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A Novel Method of Induction Motor Speed Control Using PLC

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Abstract*— In any industry the induction motor plays an important role due to its low cost and simplicity. In the existing system motor speed is monitoring by HMI (Human Machine Interface). Due to this system, all parameters of motor are not monitored properly and continuous monitoring is done by man power in shift basis. The VFD consists of inverter with six power MOSFETs, PIC microcontroller and power supply. The speed of the motor is controlled by varying the frequency through Pulse Width Modulated (PWM) signals applied to the gate of the power MOSFETs. In VFD, the controls are programmed and implemented in PIC microcontroller to generate PWM gating pulses for the MOSFETs. PWM signals are pulse trains with fixed frequency and magnitude and variable pulse width. When a PWM signal is applied to the gate of power MOSFETs, it causes the output voltage of the VFD according to its turn on time. The inverter converts DC power to AC power at the required frequency and amplitude. By this the variable frequency is set by VFD and the motor speed can be changed to the required speed. The entire control system is switched by using PLC. Therefore, the main contribution of this paper is the monitoring, speed control of motor was done based on programmable logic controller, variable frequency drive and SCADA unit.
***Keywords*— Induction Motor, PLC, SCADA, VFD, PWM**

I. INTRODUCTION

In any industry the induction motor plays an important role due to its low cost and simplicity. By implementing a monitoring and control system for the speed of motor, the induction motor can be used in high performance variable-speed applications. By using open loop v/f control method, frequency can be varied from 5Hz to 75Hz but by using VFD, frequency can be varied upto 1500Hz. The induction motor can run only at its rated speed when it is connected to the main supply. However, they are constant motor. To control the speed of these motor, a motor drive and control system with different methods can be used. An induction motor's speed enable affected by the supply frequency, change the number of motor stators, adjust the power input. In an induction motor, there is no electrical connection to the rotor, but currents are induced in the rotor circuit. The rotor conductors carry current in the stator magnetic field and thereby have a force exerted upon them tending to move them at right angles to the field. When the stator winding of a three phase AC supply, a rotating magnetic field is established and rotates at synchronous speed. The direction of rotation of the field can be reversed by interchanging the connection to the supply of any two leads of a three phase induction motor.

The number of magnetic poles of the revolving field will be the same as the number of poles for which each phase of the stator winding is wound. The speed at which the field produced by the primary currents will revolve is called the synchronous speed of the motor. AC motor drives are widely used to control the speed of conveyor systems, blower speeds, pump speeds, machine tool speeds, and other applications that require variable speed with variable torque. The complete system consists of an ac voltage input that is put through a diode bridge rectifier to produce a dc output which across a shunt capacitor, this will, in turn, feed the PWM inverter. The PWM inverter is controlled to produce a desired sinusoidal voltage at a particular frequency, which is filtered by the use of an inductor in series and capacitor in parallel and then through to the squirrel cage induction motor.

A modern adjustable speed AC machine system is equipped with an adjustable frequency drive that is a power electronic device for speed control of an electric machine. It controls the speed of the electric machine by converting the fixed voltage and frequency of the grid to adjustable values on the machine side.

Synchronous speed,

$$N_s = 120 f_s / P \quad (1)$$

Where, f = supply frequency

P = poles

Synchronous speed is directly proportional to the supply frequency. Hence, by changing the output frequency, the synchronous speed and motor speed can be control below and above the normal full-load speed. For this now a days the variable frequency drive is using.

The traditional variable-frequency drive (known as volts per hertz (V/Hz) changes the motor's frequency and voltage using solid-state control units. The modern strategy for controlling the AC output of such a power electronic converters is the technique known as Pulse Width Modulation (PWM), which varies the duty cycle of the converter switches at a high switching frequency to achieve a target average low frequency output voltage or current. In principle, all modulation schemes aim to create trains of switched pulses which have the same fundamental volt–second average as a target reference waveform at any instant. Process control plays an important role in any industry/manufacturing unit. There are number of applications to control the process, SCADA is an important application that allows a utility operator to monitor and control processes that are distributed among various remote sites.

II. SUPERVISORY CONTROL AND DATA ACQUISITION

SCADA stands for Supervisory Control and Data Acquisition. SCADA refers to a system that collects data from various sensors at a factory, plant or in other remote locations and then sends this data to a central computer which then manages and controls the data. SCADA is a term that is used broadly to portray control and management solutions in a wide range of industries. One of key processes of SCADA is the ability to monitor an entire system in real time.
The main purposes for the use of a SCADA system would be to collect the needed data from remote sites and even the local site, displaying them on the monitor of the master computer in the control room, storing the appropriate data to the hard drive of the master computer and allowing the control of field devices (remote or local) from the control room. SCADA systems are equipped to make immediate corrections in the operational system, so they can increase the life-period of your equipment and save on the need for costly repairs. It also translates into man-hours saved and personnel enabled to focus on tasks that require human involvement.

III. PROPOSED SYSTEM

Proposed system block diagram shown in Fig.1 and it consists of two power supplies, one is 230V and other is 440V.The 230V supply from main is converted into 24V DC and it is given to the PLC unit. The second supply from main 440V is directly given to the VFD. The PLC (Programmable Logic Controller)unit in the block diagram is used to control the VFD and through the VFD the motor is controlled.

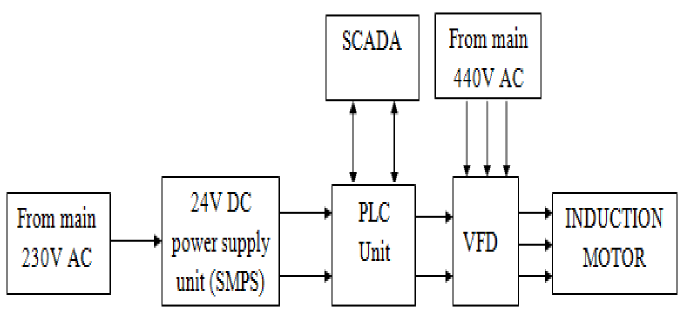

Fig.1 Block Diagram

PLC has memory for storing the user program or logic as well as a memory for controlling the operation of a process machine or driven equipment. The PLC is programmed in LADDER LOGIC (A high level, real world, graphic language that is easily understood by engineers).The speed of the motor is controlled by varying the frequency through Pulse width modulation controller. The variable frequency is set by using VFD. The VFD is connected with motor. By changing the output frequency the motor speed can be varied.

IV. PLC UNIT

Richard E. Morley, who was the founder of the Modicon Corporation, invented the first PLC in 1969.A PLC is a solid state device designed to perform the logic functions previously accomplished by components such as electromechanical relays, drum switches, mechanical timers/counters etc. for the control and operation of manufacturing process equipment and machinery. Even though the electromechanical relay (control relays, pneumatic timer relays, etc.) have served well for many generations often under adverse conditions, the ever increasing sophistication and complexity of modern processing equipment requires faster acting, more reliable control functions that electromechanical relays or timing devices cannot offer. Relays have to be hardwired to perform a specific function, and when the system requirements change, the relay wiring has to be changed or modified.

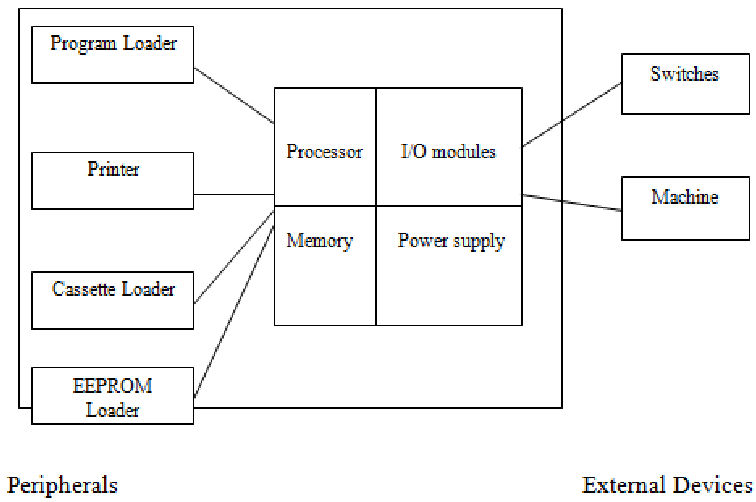

Fig.2 PLC Architecture

A. Processor

The processor show in Fig. 2 unit houses the microprocessor, memory and communications circuitry necessary for the processor to operate and communicate with the I/O and other peripheral equipment. The DC power required for the processor is provided either by a power supply that is an integral part of the processor unit or by a separate power supply unit. Processor or "brain" of the PLC is the decision maker that controls the operation of the equipment to which it is connected. It also controls the operation of the output devices that are connected to the output modules based on the status of the input devices and the program that has been entered into memory. Processors control as few as 8 or as many as 40,000 real word inputs outputs. The larger the number of input and output devices that are required for the process, the more powerful the processor must be to properly control the number of I/O that will be connected.

Processor scan does the following

- Determines the status of input device
- Interrupt logic of program (Read and solve ladder logic)
- Communication with connected devices and house keeping
- Update (Turn ON or OFF output device)

B. Memory Unit

For PLC to function properly and control a process it must be label to perform the user program repeatedly, accurately and speedily, which is achieved by processing all information in binary signals. Binary information has only two states 1 or 0 (ON or OFF, High or Low, True or False). There is no in between state or condition.

In extreme cases, such as in the auto industry, complete control panels had to be replaced since it was not economically feasible to rewrite the old panels with each model changeover. The requirement of highly specialized, high speed manufacturing process created a demand for smaller, faster acting, more reliable, low power consuming, expandable eliminating much of the hard wiring control devices called PLC's. PLC's are designed to be operated by plant engineers and maintenance personnel with limited knowledge of computers. Like the computer, PLC also has memory for storing the user program or logic as well as a memory for controlling the operation of a process machine or driven equipment. But unlike the computer, the PLC is programmed in LADDER LOGIC. The LADDER LOGIC is a high level, real world, graphic language that is easily understood by engineers.

C. Advantages of plc

Reduced space
Energy saving
Ease of maintenance
Economical

V. VFD UNIT

Among the electrical quantities, the sine wave frequency is probably the most complicated to change. Today there are two usual ways to do this, either by rotary motor-generators or by electronics. Rotary converts can convert between fixed frequencies like 50 to 60 Hz, or DC (0Hz) to AC and the opposite, but if the frequency needs to change often/dynamically like in servo motors, it can only be done by electronics.

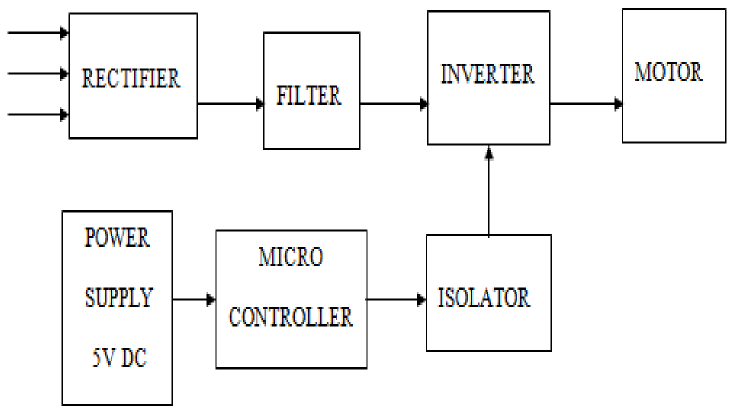

Fig.3 VFD Block Diagram

Fig.3 shows the block diagram of VFD with rectifier, filter, inverter and controller. Electronic VFD's rectifies the 50 Hz current and make a smooth DC voltage in capacitors (working like small batteries). In other words the frequency is "eliminated" from the system, or changed to zero. Then the VFD must create its own frequency by alternating the DC – voltage through transistors at the desired frequency. Also (very important) the voltage must be proportional to the frequency. It cannot output all 230 volts when the motor is near zero speed. The voltage is usually controlled by the amplitude of the sine output. Another way is to control the voltage at the input (rectifier) side.

There are two "bridges" in the VFD circuit, one is rectifier and one is Inverter Bridge. The rectifier (left) is working without any additional electronics. All electrical current is simply conducted in the same direction. When the rectified current is stored in the capacitors, the value of the voltage reach the peak value of 230V RMS which is 230*1.41 = 325V. This is a DC- Voltage like what is coming from batteries, the frequency is zero. A VFD can run from batteries (like in electric vehicles) or single phase.

The inverter bridge (the transistor) is one kind of circuit which is opposite to the rectifier. The current is conducted into the motor in the same direction as the arrows in the transistor-symbols, BUT, the transistors are not conducting at all the time like the diodes. Actually if all transistors were conducting, it would short-circuit the whole system.

VI. HARDWARE MODEL

The Fig.4 shows overall hardware model of this project. Power supply is a reference to a source of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of load is called a power supply unit or PSU. To control the speed of induction motor, a motor drive and control system with different methods can be used. The three phase induction motor is, by a very considerable margin, the most widely used AC motor in industries. The reasons are its low cost, simple and rugged construction, absence of commutator, good speed regulation. An induction motor of a medium size may have an efficiency as high as 90% and a power factor of 0.89.

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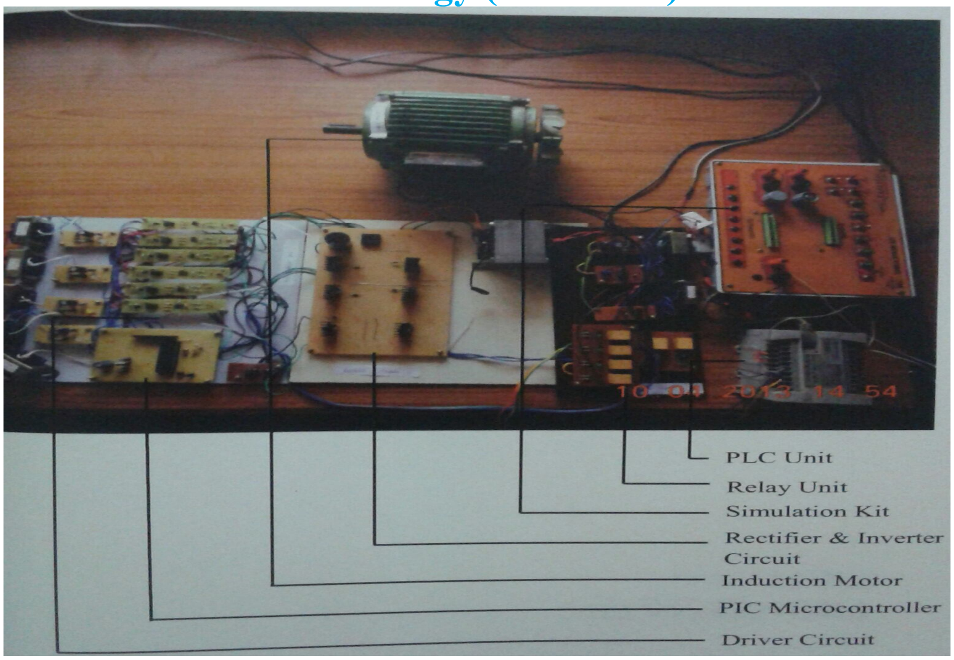

Fig.4 Hardware Model

VII. CONCLUSIONS

In this project, 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 this efficient method is connected along with PLC and SCADA 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 SCADA monitoring system can also be implemented in large scale.

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