RESEARCH ARTICLE OPEN ACCESS

Analysis of 3 phase Induction Motor Protection Using Numerical Relay

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Abstract:

Induction motors are widely used in industries and house hold applications due to high robustness, reliability, low cost and maintenance, high efficiency and long service life. At present, the concept of SMART system would be implemented in drive applications. Automation of group or individual drive needs monitoring and protection against hazards caused either by electrically or externally. Consequence of that, motor protection is an emerging area of research. This paper presents a combined protection approach for induction motor such as over current, short circuit and single phase fault. The control logic is derived from the equivalent circuit of the motor. MATLAB/SIMULINK software is used to simulate the system behaviour with different conditions and verified experimentally. Simulated and experimental results are discussed and presented.

Keywords – **Induction motor, protection, microcontroller, over current, numerical relay.**

I. INTRODUCTION

Three-phase asynchronous motors are widely preferred over many other motors for the AC motor driven applications due to its robust construction of rotor and ease of control. It is accountable for larger load operations in several applications like goods and lift hoists, conveyors, compressors, pumps, ventilation systems, industrial fan controllers, etc., Induction motors drive accountable for 85 percent of the installed capacity of the industrial driving systems. Therefore, the protection of these motors is necessary for reliable operation of loads. Failure of the motor could be classified as electrical, mechanical and environmental. Overheating resulting in the rotor bearings' wear and tear caused by mechanical stresses draws large amount of currents results in increasing in temperatures.

Controlling an induction motor is difficult due to its strong nonlinear behaviour stemming from magnetic saturation effects and a strong temperature dependency of the electrical motor parameters. Especially, the rotor time constant of induction motors can change in a wide range due to rotor temperature. These factors make mathematical modelling of motor control systems difficult. In real applications, only simplified models are used. The commonly used control methods are voltage/frequency, stator current flux and field oriented controls [1].

Monitoring techniques have concentrated on the use of measurements for detecting stator winding failures, whereas spectral analysis of the stator currents has been employed for sensing rotor faults. The motor current signature analysis for fault detection has received much attention in particular [2]. There has been extensive research on detecting mechanical faults [3] – [7]. Most of the proposed approaches for current based motor condition monitoring ignore the load effects or assume that the load is known. More sophisticated analysis, performed in the time frequency domain, has been reported considering the non-stationary characteristics of the motor current [8] and time scale domain analysis has been attempted for the vibration signature of a machine [9] – [10].

Most of the methods developed for detecting insulation failures are based on the motor currents. To detect stator winding faults, several other techniques have been proposed. Statistical process control techniques have been applied[11], and the detection of stator voltage imbalance and single phasing effects using advanced signal processing techniques have also been presented [12].

The aim of this work focused on numerical relay based protection of three phase induction motor. The protective logic are developed in MATLAB / SIMULINK software version 16a [13], and imported to **PIC16F877** micro controller; thus an embedded protection scheme is proposed and implemented. In section I, different protection of an induction motor and detection of the problems occurring in operation have been discussed, proposed scheme presented in section II, characteristics of motor presented in section III, by using the characteristics set time of the study discussed. Simulation and experimental work presented in section IV, and results are discussed in section V, at the end conclusion of the work described.

II. PROPOSED PROTECTION SCHEME

Figure 1 shows the overall block diagram of the proposed motor protection system. PIC16F877 block stands for PIC16F877 chip, which is developed by Microchip Co. US. Since it adopts RISC (Reduced Instruction224Set Computing) as kernel structure, it behaves more excellent than the average 8-bit single chip. Meanwhile, it is easy to learn and supports ICD (In Circuit Debug).

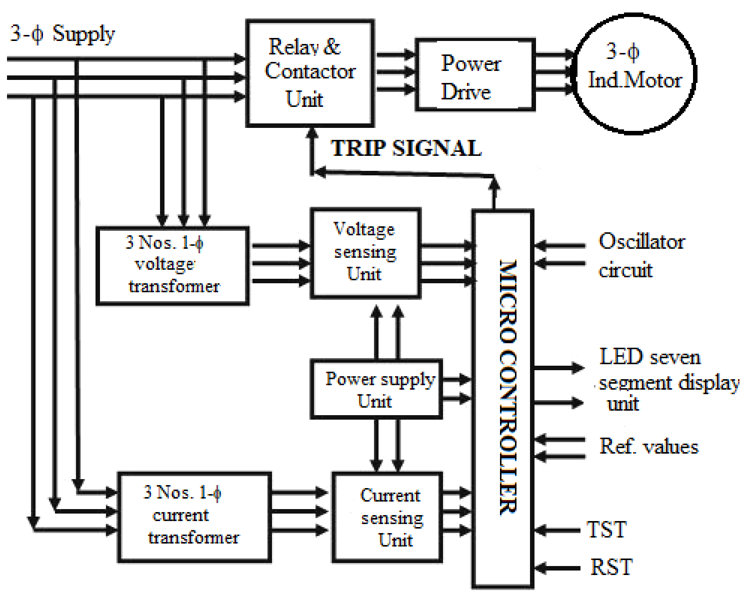

Figure 1 Proposed Protection Scheme of 3-Ø Induction Motor

Voltage and current measuring circuit blocks stand for relative measuring circuits. The measured results are transmitted to corresponding pins of PIC chip through interface circuit such as zero crossing detectors, ADC and relay logic imported to the micro controller, which is designed to interface the measuring circuit and microcontroller.

Protecting circuit block represents the corresponding protecting circuit. Once needed, the microcontroller will output an operating signal, the protecting devices act immediately and correctly to protect the motor, by operating the drive circuit. The keyboard block and display block are also given. User can use keyboard to set the reference values and observe the fault status of the motor through display block.

The setup consists of current transformer, potential transformer, and relay and contactor unit along with PIC microcontroller. Initially, PIC microcontroller is programmed using MPLAB development tool based on the values obtained from fault analysis shown in Table 7.2. Once micro controller is programmed the complete hardware setup is developed as shown in Figure 7.2. The current transformer (CT) and potential transformer (PT) are used for monitoring line current and line voltage under running condition.

The data gathered from current transformer (CT) and potential transformer (PT) are transferred to the micro controller digitally by passing through the current and voltage measuring circuits. The PIC 16F877 microcontroller having in build analogue to digital (ADC) converter. So, no need of external ADC unit. Normally PIC microcontroller A/D converter (ADC) is capable of processing an input, which is less than 5V signal. So, sensors should be selected as per the controller design value.

The needed comparisons are made in micro controller according to limit values, which are previously entered or programmed. When an unexpected situation is encountered, the motor is being stopped by means of the control signal. The reference values of the motor are entered through the keypad and the output values such as load current, type of fault, etc., are displayed using a LED seven segment display unit. The motor parameters like the full load current in amperes, service factor and class of motor, etc., are needed to be entered into the relay programming unit to automatically calculate the correct motor protection curve.

III. CHARACTERISTICS OF MOTOR PROTECTION RELAY

The characteristic of the motor application are shown in Fig.2 WITH the starting current of an induction motor. In the motor application, definite – time and instantaneous elements provide protection for faults in the motor leads and internal faults in the motor itself. A definite time setting of about 6 cycles allows the pickup set to 1.2 to 1.5 times locked rotor current to avoid tipping on the initial inrush current. The instantaneous element can then be set at twice the locked rotor current for fast clearing of high fault currents.

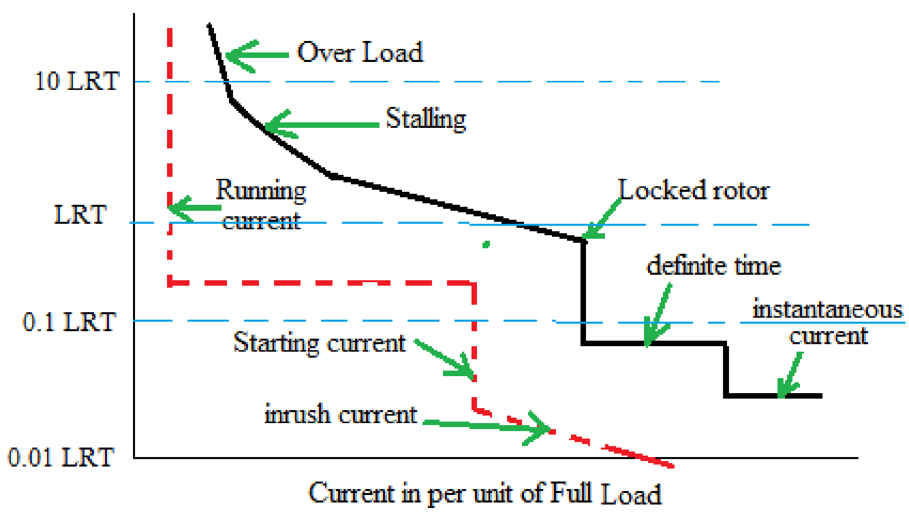

Figure 2 Motor Characteristics

IV. SIMULATION AND EXPERIMENTATION

The proposed scheme tested by simulation and experimentally using the motor parameters as show in Table-1.

Table 1: 3-Ø Induction motor parameters

Description	Specifications
Rating	2.2kW
Voltage	415 V L - L
Current	4.6 A
Frequency	50 Hz
Poles	4
Speed	1440 RPM
Connection	delta
Class type	E

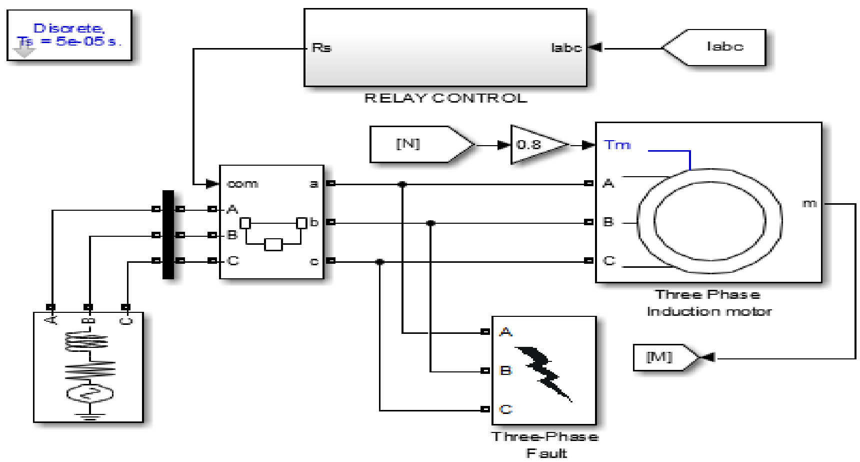

Figure 3 :Three phase fault circuit diagram

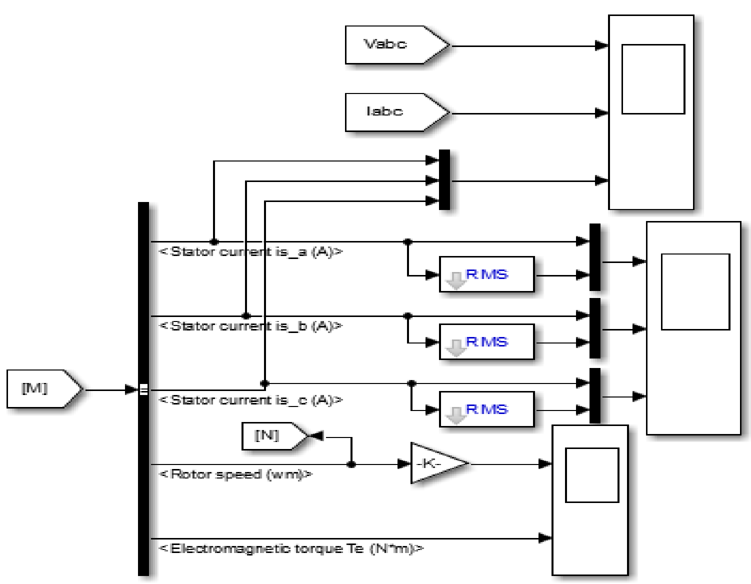

Figure 4 :Fault level simulation method - I

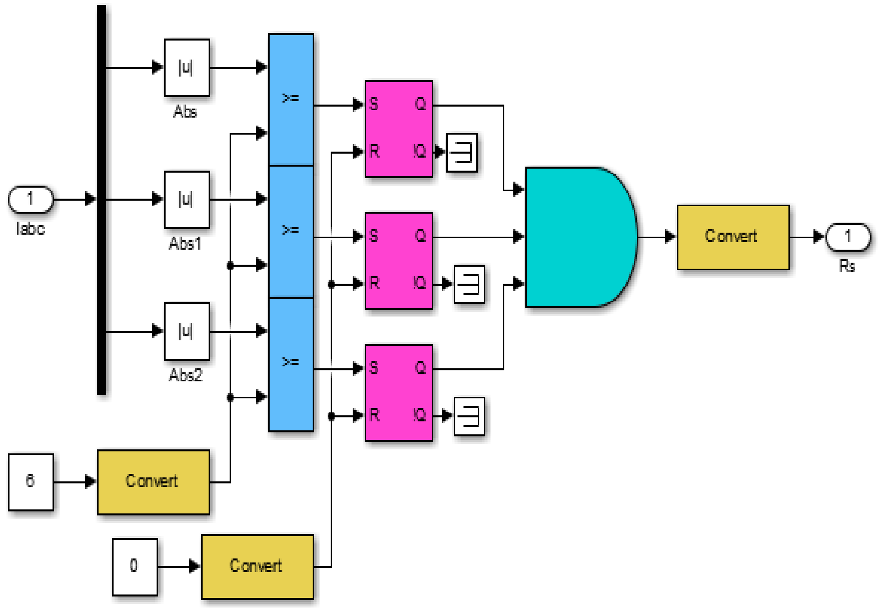

Figure 5: Fault level simulation method -II

SOFTWARE ALGORITHM

The algorithm used for developing embedded programming is given below:

Step 1: Implement the complete microcontroller based integrated protection system.
Step 2: The tolerable value obtained from simulation results are entered as reference values to the microcontroller unit.
Step 3: Start the machine at rated condition.
Step 4: Monitor and read supply voltages V_a,V_b,V_c and linecurrents I_a,I_b,$I_c$through the potential transformer (PT) and current transformer (CT)
Step 5: Measured voltages and currents are digitally passed to microcontroller unit via voltage and current sensing circuits.
Step 6: Comparisons are made between measured values and the reference values (Tolerable Value).
Step 7: If $(\angle A - \angle B = 240^{o})$ then stop the motor and display message as **"Phase reversing (PR)".**Otherwise,
Step 8: If $(|V_a| - |V_b| = |V_c| = 0)$) then generate trip signal to stop the motorand display message as **"Single Phasing (SP)".**Otherwise,
Step 9 If (% of Voltage Unbalance > 5%) then stop the motor and display message as **"Voltage unbalance condition (UB)"**Else,
Step 10: If (% of Current Unbalance > 40%) then stop the motor and display message as **"Current unbalance condition (CU)"**Else,
Step 11: If the mean value ofV_{sa}, $V_{sb}$and V_{sc} is less than 0.8 timesof rated voltage (set value), than trip the motor after aspecified time delay and display message as **"Under Voltages (UV)".**Otherwise,
Step 12: If the mean value of V_{sa}, $V_{sb}$and V_{sc} is more than 1.1 times ofset value, then trip the motor after a time delay and displaymessage as "Over Voltage (OV)"otherwise
Step 13: If the amplitude of IR, IY, IB is ≥ 9 times of set value for time T, then trip the motor and display ever message as **"Instantaneous current (IC)".** Otherwise,
Step 14: If amplitude of I_a, I_b, I_c≥ 7 times of set value for time T, thentrip the motor after a specified time delay and display the error message as **"Locked rotor (LR)".**Otherwise,

Step 15: If amplitude of I_a, I_b, $I_c \geq$ 2.5 times of set value for time T, then trip the motor after specified time delay and display error message as **"Stalling (ST)".**Otherwise,
Step 16: If amplitude of I_a, I_b, $I_c \geq \geq$ 1.5 times of set value for time T, then trip the motor after specified time delay and display error message as **"over current (OC)".**Otherwise,
Step 17: If the phasor sum of I_a, I_b, $I_c \geq >$ 1A, then trip the motor after a specified time delay and display error message as **"Ground Fault (GF)".**Otherwise,
Step 18: Goto step:4.

The above cited algorithms embedded programming for protection system is done using Microchip product MPLAB IDE. The MPLAB IDE is a software program runs on personal computer to provide development environment for embedded microcontroller design. The design cycle for developing an embedded controller application (PIC 16F877).

V. RESULTS

The simulation results of the fault motor and healthy motor are in agreement with the reported results using test set up. Based on the results of this study, the condition monitoring of induction machines is proposed. Table 2, shows the value obtained from electrical fault analysis of induction motor and their permissible value, which is used for hardware implementation of protection system.

Table 2 OBSERVATION FROM FAULT ANALYSIS

Faults	**Tolerable value**	**Permissible value**
Unbalanced supply voltage	1% to 5%	1% to 5%
Current unbalance	Up to 45%	Up to 40%
Over current	2 times rated value	1.5 times rated value
frequency	Up to 50Hz	-----
Single phasing	Motor will run up to 75% of its rated load	Not permitted
Phase reversing	Motor will run in reverse direction	Not permitted
Under voltage	Up to 30%	Up to 20%
Over voltage	Up to 20%	Up to 10%
Ground fault	Up to 2A	Up to 1A

VI. CONCLUSION

This paper has successfully presented a reliable, fast and efficient system for induction motor protection. This system can be implemented in any industries and paper mills where motor protection is an essential requirement. This system will save time, reduce the amount of work of the administrator has to do. Protection of three phase induction motor from over/ under voltage, over current, over speed, temperature, frequency and phase failure provide the smooth running of motor which also improves its lifetime and efficiency. Hence protecting the Induction Motor by various faults. This prototype model of microcontroller based protection system is very simple in design, reliable, highly versatile, and cost effective and gives quick response.

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