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LOAD IDENTIFICATION AND PROTECTION OF IGBT POWER SWITCH SYSTEMS FOR INDUCTION HEATING

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Abstract- This paper presents Load Identification and IGBT Power switch protection systems for an induction heating. Pulse Load Identification method is shown in this paper. In this, the switching power device IGBT turned off under the absence of the Load and power switch protected from the damage. The work coil and the resonant capacitor of Induction heating system form as an oscillator. The oscillator formed to make a long time damped oscillations. These oscillations used as input to one of the comparators, which determine whether Load present or not. The Presented method is more reliable for low power induction heating applications. The introduced process simulated in the multi-sim environment and validated with experimental results.

Keywords: IGBT power switch, Induction heating, Oscillator, Synchronous signals, MCU and Comparator.

I. Introduction

Utilization of Heat energy is essential for the human beings. Several ways of obtaining this heat energy. The efficient and nonpolluting way of achieving the heat energy is through electrical power. Induction heating is one of the efficient heating's among the conventional electrical heating methods. Induction heating has several applications such as induction cooking, metals heating, annealing, and hardening, etc. Induction heating requires high-frequency AC supply of 20 kHz to 400 kHz. The selection of frequency depends upon the type of application. Nowadays there have been lot developments in semiconductor technologies and converter configurations. It is enabling the use of power semiconductor devices such as MOSFETs and IGBTs for higher frequency level operations with lower power losses. In induction heating, eddy currents are generated in the load by high-frequency magnetic flux linkage with it based on Faraday's law of electromagnetic induction principle [1]. In the conventional electric heating methods, the heat transferred to the load by conduction or radiation. In induction heating, the temperature is raised directly inside the load due to the eddy currents. The depth of penetration of eddy currents is skin depth (δ) level in the load [2] given as follows

$$\delta = \sqrt{(\rho/\mu\pi f_s)} \qquad (1)$$

Where ρ is electrical resistivity, μ is magnetic permeability of load material, and f_s is the switching frequency of the converter circuit.

Often Quasi-resonant inverter, half-bridge inverter [2], and full-bridge inverter [3], topologies are used in induction heating applications. Out of these, the full-bridge inverter has become the favored topology due to the supply of peak to peak voltage across the load, which is the double that of the source voltage.

II. Topology of Induction Heating

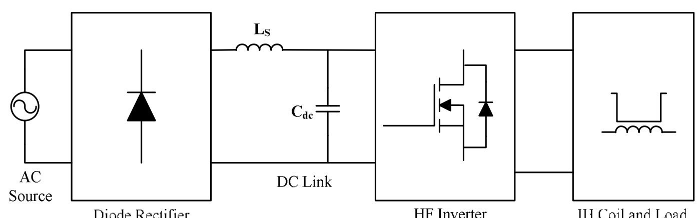

Fig.1. Topology of Induction Heating

Fig.1 shows the Topology of Induction Heating. The utility AC power rectified to a DC by diode bridge rectifier. The output of bridge rectifier DC link connected to the High-Frequency inverter. A high-frequency current of Inverter applied to the work coil. This current generates a high-frequency magnetic flux, which in turn induces eddy currents in the load. These eddy currents directly heat the load.

III. Induction Heating Control Block diagram

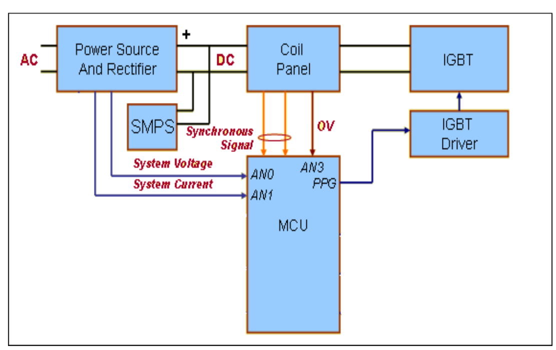

Fig.2. Control block diagram of resonant inverter

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Fig.2 Shows the Control block diagram of resonant inverter. The 8-bit MCU is the central control. It deals with the Analog inputs such as system voltage, system current, over voltage and synchronous signals. The MCU generates the required driving pulses to turn on and off the IGBT power switch. Pulses generated from the MCU amplified by the IGBT driver for proper triggering of the power switch. The SMPS converts the rectified DC voltage into several low voltage DC output supplies. +5V for peripheral circuits as well as the MCU, +12V to the fan for cooling, and +18V for the IGBT driver.

3.1 System Voltage and System Current measurement

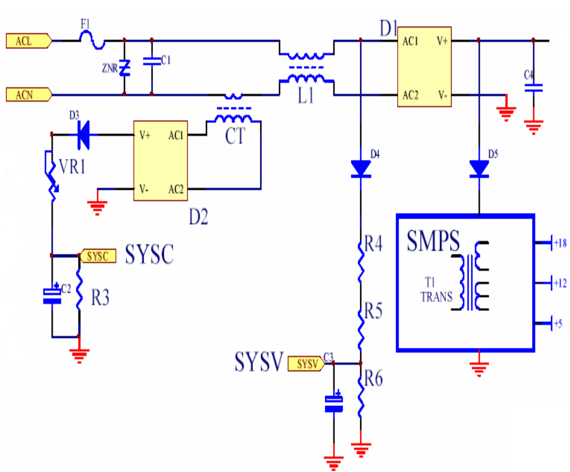

Fig.3 Voltage and Current measurement as the input to MCU.

For safety and protection, system voltage (SYSV), and current (SYSC) measurements made as shown in Fig. 3. These measured values are input to one of the MCU internal Analog to Digital Converters. This data check whether power corresponds to the required amount. The VR1 used to correct the system power.

3.2.1 Synchronous signals and Overvoltage

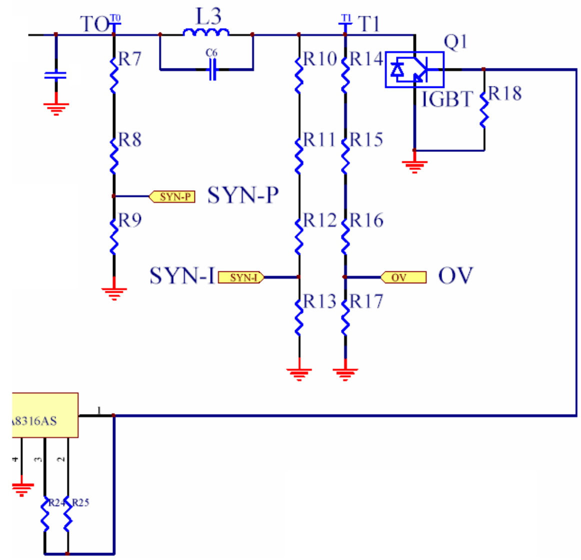

Fig.4. Synchronous signals and Overvoltage Measurement

The Synchronous signals SYN-P, SYN-I, and Overvoltage, is shown in Fig.4. The work coil (L3) and resonant capacitor (C6) forms an oscillator. Its oscillation period is about 40 microseconds. The two synchronous signals alternately change. These signals used in the identification of the load presence. During the Induction heating, there will be the generation of Overvoltage by the IGBT due to its turn on and off repeatedly. This overvoltage might also generate due to the sudden removal of the load during Induction heating. This over voltage measured with an additional potential divider to protect IGBT power switch. Overvoltage signal connected to ADC input (AN3) of MCU. The MCU then turn off the gate pulses to the IGBT. This way IGBT protected from damage due to over voltage.

3.3 LOAD detection circuit

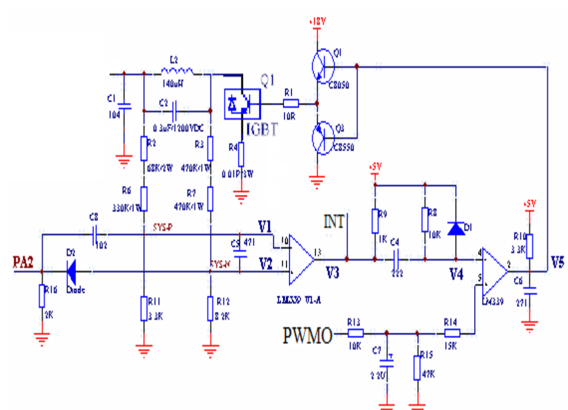

Fig.5. Load detection circuit

The two synchronous signals SYN-P and SYN-I given as V1 and V2 respectively to a comparator as shown in Fig.5. These two signals change alternately, and the comparison outputs pulses as V3. The comparator output pulses fed to the MCU as external interrupt through INT line. In case of load presence, the number of comparator output pulses will be less than that of the number of pulses in the absence of load. With this method, the load presence identified.

IV. Specifications and circuit Parameters

Table 1: Specifications

Component	*Symbol*	*Rating*
AC input	*Vs, f*	*230V, 50Hz*
Rectified Voltage	V_{dc}	310V
Load inductance	L_r	140μH
Resonant Capacitor	C_r	0.3μF
Resonant	F_r	24.56kHz
IGBT	20N120R3	1200V, 20A
MCU	HT45R38	8-bit
Comparator	LM U-A1	LM339

V. Synchronous signals Resultant waveforms

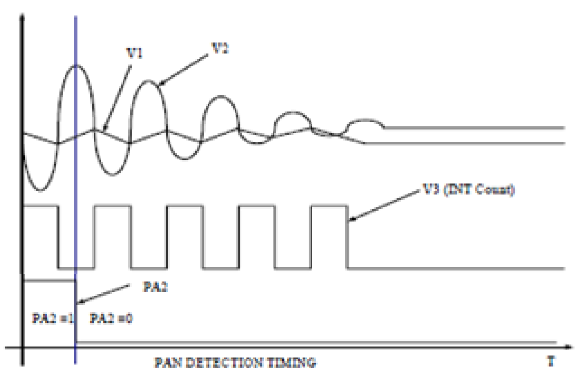

Fig.6. Synchronous signals V1, V2 and Comparator Output pulses V3 under the absence of load.

Fig.6 shows the Synchronous signals which are input to the comparator under no load. These oscillations are a long time damped oscillations. The comparator outputs the pulses as a result. These pulses read by MCU through INT line and counted. Then PA2 set as low, which in turn turns off the IGBT through.

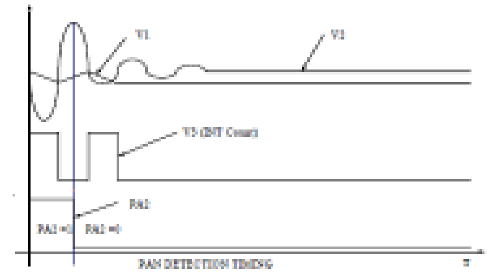

Fig.7. Synchronous signals V1, V2 and Comparator output Pulse V3 under the presence of the load.

Fig.7 shows the Synchronous signals under the presence of the load. The comparator outputs less number of pulses as a result. These pulses read by MCU through INT line and counted. The total count compared with the setup standard, the result of which indicates the presence of the load. Then the PA2 set as High and turns on the IGBT for Heating.

VI. Experimental setup

Fig.8. Experimental setup showing Synchronous signal V2 and comparator output V3 under the presence of the load.

Fig. 8 shows the Synchronous signal V2, which oscillates with decreasing amplitude and comparator output pulses V3 under the presence of the load. Due to the availability of only two-channel oscilloscope just two signals measured at a time.

Fig.7.1. Experimental setup of Circuit with the load Vessel

Conclusion

In this paper, pulse load identification implemented to identify the presence of the load. In the absence of the load, the identification circuit turns off the IGBT power switch by controlling the gate drive through MCU. During the heating of the load, the identification process also carried out for every 4 to 5 seconds. The experimental results of pulse load identification method showed that the power required for load detection is low, detection distance is stable. On the other hand, the identification resolution is high and not affected by input voltage variations. Also, the work coil size and the resonant capacitor do not change identification method. This proves that, the Pulse load identification superior over the load current detection method. This system can be extended to multiple loads detection.

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