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# Selection of Appropriate Semiconductor Switches for Induction Heated Pipe-Line using High Frequency Full Bridge Inverter

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**ABSTRACT**

An exhaustive method for the choice of different power semiconductor switches for high frequency full bridge inverter fed induction heater is presented. Heating coil of the induction heater is made of litz wire which minimises the skin effect and proximity effect at high operating frequency. With the calculated optimum values of inductance and resistance of heating coil at a particular operating frequency, high frequency full bridge inverter topology has been simulated using P-SIM software as well as constructing the experimental model of same rating. Obtained the voltage waveforms across heating coil and current waveforms through it, have been taken for further analysis. From this analysis selection of suitable power semiconductor switches like IGBT, GTO and MOSFET are made. Waveforms have been shown to justify the feasibility for real implementation of high frequency full bridge inverter fed induction heater in industrial applications.



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## 1. INTRODUCTION

Induction heater for industrial applications operates at a high frequency range from 1kHz to 100kHz as described by Sadhu et.al in. In the application of low frequency induction heating [2], [6] the temperature distribution can be controlled by slowly varying magnetic fields below a frequency as low as 300Hz. For medium frequency application, an auxiliary voltage-fed inverter [3], [5], [7], [9] is operated in parallel with the main current-fed inverter since the current- fed parallel inverters alone, when used for induction heating, fail to start. Full Bridge inverters [10] for high frequency [4] induction heating and melting applications are self-started. For self-commutation, a resonant [11] circuit is essential. It is assumed that the circuit is under damped; a mandatory condition for the circuit. The capacitor required for under damping can be connected in series or in parallel with the load. In the modern times, IGBTs, GTOs, MOSFETs are preferred to SCRs mainly because they offer convenient turn OFF characteristics. Some auxiliary circuits and equipment are required to minimize switching [1] losses occurring at high frequencies. In this present paper, response of high frequency full bridge inverter[10] is tested & verified with different power switches and finally appropriateness of the switches is confirmed. With the same designed parameters of the said inverter circuit, various switches such as IGBT, GTO and MOSFET have been used. Complete inverter configuration then has been simulated [8] using P-SIM.

## 2. ANALYSIS OF HIGH FREQUENCY FULL BRIDGE INVERTER

The circuit operation has been discussed in the following. The exact circuit diagram of the Full Bridge inverter is shown in Figure 1.

Figure 1 indicates a specially designed eddy current heated metallic package which is tightly incorporated into the non- metallic vessel or tank in the pipeline. The mechanically processed thin stainless-steel layer package with many spots and fluid channels for cylindrical induction-heated assembly is demonstrated in Figure 2.

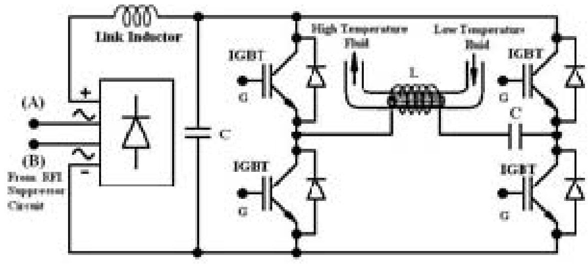


Figure 1. Full bridge inverter fitted induction heating equipment

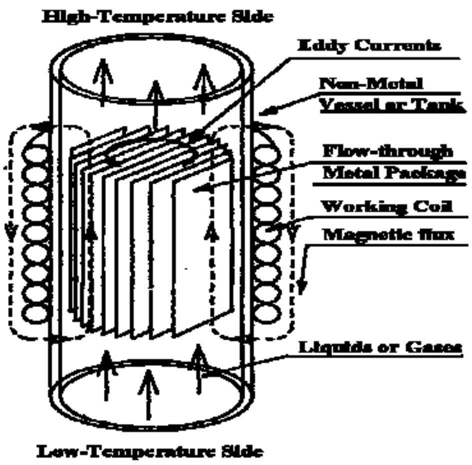


Figure 2. Heating package in the vessel and tank in pipeline system

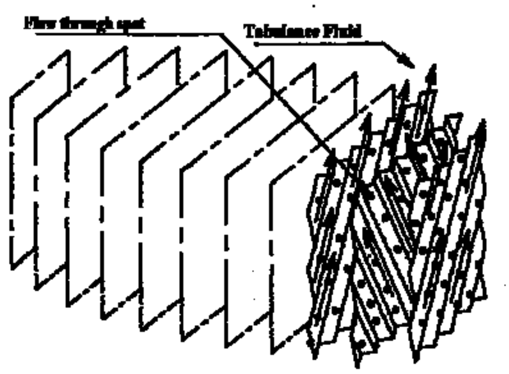

Figure 3. Internal structure of fluid through specially designed metal layer packing to generate turbulence flow

When the fluid flows through the inherent package in the vessel or tank having a working coil connected to pipeline, the turbulent fluid is heated abruptly by eddy current losses generated inside the stainless-steel package. Internal structure of this metallic package to be heated by eddy current losses is indicated in Figure 3. For operational analysis, equivalent circuit diagram as shown in Figure 4.

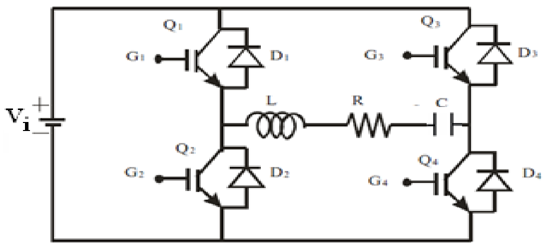


Figure 4. Full bridge series resonant inverter

Full bridge circuit is normally used for higher output power. Basic circuit is shown in the Figure 4. Four solid state switches are used and two switches are triggered simultaneously. Anti-parallel diodes are connected with the switch that allows the current to flow when the main switch is turned OFF.

The circuit is on when switches Q1 and Q4 are triggered simultaneously. The current flows for a half cycle of the resonant frequency and become zero when both switches Q1 and Q4 are turned off. When Q1 and Q4 stop conducting and switch Q2 and Q3 are not yet turned ON the current through the load reverses and is now carried by D1 and D4, the IGBT which are connected with the respective switches. The voltage drops across IGBT appear as a reverse bias across switch Q1 and Q4. If duration of the reverse bias is more than the switch turn-off time then switch Q1 and Q4 get commutated naturally and therefore, commutation circuit is not required. This method of commutation is called load commutation and used in high frequency inverter for induction heating.

In view of the difficulties of constructing four control circuits and complexity of firing/triggering signal for the above mentioned configurations of high frequency resonant inverters Full Bridge inverter (high frequency series resonant point image current source inverter) is chosen.

Firstly, the inverter circuit is simulated with IGBT as power switch. There after IGBT has been replaced by GTO& MOSFET. In each case, coil current waveform & voltage across it have been recorded & investigated. A real time experiment has been carried out to validate the simulation result.

## 3. SIMULATION AND RESULT

In this present work, the high frequency Full Bridge Series Resonant inverter has been simulated using P-SIM with the help of equivalent parameters connected at the input of the induction heated system. The circuit configuration and waveforms in P-SIM is shown below. With the selected circuit parameters & configuration, following waveforms have been obtained using P-SIM software and real time experimental model using different power semiconductor switches using IGBT in the Full Bridge series Resonant inverter circuit, it is observed in Figure 12 & 13 that magnitude of current through the coil has almost equal in both positive and must be indented negative half. Such a peak to peak symmetrical current produces more heat. Hence heating effect becomes very prominent for the same operating frequency range. Further, it is observed that the real voltage across heating coil and current through it, are almost identical to the P-SIM simulated result.

Figure 6 & 7 depict that using MOSFET in the Full Bridge Series Resonant inverter circuit & Figure 9 & 10 depict that using GTO in the Full Bridge Series Resonant inverter circuit, the real voltage across heating coil and current through it, are almost same to the P-SIM simulated result. Here also, coil current doesn't have equal positive and negative peaks. Hence, rms value of the current will be less. So heating effect will also be less compared to IGBT.

### 3.1. When using MOSFET

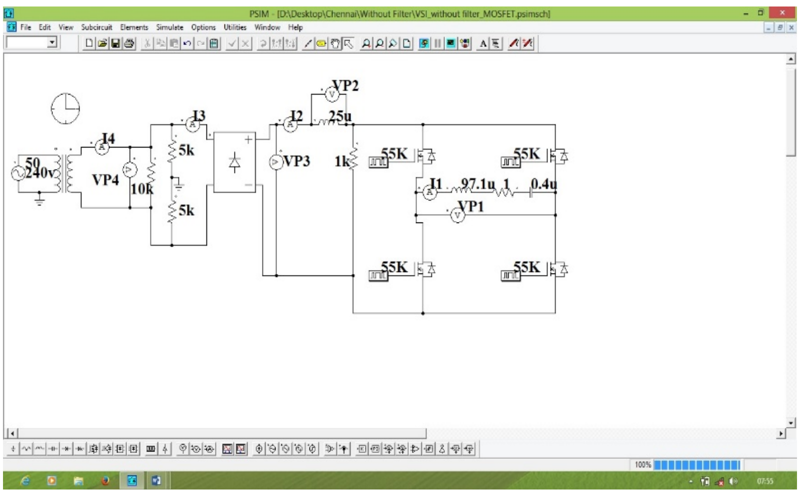


Figure. 5. Full Bridge inverter using MOSFET by PSIM software

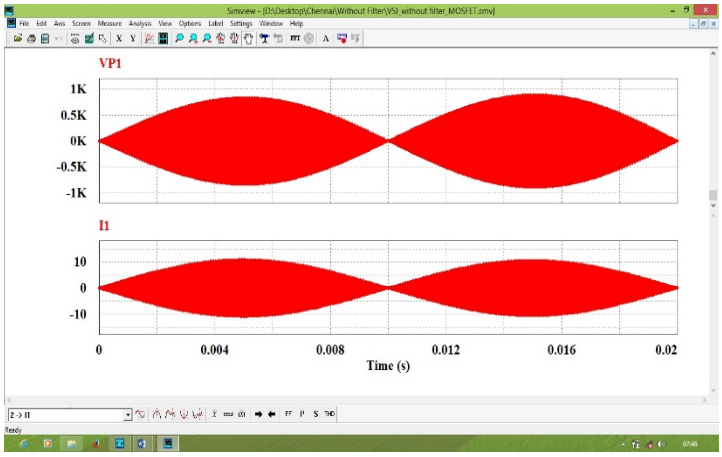


Figure 6. Coil Current & Coil Voltage using MOSFET by PSIM Software

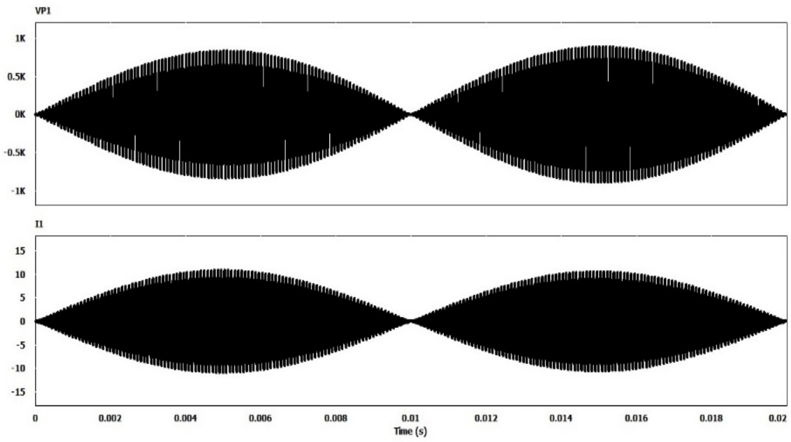


Figure 7. Coil current & coil voltage using MOSFET by real time experimental model

### 3.2. When using GTO

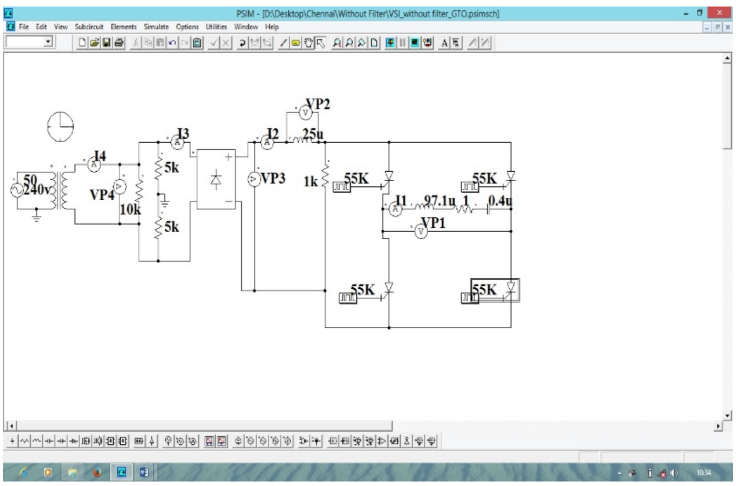


Figure 8. Full Bridge inverter using GTO by PSIM software

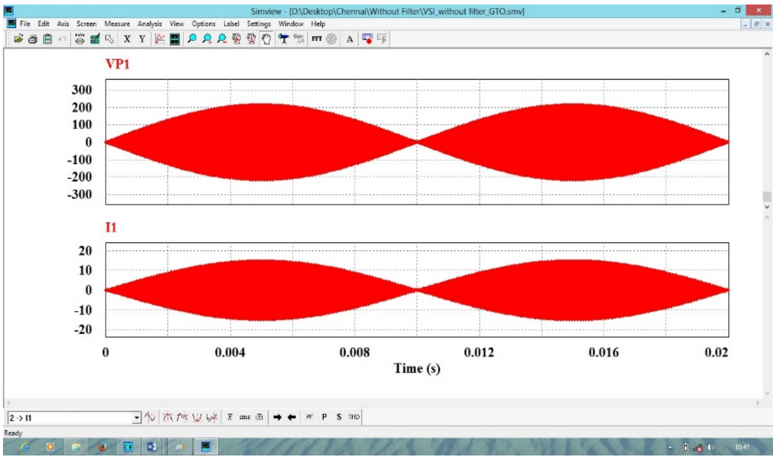


Figure 9. Coil Current & Coil Voltage using GTO by PSIM Software

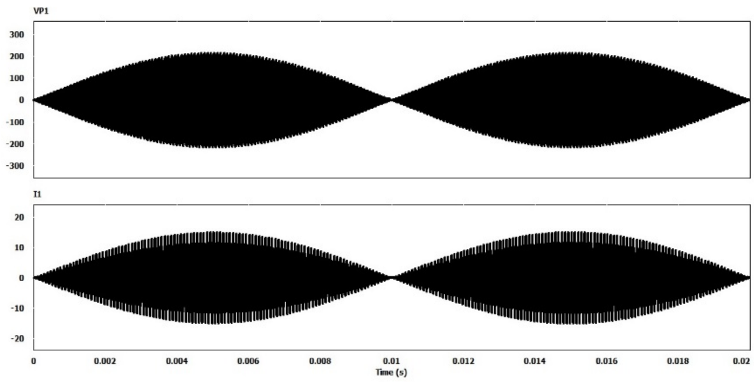


Figure 10. Coil current & coil voltage using GTO by real time experimental model

### 3.3. When using IGBT

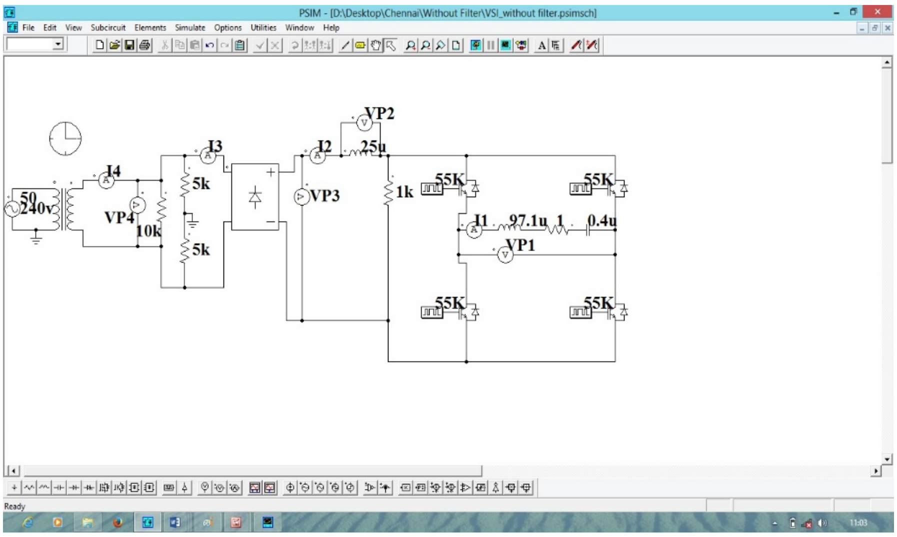


Figure 11. Full Bridge inverter using IGBT by PSIM software

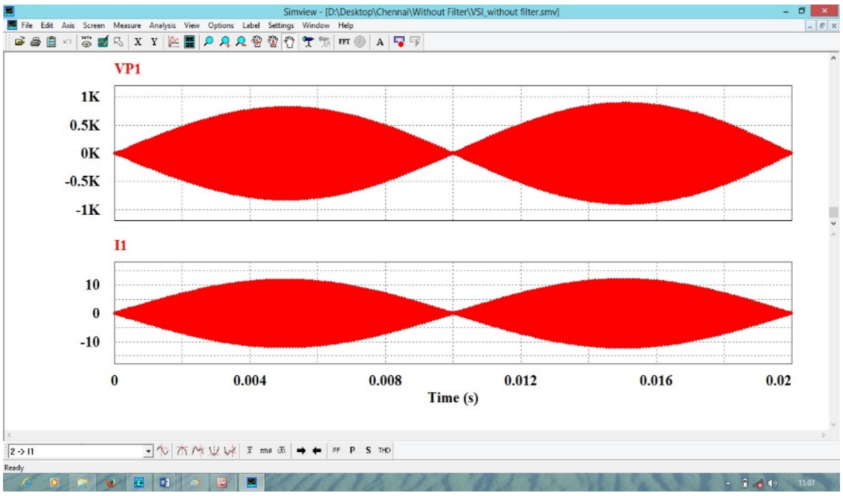


Figure 12. Coil Current & Coil Voltage using IGBT by PSIM Software

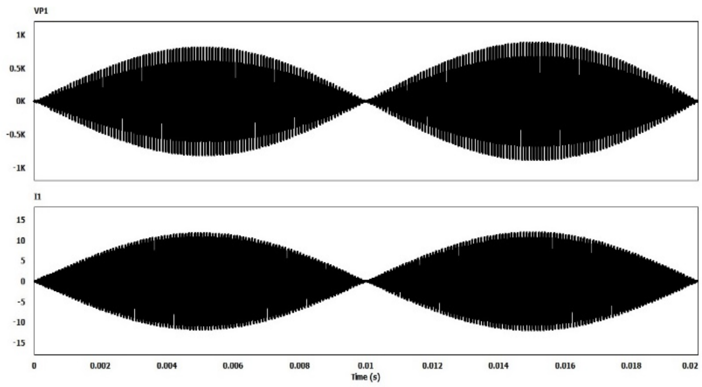


Figure 13. Coil current & coil voltage using IGBT by real time experimental model

## 4. CONCLUSION

After having compared the wave-forms of P-SIM simulation and real time experiment, it is quite obvious that the selection of IGBT as a power semiconductor switch in high frequency full bridge inverter is advantageous and most suitable for induction heating purposes for frequency below 55 kHz and highly acceptable. IGBT offers highest rms value of coil current among all the probable configurations using different power semiconductor switches. For a frequency range of above 55kHz, MOSFET& GTO will be a better option due its low switching& conduction losses.

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