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Performance Evaluation of PFC Boost Converters

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Abstract: The use of electronic equipment has increased in last few years. Therefore there is an immense need to ensure that the line current harmonics of any equipment connected to AC main line is limited to comply the regulatory standard. This requirement is satisfied by introducing some form of Power factor Correction (PFC) techniques to make the input current sinusoidal and reduce the harmonics. In this paper, a systematic review of power factor correction (PFC) boost rectifiers is presented. Performance comparison of conventional PFC boost rectifier at different duty ratio and voltages are shown and their efficiency is calculated.

Keywords: Power factor Correction (PFC), Efficiency, Active and Passive PFC, Boost Converter

I. INTRODUCTION

Power Factor (PF) is defined as a measure of how a load draws power from the AC source. Leading or lagging PF causes transmission and distribution losses and also the poor utilization of electrical power. A high power factor means better utilization of electrical power, while a low power factor represents poor utilization of electrical power. Due to leading or lagging power factor the electrical energy is to be transferred back and forth between the load and the source and only a part of this electrical energy is utilized for real work. The nonlinear loads such as DC drives, variable frequency drives, programmable controllers, uninterruptible power supplies (UPSs), arc-type lighting has led to harmonic distortion that reduces the power factor and as well as efficiency. And also degrades the performance of other equipment which is connected to the line. [1]. Total harmonic distortion gives how much of a waveform power is distorted caused by harmonics. It is defined as the ratio of power of all the harmonics with the power in the fundamental frequency.

THD is used to characterize nonlinearity of a system, while applying a single sinusoidal to it. When sinusoidal is applied to a nonlinear system it will produce an output with the same fundamental frequency as of the sinusoidal input, but will also generate harmonics at multiples of the fundamental frequency which termed as THD.

Many active and passive PFC technologies can be used to shape the current drawn by power supplies in order to comply with the requirements of international standards, such as IEC 61000–3–2 and IEEE-519.PFC technique can reduce the harmonics, increase the efficiency and capacity of power systems, and reduce customers' utility bill [2].

II. POWER FACTOR CORRECTION TECHNIQUES

Power Factor Correction (PFC) allows power distribution to operate at its maximum efficiency. PFC is classified into two categories: Passive and Active PFC [3].

Passive PFC

The easiest way to control the harmonic current is to use a filter that allows current only at line frequency (50 or 60 Hz). A passive PFC uses a filter at the AC input to correct poor power factor. The filter consists of some passive elements such as capacitors or ferrite core inductors, and looks a non-linear device more like a linear load. PFC circuit attains low Total Harmonic Distortion (THD). Also, because circuit operates at the low line power frequency of 50Hz or 60Hz, normally the passive elements are bulky and heavy. Passive PFC requires larger inductors or capacitors than an equivalent power active PFC circuit also passive PFC is often less effective than active PFC in improving the power factor.

Active PFC

An active PFC circuit consist of power electronic devices that control the amount of power drawn by a load in order to achieve a power factor as close as possible to unity. The preferable type of PFC is Active Power Factor Correction. Active PFC circuitry consists of some switching regulators with active elements such as ICs, FET, MOSFET and diodes. Active PFC increases power factor, reduces harmonics and automatically adjusts for AC input voltage. The drawback of this technique is it requires a complex EMI filter which is costly to build. Active PFC technique offers lower THD and is comparatively small in size and lighter than a passive PFC circuit. Active PFC perform several task such as active wave shaping of the input current, filtering of the high frequency switching, feedback control to regulate output voltage. Various Active topologies are used such as Buck converter, boost converter, fly back converter and other converter topologies out of which Boost converter topology is considered the best suited topology. [4]

III. BOOST CONVERTER

A Boost converter is simply a DC to DC converter in which the output voltage is greater than the input voltage.

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It is also called as step up converter. It is an active power factor correction topology which employs a boost converter associated with a conventional diode bridge rectifier, with the rectifier's output being fed to the boost converters input[5]. The circuit diagram of this topology is shown in Figure 1.

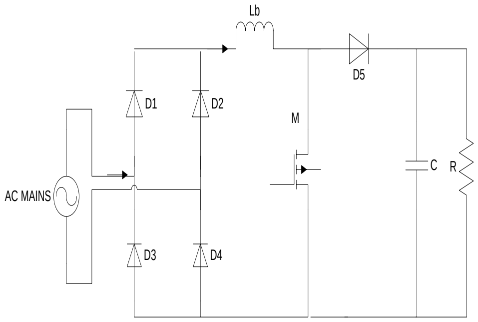

Fig. 1: Boost Converter

When the switch (M) is closed, the AC source converted into DC source energizes the inductor. Meanwhile, the capacitor maintains the output voltage using previously stored energy. When the switch is opened, both the DC source and the energy stored in the inductor will supply power to the load, thus boosting the output voltage.
A desired value of output voltage, higher than the input voltage can be obtained by controlling the duty ratio appropriately. The values of vital parameters are designed using the following consideration:
The duty ratio (D) of a typical boost converter is given by

$$D = \frac{(Vo - Vin)}{Vo}$$

The inductor shown can be designed using the expression

$$L = \frac{R*D*(1-D)^2}{2f}$$

Where R= Load resistance and f = switching frequency
The value of capacitance is given by the expression

$$c = \frac{Vo.*D}{f*\Delta V*R}$$

Where ΔV = Output voltage ripple
Boost converter topology has several advantages such as simple circuit, boosts the output voltage, the active switch is grounded, high efficiency.[6] This topology is extensively used for power factor correction applications in spite of its drawbacks, which are as high input current ripple, high switching and conduction losses, low efficiency at higher power levels due to diode bridge losses.[7]

IV. SIMULATION ANALYSIS

Simulation circuit of conventional PFC boost rectifier is shown in Figure 2. Simulated line current waveforms of conventional PFC boost rectifier operating at 24 Vrms line voltage are shown in Figure 3. The power factor is obtained as 0.8854 and efficiency is found to be 72.09% is found. The FFT analysis of input current waveform is shown in Figure 4 and is found to be 11.14%.
The simulation of the model was done for t=0.02s for input voltage= 24 V, 48V, 115V and 230V at different

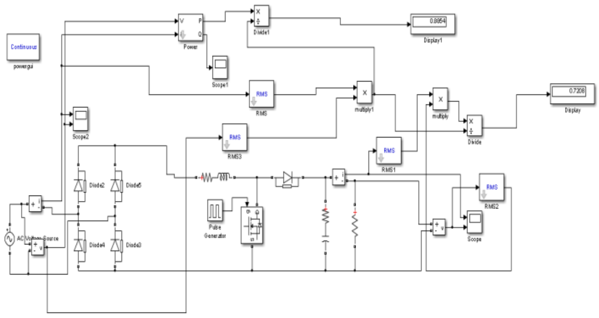

Fig. 2: Conventional Boost Converter

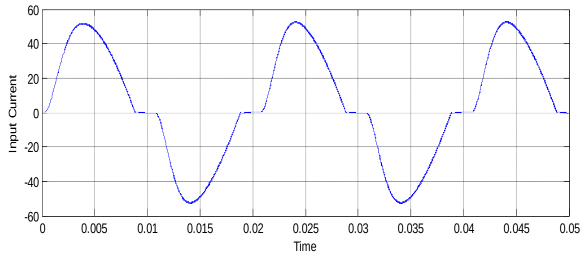

Fig. 3: Input current at duty ratio 80

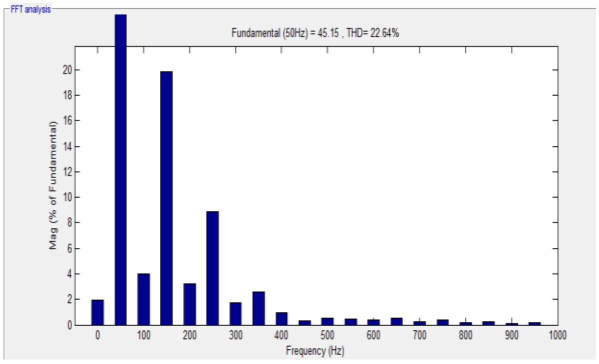

Fig. 4: FFT Analysis of conventional Boost Converter

duty ratios from 10 to 80 and the result are tabulated from table 1-4. Efficiency measurements are presented from figure 5-8.The table shows that as duty ratio increases the efficiency decreases as losses which include switching losses and conduction losses depend upon switching frequency and duty ratio. The calculation of switching losses includes the switching loss of the boost switch, the gate-drive losses. The switching loss of the boost switches is based on the turn-on loss due to the effective capacitance of the MOSFET. [8]

At 24 Volt

TABLE.1: EFFICIENCY VS DUTY RATIO

Duty Ratio	Efficiency
10	0.7293
20	0.7316
30	0.7319
40	0.7303
50	0.724
60	0.708
70	0.668
80	0.5575

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At 48 Volt

TABLE.2: EFFICIENCY VS DUTY RATIO

Duty Ratio	Efficiency
10	0.7853
20	0.7851
30	0.7833
40	0.7793
50	0.7701
60	0.7509
70	0.7062
80	0.5877

At 115 Volt

TABLE.3: EFFICIENCY VS DUTY RATIO

Duty Ratio	Efficiency
10	0.8183
20	0.8167
30	0.8137
40	0.8082
50	0.7973
60	0.7762
70	0.7286
80	0.6054

At 230 Volt

TABLE.4: EFFICIENCY VS DUTY RATIO

Duty Ratio	Efficiency
10	0.8302
20	0.8281
30	0.8246
40	0.8185
50	0.8071
60	0.7853
70	0.7367
80	0.6118

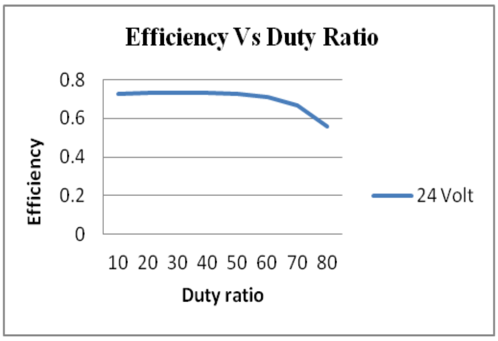

Fig: 5

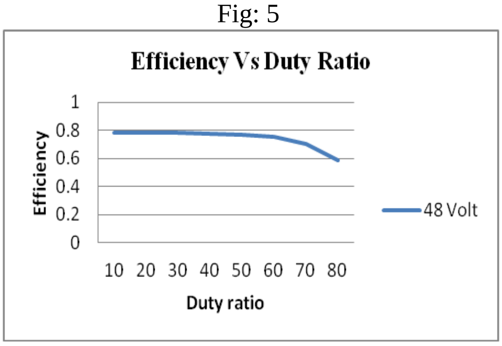

Fig: 6

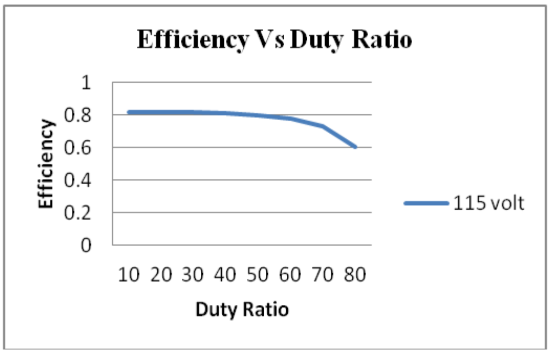

Fig: 7

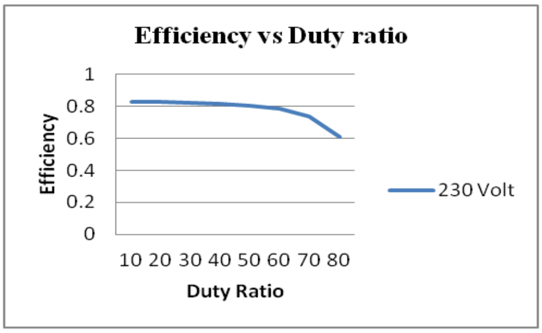

Fig.:8

V. CONCLUSION

A single-phase Bridgeless PFC Boost Converter is modelled and simulated using Matlab/Simulink. The boost converter not only improves the power factor of the circuit but it is also seen that as duty ratio changes the efficiency of the system changes as losses in the system which include switching losses and conduction losses varies. The efficiency is seen to increase with increase in input voltage and decrease with increase in duty ratio.

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