

Design and Simulation of Induction Heating Equipment using MATLAB / SIMULINK Environment

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Abstract: This paper describes the design of power electronic converter circuit and simulating the power electronic converter circuit using Matlab/Simulink for induction heating equipment. The circuit designed has the load as induction coil and high frequency electricity is required to heat the workpiece placed within the induction coil. The output power of the load coil is varied by changing the frequency of the inverter.

Keywords: power electronic converter, induction heating, simulation.

1. Introduction

Induction heating is a non contact heating process. Induction heaters use high frequency electricity to heat the materials that are electrically conductive. The high frequency electricity is provided by the power electronic converter circuit. Induction heating is fast, precise, clean, energy efficient, controllable and repeatable [1]. Since it is non-contact, the induction heating process does not contaminate the material being heated. Induction heating is also very efficient since the heat is actually generated inside the workpiece. This can be contrasted with other heating methods where heat is generated in a flame or heating element, which is then applied to the workpiece [2]. For these reasons Induction Heating lends itself to some unique applications in industry. It is frequently applied in several thermal processes such as heating of metals [3].

Induction heating equipment and induction heater are widely used in induction heat treatment, induction heating, induction bonding, induction brazing, induction welding, induction forging, induction melting and induction heat fitting solutions. Induction heating equipment can be used for any application where we want to heat an electrically conductive material in a clean, efficient and controlled manner [3]. The principle on which Induction heating works is mutual inductance. A source of high frequency electricity is used to drive a large alternating current through a induction coil. The passage of current through this induction heating coil generates a very intense and rapidly changing magnetic field in the space within the work coil. The workpiece to be heated is placed within this intense alternating magnetic field.

2. Simulation Model

The Simulation model has a three phase, 415 volts, 50 hertz source, which is connected to three phase V-I measurement block. It is then connected to source inductance and scope 1. Scope 1 display's the input voltage and current. Then we come across universal diode bridge rectifier, it is connected to the IGBT inverter. The pulses to the gate of IGBT's are fed from pulse generator. Scope 2 display's the pulse generator output and its inverted output. IGBT's 1 and 2

receive gate pulses from the pulse generator which is inverted and applied to the IGBT's 3 and 4. High frequency series capacitor is connected to primary of the linear transformer, whose secondary is connected to the load inductance and resistance through filter capacitor and inductor. Scope 3 display's the DC link voltage and current, snubber capacitor voltage and current. Scope 4 display's the high frequency series capacitor current, linear transformer voltage and current (both primary and secondary winding). Scope 5 display's filter inductor current, filter capacitor current, load inductance current, load resistance voltage and current respectively.

The inverter panel accepts three phase, three wire/four wire, 415V, 50Hz supply. The required auxiliary power supply for electronic cards supply regulator, cooling fans supply and control supply are derived from this source. The main 415V supply is fed to converter power stack through miniature circuit breaker, pre-charging resistors and the three pole contactor. The DC output of the diode bridge in power stack is fed to the IGBT inverter bridge in the power stack. The firing pulses from the controller to the inverter IGBT's are fed through the gate driver which are mounted on the power stack itself. Output of the inverter is amplified using a high frequency power transformer and supplied to the load coil through the series air core high frequency inductor and the load capacitor connected across the output. The capacitors are used to compensate the poor power factor of the load coil. The capacitor bank in parallel with the load coil acts as net load to the inverter. Output power of the load coil is varied by changing the frequency of the inverter.

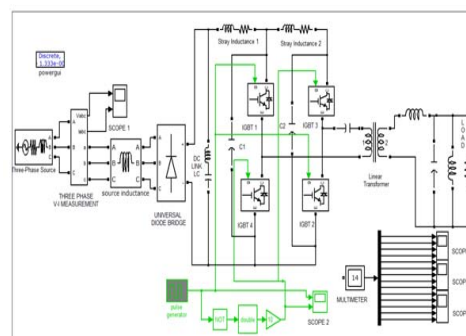


Figure 1: Simulation model

3. Hardware Circuit

The hardware circuit has heat sink upon which all the components are mounted. It is connected to a fan as shown in the figure 2, for cooling (forced air cooled). The three phase diode rectifier is supplied by an autotransformer, so that the required voltage can be built in steps. It is further connected to the DC-link capacitor via positive and negative bus bars; bus bars are used to reduce the inductance effect. DC-link capacitor is then connected to the IGBT's. Two IGBT modules, SEMiX 604GB12T4s IGBT's are used; each module has two IGBT's connected in series, which forms one leg of the single phase full bridge circuit.

Each module has an IGBT gate driver mounted on them; SKYPER 32 is used as the gate driver. Firing card is used to provide pulses for firing the IGBT's at a frequency of 10k Hz. Firing card needs a 15V supply which is provided by the power supply shown in figure 3. The IGBT's are then connected to the high frequency filter capacitor and then to the inductive load. The CRO is connected to the voltage probe and Rogowski transducer (10mV/A), that are used for measuring the high frequency voltage and current respectively, they are connected to the output terminals.

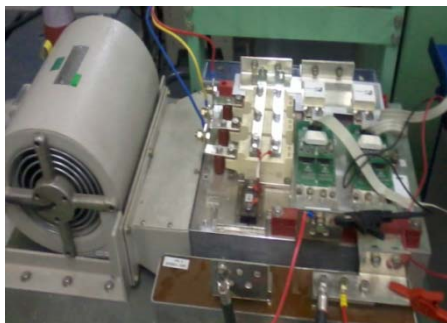


Figure 2: Hardware circuit



Figure 3: Power supply for the firing card

4. Simulation Results

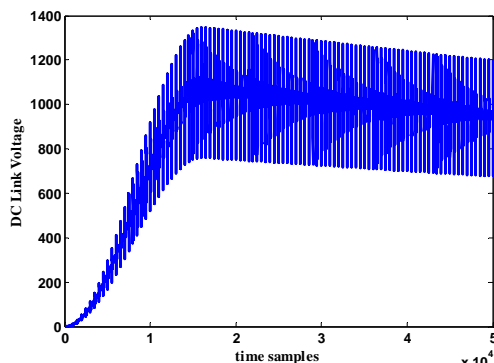


Figure 4: DC link voltage

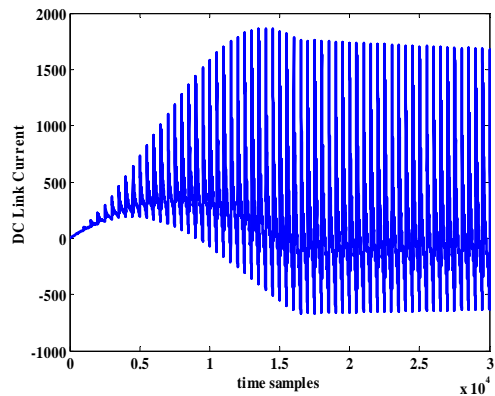


Figure 5: DC link current

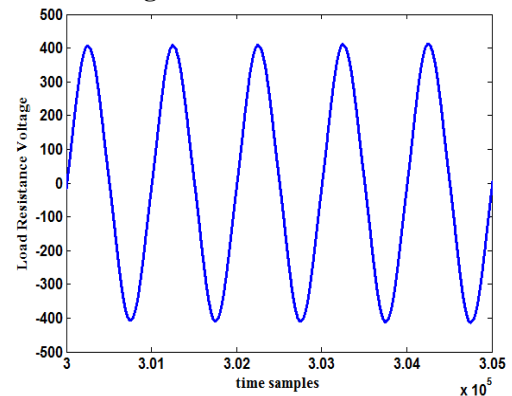


Figure 6: Load resistance voltage.

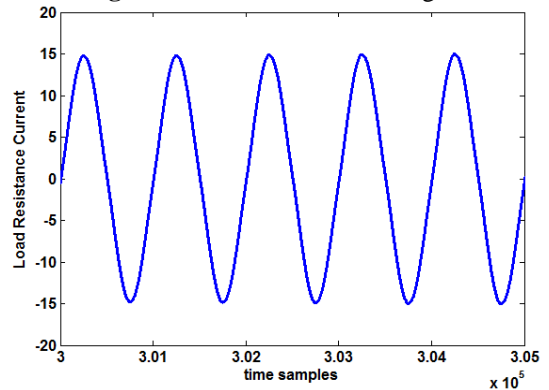


Figure 7: Load resistance current.

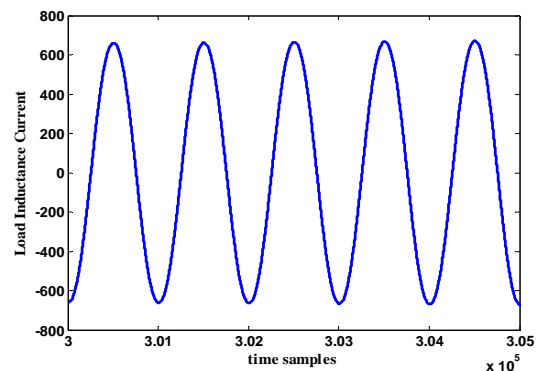


Figure 8: Load inductance current

The DC link voltage and the DC link current are as shown in figure's 4 and 5. The load resistance voltage is as shown in figure 6, it is sinusoidal with amplitude of 420 V (AC) and it is single phase, figure 7 shows the load resistor current which is single phase, sinusoidal and is 15A. The current through the load inductor is shown in figure 8. For a frequency of 7.5k Hz, we get load inductor current of 680A,

which is of single phase pure sinusoidal current. For a frequency of 10k Hz, we get pure sinusoidal current of approximately 5kA. As the frequency changes the output power also changes.

5. Hardware Results

Table 1: Values of AC voltages and its corresponding DC voltages

AC Voltage (V)	DC Voltage (V)
40.7	57.8
82.2	116.5
116.5	165.7
155	217
190.5	269.4
234.7	317
256.5	362
310	439
352	468
396	554

The values of AC voltages and its corresponding DC voltages are plotted in the graph shown in the figure 9. It can be observed from the graph that for a given AC voltage 35% more DC voltage is obtained. The load current and load voltage are as shown in the figure 10.

6. Conclusion

Hence by verifying the simulation results we can conclude that the high frequency electricity required by the Induction heating equipment is supplied by the Power Electronic Converter circuit designed.

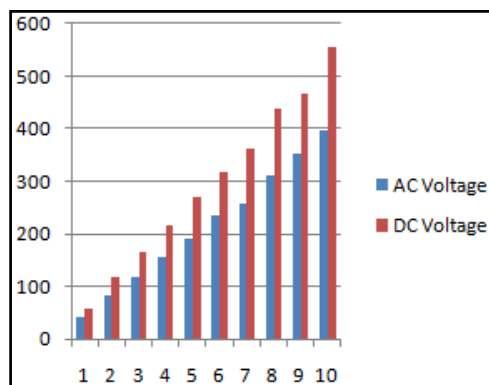


Figure 9: AC voltages and its corresponding DC voltages

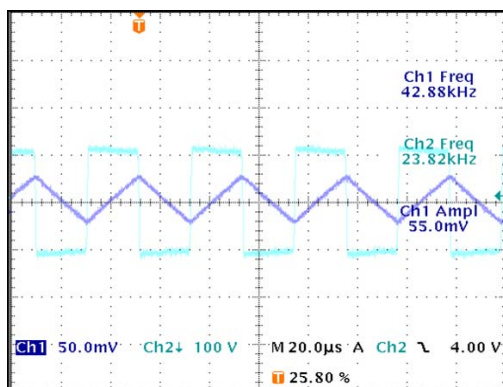


Figure 10: Load current (ch.1) and output voltage (ch.2)

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Appendix A

Model Rating

1. Power rating: 75KW
2. Input feeder voltage: 415VAC ±5%
3. Input feeder current: 130 Amps.
4. Input phase/frequency: 3phase/50Hz.
5. Cooling: Forced air
7. Load: Induction coil
8. Output voltage: 180 to 1050VAC
9. Output current (max.): 950 Amps.
10. Output phase: Single
11. Output frequency: 7.5 to 10 KHz.
12. Inverter type: IGBT H Bridge.

Authors Profile



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