iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** V **Month of publication:** May 2016

DOI:

www.ijraset.com
IC Value: 13.98
Volume 4 Issue V, May 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Automation of VFD Based Sugarcane Crusher with PLC and SCADA Control

N. Sadeesh[1], P. Hema[2], E. Prasannakumar[3], S. Leelakrishnan[4]

Abstract— Three phase induction motors are widely used motor in sugar industry because of its simple maintenance. In recent years, Variable Frequency Drive is used to change the rotating direction and speed of three phase induction motor. The speed of three phase induction motor is controlled and monitored using Programmable Logic Controller and Supervisory Control and Data Acquisition system in a sugar plant through Variable Frequency Drive. The sugar plant contains various stages for the production of sugar starting from the inflow of sugarcane into the crushing machine. The induction motor is used to operate the crushing machine in the sugar plant. The speed of the crushing machine depends on the quantity of sugarcane flowing into the machine. The Variable Frequency Drive controls the speed of the crushing machine depending upon the load entering by increasing or decreasing the RPM of the crushing machine. This operation is controlled by the Programmable Logic Controller and monitored using Supervisory Control and Data Acquisition system. The sensors are present in the conveyor belt which acts as input for programmed logic controller which senses a sugarcane load on the belt and send the signals to the Programmable Logic Controller.

Index Terms— VFD, Induction Motor, PLC and SCADA, Sugar Plant.

I. INTRODUCTION

A Variable Frequency Drive is consisting of the following three main sub-systems: AC machine, primary drive controller assemblage, and operating equipment interface. The AC electric motors are used in a VFD system. The three-phase induction motor is frequently the most economical motor choice.

N.Sadeesh, Electrical and Electronics Engineering, Jay Shriram Group of Institutions, Tirupur, India, Mobile No: +91-9715511180 (Email:nsadeesh@gmail.com).

P.Hema, Electrical and Electronics Engineering, Jay Shriram Group of Institutions, Tirupur, India, Mobile No: +91-7502107564.(Email:phemachoudary@gmail.com)

E.Prasannakumar, Electrical and Electronics Engineering, Jay Shriram Group of Institutions, Tirupur, India, Mobile No: +91-9842141643.(Email:prasannakumareswaran@gmail.com)

S.Leelakrishnan, Electrical and Electronics Engineering, Jay Shriram Group of Institutions, Tirupur, India, Mobile No: +91-9976285558 (Email:leelakrishnaneee@gmail.com)

The VFD controller is a power electronics conversion system consisting of three sub-systems: an AC to DC converter, a buffer and filter link, and DC to AC converter. In a VSI drive, the DC link consists of a capacitor which removes to the converter's DC output noise signal and provides a normal input to the inverter. This filtered DC voltage is changed to quasi-sinusoidal AC voltage output using the inverter's active switching elements.VSI drives supply higher power factor and lower harmonic distortion.VFD control has been chosen specifically because they give the advantages of energy savings, little motor starting current, reduction of thermal and mechanical losses on motors, simple maintenance, high power Factor and lower KVA.

Variable Frequency Drives are normally required because several applications are not run at the same speed at all the time due to surrounding circumstances. The speeds of the driven shaft need to be increased or decreased depending on load variation, application requirement. The PLC has been controlled and monitors a VFD which are the acts as a go-between 3phase induction motor and the PLC. A conveyor is connected to the induction motor and cell sensor input is connected uniformly across the conveyor. The sensor input is connected to the PLC. This processes the input according to the ladder logic programming and initiates corresponding output to the VFD.

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II. SPEED CONTROL USING VFD

The sugarcane is given to the motor in the way of conveyor. Sensor is placed in a conveyor. The sensor is sense to the weight of sugarcane. The signal is send to the PLC. Depending upon the signal information the input and also output is turned on.

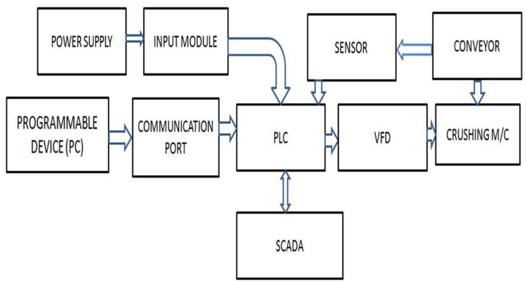

Fig.1 Block Diagram of VFD

The output is interfaced with VFD. It is get the signal from the PLC. It gives variable frequency depending upon the load. The output of the VFD is connected to the crushing machine. It gets the signal from the VFD. Depending on load the frequency is varying also speed is varying. The whole process is monitored and controlled. It is interfaced with PLC.

A. Programmable Logic Controller

A PLC is solid state equipment designed to perform the logic operations previously accomplished by components such as relays, switches, timers, counters etc. for the control and operation of developed process equipment and machinery. Even though the relays have served healthy for many generations often under unfavorable conditions, the ever increasing difficulty and complexity of recent processing equipment requires quicker acting, more reliable control functions that relays or timing devices cannot offer. Relays include to be hardwired to perform a specific function, and when the system necessities change, the relay wiring has to be adapted.

B. Supervisory Control And Data Acquisition Systems (SCADA)

SCADA is the fastest and easiest technique to create Human Machine Interface (HMI) applications for the Microsoft Windows operating systems. In intouch is a component of the wonderware factory suite. In intouch applications span the globe in a multi tube of vertical markets shared with semi-conductors, oil and gas, automotive, chemical, and pharmaceutical, pulp and paper, utilities, transportation and more. By using intouch, you can create powerful, full future applications that exploit the key techniques of Microsoft windows, it includes active X controls, ole, graphics, more. Intouch can also extended by adding custom active X controls, generic objects wizards and creating Intouch rapid script extensions. Intouch consists of three major windows, the Intouch application manager, window maker and window viewer. Intouch also includes the diagnostic program.

C. Variable Frequency Drive (VFD)

The electrical quantity, the sine wave frequency is probably the most complex to change. Today there are two normal ways to do this, either by electronics or rotary motor-generators. Rotary converters can converter between fixed frequencies like 50 to 60 Hz, or DC to AC and the opposite, but if the frequency needs to change often dynamically like in induction motors, it can only be done by electronics. Electronic VFD's rectifies the 50Hz 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. You 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.

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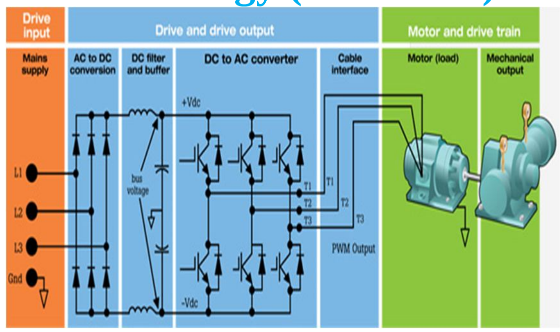

Fig.2 Circuit diagram of VFD

The figure shows the power parts of a VFD. There are two "bridges" in the circuit, one three phase rectifier and one three phase inverter bridge. The rectifier (left) is working without any additional electronics.

All electrical current is simply conducted in the same direction as the arrows in the diode symbols. When the rectified current is stored in the capacitors, the value of the voltage reach the peak value of $230V_{RMS}$ (Root Mean Square) 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 transistors) is kind of the opposite to the rectifier.

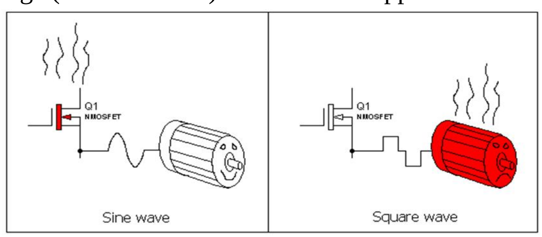

Fig.3 Sine wave VFD's have High Transistor-Losses.

The current is conducted into the motor in the same direction as the arrows in the transistor-symbols, but the transistors are not conducting all the time like the diodes. Actually if all transistors were conducting, it would short-circuit the whole system. The transistor bridge is controlled by a switching pattern corresponding to the new frequency that is to be generated. These signals are made by ordinary low power electronics like analog signal generators and amplifiers, digital circuitry and/or microprocessors. The signal pattern can be simple like square waves or more sophisticated sine-like waves. Square waves generate losses in the motor. For example a "true sine" DC to AC converter might discharge less electromagnetic noise, the motor is running smoother (less noise, more stable torque), but the inverter is more expensive and usually less efficient. If the transistors are controlled by square waves, the power loss in the transistors reach its minimum (because voltage and current are not present in them at the same time), but the motor which filter the "noise shaped" current resulting in jerky mechanical torque and power loss in the windings. Also the uneven torque generates power loss as well as unnecessary wear on the mechanical parts the motor is driving.

D. Pulse Width Modulation

Pulse width modulation is a compromise between sine wave (or any arbitrary waveform) and square wave signals. The idea is that transistors can switch the current on and off (creating a square wave) at such a high frequency the motor would not react to it. Of course this high switching frequency is not the one controlling the speed of the motor.

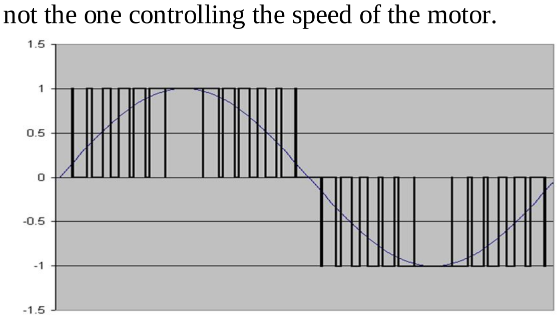

Fig.4 Wave form of PWM

Volume 4 Issue V, May 2016
ISSN: 2321-9653
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The much lower motor frequency is embedded into the higher frequency by changing the rate between the high and low states according to the low frequency. This is called modulation and is similar to radio waves carrying lower frequency music, although the modulation principle is different. The goal is to run square waves in the transistors (remember less power loss) and sine-like current in the motor (also less power loss).

The switching frequency is usually ten to hundred times more than the motor current (modulating) frequency. The result from this frequency difference is that the motor is acting like a low pass (averaging) filter to high frequencies, and it only "sees" the lower frequency. One might think there is a power loss in such a filter, but reactive loads like motors are storing the electrical energy into the magnetic field, and the unused energy is fed back to the inverter bridge via reverse diodes in the transistors. By switching the full voltage on and off there is minimal voltage drop and losses in the transistors.

III. THREE PHASE INDUCTION MOTOR

Three phase induction motors are most commonly encountered in industry. They are simple, strong, low amount, and easy to maintain. They run at essentially steady speed from nil to full-load. The speed is frequency-reliant, these motors are not easily adapted to change speed. However, VFD are being used more and more to control the speed of marketable induction motors. In this section we cover up the necessary principles of the 3-phase induction motor and develop the basic equations describing its behavior. We discuss its common construction and the way the winding saremade. Squirrel-cage, wound-rotor ranging from a few horse powers to several thousand horse power permits there a dextrose that they all operate on the similar basic principles.

A. Simulation Of Automation Based Sugarcane Plant

SCADA is (INTOUCH) the quickest and easiest way to create human machine interface (HMI) applications for the micro soft Windows 95 and Windows NT operating systems[5][8].

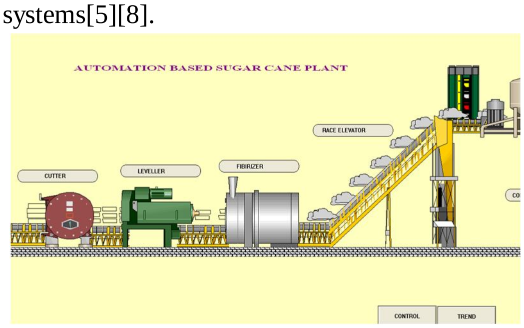

Fig.5 Automation Based Sugar Cane Plant

In Intouch is a component of the wonder ware factory suite and is shown in fig.5. The motor load section, Motor RPM section, control panel are all available in the control window and is shown in fig.6. Here the load-1 is in ON condition.

CONTROL WINDOW ON LOAD-1 STAGE

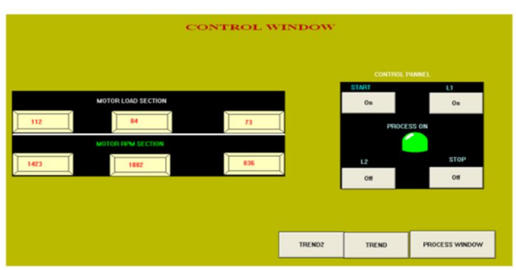

Fig.6 Control Window on Load-1 Stage

B. Motor Load And Rpm Ratings

The motor RPM will change depends upon the Load given to the conveyor. If load increases, the speed of motor will decrease and if the load decreases, the motor RPM will increase which is shown in fig.7

Volume 4 Issue V, May 2016
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MOTOR LOAD AND RPM RATINGS DURING LOAD-1 CONDITION

Fig.7 Motor Load and RPM Ratings during Load-1 Condition.

The above fig.6 shows the load-1 ON condition and fig.7. Shows the increases the load 100 to 112 and rpm 1100 to 1400.

C. Control Window

The motor load section, Motor RPM section, control panel are all available in the control window and is shown in fig.6. In this control window the load-2 is in ON condition, that means the load given to conveyor becomes increases so that the speed of motor gets reduced, which can be identified using this control window. The graph while increasing and decreasing the conveyor load and the corresponding RPM of motor is shown in fig.9.

CONTROL WINDOW ON LOAD-2 STAGE

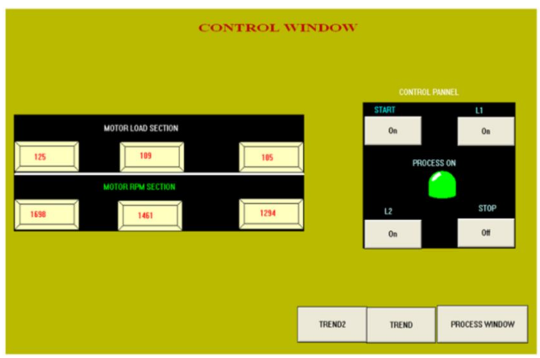

Fig 8 Control Window on Load-2 Stage

D. Motor Load and Rpm Ratings

The fig.9 shows that the load-1 and load-2 is in ON condition and also shows increases the load from 112 to 125 and the speed from 1400 to 1600 rpm.

MOTOR LOAD AND RPM RATINGS DURING LOAD-2 CONDITION

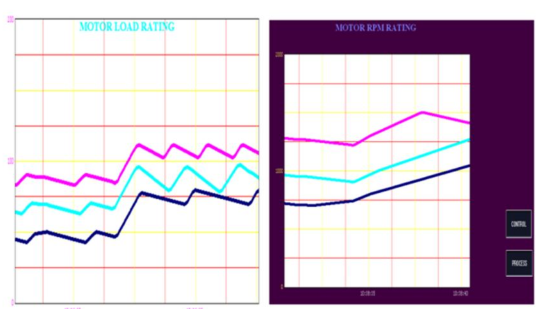

Fig 9 Motor Load and RPM Ratings during Load-2 Condition.

D. Real Time Model

The three-phase induction motor was fully computerized and automated using a VFD and PLC.

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Fig.10 Real Time Model Hardware Assembly

The hardware assembly of input and output sources, PLC, VFD and motor are shown in fig.10. The drive used in this set-up offered different control modes of motor operation.

IV. CONCLUSION

The present work was motivated to develop a scheme and PLC is used to monitor and control a Variable Frequency Drive. A thorough study of all the hardware machinery was done including their functioning, specifications and overall performance. A 0.75 KW three-phase induction motor was fully computerized and automated using a VFD and PLC. The drive used in this set-up offered different control modes of motor operation. The pattern and settings to run the motor in two control modes viz., speed and arrangement were completed systematically. A ladder logic program was developed and verified in RSLinx software which enabled the motor to obtain two different positions in order with a specified time interval between the positions. A complete study and useful hands on the PLC and the drive process have imparted a fairly good idea about the industrial automation systems.

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