ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*An ISO 3297: 2007 Certified Organization* *Vol. 5, Special Issue 3, March 2016*

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE'16)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 17th & 18th March 2016

# Power Factor Correction with Input Voltage Feed Forward Compensated Two Switch Buck-Boost Converter

Anjali K Joy[1], Renu Jose[2]

PG Student [PE], Dept. of EEE, Toc H Engineering College, Arakkunnam, Kerala, India[1]

Assistant Professor, Dept. of EEE, Toc H Engineering College, Arakkunnam, Kerala, India [2]

**ABSTRACT:** The usage of power electronic systems has expanded to new and wide application range but the presence of harmonics is a major problem. The non-linear operation of power semi converters and presence of bridge rectifiers in electronic devices for AC-DC conversion resulted in a high Total Harmonic Distortion (THD) and low Power Factor (PF). There comes the need for a power factor correction circuit along with the power converters for limiting the allowable harmonics on the power lines, and hence to improve the power factor. For the power converters of power factor correction application, there is a great need for less component stress, smaller component size and higher efficiency. The main objective of this paper is to conduct performance analysis of Two Switch Buck-Boost (TSBB) converter in power factor correction when input voltage feed forward compensation technique is incorporated with it. Also if the transient response of voltage is not satisfactory, it creates problems on the output response of the system. By adding feed-forward techniques, the proposed converter can improve transient response by reducing the influence of the input voltage and load disturbances on the output. These input voltage feed forward(IVFF) compensation is then proposed for two switch buck boost converter which realizes the automatic selections of operating modes and input voltage feed forward functions. Simulation results are presented to validate the proposed theory by using SIMULINK/MATLAB.

**KEYWORDS:** Two switch buck-boost converter, Two mode control scheme, Input voltage feed forward compensation, power factor correction.

## I.INTRODUCTION

Now a day with increasing use of power converter devices and power electronic loads, more emphasis is given to power factor correction (PFC) and reduction in total harmonic distortion (THD) in the current drawn from the power utility. In order to improve the power quality, researchers have given more attention on development of new topologies on power converter. Improvements can be achieved by PFC techniques[9]. Since now, various passive and active power factor correction circuits have been proposed, of which active power factor circuits found to be more advantageous. Thus active PFC techniques have rapidly become a vigorous research topic in the power electronics field and efforts have been made on the development of the PFC converters [1]. Various power factor correction (PFC) techniques for buck converter, boost converter, buck boost converter topologies are employed to overcome the power quality problems. This paper proposes a Two Switch Buck Boost converter along with a power factor correction control to improve the power factor and hence reduce the THD.

The two-switch buck-boost (TSBB) converter is a simplified cascade connection of buck and boost converters. Compared with other basic converters such as buck, boost, buck-boost, CUK,ZETA,SEPIC converters ,TSBB converter has lower voltage stress for power component[2]s ,fewer passive components[3], higher voltage conversion efficiency[5] and positive output voltage[6]. If input voltages from battery and fuel cell fluctuate with the output power, and the input voltage in the PFC applications varies with the sinusoidal line voltage, a satisfactory input transient response preventing large output voltage variation in case of input voltage variation is also desired for the TSBB converter[8].

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Vol. 5, Special Issue 3, March 2016

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE'16)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 17th & 18th March 2016

## II. TWO SWITCH BUCK BOOST CONVERTER

The TSBB is suitable for wide input voltage applications. In order to achieve high efficiency over the entire input voltage range, the TSBB converter is operated in buck mode at high input voltage and boost mode at low input voltage. Such operation is called the two-mode control scheme. Figure 1 shows the circuit diagram of TSBB converter. There are two active switches in the TSBB converter, which provides the possibility of obtaining various control methods for this converter. If *Q*1 and *Q*2 are switched ON and OFF simultaneously, the TSBB converter behaves the same as the single switch buck-boost converter. This control method is called one mode control scheme .If $Q_1$ and $Q_2$ are controlled independently, it is two mode control scheme.

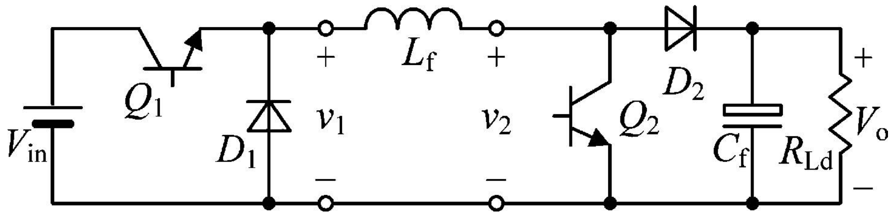


Fig. 1 Circuit Diagram of Two Switch Buck-Boost Converter

Modes of operation can be explained in two stages, when switch $Q_1$ is controlled and $Q_2$ is off and when $Q_1$ is continuously on and $Q_2$ is controlled to regulate the output voltage.

a. When the input voltage is higher than the output voltage, *Q*2 is always kept OFF, and *Q*1 is controlled to regulate the output voltage, and as a result, the TSBB converter is equivalent to a buck converter, and is said to operate in buck mode
b. When the input voltage is lower than the output voltage, *Q*1 is always kept ON, and *Q*2 is controlled to regulate the output voltage, and in this case, the TSBB converter is equivalent to a boost converter, and is said to operate in boost mode.

Compared with one-mode control scheme, two-mode control scheme can reduce the conduction loss and switching loss effectively, leading to a high efficiency over a wide input voltage range, as explained in [4]. Besides, in order to achieve automatic switching between buck and boost modes, the two-mode control scheme based on two modulation signals with one carrier signal is used. For the converter in the applications with wide input voltage variation, input voltage feed-forward (IVFF) compensation is an attractive approach for improving the transient response of the converter, for it can eliminate the effect of the input voltage disturbance on the output voltage .

For one stage PFC converters, the main challenge is the availability of only one control variable to perform voltage regulation and power factor correction in a single step. As a result, in the design of the controller, a trade off needs to be considered between output voltage regulation and power factor correction. IVFF control circuit perform both voltage regulation and power factor correction. The IVFF of the buck or boost converter can be implemented in several methods.

a. Vary either the amplitude of the carrier signal or the value of the modulation signal according to the input voltage. However, the variations of the carrier signal for the IVFF of the boost converter and the modulation signal for IVFF of the buck converter are both inversely proportional to the input voltage, which imply that the implementation of this IVFF method is complicated relatively for the TSBB converter.
b. Calculating the duty ratio. Since the duty ratio for the buck converter is inversely proportional to the input voltage results in complicated design.
c. Deriving IVFF functions in both buck and boost modes of operation which is easy to implement.

## III.TWO MODE CONTROL SCHEME FOR TSBB CONVERTER

Voltage conversion ratio for TSBB converter in continuous current mode is,

$$V_o = \frac{d_1}{1 - d_2} V_{in}$$

In the two-mode control scheme, *d*1 and *d*2 are controlled Independently. When the input voltage is higher than the output voltage, the TSBB converter operates in buck mode, where *d*2 = 0 and *d*1 is controlled to regulate the output

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

**International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering**

*An ISO 3297: 2007 Certified Organization* *Vol. 5, Special Issue 3, March 2016*

**National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE'16)**

**Organized by**

**Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India**

**On 17th & 18th March 2016**

voltage. When the input voltage is lower than the output voltage, the TSBB converter operates in boost mode, where $d_1 = 1$and $d_2$ is controlled to regulate the output voltage. Thus, the voltage conversion of the TSBB converter is ,

$$V_o = \begin{cases} d_1 V_{\text{in}}, \; d_2 = 0 \;\; (V_{\text{in}} \geq V_o) \\ \dfrac{V_{\text{in}}}{1 - d_2}, \; d_1 = 1 \;\; (V_{\text{in}} < V_o) \end{cases}$$

TSBB converter under the two-mode control scheme based on two modulation signals and one carrier which is shown in Fig.2

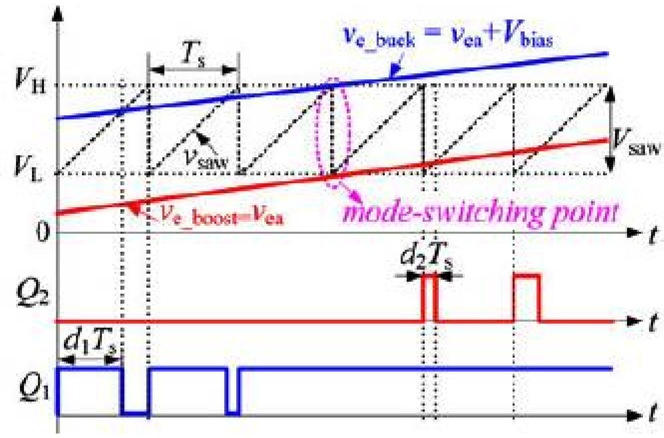


Fig. 2 Two mode control scheme.

In two mode control scheme v $_{e\text{-buck}}$ and v $_{e\text{-boost}}$ are the modulation signals for switches Q $_1$ and $_{Q2}$ and v $_{saw}$ is the carrier. The maximum and minimum values of carrier are V $_L$ and V $_{H.}$ To achieve two mode control scheme only one of the modulation signals can intersect with carrier v $_{saw}$ at any time.

*a.* When V$_{in}$ > V $_{out}$ , v $_{e\text{-buck}}$ will be within [VL, VH ], and it intersects V$_{saw}$ and thus determines d1 and v $_{e\text{-boost}}$ < VL and thus d2 = 0 which is corresponds to the buck mode of the TSBB converter.

*b.* When V$_{in}$ < V $_{out}$ , v $_{e\text{-boost}}$ will be within [VL, VH ], and it intersects V$_{saw}$ and thus determines d2 and v $_{e\text{-buck}}$ > VH and thus d1= 1 which is corresponds to the buck mode of the TSBB converter.

## IV.DESIGN OF TSBB CONVERTER

The Two Switch Buck Boost converter is designed for CCM mode depending on the input voltages, output voltage and power. The input voltage variation is from (200 V-240 V) for an output of 220 V. The design steps are given as follows:

$$D = \frac{V_o + V_D}{V_o + V_{in} + V_D}$$

Where $V_D$ represents diode voltage, $V_o$ and $V_{in}$ represents the output and input voltage respectively. The inductor and capacitor design is as,

$$L = \frac{V_0 \text{ x } D}{f \text{ x } \Delta I_L}$$

$$C = \frac{I_o \text{ x } D}{f \text{ x } \Delta V_o}$$

## IV.TSBB CONVERTER WITH POWER FACTOR CORRECTION CIRCUIT

Schematic diagram of the two-mode control scheme with IVFF is shown in Fig. 4. This IVFF compensation circuit is here acting as power factor correction circuit. From this schematic diagram control block diagram for TSBB converter with IVFF is obtained which is in Fig.5.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization | Vol. 5, Special Issue 3, March 2016

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE'16)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 17th & 18th March 2016

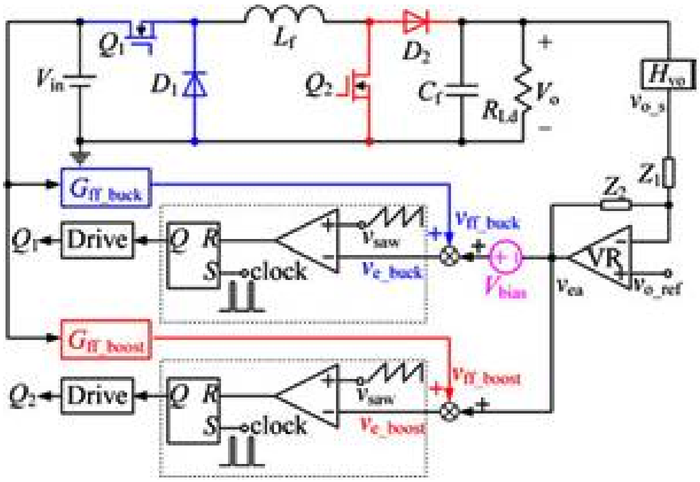


Fig. 4 Schematic Diagram of TSBB Converter with Power Factor Correction Circuit.

The disturbance of input voltage $v_{in}$ affects the output voltage through the path with transfer function $G_{v\,o\text{-}v\,in}(s)$. This effect can be eliminated by introducing an additional path with transfer function $-G_{v\,o\text{-}v\,in}(s)$ from the input voltage to the output voltage. Moving the output of $-G_{v\,o\text{-}v\,in}(s)$ to the output of voltage regulator and corresponding transfer function being changed to $G_{ff}(s)$. The path from $v_{in}$ to $v_{ff}$ is called the IVFF path and the IVFF function is

$$G_{ff}(s) = \frac{\hat{v}_{ff}}{\hat{v}_{in}} = -\frac{G_{vo\_vin}(s)}{G_{PWM}(s)\,G_{vd}(s)}$$

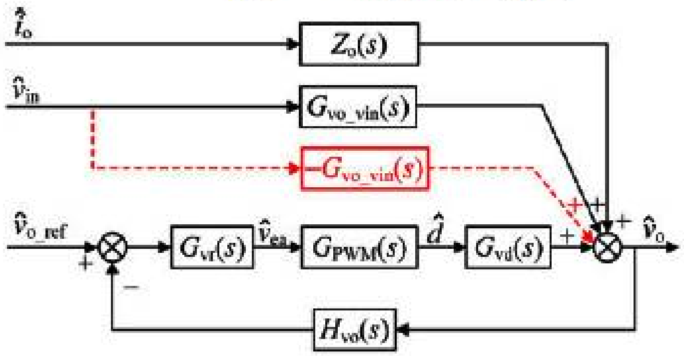


Fig-.5 Control block diagram of TSBB converter with IVFF

IVFF transfer function in buck mode,

$$G_{ff\_buck}(s) = -\frac{V_o}{V_{in\_dc}^2} V_{saw}$$

IVFF transfer function in boost mode,

$$G_{ff\_boost}(s) = -\frac{1}{V_o} V_{saw}$$

The output signals of the IVFF path under different operating modes are,

$$v_{ff\_buck} = G_{ff\_buck} V_{in} = -\frac{V_o}{V_{in\_dc}^2} V_{saw} V_{in}$$

$$v_{ff\_boost} = G_{ff\_boost} V_{in} = -\frac{1}{V_o} V_{saw} V_{in}.$$

The modulation signals of the TSBB converter under the two-mode control scheme with IVFF compensation are,

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization

Vol. 5, Special Issue 3, March 2016

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE'16)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 17th & 18th March 2016

$$v_{c\_buck} = v_{ff\_buck} + v_{ea} + V_{bias} = -\frac{V_o V_{saw}}{V_{in\_dc}^2} V_{in} + v_{ea} + V_{bias}$$

$$v_{c\_boost} = v_{ff\_boost} + v_{ea} = -\frac{V_{saw}}{V_o} V_{in} + v_{ea}.$$

These modulation signals controls the switches in such a way that both voltage regulation and power factor correction is achieved. This is possible with IVFF control. The variation of $v_{ea}$ under the two-mode control scheme with IVFF compensation is much smaller than that without IVFF compensation over the entire input voltage range, which implies that the IVFF mainly regulated the output voltage, extremely alleviating the task of the voltage regulator and improving the transient response on the disturbance of the input voltage. Also it improves the power factor and reduces THD.

## V. RESULT AND DISCUSSION

The operation of TSBB with and without PFC has been simulated using MATLAB/ Simulink . THD analysis has been done for both cases. Table I shows the simulation parameters.

Table I. Simulation Parameters

| PARAMETERS | VALUES |
|---|---|
| Input Voltage | 200-240 V |
| Output Voltage | 220 V |
| Filter Capacitor | 4080 μF |
| Filter Inductor | 320 μH |
| Load Resistor | 100Ω |
| Load Inductor | 1 H |

### I Simulation of TSBB without PFC

Fig. 6 shows the simulink diagram of TSBB without PFC. A controlled voltage source is used to vary input supply voltage ranging from (210-240) V. Without PFC, the voltage regulation and power factor correction is not possible. THD analysis of input current is shown in Fig.7 and is found to be high.

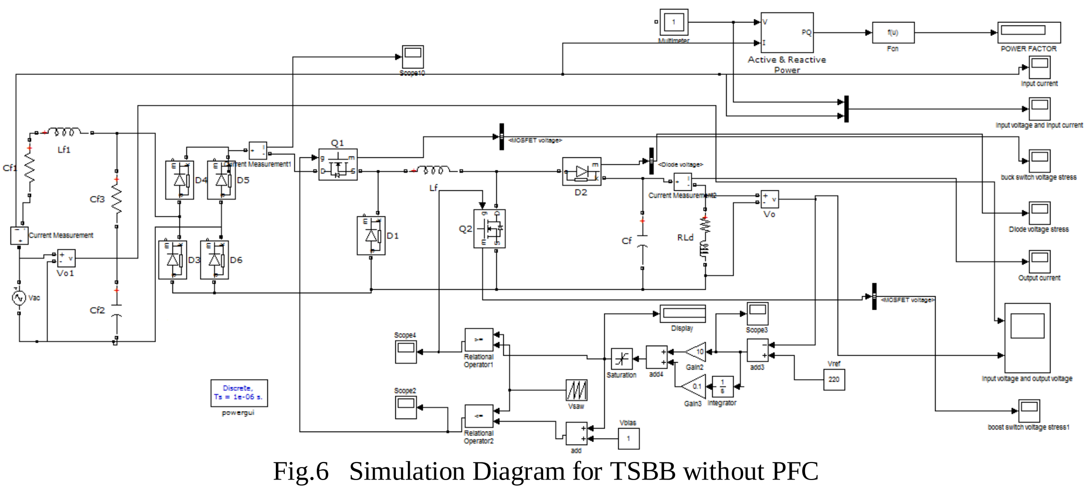


Fig.6 Simulation Diagram for TSBB without PFC

IJAREEIE

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*An ISO 3297: 2007 Certified Organization* *Vol. 5, Special Issue 3, March 2016*

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE'16)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 17th & 18th March 2016

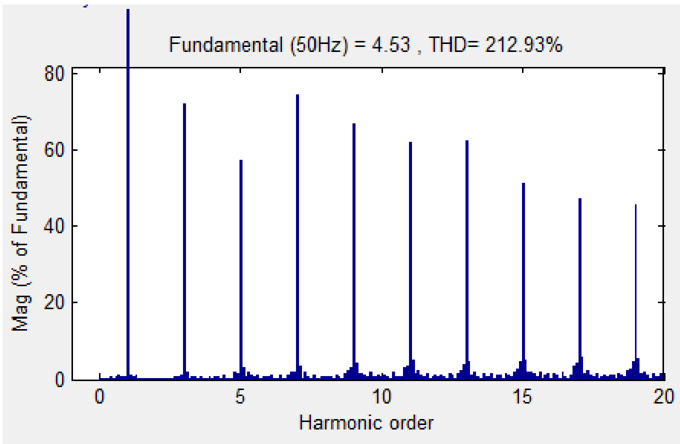


Fig.7 THD of Input Current without PFC circuit

### II Simulation of TSBB with PFC

Simulation diagram for TSBB converter with PFC is shown in Fig.8 . With PFC efficient voltage regulation is achieved and power factor is improved along with reduced THD. Regulated voltage is 220 V over the input voltage range(200-240)V shown in Fig.9 .THD analysis of input current is shown in Fig.10 .

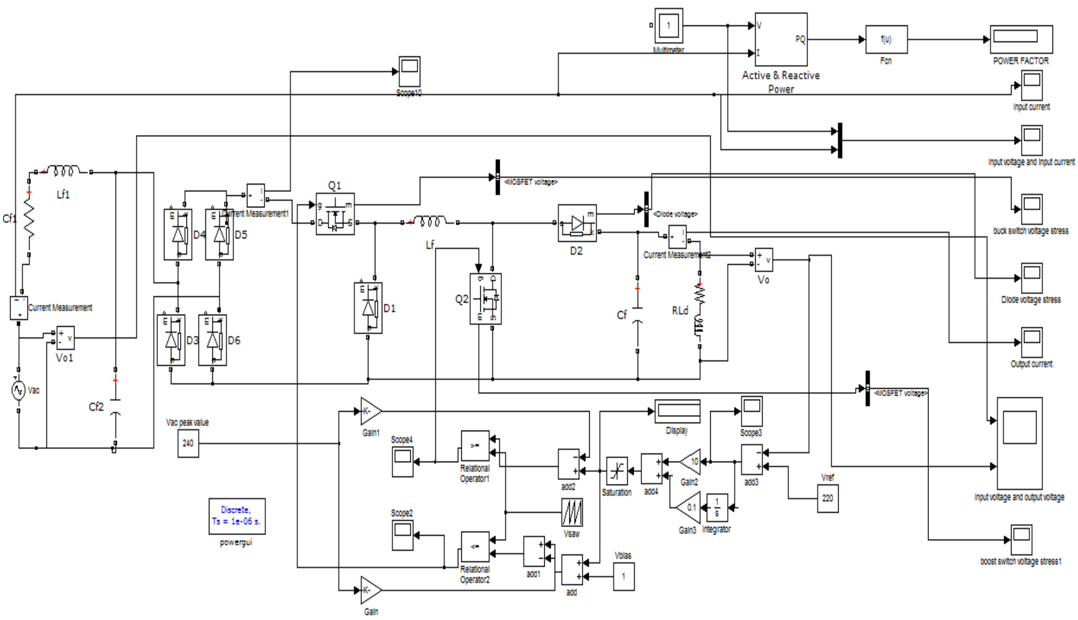


Fig.8 Simulation Diagram for TSBB converter with PFC

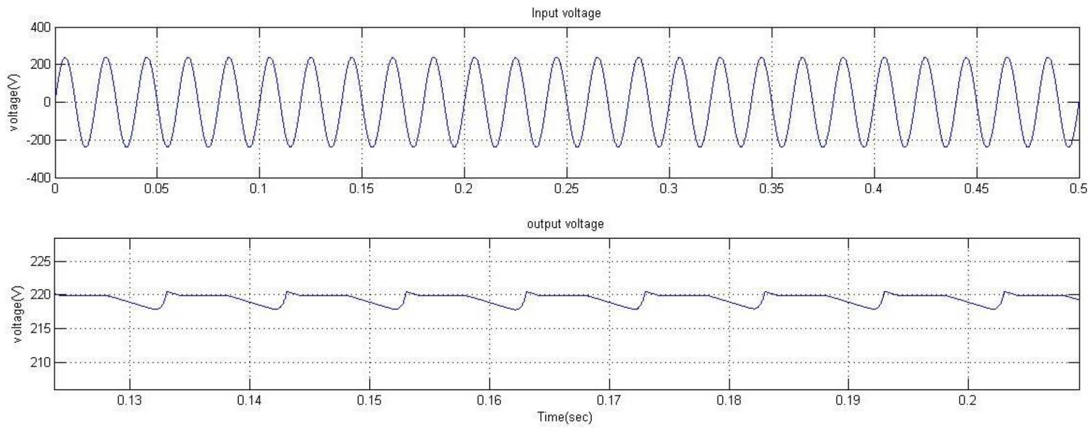


Fig.9 Output Voltage Waveform for TSBB with PFC

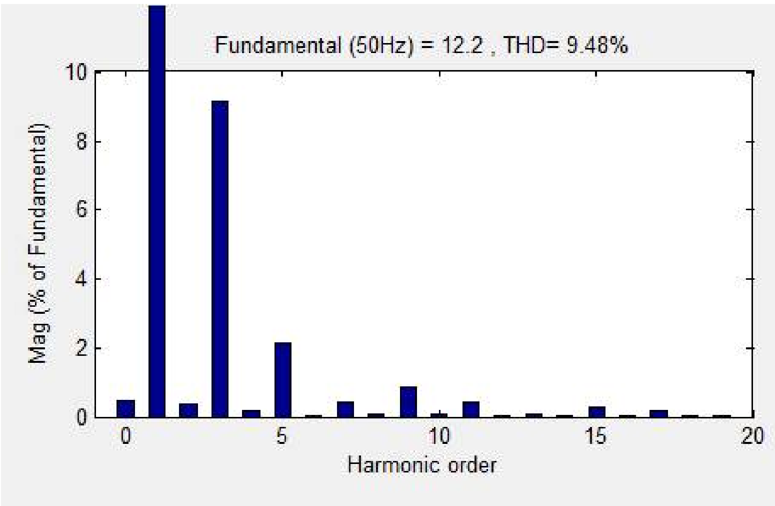


Fig.10 THD of Input Current with PFC Circuit

Table II shows comparison for TSBB converter with and without PFC circuit.

Table II. Comparison for TSBB with and without PFC

| PARAMETERS | With PFC Controller | Without PFC Controller |
|---|---|---|
| THD of Input Current | 9.48 | 212.9 |
| Power Factor | .98 | .76 |

## VI.CONCLUSION

Widespread use of power electronics loads has given more attention to power factor correction (PFC) and reduction in harmonic distortion in the current drawn from the electric power utility. Various power factor correction (PFC) techniques such as buck converter, boost converter, buck boost converter topologies are employed to overcome the power quality problems. This paper proposes a Two Switch Buck Boost converter along with a power factor correction control to improve the power factor and hence reduce the THD. The Two Switch Buck Boost Converter has the advantage of reduced switching losses. Here the IVFF is acting as PFC control circuit. Simulation of the converter with and without PFC controller has been performed in MA TLAB/Simulink. Using this controller power factor correction and voltage regulation were achieved with single stage.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*An ISO 3297: 2007 Certified Organization* *Vol. 5, Special Issue 3, March 2016*

National Conference on Recent Advances in Electrical & Electronics Engineering (NCREEE'16)

Organized by

Dept. of EEE, Mar Baselios Institute of Technology & Science (MBITS), Kothamangalam, Kerala-686693, India

On 17th & 18th March 2016

## REFERENCES

1. D. C. Jones and R. W. Erickson, "A nonlinear state machine for dead zone avoidance and mitigation in a synchronous non inverting buck-boost converter," IEEE Trans. Power Electron., vol. 28, no. 1, pp. 467–480, Jan. 2013.
2. C. Yao, X. Ruan, and X.Wang, "Isolated buck-boost dc/dc converters suitable for wide input-voltage range," IEEE Trans. Power Electron., vol. 26, no. 9, pp. 2599–2613, Sep. 2011.
3. X. Ren, X. Ruan, H. Qian, M. Li, and Q. Chen, "Three-mode dual frequency two-edge modulation scheme for four-switch buck-boost converter," IEEE Trans. Power Electron., vol. 24, no. 2, pp. 499–509, Feb. 2009.
4. Y. J. Lee, A. Khaligh, A. Chakraborty, and A. Emadi, "A compensation technique for smooth transitions in a non inverting buck-boost converter," IEEE Trans. Power Electron., vol. 24, no. 4, pp. 1002–1016, Apr. 2009.
5. Y. J. Lee, A. Khaligh, A. Chakraborty, and A. Emadi, "Digital combination of buck and boost converters to control a positive buck-boost converter and improve the output transients," IEEE Trans. Power Electron., vol. 24, no. 5, pp. 1267–1279, May 2009.
6. E. Schaltz, P. O. Rasmussen, and A. Khaligh, "Non-inverting buck-boost converter for fuel cell application," in Proc. IEEE Annual Conf. IEEE Ind. Electron., 2008, pp. 855–860.
7. H. Qu, Y. Zhang, Y. Yao, and L. Wei, "Analysis of buck-boost converter for fuel cell electric vehicles," in Proc. IEEE Int. Conf. Veh. Electron. Safety, 2006, pp. 109–113.
8. G. K. Andersen and F. Blaabjerg, "Current programmed control of a single-phase two-switch buck-boost power factor correction circuit," IEEE Trans. Power Electron., vol. 53, no. 1, pp. 263–271, Feb. 2006.
9. R. Morrison and M. G. Egan, "A new modulation strategy for a buck boost input ac/dc converter," IEEE Trans. Power Electron., vol. 16, no. 1, pp. 34–45, Jan. 2001.