

Simulation and implementation of Variable Duty Cycle Control to Achieve High Input Power Factor for DCM Boost PFC Converters

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Abstract: A discontinuous-conduction-mode (DCM) boost power factor correction (PFC) converter features zero-current turn-on for the switch, no reverse recovery in diode, and constant-frequency operation. But the input power factor (PF) is relatively low when the duty cycle is constant. This paper describes variable duty cycle control to achieve high input power factor for DCM boost power factor correction converters.

Keywords:- Power factor correction, Discontinuous Conduction Mode, Feed forward loop, Boost converter

1. INTRODUCTION

In the industrial, commercial, aerospace, residential and military environment switch mode ac to dc power converters have been increasingly used. This is because it is having the advantages of high efficiency and smaller size and weight. But these power converters will draw pulsating input currents from the utility line, results in poor input power factor of the converters and also injects a significant amount of harmonic current to the utility line. So Power factor conversion (PFC) converters have been introduced in ac-dc power conversions to achieve high power factor (PF) and low harmonic distortion. The Converters operated in discontinuous-conduction- mode (DCM) is suitable for lighter and higher loads, respectively. Various methods for achieving PFC can be classified into active and passive types. While comparing with a passive PFC converter, an active PFC converter can be used to achieve a high power factor and a small size. There are various topologies available for implementing active PFC techniques, among which the boost converter is the representing topology because it has many advantages such as small input-current ripple due to the series connection of the inductor at the input side, high PF over the whole input-voltage range, small size in the output capacitor due to its high voltage, and simple circuit. The boost PFC converter may be designed to operate in discontinuous current mode (DCM). DCM boost PFC converter features zero-current turning-on for the switch and no reverse recovery of the diode, and

it operates in constant switching frequency. Therefore in this paper a variable duty cycle scheme has been introduced and also a method for fitting the duty cycle has been proposed. When the input power factor is improved, the pulsation of the input power is much reduced and this leads to the reduction of output-voltage ripple. Meanwhile, when variable-duty-cycle control is adopted, the critical inductance can be increased, so the inductor current ripple is reduced, leading to higher efficiency. The simulation of DCM based Boost PFC Converter with its control loops, feed forward and feedback loops, is implemented in MATLAB/SIMULINK.

II. DISCONTINUOUS CONDUCTION MODE (DCM):

When the ideal switches of a dc-dc converter are implemented using current unidirectional and/or voltage-unidirectional semiconductor switches, one or more new modes of operation known as *discontinuous conduction modes* (DCM) can occur. The discontinuous conduction mode arises when the switching ripple in an inductor current or capacitor voltage is large enough to cause the polarity of the applied switch current or voltage to reverse, such that the current- or voltage-unidirectional assumptions made in realizing the switch with semiconductor devices are violated. The DCM is commonly observed in dc-dc converters and rectifiers, and can also sometimes occur in inverters or in other converters containing two-quadrant switches. The discontinuous conduction mode typically occurs with large inductor current ripple in a converter operating at light load and containing current-unidirectional switches. Since it is usually required that converters operate with their loads removed, DCM is frequently encountered. Indeed, some converters are purposely designed to operate in DCM for all loads. The properties of converters change radically in the discontinuous conduction mode. The conversion ratio M becomes load-dependent and the output impedance is increased. Control of the output may be lost when the

load is removed. The principles of inductor volt-second balance and capacitor charge balance must always be true in steady-state, regardless of the operating mode.

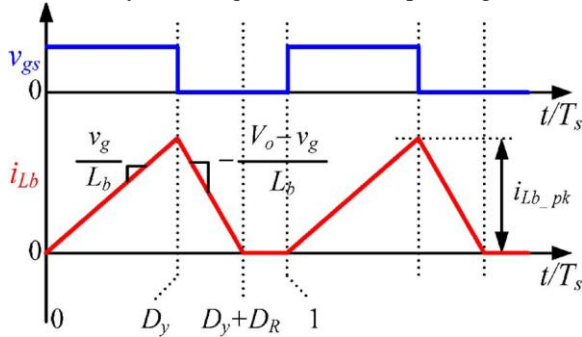


Fig.1. Inductor current waveform in a switching cycle.

III. CONTROL STRATEGIES USED

There are 3 control strategies been used for controlling the duty cycle. They are

- a. Power factor control loop
- b. Current ripple control loop
- c. Voltage control loop

A. POWER FACTOR CONTROL LOOP:

The power factor of an AC electric power system is defined as the ratio of the real power flowing to the load over the apparent power in the circuit and is a dimensionless number between 0 and 1 (frequently expressed as a percentage, e.g. 0.5 power factor = 50% power factor). Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power. Here a power factor loop is there, it will be analyzing the input voltage along with the output voltage. By varying the gain in the loop power factor can be controlled in the desired manner.

B. CURRENT RIPPLE CONTROL LOOP:

In this loop, actually we are using one bistable flip-flop. Here the input current and the feed forward gain controlled current has been compared. In flip flop, if inputs S (set) and R (reset) are TRUE (1) simultaneously, the output Q is set to TRUE (1). If inputs S (set) and R (reset) are TRUE (1) simultaneously, the output Q is reset to FALSE (0). The Q output is the complement of the Q output. The initial value of the Q output is specified by the parameter "Initial Q output". Thus the current ripple is controlled.

C. VOLTAGE RIPPLE CONTROL LOOP:

Output voltage ripple is the name given to the phenomenon where the output voltage rises during the On-state and falls during the Off-state. Several factors contribute to this including, but not limited to, switching frequency, output capacitance, inductor, load and any current limiting features of the control circuitry. At the most basic level the output voltage will rise and fall as a result of the output capacitor charging and discharging:

During the Off-state, the current in this equation is the load current. In the On-state the current is the difference between the switch current (or source current) and the load current. The duration of time is defined by the duty cycle and by the switching frequency.

The output capacitor or switching frequency increase, the magnitude of the ripple decreases. Output voltage ripple is typically a design specification for the power supply and is selected based on several factors. Capacitor selection is normally determined based on cost, physical size and non-idealities of various capacitor types. Switching frequency selection is typically determined based on efficiency requirements, which tends to decrease at higher operating frequencies. Higher switching frequency can also reduce efficiency and possibly raise EMI concerns. Output voltage ripple is one of the disadvantages of a switching power supply, and can also be a measure of its quality.

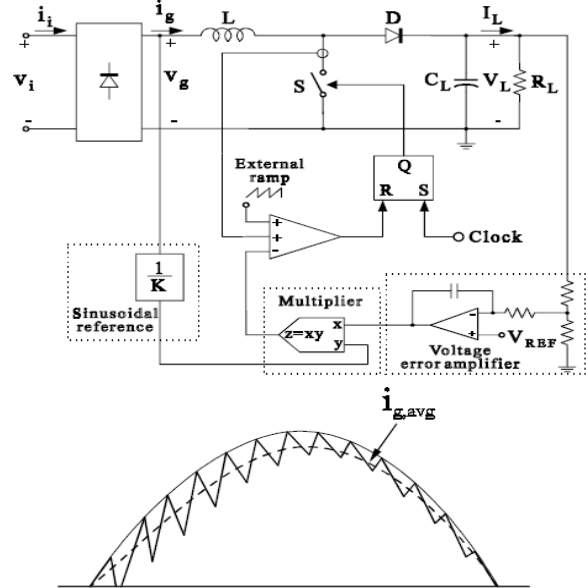


fig.2. Feedback control loop and average current

IV. SIMULATION RESULTS AND DISCUSSION

The simulated circuit is given below. The load used is a 5 hp 240V induction motor. The output of the motor is adjusted by making use of duty cycle control.

Input of 230V is given to the rectifier section, so produced DC voltage is 203V. This has been fed to a Boost converter which will be boosting up the input DC to 400V DC.

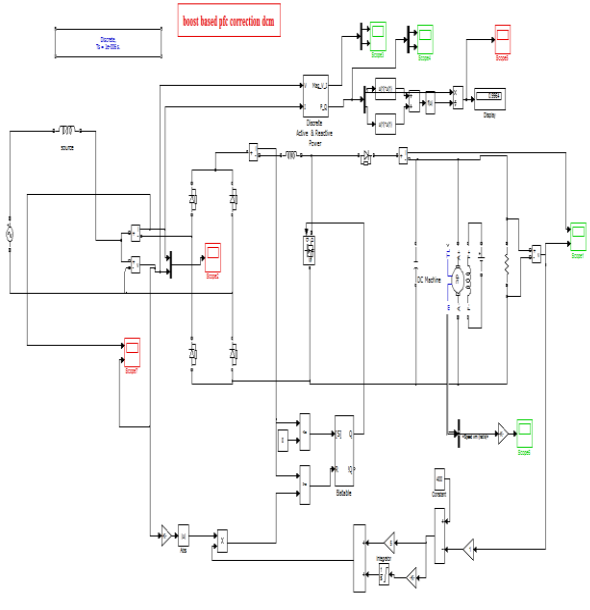


Fig.3.Simulated circuit

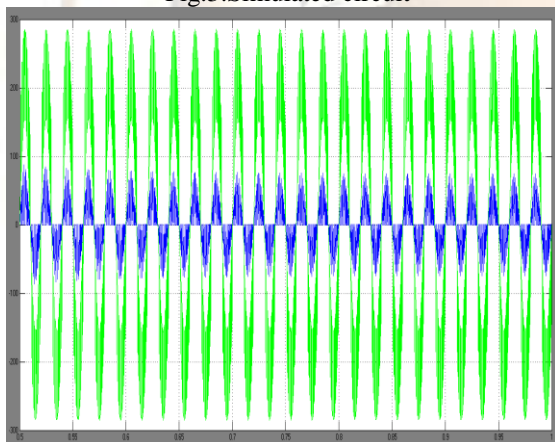


Fig.4.Input voltage and input current

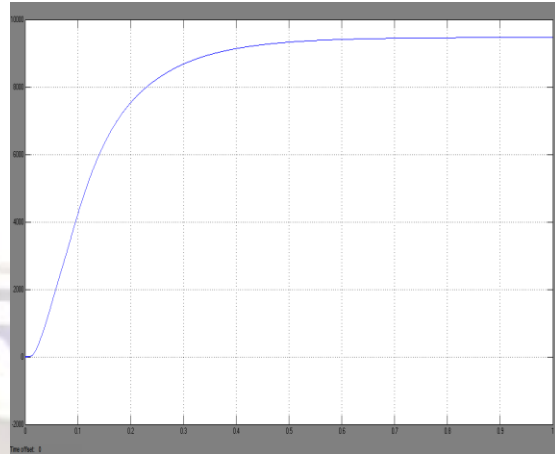


Fig.5.Motor Speed

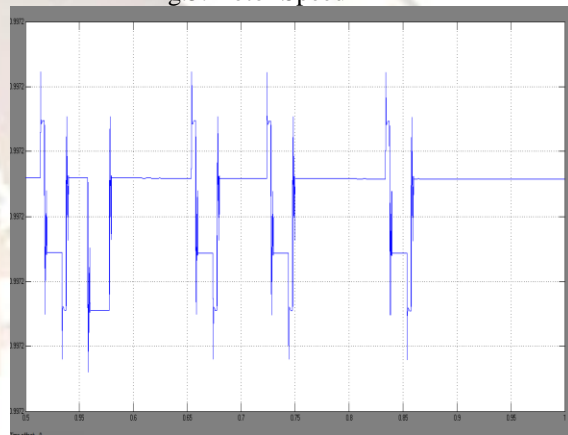


Fig.6.Power factor

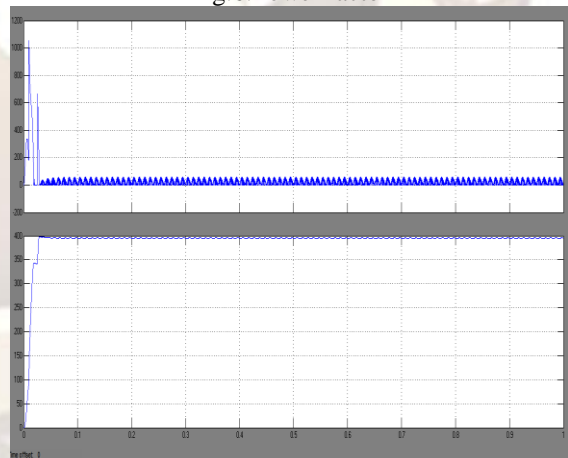


Fig.7.Output voltage and current

Here the output voltage has been fed to a comparator which will be comparing the output voltage with the reference voltage. Thus a proportional signal is produced. This is then given to a PI controller. Then this PI controller output is given to a multiplier section, which multiplies the PI controller output with the input voltage. Multiplied output is given to a relational operator section and then to a SR flip flop. Thus the

duty cycle is controlled and is given to the switch. There by the power factor can be reached near unity.

V. CONCLUSION

Power factor has been a greater concern in the distribution side. So the improvement of power factor has been given much importance. By varying the duty cycle only the power factor can be improved. Based on the ON and OFF time of switch present in both CCM and DCM boost converter. Normally N channel MOSFET is used as switch. Here soft switching is done. Here for controlling the duty cycle, 3 control loops are framed. Each one for controlling power factor, current ripple, and voltage ripple. Each loop gain can be changed, without altering the other values. Thus power factor is improved to a near unity power factor value.

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