Chapter 6

CONCLUSIONS

6.1 General

This thesis has addressed modulation techniques for IDH system, mathematical model of heating for conducting and non-conducting material, simulation results and experimental verification for induction dielectric heating system. The main contribution of the thesis includes the development of,

- A symmetrical space vector modulation pattern, to reduce Total Harmonic Distortion (THD) without increasing the switching losses. The design and implementations of a 3 phase PWM inverter for 3 phase IDH to control temperature using space vector modulation (SVM) as described in Chapter 2,
- A mathematical model of IDH for obtaining a reflection coefficient, transmission coefficient and electromagnetic wave properties for the work-piece, as descried in Chapter 3,
- An induction dielectric heating device with high frequency transformer structure has been developed. Comparison of results of proposed circuit has been carried out both by mathematical analysis and simulation and is described in Chapter 4 and
- An induction dielectric heating experimental control structure has been developed. The IDH concepts and their advantages are discussed in Chapter 5.

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.

6.2 Summary of Important Findings

In chapter 2 design and implementation of a 3-phase pulse width modulation for three phase induction dielectric heating has been described. The system has been used to control temperature using symmetrical space vector modulation and the effect on temperature of frequency. The mathematical model has been developed and it has been simulated using Matlab.

The main finding of this chapter reveals following:

1. Space vector modulation requires only a reference space vector to generate three phase sine wave.
2. The amplitude and frequency of load voltage can be varied by controlling the reference space vector.
3. The algorithm proposed is flexible and suitable for advanced vector control.
4. The strategy of the switching minimizes the distortion of load current as well as loss due to optimum number of commutations in the inverter.
5. The effectiveness of the SVM to reduce the switching power losses reduction has been proved.
6. SVM is among one of the best solutions to achieve good voltage transfer and reduce harmonic distortion in the output of three phase inverter for IDH.
7. SVM provides excellent output performance, optimized efficiency and high reliability compared to similar three phase inverter with conventional pulse width modulations.

Chapter 3 has been devoted to mathematical model for obtaining a reflection coefficient, transmission coefficient and electromagnetic wave properties for the work-piece contribution to the impedance of a given IDH system. This is intended to assess how work-piece is linked to the excitation loop and to find out conditions where the eddy current or displacement current occurrence is enhanced. Empirical rules already known by IDH practitioners have been proved and the finding can be extrapolated to design new possibilities. The proposed approach has been validated using MATLAB and FEM software.

The main finding of this chapter reveals following:

1. As frequency increases, the current becomes concentrated along the outer surface of the object.

2. The electromagnetic shield may be necessary to prevent waves from radiating out of the shielded volume or to prevent waves from penetrating into the shielded volume.

3. Attenuation constant, phase constant and propagation constant increases with increase in frequency in conducting material and non-conducting material.

4. Intrinsic impedance increases with increase in frequency in conducting material and is remaining constant with increase in frequency for non-conducting material.

5. Velocity of propagation and intrinsic impedance of conducting material exponentially increases with increase in frequency and reactive component of conducting material remains constant at 45^0.

6. Velocity of propagation and intrinsic impedance of non-conducting material remains constant with increase in frequency and reactive component of non-conducting material is small.

In chapter 4 an induction dielectric heating device with high frequency transformer structure has been described. Comparison of proposed circuit has been carried out both by mathematical analysis and by simulation. The result shows that value of power factor obtained is unity. Flexibility aspects of switching transformer leads to several advantages such as unity power factor without using any reactive element, symmetric loading from utility point of view, isolation of working coil, compact dimensions and almost uniform sinusoidal output.

Additionally, this topology can provide any voltage level conversion ability, which leads to desired power even at low input voltage levels. Furthermore, proposed topology provides maximum output power and reduced THD utilization. This requires comparatively smaller size of matching filter coil which work suitably with auto tuning switching frequency controller.

An induction dielectric heating experimental control structure has been described in chapter 5.

The main finding of this chapter reveals following:

1. This experiment demonstrated the ability of voltage level conversion ability, which leads to desired power even at low input voltage levels.

2. As frequency increases, the current becomes concentrated along the outer surface of the object.

3. The frequency of load can be varied by encoder.

4. The proposed algorithm is flexible and suitable for advanced vector control.

5. The strategy of the switching minimizes the distortion of load current as well as loss due to minimization commutations in the inverter.

6. Experimental technique of Induction Dielectric Heating (IDH) has been developed using micro controller.

7. The effectiveness of the SVM in the contribution in the switching power losses reduction has been demonstrated by performing an experiment.

8. SVM is one of the best solutions to achieve good voltage transfer.

9. It also provides excellent output performance optimized efficiency and high reliability compared to similar three phase inverter with conventional pulse width modulations.

10. Flexibility aspects of switching transformer leads to several advantages such as nearly unity power factor without using any reactive elements, symmetric loading from utility point of view, isolation of working coil, compact dimensions and almost uniform output voltage and temperature. It is proved by experimental setup.

6.3 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 different modulation techniques, the effect on performance like efficiency, rate of heating and most efficient production equipment can be made.
2. With the use of IDH method adopted, the characteristic behaviour of metal or food on rate of heating can be analyzed.
3. Three phase induction dielectric melting can be investigated.
4. In chapter 5, an open loop approach was used for IDH system. It can be extended for a close loop approach.
5. The feasibility of use of IDH in place of microwave oven can be investigated.