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PLC Based Solar Tracking System

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Abstract: *Sun is a low cost source of electricity and instead of using the generators; solar panel can convert direct sun rays to electricity. Conventional solar panel, fixed with a certain angle, limits there area of exposure from sun due to rotation of Earth. This project presents the design and development of an automatic solar tracking system to enhance the efficiency of solar energy collection. The system uses a Mitsubishi Fx2S- 30M PLC as the central controller, ensuring precise and reliable operation. A 12-volt solar panel serves as the primary energy harvesting component, while a DC motor adjusts the panel's orientation based on sunlight intensity. To detect the sun's position, the setup employs five Light Dependent Resistors (LDRs) strategically positioned to sense light from various directions. These sensors feed analog signals into the system, allowing the PLC to compute the optimal angle for maximum solar exposure. Limit switches are installed to restrict the motor's movement within a safe mechanical range, preventing over-rotation. A Switch Mode Power Supply (SMPS) is used to convert AC input to a stable DC output, powering the PLC and control components. The system is designed to operate autonomously with a reliable power supply, offering a low-maintenance and efficient solution for solar energy systems. This integration of simple yet robust components results in a smart and cost-effective solar tracking mechanism suitable for small-scale applications*

Keywords: PLC , Solar Panel, Worm Gear Box Motor, LDR, Limit switch, SMPS

I. INTRODUCTION

PLC (Programmable logic control) :In the global energy industry there is always the push for more efficient energy production, which is measured by the LCOE (levelized cost of electricity). Solar energy can already provide the lowest LCOE for most parts of the world in most applications, but there are more breakthroughs on the horizon for solar PV plants to enable them produce electricity even more efficiently. Solar energy is one of the most abundant and renewable sources of power available on Earth. However, the efficiency of a solar panel largely depends on how effectively it can capture sunlight throughout the day. Since the sun moves across the sky, a fixed solar panel often fails to absorb maximum sunlight, especially during the morning and evening hours. To overcome this limitation, solar tracking systems are designed to automatically adjust the position of the solar panel to follow the sun's movement, ensuring maximum exposure and energy generation.

This project aims to design and implement an automatic solar tracking system using a combination of simple yet effective components. A **Mitsubishi Fx2S- 30M PLC** acts as the brain of the system, providing reliable control logic for precise movements. The tracking mechanism uses a **DC motor** to rotate a **12-volt solar panel** based on the input from **five Light Dependent Resistors (LDRs)** that detect sunlight intensity from different directions. **Limit switches** are included as safety devices to restrict the range of motion and prevent mechanical damage. The system is powered by a **Switch Mode Power Supply (SMPS)**, which ensures stable voltage levels for the entire setup. By continuously adjusting the solar panel's position throughout the day, this solar tracking system aims to improve the efficiency of solar power generation compared to fixed-tilt panels. The project demonstrates how integrating simple sensors, a PLC, and basic electrical components can result in a low-cost, high-performance system that contributes to the sustainable use of renewable energy resources.

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II. METHODOLOGY

Identifying Worm Gear Box Motor

A **12V 20 RPM Worm Gearbox Motor** is a type of **DC gear motor** that incorporates a **worm gear mechanism** to achieve high torque at low speeds.

Working: The DC motor rotates a worm (screw) which meshes with a worm wheel (gear). The worm drive reduces speed and increases torque. Power is applied to the motor's terminals, creating a magnetic field that rotates the shaft.

Fig 1: Worm Gearbox Motor

- **Voltage:** 12 Volts DC
- **Speed:** ~20 RPM (rotations per minute)
- **Gear Type:** Worm gear—offers high torque and self-locking properties

Observed Features

- **High Torque Output:** Due to worm gear reduction, it can deliver high torque (e.g., 10–50 kg·cm depending on size).
- **Self-Locking:** The worm gear design prevents back-driving, making it ideal for holding loads.
- **Compact and Durable:** Usually made with metal gears and robust housing.
- **Low Noise and Smooth Operation:** Suitable for automation and robotics.
- **Mounting Flexibility:** Comes with multiple mounting holes and a D-shaft or keyway.

Advantages of Motor

- **Precision Control:** Low RPM allows for accurate positioning.
- **Safety:** Self-locking gear reduces risk of sudden reverse motion.
- **Energy Efficiency:** Consumes less power under load due to gear support.
- **Long Lifespan:** Metal gear design resists wear and tear.

Identifying The Limitations Of Motor

- **Lower Efficiency:** Worm gears can be less efficient (50-70%) due to sliding friction.
- **Heat Generation:** Prolonged operation under heavy load may cause heating.
- **Non-reversible Drive:** Cannot rotate output shaft manually due to self-locking.

PLC Mitsubishi Fx2S- 30M

Fig 2: PLC Mitsubishi Fx2S- 30M

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PLC used is **Mitsubishi Fx2S- 30M** and the software used is GXWorks2_Basic_v1.87r. The Mitsubishi FX3S-30M is a compact, basic PLC with 16 digital inputs (24VDC) and 14 relay outputs. It offers RS-232C/RS-422/USB programming and networking options, including Ethernet and Modbus. The FX3S-30M is designed for straightforward processes and space-conscious applications, with a minimal expandability and a battery-less, maintenance-free design.
Key Features and Specifications:

- **I/O:** 16 digital inputs (24VDC), 14 relay outputs.
- **Communication:** RS-232C/RS-422/USB programming, Ethernet, and Modbus.
- **Programming:** Ladder Logic.
- **Memory:** Up to 16,000 steps for the program, file registers, and comments.
- **Power Supply:** 30 VDC.
- **Operating Temperature:** Up to 55°C.
- **Humidity:** Up to 95% RH.
- **Altitude:** Up to 2000 meters.
- **Installation:** Suitable for inside a control panel.
- **Expansion:** Limited expansion options, including digital input/output expansion boards and adapters for analog inputs, Ethernet, and Modbus.

Design of Solar Panel Base With Motor

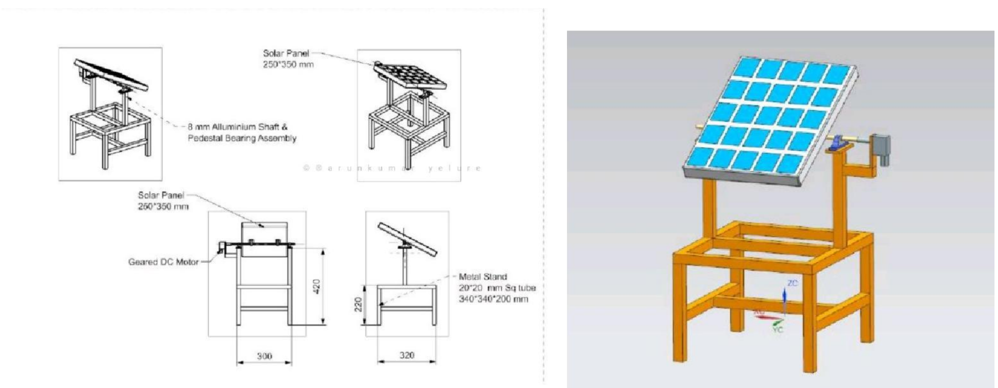

Fig 3: Design Of Solar Panel Base .

The given design illustrates a **solar tracking system structure** that utilizes a 12V geared DC worm motor to rotate a PV solar panel based on sunlight direction. The panel used has dimensions of **250 mm × 350 mm**, and it is mounted on an **8 mm aluminum shaft** supported by **pedestal bearing assemblies**, which enable smooth and stable rotation. The motor is responsible for the panel's angular movement and is mounted securely beneath the rotating shaft to ensure torque transmission and mechanical stability. The supporting structure is built using **metal square tubes of 20 mm × 20 mm**, forming a firm base frame measuring **340 mm × 340 mm × 200 mm**. This frame holds the rotating mechanism and motor assembly above it at a total height of **420 mm**, providing the required elevation and clearance for safe rotation. The design also accounts for lateral dimensions of **300 mm width** and **320 mm depth**, ensuring compactness and rigidity while still allowing for smooth motion.
Overall, the design demonstrates a well-planned implementation for a small-scale solar tracking system. The integration of an aluminum shaft, geared motor, and pedestal bearings ensures accurate panel movement, while the rigid frame maintains structural integrity. This setup is ideal for educational, experimental, or prototype-level solar projects aiming to increase energy efficiency by aligning the panel with the sun throughout the day.

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LDR Matrix Sun Sensor

A Single Matrix Sun Sensor (MSS) controls both axes of the tracking system . The inspiration of the MSS is the antique solar clock. MSS comprises of 8 photo resistors and cylinder (pen cap). The location of the cylinder is at the Centre of the matrix structure of the photo resistors, which are evenly distributed around a circle. If the position of the collector is not optimum, the shadow of the cylinder covers one or two

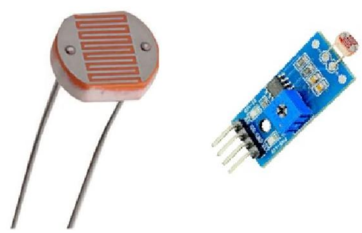

Fig 4: LDR matrix sun sensor

photo resistors. The photo resistors are mounted circular, around the cylinder. There are two important observations about MSS operation

The MSS works in a digital kind of way: each LDR has 2 states ; illuminated state and shaded state

The sensor is robust, low cost and determines a simple digital control of the actuators of sun trackers.

Voltage Check with SMPS

A switch mode power supply is a power converter that utilises switching devices such as MOSFETs that continuously turn on and off at high frequency; and energy storage devices such as the capacitors and inductors to supply power during the non-conduction state of the switching device.

The supplies have higher efficiencies of up to 90%, are small in size and widely used in computers and other sensitive electronic equipment.

The basic switch mode power supplies (SMPS) are categorized based on supply input and output voltage. The main four groups are:

AC to DC – Off-line DC power supply

DC to DC – Converter

DC to AC – Inverter

AC to AC – Cycloconverter of frequency changer

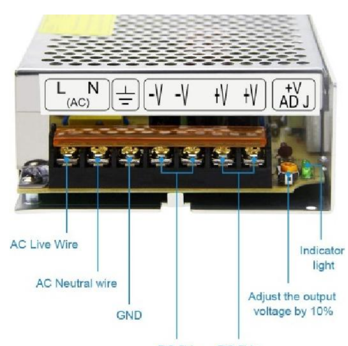

Fig 5: Power Suppy

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Basic operation of a switch mode power supply (isolated)

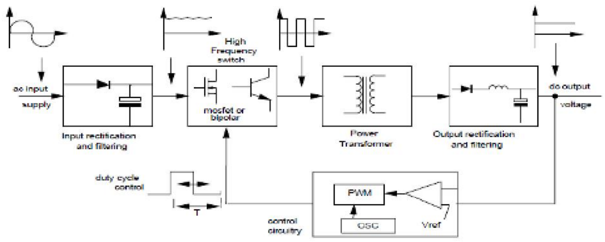

Fig 6: SMPS Block Diagram

The main components of an SMPS are:

- Input rectifier and filter
- Inverter consisting of a high frequency signal and switching devices
- Power transformer
- Output rectifier
- Feedback system and circuit control

The unregulated input dc, either from a dc source such as rectifier or a battery, is fed to the inverter section consisting of fast switching electronic devices such as MOSFETS and bipolar transistors which are driven on and off. This causes the input voltage to appear at the primary winding as pulses at the switching frequency of between 20 and 200 kHz.

The transformer output is then rectified and smoothed to produce the required D.C voltages. The frequency, which is outside the audible range, is usually fixed while the duty cycle is variable to provide the suitable voltage level required.

***Block diagram** of Interfacing the Sensor and Comparator Circuit to PLC*

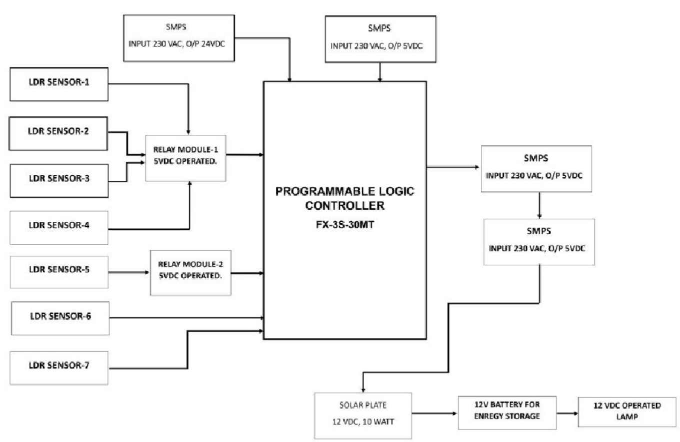

Fig 7: Block diagram of Interfacing the Sensor and Comparator Circuit to PLC

4 Channel 5V Relay Module

This is a LOW Level 5V 4-channel relay interface board, and each channel needs a 15-20mA driver current. It can be used to control various appliances and equipment with large current. It is equipped with high-current relays that work under AC250V 10A or DC30V 10A. It has a standard interface that can be controlled directly by micro-controller.

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Fig 8: 4 Channel Relay 5V

Features of 4 channel 5V Relay

- Power Supply Voltage: 5VDC, 12VDC
- Current: Greater than 100mA
- Load: 250V 10A AC or 30V 10A DC
- Size: 73mm x 54mm x 19.5mm (LxWxH)
- Equipped with mounting holes around, hole diameter 3.1mm
- Relay Type: Single Pole Double Throw (SPDT)

Optocoupler isolation, good anti-interference capability
When input is at low level, the relay is off, and the indicator light is on.
Standard interface that can be directly controlled by microcontroller (8051, AVR,PIC, DSP, ARM, MSP430)

III. WORKING OF SOLAR TRACKER

STEP 1: Initially input pin of PLC is switched on to start the whole process
STEP 2: As soon as the input is on motor one (5 wire unipolar motor) will start rotating. After the motor one completes its rotation motor two (6 wire stepper motor) rotates to a predefined angle.
STEP 3: Once the initial rotation is completed then depending on Sun's position the sensor output will be given to the PLC as input. The output of the PLC will be given as input to the motor
STEP 4: Motor starts rotating in steps based on the sensor output.


Fig 9: Final Interfacing of the Hardware with PLC

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IV. RESULT ANALYSIS

The hardware designed is a dual axis solar tracker which is rotated by two motors. As Sun starts to change its position during the day the solar panel tracks Sun on the basis of the Sensor outputs given to it. Following are the different positions of the solar panel at different intervals of time:

CASE 1: The figure below shows the solar panel's position in the morning.

Fig 10 : Solar panel's position in the morning

CASE 2**:** The below figure shows the solar panel's position at noon.

Fig 11 : Solar panel's position at noon

CASE 3: The below figure shows the solar panel's position in the evening.

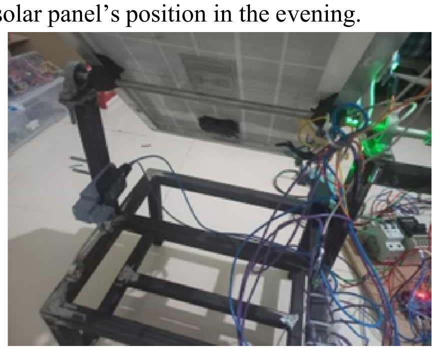

Fig 12: Solar panel's position in the evening

Analysis

From this tracker we can increase the solar panel efficiency of over the steady solar panel below are the observation taken from that we can identify easily. We know that the angle between the sun's rays and the solar panel is crucial for achieving maximum efficiency. We can conduct an observation by changing the angle of the solar panel at the same time with the same load to determine how the output changes in relation to the position of the solar panel.

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Time	Voltage (V)	Current (A)
08:00 AM	8.5	0.681
10:00 AM	9.5	0.692
12:00 PM	9.8	0.705
02:00 PM	10.9	0.706
03:00 PM	10.3	0.705
04:00 PM	10	0.699
05:00 PM	9.4	0.698

Table 1 : Output of the steady 10 w solar panel with respect to time

Time	Angle	Voltage (V)	Current(A)
08:00 AM	80	10.2	0.699
10:00 AM	75	10.1	0.702
12.00 AM	85	10.2	0.709
02.00 PM	90	10.3	0.710
04.00 PM	85	10.2	0.705
06.00 PM	80	10.1	0.698

Table 2: Output of the 5 watt solar panel with tracker with respect to time

V. CONCLUSION

Solar power, unlike other energy sources is now considered to be the best alternative due to its versatility in terms of renewability, cost-effectiveness, improved operating efficiency and its unlimited reserve, mainly being the Sun. Sun moves from east to west and tracking the sun during its movement helps us to achieve maximum utilization of the solar energy. The solar panels, being the modern technology of alternative power source is the best possible way to absorb maximum amount of sunlight and converting into usable electricity, and thus achieving increasing popularity since the realization of fossil fuels shortcomings. The objective of the proposed work was to design a PLC based automated tracking of solar panel for maximum throughput using photo sensors. Solar panel will track Sun based on the output from the sensor successfully. The sensor output keeps varying based on the amount of sunlight falling on it. The output from the sensor is converted to digital (logic zero or one) and given to the PLC as input. The PLC output drives the motor to the position. The stepper motor is used for precise control of the solar panel here. The solar panel along with the sensor is interfaced and the tracking of solar panel is efficient. PLC provides precise control signals to the motor which rotates to the particular position based on the sensor's output.

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