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Active Solar Tracking System Using PLC and SCADA

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Abstract-— **In the coming years, we will be more or less dependent on renewable energy as conventional energy resources are exhausting progressively. Solar energy is the dynamic resource of renewable energy. Yet with fixed assembly of Solar Panel, we cannot gain maximum output throughout a day. To enhance optimum energy output from the solar panel it should be accompanied with the Sun tracking system so that it will control the solar panel position according to the location of the Sun even in the bad weather conditions. In this paper, monitoring and controlling of solar panel is executed by Allen Bradley MicroLogix 1400 PLC which is the main controller of system and SCADA. With the help of LDR sensors, position of solar panel is controlled through programming by scaling, comparing LDR sensors output and accordingly PLC actuates the linear actuator to adjust solar panel to the direction of the Sun with the intention that maximum sunrays will fall on it. The generated power by solar panel is stored into the batteries using Solar charge controller and fed to the load after converting DC power to AC with inverter circuit. By PLC SCADA interface continuous monitoring of solar power generated using Real-time Trend and Historic Trend is done. DHT11 sensor is used to monitor weather conditions. A DC motor with wiper is used for cleaning mechanism of the solar panel. The proposed system is self-reliant and power generation efficiency is improved approximately to 25%.**

Keywords - Programmable Logic Controller (PLC), Supervisory Control and Data Acquisition (SCADA), Light Dependent Resistor sensor (LDR), Digital Temperature Humidity sensor (DHT11).

I. INTRODUCTION

In India, coal is considered as main source of energy. In 2018 about 74% of India's electricity generation is done by coal and 18% of power generation by renewable energy [6]. As we can observe we are more dependent on non-renewable energy which will exhaust in time. Due to this reason we have to harness as much as possible amount of energy from renewable energy sources. Nowadays, many people are investing their money in Solar Power as it is the most promising source which is available through out a day in India [2]. But stationary arrangement of solar panel cannot produce efficient amount of energy. To overcome this drawback, solar tracking is the best method for improving output of a solar panel [1]. When a solar panel is controlled by an actuator which tracks the position of the Sun and tilts the panel accordingly, more sunlight incidents on panel and generation of optimum power is achieved. In traditional tracking systems, microcontrollers were used, which moved the solar panel on solar map or time basis [3]. But the output generated by earlier tracking system was not up to attainable level. With change in weather conditions controller was unable to adjust the direction of solar panel. Accuracy was poor and monitoring of produced power was not possible. In traditional tracking system, DC motor / Stepper motor was used as actuator to change the direction of solar panel through program [4].

In proposed system, we have used PLC (Programmable Logic Controller) as main controller which is superior to microcontroller. It has internal memory for storing program and many features such as timing, sequencing, counting,arithmetic and some special features as well. For sensing the light-intensity we have used 4 LDR sensors, which senses the light intensity and gives input to the PLC. LDRs are mounted on stationary hemisphere along the vertical axis. For 4 LDR positions we calculated possible conditions, developed ladder logic and programmed PLC to execute the logic.

Through program each LDR output is read and compared then accordingly PLC output signal is given to linear actuator for adjusting the solar panel. This closed loop operation repeats as input to the PLC varies. This improves the output power generation simultaneously the efficiency is increased approximately to 20-25% [7].

Power generated by solar panel is stored into batteries through solar charge controller to ensure protection of batteries. After converting DC power to AC power by

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inverter circuit we can supply the power to household appliances or to the grid to compensate power demand.
Monitoring of solar power generated is done by PLC-SCADA interface through real-time Trend and historic Trend [5]. For observing weather conditions DHT11 sensor is used which can sense the temperature up to 50degree Celsius and humidity up to 100%. Self-cleaning mechanism is installed for maintenance purpose of solar panel. DC motor is used which moves wiper after fixed interval of time. It removes dust from the surface of solar panel and hence output power is increased. The proposed system is self-reliant, maintenance free and maximum output power is achieved from it.

A.BLOCK DIAGRAM

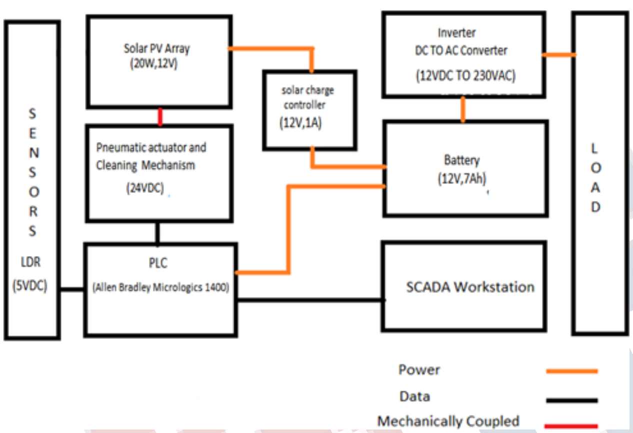

Fig.1. Block Diagram of Solar Tracking System.

1. Sun tracking algorithm:
Close loop control algorithm involves detection of position of sun by real time light sensing method is required to eliminate error due to variability in installation, calibration and sensors mounting.

2. Tracker control unit:
The tracker unit usually execute the sun tracking algorithm and necessary calculations. PLC system is used as main control unit. It collects input and gives output to execute drive mechanism.

3. Drive mechanism:
Tracking system moves the solar arrays according to the preference of control unit. Sensors and linear actuator used to monitor the current position of panels and moved to desired position. Drive mechanism includes linear actuator.

4. Sensors:
Sensors are used to detect the accurate position of sun. Closed loop system usually uses several light sensors like LDRs.

5. Cleaning Mechanism:
To maintain the efficiency cleaning mechanism is opted within the system. As the panel are cleaned on the daily basis maximum solar irradiance will penetrate into solar cell ensuring more generation of power. As it is interfaced to PLC, every 6 hrs. panel is cleaned automatically, thus reducing human efforts.

6. Interfacing of PLC – SCADA:
Monitoring of power generated by solar panel can be observed by Real Time Trend and Historical Trend. The information can be remotely accessed. Graphical representation makes understanding of data easier and also useful for data analysis during audit.

A. AIGORITHM

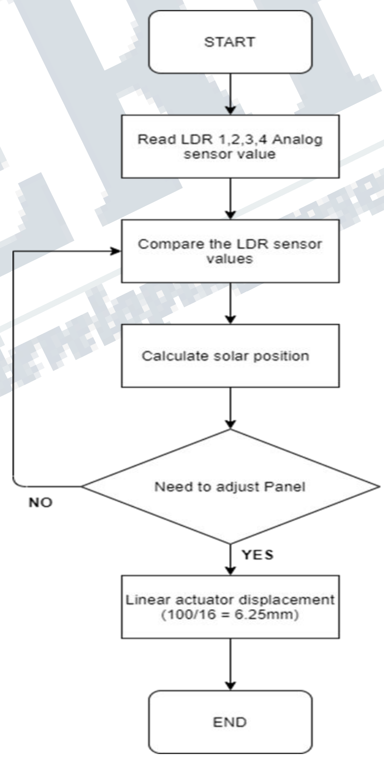

Fig.2. Algorithm of Solar Tracking System.

B. COMPONENT

a) Programmable Logic Controller:
For solar panel controlling PLC is used as main controller in closed loop. A PLC is a Microprocessor-based control system. We have used Allen Bradley MicroLogix 1400 series PLC manufactured by Rockwell Automation. Catalog No. 1766-L32BWAA. It is a compact type of

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PLC. It has total 38 I/O points, out of which 20 are Discrete Inputs, 12 Discrete (Relay) outputs, 4 Analog inputs, 2 Analog outputs, 100/240VAC power supply, and 20KB memory. Communication ports available to transport program from software to CPU are RS232/RS485, Ethernet, and RS232. RS232 cable is 9 pin connector used for single ended data transmission. For interfacing RS232 Cable is used. Fig.3 shows Input/output ports of PLC. Analog input signal range is 0 to 10VDC. Software used for programming is RS Logix 500
Micro. Due to continuous sensing of sunlight intensity using LDR sensor controlling action executed by PLC is more accurate. The controller is precise and provides flexible provision to program. PLC is programed to sense, actuate field devices. Ladder diagram program language is used to write the logic. In program, output of LDR sensor is fed to PLC input module then using SCP (scale with parameter) instruction this data is read and then by writing logic using comparative, timing instructions required position of solar panel is adjusted. We have used 2 analog inputs, one for linear actuator to adjust solar panel direction, another for DC motor to move wiper serving cleaning mechanism.

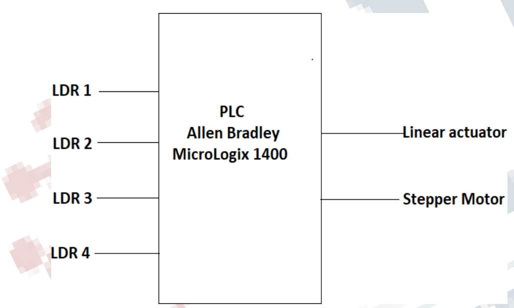

Fig.3. Input/Output ports of PLC.

b) Solar Panel:
A solar panel, or photo-voltaic (PV) module, is an assembly of photo-voltaic cells mounted in a framework for installation. Solar panels use sunlight as a source of energy and generate direct current electricity. A collection of PV modules is called a PV panel, and a system of panels is an array. Arrays of a photovoltaic system supply solar electricity to electrical equipment. When the sun rays fall on solar panel they generate maximum energy. The solar panel which we are using is polycrystalline panel which is having 15% Efficiency. Solar panel rating is 20watt 12volt, the panel is specially designed to charge small batteries up to 7Ahr to 10Ahr. The nominal operating cell temperature ranges from - 0.43 to 44 degree Celsius. It comprises of 36 photovoltaic cells arranged in 9*4 parallel-series combination.

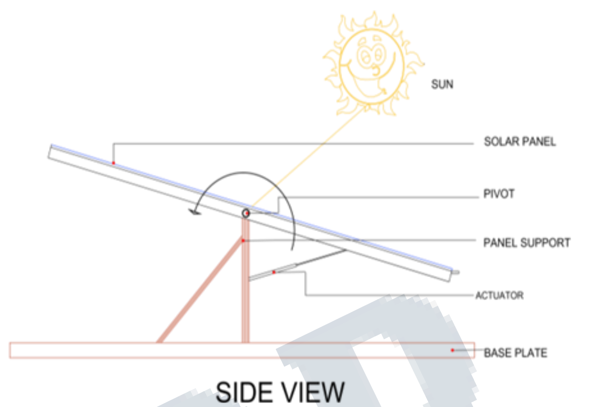

Fig.4. Solar panel and linear actuator arrangement

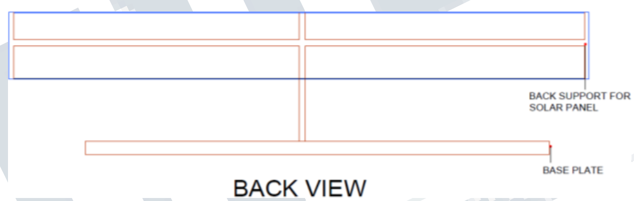

Fig.5.Back View of Solar Assembly.

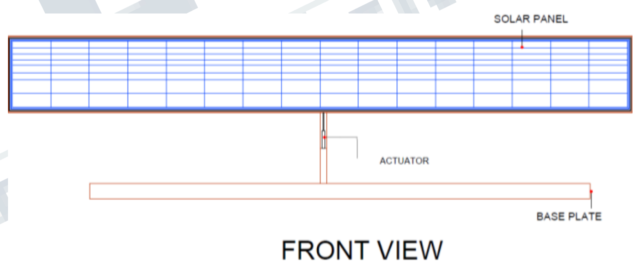

Fig.6.Front View of Solar Assembly.

c)DHT11 Sensor:
Weather conditions affect the performance of solar panel. To observe the temperature and humidity we have used DHT11 sensor. It is a commonly used digital humidity temperature sensor. It operates on 3.5V to5.5V, 0.3 milli-ampere current. It gives output in the form of serial data. The temperature range is 0 to 50 degree and humidity range is 20 to100 %. DHT11 sensor comprises of 8-bit Microcontroller and dedicated NTC to measure temperature and humidity. For environment monitoring this data is useful. By observing temperature and humidity we can observe the corresponding power generation on SCADA screen. Basic purpose of this sensor is to measure temperature and humidity.

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d) Battery:

Lead acid battery is world's most recycle product, it is basically used in automotive and traction application. The battery covers all the aspects such as standby/ backup/ emergency power for electrical installation. When constant dc current is applied it takes 16-24 hr. which is safe charging method, but slow as compared to constant DC voltage, it is a fast method of charging but considering it is not safe and decreases life cycle of battery therefore constant DC current charging method is used.

The solar power generated by solar panel is stored in lead-acid battery through solar charge controller, and it also connected to PLC to power the PLC, Because of this no extra power is needed for PLC which makes proposed system self-reliant. The rating of battery is 12v 7Ahr DC.

e)Inverter:

The inverter proposed within the system converts DC power to AC power. We are using String inverter, which is having power of 1-10kw and its efficiency is in the range of
96%-98%, it can be used as single/ three phase inverter. We can also connect it to grid for future expansion

Power stored in lead acid battery is supplied to inverter then after converting it into single phase power is supplied to load. A solar inverter works by taking in the variable direct current, or 'DC' output 12v DC, from your solar panels and transforming it into alternating 230V current, or 'AC' output. The appliances in your home run on AC, not DC, which is why the solar inverter must change the DC output that is collected by your solar panels.

f) Solar Charge Controller:

A solar charge controller is basically a voltage and/or current regulator to protect batteries from overcharging. It regulates the voltage and current coming from the solar panels going to the battery. A solar charge controller manages the power going into the battery bank from the solar array. It ensures that batteries are not overcharged during the day, and that the power doesn't run backwards to the solar panels overnight and drain the batteries.

A charge controller is connected in between solar panel and the battery. Power is generated by solar panel, it will not directly be stored into the battery, and it goes from a charge controller. A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan and may pose a safety risk. We have designed a solar charge controller to charge a lead acid battery of rating 7Ahr to 10Ahr.

g) LDR (Light Dependent Resistor):

LDRs (light-dependent resistors) are used to sense illumination levels (10lux-100lux). The module consists of LDR & comparator IC. The LDR receives light and indicate on module with blinking of LED. It has a (variable) resistance that changes with the light intensity that falls upon it. This allows them to be used in light sensing circuits.

The working principle of an LDR is photoconductivity, which is nothing but an optical phenomenon. When the light is absorbed by the material then the conductivity of the material enhances. When the light falls on the LDR, then the electrons in the valence band of the material are eager to the conduction band. When sun rays fall on the solar panel these light rays are detected by these LDR, then LDR pass these values to the PLC, in PLC the values of LDR get compared and if one of the LDR is having more value than other LDR then the solar panel will get tilted towards respective LDR.

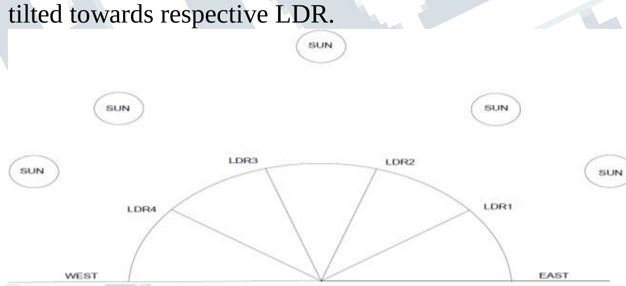

Fig.6. LDR Positioning on hemispherical solid

Sr No.	Angle between Adjacent LDR(Degree)	Displacement of Actuator (mm)	Timer Delay(Sec.)
LDR1	36	20	2.857
LDR2	72	40	5.714
LDR3	108	60	8.571
LDR4	144	80	11.428

Table 1. Dimensions of LDR Positioning on hemispherical solid

In the Fig.6 hemisphere is shown, it is divided into 5 equal parts for mounting 4 LDRs. On the extreme position sun's intensity is less in the (early morning and evening). Therefore, 180/5=36 degree. We have placed the LDRs equally 36 degrees from EAST to WEST. The condition where two LDR outputs are same lies exactly in the middle of two corresponding LDR sensors. The arrangement of LDR sensors is kept stationary.

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h) Linear Actuator:

Linear actuator has dc motor drive, having stroke length of 100MM (7mm/S) and 1500N of self-locking force. It is electric driving device which transforms the rotary motion of the motor into the linear reciprocating motion of the pushrod. It has compact design, low noise, built in noise switch and long-life operation. It has aluminium frame body and it is lightweight. It can be used in various simple or complex processes as executive machinery to realize remote control, centralized control or automatic control.

i) Self-Cleaning Mechanism:

To enhance efficiency of solar panel self-cleaning mechanism is opted in the system. It removes dust from panel surface. A 12 V 300 rpm DC motor is used to move wiper periodically. After every 6-hour DC motor will run in forward and reversed direction. This will help in regular cleaning of the panel ensuring maximum output power is generated. A PLC timer is used to repeat the process and a discrete output is connected to DC motor. To start the cleaning mechanism discrete input start switch is used. Because of the cleaning mechanism timely maintenance is not required

II. INTERFACING, SIMULATION AND RESULT

The LDR sensors outputs is sent to the PLC system where control algorithm reads the input signals. Output to linear actuator by PLC system is given as per desired position of solar panels. Generated output power is given to the charge controller then battery. For ac loads there is inverter to convert dc voltage into ac voltage. Operation of actuator is controlled by the four timers (T4:0, T4:1, T4:2, T4:3) using different timer delay. Operation of cleaning mechanism is controlled by using LIMIT TEST along with single timer as a source. While doing the interfacing of PLC with SCADA, we are using Dynamic Data Exchange (DDE) protocol through Rslinx communication software. Scada (Supervisory Control and Data Acquisition System) interfacing with Micrologix 1400 Programmable controller is helpful for monitoring and supervising the solar tracking system.

Fig.6. LDR Positioning on hemispherical solid

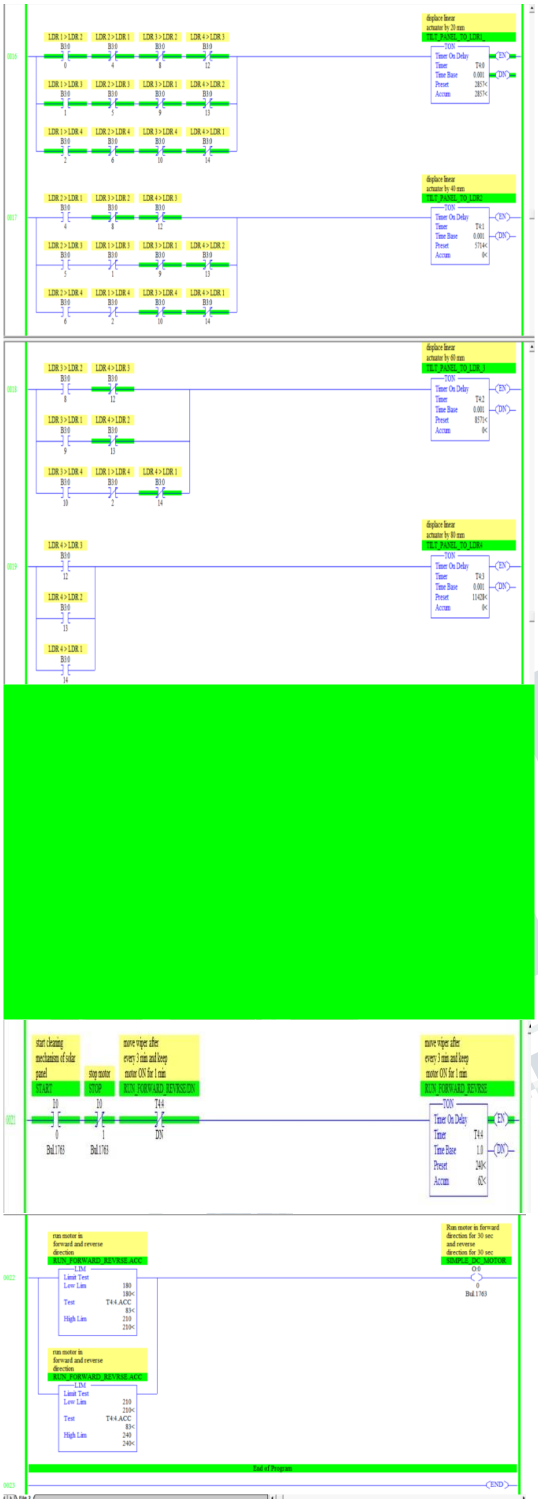

Fig.7. Program for Solar Tracking System

III. CONCLUSION

A model of active solar tracking system is implemented using LDR Sensors and Actuator. Allen Bradley PLC is used to control the position of Solar Panel, for continuous monitoring the Power generation SCADA is used. Using this system approximately 25-30% more output is generated during summer season and 15% during Winter and Rainy season. We can remotely monitor the system. Temperature and humidity can be measured using DHT11 sensor. The proposed system is totally “Self-reliant” as it powers all the components within the system. In the proposed tracking system program is designed in such a way that solar panel always keeps tracking with the sun all over the day and throughout the year with a simple mechanical arrangement and a well advanced control algorithm with high accuracy to obtain efficient output from the tracking system. So high output power and energy savings with safety and working conditions achieved, to meet developing demand of constructing environmental ecofriendly.

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