Automatic Solar Tracking using Crouzet Millenium PLC

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Abstract : The Solar Tracker is basically a mechanical device consisting of an induction motor and moves according to the command from the controller in response to the sun's direction. The controller used is Programmable Logic Controller (PLC). Speed and direction of the motor is controlled by the V/f Drive. The tacking is done by programmed Time-Delayed movement of the panel throughout the day. The delay is set in the PLC and the step-by-step movement is achieved by proximity sensor which senses the teeth of a Cog wheel there by providing the feedback to the PLC. The output from the panel is measured with a multimeter.

Keywords- PLC, Tracking, V/f Drive, Proximity Sensor (key words)

I. INTRODUCTION

The Automatic Solar Tracking system is used to track the Sun automatically with the incorporation of the PLC and VFD. The panel is made to track the sun by programming of PLC. The VFD controls the motor direction of rotation as well as the speed. The panel is made to rotate in steps with the help of Proximity Sensor-Cog Wheel setup. The VFD itself is controlled by PLC but the motor control is achieved by preset values set in it. The cog wheel teeth are detected by the proximity sensor which sends the signal to the PLC. In the PLC, it is programmed to stop the motor for every teeth undetected. The detection of tooth starts the motor with a preset delay of 32 minutes. The delay is incorporated to track the sun as it moves along the horizon. An 8-channel Relay is used to automate the switches of the VFD which control the direction of the motor. The input of the relay is given from the PLC and the output is connected to the VFD by overriding its switches. The output of the Solar Panel is measured with a multimeter to be 6.41volts DC.

II. DESCRIPTION OF SET UP

The Automatic Solar Tracking is done by using PLC. Power supply to the PLC and the Proximity sensors is given by the AC-DC Convertor whose input voltage is 230V AC and the output is 24V DC. The PLC is programmed in Computer. Output of the PLC is given to 8-Channel Relay Module. The Speed and Direction Control of the motor is done by the VFD. The Drive is connected to the motor input. The speed of the motor is preset and the direction is controlled by the input switches provided to the drive. The drive is controlled by the PLC by overriding the switches through the Relay Module. The input of the PLC is the proximity sensor which provides feedback to the PLC. The sensor is made to sense the teeth of the Cog Wheel. The power supply for the sensor as well is provided by the converter.

III. HARDWARE SETUP

The Hardware setup of the tracker consists of:

- Solar Photo Voltaic Panel

- 3 Phase 0.5 HP Induction Motor
- Crouzet Millenium 3XD26 Programmable Logic Controller
- Emerson Control Commander SK VFD
- 8-Channel Relay Module
- Proximity Sensor
- Cog Wheel
- Computer

The entire setup is placed on a pair of railings on which the motor base made of wood is placed as well as two stands on whom the shaft is placed with the help of bearings. The solar panel is attached to the shaft rod by means of clamps. A cog wheel is framed as well. The proximity sensor is affixed right below the cog wheel teeth with the help of an L-shaped clamp which is fixed to one of
the stands. The balancing of the panel is done with the help of a wooden solid cuboid affixed to the rod with two tall bolt-nut arrangements which is perpendicular to the panel.

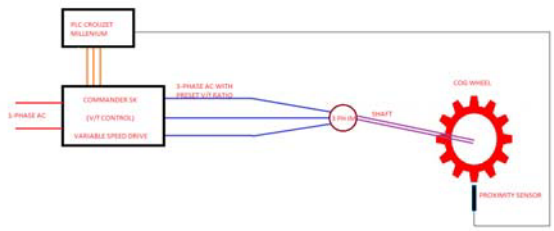


Figure1: Power and logic circuit

IV. PROCEDURE

1. The input power supply to the motor is given by the VFD which applies the required voltage and frequency so as to rotate the motor at a preset speed.
2. The preset speed is set by applying the “AV.Pr” mode in the V/f Drive.
3. The speed is preset at 5 rpm.
4. The direction of the motor can be changed by the command from the PLC to the V/f drive.
5. The logic is written in the millennium software for the PLC.
6. The PLC output is given to an 8-Channel Relay module which is in turn connected to the V/f Drive.
7. A proximity sensor is placed beneath the teeth of the Cog Wheel which is placed on the PLC.
8. The motor starts with a delay of 32 minutes at 5.40 am in the morning
9. As soon as the next tooth is detected by the sensor, the motor is programmed to stop and delay is incorporated.
10. The procedure is continued till 6 pm in the evening and then it is programmed to rotate continuously forward without stopping in steps till it reaches the original position.
11. The reading of the power output of the panel is recorded using a multimeter.

V. DELAY CALCULATION

- 1 Day = 24 Hours =1440 minutes
- Cog Wheel = 44 teeth
- Delay =32.72 minutes
- Total Revolution of Cog Wheel =15* 32.72 = 1440 minutes
- Frequency = 5 Hz

VI. PLC LOGIC

The Logic for the entire tracking is done in the PLC software Millenium 3. The Logic consists of following steps :
1. Starting of the motor
2. Presetting Delay of 32 minutes
3. Detection of Depression of the Cog wheel by proximity sensor
4. Automatic Stopping of the motor on the detection of depression

5. Automatic restarting of the motor after 32 min delay
6. Counting of the no. of teeth i.e. 44 teeth
7. After attaining the above step, either reverse motion of the motor or continuous forward motion till original position is attained, is to be started.

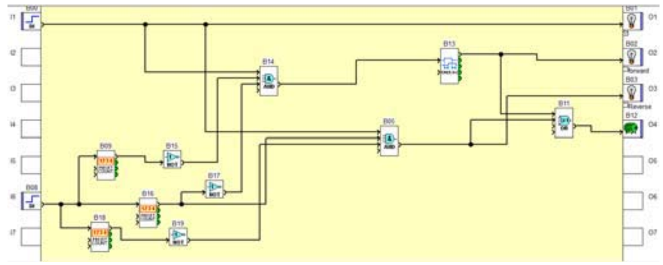


Figure2: PLC logic circuit

VII. V/F CONTROL:

For the speeds below rated speed for large variation of voltage, small change in speed occurs. Therefore normally ‘v/f control is used. In this method, voltage and frequency are varied with respect to each other, so that the ratio is maintained constant. Therefore the flux density will be maintained constant. This method combines the advantages of both above two methods. But this method requires a Converter- Inverter circuit at the stator.

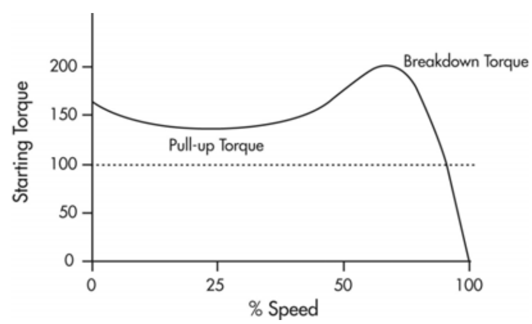


Figure3: V/F Control

VIII. PROGRAMMABLE LOGIC CONTROLLER (PLC)

A Programmable Logic Controller (PLC) is a digital operating electronic apparatus which uses a programmable memory for internal storage of instruction for implementing specific function such as logic, sequencing, timing, counting and arithmetic to control through analog or digital input/output modules various types of machines or process. Control engineering has evolved over time. In the past humans was the main method for controlling a system. More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls.
The above figure shows the XD 26 PLC. This is the heart of the project. I t works on the software of MILLENIUM 3 Programming Language.

The type of PLC used in this context :

Figure4: XD 26 PLC

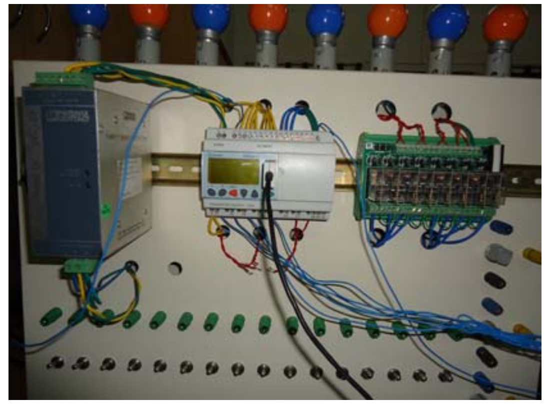


Figure5: PLC and RELAY Module installed on panel

Description of XD 26 PLC

Part Number	Power Supply	Inputs	Output
88970162	24 V DC	16 digital (of which 6 are analogue)	10 Discrete Static Relay Outputs

Figure6: XD 26 data

The numbering for the XD 26 PLC is given in such a way that as it is containing 16 Digital (of which 6 are analog) inputs and 10 discrete static relay outputs. And the sum of these inputs and outputs gives us 26.

IX. ADVANTAGES OF PLC

- Shorter project implementation time.
- Easier modification.
- Project cost can be accurately calculated.
- Shorter training time required.
- Design easily changed using software (changes and addition to specifications can be processed by software).
- A wide range of control application.
- Easy maintenance.

X. VARIABLE-FREQUENCY DRIVE

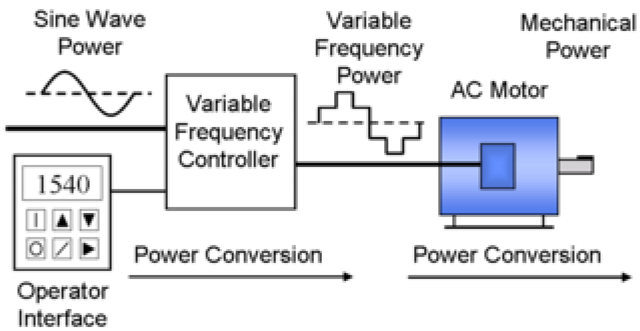
- *Introduction*

A variable-frequency drive (VFD) (also termed adjustable-frequency drive, variable-speed drive, AC drive, micro drive or inverter drive) is a type of adjustable-speed drive used in electromechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage.

VFDs are used in applications ranging from small appliances to the largest of mine mill drives and compressors. However, about a third of the world's electrical energy is consumed by electric motors in fixed-speed centrifugal pump, fan and compressor applications and VFDs' global market penetration for all applications is still relatively small. This highlights especially significant energy efficiency improvement opportunities for retrofitted and new VFD installations.

Over the last four decades, power electronics technology has reduced VFD cost and size and improved performance through advances in semiconductor switching devices, drive topologies, simulation and control techniques, and control hardware and software.

➢ *System Description and Operation*



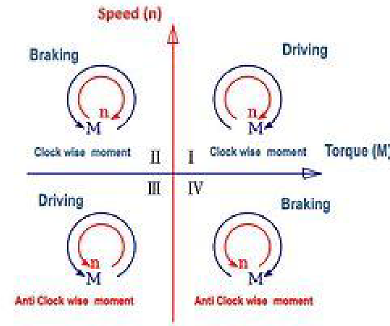


Figure7: PowerConversion Operation

Figure8:Quadrant

➢ *Operator interface*

The operator interface provides a means for an operator to start and stop the motor and adjust the operating speed. Additional operator control functions might include reversing, and switching between manual speed adjustment and automatic control from an external process control signal. The operator interface often includes an alphanumeric display and/or indication lights and meters to provide information about the operation of the drive. An operator interface keypad and display unit is often provided on the front of the VFD controller as shown in the photograph above. The keypad display can often be cable-connected and mounted a short distance from the VFD controller. Most are also provided with input and output (I/O) terminals for connecting pushbuttons, switches and other operator interface devices or control signals. A serial communications port is also often available to allow the VFD to be configured, adjusted, monitored and controlled using a computer.

➢ *Drive operation*

Electric motor speed-torque chart

Referring to the accompanying chart, drive applications can be categorized as single-quadrant, twoquadrant or four-quadrant; the chart's four quadrants are defined as follows:

- Quadrant I - Driving or motoring, forward accelerating quadrant with positive speed and torque.
- Quadrant II - Generating or braking, forward braking-decelerating quadrant with positive speed and negative torque
- Quadrant III - Driving or motoring, reverse accelerating quadrant with negative speed and torque
- Quadrant IV - Generating or braking, reverse braking-decelerating quadrant with negative speed and positive torque.

Most applications involve single-quadrant loads operating in quadrant I, such as in variable-torque (e.g. centrifugal pumps or fans) and certain constant-torque (e.g. extruders) loads. Certain applications involve two-quadrant loads operating in quadrant I and II where the speed is positive but the torque changes polarity as in case of a fan decelerating faster than natural mechanical losses. Some sources define two-quadrant drives as loads operating in quadrants I and III where the speed and torque is same (positive or negative) polarity in both directions. Certain high-performance applications involve four-quadrant loads (Quadrants I to IV) where the speed and torque can be in any direction such as in hoists, elevators and hilly conveyors. Regeneration can only occur in the drive's DC link bus when inverter voltage is smaller in magnitude than the motor back-EMF and inverter voltage and back-EMF are the same polarity. In starting a motor, a VFD initially applies a low frequency and voltage, thus avoiding high inrush current associated with direct on line starting. After the start of the VFD, the applied frequency and voltage are increased at a controlled rate or ramped up to accelerate the load. This starting method typically allows a motor to develop 150% of its rated torque while the VFD is drawing less than 50% of its rated current from the mains in the low speed range. A VFD can be adjusted to produce a steady 150% starting torque from standstill right up to full speed. However, motor cooling deteriorates and can result in overheating as speed decreases such that prolonged low speed motor operation with significant torque is not usually possible without separately-motorized fan ventilation. With a VFD, the stopping sequence is just the opposite as the starting sequence. The frequency and voltage applied to the motor are ramped down at a controlled rate. When the frequency approaches zero, the motor is shut off. A small amount of braking torque is available to help decelerate the load a little faster than it would stop if the motor were simply switched off and allowed to coast. Additional braking torque can be obtained by adding a braking circuit (resistor controlled by a transistor) to dissipate the braking energy. With a four-quadrant rectifier (active-front-end), the VFD is able to brake the load by applying a reverse torque and injecting the energy back to the AC line.

➢ *Emerson Commander SK AC Drive:*

The VFD drive used in the project is a product manufactured by Emerson. The figure shown below is Emerson commander sk ac drive. This is the AC drive used for controlling the speed of the 3-phase induction motor. In this drive we can adjust the voltage and frequency at a time, so the speed of the 3-phase induction motor is increased or decreased according to the values given. The Commander SK is an open loop vector AC variable speed inverter drive used to control the speed of an AC induction motor. The drive uses an open loop vector control strategy to maintain almost constant flux in the motor by dynamically adjusting the motor voltage according to the load on the motor. The AC supply is rectified through a bridge rectifier and then smoothed across high voltage capacitors to produce a constant voltage DC bus. The DC bus is then switched through an IGBT bridge to produce AC at a variable voltage and a variable frequency. This AC output is synthesized by a pattern of on-off switching applied to the gates of the IGBTs. This method of switching the IGBTs is known as Pulse Width Modulation (PWM).

➢ *Specifications:*

The specifications of V/F AC drive are:

- Model No.: SKA1200075
- Voltage : (200-240)V
- Current: 10.5A
- Frequency: 50-60Hz
- Driving capability: 3-phase
  0-240V
  0-1500rpm
  4A

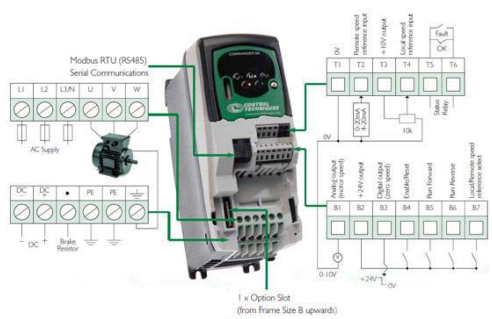


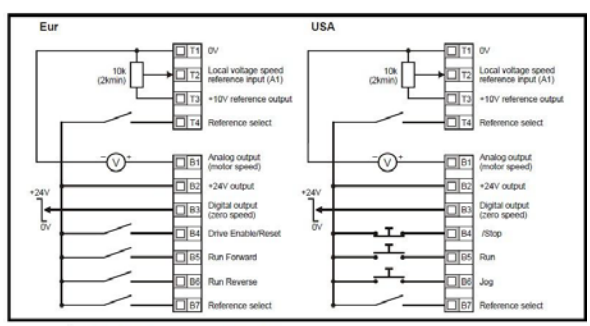
Figure9: SK Emerson Module

➢ *Description:*

The V/F drive being used has 9 different configurations i.e., the V/F drive can be operated in 9 different modes. Each mode or configuration has some pre-defined operation. There are three physical sizes comprising 15 different models. The input voltage ranges are single phase input, 200 to 240V, three phase input, 200 to 240V, three phase input 380 to 480V and are power dependent.
The 9 different configurations are

Table 1:

Configuration	Description
AI.AV	Voltage and current input
AV.Pr	Voltage input and 3 preset speeds
AI.Pr	Current input and 3 preset speeds
Pr	4 preset speeds
PAd	Keypad control
E.Pot	Electronic motorized potentiometer control
tor	Torque control operation
Pid	PID control
HVAC	Fan and pump control



T4	B7	Reference selected
0	0	A1
0	1	Preset 2
1	0	Preset 3
1	1	Preset 4

Figure10: AV.Pr mode of V/F Drive

Voltage Preset Mode:

Each mode has a pre-defined operation. The mode we are using in this project is AV.PR (voltage preset). In this mode three speeds can be preset. The figure below shows the basic terminals of the AC drive in AV.PR mode. Using this V/F drive not only the speed but also the direction of rotation of
the motor can be controlled. The switches B4,B5,B6 denotes enable, run forward and run reverse. The motor rotates in forward or clockwise direction when both the switches B4 and B5 are closed or are in ON position. The motor rotates in reverse direction or anti-clockwise direction when the switches B4 and B6 are closed or in ON position. The switch B4 must be always ON or in closed position for ant operation to take place. The drive consists of switches name T1-T4 and B1-B7. The connections are made according to the one as shown in the fig below for the drive to operate in Av.PR mode. By operating or connecting the switches T4 and B7 as shown in the table below, the speed of the induction motor can be set to a preset value.

XI. PROXIMITY SENSOR

Figure11:ProximitySensor

A proximity sensor is a sensor which is able to detect the presence of nearby objects without any physical contact. A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. For example, a capacitive photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target. The maximum distance that this sensor can detect is defined "nominal range". Some sensors have adjustments of the nominal range or means to report a graduated detection distance. Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between sensor and the sensed object. Proximity sensors are also used in machine vibration monitoring to measure the variation in distance between a shaft and its support bearing. This is common in large steam turbines, compressors, and motors that use sleeve-type bearings.

XII. RELAY MODULE

The relay module is a separate hardware device used for remote device switching. With it you can remotely control devices over a network or the Internet. Devices can be remotely powered on or off with commands coming from Clock Watch Enterprise delivered over a local or wide area network. You can control computers, peripherals or other powered devices from across the office or across the world. The Relay module can be used to sense external On/Off conditions and to control a variety of external devices. The PC interface connection is made through the serial port. The Relay module houses two SPDT relays and one wide voltage range, optically isolated input. These are brought out to screw-type terminal blocks for easy field wiring. Individual LED‟s on the front panel monitor the input and two relay lines. The module is powered with an AC adapter.

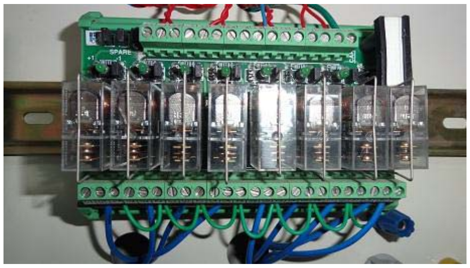


Figure12: RelayModule

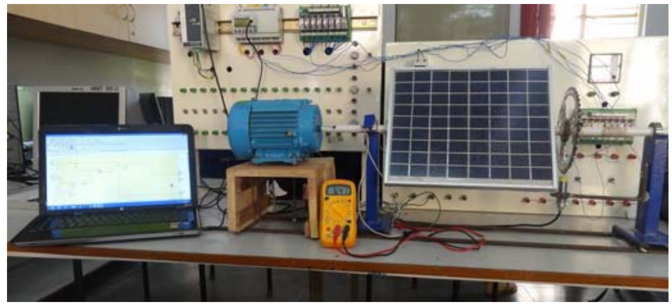


Figure13: Hardware setup

XIII. RESULTS:

The Solar Tracking System thus rotated the Solar Panel in discrete steps according to the preset delay and in the preset speed. After completing the whole 44 steps, it rotated further forward without stopping till it reached the original position. The voltage output of the Solar Panel has been recorded in a multi meter as 6.41 V DC in the morning 7.30 am.

The Automatic Solar Tracker thus, is able to trace the sun in discrete steps from morning to evening without any manual intervention. This automation is achieved by the PLC thus rendering the setup more accurate and reliable. The PLC programming is User-Friendly and easier to program as it is Block-Programming. The V/f drive has made it easy to use the Induction Motor speed Control and the direction control. Different preset speeds could also be achieved by this drive.

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