Design and Implementation Of Vienna Rectifier For Induction Heating Appliances Using Dspic

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ABSTRACT- This work describes the main consideration in the design of power converter for a induction heating system with the particular attention to the choice of converter topology, and to study and develop the resonant converter, PID controller and VIENNA rectifier for an induction heating appliances. More number of topologies is available among which half bridge topology is found to be efficient. The approach is based on the closed loop operation in order to improve the efficiency and safe operation of power electronics switches which are used in the circuit, the controller used is dsPIC (digital signal controller) for producing switching pulses to the inverter section, Vienna rectifier and the simulation is obtained using MATLAB/SIMULINK tools.

Keywords- PWM, PID, dsPIC, MPLAB IDE, MATLAB/SIMULINK

I. INTRODUCTION

Induction heating appliances are widely used due to improvement in power electronics devices and digital control system[1]-[5]. It is more desirable due to its to its fastest heating time and efficiency .The principle of operation is based on the generation of a variable magnetic field by means of a planar inductor below a metallic vessel .The main voltage is rectified and after that an inverter provides a medium-frequency current to feed the inductor. The operating frequency of the switch should be higher than 15 KHz and lower than 70 KHz in order to reduces the switching losses and also safe operation of power electronics devices. Several resonant inverter architectures have been applied to domestic heating applications: half bridge, full-bridge, SW-ZVS, SW-ZCS inverter topologies[9].Among them, the half-bridge series resonant converter is the most used topology due to its good balance between the cost and performance[11][12].

The digital signal Peripheral Interface Controller is used for the implementation of the Vienna rectifier and inverter section. dsPIC controller is coded with the help of the software MPLAB to get the PWM pulses which are the input for the converter part. In the closed loop system, the feedback signal is given as the input to the PID controller (Proportional Integral Derivative). PID controller is tuned by using ZIEGLER – NICHOLS method (Z-N). Thus, the PID controller tunes the value and gives a stabilized output. The controller has a separate PWM port, which provides ease of operation. The coding is compiled and debugged and loaded into the controller. Here, dsPIC 30F4011 is compiled using MPLAB software and loaded into hardware using WINPIC 800.

II. BLOCK DIAGRAM

The block diagram of dsPIC based induction heating system is shown in Fig.1. The digital signal controller plays a major role in generation of pulses. The output from the controller is given as input to the IGBT switches.
**Fig.1 dsPIC based induction heating system**

### 2.1 POWER SUPPLY UNIT

The user selects the desired power level through the user interface. Then, the IH cooktop has to perform accurate and smooth power control in order to supply the desired power level to the vessel. The energy conversion block diagram of a dsPIC based induction heating system is shown in Figure 1. First an electromagnetic compatibility filter is included in order to fulfill the EMC regulations. Next, a rectifier and a filter convert the ac mains voltage to a dc bus. Finally, the inverter stage converts the bus voltage into a medium-frequency ac current that flows through the inductor coil heating up the vessel.

### 2.2 dsPIC MICROCONTROLLER

The dsPIC 30F4011 by Microchip is a 16-bit microcontroller with digital signal processing capabilities. This controller runs at a full clock speed of 40MHz. Single clock cycle DSP operations are available which allow for real-time digital filtering and digital control algorithms.

### 2.3 VIENNA RECTIFIER

The Vienna rectifier circuit is the combination of a half bridge rectifier and boost converter[7][8]. The AC supply is rectified using the Diodes. During the positive half cycle the diode D1 is in the ON state and during the negative half cycle the diode D2 is in the ON state. Based on the Duty cycle to the bidirectional switch the boost output is controlled.

### 2.4 HALF BRIDGE INVERTER TOPOLOGY

Several resonant inverter architectures have been applied to domestic induction heating applications: half bridge, full-bridge, SW-ZVS , SW-ZCS inverter topologies[9]. Among them, the half-bridge series resonant converter is the most used topology due to its good balance between the cost and performance[11][12].The most common switch circuit topologies is half-bridge configuration is one of the most common topologies used in power electronics . The topologies is used in various applications such as buck converters, resonant converters, motion control and induction heating and also offers such benefits as zero-voltage switching (ZVS)[11], high efficiency, low EMI and high-frequency operation.

### 2.5 PID CONTROLLER

The system uses the PID controller, which helps in tuning the system. The output of the system is taken as feedback and compared with the reference signal.

The PID controller produces an output signal consisting of three terms, they are:

- Proportional to error signal.
- Proportional to integral of error signal.
- Proportional to derivative of error signal.

The Ziegler – Nichols (Z-N) method is a heuristic method of tuning PID controller. First the integral (I) and derivative (D) is set to zero[10]. And proportional gain (P) is varied until it reaches the ultimate gain or critical gain. This tuning rule (Trial and Error method) is meant to give PID loops best disturbance rejection.

By using this tuning rule the values for $K_p$, $K_i$, and $K_d$ are determined as shown in, TABLE 1.

**TABLE 1: Ziegler – Nichols method Values**

<table>
<thead>
<tr>
<th>CONTROL TYPE</th>
<th>$K_p$</th>
<th>$K_i$</th>
<th>$K_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>VALUE</td>
<td>2.924</td>
<td>3.345</td>
<td>0.0029</td>
</tr>
</tbody>
</table>

**2.5 Closed loop Vienna rectifier – proposed topology**

The Fig 2 shows the closed loop vienna rectifier. A Vienna rectifier circuit is the combination of a half bridge rectifier and boost converter[7][8]. The AC supply is rectified using the Diodes. During the positive the diode $D_{ap}$ is in the ON state and during the negative cycle the diode $D_{an}$ is in the ON state.

PARAMETERS : $L, C_1, C_2$
The ratio of the peak voltage to the peak current in an inductor energized from a sinusoidal source is called the reactance

\[ X_L = \frac{V_p}{I_p} \]

I/P voltage = 24V

The voltage drop across the inductor limited to 10%

Therefore, Input voltage = 2.4V

In order to calculate the \( L_a \) value,

\[ X_L = 2\pi fL \]

\[ L = \frac{X_L}{2\pi f} \]

\[ X_L = 10 \]

\[ f = 50Hz \]

\[ L = \frac{10}{2\pi*20*10^3} \]

\[ L = 31 \text{ mH} \]

In order to calculate for \( C_1, C_2 \)

\[ C_1 = \frac{I_o}{V_c*f} \]

\[ I_o = 2.499 \text{ A} \]

\[ C_1 = 2200*10^{-6}\text{F} \]

\[ C_1 = 2200\mu\text{F} \]

\[ C_2 = \frac{I_o}{V_c*f} \]

\[ I_o = 2.499\text{A} \]

\[ C_2 = 2200*10^{-6}\text{F} \]

\[ C_2 = 2200\mu\text{F} \]

III. SIMULATION RESULTS

In this section, the simulation result of induction heating system using Vienna rectifier, half bridge inverter, PID controller is presented. The output waveform of power for closed loop system and open loop system is shown.

For the closed loop system, the values obtained in PID controller by using the Z-N method are determined. The error signal is compared with reference signal and fed to PID controller, and values are determined. The waveform from relational operator is given as input to the IGBT (INSULATED GATE BIPOLAR TRANSISTOR). IGBT acts as a switch.

The Fig 3 describes the induction heating system model in which the AC supply is provided to rectifier part and the output DC voltage is provided to the inverter section. In which the inverter section is a half bridge inverter circuit that converts dc voltage to ac voltage, because ac voltage is provided to inductor system for quick heating process.

![Simulation model of Induction Heating system](image)

Fig 3: Simulation model of Induction Heating system.

![Input current waveform for induction heating system](image)

Fig 4: Input current waveform for induction heating system.
The input voltage given to the induction heating system is 24V. The Fig 4 shows the input voltage waveform.

Fig 5: Output voltage and current waveform for induction heating system

The above Fig 5 shows the simulation result of output voltage and current waveform for induction heating system. The output voltage and current waveform is found to be 22 V and 2.1 Amps.

Fig 6: Output waveform of open loop system.

The above Fig 6 shows the output power waveform. From the graph the output is found to be 480 Watts. The input voltage provided is 24V and output achieved is 42 Watts.

Fig 7: Simulation model of Induction Heating system (closed loop approach)

The Fig 7 describes the closed loop system for induction heating system is shown in which the AC supply is provided to rectifier part and the output DC voltage is provided to the inverter section. In which the inverter section is a half bridge inverter circuit that converts DC voltage to AC voltage, because AC voltage is provided to inductor system for quick heating process.

Fig 8: Input current waveform for induction heating system
The input voltage given to the induction heating system is 224V. The Fig 4 shows the input voltage waveform.

Fig 9: Simulation result for Vienna rectifier

The Fig 9 shows the Simulation result for Vienna rectifier, since the Vienna rectifier circuit is the combination of a half bridge rectifier and boost converter. The given input voltage 24V get boosted to 65V. Fig 9 shows the output voltage waveform for closed loop Vienna rectifier. From graph the output voltage is inferred to be 65V.

Fig 10: Output voltage and current waveform for induction heating system

The above Fig 10 shows the simulation result of output voltage and current waveform for induction heating system. The output voltage and current waveform is found to be 27 V and 3 Amps

Fig 11: Output waveform of closed loop system.

The above Fig 11 shows the output power waveform. From the graph the output is found to be 71 Watts. The input voltage provided is 24V and output achieved is 71 Watts. Table 2: Specifications for induction system model

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Open Loop Approach</th>
<th>Closed Loop Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>INPUT VOLTAGE</td>
<td>24V</td>
<td>24V</td>
</tr>
<tr>
<td>F&lt;sub&gt;min&lt;/sub&gt;</td>
<td>20 KHz</td>
<td>20 KHz</td>
</tr>
<tr>
<td>F&lt;sub&gt;max&lt;/sub&gt;</td>
<td>50 KHz</td>
<td>50 KHz</td>
</tr>
<tr>
<td>OUTPUT POWER</td>
<td>42 W</td>
<td>72 W</td>
</tr>
<tr>
<td>IGBT SWITCH</td>
<td>FGA25N120AND</td>
<td>FGA25N120AND</td>
</tr>
<tr>
<td>DIODE</td>
<td>6A4</td>
<td>6A4</td>
</tr>
<tr>
<td>PID CONTROLLER</td>
<td>-------</td>
<td>K&lt;sub&gt;p&lt;/sub&gt; = 2.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K&lt;sub&gt;i&lt;/sub&gt; = 3.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K&lt;sub&gt;d&lt;/sub&gt; = 0.0027</td>
</tr>
</tbody>
</table>

The Table 2 shows the specification and parameter values for induction heating system model.

IV. HARDWARE DESCRIPTION

The dsPIC 30F4011 by Microchip is a 16-bit microcontroller with digital signal processing capabilities. This controller runs at a full clock speed of 40MHz. Single clock cycle DSP operations are available which allow for real-time digital filtering and digital control algorithms. The below fig 12. dsPIC development board.

Fig 12: dsPIC development board
The digital signal Peripheral Interface Controller is used for the implementation of the Vienna rectifier and inverter section. dsPIC controller is coded with the help of the software MPLAB to get the PWM pulses which are the input for the converter part. The controller has a separate PWM port, which provides ease of operation. The coding is compiled and debugged and loaded into the controller. Here, dsPIC 30F4011 is compiled using MPLAB software and loaded into hardware using WINPIC 800.

The above Fig 13 shows the closed loop Vienna rectifier. In which it is the combination of a half bridge rectifier and boost converter [7][8]. The AC supply is rectified using the Diodes. During the positive half cycle the diode \( D_1 \) is in the ON state and during the negative half cycle the diode \( D_2 \) is in the ON state. Based on the Duty cycle to the bidirectional switch the boost output is controlled.

The user selects the desired power level through the user interface. Then, the IH cooktop has to perform accurate and smooth power control in order to supply the desired power level to the vessel. The energy conversion block diagram of a dsPIC based induction heating system is shown in Figure 1. First an electromagnetic compatibility filter is included in order to fulfill the EMC regulations. Next, a rectifier and a filter convert the ac mains voltage to a dc bus. Finally, the inverter stage converts the bus voltage into a medium-frequency ac current that flows through the inductor coil heating up the vessel. The above Fig 14 is the prototype model of Induction heating system.

V. CONCLUSION

Thus the analysis for closed loop system is simulated in MATLAB/SIMULINK software tool. From the simulation results, the proposed system using Vienna rectifier and half bridge inverter topology increases the output power and efficiency. The prototype model and simulation block diagram of the induction heating system is discussed and analyzed. In the proposed induction heating system the output power is achieved to 72 Watts and efficiency is also improved.

REFERENCES

[8] Zhang Xianjun, Fan Caihong, et al.,”Research on 3-Phase 4-Wire VIENNA Rectifier Based on One Cycle Control,”2012 Fifth International


