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Inrush Current Mitigation using Multi-Level Inverter

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***Abstract*---Induction motor is a major load which consumes the power in a considerable extent when compared to other load in the industries. The power consumed depends on the amount of current consumed by different types of load at a particular time. When an AC motor is energized, a high inrush current occurs. Typically during the initial half cycle the inrush current is often higher than 20 times the normal full load current. When the motor begins to rotate after the first half cycle, the starting current subsides to 4 to 8 times the normal current for several seconds. This large starting current will produce large voltage drop in line which may affect the operation of other devices connected in line.**

The main objective of this paper is to control the inrush current using seven level inverter which helps in producing pure sine wave with a novel pulse width modulation (PWM) control, thus increasing the performance. The pulse generation is essential in order to trigger the switches with appropriate pulse pattern to produce the desired seven level output. The supply to the motor is given through the seven- level inverter. The output produced from the inverter is free of harmonic content. With decrease in the harmonic content the requirement of large rating of capacitors are avoided. The decrease in harmonics also increases the efficiency of the motor, thus increasing the performance.

Keywords: Inrush Current, Seven level Inverter, Hall Effect Transducer, Induction Motor, Phase controlled rectifier

I. INTRODUCTION

Electrical energy requirement is increasing day by day due to the increase in the development of technology. Due to this development apart from the advantages there are also certain problems which greatly affect the devices and finally lead to a great loss. One of them includes the inrush current into a motor when it is first switched on. (or switched on or off suddenly)

This inrush current is an over current which exceeds the normal full load amps of the motor.. It can be in the form of an overload or short circuit. When applied to motor circuits, an overload is any current flowing within the normal circuit path, which is higher than the motors normal full load amps. A short circuit is an over current which greatly exceeds the normal full load current of the circuit. Motors can be damaged by both types of currents.

Many of the electrical advances are focusing on the techniques to reduce the inrush current from entering into the devices.

One of the techniques includes the usage of a seven level inverter. The main aim of this paper is to limit the power consumption by limiting the inrush current using a seven level inverter thus making it to operate effectively according to the condition.

The term “multilevel inverter” was rooted years ago. Multilevel inverters offer various applications in voltage ranging from medium to high such as in renewable sources, industrial drives, blowers fans and conveyors. A small step in

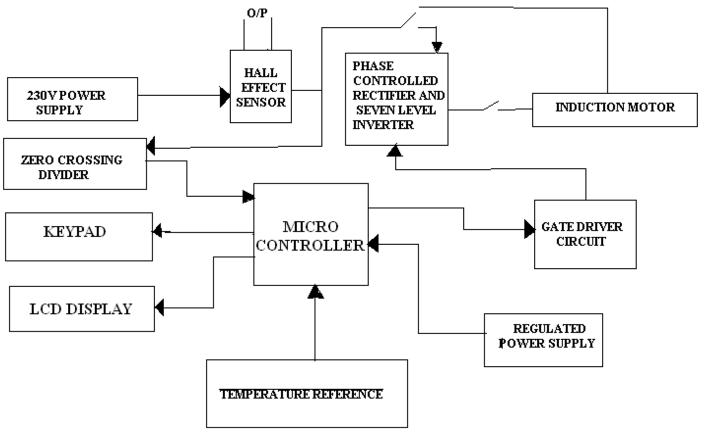

Fig.1 Functional Block diagram

voltage results in making the multilevel inverters withstand better voltage, fewer harmonics, high electromagnetic compatibility, reduced switching losses and high power quality.

II. METHODOLOGY

A. DESCRIPTION

From the Fig.1 multilevel inverter is a conventional seven-level inverter that uses high switching frequency pulse width modulation (PWM). A rated (230V, 50Hz) single phase AC supply is given to the phase controlled rectifier which converts it into DC input. This input is given to the seven-level inverter. As per the function, it produces pure sine wave which is given to the induction motor. But the output of the rectifier is controlled by a microcontroller unit.
The microcontroller is used to produce PWM (pulse width modulation) sequences with references to the temperature which controls the output. In order to drive the phase controlled rectifier and seven -level inverter a gate driver circuit is used.

B. PHASE CONTROLLED RECTIFIER

Phase controlled rectifiers are like AC to DC converters which convert a fixed frequency fixed voltage power supply into a variable DC output voltage. These are extensively used in a number of power electronic based converters.
In most cases they are used to provide an intermediate unregulated dc voltage source which is further processed to obtain a regulated dc or ac output. They have in general been proved to be efficient and robust power stages. However they suffer from a few disadvantages.
The main among them is the inability to control the output dc voltages or current magnitude when the input ac voltage and load parameters remain fixed. They are also unidirectional in the sense that they allow electrical power to flow from the ac side to the dc side only. These two disadvantages are the direct consequences of using power diodes in these converters which can block voltage only in one direction. These two disadvantages are overcome if the diodes are replaced by thyristors. Thus the resulting converters are called fully controlled converters.

C. GATE DRIVER CIRCUIT

A gate driver is actually a power amplifier which accepts a low power input from a controller and produces a high current drive input for a high power transistor. It can be provided either on-chip or as a discrete module.

III. RESULTS AND DISCUSSION

From fig.2 the 230V, 50Hz power supply is given to the phase controlled rectifier which is connected to the seven-level inverter. The gate driver circuit makes the phase controlled rectifier to function by isolating the high voltage and low voltage. A zero crossing detector is used to find the firing angle point (delay) for the phase controlled rectifier. In order to detect the firing angle point the following functions are to be done by the zero crossing detectors:

- Phase and gain adjustment
- Square wave generation
- Unity gain power factor
- Precession of rectifier(by processing the above functions)

The phase controlled rectifier converts AC to DC with the help of its diode present in the setup. The other elements such as the microcontroller, keypad and LCD are initialized. The seven-level inverter gets its supply from the gate driver circuit. It increases the voltage and step by step and gives to the induction motor. Due to this a step by step increase in voltage, the motor starts to function slowly when its rated voltage is reached. Thus this process controls the inrush current of the induction motor. A Hall Effect sensor is also connected between the induction motor and seven level inverter. It measures the variation of inrush current when the seven-level inverter is connected and not connected.

A constant current is required to maintain the power consumed in an average value. Once the temperature is reached the inrush current is maintained constant. Thus next the Seven Level Inverter produces a pure sine wave. This wave thus produced free of harmonics. Thus the performance of the system is improved.

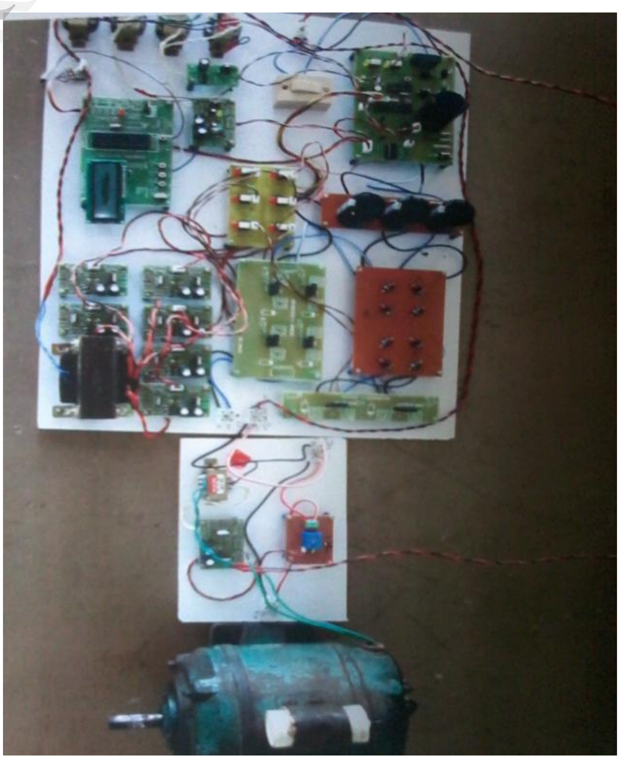

Fig.2 Experimental Setup

Fig.3 Without Seven Level Inverter

From fig.3 the Seven Level Inverter not available between the motor and phase controlled rectifier. In this stage the sensor measure the Inrush current within 20ms, 2.0 V after switching on the power supply. The Width of inrush current wave shape per half cycle: 60ms. The Digital CRO captures this waveform.

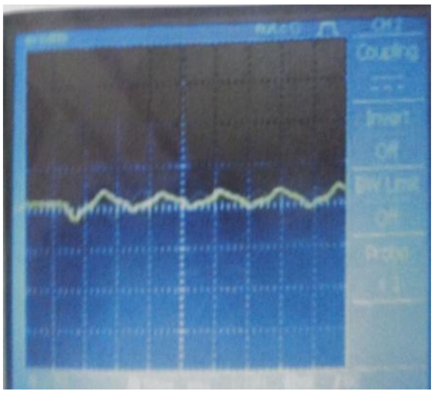

Fig.4 With Seven Level Inverter

From fig.4 the Seven Level Inverter connected between the motor and phase controlled rectifier. With this arrangement the sensor measure the Inrush current. It occur within 15ms, 1.5V after switching on the supply. Width of inrush current wave shape per half cycle: 45ms. The Digital CRO captures this waveform.

CONCLUSION

Due to the sudden increase in load when an induction motor is switched on, the inrush current increases. Thus the power consumption also increases. It is seen from a basic study that before using the seven-level inverter the voltage consumption was about 2 volts of 60ms. But after using the seven-level inverter the voltage consumption decreased to 1.5volts of 45m. It produces pure sine wave which is free of harmonics that is fed to the induction motor. Due to the decrease in harmonics the inrush current is decreased. Thus the power consumption also reduces and the system will be efficient. The features that make this seven level inverter more efficient than the other inverters are:

A. *Staircase waveform quality*

Multilevel inverters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses. Therefore electromagnetic compatibility (EMC) can be reduced.

B. *Common-mode (CM) voltage:*

Multilevel inverters produce smaller CM voltage. Therefore the stress in the bearings of a motor connected to a multilevel motor drive can be reduced.

C. *INPUT Current:*

Multilevel inverters can draw input current with low distortions.

D. *Switching frequency:*

Multilevel converters can operate at both fundamental switching frequency and high switching frequency.

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