Vol. 5(16) Jul. 2015, PP. 2239-2245

Contents list available at IJMEC

International Journal of Mechatronics, Electrical and Computer Technology (IJMEC)

Journal Homepage: www.aeuso.org

PISSN: 2411-6173 - EISSN: 2305-0543

Design and simulation of Fuzzy Logic Controller Based Modified Half Bridge Resonant Inverter Fed Induction Heating System

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Abstract

This paper presents the fuzzy logic controller based power semiconductors switching of an energy efficient induction heating system. In induction cooking system, an alternating current is made to flow through a disc of metal which is surrounded by copper coil. The disc has a specific diameter and thickness. The secondary current is induced in the disc and it circulates around the outer surface of the disc results heating effect. The switching of power electronic switches is done at various frequencies to get sufficient quick heating response. The fuzzy logic controller uses the error and the rate of change of error as input and the frequency is fed as output to maintain required temperature and in order to minimize losses for modified half bridge resonant inverter fed induction heating system. Here the fuzzy logic controller is designed and simulated with the help of MATLAB to get switching frequency.

Keywords: *Induction Heating Modified Half Bridge Resonant Inverter, Fuzzy Logic Controller, MATLAB.*

1. Introduction

In now-a-days high frequency induction heating is created a role of awareness regarding selection power semiconductor switches. The conventional power switch is IGBTs in induction heating purposes [1]. The selection of IGBTs as power Semiconductor switches in high frequency fitted induction heating purposes for frequency above 50 KHz and highly preferable. Again, there are many research works going by reconstructing with other power semiconductor switches like MCTs, SITHs etc. The application areas of high frequency induction heating are widening very fast. Normally, the different power semiconductor switches like IGBTs, GTOs and MOSFETs etc. are used for power semiconductor switching purposes [3]. In existing system uses IGBTs for induction heating. The selection of IGBTs as power Semiconductor switches in high frequency fitted induction heating purposes for frequency above 50 KHz and highly preferable. It combines the simple gate drive characteristics of the MOSFETs with the high current and low voltage capability of bipolar transistors as a switch. But it can work satisfactorily in the medium range of frequency due to its low switching and conduction losses [4-7]. In the proposed scheme have unique advantages with absolutely safe from shock hazard and also rugged. There is no conduction loss during transfer of heat from source to pan material in high frequency induction heating system and it is possible to get an efficiency about 85% to 95%.

Article History:
IJMEC DOI: 649123/10146
Received Date: Apr. 01, 2015
Accepted Date: Jun. 27, 2015
Available Online: Jun. 03, 2015

2. Analysis of Modified Half Bridge Resonant Inverter

Modified half bridge circuit is normally used for medium power output [12-13]. The circuit diagram of modified half bridge resonant inverter is shown in the fig. 1. One IGBT is used to trigger at a time. Anti-parallel diodes are connected with the switch that allows the current to flow when the main switch is turned OFF.

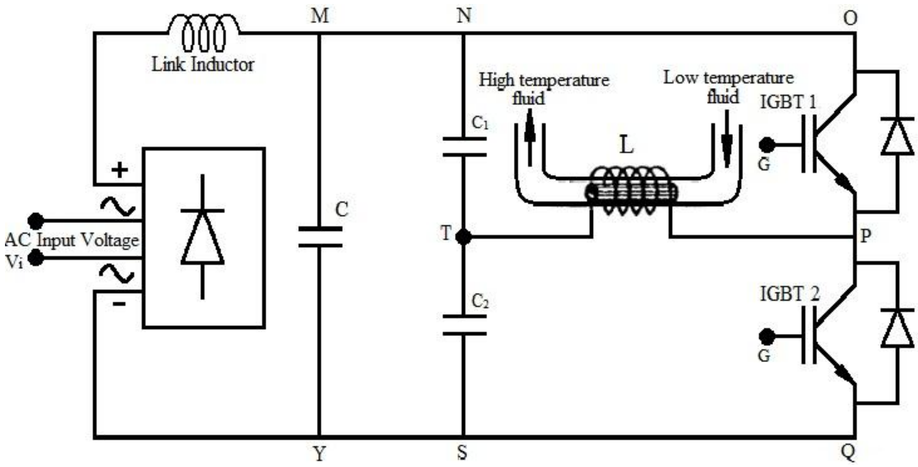


Figure 1: Modified half bridge resonant Inverter Fed Induction Heating System

TABLE 1: SWITCHING ON-OFF CHART OF IGBTS

IGBT1	IGBT2	V_{out}
ON	OFF	$+V_i/2$
OFF	ON	$-V_i/2$

Here IGBTs are used as solid state switches because it can be exist at high frequency applications. Anti-parallel diodes D1 and D2 are connected with the switches IGBT1 and IGBT2 respectively that, allows the current to flow when the main switch is turned OFF. Table 1 represents the Switching ON-OFF chart of IGBTs. According to fig. 2, when there is no signal at S_1 and S_2, capacitors C_1 and C_2 are charged to a voltage of V_i /2 each. The Gate pulse appears at the gate G to turn IGBT1 ON. Capacitor C_1 discharges through the path NOPTN. At the same time capacitor C_2 charges through the path MNOPTSYM. The discharging current of C_1 and the charging current of C_2 simultaneously flow from P to T. In the next slit of the gate pulse, S_1 and S_2 remain OFF and the capacitors charge to a voltage V_i /2 each again. The Gate pulse appears at the gate G so turning on IGBT2. The capacitor C_2 discharges through the path TPQST and the charging path for capacitor C_1 is MNTPQSYM. The discharging current of C_2 and the charging current of C_1 simultaneously flow from T to P. The both switches must operate alternatively otherwise there may be a chance of short circuiting. In case of resistive load, the current waveform follows the voltage waveform [2]. The feedback diode operates for the reactive load when the voltage and current are of opposite polarities.

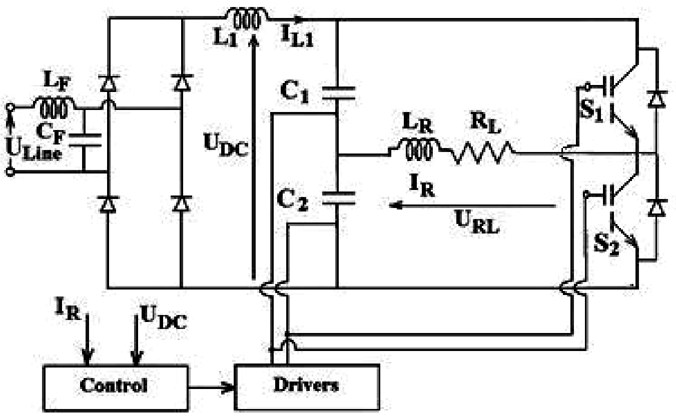


Figure 2: Equivalent circuit diagram for Modified Half Bridge Inverter system for one heating zone

The logic circuit is designed in such a way that IGBT1 and IGBT2 are not turned ON at the same time to avoid short-circuiting of the DC source. There must be a dead zone of time between the switching modes.

3. Proposed Methodology and Discussion

In high frequency induction heating system the input is the frequency of switches S1 and S2. The output is generated heat. The output is also converted in the range (0-1) and is fed as input to the fuzzy system [14]. The error is the difference between input and output which is calibrated to the range (-5, 5). This is fed to the fuzzy logic controller. The output of the fuzzy logic controller is the frequency which is given to the comparator where the square pulses are generated [15-17]. This square wave is used to activate the switch S1. S1 and S2 are connected are taken in consideration so that either S1 or S2 will be turned ON at a time. This is simulated in MATLAB SIMULINK as shown in the fig. 3. The pulses generated are shown in the fig. 4.

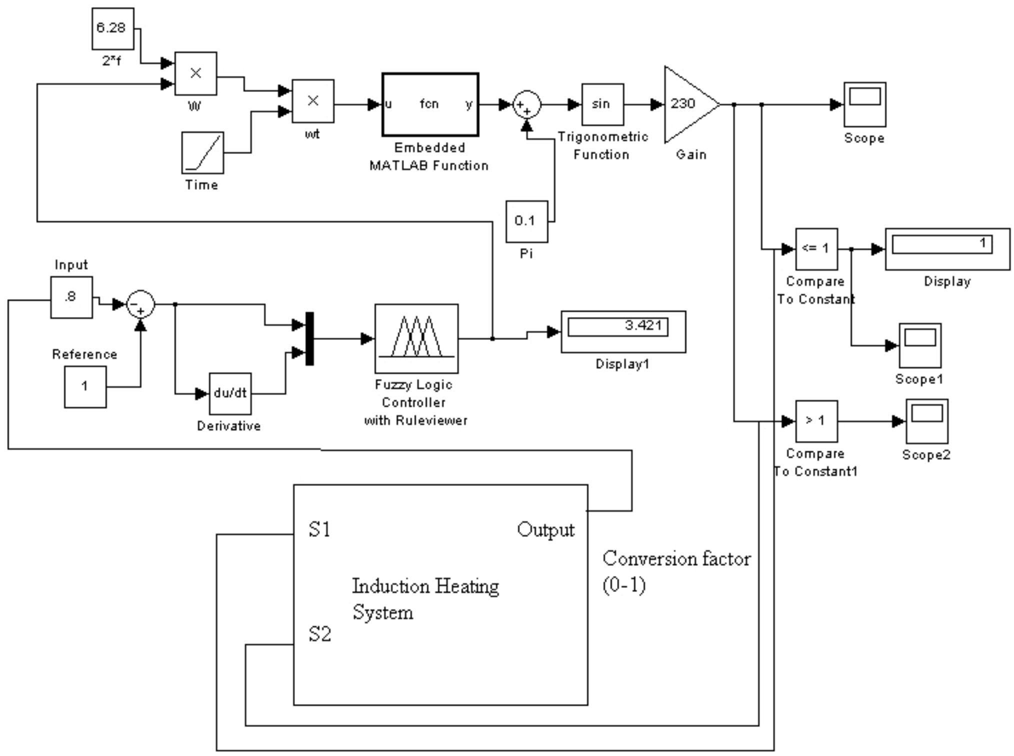
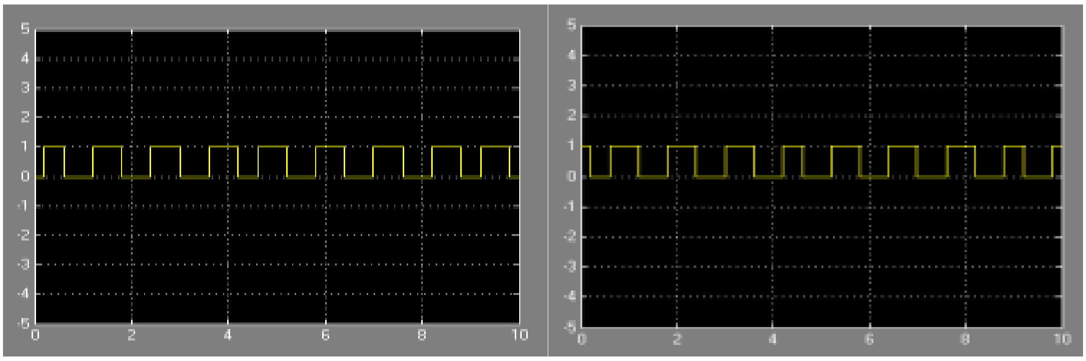


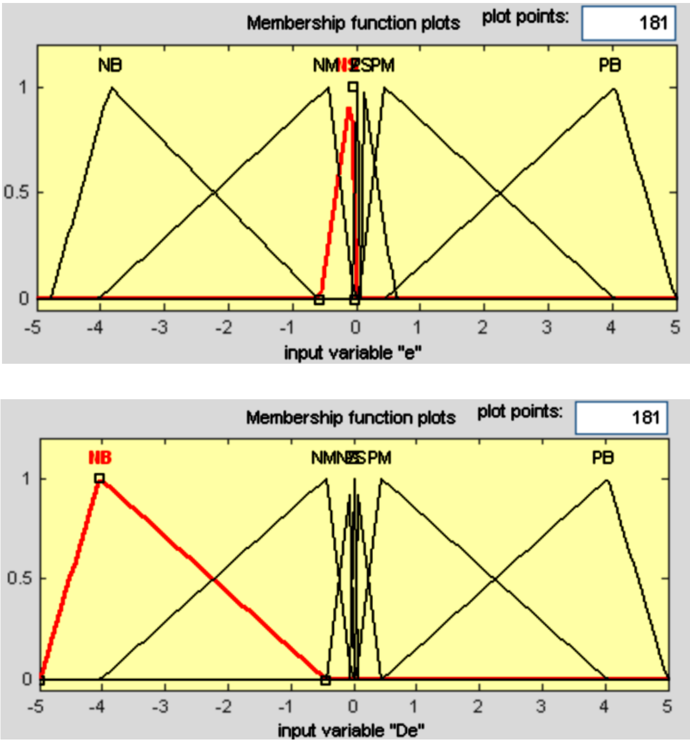
Figure 3: Implementation of Fuzzy Logic to the modified half bridge resonant inverter fed Induction Heating System with MATLAB.



(a) (b)

Figure 4: Square pulses to (a) S1 and (b) S2 for modified half bridge resonant inverter

In fuzzification, error (e) and rate of change of error (de) are used as inputs. The error is divided into various ranges in the range (-5, 5). The ‘e’ and ‘de’ are categorized as NB (Negative Big), NM (Negative Medium), NS (Negative Small), Z (Zero) and PS (Positive Small), PM (Positive Medium) and PB (Positive Big) as depicted in fig. 5.



(a) (b)

Figure 5: Fuzzification of (a) error and (b) rate of change of error for modified half bridge resonant inverter

The defuzzification is also divided in to the ranges PVS (Positive Very Small), PS (Positive Small), PM (Positive Medium), PB (Positive Big) and PVB (Positive Very Big). The defuzzification designed in MATLAB is shown in the fig. 6.

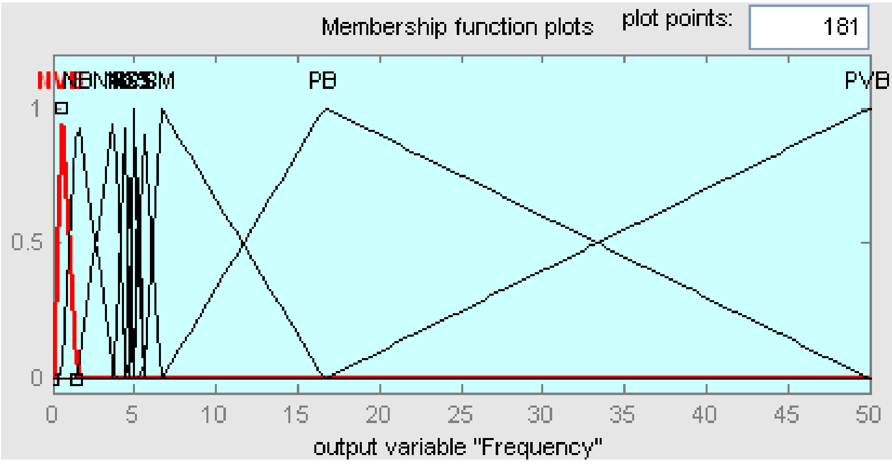


Figure 6: Defuzzification of Frequency for modified half bridge resonant inverter

The rule base which selects the output range for the corresponding input range is shown in the Table 2. For example the first cell indicates that if the 'de' is NB (Negative Big), and 'e' is NB (Negative Big) then the output falls in the range PVB (Positive Very Big). It means that the frequency falls in the range PVB which is from 15 to 50 KHz.

TABLE 1: RULE BASE RELATED TO FUZZY LOGIC SYSTEM FOR MODIFIED HALF BRIDGE RESONANT INVERTER

DE/E	NB	NM	NS	Z	PS	PM	PB
NB	PVB	PVB	PB	PM	PS	PVS	NS
NM	PVB	PB	PM	PS	PVS	NS	NVS
NS	PB	PM	PS	PVS	NS	NVS	NS
Z	PM	PS	PVS	NS	NVS	NS	NM
PS	PS	PVS	NS	NVS	NS	NM	NB
PM	PVS	NS	NVS	NS	NM	NB	NVB
PB	NS	NVS	NS	NM	NB	NVB	NVB

After selecting the range from rule base the defuzzifier identifies the output in this range. The output for every change in error (e) and the rate of change of error is shown in the fig. 7.

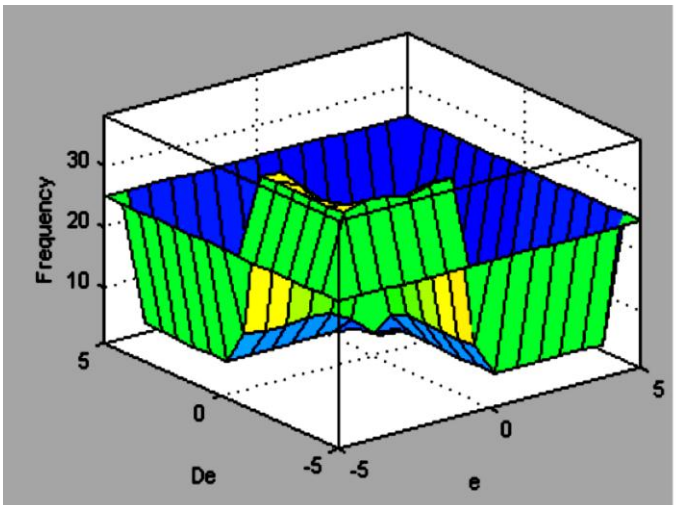


Figure 7: Error, Rate of Error Vs Frequency

4. Analysis of load circuit

The different power semiconductor switches like IGBTs, GTOs, MCTs and MOSFETs etc. are used as power semiconductor switching purposes. The modified half bridge resonant inverter can be used in low power, medium power as well as high power applications [6]. A thermal insulator is placed in between cooking vessel and the heating coil to protect the coil from overheating and it can give support to the vessel. A ferrite disc is often used to improve the coupling but expensive. To obtain maximum coupling, the space between the vessel and the coil should be kept as minimum as possible [8-11]. But at the same time the gap should be large enough for sufficient strength of support, insulation and airflow. The vessel must be made up of material with the product of high resistivity and relative permeability to obtain an acceptable efficiency.

CONCLUSION

The fuzzy logic controller is designed and simulated with MATLAB to get various errors and the rate of change of error. The frequencies are fed to MATLAB embedded function to achieve the square pulses. Then the square pulses are used to the switch at various frequencies of modified half bridge resonant inverter fed heating equipments. However the fuzzy logic controller uses the error and the rate of change of error as input and the frequency is fed as output to maintain required temperature and in order to minimize losses for modified half bridge resonant inverter fed induction heating system. The proposed scheme is simulate to obtained efficiency at different frequencies and it is found the efficiency is maximum at 33 KHz.

ACKNOWLEDGEMENTS

Authors are thankful to the UNIVERSITY GRANTS COMMISSION, Bahadurshah Zafar Marg, New Delhi, India for granting financial support under Major Research Project entitled “Simulation of high-frequency mirror inverter for energy efficient induction heated cooking oven using PSPICE” and also grateful to the Under Secretary and Joint Secretary of UGC, India for their active co-operation.

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