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Design and Development of Microcontroller based Auto-Start Three-Phase Induction Motor Protection Unit

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Abstract

Three-phase Induction motor is the workhorse of many Industries and Agricultural purposes. It consumes about 61% of the total power generated. Induction motors in agriculture sector consumes about 21% of power generated and in Industries it consume about 40% and domestic sector about 24% of the total power generated. Even a small fault in induction motor can lead to great loss for industries. The objective of this paper is to present a new methodology for protecting the three-phase induction motor against unbalanced voltage, single phasing and wrong phase sequencing. The designed circuit for protection of motor has a set circuit like 6-pulse three-phase rectifier, relay circuit, bridge rectifier and arduino board. The circuit is completely controlled by a programmed microcontroller which gets the input from six pulse converter circuit. When no fault is detected, the microcontroller sends signal to relay circuit to operate. This relay circuit in turn energizes the main contactor of the motor and hence motor starts operating. This protection system provides complete protection against major faults like unbalanced voltage, wrong phase sequencing and single phasing. The three phase induction motor starts only after checking the healthy condition of the three-phase supply by the auto start unit. In case of any faults, an LED glows to indicate the unhealthy condition and hence motor fails to start. Further in case of any maintenance purpose, the motor can also be operated manually using push button. The system is simulated in proteus software and it is also implemented in hardware.

Keywords: Induction motor; Three phase rectifier; Unbalanced voltage; Phase sequencing; Microcontroller

INTRODUCTION

Three-phase induction motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from magnetic field of the stator winding. Despite the fact that IMs are rugged, they are subjected to unhealthy supply voltages resulting in malfunctioning of the induction motor. The electrically related faults are for ex, Overvoltage, Over-current, Under-voltage, Under-current, Over-load, Excessive rise in temperature etc. The cause for over voltage and over current can be manmade or natural. Possible causes for over-current incorporate short circuits, excessive loads etc. The monitoring of parameters such as voltage, current, speed, load and temperature has also become very important for the health of the induction motor.

In a conventional induction motor when main contactor is energized the NO contacts connected in the series with induction motor closes. This simple set up has a provision to measure the important parameters of three phase supply which are vital for proper functioning of induction motor. The present work is related to incorporating a sensing device to measure these parameters before giving a green signal to the main contactor.

DESIGN PRINCIPLE

In this paper, we have designed a sensing circuit shown in Fig.1 to be incorporated across any two lines of three-phase supply on which the three-phase induction motor is expected to operate. Under normal operation, the main contactor coil gets energized by the manual operation of push button with no considerations regarding unbalanced voltage, phase sequence and single phasing. While in this paper, the manual switching is replaced by an electronic switching which is carried out by the sensing circuit after checking the healthy conditions of three phase supply. The factors influencing the design of sensing circuit is its ability to sense unbalanced voltage, wrong phase sequence and single phasing.

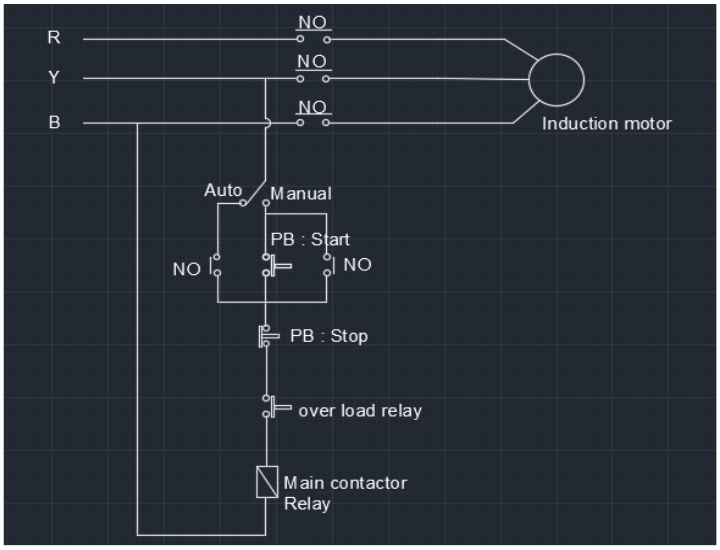

Fig.1. Sensing Circuit

SYSTEM DISCRIPTION

The sub circuits of the designed autostart circuit given in Fig.2 are:

- Resistive circuit for reducing the AC voltage to a suitable low voltage.
- Six pulse three phase rectifier.
- Arduino board with Atmega 328p microcontroller.
- Relay circuit.
- Circuit for generating auxiliary 24v DC supply for relay and 5v DC for microcontroller.

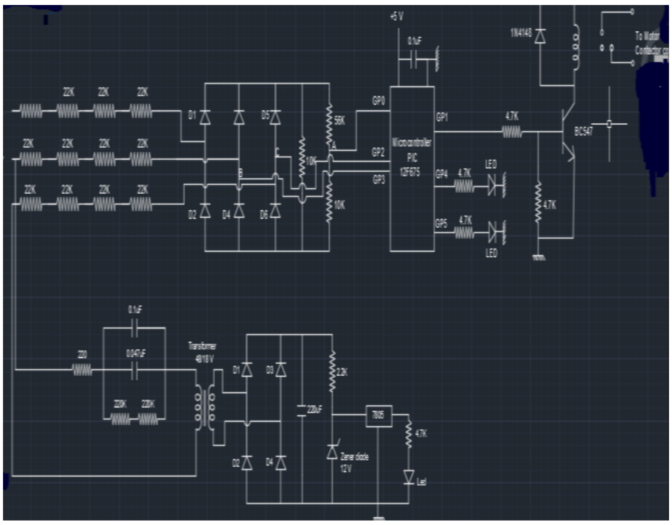

Fig.2. Autostart Circuit

The resistive circuit comprises of 4 numbers of 22 kilo ohm carbon resistor connected in series in each phase. The series connection is to ensure that resistor circuit withstand heavy voltage.

The three phase rectifier comprises of 6 numbers of IN4007 (diodes). It is designed to sense unbalanced voltage, wrong phase sequence and single phasing of the supply voltage given to induction motor.

Arduino board which is an open source electronic platform based on easy to use both software and hardware. In our project we are using arduino Uno which is a microcontroller board based on the ATMEGA 328P datasheet. It consists of 14 digital input/output pins, among which 6 pins are used as PWM outputs and other 6 pins are used as analog inputs. It also consists of 16MHz quartz crystal, a USB connection, a power jack, an ICSP header and the reset button.

The relay circuit comprises of an electromechanical relay, a resistive network and a transistor. A transistor will act as a closed switch under healthy conditions and open switch under unhealthy conditions.

Power supply circuit comprises of a high voltage capacitor, Transformer, Bridge rectifier, Zener diode, Regulator and a filter capacitor. The high voltage capacitor is used deliberately for dropping the supply voltage to a considerable level with a resulting reduction in the size of transformer.

The complete circuit diagram of autostart unit incorporating the various sub circuits explained above is shown in Fig.2.

RESULTS AND DISCUSSIONS

The project work consisting of two parts, namely simulation by proteus software incorporating arduino board is given in Fig.3 and hardware implementation of simulated circuit is given in Fig.4. The results obtained through simulation and hardware implementation are given in this section.

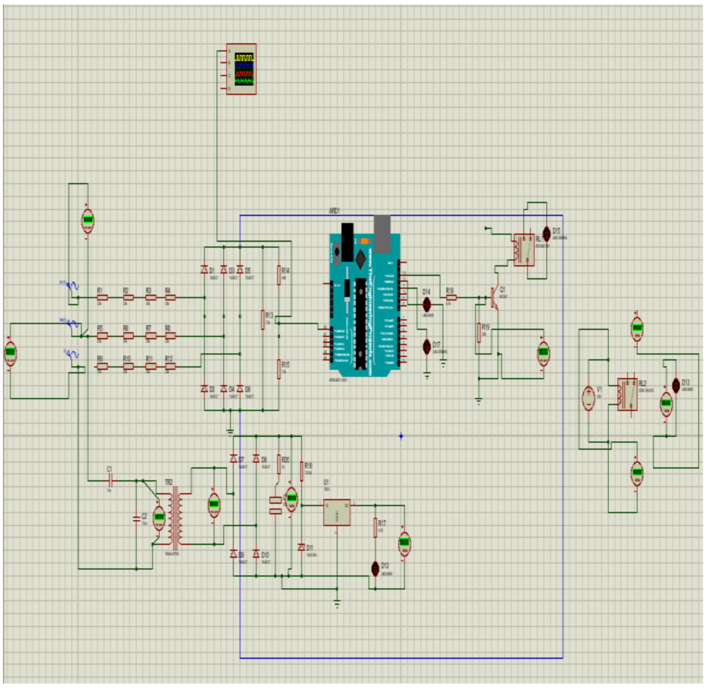

Fig.3. Main circuit in proteus software

Fig.4. Hardware experimentation setup.

A. Results obtained from six pulse three-phase converter

The six pulse three-phase converter is shown in Fig.5 which has been designed to sense unbalanced voltage, wrong phase sequence and single phasing is tested. Waveforms at points A, B and C referring to Fig.5 are recorded. These recorded waveforms are further used as input to the microcontroller for protection.

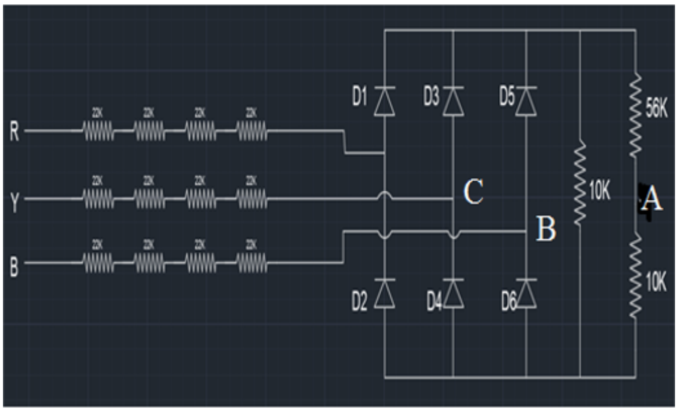

Fig.5. Six pulse three-phase converter

1. Results obtained with balanced supply voltage at point A

Waveforms obtained using proteus software simulation for 3-phase balanced supply of 415 volts at point A is shown in Fig.6. Maximum and minimum voltages obtained after rectification are 4.6 and 3.9 volts respectively.

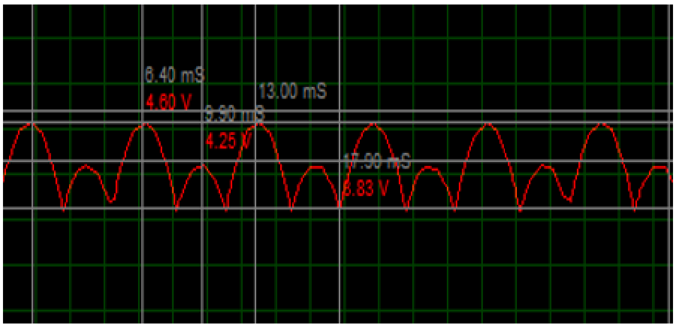

Fig.6. Waveform at point A

Waveforms obtained at points A, B and C of hardware experimentation referred to Fig.5 under balanced voltage supply is shown in Fig.7. Supply voltage of 400 volts is rectified to nearly 5 volts DC at point A of six pulse three-phase rectifier. A continuous analog waveform with maximum voltage approximately equal to 4.5 volts and minimum voltage equal to 4 volts is obtained.

The results obtained at point A of six pulse three-phase converter for both simulation and hardware is approximately equal referring to figures Fig. 6 and Fig.7 for a balanced power supply of 415 volts AC with phase sequence of RYB in anticlockwise direction.

2. Results obtained with balanced supply voltages at point B and C

Voltage waveforms obtained by simulation using proteus software are shown in Fig.8 at the intersection of the diodes D3, D4 and D5, D6 referred to six pulse three-phase converter, Fig 5.

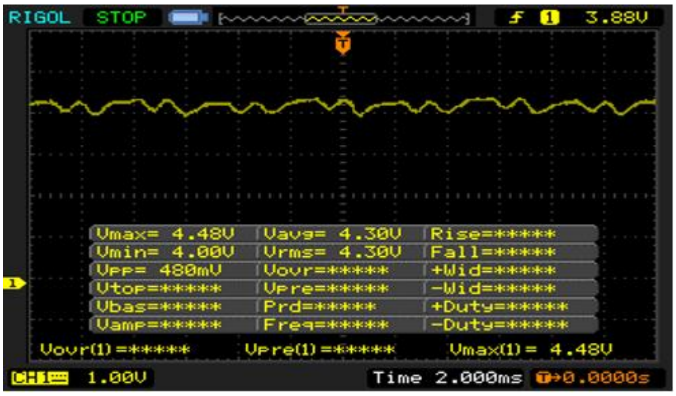

Fig.7. Waveform at point A

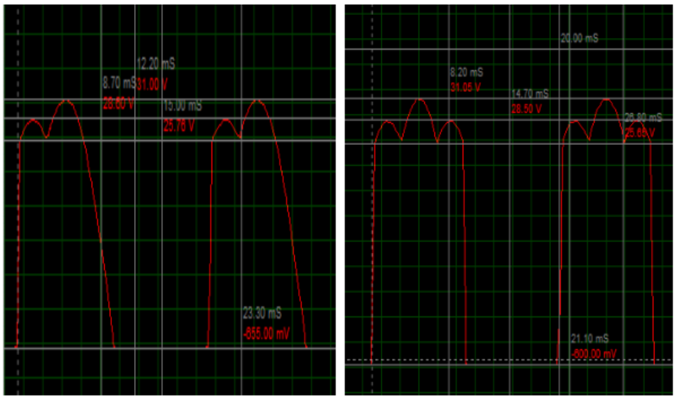

Fig.8. Waveforms at point B and C

Waveforms obtained during experiment on hardware at points B and C are analyzed and are used to sense the phase sequence of the three-phase power supply. Under healthy conditions, the waveforms obtained at points B and C are shown in Fig.9 where CH2 indicates Y phase and CH1 indicates B phase. Under correct phase sequence B phase lags Y phase by 120 degrees as shown.

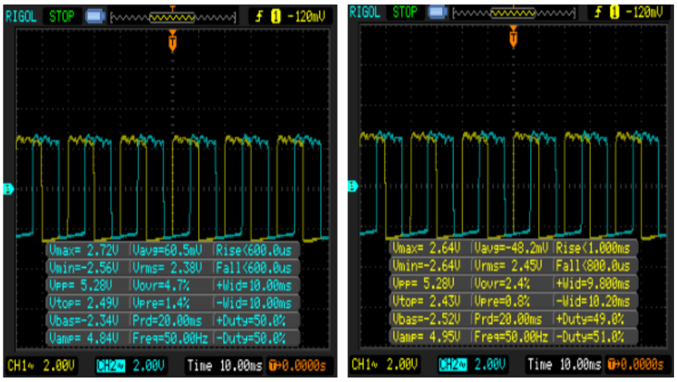

Fig.9. Waveforms at point B and C

3. Results obtained with wrong phase sequence of supply voltage

Waveforms obtained during experiment on hardware model at points B and C are shown in Fig.10 where CH1 indicates Y phase and CH2 indicates B phase. During wrong phase sequencing B phase leads Y phase by 120 degrees. Magnitudes of voltages of both the phases remain almost equal.

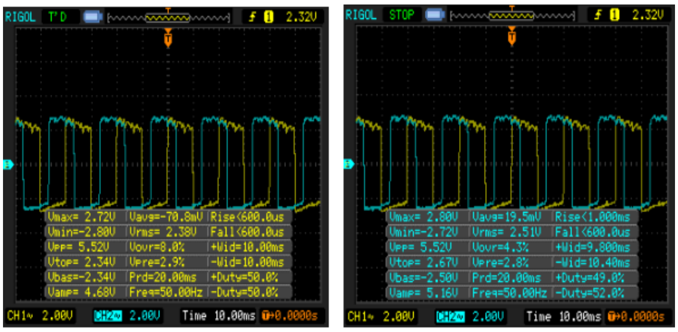

Fig.10. Waveforms at points B and C during wrong phase sequencing

4. Results obtained during single phasing

Waveforms obtained during simulation using proteus software at points B and C using proteus software at six pulse three-phase converter is shown in Fig.11. Minimum voltage dropped to zero at point A during single phasing.

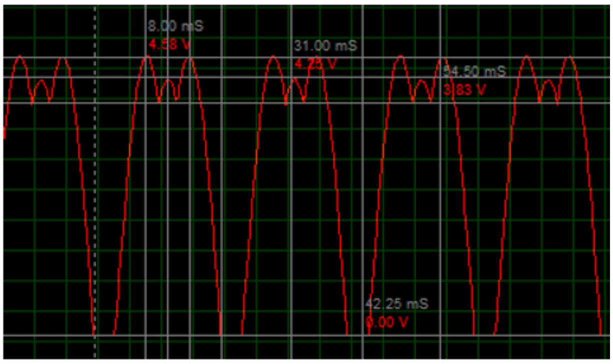

Fig.11. Waveforms at point A

Waveform at point A referred to Fig.5 under single phasing using hardware is shown in Fig.12. Here maximum voltage obtained is about 4.5 volts and minimum voltage obtained is nearly zero volts.

5. Results obtained during unbalanced voltage

Waveform observed during simulation using proteus software at point A for unbalanced supply voltage is shown in Fig.13.

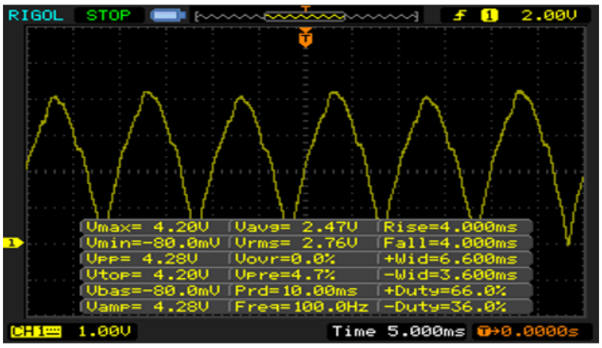

Fig.12. Waveform at point A during single phasing

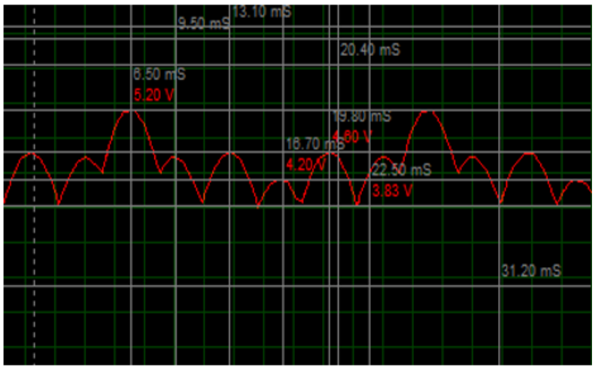

Fig.13. Waveform at point A for unbalanced voltage

Waveforms obtained during hardware experimentation are shown in Fig.14. Unbalanced supply voltage of VRY= 400 V, VYB=345 V and VBR= 355 V was supplied and waveform shown below was observed with maximum voltage was 4.48 volts and minimum voltage of 2.96 volts.

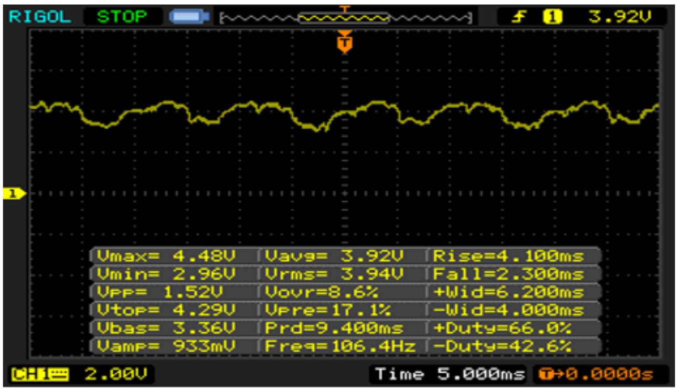

Fig.14. Waveform at point A for unbalanced voltage

The developed prototype provides protection to the induction motor against faults such as unbalanced voltage, single phasing and wrong phase sequencing. Voltages and waveforms at different points during different fault conditions are shown in this paper. Results obtained in this project are for three-phase AC supply.

CONCLUSIONS

In this paper the prototype developed is suitable for developing a marketable product with features such as preventing single phase, wrong phase sequencing and unbalanced voltage operation of three-phase induction motor. The maximum rms voltage with which the circuit was tested is 415 volts AC line to line supply. The model developed is fairly rugged, cost effective and suitable in actual site.

FUTURE WORK

The prototype designed in this paper could be extended for model involving high tension voltages suitable for HT motors.

Also, it could be extended to test the space sequence of three-phase induction motor. The mismatch between phase sequence of three-phase supply and space sequence of motor be detected and corrected automatically.

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