Chapter 9

CONCLUSION & FUTURE SCOPE

This chapter describes the conclusions about the results and remarks about it. Also some future scope suggested here to extend the project for further real time implementations.

9.1 General

This thesis has addressed the modified Quasi-resonant converter system, simulation results and experimental verification for induction melting system. The main contribution of the thesis includes following:

- Principle of induction melting is explained & different power topologies & different tuning methods for pid are elaborated in chapter 2.
- Design of a quasi-resonant converter is described in chapter 3. Simulation study of the quasi-resonant convert is carried out & waveforms are generated.
- Chapter 4 proposes modified quasi-resonant converter and gives detailed study of the same. Simulation study is carried out.
- Development of power circuit for quasi-resonant converter is included in chapter 5.
- The micro-controller board, ARM-7 controller board, driver board developments are presented in chapter 6 & 7.
- The chapter 8 describes an induction melting experimental control structure.

The objective of this concluding chapter is to highlight the main finding of the work carried out in this thesis and provide suggestions for further research work in this area.
Some of the main findings are given below.

9.2 Summary of Important Findings

Chapter 2 describes induction melting principle and different power topologies. The main finding of this chapter reveals following:

1. As a resonant converter provides most of the energy conversion efficiency in a power system by minimizing switching loss, they are best suited for DC-AC converters as compared to PWM converters.
2. Due to skin effect the high frequency switching creates heat on the surface of the load, hence medium switching frequency is used for melting applications.
3. Zero-voltage switching refers to eliminating the turn-on switching loss by having the voltage of the switching circuit set to zero right before the circuit is turned on.

4. Zero-current switching is to avoid the turn-off switching loss by allowing no current to flow through the circuit right before turning it.
5. Different Tuning methods for PID loop are surveyed. It is found that the Ziegler and Nichols method for tuning is simple, accurate and can be easily implemented in digital PID control.

In chapter 3 a quasi-resonant converter has been proposed, to reduce total switching loss. The design and implementations of a quasi-resonant converter for melting at a high temperature has been carried out.

The main findings of this chapter reveals following:

1. The half-bridge series resonant converter is having stable switching & low cost. As the voltage of the circuit is limited to the level of the input voltage, the switching circuit can have low internal pressure, which helps reduce the cost.
2. As the half-bridge method requires two switching circuits, the overall working process becomes more complicated and the size of heat sink and PCB should be also bigger. In addition, the gate operating circuits must be insulated.
3. As compared to half-bridge series resonant converter the quasi-resonant converter needs only one switching circuit inside. This enables a relatively smaller design for the heat sink and PCB, making the working process far simpler. Another strong point is the fact that the system ground can be shared.
4. In case of quasi-resonant converter the high internal pressure of the switching circuit, caused by the resonant voltage administered to both sides of the circuit, pushes the cost of the circuit higher. But as mentioned earlier, technological development in high frequency semiconductor switching devices has lead to an innovation in terms of low price, high performance, and reliability. Quasi-resonant converters are now more generally used because of the smaller heat sink and PCB size and simpler operation process.

In chapter 4 a modified quasi-resonant converter is proposed to eliminate large amount of filter capacitors. It also includes the simulation study of control strategy using MATLAB/SIMULINK.

The main findings of this chapter reveals following:

1. The modified quasi resonant converter is low cost as the filter capacitor is eliminated as compared to quasi resonant converter. This new scheme also requires one switching device which maintains the advantage of a relatively smaller design for the heat sink and PCB.
2. This new scheme is more advantageous as the positive & negative current flows through the same resonant path resulting into a pure sine wave of current.
3. This system has advantages like low switching losses, reduced stress and increased power density.

4. The variation in power can easily be obtained by changing the operating frequency of IGBT gate pulses.
5. The simulation results are in line with the predictions.

Chapter 5 discusses Design, Analysis and Simulation of power circuit for the proposed topology. The chapter includes the implementation of Power circuit.

The calculations are shown & how to prepare inductor & capacitor are explained. The IGBT's are introduced & their types are explained. The new generation Trench/Fieldstop IGBT4 is selected and it is described how to connect two IGBT's in parallel. The need and details of RCD snubber is explained.

Chapter 6 describes the development of the control circuit for quasi-resonant converter. It also contains the development and design of main generator card with new generation SCALE-2 IGBT-driver circuits.

The Micro-controller Board & Arm-7 controller board are developed and tested.

In comparison with other driving methods, active clamping allows enhanced utilization of the IGBT modules during normal operation by increasing the switching speed and therefore reducing switching losses. The overvoltage at fault-current turn-off is also managed by active clamping.

Chapter 7 discusses the software implementation for micro-controller board & ARM-7 board. As well as development and design of MMI with TFT, touch screen and all modern facilities are presented.

The micro-controller board software automatically tunes the gate firing of IGBT according to the changes in load inductance. ARM-7 board software takes care of graphical user interface to view/insert machine parameters. The PID & Autotuning is explained with respect to ARM-7 controller.

Chapter 8 deals with the experimental verification of proposed induction Melter. The auto-tuning algorithm, the temperature accuracy and efficiency is verified.

This chapter has described an induction melting experimental control structure and following are the findings:

1. The experiment demonstrated the ability of controlling temperature of crucible at desired set power.
2. As work pieces are added the inductance changes & the converter automatically tunes itself to match the resonance frequency.
3. The frequency of operation can be valued by changing the set value of power.
4. The switching strategy minimizes the distortion in input current which improves power factor.

5. It also provides excellent output performance optimized efficiency and high reliability compared to similar conventional converters.
6. It leads to several advantages such as nearly unity power factor without any reactive elements, symmetric loading from utility point of view and almost uniform temperature. It is proved by experimental setup.

9.3 Scope for Further Research

Consequent to investigations carried out in thesis, the following aspects are being suggested as future work to be carried out.

1. By using new techniques the 3 phase input transformer can be removed to reduce size of Melter so as to design as a table top model as well as providing Ethernet connectivity to the machine to monitor as well as service the machine from remote.
2. Though the PID controller is developed for temperature as a parameter of performance, the second PID loop can be incorporated to control the power of Melter. This can be made possible by interposing suitable software with slight modification as per parametric requirement.
3. More optimization techniques can be used to carry out autotuning of the PID to get better accuracy.