Simulation and analysis of single-stage single phase buck-boost pfc converter

D Dani Shaffrya[1], R Siva Sankari[1], S Vishnu Priya[1], Sasikumar M[2]
[1]PG Scholar, Dept. of Power Electronics and Drives
[2]Professor & Head, Dept. of Power Electronics and Drives
Jeppiaar Engineering College, Chennai-119.
***Corresponding author: Email:** shaffrya94@gmail.com

ABSTRACT
This Paper presents a simulation study and characteristic behavior of modified buck-boost Chopper for power factor correction. The entire power electronics component in the projected buck-boost converter likes rectifier unit, filter, converter and load system are modeled and simulated using MATLAB7.10. The parameter of the buck-boost topology is verified by varying load conditions. This proposed converter is able to achieve efficient Power Factor Correction and low voltage stress for varying load conditions.
Keywords – Power factor correction (PFC), Single-Stage (SS), Buck Boost Converter (BBC)

INTRODUCTION

The Switched mode chopper is the power electronic circuits which alter electrical voltage into another level by switching action. The types of dc-dc converter are buck converter; boost converter, buck-boost converter and cuk converter. A BBC yields a voltage which can be either higher or lower than the contributed voltage. The yield voltage polarity is opposite to that of the supply voltage. This converter is also called as inverting regulator. This BBC can operate with high efficiency than other single-stage converter. The buck-boost converter can either be step up or step down chopper. In this converter, it is trouble-free to execute output short-circuit protection. The isolation is prepared in the PFC stage for some multistage power electronics applications. The foremost negative aspect of boost converter is it cannot limit the inrush output current.

The BBC PFC gives high efficiency and limits the contributed voltage range for better performance requirement. The PFC cell is worn to lessen intermediate bus voltage. SCR is compact and posses high consistency and has very low loss. Due to this, useful features they are universally employed for all high power controlled devices. It is an oldest member of the thyristor family and it is a solid state device, their characteristic is similar to thyratron tube. For large current applications, thyristors need better cooling and it would be achieved with great extent by installing huge amount of heat sinks. Due to this, the rating of SCR has drastically improved since its introduction in 1957.

A SCR with voltage evaluation of 10KV and RMS current rating of 3000A. Along with the power usage capacity of 30MW are available. The yield voltage polarity provided by this regulator is reversed. Under a liability condition of the transistor, the di/dt of the fault current is restricted by the inductor L and will be V_s/L. The voltage produced by this converter is higher in scale than the input voltage. The properties of BBC are steady-stage voltage conversion ratio, the nature of input and output current, and the quality of output voltage ripple. The imperative property is the frequency reaction of the duty cycle to output voltage relocates function. The steady state process of this converter is continuous and discontinuous. The yield current of this converter power stage is discontinuous or pulsating as the output diode only conducts during a part of switching cycle.

CIRCUIT DISCRIPTION

The BBC PFC consists of input filter, a MOSFET switch, BBC, and RL load. For each switching cycle, the capacitor supplies a load current. The filter connected at the input consists of combination of inductor and capacitor which gives an effective output. For this analysis n-channel MOSFET is used and pulse is given to gate terminal. The advantages of using n-channel MOSFET is its lower ON state resistance. In continuous mode of operation, for each switching sequence, the current flows through inductor; but in discontinuous mode of operation, there won't be any current in both inductors. The inductor L_3 cannot be a PFC cell since it does not contribute to the cell electrically. The BBC gives negative polarity output with esteem to the input terminal.

MODES OF OPERATION

MODE-1: During mode-1 switch M1 is in ON state and the input ac voltage applied is larger than the intermediate bus voltage and the output voltage. The voltage gets step down in the output voltage due to buck-boost converter. When switch is in ON condition, diode D_5 starts to conduct and inductor connected parallel to this diode gets charged linearly. The output capacitor C_4 delivers power to the RL load. If load current is less than the critical rate, the inductor current will be zero for the portion of switching cycle. In BBC PFC system, if inductor current drops to zero, it stops the operation and remains until next switching begins. The duration of ON state is $T_{on}=D*T_s$. In this mode, diode D_5 gets reverse biased thus the output circuit is isolated.

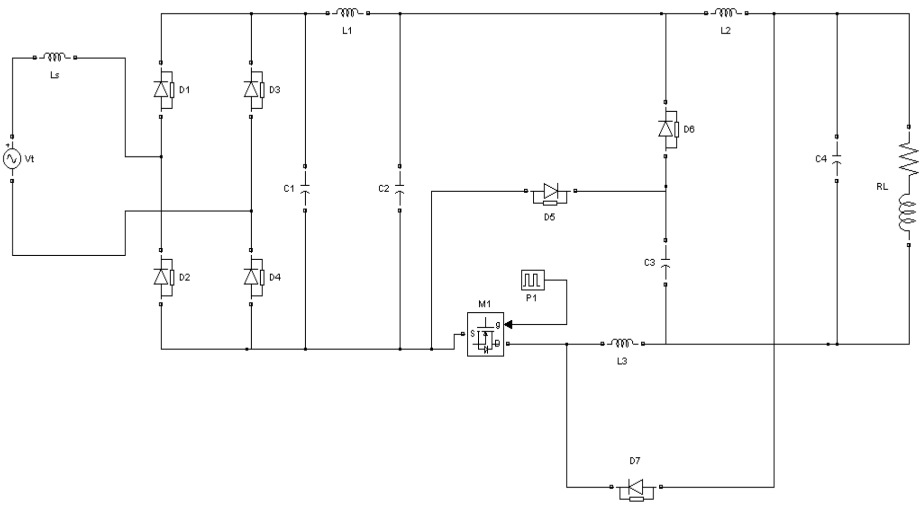

Figure.1.A Proposed circuit analysis for single stage single-phase PFC converter.

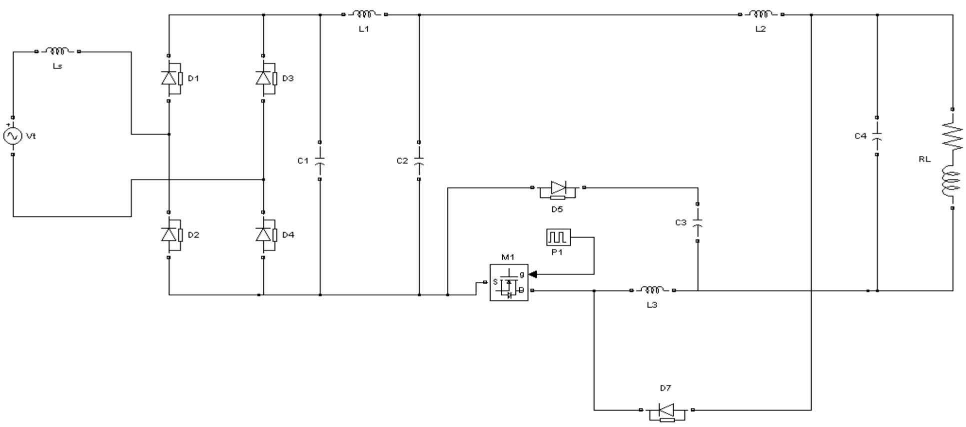

Figure.2.The analysis of the buck-boost converter in mode-1.

MODE-2: During mode-2 the switch M1 is in OFF state. The inductor current decreases and the capacitor connected to the inductor starts to charge. The energy stored in inductor gets transfer to the load and capacitor C_4. The duration of OFF state is T_{off}=(1-D) * T_s. The stage ends when inductor gets fully discharge. Only capacitor C_4 delivers all the output power. The diode D_6 conduct when the switch is in OFF condition, and current flows all the way through inductor L_3, capacitor C_3**,** diode D_6, and RL load.

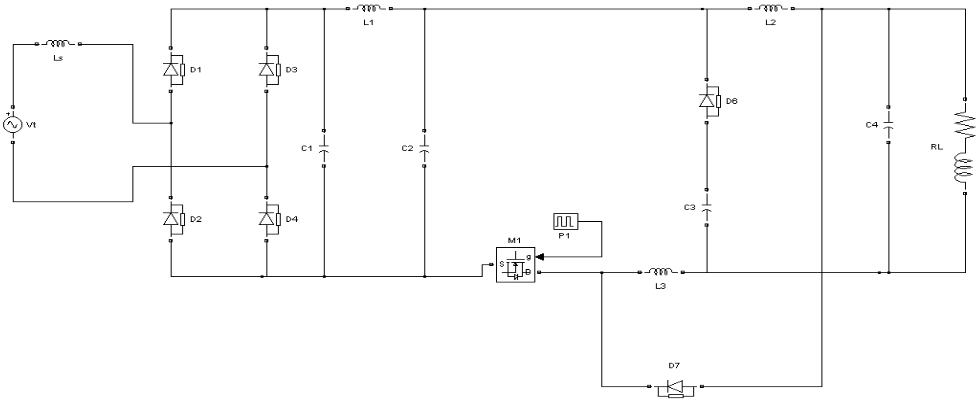

Fig3: The analysis of buck-boost converter in mode-2.

METHODS AND MATERIALS USED IN PFC BUCK-BOOST CONVERTER

For analysis of the circuit, a few assumptions are made,

(a) Switches are idyllic.

(b) Incessant conduction mode.

The inductor L_3 current increases in the ON period of the chopper (T_{on}),

$$V_t = L_3(I_{max} - I_{min}) \div T_{on}$$

$$= L \times I_s \div T_{on}$$

$$T_{on} = I_s \div V_t$$

$$I_s = V_t . T_{on}/L_3$$

The inductor current decreases in the OFF period of the chopper (T_{off}),

$$V_o = -L_3 . I_s/T_{off}$$

$$T_{off} = -I_s . L_3/V_o$$

$$I_s = -T_{off} . V_o/L_3$$

Where I = $I_2 - I_1$ is the peak-to-peak inductor ripple current.

From above equations,

$$I_s = V_t . T_{on}/L_3$$

$$= -T_{off} . V_o/L_3$$

$$V_t . T_{on} = -T_{off} . V_o$$

$$V_o = -V_t T_{on}/T_{off}$$

$$= -V_t T_{on}/(T_1 - T_{on})$$

$$V_o = -V_t \alpha/(1-\alpha)$$

Where α = duty cycle = T_{on} / T

Output voltage

$$V_o = -V_t \alpha/(1-\alpha)$$

$$V_o = -V_t T_{on} f/(1 - T_{on} f)$$

$$V_{on}(1 - T_{on} f) = -V_t T_{on} f$$

$$T_{on} = V_o/(V_o - V_s) f$$

Assume no losses in the circuit,

$$V_t I_t = -V_o I_o$$

$$= \alpha V_t I_o/(1-\alpha)$$

Average source current,

$$I_t = I_o \alpha/(1-\alpha)$$

The switching period,

$$T = T_{on} + T_{off}$$

$$T = \left(\frac{I_s L_3}{V_t}\right) + \left(\frac{I_s L_3}{V_t}\right)$$

$$I_t = V_t V_o/f L(V_o - V_t)$$

$$I_t = V_t \alpha/f L_3$$

When the switch is ON, the output current is supplied by the filter capacitors. The discharging capacitor current is same as the output current and the peak-to-peak undulated capacitor voltage is specified as,

$$V_c = I_o . T_{on}/C_4$$

Substituting T_{on} value in above equation,

$$V_c = I_o \alpha / f C_4$$

Applying KVL in the circuit,

$$I_c + I_r = 0$$

$$C.V_{c'} + (V_c/R) = 0$$
$$V_{c'} = V_c/ RC$$

When switch is in OFF condition,

$$V_L + V_c = 0$$
$$I_{L'} = V_c/L$$

Applying KCL to the circuit,

$$I_c + I_r = I_L$$
$$V_{c'} = \left(\frac{I_L}{C}\right) - \left(\frac{V_c}{RC}\right)$$

Output equation,

$$y = Cx + D$$

Average model,

$$A = A_1K + A_2(1-K)$$
$$B = B_1K + B_2(1-K)$$
$$C = C_1K + C_2(1-K)$$
$$D = D_1K + D_2(1-K)$$

Average inductor voltage over a time period must be equal to zero,

$$\frac{V_o}{V_t} = D/(1-D)$$

Assuming lossless circuit,

$$\frac{I_o}{I_t} = (1-D)/D$$

The steady-state equation is given by,

$$V_o = -[(V_1 - V_t) \times \left(\frac{D}{1-D}\right) - V_t - \frac{I_L R_L}{1-D}]$$

Depending on the duty ratio, the yield voltage can be either higher or lower than the input voltage. The parasitic elements are due to losses associated with inductor, capacitor, switch and diode. Parasitic elements have significant effect on voltage transfer ratio.

RESULTS AND DISCUSSIONS

The Stimulant Model for the proposed converter with RL load is revealed in fig.6 and output voltage waveform for the proposed converter is exposed in fig.5(a).

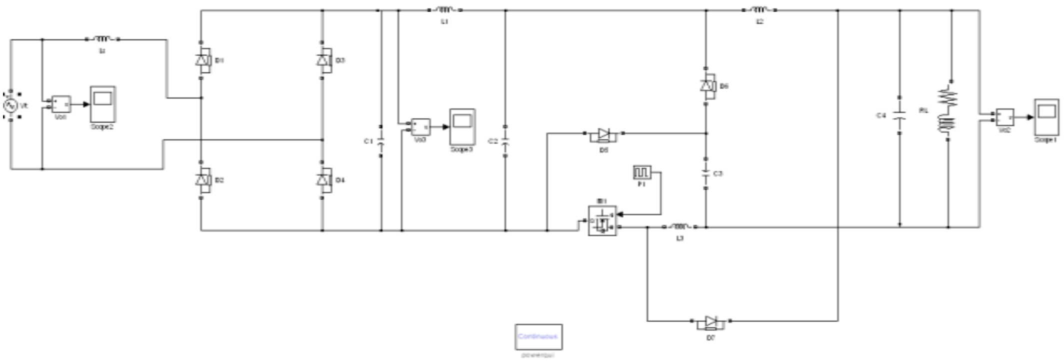

Fig.4: Simulation circuit for the single phase buck-boost PFC converter.

When the voltage across capacitor C_3 becomes larger it results in increase in input voltage, and power transfer from input to output gets decreased. The efficiency of buck-boost converter is better than the boost converter. The Buck-Boost converter is able to achieve efficiency around 97%.

By using the capacitor and inductor the efficiency of the proposed chopper is improved. It limits the high inrush input current. It gives negative polarity output. The output voltage produced by this converter is higher in magnitude than input voltage.

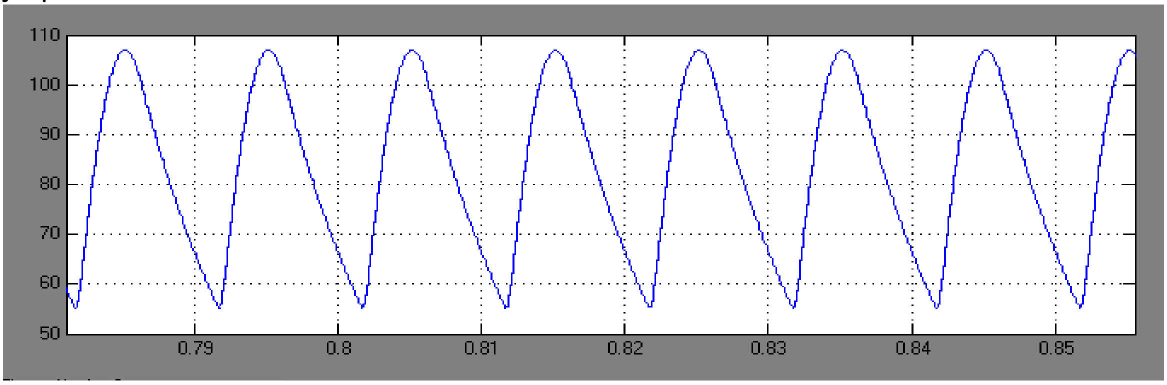

Fig.5.1 Output voltage waveform

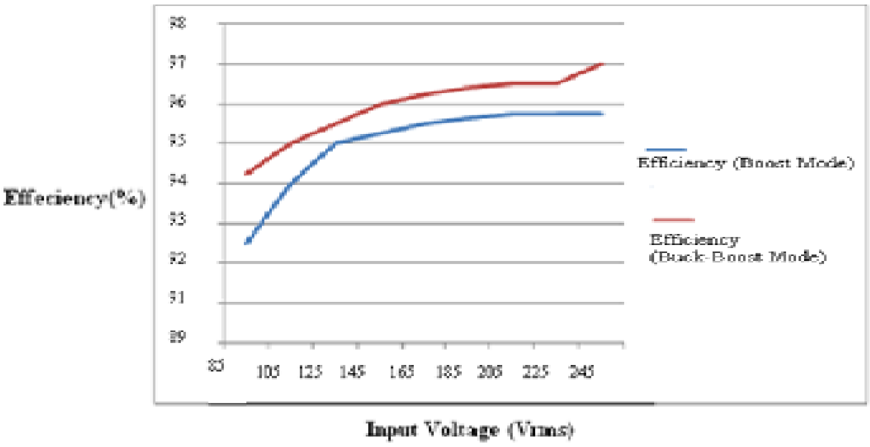

Fig.5.2 Discussion of the efficiency of proposed and existing systems.

CONCLUSION

A high efficient Buck-Boost converter is proposed in this paper. The operation of Buck-boost converter PFC cell is illustrated by RL load and is studied by using MATLAB simulation. A high inrush current is limited by improving efficiency of the chopper. The experimental results prove that high efficiency and voltage gain is achieved.

REFERENCES

Hui SY and Henry shu hung Chung A bidirectional ac-dc power converter with power factor correction, IEEE, Power electronics, 2000, 942-948.

Itoh R and Ishizaka, Single phase sinusoidal rectifier with step up-step down characteristics, IEE proc, 1991, 338-344.

Petersen L and Andersen M, Two-stage power factor corrected power supplies: The low component-stress approach, in Proc. IEEE Appl. Power Electron. Conf. Expo., 2, 2002, 1195–1201.

Sasikumar M, Pandian SC, Modified bi-directional AC/DC power converter with power factor correction, International Journal of Engineering, Transactions B: Applications, 25, 2012, 175-180.

Singh B, Singh BN, Chandra A, Al-Haddad K, Pandey A, and Kothari DP, A review of single-phase improved power quality AC/DC converters, IEEE Trans. Ind. Electron., 50(5), 2003, 962–981.