DEVELOPMENT AND DESIGN OF RESISTANCE WELDING CONVERTER FOR HIGH CURRENT RATING

Jyoti Kumari[1], Priyanshu Shekhar[2], Amit Kumar Mishra[3], Praveen Kumar[4]

[1]PG Scholar, M.Tech, Department of Electrical Engineering, BIT Sindri
[2]PG Scholar, M.Tech, Department of Mechanical Engineering, BIT Sindri
[3]Assistant Professor, Department of Mechanical Engineering, BIT Sindri
[4]Assistant Professor, Department of Electrical Engineering, BIT Sindri

Abstract: *Resistance welding is commonly used in many branches of industry as no filler metal is needed and the heat required for the weld pool is created by means of resistance when a high welding current is directed through the welded work-pieces. An electro-conductive contact surface is created between the work-pieces by pressing them together. For this purpose we need very high current of the order of hundreds of amperes and low voltage which are supplied by dedicated power electronic converters. Our perspective is to design the power electronic converter for this purpose. This power electronic converter consists of three-phase rectifier (IGBT switches), single phase inverter (also IGBT switches), step down transformer and diode rectifier. All these components are in a cascaded manner. Filters are used at every step to obtain desired voltage and current waveforms.*

Keywords- Three phase Rectifier (using IGBT switches), Single phase Inverter (also using IGBT switches), Single phase step down Transformer, Single phase Diode rectifier, LC filters

I. INTRODUCTION

Resistance welding is the most commonly used method for joining steel sheets. No filler metal is needed and the heat required for the weld pool is created by means of resistance when a high welding current is directed through the welded workpieces. An electro-conductive contact surface is created between the workpieces by pressing them together. Contact is made using the shape of either the welded surfaces of the workpieces or the shape of the electrodes. Water-cooled electrodes made of alloyed copper are used in resistance welding. Electrodes convey a pressing force to the joint and direct the welding current to the joint in the appropriate manner. After welding, the electrodes rapidly cool down the welded joint. Work stages in resistance welding are very fast. The surfaces to be welded do not usually need to be cleaned before welding, in addition to which the weld does not usually require grinding or post heating. The resistance welding process can be easily automated.

Resistance welding is a highly efficient production method that is particularly well-suited for automated production lines and mass production. Resistance welding is also suitable for small batch production, because the method is flexible, equipment simple and the welding process is easy to control. In addition, an important advantage of the method is that it can be used for joining a great number of metallic materials. Resistance welding is also suitable for the welding of the most common metal coated steel sheets

The most common resistance welding machines use AC that has not been transformed from the supply frequency. DC machines have become slightly more common than before. Their welding current can be slightly lower than in AC machines. Some welding machines transform the supply frequency of the

welding current to be higher, which has several advantages e.g. smaller transformers. Generally two types of Resistance Welding are to be discussed.

Resistance spot welding: Resistance spot welding is the most commonly used resistance welding method. Spot welding is used to join sheets together by means of lap joints. Spot welding produces single spot-like welds, which are also called nuggets. Welding current is directed to the workpieces through electrodes, which also generate pressing force. Electrodes are usually located on both sides of the workpiece and either one or both move and transmit force to the workpiece. The welding current of 4–20 kA is used for making a single weld. The welding current depends on the material to be welded and workpiece thickness.

Seam welding: Seam welding is similar to spot welding. Equipment is very similar both in terms of welding current production, control and pressing force. Seam welding, however, differs from spot welding mainly because of the rolling welding wheel. In most applications, wheels on both sides of the workpiece produce the weld. The method allows producing continuous tight weld or separate spot welds at defined intervals. A tight weld is also made of overlapping spot welds. The roller seam weld width is usually about 80 % of the electrode face diameter. The contact surface of the electrode wheel may be convex or flat. Similar to spot welding, the face width of a flat electrode is chosen according to the workpiece thickness $d = 5\sqrt{t}$, where t is workpiece thickness. The angle between the wheels and workpiece can be changed in some applications if the form of joint or accessibility.

II. LITERATURE REVIEW

Mariusz Stępień et.al. has analyzed and determined the efficiency and power losses experimentally in two different spot resistance welding systems [1]. Ievgen Verbytskyi et.al. [2] has find out the efficiency of Cuk converter using its mathematical model. Theoretical considerations are proved with developed Simulink model of current regulator. Swati Narula et.al. [3] has performed theoretical analysis of boost and three phase full wave converters and verified the performance of proposed arc welding power supply (AWPS) through experimental results and the results confirm the effectiveness of proposed AWPS in maintaining excellent power quality at utility interface point over a wide load range while over-current handling capability leads to improved welding performance and weld bead quality. Rui Chen et.al. [4] has analyzed and designed a non-isolated hard switching DCM SEPIC PFC with adjustable output voltage along With PWM switching averaged model, DC-DC and PFC operation by reducing THD current.

III. DESIGN OF THE CONVERTER

In order to analysis and designing the converter, the various components required are discussed as: **Three phase rectifier:** Three phase rectifier is used to rectify the input/source voltage (usually 220V, 50Hz). LC filter is also designed to get desired waveforms (voltage and current waveform) at the output of three phase rectifier. We can use IGBTs or MOSFETs or DIODEs in the construction of three phase rectifier. But we prefer IGBT switches and give PWM pulses to the switches. DIODE rectifiers are widely employed in industrial fields and consumer products thanks to advantages of low cost, simple structure, robustness and absence of control. However, this type of converters results in only unidirectional power flow, low input power factor, high level of harmonic input currents, malfunction of sensitive electronic equipment,

increased losses and also contributing to inefficient use of electric energy. Recently, many promising power factor correction (PFC) techniques have been proposed for rectifiers. Apart from application of active and passive filters, the best solution is in using pulse width modulated (PWM) rectifiers. Research interest in three-phase PWM rectifiers has grown rapidly over the last few years due to some of their important advantages, such as power regeneration capabilities, control of dcbus voltage over a wide range, and low harmonic distortion of input currents. Since the converter has abilities to control the input currents in sinusoidal waveform, unity power factor operation can be easily performed by regulating the currents in phase with the power-source voltages.

Single phase Inverter: Output of the three phase rectifier is given to single phase inverter. Inverter also consists of IGBT switches. MOSFETs are not used because of its limitations to operate efficiently only at low voltages (250V). But MOSFETs can operate at high frequencies (>200 kHz). But we do not require high frequency operation so we can use IGBTs. The main reason for choosing IGBTs as switches is operating at also in high voltages and high load power. MOSFETs can only provide output power unto 500W. So IGBTs are most preferred. In PWM career frequency is 10k, reference frequency of sinusoidal wave is 500Hz. Frequency of output voltage and current will be 500Hz.

Single phase step down Transformer: Output of Single phase Inverter is given to single phase step down transformer. Step down transformer is used because of high current desired. Welding process happens at high currents (100A to 100kA). Voltage range for welding is 2-50 V. Nominal power and frequency are 2000VA and 500Hz respectively.

Single phase Diode rectifier: Diode Rectifiers are used to convert AC into DC voltage. Output of Single phase step down Transformer is given to Single phase Diode rectifier. We use Single phase full wave Diode rectifier.

LC filters: An LC filter is added between output of Single phase Diode rectifier and load. For LC filter inductor and capacitor are tuned at 1000Hz. Inductor is of 1mH and Capacitance is of 25.33uH. LC filters are required to reduce Ripple content at the output. LC filters are less dependent on the load current.

IV. SIMULATION AND RESULTS

Circuit Diagram of Resistance Welding Inverter is shown below:

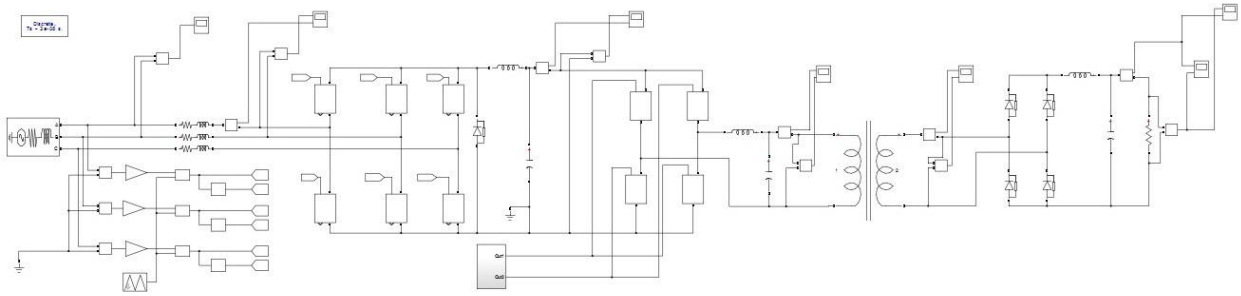

Fig 1: MATLAB Simulink model of the Converter

The various waveforms obtained using MATLAB Simulations are shown as follows:

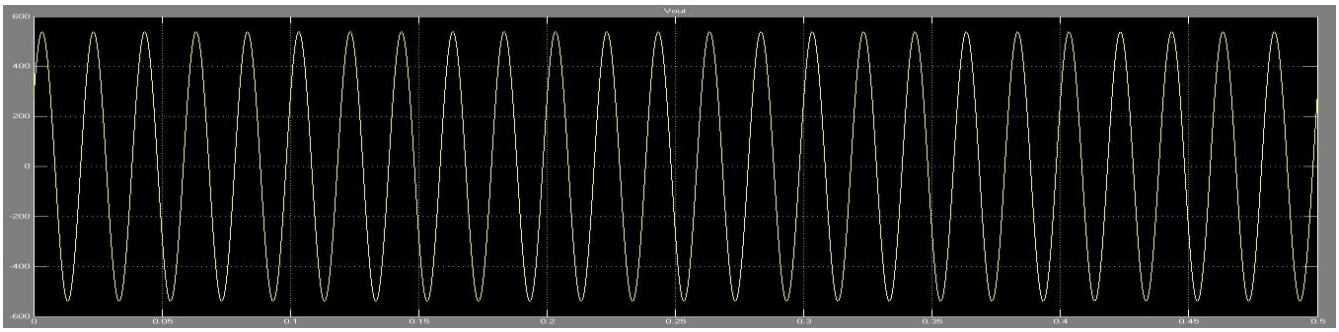

Fig 2: Input Voltage waveform: 381V p-p rms or 220V per phase, 50Hz

The output waveform of single phase inverter and single phase transformer is shown below provided PWM to inverter parameters as Modulating frequency: 500Hz (sinusoidal) and Carrier frequency: 10 kHz (triangular):

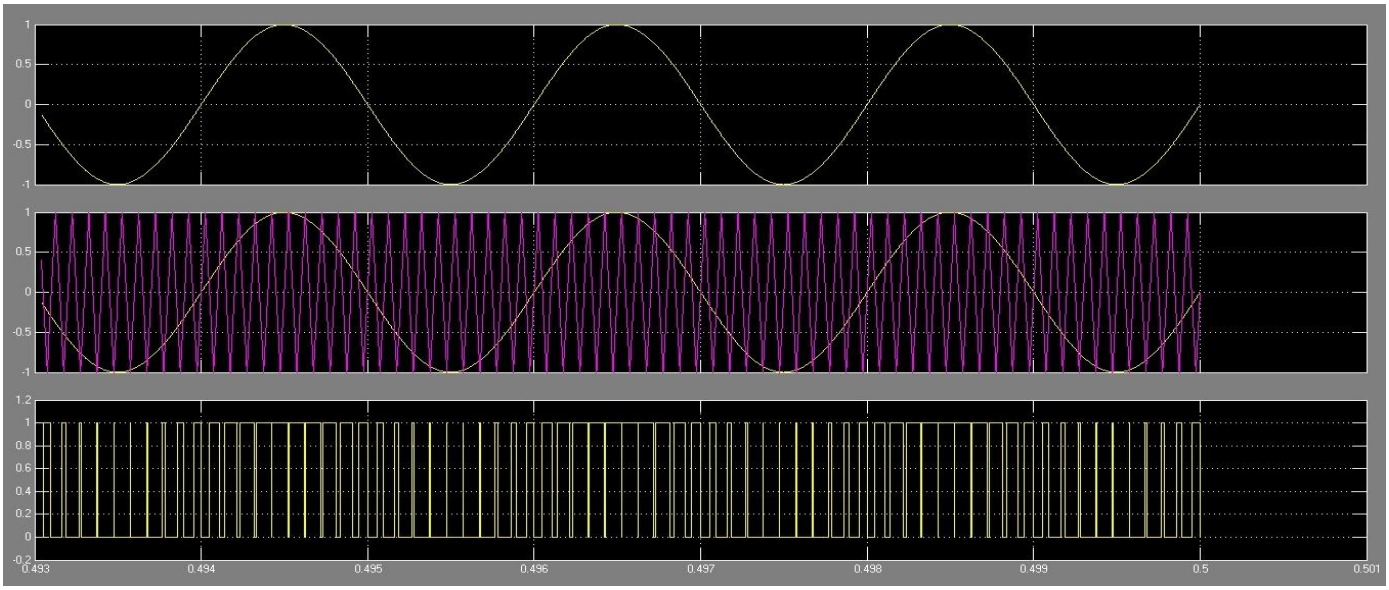

Fig 3: Output waveform of Single phase Inverter

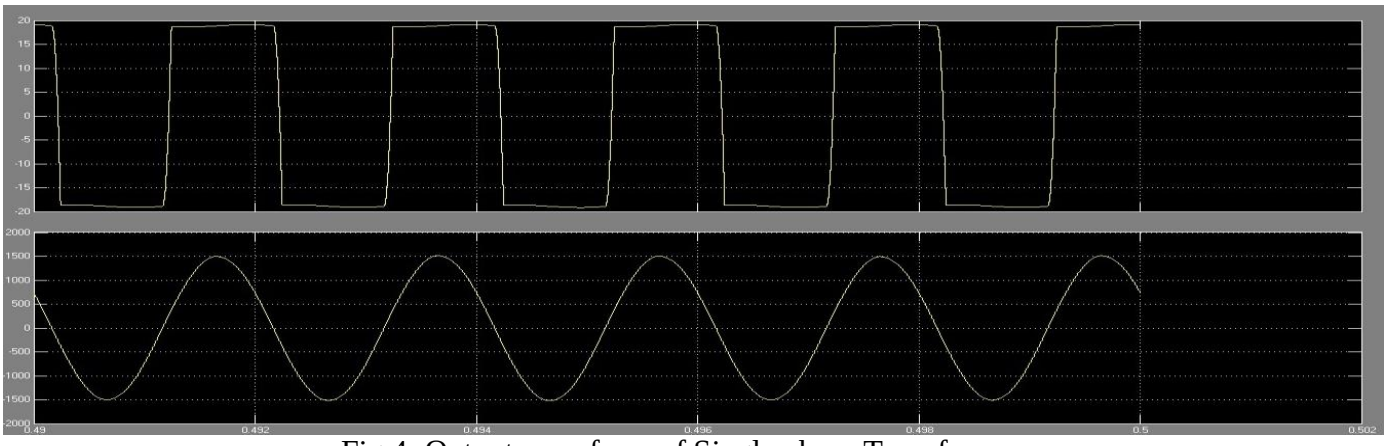

Fig 4: Output waveform of Single phase Transformer

The current amplitude waveform is as shown as:

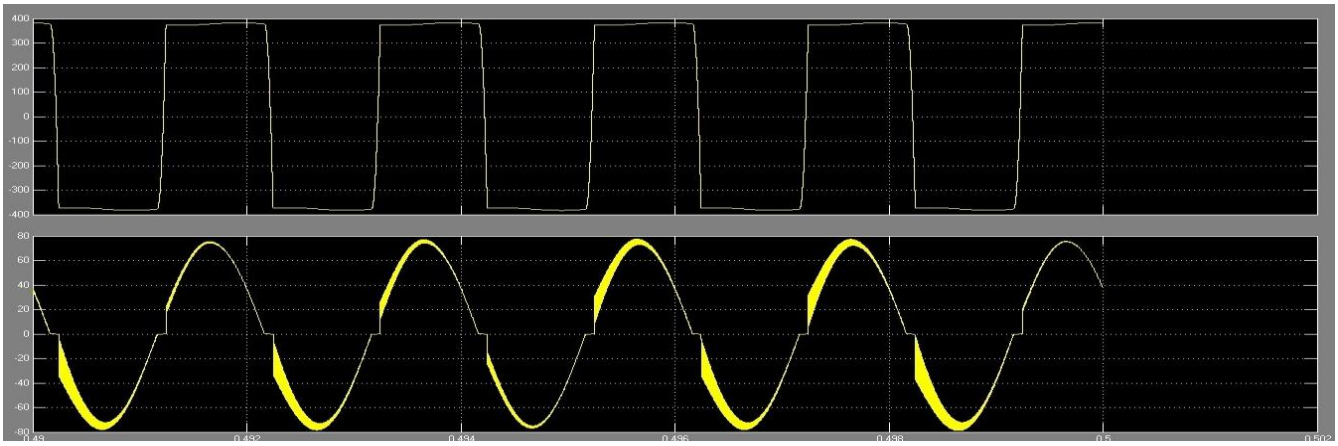

Fig 5: Current amplitude: 382A (rectangular), 500Hz Voltage amplitude: 75V (sinusoidal), 500Hz

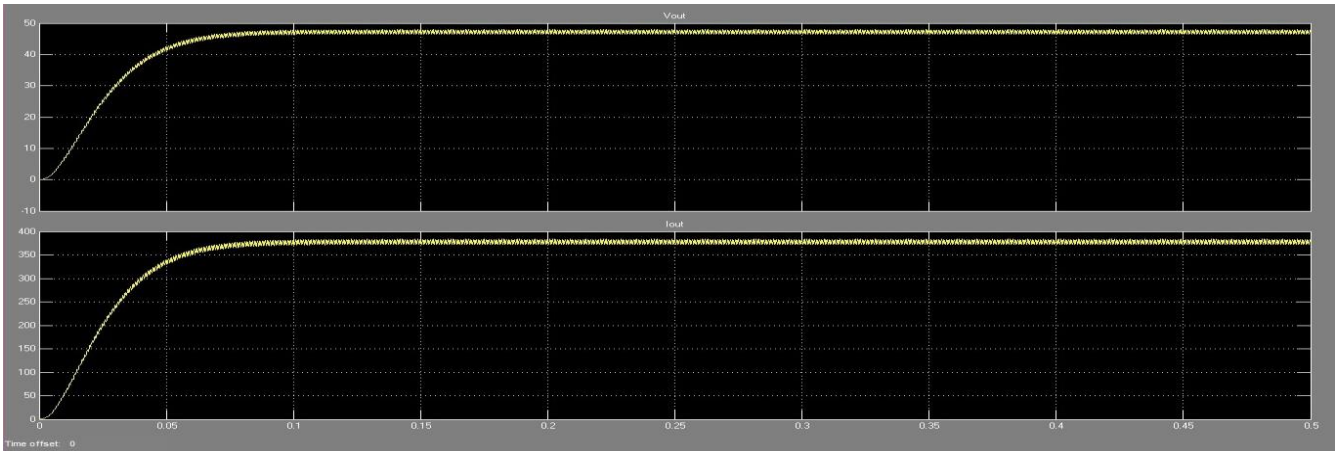

Fig 6: Final output waveform without Zooming

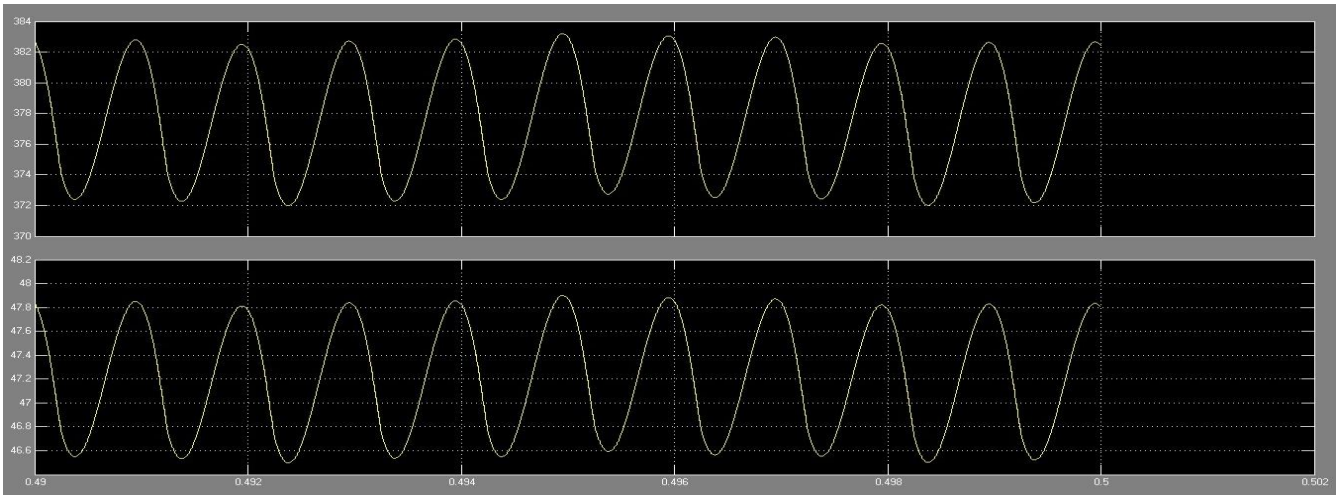

Fig 7: Final output waveform after Zooming

The various ratings related to the resistance welding that is obtained from the simulation are as shown in Table 1.

Table 1: Various electrical Parameters of High current resistance welding

Current	Voltage	Voltage ripple	Current ripple
378 ± 5 A	47.2 ± 0.7V	2.96%,	2.64%

V. CONCLUSIONS AND FUTURE SCOPE

Resistance Welding is very popular used in most of the Automotive / auto suppliers, Aerospace / air plane, Train carriage / rail, Radiator / container, Domestic hardware, Medical instruments, Nuclear equipment, Food and drink and Other metal processing industries as it is cost effective and operated for high current welding. This technique is easier to implement and have no any other harm. This type of welding is used where long production runs & consistent conditions can be maintained. Welding is performed with operators who normally load and unload the welding machine and operate the switch for initiating the weld operation. The automotive industry is the major user of the resistance welding processes, followed by the appliance industry. Resistance welding is used by many industries manufacturing a variety of products made of thinner gauge metals. This type of welding is also used in the steel industry for manufacturing pipe, tubing and smaller structural sections. It has the advantage of producing a high volume of work at high speeds and does not require filter materials. Welds are reproducible and high-quality welds are normal.

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