Fuzzy based Numerical Relay - a Protection Scheme for Three Phase Induction Motor using Arduino Uno

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ABSTRACT:

A three phase AC induction motor is a rotating electric machine that is designed to operate on a three-phase supply and is widely used in industries for pumps, pressing machine, conveyor, Flour mills compressor and other low mechanical power applications. A three-phase induction motor is subjected to many faults such as Thermal Overloading, bearing fault, Stator winding related faults etc. Numerical Relays are used to overcome those faults. Thermal and current related faults are recovered by connecting current and temperature sensor to sense the overcurrent and temperature (heating) in the motor which are then processed by the microcontroller to provide control signal to the relay unit when the value exceeds a pre-set limit. The same is validated using MATLAB 2020.The results of software and hardware fall in adequate agreement.

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I. INTRODUCTION

A three phase AC induction motor is a special type of motor having its own typical characteristics and performance in terms of starting, speed control, protection and so on. These motors are self-starting so capacitors, centrifugal switch or another starting device are not needed. These three-phase induction motor consists of stator and rotor. The stator is a stationary part of the motor and it is made up of stampings with slots to carry three phase windings. It is wound for a distinct number of poles. The rotor is the rotating part of the motor. The principle of three phase induction motor is Faraday's law of electromagnetic Induction. Numerical relays with various microprocessor is used to protect the induction motor during the occurrence of fault. With the help of ACS712 Current sensor, we measure a current value and by using MLX90614 Temperature sensor, we measure a temperature in the motor. If current and temperature value exceeds a limit, the relay will stop the motor using a control signal received by Microprocessor.

II. LITERATURE REVIEW

Infrared Thermography is mainly used for Fault detection in static machines such as power transformers, transformers. But, with regard to the rotating electrical machines, its use had become limited which was proposed by D. Lopez-Perez and J.Antonino -Daviu et al. (2016).Inter turn fault detection in Induction motor using infrared thermographic analysis were referred from the concepts proposed by Singh, G.,Kumar,T. C. A.,& Naikan, V. N. A. Digital Signal processing technique based current monitoring are often used for the fault analysis of Induction Motors as administered by Miss Mugdha P. Kulkarni et al. (2013). These are often implemented and verified using floating point DSP controller. Fault diagnosis for induction machines using efficient digital signal processing techniques proposed by Kia, S.H., Henao, H., &Capolino,G.A., in the Workshop on Electrical Machines Design, Control and Diagnosis (WEMDCD) (IEEE. March 2013). The paper published by Yogesh Mandekar, et al, includes a protection scheme for three phase induction motors against single-phasing faults. A simulation circuit using Matlab /simulink was proposed (Gunapriya, B., et al, 2020) which was used to determine the impact of single-phasing on any three-phase induction motor. The hardware part of this circuit is completely controlled by using the microcontroller that monitors all the voltages of three phases. As proposed by Anjali P. Wadekar, et al (2017), principal component analysis (PCA) technique was used to analyse the stator current data obtained from the healthy and faulty three phase induction motors. Principal Component Analysis may be a non-parametric statistical procedure which is used to reduce the number of original variables, which are correlated. A fuzzy logic approach can also be used to diagnose and reduce the induction motor faults. The paper proposed by Mahadev Kokare, et al, explains how the fuzzy logic is used to analyse, compare & diagnose health condition of induction motor under stator faults. Fault detection of induction motors is to avoid operation of the machine in unsafe condition and to reduce unexpected failures and downtimes which is done by using fuzzy logic. Detection of stator winding fault in induction motor using fuzzy logic, Applied Soft Computing, these Techniques were referred from the paper 1112-1120.IEEE, (2008)published by Rodríguez, P. V. J.,& Arkkio, A. Protection and analysis of 3 phase Induction Motor Using Numerical Relay concepts were referred from the paper IJET-Volume 4 Issue 2, Mar-Apr 2018, which was published by Prabakaran,S., &Venkatesan, S. M. Protection of 3 phase Induction Motor Using Numerical Relay concepts were also referred from'3 Phase Induction Motor Protection using Numerical Relay'-paper the International Journal of power electronics,(2017)which was proposed by Gediya, A. B., Modha, H. M., Khant, K. V., Zala, J. B., &Tita, Y. D. As proposed By Ketan P. Diwatelwar, Soniya K. Malode, Fault Detection, protection and Analysis of three-phase induction motors by using MATLAB Simulink model, IRJET, May 2018.Overcurrent protection system for induction motor by using fuzzy logic which was proposed by Nath,P., Das, J., Rohman, A., & Das,T. 'Numerical Relay-Based Protection System For Induction Motor' concepts were referred from the paper proposed by Ms.Bavithra Karunanidhi, Ms.Jeyashree Arthanareeswaran, Mr. Ravikrishna Sivakumar.

III. PROBLEM FORMULATION

A. LOAD TEST:

Load test has been carried out in 3 phase,5.4 H.P,400V 50 Hz,1430 RPM motor modelled as a squirrel cage induction motor. Whenever a fault such as Thermal overloading, Single phasing, bearing effects occurs in an induction motor, it is important to detect the severity of the fault for the efficient relaying operation.

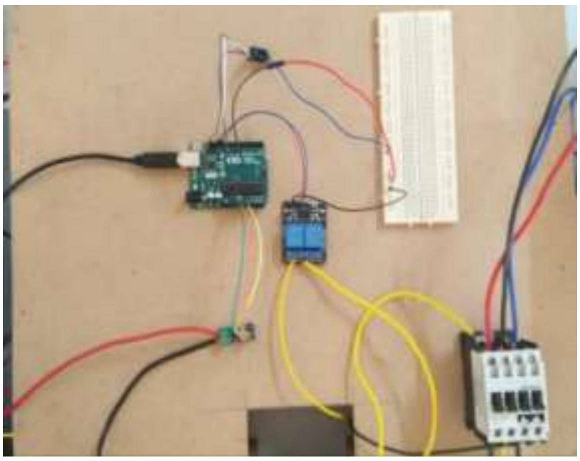

FIGURE 1: RELAY CONTROL CIRCUIT

B. RELAY

A relay is an electrically operated or electromechanical switch composed of an electromagnet, an armature, a spring and a set of electrical contacts. The electromagnetic switch is operated by a small electric current that turns a larger current on or off by eitherreleasing or retracting the armature contact, thereby cutting or completing the circuit. Relays are necessary when there must be electrical isolation between controlled and control circuits, or when multiple circuits need to be controlled by a single signal.

C.ARDUINO**:**

FIGURE 2: ARDUINO UNO

The Arduino Uno is a single board microcontroller based on the ATmega328. It consists of 14 digital input/output pins (6 can be used as PWM outputs), 6 analog inputs, a 16MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. To power up the Arduino connect it to a computer with a USB cable or with an AC-to-DC adapter. The Arduino can be programmed using Arduino software which is available as an open-source file. The reason for going with Arduino is that it is simple and clear programming environment, inexpensive, cross-platform open source and extensible hardware and software.

D. ACS712 CURRENT SENSOR

FIGURE 3: ACS712 CURRENT SENSOR

Economical and precise solutions for AC or DC current sensing is done by Allegro™ ACS712. Applications of ACS712 Current sensor includes motor control, load detection and management, switch mode power supplies and overcurrent fault protection. Current applied is flowing through the copper conduction path that generates a magnetic field in which the Hall IC converts into a proportional voltage.

E. MLX90614TEMPERATURE SENSOR

FIGURE 4: MLX90614 TEMPERATURE SENSOR

For noncontact temperature measurements MLX90614 is used. To process the output of IR sensor, thermopile detector and a signal conditioning unit are used.

IV. FLOW CHART

Figure 5 shows the flow chart of our overall project hardware setup. In this, we are using temperature and current sensor to measure the temperature and current value and these data is processed by Arduino. The control signal from Arduino decides whether to trip the contactor or not

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FIGURE 5: FLOW CHART OF OVERALL HARDWARE SETUP

V. FUZZY LOGIC

Fuzzy Logic (FL) is a type of logic that is similar to human reasoning. FL's approach is modelled after how humans make decisions, which includes all options in between the digital values YES and NO. Today, control systems are typically characterised by mathematical models that follow physical principles, models derived from mathematical logic. One of the most difficult aspects of such a built model is figuring out how to get from a given situation to a proper mathematical model. During the modelling phase, a tolerance margin for an acceptable level of imprecision, ambiguity, and uncertainty can be used to simplify these complicated systems. As a result, it is capable of fixing the problem effectively. In knowledge-based systems, even missing input data has been found to be sufficient. Fuzzy logic reduces complexity by allowing the intelligent use of imprecise knowledge.

A. FUZZIFICATION

Using fuzzy linguistic variables, fuzzy linguistic words, and membership functions, a crisp set of input data is gathered and converted to a fuzzy set. Fuzzification is the term for this process.

B. LINGUISTIC VARIABLE

Linguistic variables are system input or output variables whose values are natural language words or sentences rather than numerical numbers. In most cases, a linguistic variable is deconstructed into a set of linguistic terms.

C.MEMBERSHIP FUNCTION

In the Fuzzification and Defuzzification processes of a FLS, membership functions are employed to transfer non-fuzzy input data to fuzzy linguistic concepts and vice versa. To quantify a linguistic term, a membership function is used. The fact that a numerical value does not have to be fuzzified using only one membership function is a key feature of fuzzy logic.

D. FUZZY RULE

A rule base is built in a FLS to regulate the output variable. An IF-THEN rule having a condition and a conclusion is known as a fuzzy rule.

F. INFERENCE MECHANISM

The inference mechanism uses fuzzy logic to map a given input to an output. It employs all of the previous sections' components, including membership functions, logical operations, and if-then rules. Mamdani and Sugeno are the two most popular forms of inference systems. The methods for determining outputs differ.

G. DEFUZZIFICATION

The total result of the inference stage is a fuzzy value. To produce a final crisp output, this result should be defuzzied. The defuzzifier component of a FLS serves this purpose. The membership function of the output variable is used to defuzzify the data.

VI. MATLAB

MATLAB is used for the modeling of numerical relay for the protection of induction motors. The short circuit faults such as LG, LL, LLG, LLL faults are created. Then the fault current at the end point is tabulated.

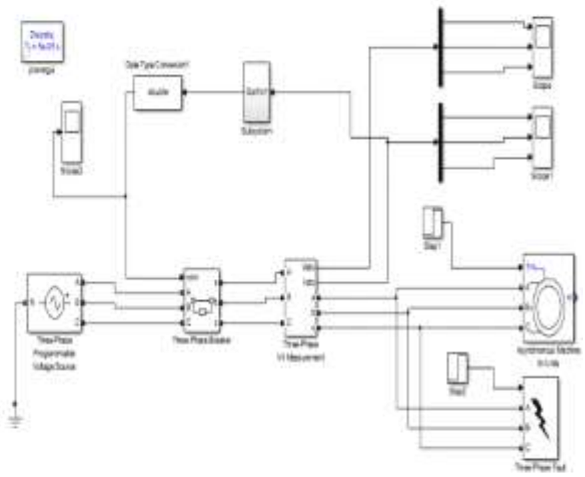

FIGURE 6: MATLAB SIMULATION CIRCUITDIAGRAM OF OVERCURRENT RELAY

In the above figure 6, voltage magnitude and operating frequency is given in the three-phase programmable voltage source block. Closing and opening times of a three-phase circuit breaker is controlled either by Simulink signal given externally or from control timer internally. VI measurement block gives voltage and current values. Three phase fault block is used to create fault in the three-phase induction motor.

VII. TRIP LOGIC CIRCUIT:

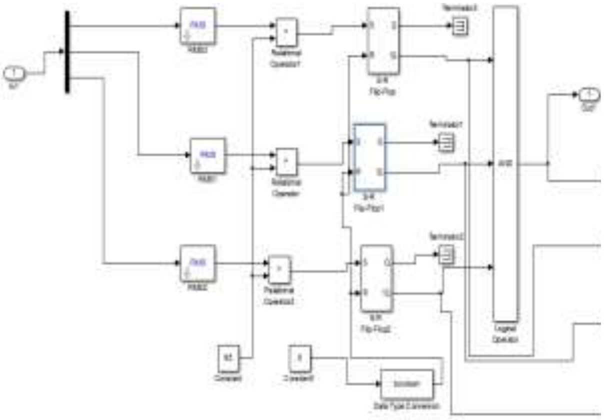

FIGURE 7: MATLAB SIMULATION CIRCUIT DIAGRAM OF TRIP CIRCUIT LOGIC

The above figure 7 shows the simulation of trip logic circuit for the circuit breaker operation.

VIII. RESULTS AND DISCUSSIONS

FIGURE 8: OVERALL HARDWARE SETUP

The figure 8 shows the control circuit to trigger the contactor in case of occurrence of fault in the induction motor which consists of temperature sensor to measure a temperature in the motor and current sensor to measure a current flowing through the motor which are then processed by the Arduino to provide control signal to the relay unit when the value exceeds a pre-set limit. The 230 V relay output signal is then fed to the contactor which will turn on/off the motor with respect to current and temperature value.

By varying load torque, different values of current and speed are obtained and tabulated as below

TABLE 1: CURRENT AND SPEED OUTPUT FOR LOAD TEST

Torque (Nm)	Current(A)	Speed (RPM)
4	2	1490
8	3.7	1481
12	5.1	1471
16	6.6	1462
22	9.8	1450

Initially the current value is about 10A, as soon as the fault occurs, the current shoots about 1000A. The current value is compared with the normal range using the trip circuit model and if it exceeds the limit, it gives trip signal to the circuit breaker. So, when the circuit breaker is turned off, the current and voltage values go to zero.

When current value exceeds the limit, it gives trip signal to the circuit breaker. Trip circuit model uses AND logic and it is built with the comparators and latches, and so trip signal is given to the breaker even if the fault is detected in any one of the phases.

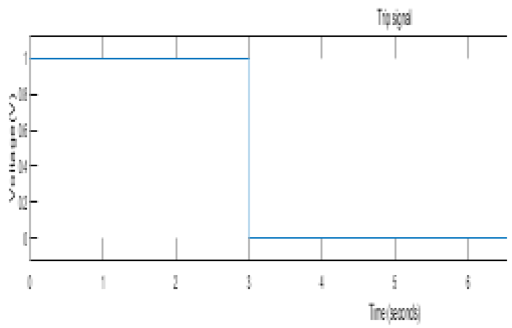

FIGURE 9: WAVEFORM OF TRIP SIGNAL

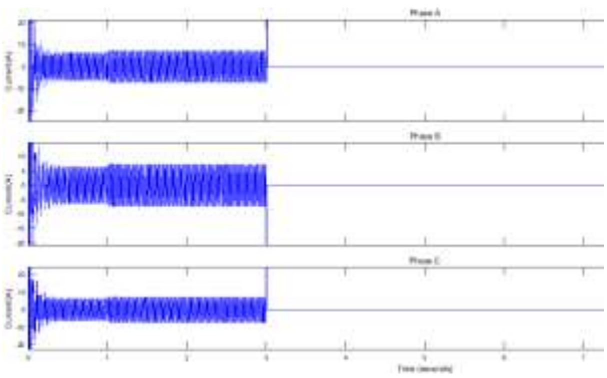

FIGURE 10: OVER-CURRENT RELAYSIMULATION -OUTPUT WAVEFORM

The above figure 9 and 10 shows the observation made from simulation in MATLAB. When the three-phase fault is created in the induction motor, the results are obtained as shown in the above waveform, the trip logic subsystem sends signal to the circuit breaker. The current values go to zero, as the circuit breaker trips.

IX. CONCLUSION

The induction motor is protected from thermal and current related faults using Numerical Relay. By analyzing the magnitude of parameters like current, temperature and time duration, fault occurrence of the system is classified and it take tripping decisions appropriate to the critical care level. The system is realized using MATLAB. This prototype model of microcontroller-based protection system is very simple in design, reliable, highly versatile, and cost effective and gives quick accurate response. Thus, this system ensures the protection of induction motor and thereby prolonging its lifetime.

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