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Design and Analysis of Boost DC-DC Converter with PI Controller

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Abstract: ***This paper covenants owing to the working of PI Controller fed Boost converter. As PI controller removes the delay and offers quick control, it is preferred in this paper. Out of many controllers which provide effective output, PI is chosen which eliminates the necessity for constant operator attention and instinctive control to the system. In the PI Controller, the gains K_p and K_i are calculated by Ziegler and Nichols method. This PI Controller is used as the effective controller for the Boost Converter. In this converter the output voltage is stepped up (increased) for the given input voltage. The PWM Signal generator is used for commutation purpose in the proposed circuit. The Boost converter maintains a constant voltage at the output.***

Keywords : Boost converter, PI controller, PV system, PWM Generator.

I. INTRODUCTION

In many industrial applications, it is often a mandate for the conversion of a fixed DC voltage into variable DC voltage, simply termed as DC-DC Converter. Generally, a DC converter is treated as a DC analogous of an AC Transformer with continuous changeable turn's ratio similar to a traditional transformer, and also steps up or steps down the DC voltage source [1]. The applications of DC Converters include traction motor control in trolley cars, electric automobiles etc. These converters yield better output and quick time response [2]. DC Converters are employed in regenerative breaking of DC motors to reciprocate the energy again to the supply. In DC Voltage regulators and also in Current Source Inverter, these DC Converters are used [4]. In this paper, a PI (Proportional Integral) controller is used in the Boost converter which converts DC to DC as well as steps up the supply voltage and provides a constant DC output which is then used for DC Motor Load [5]. The Boost converter's output is related to the reference voltage which produces an error signal. This error signal is considered as an input to the PI controller where the tuning of Kp and Ki gains are done. The PI Controller output is given to the PWM Generator that produces PWM Pulses which are then fed as input to the MOSFET Switch [6]-[8]. When the MOSFET is in OFF condition, the diode gets forward biased and supplies the load [9]. When the MOSFET turns on, the inductor gets energized and the load is supplied by the capacitor. During both the cycle, the load gets constant voltage [10]. In the Boost Converter, the output voltage regulation is attained by regulating the absorbed energy from the supply and the energy introduced into the load constantly. The above process of absorption and injection of energy forms the duty cycle.

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II. BOOST DC- DC CONVERTER

The Boost converter generates the output voltage which is very much larger than the supply voltage. Fig.1 shows the conventional Boost converter circuit diagram. In this converter IGBT is used as a Switch. The working of Boost converter is classified into two modes.

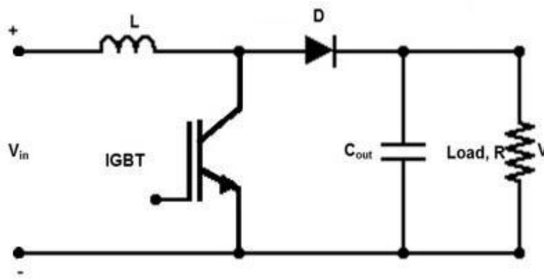

Fig.1. Conventional Boost Converter

Mode I: During this mode, IGBT is turned ON. The input current begins rising and flows though the inductor as well as the switch.

Mode II: During this mode, IGBT turns OFF. The current I_s starts flowing through inductor, diode, load and output capacitor. The inductor decreases until the IGBT switches ON again. The stored energy in the capacitor is conveyed to the load [11]. The capacitor is also used to reduce the ripple component.

The inductor voltage during this period is considered to be V_i-V_o. During steady state, the time integral of the inductor voltage through a single time period would be zero

$$V_i * t_{ON} + (V_i - V_o) * t_{OFF} = 0 \quad (1)$$

Where
V_i = input voltage
V_o = output voltage
t_{ON} = switch ON time
t_{OFF} = switch OFF time

III. PI CONTROLLER FED BOOST CONVERTER

Fig.2 illustrates the circuit diagram of PI Controller fed Boost converter for Photovoltaic application. The main parts in the circuit diagram are Boost Converter, PI Controller and PWM Generator. Initially the output voltage is constant. If there is any change in the output, the output is affected. In order to get the constant output, Boost converter's output is given to the comparator where it is related with the input reference signal. The error signal, called comparator output, is fed to the PI Controller and the controller output is given to the PWM Generator which compares the Controller output with the Triangular waveform and produces pulses which are used to commute the MOSFET duty cycle [12]. The Proportional Integral controller regulates the output voltage. The PWM generator controls the duty cycle of MOSFET. Again the output voltage is continuously controlled to produce a stable output voltage.

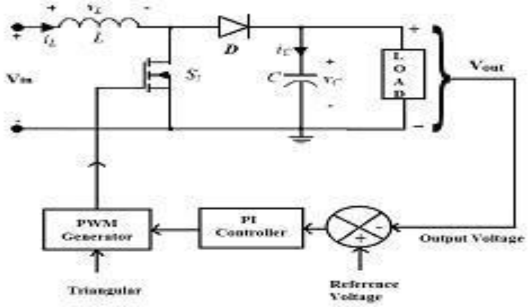

Fig.2. Circuit diagram of PI Controller fed Boost Converter

IV. PI CONTROLLER

The PI Controller is often treated as the standard and proved solution for the Industrial Applications. Fig.3 represents the block diagram of Proportional Integral (PI) Controller. A PI controller is feedback loop controlling technique. A PI controller revises the error which is often occurred due to the deviations in the measured value and the required set point and evaluation and rectification action has been done as per the requirement. The calculation of PI controller involves two separate terms; they are i) Proportional (P) and ii) Integral term (I). The Proportional value (P) regulates the current error reaction, the Integral (I) finds the reaction based on the addition of these errors. The weighted sum of these two works controls the process through the control element. The Proportional controller produces the output proportional to the error signal. When a proportional controller is used, there may be a chance of getting offset (a drift from set-point). As the controller gain increases, the loop may become unstable. Hence, Integral part was introduced in the controller to remove this offset. In Integral (I) action, the controller output is the amount of time the error occurs. The Integral part removes the offset. Also the addition of integral controller removes the steady state error and also reduces the forward gain.

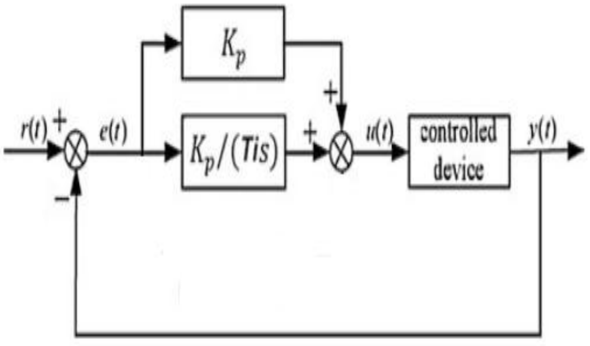

Fig.3. Block Diagram of Proportional Integral Controller

Controller tuning is referred to as the method of changing the controlling parameters to meet the desired conditions. Ziegler and Nichols proposed some rules for fine-tuning PI controller (to set K_p and K_i value) based on the investigational step response. These rules are used to tune K_p and K_i values such that the system is stable. However, the obtained system shows a high maximum overshoot for step response, which is undesirable. In the above case, a series of tunings are needed until a tolerable output is attained. The Ziegler-Nichols tuning rule provides an initial point for fine tuning and later gives the last settings for K_p and K_i. In this paper, Ziegler and Nichols method is used to tune the K_p and K_i parameters to meet the desired specification.

V. PULSE WIDTH MODULATION

Pulse Width Modulation is considered to be one of the effective techniques of delivering intermediary amounts of electric power between completely ON and completely OFF. An easy power switch with a classic power source provides exact full power only if the switch is ON. Recently, PWM technique is quite popular which is made by modern electronic power switches.

Fig.4 shows the PWM signals generator for the Boost converter. The PWM generator block produces pulses for converters having two-level configuration. The PWM block can be employed to stimulate the forced-commutated devices of 1Φ as well as 3 Φ two-level bridges. The generation of PWM pulses is achieved by relating the triangular waveform with the reference signal. The PWM generator produces the required pulses. A single reference signal is required to generate pulses for the bridge. The phase, magnitude and frequency of the reference signal controls an output voltage of the bridge associated to the PWM generator block.

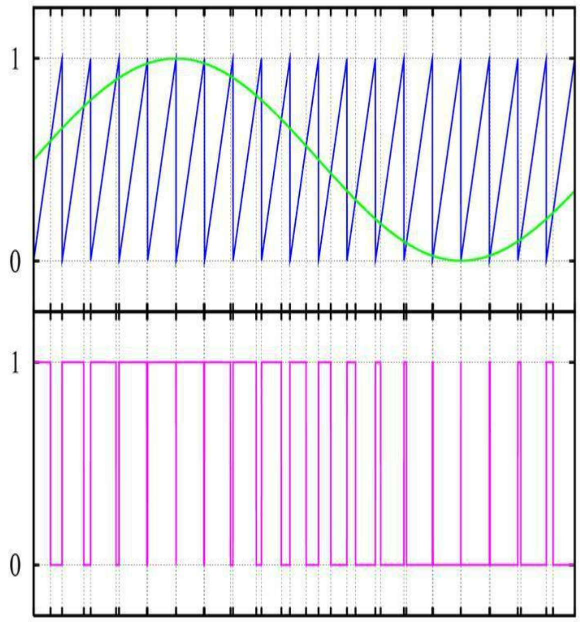

Fig.4 Source Signals and PWM Signals

VI. SIMULATION RESULTS AND DISCUSSION

Fig.5 illustrates the simulation model of PI Controller fed Boost Converter. Here IGBT is used as a power switch inorder to have better voltage control, fast switching frequency. Input voltage is represented as V_{dc} and in turn the output voltage is increased with the help of Boost Converter for RL load. The function of freewheeling diode is to maintain the continuous current path in the input supplies. The PI controller gains (K_p and K_i) are chosen by Zieglar Nichols method. In that PI controller output is given as one of the inputs to the comparator whereas the other input is the triangular wave. The maximum reference value of PI controller output is set. When the triangular signal is greater than reference voltage then IGBT goes to OFF state it remains in the ON State.

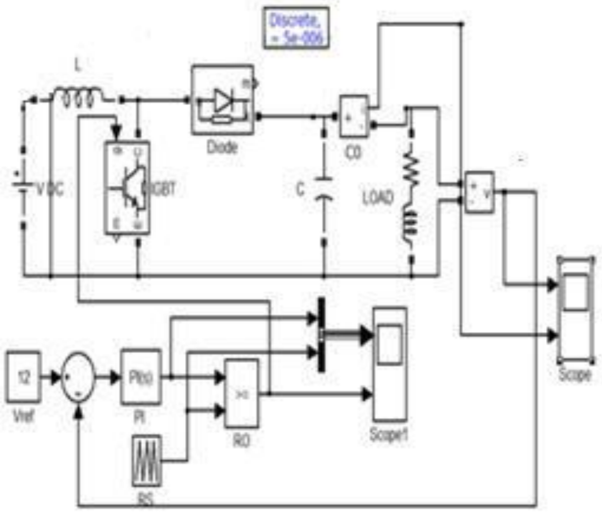

Fig.5 Simulation model of PI Controller fed Boost Converter

Fig. 6 gives the output voltage for the boost converter which is a regulated output. Fig.7 shows the output current for the boost converter. The Boost Converter's output gets regulated using PI Controller.

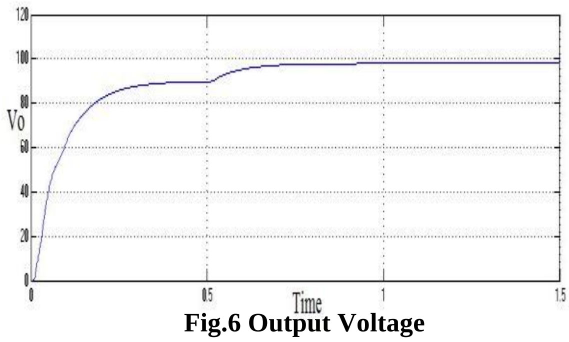

Fig.6 Output Voltage

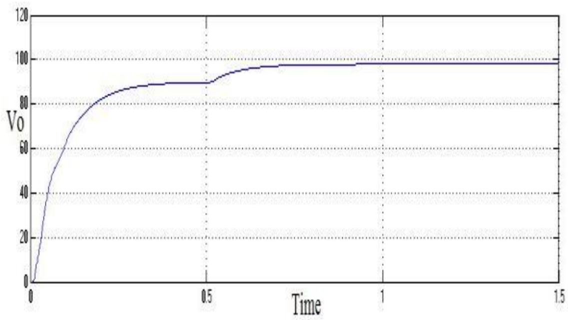

Fig.7 Output Current

VII. CONCLUSION

Boost converter can be used for constant output voltage application. The Proportional Integral (PI) controller controls the output voltage of the Boost converter, by tuning the K_p and K_i values of the controller using Ziegler Nichol's Method. The carrier signal, PI controller signal and PWM pulses are shown in the scope, IGBT switch is used as the power switch. The turning ON and OFF of the switch is controlled by the PWM pulses which is obtained by relating the PI Controller output with the triangular wave. The turning ON and OFF of the switch produces the regulated voltage at the output.

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AUTHORS PROFILE

Mrs.Sasikala.K obtained her UG Degree in Electronics and Instrumentation Engineering from Bharathiar University and PG Degree in Power Electronics from Anna University, Chennai in 2003 and 2005 respectively. Sheworks broadly in design and Simulation of SMPS using Embedded Controllers. Her 8 research articles have been anthologized widely. Currently she is currently working as an Assistant Professor in the Department of Electrical and Electronics Engineering, Vels Institute of Science, Technology &Advanced Studies (VISTAS), Chennai, India.

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