TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 12, No. 8, August 2014, pp. 5766 ~ 5773
DOI: 10.11591/telkomnika.v12i8.6247

PLC Scada Based Fault Identification and Protection for Three Phase Induction Motor

L. Venkatesan*[1], S. Kanagavalli[2], P.R. Aarthi[3], K.S. Yamuna[4]
[1]Department of PED, Sona College of Technology, Salem, Tamil Nadu, India
[2,4]Department of EEE, Sona College of Technology, Salem, Tamil Nadu, India
[3]Department of EIE, New Prince Shri Bhavani College of Engineering and Technology, Chennai, Tamil Nadu, India
*Corresponding author, e-mail: venkatesan.control@gmail.com[1], kanaganchala@gmail.com[2], jehovahaar@gmail.com[3], yamuna.sona@gmail.com[4]

Abstract

Today overvoltage, over current, overload, over temperature, and under voltage are the most commonly occurred problems in protection circuits of induction motor. We usually design Protection circuits with components such as timers, contactors and current relays. In order to reduce the mechanical components usage we prefer to use Personal Computer (PC) and Programmable Logic Controller (PLC). In this method Induction motors current, voltage, Speed, temperature values and fault occurred history are monitored in PC with an Alarm Message during fault occurrence. PLC-based protection methods are costs less, provides higher accuracy with safe mode of operation when compared with the other protection systems.

Keywords: *fault Identification, induction motor (IM) protection, programmable control controller (PLC)*

1.Introduction

In many Industrial applications we use AC induction Motors as Actuators. Fault occurs in this case when we apply more stress on it. We can easily avoid Initial Faults on Induction motor by Various Monitoring methods. Two types of Monitoring techniques are the conventional and the digital techniques.

Monitoring Devices can be arranged for monitoring the three phase Induction motor by using Electrical and Mechanical Units. On Motor we will use sensors for sensing stator insulation failures. Many researchers have experimentally tested the Performance of Induction Motor by monitoring process. In this paper, SCADA interfaced with PLC is used to monitor the values of the voltages, currents, temperatures, and speed of the three phase induction motor. In this paper, for considering all the variables of the motor we use an analog-to-digital conversion (ADC) card.

By Using Microcontroller there are various solution identified to troubleshoot errors on the currents, voltages, speed, and the winding temperatures of an Induction Motor in operating mode [3]. Recently on control circuits programmable logic controller (PLC) are widely used in industrial automation systems. The input temperature sensors modules can be directly connected to the input and the output components such as contactors, relays and solenoid valves are connected to output ports on PLC [7].

In PLC also we can achieve fault identification as we do with Micro controller. PIC application can be replaced easily by PLC Control. In this paper is chapter II we discuss about the PLCs. chapter III presents Protection System implemented details of System, Electronic Circuits and PLC software. Chapter IV Experimental Analysis setup of IM fault detection and protection. The research is finally concluded in Chapter V.

2. Programmable Logic Controller

A PLC Controller is used for automation processes to sense, activate, and control industrial equipment. A PLC has a number of I/O ports which allows electrical signals to be interfaced. The basic structure of the PLC is shown in Figure 1.

Received March 4, 2014; Revised May 21, 2014; Accepted June 5, 2014

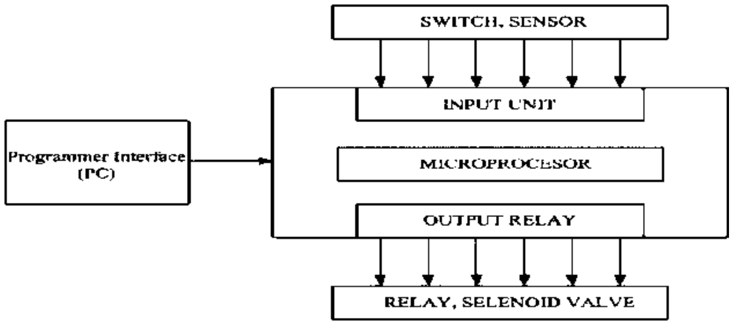

Figure 1. Basic Structure of PLC

In this research we use PLC to measure IM the current, voltage, temperature, speed via Analog Input. Also we can continuously monitor the inputs and control the signal [6].

For Experimental analysis Siemens S7-200 PLC module with 14/10 digital input/ output addresses with CPU 224 sample (14∗DI 24 V dc/10∗DO 24 V dc) is preferred. STEP 7—Micro/Win 32 programmer was used to Read/Write program in PLC. We can use ladder diagram (LAD) programming languages. PLC ladder program is developed and loaded in to PLC memory through RS232-RS485 Cable. While the program prepared for transferring to PLC from the computer, the most important point is we need to use same baud rate between the PLC and the computer.

For reading analog signal as PLC'S input we need to use an analog module. Analog modules usually available with 8 or 12 bit systems. Inputs are expressed as A, B, C, and D in the Analog module. Only word can be processed by each channel, so Analog data are processed first, and then, they are transformed into digital data. Analog measurement signals cannot be directly read by an PLC since it senses only logic signals. So analog module is needed for sensing the four analog signal inputs. The phase currents and the voltages, the temperature, and the speed of motor values are the analog signals measured with this analog module. Figure 2, shows the Analog and digital PLC module.

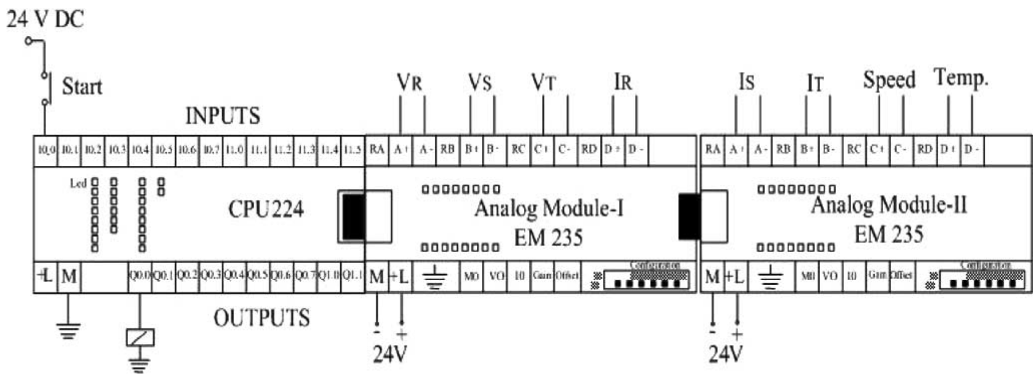

Figure 2. Analog and Digital PLC Module

3. Protection System of Induction Motor

The Three phase induction motor protection circuit layout is shown in Figure 3. The measurement card consists of the current transformer, the voltage transformer, the rotor speed is measured by an encoder, and winding temperature is measured by the temperature Sensor [4].

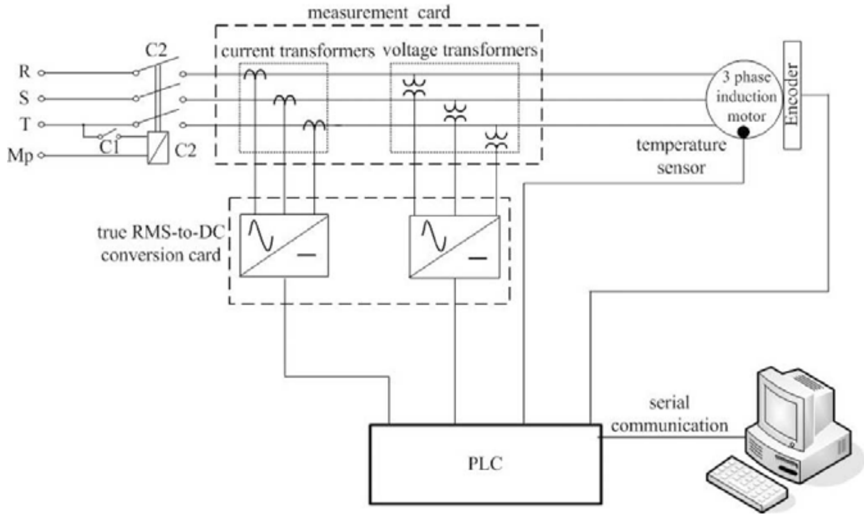

Figure 3. Protection System Layout

3.1. System

The protection system used here consists of an 1.5kW/2800r/min three-phase Induction motor. A Linear temperature sensor with ratio of 10mV for each 1°C increasing temperature, and we use incremental encoder with 360 pulse per revolution for speed measurement, a true RMS to DC Conversion card and S7 200 series PLC. System Prototype is shown in Figure 4.

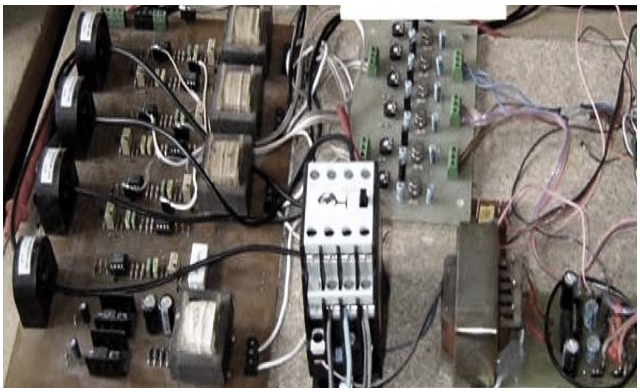

Figure 4. Hardware Circuit (measurement card and RMS to DC Conversion card)

3.2. Electronic Circuits

Three Phase current & Voltage transformer are used in Protection measurement card circuits to measure the Induction Motor current & voltages as shown in Figure 5 [9]. In Measuring card we use Op Amp, Gain Potentiometer and filter circuit to change the present value. RMS to DC Conversion card receives signal from this Measurement card as shown in Figure 4.

An Incremental encoder connected on motor shaft to measure the speed of the motor, as shown in Figure 5. Conversion circuit shown in Figure 6 will convert these PWN signal to DC voltage. LM-35 Temperature sensor is placed on motor coils is used to measure the temperature of the motor. The LM-35 sensor can produce 10 mV voltages per 1°C [21]. On PLC Analog module input receives the coil temperature. When motor coil reaches over the prescribed coil temperature then PLC control will automatically stop the Running motor to prevent damage to Coil Burn/Overloading.

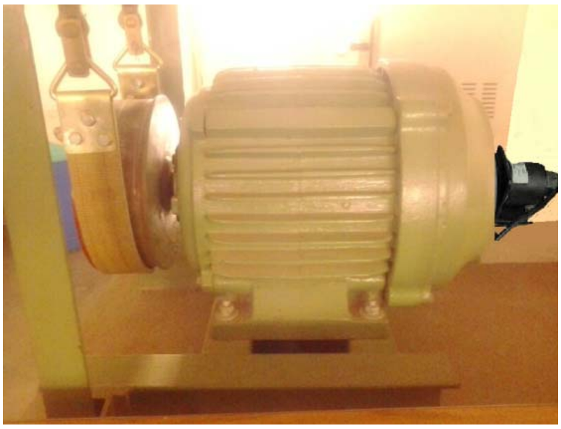

Figure 5. Three Phase IM with Incremental Encoder

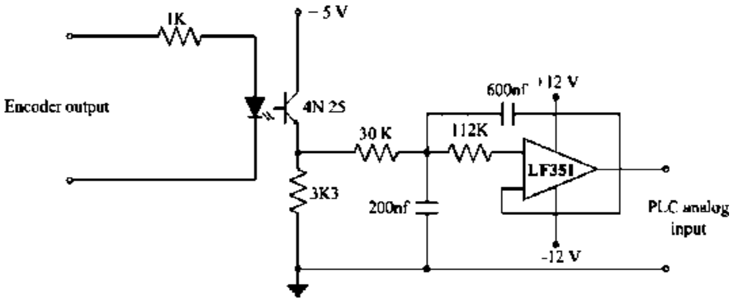

Figure 6. PWM to DC Voltage Conversion Circuit

The AD536A directly generates the true RMS value of any input waveform containing AC and DC components [19]. For changing the current & voltages values on RMS to DC conversion we used Potentiometers and filter circuits. PLC Input module receives converted current & voltage values from RMS to DC Conversion card.

3.3. PLC Software

On PLC software we go with Ladder programming method for performing control tasks. After creating the Ladder program we can run and perform simulation test on software and then program can be downloaded in to PLC's memory. Flow chart of the program is shown in Figure 7.

The software data are three phase voltages ($V1$, $V2$, $V3$), three phase currents ($I1$, $I2$, $I3$), speed (nr), and temperature (TC) of the IM, as shown in Figure 7.

The motor transient time is 100ms which is controlled continuously by the PLC program. when the transient time is greater than the defined time, then program shifts to execute the control procedure to send Stop Control signal, and the motor is stopped when it receives signal from the PLC [7]. Results are displayed at the end. Transient and renew times on software can be changed when motor load changes.

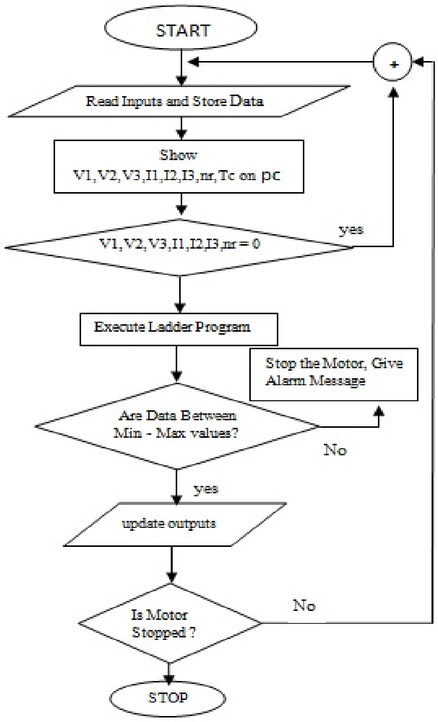

Figure 7. Flowchart of the Software Developed

Table 1

VARIABLES	SYMBOL	INPUT	UNIT
Voltage of phase 1	V_1	Analog Module-I input A	Volt
Voltage of phase 2	V_2	Analog Module-I input B	Volt
Voltage of phase 3	V_3	Analog Module-I input C	Volt
Current of phase 1	I_1	Analog Module-I input D	Ampere
Current of phase 2	I_2	Analog Module-II input A	Ampere
Current of phase 3	I_3	Analog Module-II input B	Ampere
Speed	n_r	Analog Module-II input C	Rpm
Winding Temperature	T_c	Analog Module-II input D	Degree

Now the software directly displays the phase voltages, the phase currents, the rotor speed, and the motor temperature on the PLC interfaced. From these data's only tolerance values will be decided. The program continues to run until data's are within specified limits. If there is no value to read, then program will restarted to read and calculate the new voltages, currents, speed, and temperature ($V1$, $V2$, $V3$, $I1$, $I2$, $I3$, nr , and Tc). When fault occurs, the program compares the three phase voltages, three phase currents, speed, and temperature with their set values, and the motor is stopped by receiving a stop control signal from the PLC with an error messages on pc. When an undefined fault occurs, the motor stops without giving any description. From the database file we can see the history of problems occurred. Protection circuit designed for the motor allows the motor to be started again only if error is rectified on the motor. Reset button can be activated only after troubleshooting the problems on the motor.

4. Experimental Analysis Setup of IM Fault Detection and Protection

SCADA Win log Software is used for interfacing PC with the PLC. We use Modbus protocol for communication between PC and PLC as shown below:

Channel: 1
Configuration: Modbus RTU Port: COM1
Baud rate: 19200
Stop bit: 1
Data bit: 8
Time out (ms): 1000
Query pause (ms): 20

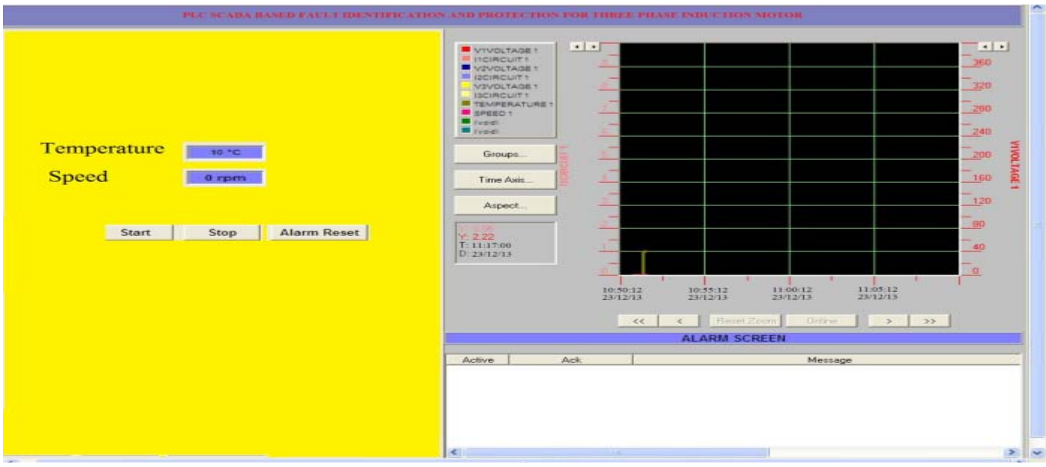

Figure 9. View of SCADA Screen on PC

The SCADA software display is shown in Figure 9. To identify and to prevent the motor from faults, the software was developed based on the following conditions.

a) To start the motor START Icon is used.
b) To stop the motor STOP Icon is used.
c) During Motor Failure Mode we can use Alarm and reset option to stop the Motor. In this when failure condition is rectified, the motor will not start again automatically, we need to start the motor by reset the icon followed by clicking the start icon.
d) Time axis is used to set the time scale as shown in Figure 10.
e) Aspect is used to set line thickness.
Voltages and the currents are shown in Graph window.

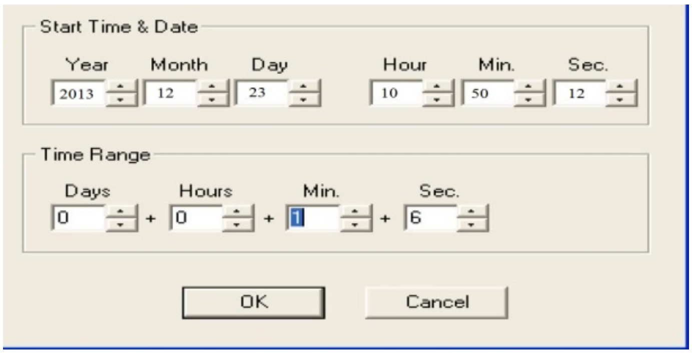

Figure 10. Display of Time Range

Before start running the Induction Motor we need to manually enter the minimum and maximum values of the voltage, the current, the temperature, and the speed. After entering all values, the motor is then ready for starting [14]. When the motor icon is clicked on, the menu shown in Figure 11 is displayed on the screen. The waveforms of currents and voltages can be seen on the oscilloscope. Rule-based control methodology is used to detect the fault on the IM.

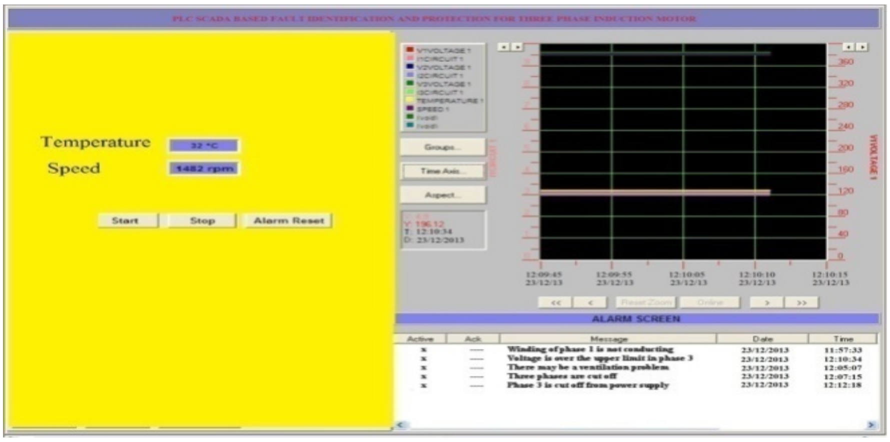

Figure 11. Screenshot of Program Page

The SCADA Software monitors when motors is in running condition. The temperature sensor was used only for finding stator current faults. Possible detectable faults are given in Table 2 [2].

Table 2. Types of Fault on Three Phase Induction Motor

Types of Faults	I_1	I_2	I_3	V_1	V_2	V_3	n_r	T_C
Motor is stopped or three phases are not present	<	<	<	<	<	<	<	*
Winding of phase 1 is not conducting	0	≥N	≥N	N	N	N	≤N	*
Winding of phase 2 is not conducting	≥N	0	≥N	N	N	N	≤N	*
Winding of phase 3 is not conducting	≥N	≥N	0	N	N	N	≤N	*
Winding of all phases are not conducting	0	0	0	N	N	N	≤N	*
Phase 1 is cut off from supply	0	≥N	≥N	<	≤N	≤N	N	*
Phase 2 is cut off from supply	≥N	0	≥N	N	<	N	≤N	*
Phase 3 is cut off from supply	≥N	≥N	0	N	N	<	≤N	*
There may be a short circuit in phase 1	>	≤N	≤N	*	*	*	<	*
There may be a short circuit in phase 2	≤N	>	≤N	*	*	*	<	*
There may be a short circuit in phase 3	≤N	≤N	>	*	*	*	<	*
Voltage is over the upper limit in phase 1	≥N	≥N	≥N	>	N	N	N	*
Voltage is over the upper limit in phase 2	≥N	≥N	≥N	N	>	N	N	*
Voltage is over the upper limit in phase 3	≥N	≥N	≥N	N	N	>	N	*
Voltage is over the upper limit in phases 1 and 2	≥N	≥N	≥N	>	>	N	N	*
Voltage is over the upper limit in phases 1 and 3	≥N	≥N	≥N	>	N	>	N	*
Voltage is over the upper limit in phases 2 and 3	≥N	≥N	≥N	N	>	>	N	*
Voltage is over the upper limit in phases 1, 2 and 3	≥N	≥N	≥N	>	>	>	N	*
Voltage is below the lower limit in phase 1	≤N	≥N	≥N	<	N	N	≤N	*
Voltage is below the lower limit in phase 2	≥N	≤N	≥N	N	<	N	≤N	*
Voltage is below the lower limit in phase 3	≥N	≥N	≤N	N	N	<	≤N	*
Voltage is below the lower limit in phases 1 and 2	≤N	≤N	≥N	<	<	N	≤N	*
Voltage is below the lower limit in phases 1 and 3	≤N	≥N	≤N	<	N	<	≤N	*
Voltage is below the lower limit in phases 2 and 3	≥N	≤N	≤N	N	<	<	≤N	*
Voltage is below the lower limit in phases 1, 2 and 3	≥N	≥N	≥N	<	<	<	≤N	*
There may be a ventilation problem with the motor	N	N	N	N	N	N	N	>
All three phases are cut off and motor is not starting	0	0	0	0<	<	<	<	*
The coil of phase 1 is cut off or there is a problem with the connection box	0	>	>	N	N	N	<	*
The coil of phase 2 is cut off or there is a problem with the connection box	>	0	>	N	N	N	<	*
The coil of phase 3 is cut off or there is a problem with the connection box	>	>	0	N	N	N	<	*

5. Conclusion

In this experimental research implemented on protection system for three phase Induction Motor. The proposed PLC-controlled protective relay deals with the most important types of these failures, which are summarized as the phase lost, the over/undercurrent, the over/under voltage, the unbalance of supply voltages, the overload, the unbalance of phase currents, the ground fault, and the excessive repeated starting. When a fault is occurred during IM is running, alarm message displayed on PC SCADA Screen and PLC will stop the motor. When an undefined fault occurs, the motor stops without giving any description.

The results showed that a reliable PLC-based protection system including all variables of the three-phase IMs and operators have been developed. In addition, it does not require any conversion card, and therefore, costs less than a computer-based protection method. Moreover, it provides a visual environment, which makes the system more user-friendly than a PIC-based rotection method. Finally, being flexible in the range settings, considering all motor variables together, eliminating the conversion card, and providing a visual environment make the proposed protection system better than other PLC-based protection systems studied.

References

[1] Venkatesan L, Arulmozhiyal R, Janarthanan AD. *Simulation approach on step speed control of Induction Motor using Lab View.* Computer Communication and Informatics (ICCCI). International Conference on, 4-6 Jan. 2013. Doi 10.1109/ICCCI.2013.6466283.
[2] Venkatesan L, Janarthanan AD, PR Aarthi, Arulmozhiyal R. Speed control of induction motor via pic controller using lab view. *Advanced Materials Research Journal*. Trans Tech Publications, Switzerland. doi:10.4028/www.scientific.net /AMR 768.3592013; 768: 359-363.
[3] M Benbouzid, M Vieira, C Theys. Induction motor's fault detection and localization using stator current advanced signal processing techniques. *IEEE Trans. Power Electron.*, 1999; 14(1): 14–22.
[4] WA Farag, MI Kamel. Microprocessor-based protection system for three-phase induction motors *Electr. Mach. Power Syst.*, 1999; 27: 453–464.
[5] R Bayindir, I Sefa. Novel approach based on microcontroller to online protection of induction motors. *Energy Convers. Manage.*, 2007; 48(3): 850–856.
[6] MG Ioannides. Design and implementation of PLC-based monitoring control system for induction motor. *IEEE Trans. Energy Convers.*, 2004; 19(3): 469–476.
[7] AR Al-Ali, MM Negm, M Kassas. *A PLC based power factor controller for a 3-phase induction motor.* Proc. Conf. Rec. IEEE Ind. Appl., 2000; 2: 1065–1072.
[8] Yassine Maouche, Mohamed El Kamel Oumaamar, Mohamed Boucherma, Abdelmalek Khezzar. A New Approach for Broken Bar Fault Detection in Three-Phase Induction Motor Using Instantaneous Power Monitoring under Low Slip Range. *International Journal of Electrical and Computer Engineering (IJECE).* 2014; 4(1): 52-63, ISSN: 2088-8708. DOI 10.11591/ijece.v4i1.4611.
[9] Xing-ping LIU. Design of Asynchronous Motor Soft Starting and Saving Energy Control Based on PLC. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2014; 12(3): 1751-1757. DOI: http://dx.doi.org/10.11591/telkomnika.v12i3.4540.
[10] R Rajendran, Dr N Devarajan. A Comparative Performance Analysis of Torque Control Schemes for Induction Motor Drives. *International Journal of Power Electronics and Drive System (IJPEDS)*. 2012; 2(2): 177-191. ISSN: 2088-869.
[11] Zicheng Li, Zhouping Yin, Youlun Xiong, Xinzhi Liu. Rotor Speed and Stator Resistance Identification Scheme for Sensorless Induction Motor Drives. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(1): 503-512. DOI: 10.11591/telkomnika.v11i1.1865.
[12] Shashidhara SM, Sangameswara P Raju. FPGA Based Embedded System Development for Rolling Bearings Fault Detection of Induction Motor. *International Journal of Reconfigurable and Embedded Systems (IJRES)*. 2013; 2(3): 127~134. ISSN: 2089-4864. DOI: 10.11591/ijres.v2i3.4746.
[13] Mihai Iacob, Cristina Anita Bejan, Gheorghe-Daniel Andreescu. Supervisory Control and Data Acquisition Laboratory. *Telfor Journal*. 2010; 2(1).
[14] Ravi Masand, Deepika Jadwani, Abhishek Sahu. PLC and SCADA based Fault Diagnosis of Induction Motor. *International Journal of Digital Application & Contemporary research (IJDACR)*. 2014; 2(6): ISSN: 2319-4863.