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Numerical Relay-based Protection System for Induction Motor

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***Abstract*—The electric motors are used in various industrial applications. 85 percent of the installed capacity of the industrial driving systems are three phase induction motors, which can be subjected to either internal or external faults or both. So, the protection of these three phase induction motors is necessary for well-grounded operation of loads. Protection relays has evolved from single function electromechanical relays to static relays and finally to numerical or digital relays, which has the advantage of less wiring and panel space. The creation of over-current relay model is done using MATLAB/Simulink software. The faults are created intentionally and the current and voltage waveforms are being observed. The current data from the simulation during normal and fault conditions and the temperature are fed as fuzzifier input. The rule is framed by applying knowledge base and it is incorporated to Mamdani fuzzy logic controller for carrying out fuzzification. The defuzzified output is verified for different values of current and temperature which classifies the severity of the fault. The hardware prototype is made achievable using arduino. Three phase supply is fed to the induction motor via relay and sensors. Sensor data's are read using arduino and the data's are analyzed using fuzzy logic incorporated in controller and the control signal is fed to the relay based on the severity of fault.**

***Index Terms*— Fuzzy Logic Controller, MATLAB, Electromagnetic Relay.**

I. INTRODUCTION

Induction motors are referred to as asynchronous motor because they are operated at a speed less than their synchronous speed. Induction motors works on the principle of faraday's law of electromagnetic in induction where electro-magnetic field is induced in the rotor when rotating magnetic field of stator cuts the stationary rotor. The types of induction motor can be classified whether they are single phase or three phase motor. The single-phase motor is not self-starting while three phase motor is self-starting without capacitors. The induction motors are vital components in industry even though, they are subjected to several faults such as Thermal overloading, Mechanical overloading, Bearing faults Stator related faults etc. Infrared thermography seems a very interesting option taking into consideration that most of the motor faults usually lead to temperature rises that may be detected via infrared data analysis. In this context, infrared thermography has recently shown potential for the motor fault detection. It is made possible by the data obtained to detect the presence of faults. These data were very useful to complement the diagnosis provided by many other tools such as proposed by D.

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Lopez-Perez and J. Antonino - Daviu et al (2016).

Induction motors are used mostly, in all the applications. Many mechanical and electrical faults may occur during the working of the induction motor. Fast and definitive diagnosis of these faults is very important for proper and smooth working of induction motor. Induction motor stator current monitoring is one of the approaches to avoid the damage to the induction motor. DSP technique based current monitoring can also be used for the analysis of fault as carried out by Miss Mugdha P. Kulkarni et al. (2013). The paper published by Yogesh Mandekar, et al, includes a protecting idea for three-phase induction motors against the single-phasing faults. A simulation using MATLAB/SIMULINK software was proposed, which will help to determine the impact of single-phasing on any three phase induction motor. Using which a case study of single-phasing was carried out .In this hardware circuit is completely controlled by the microcontroller and it monitors the voltages of all the three phases. If, the voltage goes past the limit then the motor is turned off by switching. With the current transformer, the current is sensed and it sends the signal to the microcontroller to stop the motor, if the current value exceeds a limit.

The stator current data obtained from the healthy and faulty three phase induction motors can be used to develop fault detection methods for motor fault problems, such as bearing and broken-rotor-bar faults. These data collected from induction motors were analysed using principal component analysis (PCA) technique by Anjali P. Wadekar, et al (2017) to obtain principal components of statistical parameters of stator currents. A fuzzy logic approach can also be used to diagnose induction motor faults. The paper proposed by Mahadev Kokare, et al, explains the usage of fuzzy logic to compare, diagnose and analyse the health condition of the induction motors under stator faults. To avoid the operation of the machine in unsafe condition and for reduction of unexpected failures and downtimes, fault detection of induction motor using fuzzy logic is done. The proposed method can be extended to identify as well as analyze the combined fault of an induction motor drive system. With the help of fuzzy-model the premature failures can be minimize. The work done can be extended to hardware implementation by using the fault detection algorithm.

II. PROBLEM FORMULATION

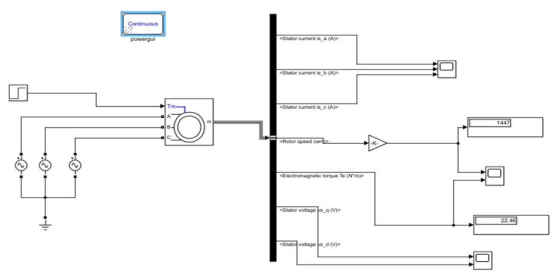

Fig 2.1 MATLAB simulation circuit diagram of load test

In fig.2.1, load test is conducted on the three-phase induction motor by applying various load torques and the corresponding current waveforms and speed and the results were tabulated.

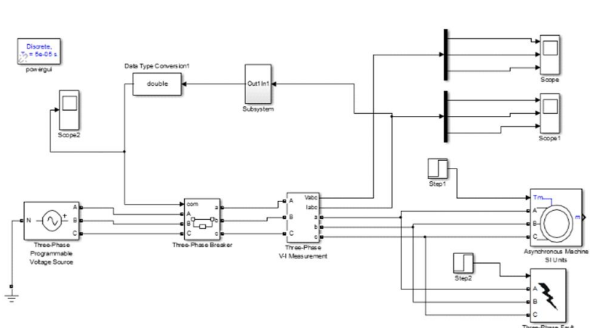

Fig 2.2 MATLAB simulation circuit diagram of over-current realy

In fig 2.2, the fault is created in three phase induction motor using the three-phase fault block. The voltage magnitude and operating frequency is given in three phase programmable voltage source block. The current and voltage values are being measured in VI measurement block. Then the data needed for computation and for plotting the graph, is obtained by using scope block.

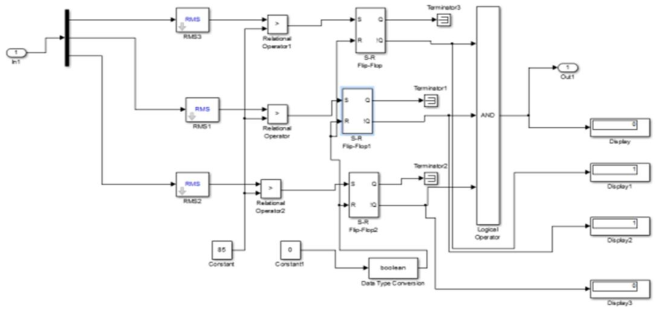

Fig 2.3 MATLAB simulation circuit diagram of trip circuit logic

The fig2.3 shows the trip circuit logic for the circuit breaker operation.

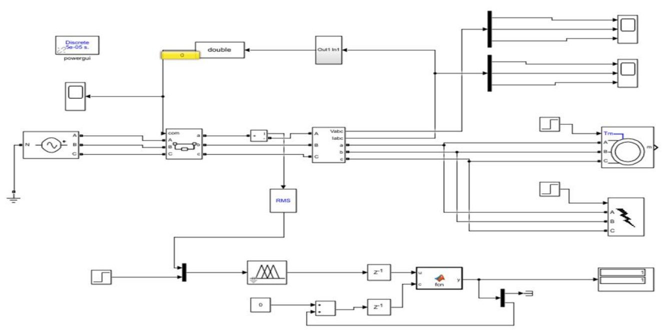

Fig 2.4 MATLAB simulation circuit diagram of over-current relay with fuzzy logic

In fig 2.4, Fuzzy logic controller is incorporated. Constant block is used for temperature input and the current input is taken from the current measurement block. These inputs are given to the fuzzy inference system which then will provide the output in the range of 0 to 1.4. This output is then given through the MATLAB function block to a circuit breaker.

A. Fuzzy logic controller

The Fuzzy logic is a fantastic research area because of its good job of trading off between prediction and significance. The Fuzzy Logic Toolbox used with MATLAB is a tool for solving problems with fuzzy logic.
The Fuzzy logic toolbox is shown in fig 2.5.

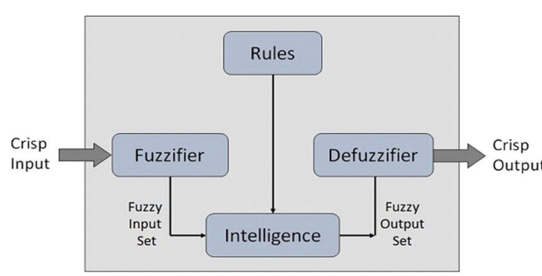

Fig 2.5 Fuzzy logic tool box

III. Results and Discussion

A. Load Test

Load test is carried out for the three-phase induction motor and the different values of current and speed are obtained by varying the load torque.

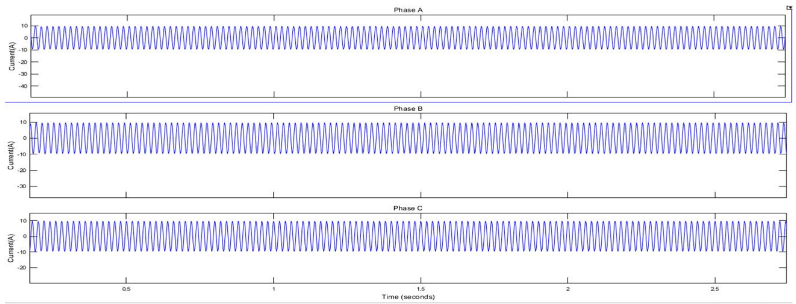

Fig 3.1 Current output waveform of load test simulation

B. Creation of Three-Phase Fault

The three-phase fault is created in the Squirrel-cage Induction Motor using three-phase fault block. Initially the current value is around 10 A, as soon as the fault is created it shoots about 1000A.The value of current before and after the fault is noted in fig 3.2.

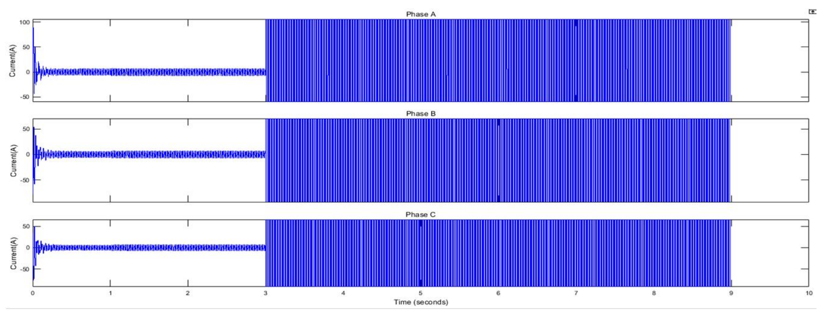

Fig 3.2 Current waveform of Three-phase fault

C. Modeling of Over-Current Relay

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. The trip signal waveform and voltage and current waveform for this model is shown in fig 3.3 and fig 3.4 and fig 3.5

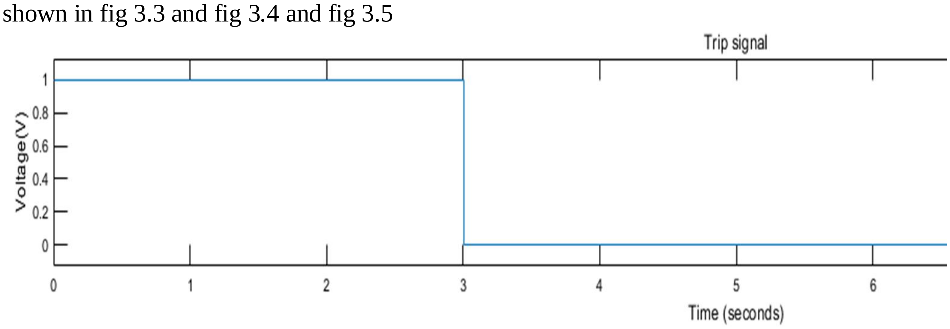

Fig 3.3 Trip signal waveform

TABLE 3.1 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

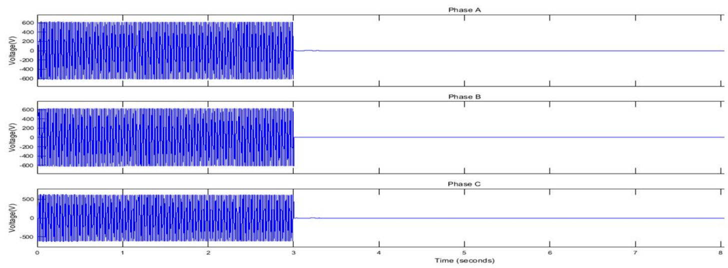

Fig3.4 Voltage output waveform of over-current relay simulation

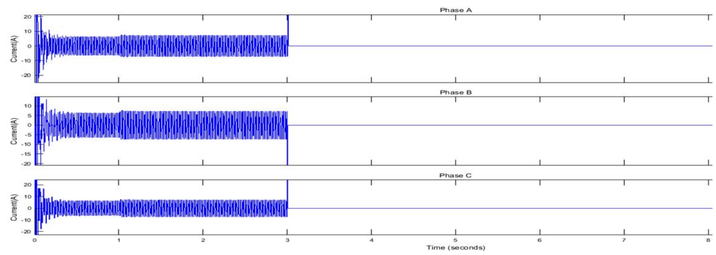

Fig 3.5 Current output waveform of over-current relay simulation

The figures show the observations made from simulation in MATLAB when the three-phase fault is created in the induction motor. When the fault is created at the instant of three seconds, the trip signal from the trip logic subsystem is sent to the circuit breaker as shown in the figure 4.3. So, when the circuit breaker is turned off, the current and voltage values go to zero as shown in figures 3.4 and 3.5.

D. Fuzzy Classifier

The fuzzy logic output variable for fuzzy logic classifier is being shown in Fig 3.6.

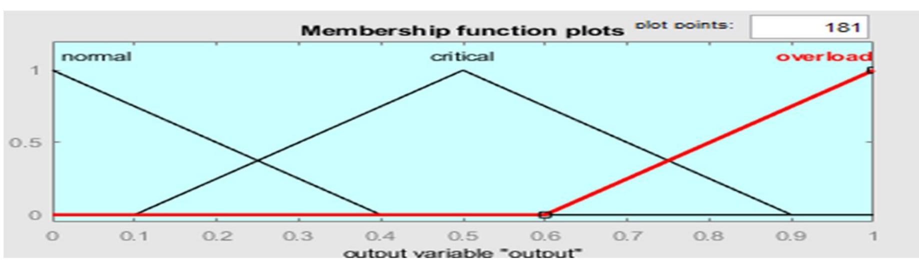

Fig 3.6 Fuzzy classifier waveform

By using the output variable, the fault severity is being determined with the usage of rule viewer. The table 3.2 shows the output values for the severity of fault,

TABLE 3.2 OUTPUT FOR FUZZY CLASSIFIER

Severity of fault	output
Normal	0-0.4
Critical	0.1-0.9
Overload	0.6-1.4

E. Classifier Rules

- If current and temperature is normal then output is normal
- If current is normal and temperature is critical then output is critical
- If current is normal and temperature is overload then output is overload
- If current is critical and temperature is normal then output is critical
- If current and temperature is critical then output is critical

- If current is critical and temperature is overload then output is overload
- If current is overload and temperature is normal then output is overload
- If current is overload and temperature is critical then output is overload
- If current and temperature is overload then output is overload

F. Rule Viewer

The rule viewer displays a roadmap of the whole fuzzy inference process from beginning to end and it is based on fuzzy inference diagram.
In this fuzzy classifier, the severity of fault and its corresponding output is shown in the rule viewer. In the rule viewer shown below, both the current and temperature values are normal, therefore the output is also in the normal range.

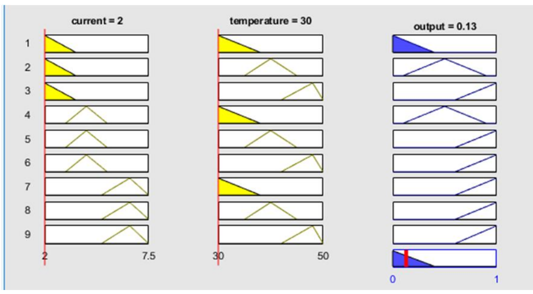

Fig 3.7 Fuzzy classifier rule viewer for normal condition

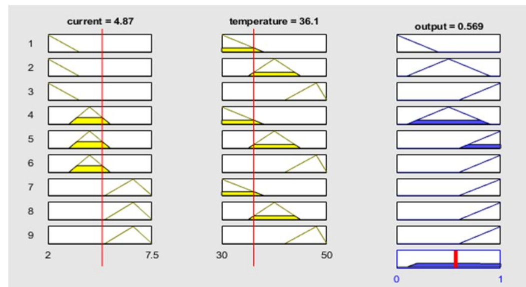

Fig 3.8 Fuzzy classifier rule viewer for critical condition

The fig 3.8 and 3.9 shows the rule viewer when the motor in the critical condition,
The fig 3.9 shows the rule viewer for the overload condition**,**

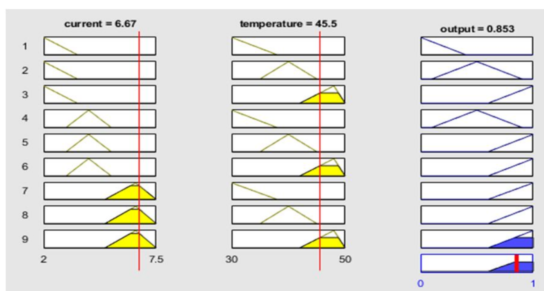

Fig 3.9 Fuzzy classifier Rule viewer for overload condition

G. Observation

The observed values from the rule viewer for the different conditions of current and temperature is tabulated and verified.

TABLE 3.3 OUTPUT FOR RULE VIEWER

Current	Temperature	Output
2	30	0.13
2	40	0.5
2	48	0.87
4.2	31	0.5
4.2	39	0.87
4.2	47.2	0.867
6.52	30.5	0.869
6.52	40	0.87
6.52	47.7	0.87

IV. CONCLUSION

Thus, this paper can protect the motor from thermal and current related faults that may occur in motor. This system can classify the fault occurrence in a scale of criticality, the action is taken by intelligent fuzzy system that solves vagueness in taking tripping decisions appropriate to the critical care level. The system is realized using MATLAB and fuzzy inference system. With help of this numerical relay scheme, better protection can be provided in the industry. This system ensures the protection of induction motor and thereby prolonging its lifetime.

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[11] https://www.youtube.com/watch?v=QoIV8FNjuEA

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