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Active Power Factor Correction for Welding Power Source

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Abstract: As welding machines are now being used in many applications even in household purposes without any trained person, the system has to be compact and should have a high safety measures. In order to make the system compact, we make use of power electronic components in the machine which decreases the size of the machine to the large extent. But with use of power electronic component there are others problems like harmonics and because of these the Power factor of the machine will decrease. In order to improve the power factor, various power factor correction techniques can be adapted. In this paper, a systematic review of boost rectifier with power factor correction using PWM IC's is presented.

Keywords: Welding power source, Active PFC, Boost rectifier, THD.

I. INTRODUCTION

Power factor of a power source is defined as a ratio of actual power (KW) used to produce the rated load (which is registered on the power meter) and apparent power drawn from the supply line (KVA) during welding. It is always desired to have high power factor (pf). Low power factor indicates unnecessary wastage of power and less efficient utilization of power for welding. Application of a welding power source with high power factor offers many advantages such as: Reduction of the reactive power in a system, which in turn reduces the power consumption and so drop in cost of power, higher effective power for the same apparent power, more economic operations at an electrical installation, Improved voltage quality and fewer voltage drops, Use of low cable cross-section smaller transmission losses.

In the welding machine, due to its operating principle, it will absorb a non sinusoidal current (non linear load). Such current causes on the supply side of the network a voltage drop of non sinusoidal type with the consequence that also the linear loads are supplied by a distorted voltage. The harmonics are the components of a distorted waveform and their use allows analyzing any non-sinusoidal periodic waveform by decomposing it into several sinusoidal components.

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 customer's utility bill.

II. POWER FACTOR CORRECTION TECHNIQUES

A. Passive PFC

The passive techniques normally use a simple line-frequency LC filter to both extend the current conduction angle and reduce the THD of the input current of the diode-capacitor rectifier. Due to its simplicity, the passive LC filter is a high-efficiency and low-cost PFC solution that could potentially meet the IEC 61000-3-2 class D specifications in the low-power range. At higher power levels, however, the size and weight of the passive components become a problem because of the presence of heavier and bulkier filter inductors. The passive techniques have certain advantages, such as simplicity, reliability and ruggedness, insensitivity to noise and surges, no generation of high-frequency electromagnetic interface (EMI), and no high-frequency switching losses.

B. Active PFC

An active power factor corrector (PFC) is a converter, which is controlled in such a fashion that the load connected to the converter is seen as an equivalent pure resistance from the source terminals. The objectives of using these converters are to draw a sinusoidal current from the input utility and in-phase with the input voltage. This consequently improves the power quality. Active PFC is the of use active electronics circuits, which contain devices like MOSFETs, BJTs, and IGBTs. Active power factor correction can be single-stage or multi-stage. The preferable type of PFC is Active Power Factor Correction (Active PFC) since it provides more efficient power frequency. Because Active PFC uses a circuit to correct power factor, Active PFC is able to generate a theoretical power factor of over 95%. Active Power Factor Correction also markedly diminishes total harmonics, automatically corrects for AC input voltage, and is capable of a full range of input voltage.

III. PFC BOOST CONVERTER

Several converter configurations, like boost, buck-boost, SEPIC, etc. are available for power factor correction. Boost converter is an excellent choice for active power factor correction due to its simplicity in control aspects and lower switch stress than the other configurations.[4] Also, boost converters have filter inductors on the input side which provide a smooth and continuous input current waveform as opposed to the discontinuous input current of the buck-boost configuration. The continuous input current is much easier to filter and causes lesser conducted electromagnetic interference. These are the major advantages of this configuration because any additional filtering at the converter input will increase the cost and reduce the power factor due to capacitive loading of the line.[1]

A. Working Principle

The working principle of boost converter is discussed with the help of Figure 1. When the switch (S) is closed, the inductor output is connected to ground and the voltage (Vi) is placed across it. The inductor current increases at a rate equal to Vi/L. When the switch is opened, however, the voltage across the inductor changes and is equal to VL-Vin. Current that was flowing in the inductor decays at a rate equal to (VL-Vi)/L. By switching the power electronic switch we can get unity power factor in source side.[6]

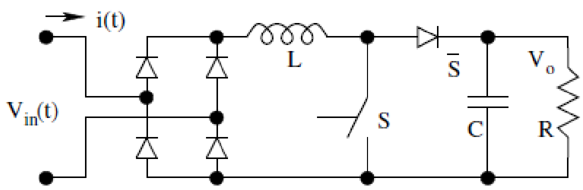

Figure 1: Boost Converter

B. Control Aspects

Several control schemes like average current control, hysteresis control, nonlinear carrier control, critical conduction mode control etc. are available in the literature. Average current control has been implemented in the present work due to some of its advantages over other competing schemes, viz., (i) production of almost sinusoidal high quality current waveforms over a wide range of input voltages and load powers, (ii) can be implemented in both continuous and discontinuous conduction modes and (iii) the problem of cross-over distortion (found in some other control schemes) can largely be avoided.

For the implementation of Average current control, PWM IC (UC3854) is used.[5] An amplifier is used in the feedback loop around the boost power stage so that input current tracks the programming signal with very little error.
This is the advantage of average current mode control and it is what makes active power factor correction possible.

Figure 2 is a block diagram which shows the basic control circuit arrangement necessary for an active power factor corrector. The output of the multiplier is the current programming signal and is called Imo for multiplier output current. The multiplier input from the rectified line voltage is shown as a current in Figure 3 rather than as a voltage signal because this is the way it is done in the UC3854.

Figure 2 shows a squarer and a divider as well as a multiplier in the voltage loop. The output of the voltage error amplifier is divided by the square of the average input voltage before it is multiplied by the rectified input voltage signal. This extra circuitry keeps the gain of the voltage loop constant, without it the gain of the voltage loop would change as the square of the average input voltage. The average value of the input voltage is called the feedforward voltage or Vff since it provides an open loop correction which is fed forward into the voltage loop. It is squared and then divided into the voltage error amplifier output voltage (Vvea).

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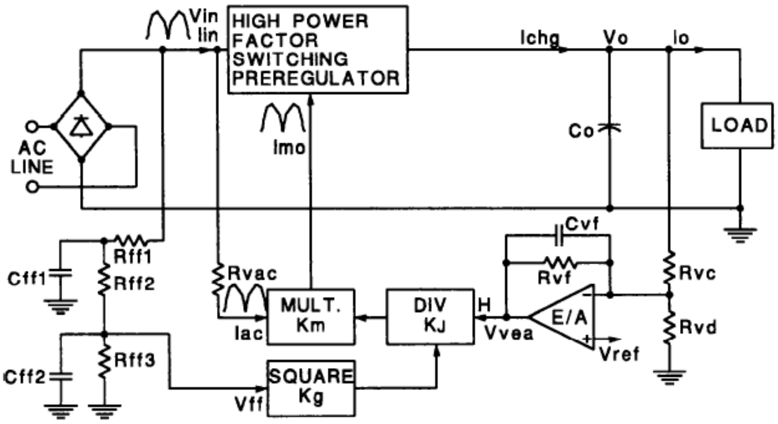

Figure 2: UC3854 Block Diagram

IV. SIMULATION ANALYSIS

A Single phase PFC is simulated using PSIM software. The specifications are shown in Table 1.

Power output	1kW
Input Voltage Range	80 - 270V
Line Frequency	47 – 65Hz
Filter Inductor	1mH
Filter Capacitor	1500 uF
Load	250 ohm
Output Voltage	500V DC

A. Diode Bridge Rectifier with output capacitor

Figure 3 shows a single phase diode bridge rectifier with output capacitor filter is simulated using PSIM Software.

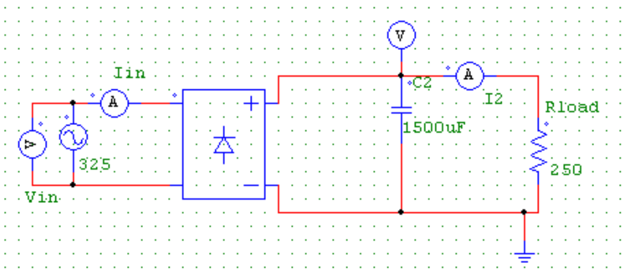

Figure 3: Power Circuit

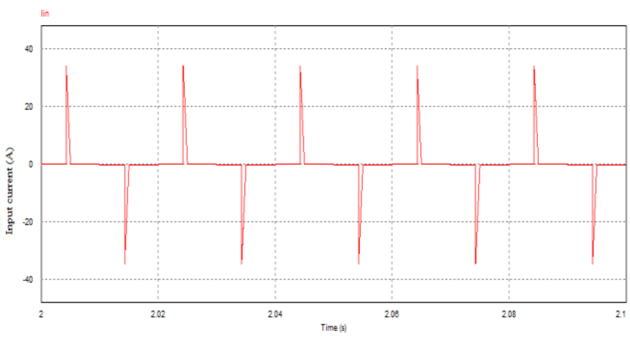

Figure 4: Input current vs Time

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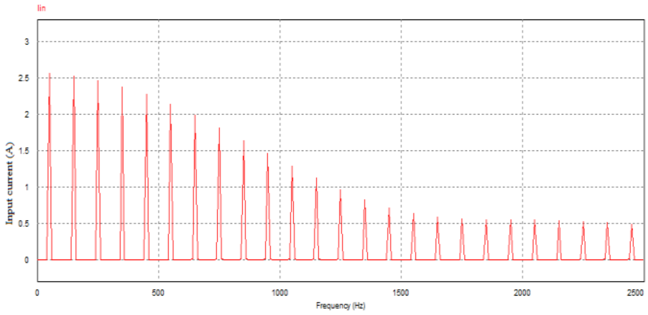

Figure 5: FFT Analysis of Input current

From the above simulation model of single phase diode bridge rectifier, the input current is analysed with the FFT analysis (Figure 4). We observe that THD value for this configuration is 285%. The input current (Figure 5) is also not sinusoidal in nature. Hence the input current is not satisfied the IEC standard 61000-3-2.

B. Diode Bridge Rectifier with output capacitor and inductor

Figure 6 shows a single phase diode bridge rectifier with output capacitor filter is simulated using PSIM Software.

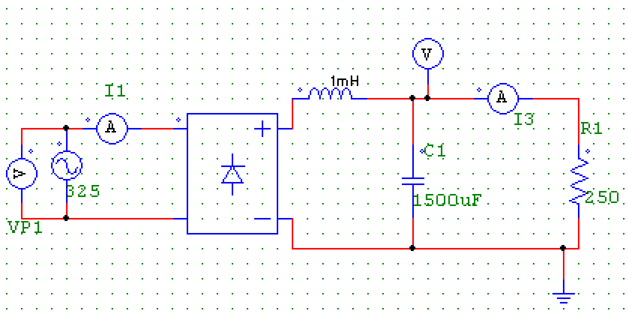

Figure 6: Power Circuit

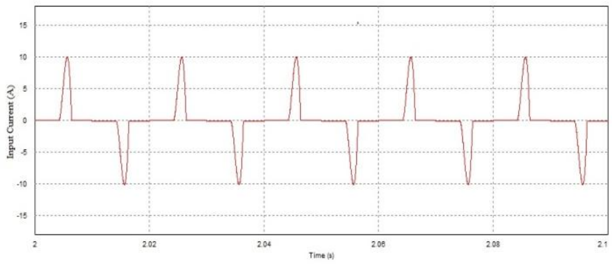

Figure 7: Input current vs Time

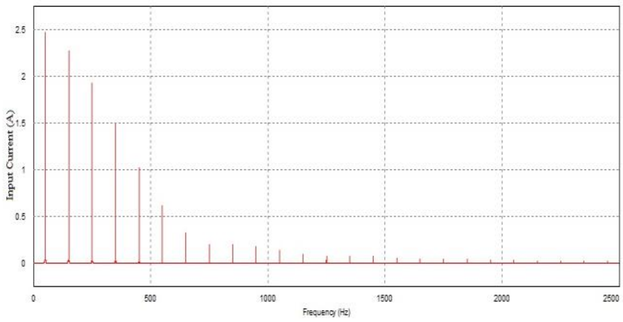

Figure 8: FFT Analysis of Input current

From the above simulation model of single phase diode bridge rectifier, the input current is analysed with the FFT analysis (Figure 7). We observe that THD value for this configuration is 145%. The input current (Figure 8) is also not sinusoidal in nature. Hence the input current is not satisfied the IEC standard 61000-3-2.

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B. Diode Bridge Rectifier with PWM IC

Figure 9 shows a single phase diode bridge rectifier with PWM IC is simulated using PSIM Software.

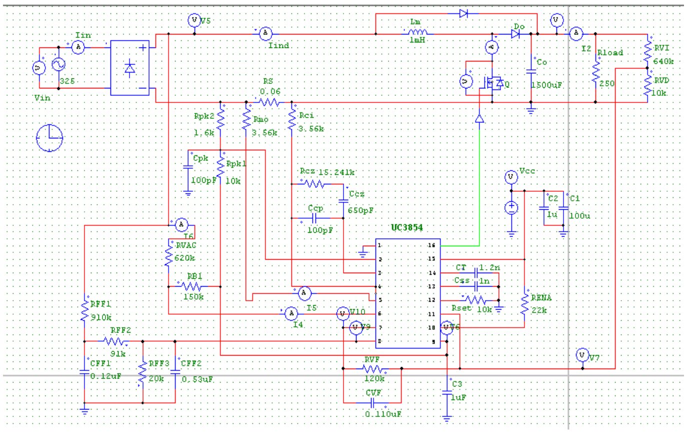

Figure 9: Power Circuit

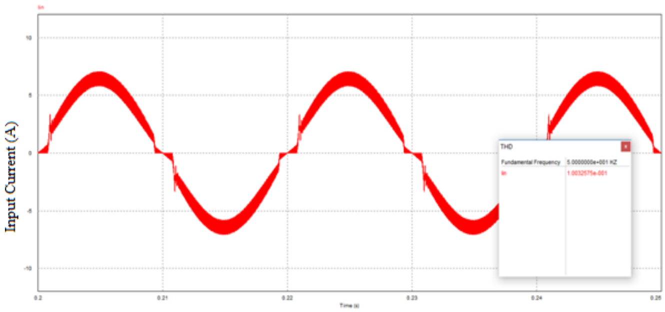

Figure 10: Input current vs Time

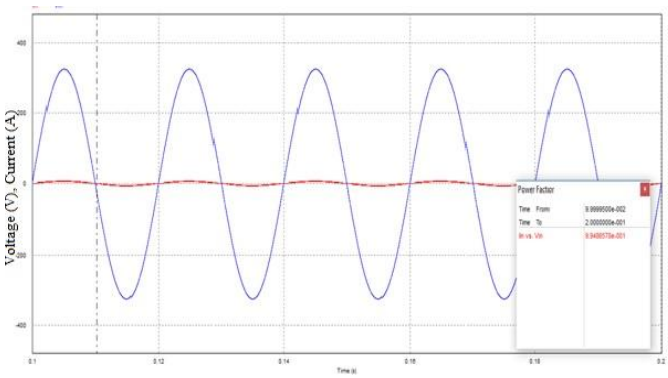

Figure 11: Input current and Input Voltage vs Time

This topology gives power factor as unity and THD is within the IEC 61000-3-2 standard (Figure 10 and Figure 11). PWM IC is used for controlling the gate pulses of mosfet with switching frequency of 100 kHz. It follows the average current mode of control.

IV. CONCLUSION

In this paper the needs for a PFC-boost rectifier, its advantages, have been discussed. A single phase diode bridge rectifier with filters is analysed and FFT analysis is performed. A single phase boost rectifier with PWM IC is modelled and simulated using PSIM software. In this model we can get unity power factor and THD within the standard. Average current control has been implemented to control the input current. Also the working of output voltage controller has been discussed.

V. ACKNOWLEDGEMENT

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