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Safe operation of Induction Motor with Programmable Logic Controller and Human Machine Interface

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Abstract: Energy efficiency of Induction motor (IM) is essential in the current scenario due to the reasons such as energy conservation and economic saving. In this project, the implementation of the safe speed control of IM is done. The Programmable Logic Controller (PLC) monitors the speed and trips the motor under safety requirements. PLC is used to control three phase IM with the Variable Frequency Drive (VFD). The availability of drive data and software helps to manipulate and analyze process the information. The Human Machine Interface (HMI) is used for the visual monitoring and control of the induction motor. The PLC based control platform makes system to be communicated to other devices on network and makes the system more flexible for its operation and control. The results shows that, the speed of the induction motor varies linearly with the change in frequency in HMI and the motor trips if there is any human interference within 10 cm operating range of IM.

Keywords **:** ***Human Machine Interface (HMI), Induction motor (IM), Programmable Logic Controller (PLC) Speed Control, Variable Frequency Drive (VFD).***

I. INTRODUCTION

Nowadays the main research focus in Electrical Engineering is to improve energy efficiency and to explore new effective and more intelligent ways to utilize electricity. The awareness of concept of energy conservation is required to save electricity for the future generation. Even the energy saving of 0.01% yields lots of benefit to the nation. Electric motors are industries basic need. Industries consume about 50% of the power generated in the country and electric motors consume about 72% of the total electricity used in the industrial power. Three phase IMs are the prime source of energy consumption in industry.

Industrial applications such as elevators, cranes, lathes, drilling machine, blower, fans, pumps, etc. are actuated by induction motors due to their reliability, low cost, robustness and easy maintenance.

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The speed control of motor with human machine interface results in high performance variable-speed applications. In number of industries, motors must satisfy very strict speed requirements, both with respect to the range and smoothness of control as well as economical operation.

However, IMs take reactive power from the supply system to setup its working air gap flux causing the IM to always operate at lagging power factor (pf). Hence, organizations having a large number of IMs cause huge transfer of reactive power from the utility to the network grid. This results in an increase in the network losses and reduction in the voltage level leading to poor reliability, safety problems and higher energy costs.

On line condition monitoring of electrical machines has become n area of growing interest and importance. It relies on the graphical trend of the machine parameters for detecting machine problems before the failure takes place. Because of the key role that IMs play in many industrial processes, the prevention of machine failures causing unplanned production shutdowns can significantly increase profits.

The use of the VFDs for the starting of the induction motor reduces the high inrush current, thus preventing the sag developing the distribution lines. The speed control is also easily achieved by using the VFD. Combining these drives with PLC control can result in great energy efficiency, which can in turn have impact o global warming. The technology advancement and availability of electric drives, the automation systems in manufacturing units are introduced with PLC.

The automation processes with the use of PLC increases reliability and flexibility and also reduces production costs. Power converters, personal computers and other electric equipments are interfaced with PLC to obtain accurate industrial electric drive systems.. By the use of the PLC and Human Machine Interface (HMI) system entire system can be monitored.

II. LITERATURE REVIEW

Muawia et al. (2015) used the VFD for controlling the speed of the induction motor. The author stated that the drawback of the Field oriented control is overcome by using Hybrid Fuzzy-Fuzzy Controller. The controller is analyzed and found that the controller is an efficient, reliable one which is robust to control load and noise disturbances.

Jain et al. (2016) used the PLC for the power factor correction of the three-phase induction motors.

The three-phase induction motor has a low power factor (pf) at no load as it draws large magnetizing current and the active power delivered to the motor is low, which is utilized to overcome the no-load losses. Based on the measured pf value, the PLC switches the approximate capacitor banks into the circuit to improve pf. large scale use of PLC in industrial automation, adaptability, simple implementation and economics justified its selection as the switching controller. Use of PLC as a PFC has proved to be a versatile, efficient and cost-effective tool for an industrial application, especially for organizations employing a large number of IMs. This results in the improvement of the power quality and substantial saving in energy cost and conservation of energy.

Sánchez et al. (2013) developed an open, multilevel condition monitoring system for IMs. The parameters of the IM are measured with commercial, industrial equipment transmitted to a PLC. An OPC client-server with SCADA program is used to display the motor status, and it stores the data perform trend analysis. The use of open specifications for data communications and PLC software development has allowed the construction of the proposed system using industrial, commercially available components, instead of requiring custom-developed equipment. This approach also facilitates its integration into information networks at the enterprise level.

Bocker (2007) briefly explained various control schemes for the induction motor. He discussed the control aspects of IM drives and sensorless control of the IMs. Also, he discussed the industrial standards for the IM. The FOC is a Feed-forward control by calculating the slip frequency from the reference values. The Direct Self Control (DSC) and Direct Torque Control (DTC) govern the stator flux employing hysteresis control. The difference is that DSC performs hexagonal flux trajectory and DTC is circular. Both possess high torque dynamics compared to FOC. Both techniques have variable switching frequency and higher torque ripple. The sensorless speed control is used because of reduced cost.

Rinchen Geongmit Dorjee et al. (2014) presented the model for the monitoring and control of VFD using PLC and SCADA. VFD was controlled using SCADA integrated PLC system. The human operator also cans monitor the entire process with HMI.

Sagar P.Jain and Sanjay L.Haridas have put forward VFD for conveyor assembly in an automated bottling plant. The MicroLogix 1400 PLC is used with RSLOGIX 500 and RS LINX 500 for programming and communication.

S.Takiyarand B.K.Chauhan (2013) delineated paper on Hybrid method for customized control of Induction Motor using PLC. This system featured and adaptive control for flexible operation. This control system has the ability to evolve its control strategy for flexible operations continuously. The comparison of speed torque performance and efficiency of PLC based and inverter-based VFD were presented.

R. CharletPriya (2014) has simulated the design of VFD Induction Motor using seven-level inverters developed from modified H-bridge in air conditioners for power reduction. The use of VFD in the AC will reduce the high in-rush current which makes the AC consume more power and facilitates constant power consumption. The unipolar or bipolar output voltage switching is provided by the inverter to provide in seven different switching states. PROTEUS SIMULINK software is used for the simulation.

Ankur P. Desai et al. (2014) illustrated the energy conservation using variable frequency drive in pumping application. Torque speed characteristics of VFD were analyzed with different operating modes. The comparison analysis of pumping operation with and without VFD is shown in the paper.

Thavatchai Tayjasanant et al. (2005) presented that in Inter harmonic- Flicker curves by a limit for inter harmonics is being proposed in this paper by considering the published limits for voltage flicker. Flicker Curve is the curve of inter harmonic magnitude versus inter harmonic frequency. Enhancement is to be done with IEC flicker meter when it dealt with harmonic caused flickers. The VFDs typically produce pair of inter harmonic currents with the same magnitude. These currents will interact with the system impedance, resulting in two inter harmonic voltages of different magnitudes. The relationship between inter harmonic and flicker is determined. Generation of inter harmonics from Current Source Inverter (CSI) VFD is demonstrated and illustrated with an example for precise understanding.

Sanjay N. Huse et al. (2015) have presented a case study for the water supply system to buildings. The main concerns such as throttling were considered while designing VFD for the system. The throttling effect can be minimized, and the extra power consumption can be saved by the application of the VFD as shown in the paper. The use of the VFD drive provides significant savings in both cost and GHG emissions. The flowchart for the automatic control of motor pumps is also shown in the paper.

Robert A. Hanna (1989), discussed the harmonics that are generated in the VFDs. Various source of current and voltage harmonics and their effects are discussed. The presence and analysis of harmonics are explained with the help of a few cases. The author concludes that the order and magnitudes of the harmonics generated are dependent on drive configuration and system impedance.

Vaibhav Gupta (2018) demonstrated the induction motor speed control using PLC and SCADA in his study. The measured speed using a tachometer is fed it the PLC. PLC takes action based on the desired input, and then the signal is transferred to the motor via driver to increase / decrease the speed. In this study, the control system will be held using the available Siemens PLC.

In IM the controlling of speed is not an easy task. Various types of starters are used for the starting of the IMs. But due to low cost the DOL starter is widely used. The DOL starter is cheap and easy to operate but it has the major disadvantage that during motor starting high inrush current is drawn from the supply line which will affect the electronic devices connected to the supply line. In order to avoid this need of the soft starters are increasing.

From the above literature review, it is summarized that the number of experimental studies has been conducted to analyze the problems with the speed control of induction motor. It shows that many researchers have been taking effort on developing a precise control system for the induction motor.

The induction motor using the Direct online (DOL) Starter draws high inrush current from the distribution system. The use of the VFDs will reduce power consumption.

III. METHODOLOGY

The block diagram of Induction Motor Speed Control Using PLC and HMI is shown in figure 1.

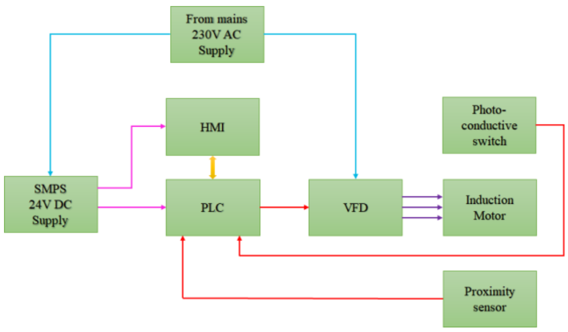

Figure 1. Induction Motor Speed Control Using PLC and HMI

The above block diagram shows the control system to control the speed of a 3-phase induction motor. The proposed system consists of Power Supply, SMPS, PLC, HMI, VFD, IM, Proximity Sensor and Photoconductive Switch. The 230V AC supply is taken from the mains and given to the VFD and the SMPS. The 24V DC supply is given to all the equipments other than the IM. The output of the VFD is 440V AC supply which is fed to the IM. In the taken project the PLC used is Siemens S7-1200 1214 AC/DC/RLY which has 14 Digital inputs and 10 Digital output each of 24VDC and two analog inputs (0-10) V. The VFD is Siemens Sinamics V20 which converts 230V single phase supply to 3-phase 440V supply. The HMI is Siemens KTP 700 Basic which has 8 Screens. Specifications of equipments used are presented in tables 1, 2, 3 and 4.

Table-I: Specifications of VFD

Power	
Input Voltage	1Φ 230V AC
Output Voltage	3Φ 400V AC
Power Factor	≥0.95/0.72
Supply Frequency	50/60 Hz
Overload Current	150% of rated current
Signal Inputs and Outputs	
Analog input	AI1: Bipolar Current/Voltage AI2: Unipolar Current/Voltage Can be used as digital inputs
Analog output	AO1: 0-20mA
Digital inputs	DI-DI4, optically isolated PNP/NPN selectable by terminal

Table -II: Specification of PLC

Product Description	
Make	Siemens
Model	SIMATIC S7-1200, CPU 1214C, AC/DC/relay
Inputs	14 DI: 24V DC 2 AI: 0-10V DC
Outputs	10 DO relay
Supply	85-264V AC
Frequency	47-63 Hz

Table -III: Specification of HMI

Product Description	
Make	Siemens
Model	SIMATIC S7-1200, CPU 1214C, AC/DC/relay
Inputs	14 DI: 24V DC 2 AI: 0-10V DC
Outputs	10 DO relay
Supply	85-264V AC
Frequency	47-63 Hz

Table- IV: Specification of IM

Make	Siemens
Type	3-phase AC induction motor
Voltage	415V AC
Current	1.2A
Power	0.37
Rated Speed	1385 RPM
Frequency	50 Hz

IV. RESULT AND DISCUSSION

The control system is designed to run the motor in the desired speed. The PLC is the controller which is used to control the speed of the IM. By the use of the PLC the motor is made to run in both forward and reverse direction. By varying the analog output (0- 10V) from the PLC, the frequency of the VFD can be changed. The speed of the induction is measured by using the proximity sensor. The output of the proximity sensor is given to the PLC. There is an inbuilt high-speed counter present in the PLC. The Photoelectric switch is used to detect any interference near the induction motor. If there is any interference, the output of the photoelectric switch goes high, and the system will stop. The connection diagram between PLC and VFD is shown in figure 2.

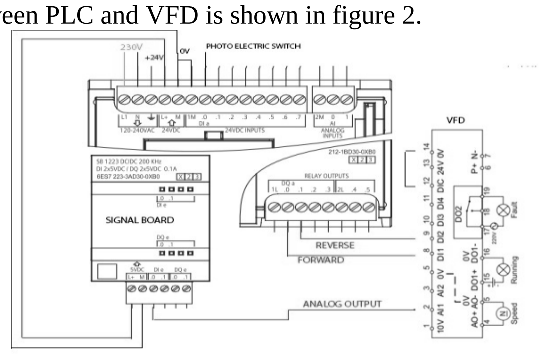

Fig 2. Connection between PLC and VFD

From the figure2, it is observed that the 230VAC supply is given to the PLC from the SMPS. The output of the photoelectric switch is given to the pin I0.0, and the output from PLC Q0.0 is given to pin DI 1 of the VFD and the output Q0.1 is given to DI 2 of the VFD. The analog output from the VFD A0 is given to AI 1 of the VFD. The human machine interface is shown in figure 3.

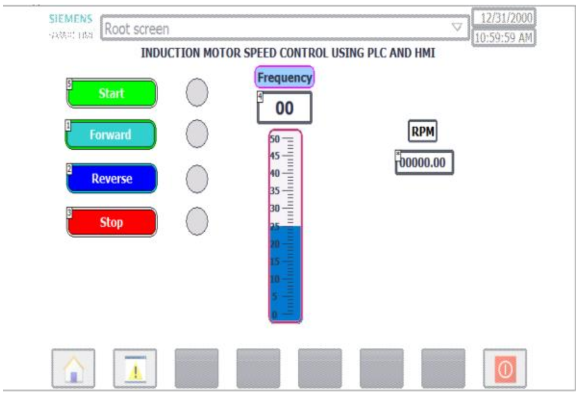

Fig 3.HMI Screen for VFD Control

From the figure3, it is seen that there are touch screen controls for the operations and mode selection. The monitoring f the speed and safety interlock is also displayed in the HMI screen. The hardware interface is shown in figure 4.

Fig 3. Hardware Setup for Induction Motor speed control using PLC and HMI

The figure 4 depicts the induction motor speed control with the Siemens PLC and HMI. The observations are tabulated in table 5.

Table-V: Performance of IM with VFD

S. No	Frequency (Hz)	Analog Output Voltage from PLC (VDC)	3-phase output Voltage from VFD (VAC)	Speed of the Motor (RPM)
1	0	0	28	0
2	2	0.39	59	58.4
3	4	0.79	76	118
4	5	0.99	89	150
5	8	1.58	110	240
6	10	1.98	123	300
7	15	2.97	163	450
8	20	3.97	195	600
9	25	4.96	234	754
10	30	5.95	244	923
11	35	6.95	245	1056
12	40	7.94	246	1204
13	45	8.93	246	1362
14	50	9.93	246	1502

From the above table, it is observed that as the input frequency to the PLC increases, the PLC output analog voltage is increased linearly. The analog output is given to the VFD analog input channel. Therefore, the increase in the analog voltage increases the 3-phase line to line output voltage which is given to the motor. The increase in the 3-phase voltage increases the speed of the motor.

V. CONCLUSION

In this paper, the design of VFD hardware system for changing the speed of the motor by changing the output frequency is presented. Finally, it is concluded that the method of speed control of three-phase induction motor using variable frequency drive is the effective and efficient method, when the operation of VFD is done by PLC. The whole system gives the operation to a level of accuracy, ability and totally with maximum safety. It is possible that, the speed control system can be implemented to control multiple motors with the same drive and programmable logic controller, the PLC system which is used in this paper also used for monitoring and controlling the other parameter of the motor with the same drive. The results show that, the speed of the induction motor varies linearly with the change in frequency in HMI and the motor trips if there is any human interference within 10 cm operating range of IM. In future the IM can be connected to various types of loads and a feedback loop control system can be implemented.

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