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Analysis and Simulation of AC to DC Boost Converter by Using IC Uc3854a

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ABSTRACT

This paper presents the analysis and simulation of ac to dc boost converter by using IC UC3854A.This paper covers the important specifications for boost converter power circuit design, power factor correction and the UC3854A integrated circuit which controls the boost converter PWM to 0.99 power factor. In this, the input voltage to the power circuit is in the range of 220V to 300V,that results the output voltage which is controlled at 450V. The simulation results prove the verification of converter design in PSIM.

Key words: Boost converter, Power Factor Correction (PFC), Pulse Width Modulation (PWM)

1. INTRODUCTION

The attention devoted to the quality of the currents absorbed from the utility line by electronic equipment is increasing due to the evolution of growing in computers, laptops, uninterrupted power supplies, telecom and biomedical equipment. In fact, a low power factor reduces the power available from the utility grid, while a high harmonic distortion of the line current causes EMI problems and cross-interferences, through the line impedance, between different systems connected to the same grid. From this point of view, the standard rectifier employing a diode bridge followed by a filter capacitor gives unacceptable performances. Thus, many efforts are being done to develop interface systems which improve the power factor of standard electronic loads. An ideal power factor corrector (PFC) should emulate a resistor on the supply side while maintaining a fairly regulated output voltage [1]. In the case of sinusoidal line voltage, this means that the converter must draw a sinusoidal current from the utility; in order to do that, a suitable sinusoidalreference is generally needed and the control objective is to force the input current to follow, as close as possible, this current reference. The most popular topology in PFC applications is certainly the boost topology[2]. PFC converters are good choice for offline power supply and other AC–DC power conversion applications as increasingconcerns about power quality and also to meet the need of power quality terms and standards. Severalcontrol techniques are evaluated and developed to meet the targetapplications. These control techniques evaluation of a system without huge investment and efforts for developing and testing of actual boost converter. These simulation is used to check and any fault condition and operating mode. One can understand the interaction of different components and influence of the overall act of the system [3]-[4].

2. AC TO DC BOOST CONVERTER

A boost converter is a non-linear load device. A load is considered non-linear if its impedance changes with the applied voltage. The changing impedance means that the current drawn by the non-linear load will not be sinusoidal even when it is connected to a sinusoidal voltage. These non-sinusoidal currents contain harmonic currents that interact with the impedance of the power distribution system to create voltage distortion that can affect both the distribution system equipment and the loads connected to it. Active PFC technique is used to regulate power factor of boost converter [5]-[6]. In conventional AC-DC conversion, a capacitor following a bridge rectifier is used to derive DC voltage from the AC power source. With this capacitor, however, the input current pulsates. This pulsating current increases the input current harmonics and results in a low power factor less than 0.64[7]. To reduce the input current harmonics and increase the power factor, a high power factor technique is desired. Power factor correction is to make the input to a power supply look like a simple resistor.

AC to DC converter cascaded with boost converter generates stable dc voltage as output for the given input ac voltage in which the output voltage must always be higher than the input voltage in magnitude. Therefore, an AC-DC converter based on power stage of boost configuration i.e., AC to DC boost converter which is as shown in Fig.1[8]has been studied as a high power factor pre-regulation circuit [9]. As shown in Fig.1, according to the current of in-ductor L, the operation modes can be specified as: CCM (continuous conduction mode), DCM (discontinuous conduction mode and CRM (critical conduction mode). The critical conduction mode operates at the boundary of CCM and DCM [10].

The input current in these converters flows through the inductor and thereforecan easily be activelywave shaped with appropriate current mode control. Moreover, boost converters provide regulated dc output voltage at unity input power factor and reduced THD of input ac current. These converters have found wide spread use in various applications due to the advantages of high efficiency, high power density and inherent power quality improvement at ac input and dc output. The preferred power circuit configuration of single-phase boost converter is the most popular and economical PFC converter consisting of diode bridge rectifier with step up chopper. This paper provides a study of single phase boost converter topology. Complete mathematical modelling of PFC converters is carried out [11]. Simulation results are provided for evaluation of converter performance under steady state and dynamic conditions and performance of single-phase boost converter is then experimentally verified. PFC converter topology considered in this work is described in this section.

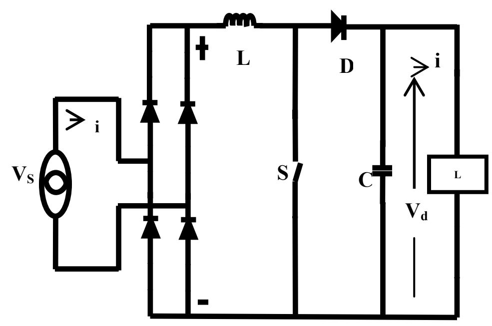

Fig.1. Ac to Dc Boost Converter

3. IC UC3854A

The UC1854 provides active power factor correction for power systems that otherwise would draw non-sinusoidal current from sinusoidal power lines in which it controls the boost PWM where its power factor is near to unity.This device implements all the control functions necessary to build a power supply capable of optimally using available power-line current while minimizing line-current distortion to <3%. The block diagram of IC UC3854A is as shown in the Fig.2.

The power section is a "boost" converter, with the inductor operating in the continuous mode[11]. In this mode, the duty cycle is dependent on the ratio between input and output voltages; also, the input current has low switching frequency ripple, which means that the line noise is low. Furthermore, the output voltage must be higher than the peak value of the highest expected AC line voltage.The UC1854's high reference voltage and high oscillator amplitude minimize noise sensitivity while fast PWM elements permit chopping frequencies above 200KHz.

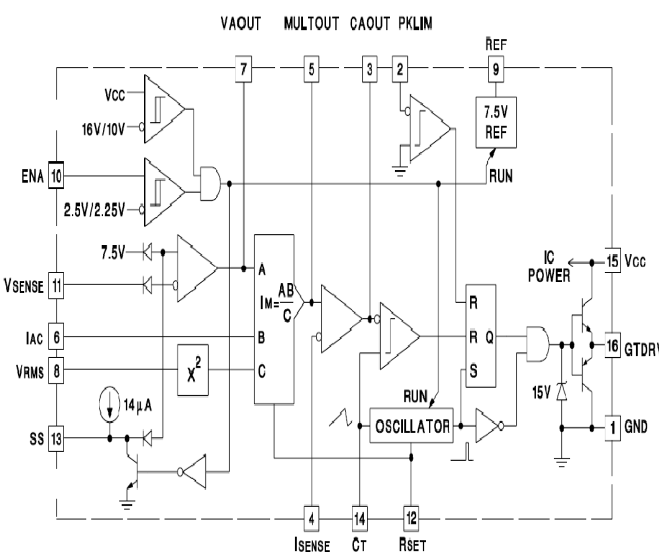

Fig.2. Block Diagram Of Ic Uc3854a

4. DESIGN OF BOOST CONVERTER USING IC UC3854A

Design of single phase AC-DC boost converter using IC UC3854A with power factor corrector is listed below:

Specifications:

Maximum power output (Po): 1500W

Input voltage range : 200-270Vac

Line frequency range (fo) : 50Hz

Output Voltage (Vo) : 450Vdc

Switching Frequency (fs) : 22 KHz

1. Inductor Selection:

i. Maximum peak line current:

$$I_{pk} = \left(\frac{\sqrt{2} * P_{in}}{V_{in}(\min)} \right)$$

Consider the input current $(P_{in}) = 1700W$ (with losses)

$$\Rightarrow I_{pk} = \left(\frac{\left(\sqrt{2} * 1700W\right)}{220V} \right)$$

$$\Rightarrow I_{pk} = 10.89A$$

ii. Ripple Current:-

$$\Delta L = 0.2 * I_{PK}$$

$$= 0.2 * 10.89$$

$$= 2.178A \text{ (peak to peak)}$$

iii. Duty Factor:

Vin(pk) is the peak of rectified line voltage at low line where we are finding the duty factor at Ipk is as follows:

$$D = \frac{V_0 - V_{in(pk)}}{V_{in}}$$

$$= \frac{450 - \left(\sqrt{2} * 220\right)}{450}$$

$$= 0.309$$

iv. Calculation of the Inductance:

$$L = \frac{V_{in} * D}{f_s * \Delta l}$$

$$= \frac{\sqrt{2} * 220 * 0.309}{22KHz * 2.178}$$

$$= 2mH$$

R_{load} calculation:

$$R_{LOAD} = \left(\frac{\left(V_{OUT}{}^{2}\right)}{P_{OUT}} \right)$$

$$= \frac{(450 * 450)}{1500}$$

$$= 135\Omega$$

2. Output Capacitor Selection:

Typical values for Co are 1 microfarad to 2 microfarad per watt. So, here in this case we consider 2 microfarad per watt and therefore output capacitor value is as follows

$$C_0 = 2 * 1500W = 3000\mu F$$

3. Select Current Sensing Resistor:

If Current Transformers are used then that include turns ratio and decide whether the output will be positive or negative relative to circuit common. Keep peak voltage across resistor low i.e., 1.0V is a typical value for Vrs.

i. Find Ipk(Max):

$$I_{PK(\max)} = I_{PK} + \left(\frac{\Delta l}{2} \right)$$

$$= 10.89 + \left(\frac{2.178}{2} \right)$$

$$= 11.979A$$

ii. Find Current Sense Resistor:

$$Rs = \frac{V_{rs}}{I_{pk(\max)}}$$

$$= \frac{1}{11.979}$$

$$= 0.0835\Omega$$

iii. Find Actual Peak Sense Voltage:

$$V_{rs(peak)} = I_{pk(\max)} * Rs$$

$$= 11.979 * 0.0835$$

$$= 1V$$

4. Oscillator Frequency:

Rset is a oscillator charging current and multiplier limit and its value is 10.135KΩ

$$C_t = \frac{1.25}{R_{set} * f_s}$$

$$= \frac{1.25}{10.135K\Omega * 22KHz}$$

$$= 5.6nF$$

5. Current Error Amplifier Compensation:

i. Current Error Amplifier Gain at fs:

$$\Delta V_{rs} = \frac{V_0 * R_S}{L_0 * f_s}$$

$$= \frac{450 * 0.0835}{2mH * 22KHz}$$

$$= 0.854$$

This voltage must equal the peak to peak amplitude of Vs, the voltage on the timing capacitor and its value is considered as 5.2V.

$$G_{ca} = \frac{V_S}{\Delta V_{rs}}$$

$$= \frac{5.2}{0.854}$$

$$= 6.089$$

ii. Feed Back Resistors:

$$R_{ci} = R_{mo} = 3.027K\Omega$$

$$R_{cz} = R_{ci} * G_{ca}$$
$$= 3027K * 6.089$$
$$= 18.431K$$

iii. Crossover Frequency:

$$f_{ci} = \frac{V_0 * Rs * R_{cz}}{V_s * 2 * 3.14 * L * R_{ci}}$$
$$= \frac{450 * 0.0835 * 18.431k}{5.2 * 2 * 3.14 * 2mH * 3.027k}$$
$$= 3.5KHz$$

The cross over frequency fci value should be $(1/6)^{th}$ to $(1/10)^{th}$ of switching frequency fs

iv. Ccz and Ccp Selection:

a. Ccz Selection:-

$$C_{cz} = \frac{1}{f_{ci} * 2 * 3.14 * R_{cz}}$$
$$= \frac{1}{3.5KHz * 2 * 3.14 * 18.431K\Omega}$$
$$= 2466\,pF$$

b. Ccp Selection:

$$C_{cp} = \frac{1}{f_s * 2 * 3.14 * R_{cz}}$$
$$= \frac{1}{22KHz * 2 * 3.14 * 18.431K\Omega}$$
$$= 392.7\,pF$$

6. Voltage Error Amplifier Compensation:

i. Output ripples voltage:-

The output ripple voltage is given by the following equation where fr is the second harmonic ripple frequency

$$V_{0pk} = \frac{P_{in}}{f_r * 2 * 3.14 * C_0 * V_0}$$

Where Co= 3000µF, Vo =450V, fr= 100Hz, Pin=1700W

$$= \frac{1700}{100 * 2 * 3.14 * 450 * 300uF}$$

$$= 2V$$

ii. Voltage Error Amplifier Gain:

$$Gva = \frac{\Delta V_{vao} * \%Ripple}{V_{0pk}}$$

$$= \frac{(5-1.5) * 0.015}{2}$$

$$= 0.026$$

iii. Set gain of voltage error amplifier:

$$R_{vi} = \frac{1}{f_r * 2 * 3.14 * C_{vf} * Gva}$$

$$= \frac{1}{100 * 2 * 3.14 * 0.0476\mu * 0.026}$$

$$= 1303.K\Omega$$

iv. Set DC output voltage:

$$R_{vd} = \frac{R_{vi} * V_{ref}}{V_0 - V_{ref}}$$

$$= \frac{1303.K * 7.5}{450 - 7.5}$$

$$= 23.4K\Omega$$

5. SIMULATION RESULTS

The circuit shown in Fig.3.is simulated using PSIM. The simulation results are as shown Fig. 4 and Fig,5.

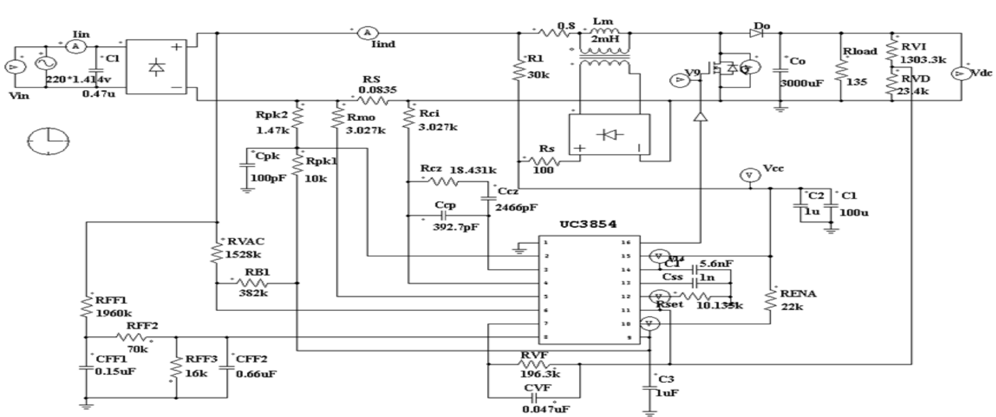

Fig.3. Simulation circuit of AC-DC boost converter using UC3854A IC.

In Fig.4. consist of waveforms for input voltage(Vin)=424V,input current (Iin) = 15A (peak to peak), input current and voltage(both are in phase), inductor current(Iind)=7.5A, pulses to the gate terminal of the switch, output voltage(Vo)=450V and output power (Po)=1500W at Vmin=220V, fs=22KHz, Po=1500W.

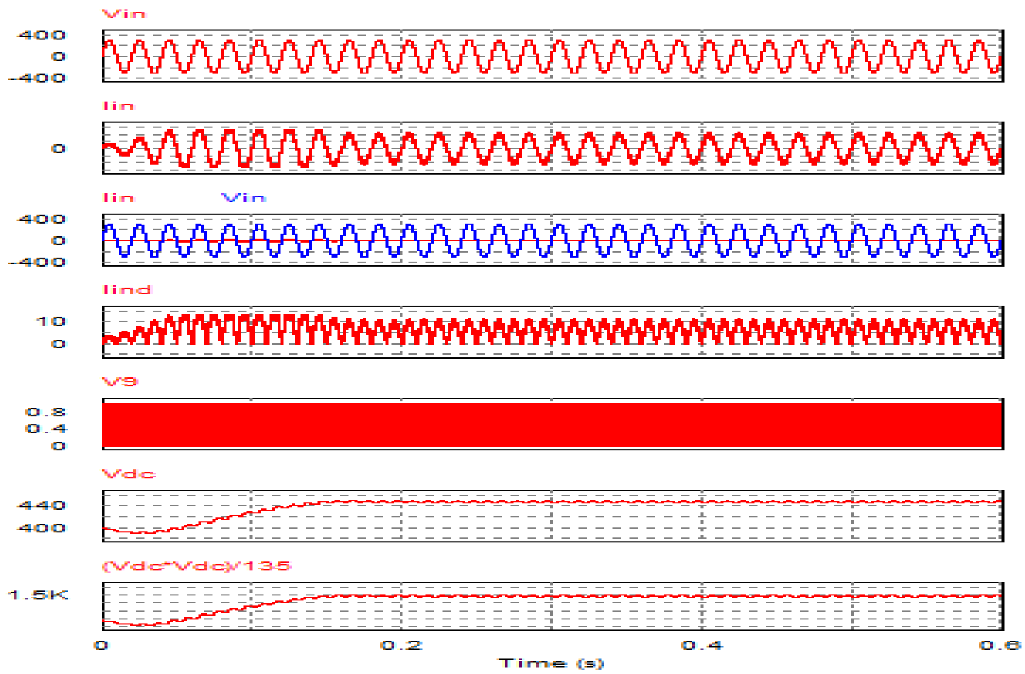

Fig.4. simulation results for V_{in}=220V

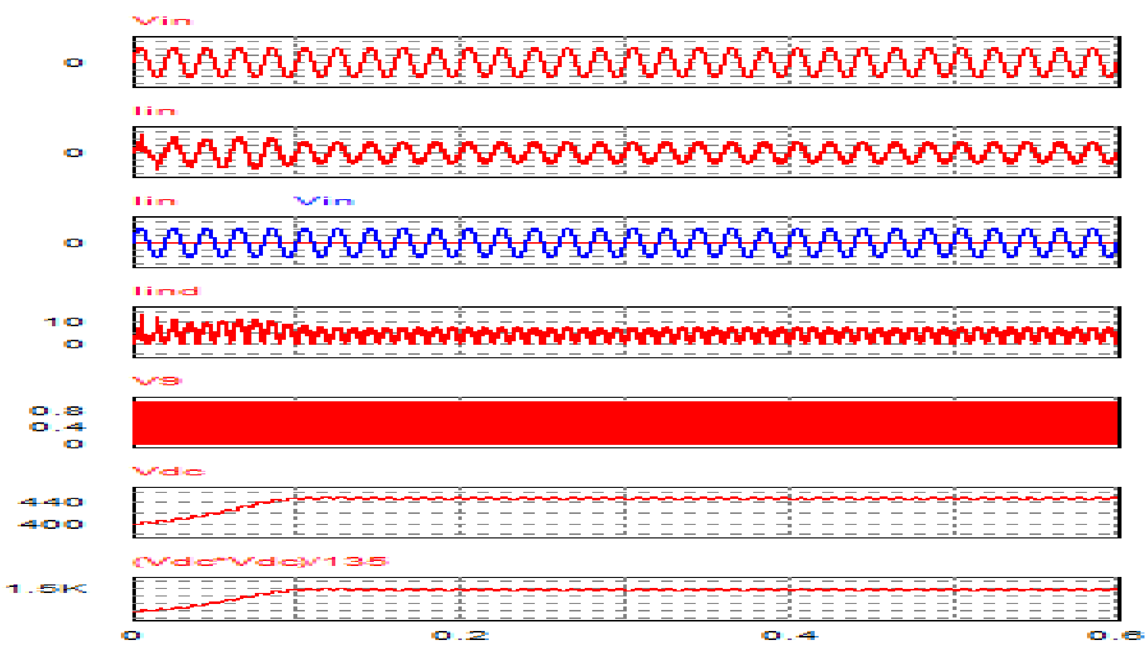

Fig.5. simulation results for V_{in}=300V

In Fig.5. consist of waveforms for input voltage(Vin)=424V, input current (Iin) = 22A (peak to peak), input current and voltage(both are in phase), inductor current(Iind)=11A, pulses to the gate terminal of the switch, output voltage(Vo)=450V and output power (Po)=1500W at Vmax=300V, fs=22KHz, Po=1500W.

Both the figuresFig.4. and Fig.5shows the same output voltage(Vo)=450V and output power (Po) of 1500W. The input current and input voltage arein phase i.e., having good power factor at the input side for the voltages Vmin=220V and Vmax=300V.

6. CONCLUSION

AC to DC boost corrector using IC UC3854A with power factor converter controls input current of load in such a way that input current wave-form is in proportional to the mains input voltage waveform. Hence, the power factor of boost converter will become nearer to unity, which can be clearly seen from the simulation results. IC UC3854A has better power limiting feature and distortion is limited to less than 3 %. Even though the input voltage is under certain variations i.e., from the range of 220V to 300V, the boost converter provides fixed DC voltage as 450Vand output power as 1500KW. Thus it's an optimal converter in terms of performance, efficiency and provides unidirectional (dc) power flow in application such as power supplies, electronic ballast and low power drive applications.

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