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Research paper

Neural Network Based Monitoring, Protection & Fault Detection of Induction Motor Using PLC

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Abstract

Induction motors used mostly in industrial, commercial applications & are seldom denominated power horse of industry. To reduce the motor starting current soft starter requirement is increasing day by day & to maintain the torque proportionally with the load requirement. Now intelligent soft starters evolved to improve the motor starting. This work is comprised of development of an Artificial Neural Network control regime for closed loop of induction motor. The same has been achieved using a standard 0.75 KW three phase induction motor using Matlab, PLC, SCADA & DRIVE. The Artificial Neural Network scheme is compared with traditional Proportional control regime. We have observed that the performance of ANN Induction Motor control Algorithm has been 14-21 % better than only Proportional Motor Control algorithm.

Keywords: *Ann; Plc; Scada; Vfd; Matlab; Motors.*

1. Introduction

In recent years industrialization & the need of electrical system for manufacturing processes are taking more consideration for use of effective, easy controllable devices. An electric motor is an electrical machine that converts electrical energy into mechanical energy. Monitoring their speed, current & torque are taking much devotion in the research and development. [1] The entire power system effects adversely while starting of induction motors. To maintain the power system flexibility suitable soft starting technique must be used otherwise connected electrical network fluctuation may occur & electronic devices connected to the system may get fatality. [3] During considering the soft starting techniques some factors may be considered which are high starting current, toughness, cost, reactive power & starting power factor.[6] In recent years soft starting techniques available are such as primary resister, star delta, auto transformer, VFD etc. To reduce the inrush current these techniques are not enough. Today's requirement is to start induction motor's smoothly according to fluctuation of load in order to avoid undesirable situation. To overcome the complications of conventional soft starter, intelligent soft starting is being used in industrial applications. The intelligent soft starter considered must be capable to adapt a new environment to changes in present environment, ability to acquire knowledge from the running environment, ability for changing load, ability to estimate & evaluate. [5]

In previous works, speed ripple effect [7], ball bearing faults [8], inter turn faults [11], motor stator winding temperature [12], and microcontroller-based fault detection[13], [14], air gap eccentricity [15], broken motor rotor bars [19], damaged bearings, motor shaft speed fluctuation, unstable voltage [9], have been recently studied papers. In these papers one or two parameters were considered for protecting the induction motors, the other parameters of the induction motors were not considered. This might be a issue in protection of induction motors. A computer based protection also proposed [16]. Measurements of the currents, voltages, temperatures, and RPM were achieved and transmitted to the computer for final protection.

The big revolution in soft starting arises with application of intelligent algorithms in control systems. Control of inrush current & to adjust the speed for a specified load can be feedback by a neural network based estimator. [30].

Induction motor mathematical modelling in healthy & in faulty condition was also proposed. Whenever fault occurred in the motor, the stator current became unbalanced. And if the number of short circuited winding turns increased, the chances of the fault also increased. By selecting number of neurons and number of parameters of induction motor in hidden layer effects on precision of fault detection. [21]

In doing this work following gaps come across:-

1. The Researchers had rarely used combination of a PLC (Programmable Logic Controller) in real time conjunction with MATLAB.
2. Most of the research has been of control Algorithms or Real time Monitoring & Protection have both been not studied simultaneously.
3. Various Researchers have worked upon Induction motor Control techniques, combination of traditional and new generation techniques have not been used.

2. Methodology

After carrying out literature review and analysis the objectives of the work were as follows:

- To design the strategy for monitoring of Induction Motor.
- To implement the fault protection of Induction Motor using supervisory control.
- To control the speed of induction motor with conventional method.
- To compare the performance of conventional method with proposed method to control the speed of induction motor.

Primary goal of this work is to fulfil the protection, fault detection, adaptive control of induction motor. Our developed system consist of five main parts supply unit, VFD unit, PLC, synchronization unit & ANN. Various control schemes have been presented for protection of induction motors. We are presenting protection of induction motor using feedback of signal into PLC then to analyse the signals into Matlab for comparing the required output. In Matlab the signals were compared with the desired output and then by deciding the Matlab method i.e. ANN or Proportional control final output comes and gives signal to PLC.

In this process the author initially set desired RPM and then started the motor and meanwhile signals coming feedback to Matlab compares the generating signal for PLC. And now PLC will trigger the signal to VFD for speed control of motor and hence motor RPM were achieved.

3. Process Flow of Proposed Work

The below diagram represents, the details of the architectural design of the proposed work, details of the input data, hardware and software which were selected to carry out the experimentation to achieve the objectives.

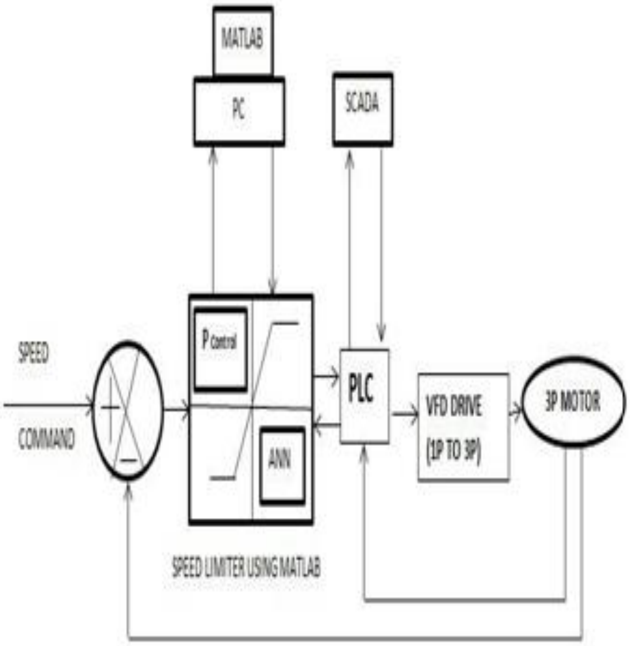

Fig. 1: Process Flow Diagram

In the above diagram speed command is given to the motor. And using motor speed signal feedback into PLC. Then analyse the signals into Matlab for comparing the required output. In Matlab the signals were compared with the desired output and then by deciding by the Matlab method i.e. ANN or Proportional control final output comes and gives signal to PLC.

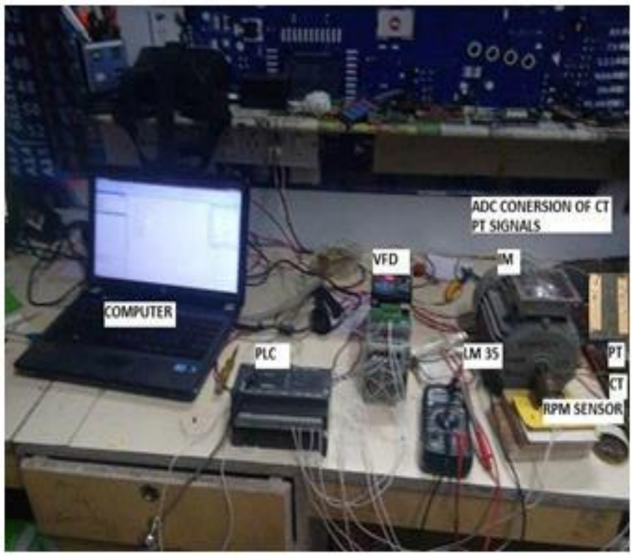

Fig. 2: set up of proposed work

As we can see in the above diagram PLC (programmable logic controller) is placed in between Computer & Induction motor. The Matlab neural network toolbox used is NNTOOL. CT's (current transformer) measures the current of all three phases. PT's (potential transformer) measures the voltage of all three phases. LM 35 IC is used for temperature measurement. The LM 35 IC is affixed on stator for measuring the temperature of stator of motor.

4. Process Flow Diagram

Process flow provides the information about the common approach that is followed in the work in order to carry out the result.

(a). Process flow of Proportional Control Algorithm

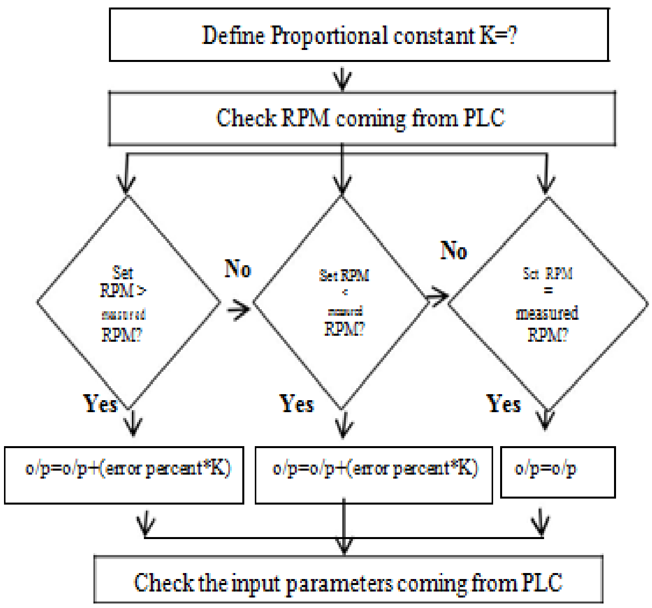

Fig. 3: Process flow of Proportional control algorithm

Fig 3 shows after selecting mode in MATlab, the operator need to define proportional constant K=?. After defining proportional constant MATlab will check parameters coming from PLC.

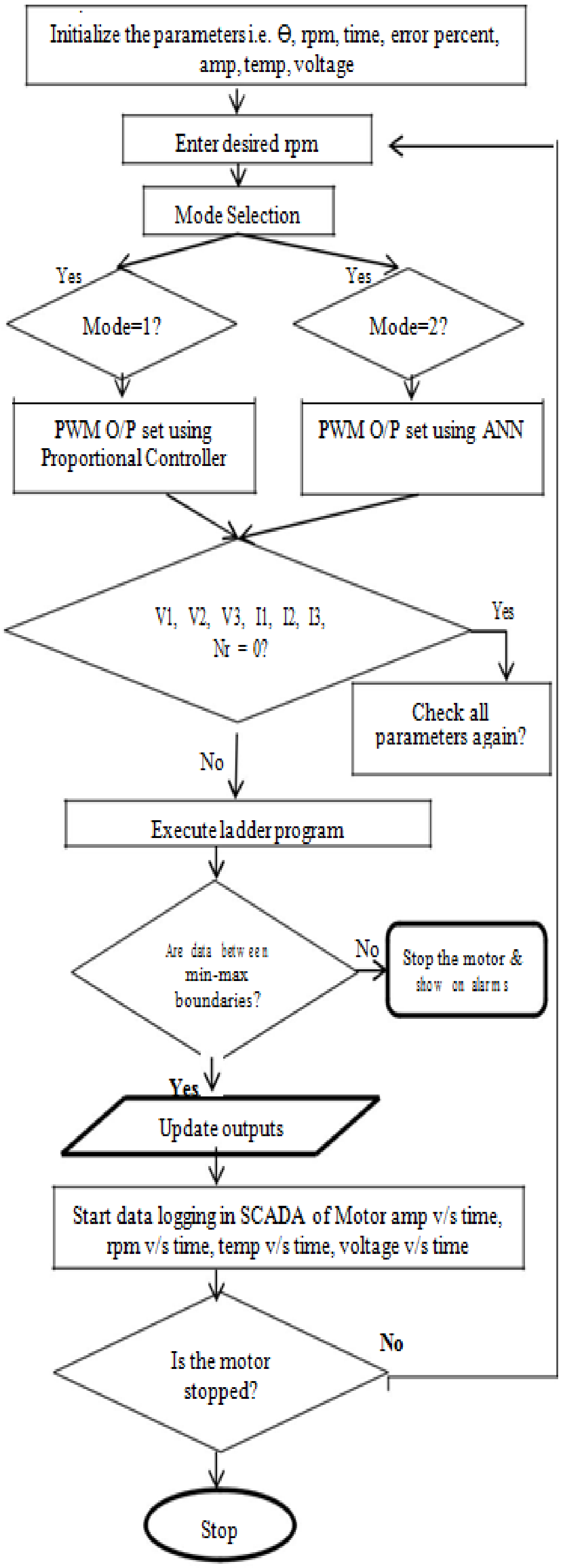

Fig. 4: Process flow of proposed work

Fig. 4 shows that first input command of desired RPM is given and then after selecting input method, motor will start to run. In Matlab the signals were compared with the desired output and the by deciding by the Matlab method i.e. ANN or Proportional control final output comes and gives signal to PLC. PLC will give signal to VFD.

(b). Process flow of ANN algorithm

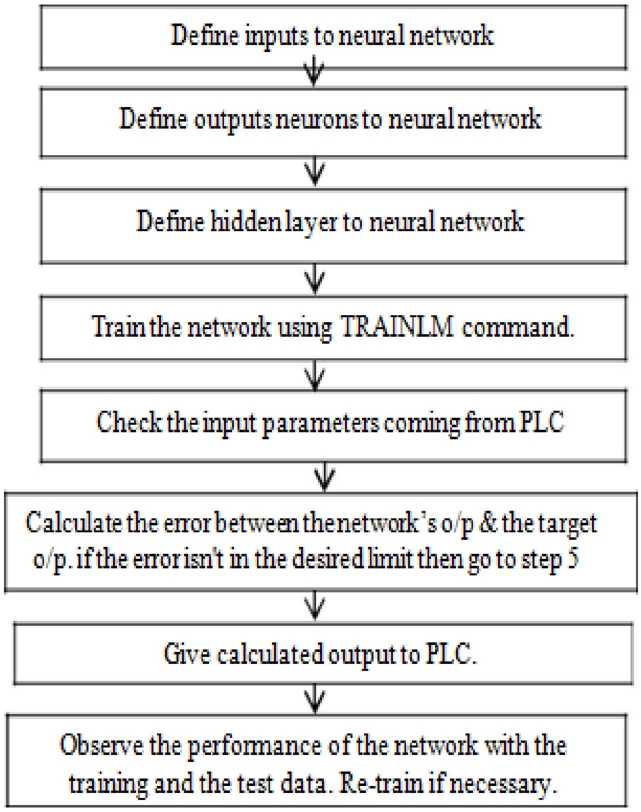

Fig. 5: Process flow of ANN algorithm

Fig 5 shows that first define inputs to neural network. Then define outputs neurons to neural network. Then define hidden layer to neural network. Then train the network using TRAINLM command.

(c). Process flow of PLC algorithm

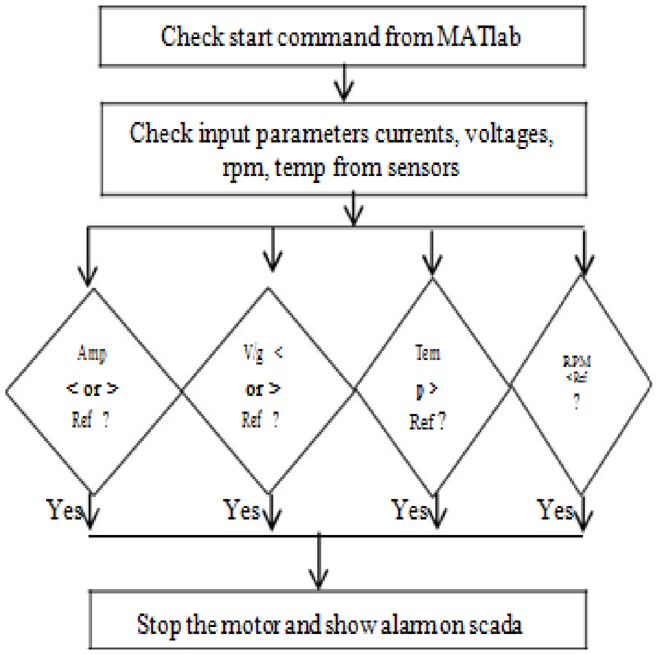

Fig. 6: Process flow of PLC algorithm

Table 1: Induction Motor Faults Monitored

		Input parameters						Faults monitored on SCADA
I1	I2	I3	V1	V2	V3	Mr	Tm	Types of faults
0	0	0	0	0	0	0	X	Motor stopped (i.e. three phase are not coming)
0	≥M	≥M	M	M	M	≤M	X	Phase 1 winding is not conducting
≥M	0	≥M	M	M	M	≤M	X	Phase 2 winding is not conducting
≥M	≥M	0	M	M	M	≤M	X	Phase 3 winding is not conducting
0	0	0	M	M	M	≤M	X	All phases winding are not conducting
0	≥M	≥M	0	M	M	≤M	X	Supply in phase 1 is cut off.
≥M	0	≥M	M	0	M	≤M	X	Supply in phase 2 is cut off.
≥M	≥M	0	M	M	0	≤M	X	Supply in phase 3 is cut off.
>Ref	≤M	≤M	*	*	*	0	X	Short circuit in phase 1 is possible.
≤M	>Ref	≤M	*	*	*	0	X	Short circuit in phase 2 is possible.
≤M	≤M	>Ref	*	*	*	0	X	Short circuit in phase 2 is possible.
≥M	≥M	≥M	>Ref	M	M	M	X	Voltage in phase 1 is over limit.
≥M	≥M	≥M	M	>Ref	M	M	X	Voltage in phase 2 is over limit.
≥M	≥M	≥M	M	M	>Ref	M	X	Voltage in phase 3 is over limit.
≥M	≥M	≥M	>Ref	>Ref	M	M	X	Voltage in phases 1 & 2 over limit.
≥M	≥M	≥M	M	>Ref	>Ref	M	X	Voltage in phases 2 & 3 over limit.
≥M	≥M	≥M	>Ref	M	>Ref	M	X	Voltage in phases 1 & 3 over limit.
≥M	≥M	≥M	>Ref	>Ref	>Ref	M	X	Voltage in all phases are over limit.
≤M	≥M	≥M	<Ref	M	M	≤M	X	Voltage in phase 1 is in lower limit.
≥M	≤M	≥M	M	<Ref	M	≤M	X	Voltage in phase 2 is in lower limit.
≥M	≥M	≤M	M	M	<Ref	≤M	X	Voltage in phase 3 is in lower limit.
≤M	≤M	≥M	<Ref	<Ref	M	≤M	X	Voltage in phases 1 & 2 is in lower limit.
≥M	≤M	≤M	M	<Ref	<Ref	≤M	X	Voltage in phases 3 & 2 is in lower limit.
≤M	≥M	≤M	<Ref	M	<Ref	≤M	X	Voltage in phases 1 & 3 is in lower limit.
≤M	≤M	≤M	<Ref	<Ref	<Ref	≤M	X	Voltage in all phases is in lower limit.
M	M	M	M	M	M	M	>Ref	Temp of motor is over the limit. Stop the motor.
0	>Ref	>Ref	M	M	M	0	X	Phase 1 is cut off or there is a Cut off in supply.
>Ref	0	>Ref	M	M	M	0	X	Phase 2 is cut off or there is a Cut off in supply.
>Ref	>Ref	0	M	M	M	0	X	Phase 3 is cut off or there is a Cut off in supply.

Different type of 29 faults monitored and used for protection of induction motor. The faults are demonstrated on the alarm screen of SCADA. To remove the alarm, the system is reset by checking on the acknowledge button on SCADA. If the alarm remains still active, it cannot be removed by checking on the acknowledge button on SCADA. Where “x” indicates none value in the table. And “M” represents the normal value & “Ref” represents the reference value.

5. Experimental Setup

VFD is generally a power conversion device which is used to convert the fixed AC voltage and its frequency supplied from the incoming power to a variable voltage at variable frequency output as required as per the load.
As we are using Allen Bradley Power Flex 4M VFD for controlling the speed of IM. The Allen-Bradley Power Flex 4M AC drive is the compact in size and less cost, which supplies powerful motor operations in a compact space saving design. It provides the application flexibility to meet the demands such as space savings, easy wiring and ease-of-programming. [13]
The application of VFD varies from small electrical appliances to the large load such as, aerospace, mine mill drives and the compressors used in various industries.
For this work we have used analog inputs selection of parameters of VFD. As from PLC 0-10 v DC is coming and this signal will become input of VFD. And hence according to PLC commanding signal VFD input will vary and hence speed will vary.

Table 2: VFD Specifications used in the Experiment

Rated output	0.75 kW (1 Hp)
Rated Voltage	240 V AC, single phase
Rated Current	4.2 A
Rated Torque	3.5 Kg

Table 3: Motor Specifications used in the Experiment

Rated RPM	3000
Rated Voltage	415 V AC
Rated Current	1.5 A
Rated Torque	0.75 KW

Different alarms are generated in this work. These are under voltage, Overvoltage, Overcurrent, over temperature etc.
The Matlab neural network toolbox used is NNTOOL. And learning rule is Levenberg-Marquardt algorithm optimisation procedure. The Levenberg-Marquardt is also known as the damped least square. It provides numerical solution for the problems by minimizing the function, generally non-linear, over a space of parameter functions. This algorithm provides best curve fitting approach. CT's (current transformer) will measure the current of all three phases. PT's (potential transformer) will measure the voltage of all three phases. LM 35 IC is used for temperature measurement. The LM 35 IC is affixed on stator for measuring the temperature of stator of motor.

6. Results

Total three scenario were taken for controlling speed of Induction motor
Scenario 1:- Speed control of Induction motor @ 1000 RPM
Scenario 2:- Speed control of Induction motor @ 2000 RPM
Scenario 3:- Speed control of Induction motor @ 2500 RPM

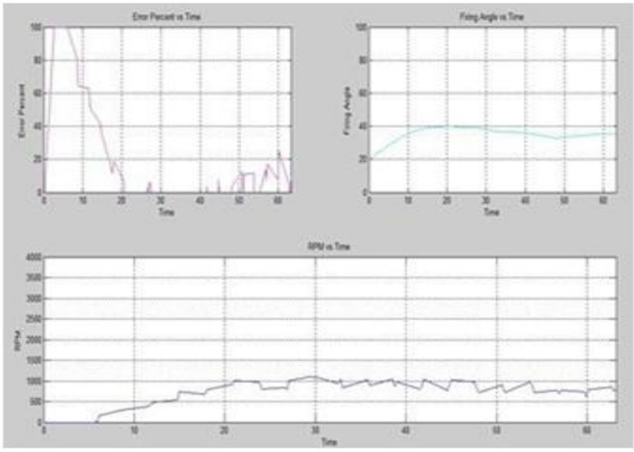

Fig. 7: Monitoring in Matlab with Proportional Control K=0.05 @ 1000 RPM

Fig 7 shows that the desired RPM is set to 1000 RPM, & use Proportional control Method, the desired RPM is achieved in 30 Sec. The Avg. Error Range in RPM is ±100 & Avg. Current 0.38Amp

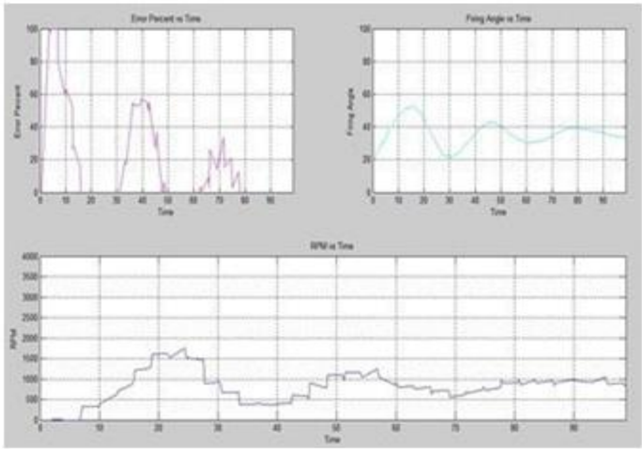

Fig. 8: Monitoring in Matlab with Proportional Control K=0.10 @ 1000 RPM

Fig 8 shows that the desired RPM is set to 1000 RPM, & use Proportional control Method, the desired RPM is achieved in 60 Sec. The Avg. Error Range in RPM is ±400 and Avg. Current 0.40 Amp.

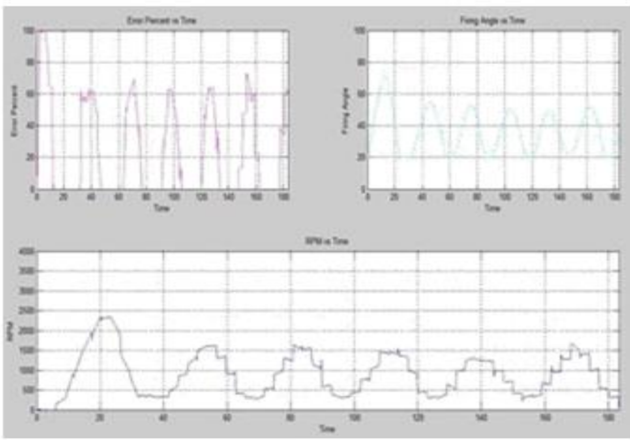

Fig. 9: Monitoring in Matlab with Proportional Control K=0.15 @ 1000 RPM

Fig 9 shows that the desired RPM is set to 1000 RPM, & use Proportional control Method, the desired RPM is achieved in 80 Sec. The Avg. Error Range is ±900 and Avg. Current 0.44 Amp.

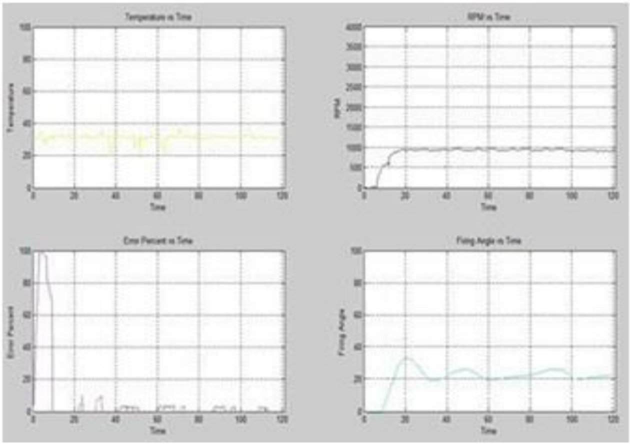

Fig. 10: Monitoring in Matlab ANN@ 1000 RPM

Fig 10 shows that the desired RPM is set to 1000 RPM, & use ANN control Method, the desired RPM is achieved in 10 Sec. The Avg. Error Range is ±50 and Avg. Current 0.31 Amp.

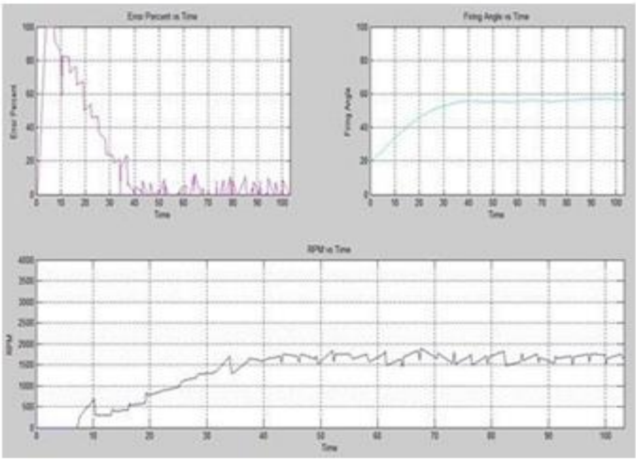

Fig. 11: Monitoring in Matlab with Proportional Control K=0.05 @ 2000 RPM

Fig 11 shows that the desired RPM is set to 2000 RPM, & use Proportional control Method, the desired RPM is achieved in 80 Sec. The Avg. Error Range is ±100 and Avg. Current 0.36 Amp.

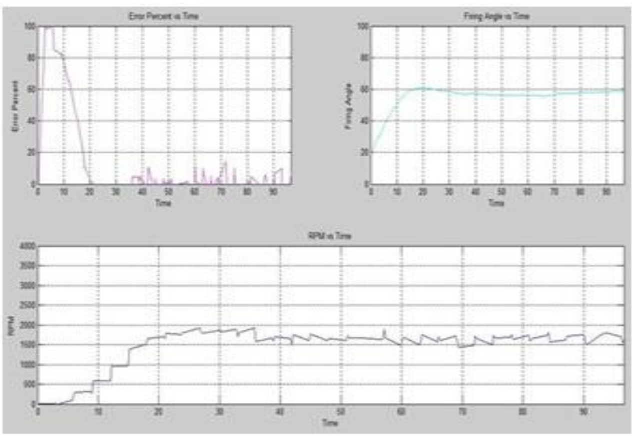

Fig. 12: Monitoring in Matlab with Proportional Control K=0.10 @ 2000 RPM

Fig 12 shows that the desired RPM is set to 2000 RPM, & use Proportional control Method, the desired RPM is achieved in 30 Sec. The Avg. Error Range is ±300 and Avg. Current 0.38 Amp.

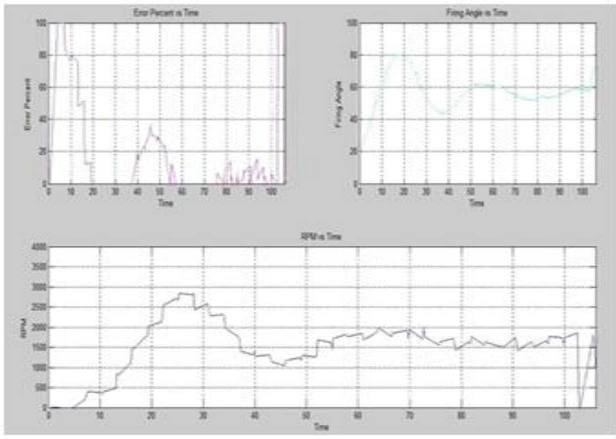

Fig. 13: Monitoring in Matlab with Proportional Control K=0.15 @ 2000 RPM

Fig 13 shows that the desired RPM is set to 2000 RPM, & use Proportional control Method, the desired RPM is achieved in 60 Sec. The Avg. Error Range is 500 and Avg. Current 0.41 Amp.

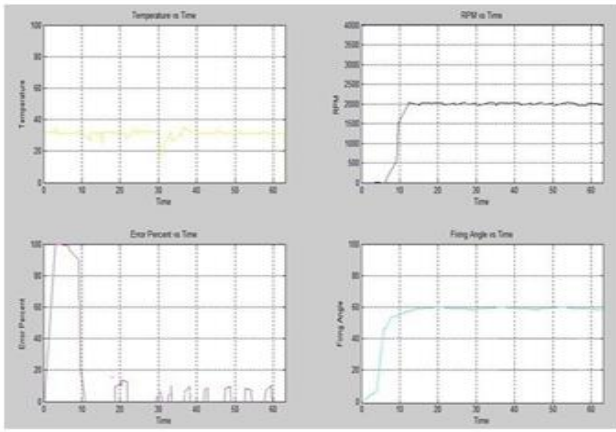

Fig. 14: Monitoring in Matlab with ANN @ 2000 RPM

Fig 14 shows that the desired RPM is set to 2000 RPM, & use Proportional control Method, the desired RPM is achieved in 10 Sec. The Avg. Error Range is ±50 and Avg. Current 0.30 Amp.

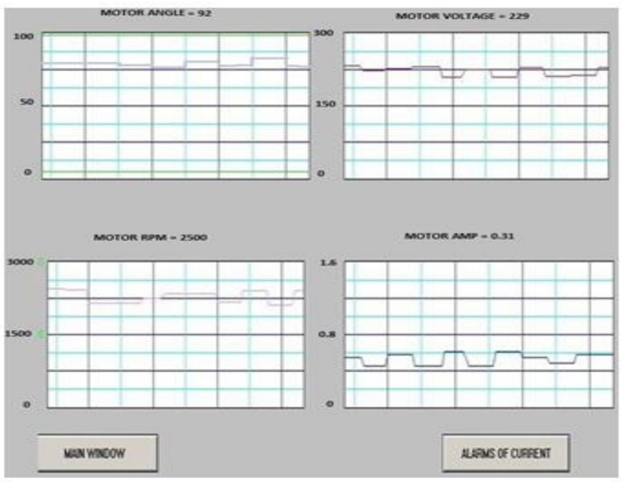

Fig. 15: Monitoring in SCADA with ANN @ 2500 RPM

Table 4: Experimental Results and Analysis

S. No.	Desired RPM	Method	RPM Settlement Time	Avg. RPM Error	Avg. Amp
1.	1000	P=0.5	30 Sec.	100	0.38
2.	1000	P=0.10	60 Sec.	400	0.40
3.	1000	P=0.15	80 Sec.	900	0.44
4.	1000	ANN	20 Sec.	50	0.31
5.	2000	P=0.5	28 Sec.	100	0.36
6.	2000	P=0.10	30 Sec.	200	0.38
7.	2000	P=0.15	60 Sec.	500	0.41
8.	2000	ANN	10 Sec.	50	0.30
9.	2500	P=0.5	20 Sec.	90	0.18
10.	2500	P=0.10	25 Sec.	150	0.23
11.	2500	P=0.15	50 Sec.	250	0.26
12.	2500	ANN	6 Sec.	30	0.16

7. Conclusion and Future Work

Following Experimental Scenarios were considered during experimentation in this Work:-

- Performance Analysis of Induction Motor Monitoring technique.
- Performance Analysis of Induction Motor Controlling technique.
- Performance Analysis of Induction Motor Fault protection technique.
- Performance Comparison of Proportional control
- Algorithm and Artificial Neural Network control Algorithm.

Table 5: Comparative Analysis of Results

Table 5: Comparative Analysis of Results

RPM	Method	RPM Achievement Time(Sec)	% Improvement
1000	Proportional @ K=0.05	30	----
	ANN	**9**	**21 %**
2000	Proportional @ K=0.05	28	----
	ANN	**10**	**18%**
2500	Proportional @ K=0.05	20	----
	ANN	**6**	**14%**

Table 5 shows that two algorithms Proportional Control and ANN had 21 % of best improvement in results at 1000 RPM. And At 2000 RPM best result 18 % was achieved. And at 2500 RPM best result was 14 %.

The experimental results showed that the performance of ANN Algorithm has been **14-21 %** better than only Proportional Control algorithm. Monitoring, fault detection & protection of induction motor was successfully achieved.

In future other algorithms may be implemented like FLC, ANN, ANFIS, SVM, SHORT TIME FOURIER TRANSFORM & DISCRETE WAVELET TRANSFORM ETC.

References

[1] N. Nakiya, M. Makwana and Ramesh Gajera." An Overview of a Continuous Monitoring and Control System For 3-Phase Induction Motor Based on Programmable Logic Controller and Scada

Technology." In International Journal of Electrical Engineering & Technology (Ijeet) on, pp. 188-196.IJEET-2013.
[2] A.mikkor, Lembit Roosimölder. "Programmable logic controllers in Process Automation." 4th International DAAAM Conference in" Industrial Engineering–innovation as competitive edge for sme.pp.1-3,2004.
[3] A. F. Kheiralla, et al. "Design and Development of a Low Cost Programmable Logic Controller Workbench for Education Purposes." International Conference on Engineering Education–ICEE. Pp. 1-3,ICEE, 2007.
[4] A. Kale, Amle, M. A., Gawade, M. S., & Tekale, M. G."Plc Based Automatic Fault Detection of Induction Motor", International Journal of Recent Innovation in Engineering and Research, pp.117-120, IJRIER, 2017.
[5] B. Kar Narayan, K. B. Mohanty, and Madhu Singh. "Indirect Vector Control of Induction Motor Using Fuzzy Logic Controller." In Environment and Electrical Engineering (EEEIC), 2011 10th International Conference on, pp. 1-4.2011.
[6] Borse, Chetan, Akshay Pandhare and Randhir kumar,." Plc Based Induction Motor Starting and Protection" International Journal of Engineering Research and General Science, pp. 893-897, IJERGS. 2015
[7] D. Sowmiya, "Monitoring and Control of a PLC based VFD fed Three Phase Induction Motor for Powder Compacting Press Machine." In Intelligent Systems and Control (ISCO), 2013 7th International Conference on, pp. 90-92. IEEE, 2013.
[8] Isam M. Abdulbaqi, abdulalrahim T. humod, Omar alazzawi," Bearing Fault Detection of Induction Motor using ANN based in LabVIEW", International Journal of Scientific & Engineering Research, pp 739-743, May-2016
[9] Irfan, M., Saad, N., Ibrahim, R., & Asirvadam, V. S. "An Intelligent Diagnostic System for the Condition Monitoring of AC Motors". In Industrial Electronics and Applications (ICIEA), (pp. 1248-1253). 2013
[10] M.G. Ioannides, "Design and Implementation of PLC-based Monitoring Control System for Induction Motor." IEEE transactions on energy conversion pp 469-476. (2004).
[11] M. Endi, Y. Z. Elhalwagy. "Three-layer PLC/SCADA System Architecture in Process Automation and Data Monitoring." In Computer and Automation Engineering (ICCAE), pp. 774-779. IEEE, 2010.
[12] M. Pineda, Puche-Panadero, R., Riera-Guasp, M., Sapena-Bano, A., Roger-Folch, J., & Perez-Cruz, J. (2011, August). "Motor Condition Monitoring of Induction Motor with Programmable Logic Controller and Industrial Network". In Power Electronics and Applications (pp. 1-10). (EPE 2011),
[13] M. Sreejeth, Parmod Kumar, and Madhusudan Singh. "Development of Supervisory Control for Distributed Drives System." In Power Electronics, Drives and Energy Systems (PEDES) pp. 1-4. IEEE, 2010.
[14] Magzoub, Muawia A., Nordin B. Saad, and Rosdiazli B. Ibrahim. "An Intelligent Speed Controller for Indirect Field-oriented Controlled Induction Motor Drives." In Clean Energy and Technology (CEAT), pp. 327-331. IEEE, 2013.
[15] M. Ambore, Prof. M. S. Badmera," PLC & SCADA based Condition Monitoring of Three Phase Induction Motor", IJRCCE Vol. 4, Issue 6,pp 11574-11580 June 2016.
[16] N.solaiyammal, N.Kanagapriya" Fault Detection, Protection and Monitoring of Induction Motor Using Zigbee", International Journal of Engineering, Business and Enterprise Applications (IJEBEA), IJEBEA 15-115; © 2015
[17] P. Ahuja, Rajiv Kumar, Kumar Dhiraj," Control and Monitoring of 3 – Phase Induction Motor Using PLC", International Journal of Innovative Research in Science,Engineering and Technology, Vol. 5, Issue 2, pp 1225-1230,February 2016
[18] P.Tripura and Y.Srinivasa Kishore Babu, "Fuzzy Logic Speed Control of Three Phase Induction Motor Drive", International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:5, No:12,pp 1769-1773, 2011
[19] Pampashree, Md.Fakhruddin Ansari," Design and Implementation of SCADA Based Induction Motor Control," ISSN : 2248-9622, Vol. 4, Issue 3(Version 5), pp 5-18, March 2014,
[20] R. Bayindir, Bektas, A., "Fault detection and protection of induction motors using sensors." IEEE transactions on energy conversion, 23(3), pp.734-741.2008.