Safety Relay Prototype Based on Fuzzy Logic to Protect 3-Phase Induction Motor

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This research aims to create a Prototype Relay to avoid fatal damage for induction motors due to unbalance voltage problem at electrical network, by using a microcontroller "AVR AT Mega 32" type based fuzzy logic. Safety relays that have been made in this research can detect troubles of random form of overvoltage, under voltage, voltage unbalance, voltage missing 1 phase, and the effect of temperature rise on the motors windings (multi trouble), which has not been found on the relays conventionally used in the industry for the only way they detect overvoltage and voltage troubles less alone. The relay is also equipped with key-pads and LCD that serves to reset, set and display all events experienced by the induction motor, as a result of trouble that occurs. Thus 3-phase induction motors will be safe from multiple troubles that occur randomly. Data analysis and laboratory testing simulation results show that the software and hardware of the relay are designed to work and function well (can be secure multi trouble) as expected.
Keywords: Multiple trouble, protection-relay, fuzzy logic, micro-controller, unbalance voltage, one phase missing voltage, 3 phasa induction motor.

1. Introduction

The electric motor is the mechanical energy producing equipment which the most practical, beautiful and efficient. Practical because it is easy to operate, does not require a lot of time to run and shut it down. Beautiful because of the form of construction and do not contaminate the surroundings. Efficient because its use can be run and stopped at any time, so that the electrical energy that is absorbed completely in accordance with actual needs.

The mechanical energy produced by the electric motor can be used as a substitute for human labor to assist the daily work easier and efficient. Thus the quality of the resulting mechanical energy is highly dependent on the quality of electrical energy as an input. If the quality of the electrical energy is being deteriorate, in this case the voltage, so the quality of mechanic energy that is produced could be deteriorated. The unbalance voltage at 3-phase system is seen as electrical energy quality issues which significantly related to the quality of the mechanical energy produced by the electric motor.

Although on the side of the generator and the voltage transmission completely balance, it does not guarantee the pad voltage distribution side as well balance, due impedance unequal system or single phase load distribution that uneven in each phase.

Induction motor single phase or 3-phase plays an important role as a driver of production machines in every industry. In operation, the induction motor is often impaired or abnormal operating conditions, both in the motors andanything that happened in the net system that supplies electric power to the motor. Trouble and abnormal operating conditions that often occur can cause damage to the motors which will eventually reduce the lifespan of the motor and add to the cost of repair.

Generally, the safety system that applied to electricity motors is in only safety against overload and safeguards against short circuits. While one of operating abnormal conditions that usually happened, even virtually continuous ongoing is motor induction operating at an unbalance supply voltage conditions (unbalance voltage).

The effects of supply voltage conditions unbalanced are dependent on the level of voltage unbalance (voltage unbalance rate). Furthermore, due to the imbalance of supply voltage motor then loading cannot be performed at normal load according name plate.

Conditions of the most extreme voltage imbalance occurs when one phase of a 3-phase supply voltage is lost (one phase lose), commonly called the single phasing operation. These conditions will cause more serious damage.

The effects of the electrical energy source voltage conditions and unbalanced load and also temperature conditions were not stable, it should be considered to complete the induction motor with a safety system that detects multi-trouble.

Therefore, the voltage imbalance in the electric power system is always change at any time following the load changes that occur in the network, then it is very difficult to predict the level of harmful voltage unbalance load system. Due to the nonlinearity of processes and model uncertainty are often difficult to describe mathematically, but can only be described as a heuristic [1]. If the algorithm can only use a conventional relay numeric data obtained from expert (human). This means that conventional approaches are only able to use numeric information only, without being able to exploit linguistic information [22]. To be able to take advantage of this linguistic information, it is required a framework of conformity, which is vague and fuzzy set logic introduced by LotfiA.Zadeh [32]

Fuzzy system is a system that directly uses fuzzy concept, which includes the set and cryptic logic, as well as linguistic variables [22]. In the classical set, we know only two possible values for membership, the member with the truth value 1, and not the members with the truth value 0.

The distribution of prices in fuzzy sets have truth value (degree of membership) which continuous between 0 and 1. In the process industry for special circumstances, the relay manual often played a role in controlling the process. A system which is difficult to control automatically usually must be controlled manually. Initial control procedures (stat up) process is an example where human expertises have a role in solving difficult problems automatically. Using a fuzzy concept, the manual operation can be replaced by an algorithm. It is encourage the founding of a smart relay system (smart relay), where the concept of fuzzy plays a fairly important.

System smart relay can be defined as a versatile relay system that is capable of learning to achieve the determined goals. The ability to do an environmental optimization of the operation in a non-linear complexis included as an intelligent control capability. The main characteristic of the smart relay system is its ability to use past experience to repair performance. In this case, a smart relay system capable of emulating a biological system that is capable of dependent controlling its environment of dynamic change.[10,18]

Smart control relays provide a systematic framework for integrating linguistic information. The main advantages of fuzzy system is that the fuzzy system can function as a universal approximator [22,23,24]. Thus, for any form of smart relay system will always be obtained. Another plus is that the system is aimed at smart relay control system which is difficult to define (ill define) and nonlinear, which generally cannot be solved using conventional algorithms. Smart relay algorithms can be added to a conventional system with a view to improve the system performance, in this case the smart relay acts at the level of supervisor.

The approach that has been define above will be developed in research study in order to find the rate of unbalance voltage, temperature influence, the load system influence, so it can be avoid the equipment system from unbalance voltage operation that is not desire.

2. Research Problem

Broadly speaking, the issues examined in this study is how to make the software and hardware prototype to detect the type of trouble that occurs in 3-phase induction motor by using a safety relay based fuzzy logic. Thus the problem in this research are: (1) How to create a prototype software relay safety induction motor 3 phase based logic faint to detect multi trouble (trouble overvoltage, under voltage, voltage unbalance, voltage missing 1 phase, and the effect of temperature) which often occur in industries; (2) How to build a prototype of a safety relay 3-phase induction motor, according to the software principles that has been designed, it uses AVR microcontroller to detect multi-trouble in industry

3. Research Objective

This study aims to: (1) create a prototype software relay safety induction motor 3-phase to detect multi trouble occurring in the industries, (2) build a prototype of the relay induction motor 3-phase according to the principles of software that has been designed, using AVR Microcontroller to detect multi trouble in the industry.

4. Review Of Related Literature And Conceptual Framework

4.1 Three-phase Induction Motor

Three-phase induction motor has a proximity method and principles symptom utilization and physical phenomena with an electric voltage transformer. Proximity resemblance induction motor with the transformer is due to the idea of design development to follow the behavior and properties of an electrical voltage transformer. Models and circuitreplacement of induction motors are almost the same as the model of a transformer (Soe, NN, et al. (2008)) [19] as showed in Figure 4.1 below

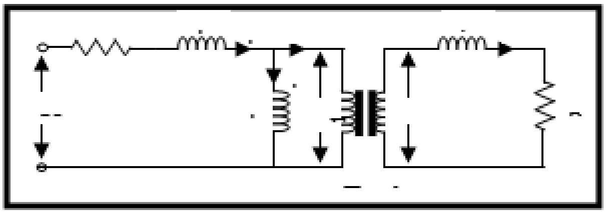


Figure 4.1. Model of elementary series induction motor replacement [19]

Three-phase induction motor is an electric motors are frequently reviewed and described its use since it has a robust construction and relatively simple and with a relatively cheap price. Section contains a number of stator windings that are connected with 3 alternating current flow with phase shift of 120°. These currents generate a magnetic field with a corner frequency equal to the electrical frequency of the stator. Winding or rotor windings (cage rotor) are exposed to a changing magnetic field so that the currents rotor can be induced. Frequency induction currents are equal to the difference between the frequency of mechanical angle and the angular frequency of the stator current slip frequency. Flow-induced current is directed perpendicular to the radial magnetic field so that it can generate Lorentz forces. This model can enlarge the scope of the non-linear effect of making it possible to broaden the basic principle of operation of induction motors. Therefore, this model is also competent for the position and speed control design. 3-phase induction motor has several major components of the primary coil, the coil-aids, capacitors, and bearing a compact and integrated. Another inherent scale, influence and reflect badly on the performance of 3-phase induction motor when be operated includes variables such as load, heat and strains. These variables are shown in the form of a state variable symptom of abnormality when the 3-phase induction motor being operated [5]

4.2. Parameter Analysis Model 3-phase induction motor

The mathematical model can be used to develop the insight and knowledge of the induction motor in order to better understand and explore in detail the nature and characteristics. Although it is very difficult to calculate all parameters with the proper induction motor, but it is a must to decide the value of parameters through estimation when being analyzed.

The good replacement circuit for each phase can be modified to observe and take into account the main losses, friction and losses anchor when the motor in the state was working in operations [9]. Stable operating characteristics (steady state) a 3-phase induction motor is often observed and investigated using a series of substitutes for each-phase [1,7,9] as illustrated by Figure 4.2 below.

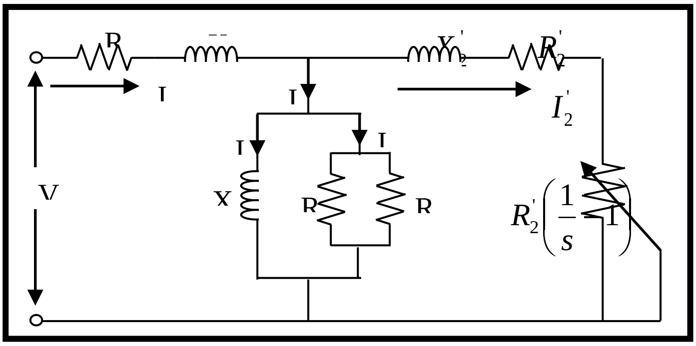


Figure 4.2. Substitute each-phase circuits a three-phase induction motor

At this replacement circuit R_1 and X_1 are listed respectively as prisoners and reactance of the stator winding. While R_2 and X_2 declared resistance and reactance of the stator winding rotor relative. The rest is a core leakage losses that is showed by resistance R_C, and reactance magnetization shown by X_M. The relative rotational speed difference between the rotor and stator or slip indicated by the variable s. Slip an induction motor is expressed by the formula (Rijanto, E, and Santoso, A. 2009) [17] below.

$$s = \frac{\omega_{sm} - \omega_{rm}}{\omega_{sm}} = \frac{\omega_e - \omega_r}{\omega_e} \qquad (2.1)$$

with: $\omega_{sm} = \omega_e$ is the synchronous speed of the motor in the mechanical rotary speed unit 'rpm'

while$\omega_{rm} = \omega_r$ is a mechanical rotational speed of the rotor is also in units 'rpm'

The circuit can be used as a substitute for calculating facilities for various operations such quantity stator current, input power, loss, induction torque, and efficiency. When the aspect of power required in the operation, custody parallel (shunt) R_C can be ignored, while losses in the core can be incorporated into the calculation of efficiency (Kothari, DP, and Nagarath, IJ (2004) [9] together with friction, winding problems, and other losses.

Therefore, the accuracy of the estimated losses suffered by an induction motor in a operation will be necessary in addition to the error means obtained when estimate efficiency [6]. Core loss depends on the applied voltage, while the losses of friction and anchor depending on the operating speed of the motor. When the motor is not loaded, the input power is only used to calculate the no-load losses in the form of losses in the stator core copper, losses anchor and friction loss [8]. Parameters and circuit replacement in Figure 2.2 above can be obtained from the power test dc, test without load, and the rotor locked test - "blocked" (ayasun, S., And Nwankpa, CO (2005) [1], Soe, NN, et al., (2008)) [19]

The following is an impedance analysis of 3-phase induction motors of the model that is depicted in Figure 4.2 above it. Replacement circuit shown it is a series that has a T shape as the respective impedances Z_1, Z_2 and Z_3.

Through the angular frequency ω, the rules and the relationship between pure resistance R, inductor L, and capacitor C, the impedance of individual can be determined as Z = R + jX, with $X = X_L = \omega_L$, for inductive reactance , and $X_C = 1/\omega C$ for capacitive reactance (Sardjono, H. (2008) [7,12,21]. Based on the rules and laws in a series-parallel electrical circuit, the impedance Z_1 is the impedance (stator dealing directly with the incoming power from the power source (Figure 4.2) can be expressed by,

$$Z_1 = R_1 + jX_1 = R_1 + j\omega L_1 \qquad (2.2)$$

Impedance Z2 is impedance (rotor) associated with motor loads, it can be expressed by the following equation.

$$Z_2 = R_2' + R_2'\left(\frac{1}{s} - 1\right) + jX_2' = \frac{1}{s}R_2' + j\omega L_2 \qquad (2.3)$$

And the impedance Z3, which is located at the foot of the T is the impedance between the input and output that is a combination of the magnetization of the motor winding reactance XM that be parallel with RT resistance. RT resistance was the result of parallel RC resistance with custody RFW. Here is a description for obtaining the impedance Z3 is.

$$R_T = R_C \,//\, R_{FW} = \frac{R_C R_{FW}}{R_C + R_{FW}}, \quad Z_3 = X_M \,//\, R_T = \frac{X_M R_T}{R_T + X_M} = \frac{j\omega L_M R_T}{R_T + j\omega L_M}$$

$$Z_3 = \frac{(\omega L_M)^2 R_T + j\omega L_M R_T^2}{R_T^2 + (\omega L_M)^2} = \frac{(\omega L_M)^2\left(\frac{R_C R_{FW}}{R_C + R_{FW}}\right)}{\left(\frac{R_C R_{FW}}{R_C + R_{FW}}\right)^2 + (\omega L_M)^2} + j\frac{\omega L_M\left(\frac{R_C R_{FW}}{R_C + R_{FW}}\right)^2}{\left(\frac{R_C R_{FW}}{R_C + R_{FW}}\right)^2 + (\omega L_M)^2} \qquad (2.4)$$

$$Z_3 = \frac{(R_C R_{FW})(R_C + R_{FW})(\omega L_M)^2}{(R_C R_{FW})^2 + \{(\omega L_M)(R_C + R_{FW})\}^2} + j\frac{\omega L_M (R_C R_{FW})^2}{(R_C R_{FW})^2 + \{(\omega L_M)(R_C + R_{FW})\}^2}$$

Last equation above it is the impedance for each-phase of the three-phase rotor referred to the parameters as shown in Figure 4.2.

The following will be explained through a detailed analysis of the trial and or through simulation (numerical) models with the application that has been available to adequately eg by using the "C ++, MATLAB / SIMULINK" or with other applications that have also been available for instance Scilab [1.3 , 6,8,11,16,19,22,23]

4.3 The Causes of Unbalance Voltage Incidence

Unbalance of 3-phase voltage that occurs in the distribution system can be observed in the phase line to neutral for each phase R, S and T. The voltage between the phase unbalance is usually caused by a faulty distribution of ‘tap connections' transformer; and the unstable supply voltage of the source. Another cause is the system of "open-delta transformer ': and come from those motors itself.

Variable voltage and unbalanced both the data interfere with the operation of motor causing energy waste. In general, the motor is designed to operate at the same voltage magnitude at each phase. Unbalance voltage has a magnitude and a different angle. A motor that operates at a voltage unbalance resulting in decreased output torque and excessive heat. The harmful effects directly related to the angle of the unbalance voltage.

Bad influence of unbalance voltage on the operation of the 3-phase induction motor is derived from the fact that 'unbalance voltage' consists of 2 components:

1. Components of positive sequence, generating a positive torque necessary. The measure of this torque is smaller than the normal torque output from the power supply when the voltage is balance. Loss-RGI that arises in such conditions is higher than normal losses in the motor, because the positive sequence voltage is usually lower than the working voltage.

2. Components of negative sequence, generating a negative torque is not required. The presence of all negative torque is absorbed by the motor, thus increasing losses. It occurs when the voltage positing order to raise the unbalance voltage while the negative sequence voltage to lower voltage imbalance.

However, the increase of the value order would interfere with the operation of the motors. Negative sequence voltage and the position can be calculated by using the method of symmetrical components.

The presence of negative sequence in 3-phase motor terminals resulted in flux rotating opposite to the flux generated by the voltage positive sequence. That why synchronous rotation, voltages and currents are induced in the rotor in twice of the frequency of the channel. Negative sequence can influence the onset of torque, loss of copper stator and rotor, rotor iron loss and overheating of the motor.

4.4. Unbalanced Voltage against the influence of currents and Losses on Motors

Unbalance voltage can cause additional unbalanced currents are quite high. Large unbalanced currents can reach 6 to 10 times the voltage unbalance occurring. For example unbalance voltage current 2.9% lead rise up to 20% (Figure 4.3). Besides, the umbalance voltage causes temperature rise and losses in the motor (Figure 4.4).

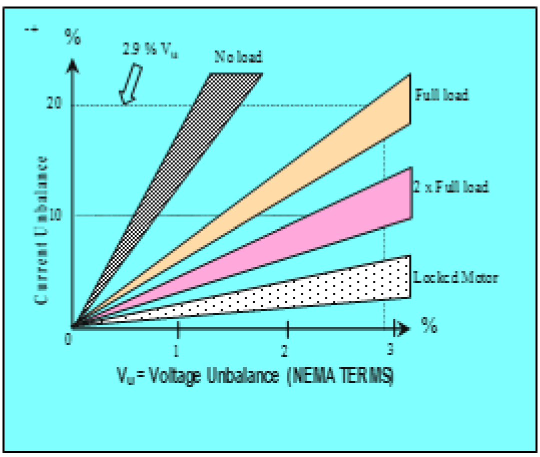


Figure 4.3 The effect of voltage unbalance on the current rise in the motor [15]

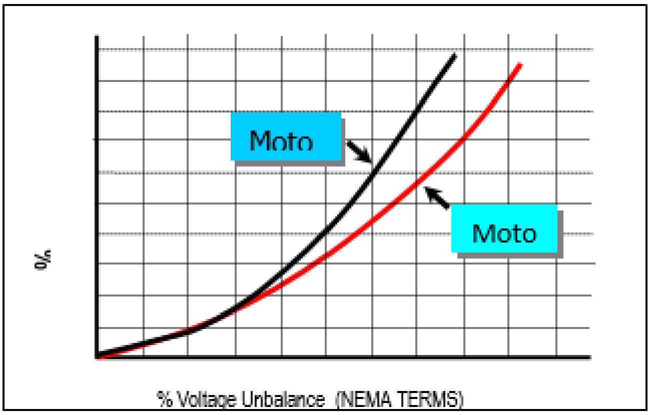


Figure 4.4 The effect of voltage imbalance is on the increase and heat losses in the motor [15]

4.5 Effect of Voltage Unbalanced Motor Winding Insulation against Age

A large current to the motor will cause overheating, there by shortening the life of the motor insulation. Influence of unbalanced voltage relative to the motor insulation life is presented in Figure 4.5

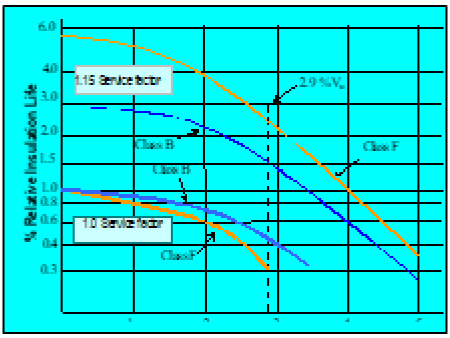


Figure 4.5 The effect of voltage unbalance on the motor insulation life [15]

The curve shows the effect of voltage imbalance relative to the motor insulation life at full load, with insulation class B and F for Service Factor (SF) respectively 1.0 and 1.15. For example at 2.9% voltage imbalance will cause overheat by 17% (as shown in Figure 4.5). By fixing SF to 1.15, then the motor insulation life relative to the type of insulation class F can be raised to 2.5%, and insulation class B rose to 1.5%.

The motors are working on a normal voltage (O% unbalance voltage) with SF 1.0 will have a life of relative isolation equal to SF 1.15 that works on voltages are not balanced around 3.5% to 4%. 1.0 on the curve for the motor, it was shown that a decline in the relative isolation of the motor age drastic case of unbalance voltage exceeds 2%. Keeping age for motor insulation unbalance voltage can be done by increasing the good maintenance. Motor efficiency would be decreased with the increase of the system voltage is unbalanced. Besides, it can lead to the occurrence of electro-mechanical vibration and damage to the motor bearings. Violent vibrations mainly occur in high-speed motor up to 3600 rpm.

From the presentation above, it appears that the imbalance voltage can cause premature damage to the motor windings, thereby shortening the life of the motor. Besides, it can decrease the efficiency of the motor due to excessive heat, hence a waste of energy, which in turn led to a large increase overall costs. Good and proper maintenance can extend the life of the motor.

4.6 Basic Concepts Application Fuzzy Logic as control and System Safety

Fuzzy logicclassifies main opinion in a group that is not definitely known fuzzy set. Therefore the fuzzy set is expressed as a class of objects with a degree of continuous membership. A fuzzy set is characterized by its membership function shown as an object on a range of values between null to one. Thus the fuzzy set can be defined mathematically. Definition represents a value that represents the degree of membership of each individual in the universe of discourse.

The fuzzy set written as a pair in order which indicates the name of the first element and the second element indicates the value of membership. For example, to declare the heat of an object that can be between 50 to 90° C then fuzzy set written A = HEAT, and formulated in a mathematical expression as follows

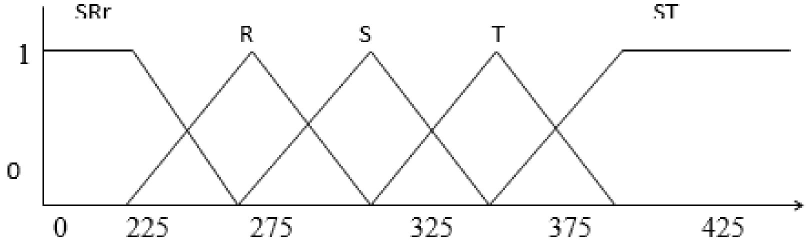
$$\overline{A} = \{(x, \mu_A(x)) \mid x \in X\}$$

With a degree of membership as follows:

$$\mu_A(x) = \begin{cases} 0 & ;\ \text{jika}\ \ x \leq 50 \\ \dfrac{x-50}{20} & ;\ \text{jika}\ \ 50 \leq x \leq 70 \\ \dfrac{90-x}{20} & ;\ \text{jika}\ \ 70 \leq x \leq 90 \end{cases}$$

At diagnosis expert system 3-phase induction motors used Tsukamoto method: fuzzy inference system that is based on the concept of reason. In the method of reasoning on regional Crisp consequent value may be obtained directly by calculation through the fuzzy set. Here below is the amount of voltage system expressed in some fuzzy sets:

VOLTAGE VALUE



1. The set voltage is very low (SR)

$$\mu_{SR}(x) = \begin{cases} 1 & ;\ x \leq 225 \\ \dfrac{275 - x}{50} & ;\ 225 \leq x \leq 275 \\ 0 & ;\ x \geq 275 \end{cases}$$

2. The set of low voltage (R)

$$\mu_{R}(x) = \begin{cases} \dfrac{x - 225}{50} & ;\ 225 \leq x \leq 275 \\ \dfrac{325 - x}{50} & ;\ 275 \leq x \leq 325 \end{cases}$$

3. The set of medium voltage (S)

$$\mu_{S}(x) = \begin{cases} 0 & ;\ x \leq 275 \\ \dfrac{x - 275}{50} & ;\ 275 \leq x \leq 325 \\ \dfrac{375 - x}{50} & ;\ 325 \leq x \leq 375 \end{cases}$$

4. The set of high voltage (T)

$$\mu_{T}(x) = \begin{cases} 0 & ;\ x \leq 325 \\ \dfrac{x - 325}{50} & ;\ 325 \leq x \leq 375 \\ \dfrac{425 - x}{50} & ;\ 375 \leq x \leq 425 \end{cases}$$

5. The set of very high

5. Himpunan tegangan sangat tinggi (ST)

$$\mu_{ST}(x) = \begin{cases} 0 & ;\ x \leq 375 \\ \dfrac{x - 375}{50} & ;\ 375 \leq x \leq 425 \\ 1 & ;\ x \geq 425 \end{cases}$$

Statement of the amount of voltage system stated above shows a large degree of membership of each voltage value in the curve of the membership function set sketchy.

A protection system based on fuzzy logic can be expressed as a closed loop control system (loop) as shown in Figure 4.6 below [10];

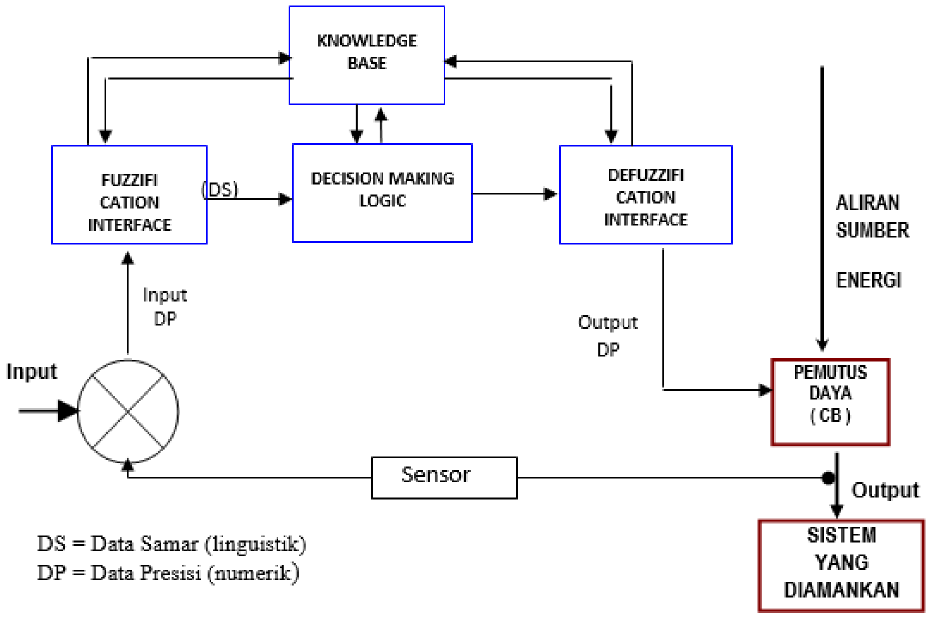


Figure 4.6. Block diagram of safety system using fuzzy logic

The basic structure of fuzzy logic controller as shown in figure 2.14 with the following main elements: fuzzification interface, decision making logic, knowledge base, and defuzzification interface. Based on the structure description, various monitoring types and fuzzy logic controller can be build along with specific planning target.

4.7. Related Studies

Three-phase induction motor test which in laboratory section included software and hardware using MATLAB is to support and enhance electric machinery education at the undergraduate level as well-described by Ayasun, S., and Nwankpa, C.O. (2005) [1] in their paper. While the negative effects of a particular unbalanced voltage or mixed fault diagnosis on the performance of three-phase squirrel-cage induction motor can be seen as referred from Faiz, J., et.al (2006,2004) [3,4] in their paper. On the other hand, Gosbell, V.J., et.al (2002) [5] launched a technical note about three-phase voltage unbalance from integral energy power quality centre of University of Wollongong in Australia.

An accurate low-cost method for determining electric motors efficiency for the purpose of plant energy management as reported by Ibiary, Y. (2003)[6] in his paper. Moreover, Kasim, et.al.(2009)[7] in PPI-KIM 2009 (Pertemuan dan Presentasi Ilmiah – Kalibrasi, Instrumentasi, dan Metrologi / Annual Scientific Conference on Metrology and Instrumentation) reported their research about the activity of design-build of a generator using permanent magnet which produces GMP (Generator Magnetik Permanen) / Permanent Magnet Generator with 3-phase specification, 1 kW, 48 V, 18 pole, 300 rpm, to show local ability and independency.

Comparison of voltage unbalance factor by line and phase voltage is explained by Kim, J.G., et.al. (2005)[8]. While you can see for basic skill of electric machines including 3-phase induction motor from book edition by Kothari and Nagrath, I.J. (2004)[9]. Lazzarini, M.V., and Filho, E. (2007)[11] reported sensorless three-phase induction motor direct torque control strategy in their paper. A research by Lee, C.Y. (1999)[12] discussed about the effect of unbalance voltage on the operation performance o a three-phase induction motor. While Mamat, M.M., et.al. (2006)[14] in an article reviewed about fault detection of three-phase VSI (Voltage Source Inverter) using wavelet fuzzy algorithm published by American Journal of Applied Sciences.

The usual kinds of three-phase induction motors in industrial drives have simple and rugged construction, good operating characteristics, low cost, compared with the others (Pillay, et.al. (2002)[16]). Rijanto, E., and Santoso, A. (2009)[17] examined in their paper about design of mechanical electrical control system for wind electrical power generator plant, and Sardjono, H. (2008)[18] in his article discussed about thermal voltage converter as each national standard has been published in Instrumentation Journal. Next, the dynamic modelling and simulation of three-phase small induction motor can be seen on the article by Soe, N.N., et.al. (2008)[19] and Suorsa, I. (2005)[20].

Yukiko Sato, Era Purwanto, et.al [34] in FT ITB (Faculty of Engineering in Institut Teknologi Bandung) Bandung(2006)[33] reported the research findings about setup for induction motor speed using artificial neural network. The controller implementation made on induction motor simulation showed the well-achieving of fuzzy logic membership function (on speed-range ration from 750 up to 1500 rpm/revolutions per minute). To simplify fault detection of abnormal performance and increase preventive and safety operation of the 3-phase induction motor which hold the big position in industrial drives, Tjandi, Yunus., and Harun, N. (2008)[22] developed an advanced method using fuzzy logic which turns the function of conventional relay system into smart relay.

4.8. Conceptual Framework

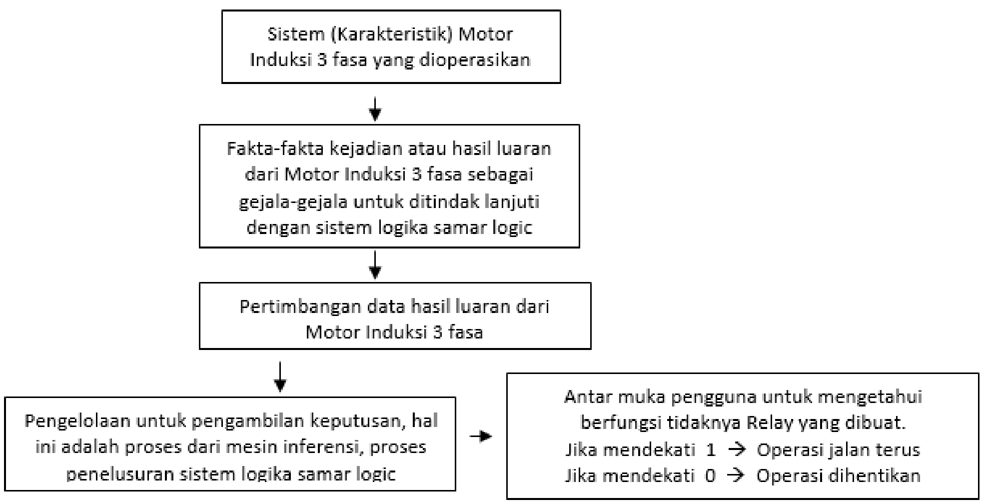


Figure 4.7 Diagram Block of Conceptual Framework

5. Research Method

5.1 Research Design

Strategy of conducting this research aims to achieve the research objective which systematically explained as follows:

- The independent variable which shows high-influenced in this research is the unbalance voltage supply and maximum weight capacity of three-phase induction motor;

- The dependent variable is the heat caused by motor's winding which can damage winding insulation resistance. Therefore, the most-used measuring instruments in this research are voltmeter, temperatures, time, and, measuring tool of mechanical load;

- If the variable measuring stated is well-calculated , then this research will have a greater chance of success. That is why, this research is started with the characteristics observation of independent and dependent variable in laboratory. The next step was designing the hardware of safety system based on its software design. The final step of this research has been done through laboratory test, that is the safety system design.

5.2. Research Location

Because of the lack of instruments, this research used some well-equipped laboratories in Makassar, such as:

- Laboratorium BLPT (Balai Latihan Pendidikan Teknik) / Engineering Education and Training Center Laboratory in Makassar, South Sulawesi Province. An observation of the effect of three-phase induction motor load on unbalance voltage supply toward starting and heat flow from the winding pipe anchor.

- Laboratorium Kontrol Teknik Elektro Universitas Negeri Makassar / Control Laboratory of Electrical Engineering of Universitas Negeri Makassar where the safety system prototype construction had been made and down load the safety system using fuzzy logic into Microcontroller AVR AT Mega 32.

- Laboratorium Kontrol dan Pengukuran pada Jurusan Teknik Elektro BLPT Makassar / Control and Measuring Laboratory in Electrical Engineering Department of BLPT Makassar where the prototype had been tested toward unbalance voltage and temperature effect with three-phase induction motor load.

- Laboratorium Mikroprosessor Politeknik Negeri Ujung Pandang / Microprocessor Laboratory of Politeknik Negeri Ujung Pandang where the completion of the protype had been done using Microcontroller AVR AT Megs 32.

5.3 Research Instrument

This research instrument includes the observed instrument, measuring instrument, decision-making instrument, and control valve instrument. The observed instrument is three-phase induction motor which is variably rotated starting from no load up to 125% loads from its capacity and supplied by three units of single-phase voltage regulator which unbalance the voltage supply.

Measuring instruments contain of 3 (three) units of digital voltmeter, 3 (three) units of digital ammeter, one (1) unit of digital thermometer, and one (1) unit of digital stopwatch. Those are used to respectively measure potential difference or the voltage and current of the observed induction motor when it operates.

Decision-making instrument contains of microcontroller hardware. Then it is filled by software program writte in C++ programming language using fuzzy logic principle.

Control valve instruments contain of 1 (one) set of analog digital converter and 1 (one) set of controller or driver. Analog digital converter is used to store the number of variables into the microcontroller. After that, the software will process the variables and the next step to do. Then the decision is done by the set of controller or relay driver which connected to the circuit breaker.

5.4. Procedure of Collecting Data

This research aims to make a system to be attached in each three-phase induction motor so it can monitor the operation, control, and detect the operation failures which can damage the induction motor caused by unbalance voltage and temperatures's effect. The most influencing factor in that case is the appropriate procedure of collecting data which provides the whole information. Then, a proper safety system can be designed to handle the information. Therefore, it will be done in phases to obtain the actual data. First, by searching the literature review related to system development of induction motor safety. Second, by doing direct measurement through laboratory test. The measurement result is provided in table to facilitate the containing information of the data in a maximum way.

5.5 Technique of Data Analysis

This is a modelling approach and system formulation which done to solve appropriately. The optional technique of data analysis used affects the precision or accuracy of a research findings. The expected result from the analysis of this research is the extent of unbalance voltage which can keep the three-phase induction motor to operate without causing damage. The problem is how to differ between normal and abnormal condition in each performance of the electric motor. Moreover, the incidence of the failure is hard to predict and its different types which identical to each other including the characteristics of normal transition. Therefore, the expanding of exact maths into fuzzy maths is stated theoretically that the possibility of proper decision making even in blur situation is very attracting to be applied in solving the research problems. The basic principle is about to model the independent and dependent variable used in this research, then drawing the inference using Max-Min inference method. It is because it is one of the reasoning inference methods which expands in fuzzy mathematics and most applied as the decision making logic, especially for the conditions where the lines are blur or fuzzy. The following discussion is data analysis using sotware in C++ programming language.

5.6. The Process of Measurement and Design of Safety System Hardware

The process of measuring data from the system into the Microcontroller is called data acquisition. The following Figure 5.1. shows the process of data acquisition from the system into the microprocessor suits to the safety goals. The circulation works constantly because the microprocessor or the microcontroller will reveal the data periodically in each input signal port into the microcontroller. The received signal by the microcontroller will be proceeded as the order of the downloaded software.

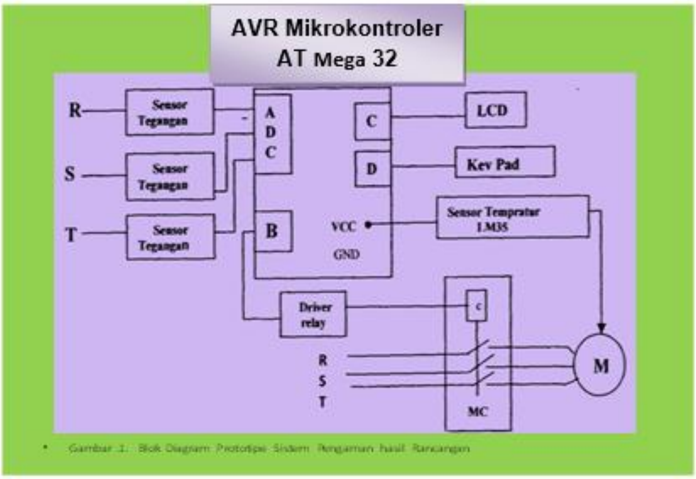


Figure 5.1. Diagram Block of Data Acquisition from The System[13]

5.7. The Main Set of Safety System

The main set of safety system contains of its functional components which shown on the figure 5.2. of equivalent set below. The set shows 3 (three) main of measuring amounts used in this safety design that is, the amount of voltage in each phase, while the winding's temperature is the derived amount as the function of the load and the extent of the unbalance voltage.

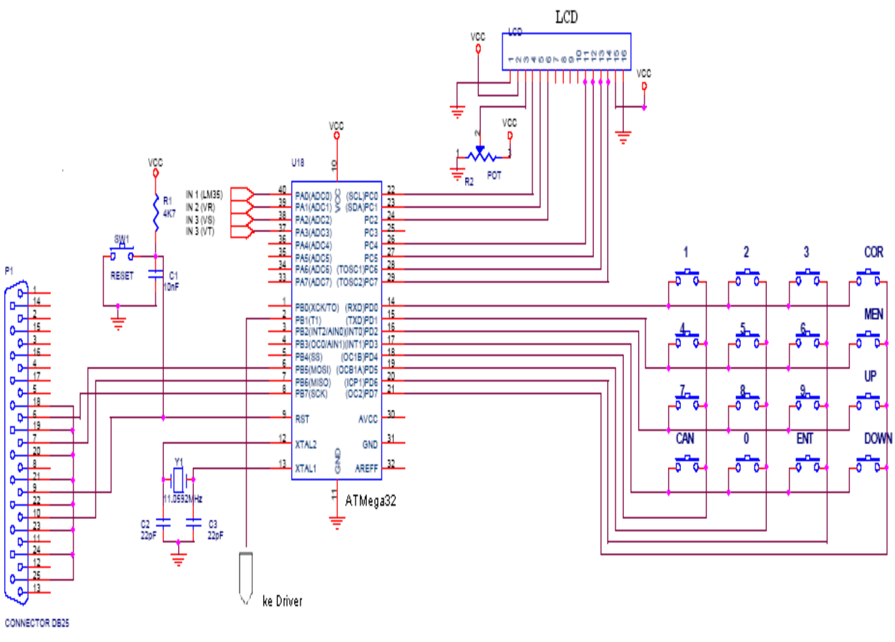


Figure 5.2. The Main Set of Safety System

6. Conclusion and Suggestion

6.1 Conclusions

Based on the findings and the discussions, it can be concluded as follows:

1. Safety relay prototype based on fuzzy logic has been developed to protect 3-phase induction motor from such failures: over voltage, under voltage, over heating, unbalance voltage, and single phasing;

2. Adjusting the performance of three-phase induction motor on the unbalance voltage supply to avoid damage succeed by setting the lowval and highval on the input of voltage supply connected to Microcontroller AVR and operated using the principles of fuzzy logic. Laboratory test of the safety system showed its detection ability of single phasing and asymmetrical condition which can damage, so we can respond properly to secure the performance of the induction motor.

3. Building safety system based on microcontroller to protect three-phase induction motor succeed by constructing safety hardware using microcontroller AVR AT Mega 32. Laboratory test of the safety hardware is well-functioned, for instance by showing the working safety if the defuzzy output ≥ 198 volts and the defuzzy output ≤ 231 volts (PBI =1) and the safety is off if the defuzzy output < 198 volts and defuzzy output > 231 volts (PBI=0);

4. The applied temperatures detector on the performance of three-phase induction motor based on microcontroller succeed by using temperature sensor type LM 35.

6.2 Suggestions

In order to complete the hardware as the research finding to be more applicable on three-phase induction motor's safety in any idustries, then it strongly recommends:

1. To conduct future researches to observe system stability and the hardware resistance of the safety system;

2. The future researches which similar to the research should expand the scope of the research in which they can involve other kinds of the safety of electrical system and complicated electric motors.

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