Ain Shams University

Faculty Of Engineering

Electrical Power and machine Department

A High Frequency modular Resonant Converter for the Induction Heating

By : Eng Omar Ramzy Mohamed Elnakeeb

A thesis submitted to the faculty of Engineering Ain shams university in a partial fulfillment of the requirements for Master of Science degree in electrical power and machines engineering

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Statement

This thesis is submitted to Ain Shams University in partial fulfillment of the requirements for Master of Science degree in electrical engineering.

The included work in this thesis has been carried out by the author at the electrical power and machine department, faculty of engineering Ain Shams University, no part of this thesis has been submitted for a degree or qualification at another university or institute.

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ACKNOLEDGMENT

First and last of all thanks to Allah

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Abstract

Induction heating was first noted when it was found that heat was produced in transformer and motor windings. It uses high frequency electricity to heat materials that are electrically conductive. Induction heating is achieved by applying a high frequency electric source through a coil. The passage of current through this coil generates a very intense and rapidly changing magnetic field in the space within the work coil. It is a very efficient heating scheme since the heat is actually generated inside the work piece

Induction heating can be used for any application where we want to heat an electrically conductive material in a clean, efficient and controlled manner such as welding and brazing, hardening metals, sealing the anti-tamper seals of medicine, induction cooking, and zone purification used in the semiconductors manufacturing industry.

The power used in heating can be controlled by many methods. It can be achieved by using a high frequency converter to convert the dc to ac with high frequency. However; the switching losses at high frequency introduce a serious problem. Switching also causes an EMI problem, because a large amount of di/dt and dv/dt is generated in the process.

To overcome these problems and reduce the switching losses, soft switching methods are used. The voltage or current administered to the switching circuit can be set to zero by using the resonance created by an L-C resonant circuit. High frequency resonant converters are used widely for induction heating. This thesis presents a modular resonant inverter to achieve the desired high frequency with reduced switching losses. A hybrid soft switching technique based on the Pulse Width Modulation (PWM) and the Pulse Density Modulation (PDM) is proposed for the modular inverter to control the furnace temperature. Matlab/Simulink software package is used to evaluate the dynamic performance of the proposed system. Simulation results confirm that the load current is sinusoidal with the desired frequency at different conditions. Moreover, the proposed hybrid switching scheme is a Zero Voltage Switching (ZVS) technique.

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Chapter 1

Introduction

1. Introduction

All applied Induction Heating (IH) systems are developed by using electromagnetic induction which was first discovered by Michael Faraday in1831. Electromagnetic induction refers to the phenomena where electric current is generated in a closed circuit by the fluctuation of current in another circuit placed next to it. The basic principle of induction heating results from Faraday's discovery. The fluctuation of current inside the primary circuit induces the current in the neighboring secondary circuit.

Faraday's discovery facilitates the development of electrical motors and transformers. As researchers generated sought to minimize the heat loss by laminating the magnetic frames placed inside the motors or transformers because heat loss which occurs during the induction heating process was one of the major factors that decreases the overall efficiency of the system.

Heat loss occurring in the process of electromagnetic induction could be turned into productive heat energy in any electric heating system by using this law. Many industries have benefited from this phenomena by implementing induction heating for furnacing and welding. Since it is non contact, the heating process does not contaminate the material being heated, Moreover, IH is very efficient since the heat is actually generated inside the work piece, in addition to the absence of any physical contact to heating devices precludes unpleasant electrical accidents [1][2].

1.1 Background

Induction heating is one of a wide range of electrical heat used in industry and household today. The particular advantage of this process is to produce the heat inside the work piece without the need for any external heat source, Hence, it is considered clean and fast heating method that meets the requirements of environmental protection.

According to the physical law of induction, an alternating magnetic field is generated around each electrical conductor through which an alternating current is flowing. By increasing this magnetic field, metals brought into close proximity will be heated by eddy current produced within the metal .Heating by induction makes use of the capability of the magnetic field to transmit energy without direct contact. This means heating is not done by direct contact such as known in resistance heating in heating plates or electrical furnaces where the direct current flow causes resistance wire to glow [1]-[4].

A basic problem of induction heating is to create a sufficiently intense electro-magnetic field and to position the component to be heated within the center of the field to obtain optimum transmission of energy from the electrical conductor to the work piece. Normally this is achieved by forming the electrical conductor to be an inductor or coil with one or more turns and the work piece is positioned in the center of the coil, thus concentrating the magnetic field onto the component. The field will then force the electrical current to flow inside the work piece.

According to the law of transmission, the strength of the current flow in the work piece is equal to that in the coil, To generate a sufficient magnetic field, the current flow in the coil must be very high from 1000 to 10000 A, normally a current of this intensity cause the coil to melt, in order to avoid this problem the coils are made of water cooled copper tubing. Also there is another method to create strong alternating magnetic field based on increasing the frequency of the current. Normally the electrical main supply operates at 50Hz frequency, and depending upon the application, the induction heating equipment can operate up to 1 million Hz[2][3][5][6].

This high frequency, which are not available from the normal electrical supplies, are obtained by a medium or high frequency converters which is the objective of this research. There is a need for large frequency range and not all induction heating processes can be carried out at the same frequency; this is due to a physical reason which is known as skin effect. The electrical current flows into the outer skin of the work piece only [3][6][7]. The thickness of the layer in which the current flows in turn is dependent on the frequency. At low frequencies, the layer is thick; at very high frequency the current flows at the surface only and the penetration depth is in range of 1 mm [5].

The most common application utilizing induction heating technologies are:

- Melting of steel and non ferrous metals at temperatures up to 1500 °C
- Annealing of metals after cold forming using temperatures in the range of 750-950°C
- Surface hardening of steel and cast iron at temperatures from 850-930°C

While for melting, forging and annealing mostly medium frequency is used as energy source [3].