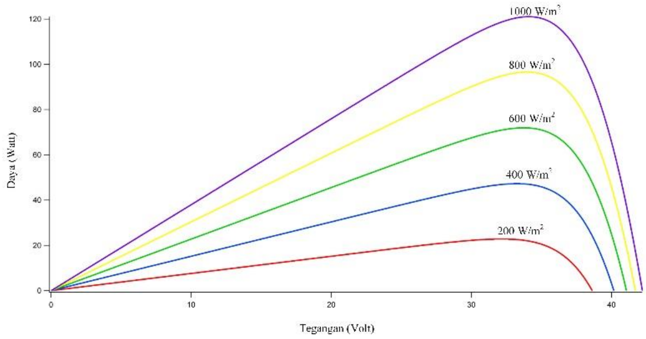


Fig 3. P-V Photovoltaic Curve

Based on Figure 3, it is represented the P-V characteristic curve of photovoltaic. From the we can see that power generated by photovoltaic is influenced by irradiation from sunlight. The greater irradiance of the sunlight, so the greater power generated by photovoltaic.

B. *Modeling of Wind system generation*

Power resulted by wind turbine is influenced by some factors expressed in the following expression.

$$P_m = \frac{1}{2}\rho A v_s^3 C_p(\lambda, \beta) = f(v_s, \omega_t) \quad (3)$$

$$T_m = \frac{P_m}{\omega_s} \quad (4)$$

$$C_p = \frac{1}{2}(116\frac{1}{\zeta} - 5)e^{(-21\frac{1}{\zeta})} \quad (5)$$

$$\frac{1}{\zeta} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{1 + \beta^3} \quad (6)$$

$$\lambda = \frac{\omega_s R}{v_s} \quad (7)$$

Wind turbine has characteristics of output power-wind speed which is shown in figure 4.

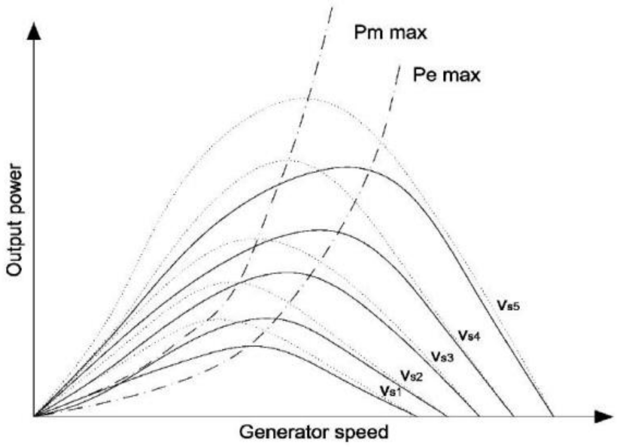


Fig 4. Output power – generator speed characteristic of wind power generator

Wind speed has an operation of maximum power point in different condition of wind speed. Therefore, it needs a control system to track the maximum power point to maximize output power resulted by wind turbine. Wind turbine has some supporting components, such as gearbox, permanent magnet synchronous generator (PMSG), rectifier and DC/DC converter, to convert the mechanical energy into the electrical energy.

III. Design MPPT using Incremental Conductance and Constant Voltage Control

A. *Design MPPT using Incremental Conductance*

Incremental Conductance (IC) is one of MPPT methods and becomes an alternative solution to overcome some P&O limitations, such as steady state error and convergence speed. IC method uses the derivative of PV curve which is shown in figure xx. The concept of IC method is that the maximum power point can be reached when the derivative of power respect to the current I or voltage V is null. This situation is expressed in the following equation.

$$\frac{dP}{dV} = \frac{d(V.I)}{dV} = I.\frac{dV}{dV} + V.\frac{dI}{dV} = I + V.\frac{dI}{dV} \quad (8)$$

$$\frac{dP}{dI} = \frac{d(V.I)}{dI} = I.\frac{dV}{dI} + V.\frac{dI}{dI} = I.\frac{dV}{dI} + V \quad (9)$$

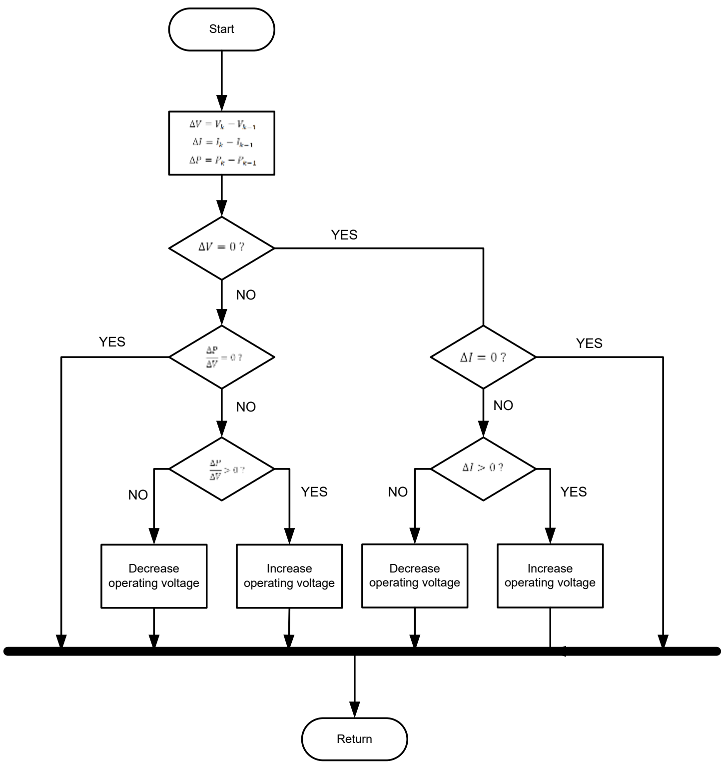


Fig 5. Incremental conductance algorithm flowchart

Furthermore, it can be seen that the power curve derivative will be null at maximum power point, positive on the left side of MPP and negative on the right side of MPP. From the calculation ΔV and ΔI based on equation xx, the algorithm decision is by comparing the instantaneous conductance I/V and the incremental conductance $\Delta I/\Delta V$, which is

(i) $\frac{\Delta I}{\Delta V} = -\frac{I}{V}$; the operation point is in the maximum power point exactly

(ii) $\frac{\Delta I}{\Delta V} > -\frac{I}{V}$; the operating point is on left of the maximum power point

(iii) $\frac{\Delta I}{\Delta V} < -\frac{I}{V}$; the operating point is on the right of the maximum power point.

Therefore, depending on the result, it takes to increase or decrease the voltage across PV array module until maximum power point is reached. To increase and decrease the voltage, it is usually used a fixed step value. The higher the value of the fixed step, the faster the PV to reach the maximum power point, but it results some oscillation around the MPP value. The lower the value of the fixed step, it will slow MPP tracking process, but the minimum oscillation will be obtained.

B. *Design constant voltage control for Zeta converter with coupled inductor and capacitor*

Output voltage of each PV and wind turbine converter should be kept constant at 311 volt to get connected in parallel, so it needs a constant voltage controlled DC/DC converter. In this case, it is used a zeta converter with coupled inductor and capacitor which has a high gain ratio by setting the number of winding turns on inductor coupled, as M. A zeta converter topology is shown in figure 6 and the gain ratio is expressed in eq. 10.

$$M_{CCM} = \frac{V_{out}}{V_{in}} = \frac{1+n}{1-D} \quad (10)$$

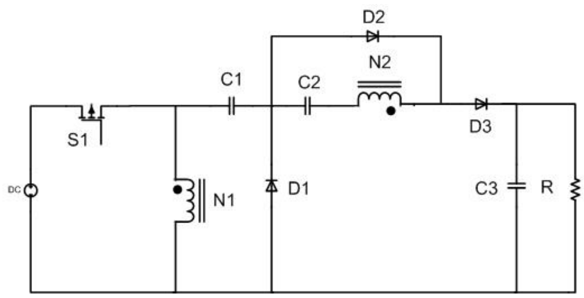


Fig 6. Circuit of zeta converter with coupled inductor and capacitor

PI controller is used to keep the output voltage as a constant, 311 volt, despite the change of input voltage. The PI controller is shown in figure 7.

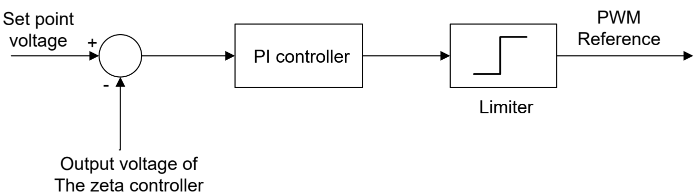
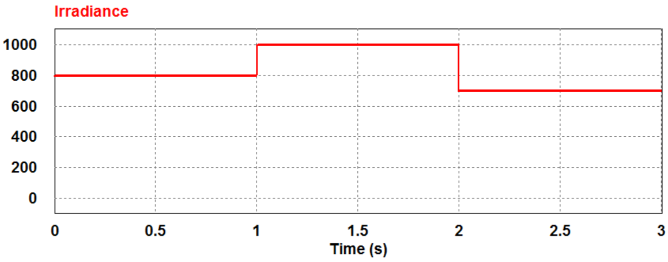


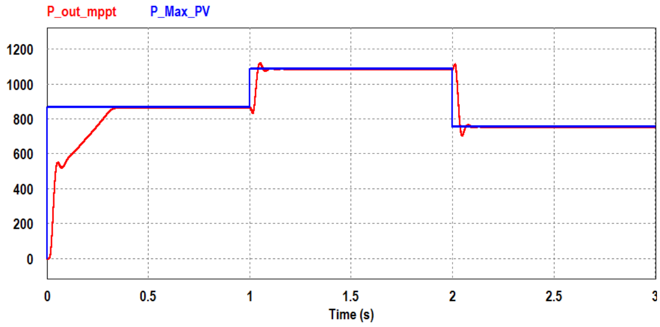
Fig 7. Control system block diagram

IV. SIMULATION RESULT

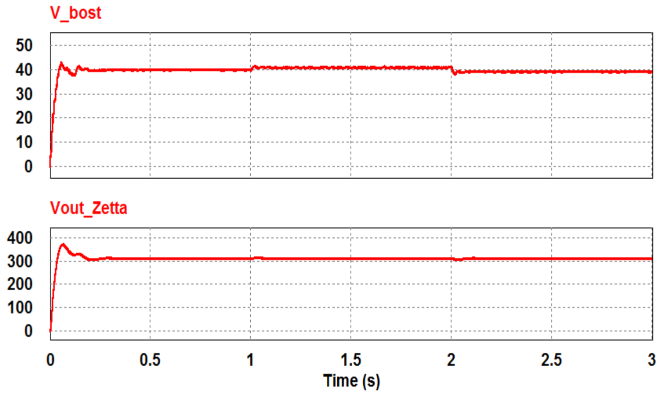
The proposed MPPT using Incremental conductance and constant volatge control in hybrid PV-Wind genetaor has been simulated and analized as follows. In this simulation use PV module with rate power 1kW and Wind Turbin with rate power 1kW. But, in wind generator system only can extract 0.275 kW into the electric power.



(a)



(b)

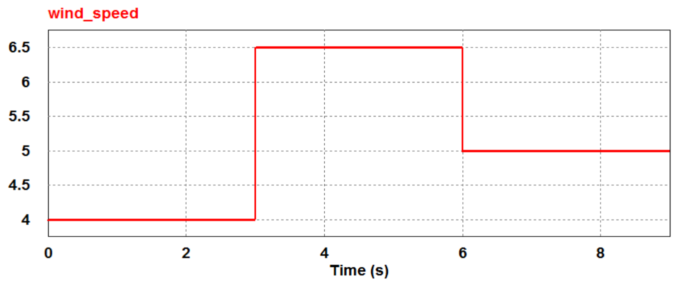


(c)

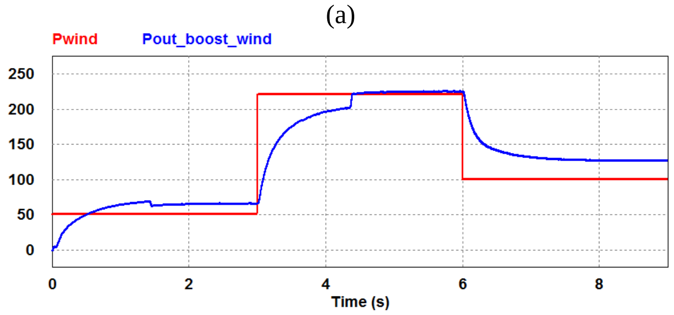
Fig 8. Power and output voltage response of PV system with change on irradiance. (a) irradiance of sun; (b) output power tracking; (c) output voltage each konverter.

From figure 8 we can see that there is an irradiance of sun has change as shown in figure 8(a), the output power of PV also change. The result is power fluctuation generated by PV module can be extract to the output of the boost converter with IC MPPT control in maximum value as shown in figure 8(b). There is also change the output voltage of boost converter, when the irradiance has increase, the output voltage of boost converter increased as shown in figure 8(c), and vice versa.

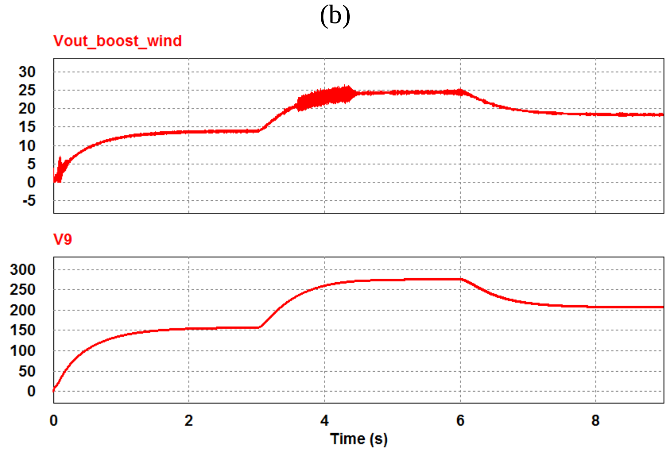
In order to integrate between PV and Wind generator system, the output voltage of each converter should have same value, so it will need a converter with constant voltage control to keep the output voltage in constant value 311 volt. In this case zeta converter with coupled inductor and capacitor has been choosen. The output voltage of zeta converter can keep constant in 311 volt is shown in figure 8(c).



(a)



(b)



(c)

Fig 9. Power and output voltage response of wind generator system with change on wind speed. (a) wind speed; (b) maksimum output power tracking; (c) output voltage each konverter.

From figure 9 we can see when wind speed has change as shown in figure 9(a), the output power of wind power generaton also change. The result is power fluctuation generated by wind generator system can be extract to the output of the boost converter with IC MPPT control in maximum value as shown in figure 9(b). There is also change the output voltage of boost converter, when the wind speed has increase, the output voltage of boost converter also increase as shown in figure 9(c), and vice versa.

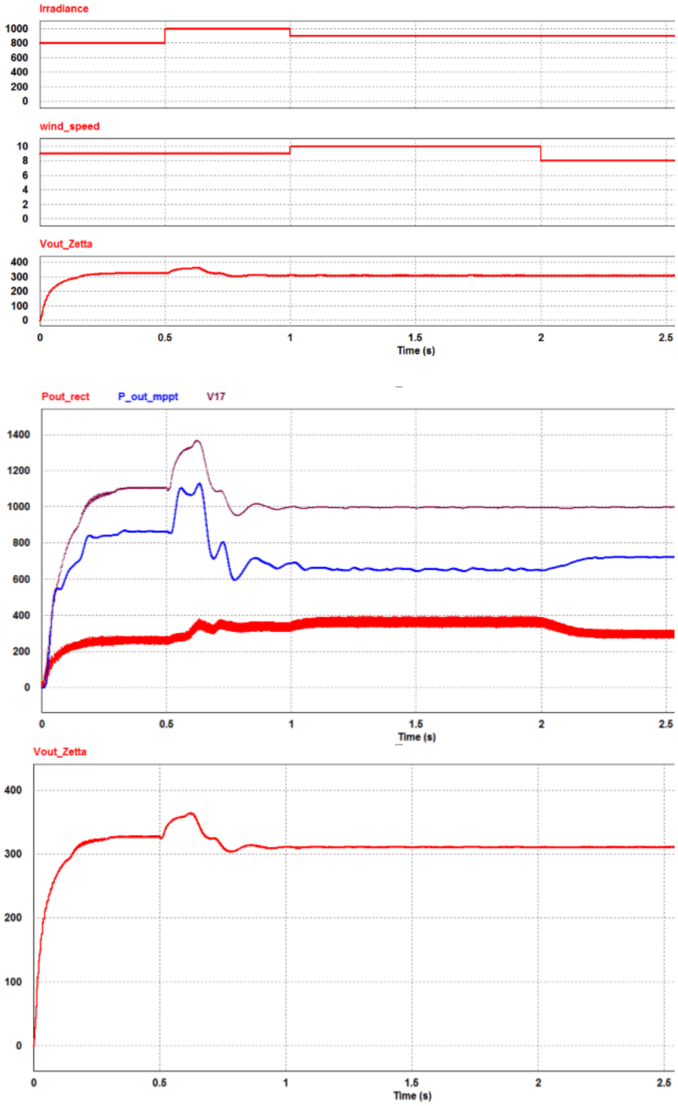


Fig 10. power sharing between PV and wind generator system when connected in parallel

In order to integrate between PV and Wind generator system, the output voltage of each converter should have same value, so it will need a converter with constant voltage control to keep the output voltage in constant value 311 volt. In this case zeta converter with coupled inductor and capacitor has been choosen. The output voltage of zeta converter of wind generation system also can keep constant in 311 volt is shown in figure 9(c).

When PV and wind generation system has connected into parallel the power transfer of the load will be shared beetween PV and Wind generation system as shown in figure 10. The voltage output of parallel system was kept constant 311 volt although irradiance of the sun and wind speed are changing. According to the simulation result, when in steady state condition, the average of output voltage is 310.96 volt.

V. Conclusion

Based on the simulation result, it can be seen that incremental conductance algorithm can track the maximum power point successfully. The efficiency of MPPT using incremental inductance reaches 93%. Zeta converter with inductor coupled and capacitor is applied to keep DC bus voltage at constant value, which is 311 volt. PI controller is applied as a control system and error compensator to set the duty cycle of zeta converter. The simulation has verified that zeta converter is able to keep DC bus voltage at constant value, although the change of wind speed and the sun irradiance occurs. The average output voltage of DC bus in steady state condition is .

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