A Review on different methods of Designing and controlling Induction Heating Application

Ashishkumar B. Patel[1] Payal D. Kansagra[2] R. B. Patel[3]

[2]Assistant Professor [3]Director

[1,2,3] Department of Electronics & Communication Engineering

[1,2]Parul Institute of Engineering & Technology, Limda, Vadodara, India. [3]RF Engineers, Manjalpur, Vadodara, India

Abstract— Induction heating is a well-known technique to produce very high temperature for applications. A large number of topologies have been developed in this area such as voltage and current source inverter, modulator resonant converter, Power System Using Half-bridge Series Resonant Converter. The series-resonant inverter needs an output transformer for matching the output power to the load but it carry high current as a result additional real power loss is occur and overall efficiency also is reduced. The higher the frequency the more the switching loss, which makes hard efforts to raise the frequency. Modulator resonant converter is using soft switching techniques like Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS). Advantages are designing of RF generator and Amplifier for Induction Heating as fast cycle time, accurate heat zones, Consistent and repeatable, efficient and environment friendly. Induction heating can reduce or eliminate the need for skilled operators in application such as brazing and soldering, annealing, medical waste, hardening. Designing RF Generator with the help of MAX038 and amplifier with TDA2030.

Key words: RF Generator, Amplifier, Oscillator, Frequency, Modulator resonant converter, Induction Heating.

I. INTRODUCTION

Induction heating is a non-contact heating process. It uses high frequency electricity to heat materials that are electrically conductive. Since it is non-contact, the heating process does not contaminate the material being heated. The method of Induction Heating is providing fast and consistent heat for manufacturing applications that involve bonding or changing the properties of metals or other electrically conductive materials. Induction heating may be used to replace a wide variety of conventional process heating methods, such as fossil/electric furnace heating, salt/lead bath heating, flame heating, and a variety of specialized brazing processes. All of these processes heat the outer surface of the work piece. In contrast, induction heating heats deep inside the work piece. The induction heating process relies on induced electrical currents within the material to produce heat. The electromagnetic field is produced by applying current with a frequency of 60 Hz to 800 kHz to an inductor coil in proximity to the work piece. Where the magnetic field intersects a work piece made from any electrically conducting material, it generates a circulating current, which generates heat. The lower the frequency, the deeper the current penetrates into the work piece.

Eddy currents oppose to the magnetic field applied to the induction target, and they produce the heating by Joule effect.

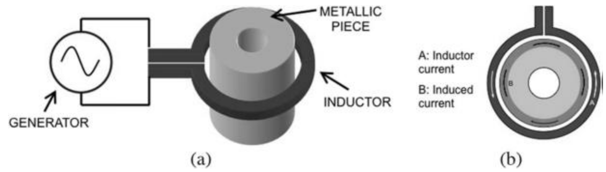

Fig. 1: Typical arrangement of an induction heating system in a longitudinal flux configuration: (a) general view and (b) top view [3]

II. MODULATOR RESONANT CONVERTER TOPOLOGY

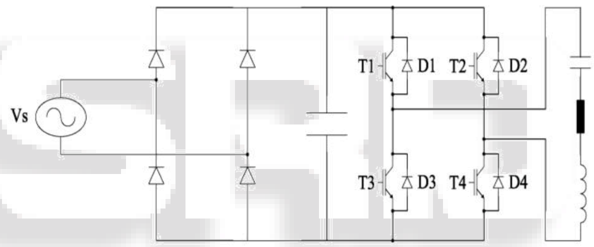

Fig. 2: Modulator resonant converter [2]

A modular resonant inverter to achieve the desired high frequency with reduced switching losses. A specific current is turned on or off at a specific level of voltage which results is switching losses in this mode. The higher the frequency the more the switching loss, which makes hard efforts to raise the frequency. Higher energy conversion efficiency at high frequency switching can be obtained using soft switching techniques which manipulate either the voltage or current at the switching instants to become zero. Soft switching techniques are subcategorized into two main methods: Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS). Resonant converters are used to achieve ZVS or ZCS by employing the resonance created by an LC resonant circuit.

Converters for induction heating applications are realized up to 1.5 MW and switching frequencies up to 150 kHz using IGBTs. For special purposes, it is desirable to increase the frequency up to 500 kHz. This very high switching frequency can be achieved using MOSFETs. However, it is a very costly approach due to the large silicon area of MOSFETs and problems with the internal diode of the MOSFET. To reduce the costs for IH converters, the modular IGBT based converter system, shown in Fig. 2, is proposed. The modules can be connected either to increase the rated power or the output frequency. The output frequency is increased by using the method of shifted gate pulse while the switching frequency of each module remains constant. [2]

III. HALF-BRIDGE SERIES RESONANT CONVERTER

A variety of design methods are available for a power system using a half-bridge series resonant converter. Figure 3 is a block diagram of a power system which is reliable and economy of the system. This system is made of an AC power supply, main power circuit, input current detection circuit, control circuit, resonant current detection circuit and gate operation circuit. All the necessary procedures for testing and designing the system are shown in the block diagram. The drawing does not contain the heater and cooling fan in the figure. The operation of a power system as a whole is illustrated in the following figure.

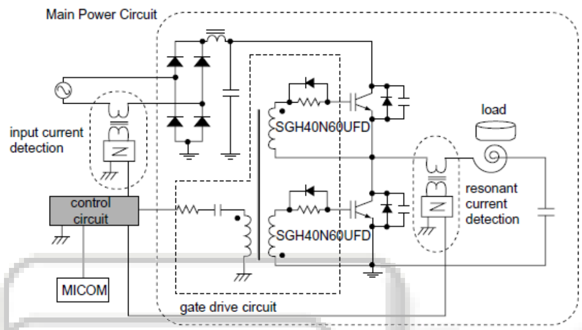

Fig. 3: Power System Using Half-bridge Series Resonant Converter. [8]

The AC power passes through the rectifier to be transmitted to the capacitor. Capacitors in existing power systems are too small in capacity to do the leveling work leading to the creation of rectified current in 120Hz, which is not the proper level for DC operation. The system for an IH rice cooker, however, does not require a big capacitor to make DC more leveled, as the primary purpose of the system is to generate heat energy. Rather, the rugged form of DC helps improve the power factor of the system. In this system, the leveling capacitor serves as a filter preventing the high frequency current from flowing toward the inverter and from entering the input part. Input current becomes the average of the inverter current, and the ripples flow to the leveling capacitor. The voltage passing the leveling capacitor is turned into a square wave in the process of high frequency switching in the inverter. The high frequency harmonics contained in the square wave are eliminated by the Lr, Cr filter. The square wave enables resonance in the resonant circuit, which in turn, creates a magnetic field around the resonant inductor affecting the load (rice container). Eddy currents are formed around the surface of the object, generating heat energy.

IV. RF GENERATOR AND AMPLIFIER

A. RF Generator

1) Introduction

An oscillator is the basic element of all ac signal sources and generates sinusoidal signals of known frequency and amplitude. It is one of the basic and useful instruments used in electrical and electronic measurement.

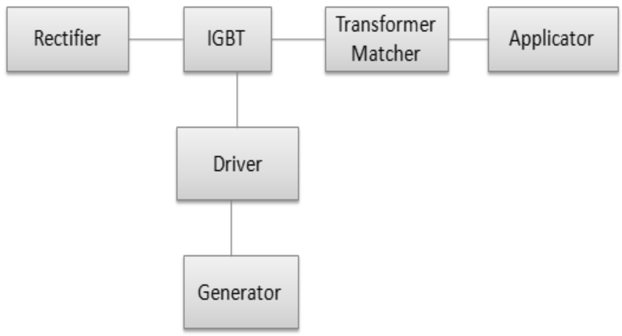

Fig. 4: Proposed Block Diagram of Induction Heating

Oscillators are used in many electronics circuits and systems providing the central clock signal that controls the sequential operation of the entire system. An oscillator is a circuit, which generates ac output signal without giving any input ac signal. This circuit is usually applied for audio frequencies only. The basic requirement for an oscillator is positive feedback. Positive feedback consist in the redirecting of the output signal to the input stage of the amplifier without a phase shift Oscillators convert a DC input (the supply voltage) into AC output (the waveform), which can have a wide range of different wave shapes and frequencies that can be either complicated in nature or simple sine waves depending upon the applications. Oscillators are also used in many pieces of test equipment producing sinusoidal sine waves, square waves, saw tooth waves or triangular shaped waveforms or just a train of a variable or constant width. RC and LC oscillators are commonly used in radio frequency circuits because of good phase noise characteristics and ease of implementation. An oscillator is basically an amplifier with positive feedback or regenerative feedback (in phase) and one of the many problem in electronic circuit design is stopping amplifier from oscillating while trying to get oscillator to oscillate. Requirements of oscillator are the power source, frequency-determining components, active device to provide gain and Positive feedback. RC networks, LC tanks, and crystals may appear in sine-wave oscillator circuits. An amplifier can be made into a sine-wave oscillator by providing regenerative feedback through an RC network.

2) SCHEMATIC DIAGRAM OF RF GENERATOR

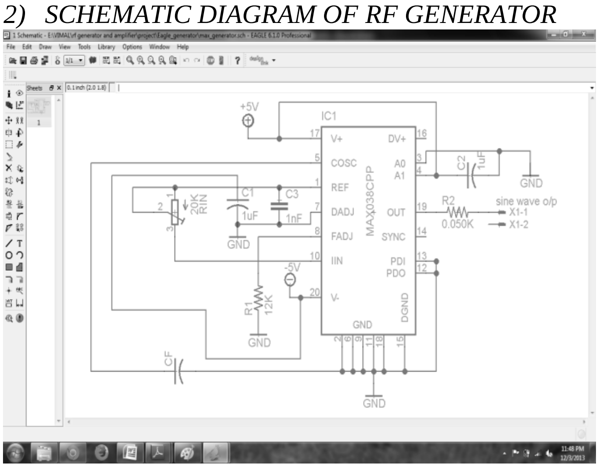

Fig. 5: Schematic of RF Generator

3) CIRCUIT DESCRIPTION

The MAX038 is a high-frequency function generator that produces low-distortion sine, triangle, or square (pulse) waveforms at frequencies from less than 1Hz to 20MHz or more, using a minimum of external components. Duty cycle and frequency can be independently controlled by programming the voltage, current, or resistance. The desired output waveform is getting the control by setting the appropriate code at the A0 and A1 inputs.

The High frequency waveform generator operates with ±5V power supplies. The basic oscillator is a relaxation type that operates by alternately charging and discharging a capacitor, CF, with constant currents, simultaneously producing a triangle wave and a square wave. The charging and discharging currents are controlled by the current flowing into IIN, and they are modulated by the voltages applied to FADJ and DADJ. The current into IIN pin can be varied from 2µA to 750µA.

Duty cycle is defined as the percentage of time that the output waveform is positive that can be controlled from 10% to 90% by applying ±2.3V to DADJ. This voltage changes the CF charging and discharging current ratio while maintaining nearly constant frequency. A stable 2.5V reference voltage (REF,) allows simple determination of IIN, FADJ, or DADJ with fixed resistors and permits adjustable operation when potentiometers are connected from each of these inputs to REF. FADJ and/or DADJ can be grounded, producing the nominal frequency with a 50% duty cycle. The output frequency is inversely proportional to capacitor CF. [6]

The sine-shaping circuit converts the oscillator triangle wave into a low-distortion sine wave with constant amplitude. The square, triangle, and sine waves are input to a multiplexer. There are two address lines, A0 and A1, control which of the three waveforms is selected. The output amplifier produces constant 2VP-P amplitude (±1V), regardless of wave shape or frequency.

4) WAVEFORM SELECTION

Based on this circuit can produce sine, square, or triangle waveforms. The address pins A0 and A1 set the waveform which user is want to get the waveforms

A0	A1	WAVEFORM
1	0	Triangle wave
0	0	Square wave
X	1	Sine wave

Table. 1: Truth table of Waveform, X= don't care

5) CALCULATION

The output frequency is determined by the current injected into the IIN pin, the COSC capacitance (to ground), and the voltage on the FADJ pin.

When VFADJ = 0V, the fundamental output frequency (Fo) is given by the formula:

$$Fo\ (MHz) = IIN\ (\mu A) \div CF\ (pF) \qquad (4.1)$$

The period (To) is:

$$To\ (us) = CF\ (pF) \div IIN\ (\mu A) \qquad (4.2)$$

For example,

$$Fo = IIN\ (200\mu A) \div CF\ (10nF) = 20KHz \qquad (4.3)$$

$$Fo = IIN\ (180\mu A) \div CF\ (6nF) = 30KHz \qquad (4.4)$$

$$Fo = IIN\ (200\mu A) \div CF\ (4nF) = 50KHz \qquad (4.5)$$

$$Fo = IIN\ (160\mu A) \div CF\ (2nF) = 80KHz \qquad (4.6)$$

B. RF AMPLIFIER

RF Power amplifiers are widely used in the applications of wireless communication, radar, and industrial, scientific, and medical (ISM) fields RF heating. The RF power class of the amplification determines the type of bias applied to an RF power transistor. Each application has a various operating condition and requirement of the power amplifier, no single or unified technique exists for the optimum design that is suitable for all applications. In RF power amplifiers, the performance issues include efficiency, output power, linearity, and spectral purity. The efficiency has been of great significance to power amplifier designers because it affects the lifetime, reliability, and cost of the entire system. Radio-frequency (RF) amplifier is one that amplifies frequencies above 20 kHz. Now in this proposed design, we want to try to design the class C and class D amplifier based on the efficiency and as per the design parameter. This is because there is little to no energy being loss to heat dissipation. Class D is a switching amplifier and when it is in the "on" state it will conduct current but have almost no voltage across the switches, therefore no heat is dissipated due to power consumption. When it is in the "off" mode the supply voltage will be going across the MOSFETs but due to no current flow the switch is not consuming any power

1) SCHEMATIC DIAGRAM OF RF AMPLIFIER

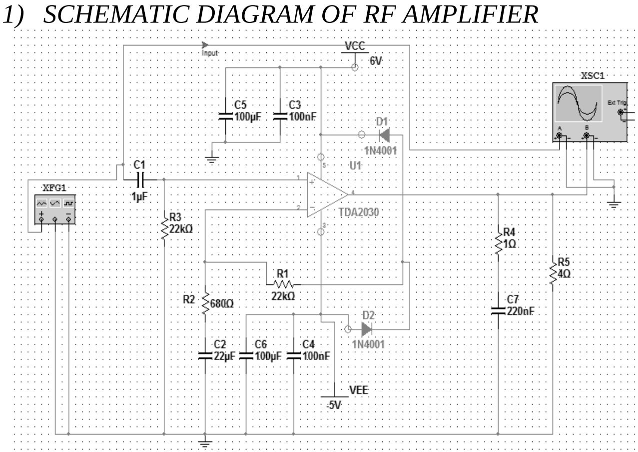

Fig. 6: Schematic of RF Amplifier

In this above circuit, provides the input signal as the sinusoidal signal with above 20 KHz frequency. Here Circuit requires maximum 36V and all the capacitors and resistor are required particular reason. We want to get the output power 10W.R1 is used to setting the input gain and R2 is used to decrease the gain.R3 is used to increase of input impedance.C3, C4, C5 and C6 are bypassing the capacitor for adjusting the supply voltage.C7 is used to frequency stability and Diode D1 And D2 are used for protecting the devise against output voltage spikes.R5 is the load resistance for adjust the output voltage. The output voltage waveform will see in the Oscilloscope and as well as input waveform. The value of R5 is important for better oscillation. Here below the circuit of working progress which is implemented on hardware and try to get 10W power for the driving the IGBT.

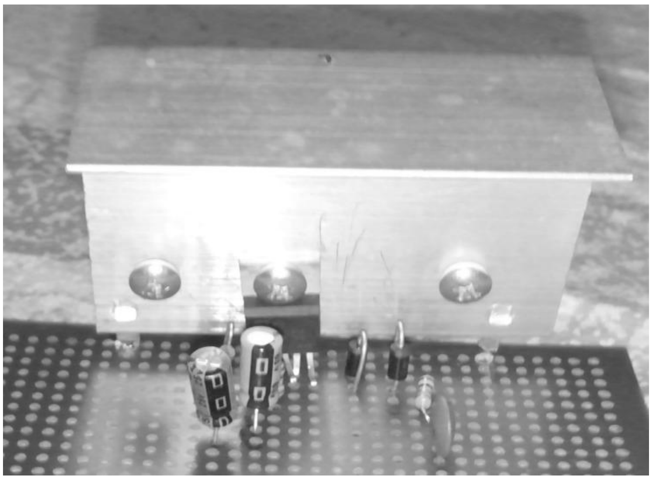

Fig. 7: Working progress implementation on Hardware of RF Amplifier

V. INDUCTION HEATING APPLICATIONS

1) Hardening: Induction hardening uses induced heat and rapid cooling to increase the hardness and durability of steel.
2) Brazing: Brazing is a materials-joining process that uses a filler metal to join two pieces of close fitting metal together without melting the base materials.
3) Annealing: Induction annealing reduces hardness, improves ductility and relieves internal stresses.
4) Forging: Induction forging uses induction to heat metal parts before they are shaped, or 'deformed' by presses or hammers.
5) Induction heating apparatus to Heat Treatment of Aluminium Alloy.
6) Cutting, Medical Waste and expansion & extraction for bearing.

(a) (b)

Fig. 6: Induction Heating Application (a) Harding (b) Brazing

VI. CONCLUSION

From the survey we have studied different technique of various Induction Heating methods like controlling the power system using modulator Resonant Converter, Half-bridge Series Resonant Converter. We have implemented on the based on the RF generator and Amplifier for the 20 to 80 KHz frequency range for Induction Heating. We will get the output waveform of generator with the help of MAX038 and 10W amplifier with the help above circuit. The Hardware is under fabrication process. Now this design is low cost, less size, better efficiency and it is used on Industrial Application mentioned above. So we will try to implement this design for Induction Heating application which is real applicable in the Industries.

ACKNOWLEDGMENT

Thanks to my Family members my father, mother, grandfather, grandmother, guides and many more for their support to carry out this work.

Finally, thanks to God, for helping me out at difficult times.

REFERENCES

[1] Sreenivas peram* vaddi ramesh, J.SRI RANGANAYAKULU "Full Bridge Resonant Inverter for Induction Heating Applications" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 3, Issue 1, January-February 2013, pp.066-073.
[2] Omar El-Nakeeb1, Mostafa I. Marei2, Ahmed A. El-Sattar," A High Frequency modular Resonant Converter for the Induction Heating" International Journal of Emerging Technology and Advanced Engineering (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 2, February 2013)
[3] Oscar Lucía, Member, IEEE, Pascal Maussion, Member, IEEE, Enrique J. Dede, Member, IEEE, and José M. Burdío, Senior Member, IEEE, "Induction Heating Technology and Its Applications: Past Developments, Current Technology, and Future Challenges" IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 61, NO. 5, MAY 2014.
[4] ANJANA M P, SIJA GOPINATHAN, ELDHOSE K A,"IMPROVED AC-AC CONVERTER FOR INDUCTION HEATING APPLICATIONS "International Journal of Electrical, Electronics and Data Communication, ISSN (p): 2320-2084, Volume-1, Issue-2, April-2013.
[5] www.tektronix.com/signal_generators.
[6] http://datasheets.maximintegrated.com/en/ds/MAX038.pdf
[7] www.unisonic.com.tw_datasheet_TDA2030.
[8] www.ehu.es_electronicaindustrial_AmpliacionElectronicaIndustrial_Proyecto _p6
[9] http://pdfserv.maxim-ic.com/en/ej/EJ19.pdf