PLC BASED SOLAR PANEL WITH TILTING ARRANGEMENT

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Abstract: In this paper Programmable Logic Controller (PLC) solar panel tilting system is designed and proposed. By using this system we can obtain uniform and higher power generation when compared to solar panels placed in fixed position. Solar panel frame is majorly affected by the various factors such as wind force, rain, fog etc., among them the major factor affecting the solar panel frame is the high wind force. Generally various frame structures are designed and analyzed by subjecting it against various wind force to select the suitable frame structure which withstands for maximum wind force with less deflection.

***Keywords*—** Solar panel, Frame, PLC.

1. INTRODUCTION

Currently, many alternative energy sources appear to be technically feasible. One of them is solar energy (Kreider and Kreith, 1981). The panels are the fundamental solar energy conversion component. Conventional solar panel, fixed with a certain angle, limits their area of exposure from the sun during the course of the day [1-3]. Therefore, the average solar energy is not always maximized. Initially the solar panel is placed at 23 ½ degree due to the position of earth in the solar system. The program to tilt the panel according to sun's position is fed on the PLC. An inclinometer fixed behind the panel measures the angle of the panel and it gives the feedback to PLC[4,5]. The PLC controls the motor to provide power to the mechanism to tilt the panel. The solar panel is tilted to nine degree in one minute for every one hour .Any changes to the existing program can be modified by the human machine interface. The main aim is to analysis the frame structure against the various wind force conditions[6,7].

TABLE.1 POSITION OF SOLAR PANEL ON VARIOUS TIMINGS

Time (hour)	7	8	9	10	11	12
Position of panel (degree)	-45	-36	-27	-18	-09	00
Time (hour)	13	14	15	16	17	
Position of panel (degree)	+09	+18	+27	+36	+45	

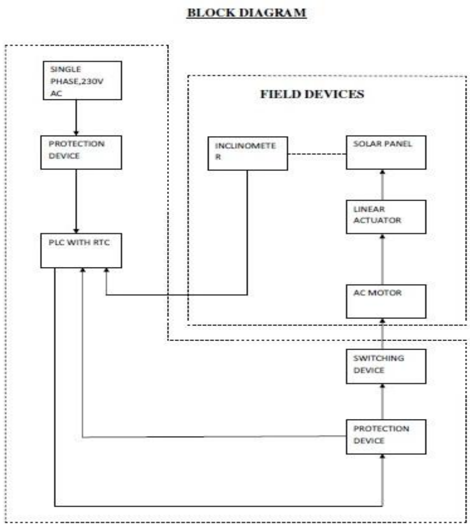

Fig.1. Block diagram of solar panel

2. MATERIALS AND METHODS

2.1 A programmable logic controller (PLC)

Programmable controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, over light fixtures. PLC's are used in many industries and machines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. A PLC is an example of a hard real time system since output results must be produced in response to input conditions within a limited time, otherwise unintended operation will result.

FIG.2 DIAGRAMATIC REPRESENTATION OF PLC

The main difference from other computers is that PLC's are armored for severe conditions (such as dust, moisture, heat, cold) and have the facility for extensive input/output (I/O) arrangements. These connect the PLC to sensors and actuators. PLC's read limit switches, analog process variables (such as temperature and pressure), and the positions of complex positioning systems. On the actuator side, PLC's operate electric motors, pneumatic or hydraulic cylinders, genetic relays, solenoids, or analog outputs. The input/output arrangements may be built into a simple PLC, or the PLC may have external I/O modules attached to a computer network that plugs into the PLC[8,9].

2.2 User Interface

PLC's may need to interact with people for the purpose of configuration, alarm reporting or everyday control. A human machine interface (HMI) is employed for this purpose. HMI's are also referred to as man-machine interfaces (MMI's) and graphical user interface (GUIs). A simple system may use buttons and lights to interact with the user. Text displays are available as well as graphical touch screens. More complex systems use programming and monitoring software installed on a computer, with the PLC connected via a communication interface.

2.3 Programming of PLC

Solar panel tilting can be controlled by using PLC pro. This can be done by programming PLC. PLC programs are typically written in a special application on a personal computer and then downloaded by a direct-connection cable or over a network to the PLC. The program is stored in the PLC either in battery-backed-up RAM or some other non-volatile flash memory. Often, a single PLC can be programmed to replace thousands of relays. The fundamental concepts of PLC programming are common to all manufacturers, differences in I/O addressing, memory organization and instruction sets mean that PLC programs are never perfectly interchangeable between different makers. In this project the sun's position at various timings are noted and according to it programming is done in PLC.

The first, and still most popular programming language, is ladder logic. Using examples, the language is developed from the electromechanical relay system-wiring diagram. After describing the basic symbols for the various processors covered by this text, they are combined into a ladder diagram. The subsequent section details the process of scanning a program and accessing the physical inputs and outputs. Programming with the normally closed contact is given particular attention because it is often misapplied by novice programmers. The ladder logic program for controlling the solar panel motion is shown below:

Fig.3, the pushbutton switch connected to input X1 serves as the "Start" switch, while the switch connected to input X2 serves as the "Stop." Another contact in the program, named Y1, uses the output coil status as a seal-in contact, directly, so that the motor contactor will continue to be energized after the "Start" pushbutton switch is released. You can see the normally-closed contact X2 appear in a colored block, showing that it is in a closed ("electrically conducting") state.

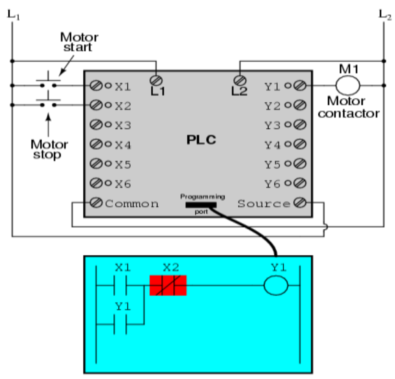

FIG.3 DIAGRAMATIC REPRESENTATION OF PLC MOTOR CONTROL

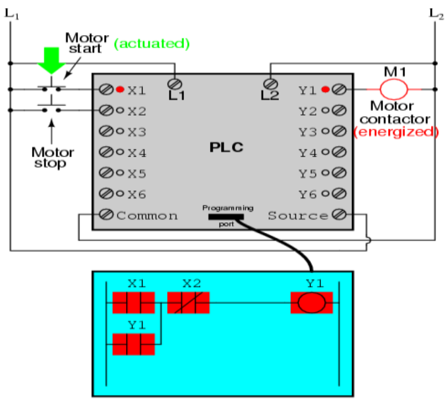

FIG.4 DIAGRAMATIC REPRESENTATION OF PLC WHEN X1 IS CLOSED (TO START)

Fig.4. If we were to press the "Start" button, input X1 would energize, thus "closing" the X1 contact in the program, sending "power" to the Y1 "coil," energizing the Y1 output and applying 230 volt AC power to the real motor contactor coil. The parallel Y1 contact will also "close," thus latching the "circuit" in an energized state.

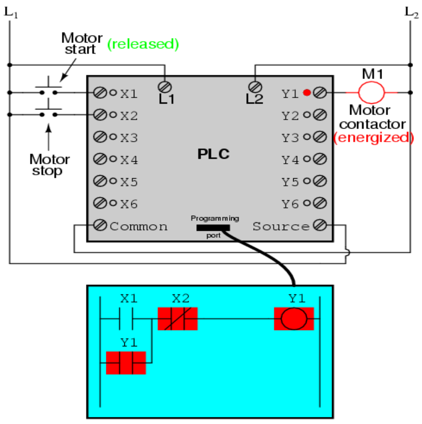

FIG.5 DIAGRAMATIC REPRESENTATION OF PLC WHEN X1 CLOSED

Fig.5. Now, if we release the "Start" pushbutton, the normally-open X1 "contact" will return to its "open" state, but the motor will continue to run because the Y1 seal-in "contact" continues to provide "continuity" to "power" coil Y1, thus keeping the Y1 output energized:

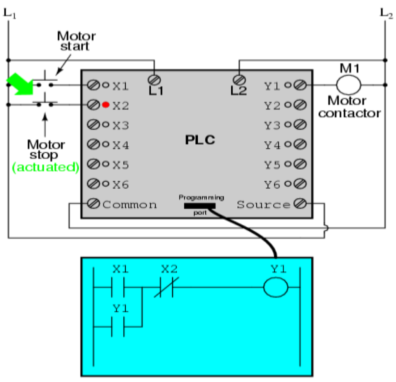

FIG.6 DIAGRAMATIC REPRESENTATION OF PLC WHEN X2 IS CLOSED

Fig.6. To stop the motor, we must momentarily press the "Stop" pushbutton, which will energize the X2 input and "open" the normally-closed "contact," breaking continuity to the Y1 "coil"

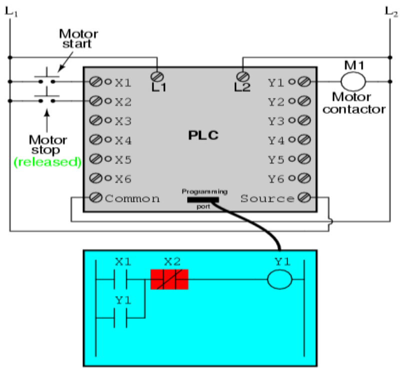

FIG.7. DIAGRAMATIC REPRESENTATION OF PLC WHEN X2 IS OPENED

When the "Stop" pushbutton is released, input X2 will de-energize, returning "contact" X2 to its normal, "closed" state. The motor, however, will not start again until the "Start" pushbutton is actuated, because the "seal-in" of Y1 has been lost:

2.4 Real Time Clock

A real-time clock (RTC) is a computer clock (most often in the form of an integrated circuit) that keeps track of the current time. Although the term often refers to the devices in personal computers, servers and embedded systems, RTC's are present in almost any electronic device which needs to keep accurate time. RTC's is used in our project for the accurate time. It is connected with the plc for their better operation. Frees the main system for time-critical tasks and sometimes more accurate than other methods.

2.5 Interface Design

Typical human-machine interface design consists of the following stages: interaction specification, interface software specification and prototyping:

- Common practices for interaction specification include user centered design, persona, activity oriented design, scenario-based design, resiliency design.
- Common practices for interface software specification include use cases, constrain enforcement by interaction protocols (intended to avoid use errors).Common practices for prototyping are based on interactive design based on libraries of interface elements (controls, decoration, etc.).

2.6 Inclinometer

An inclinometer or clinometers is an instrument for measuring angles of slope (or tilt), elevation or depression of an object with respect to gravity. It is also known as a tilt meter. Clinometers measure both inclines (positive slopes, as seen by an observer looking upwards) and declines (negative slopes, as seen by an observer looking downward).Astrolabes are inclinometers that were used for navigation and locating astronomical objects. In aircraft, the "ball" in turn coordinators or turn bank indicators is sometimes referred to as an inclinometer. This inclinometer is attached to the solar panel so as to measure the inclination and the feedback is given to the PLC.

2.7 Motor

Motor is a device which is used to convert electrical energy in to mechanical energy. It is the major component used in the project. The output of the motor is given to linear actuator and this helps to convert rotational motion into linear motion. AC motor can be used for this type of applications. It can classify into two types-Synchronous motor and Induction motor.

3. CALCULATION

3.1 Pressure Calculation

Force can be calculated by, $\mathbf{F=\rho AV^2}$

Where,

ρ=density of air=1.29kg/m^3,

A=Area of Frame Surface=16.69m^2,

V=velocity of air in m/s

The equivalent pressure exerted due to wind force can be calculated by **P=F/A** in N/m2.From the case study of Indian cyclones the maximum wind force attained is 210km/hr. So we have taken wind force range from 90 to 210 km/hr.

TABLE.2 WIND FORCE AND PRESSURE

S.No	wind force (km/hr)	equivalent pressure exerted(N/m^2)
1.	90	806.25
2.	120	1433
3.	150	2238.86
4.	180	3225
5.	210	4389.08

3.2 Torque Calculation

Total mass=620kg

link length =1.675m

maximum tilting angle for 5 minutes =45 °

To find torque:

$$t=mgr\sin\theta + i\alpha$$

where,

i= moment of inertia =mk2

k=radius of gyration

For rectangular object the radius of gyration can be obtained as,

$R_G^2=1/3((W/2)^2+(H/2)^2)$ =3.7023M

R_G =1.9241m

α=angular acceleration =θ/t2=45*(π/180)/52=0.0314 rad/m2 on substituting the values in equation 1, we get,

t=7203.78+ (620*1.9242*0.0314)

=7203.78+72.066

=7275.84n-m

4. DESIGN AND ANALYSIS OF FRAME

The frame with solar panel is designed on C- channel and box channel. The frame is designed based on different section and different materials. The Designing of Solar Panel with Structure is done by Using Pro-E Software. The Analysis of Designed Solar Panel with Structure is done by Using Ansys Software. The frame is drawn based on the following dimensional specification:

- Length of the frame: 6125mm
- Width of the frame: 2725mm

TABLE.3 CHANNELS AND DIMENSIONS

CHANNELS	HEIGHT	WIDTH	THICKNESS
C- section	100mm	45mm	3.0mm
Square section	120mm	60mm	4.5mm

By using these channels various frame structures are designed by using pro-e software.

The following are frame sections drawn in two materials such as structural steel and 6063 aluminum alloy:

1. 3*4 Section,
2. 4*4 Section,
3. 5*4 Section

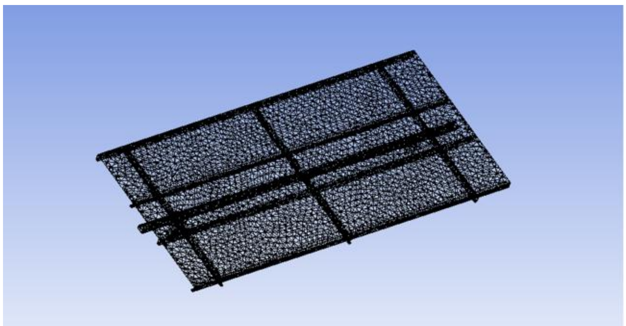

Fig.9 meshed diagram of 3*4 sections

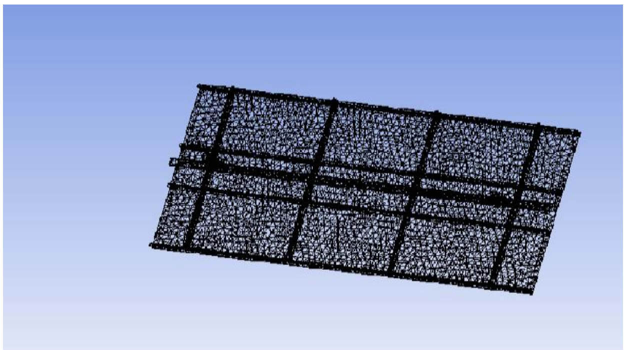

Fig.10 meshed diagram of 3*4 sections

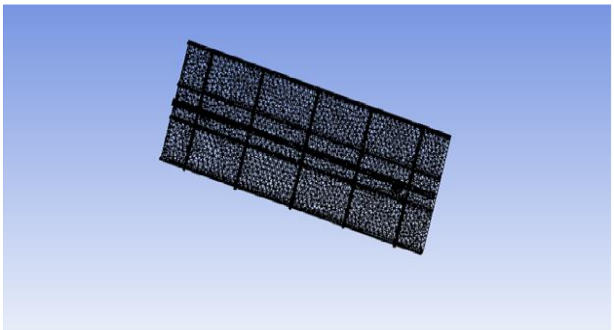

Fig.11 meshed diagram of 5*4 sections

5. CONCLUSION

From the analyzed data and graph we conclude that up to wind force of 210 km/hr act upon the 4*4 structural steel frame structure and withstands against it with minimum deformation. The 5*4 structural steel section gets higher deformation when compared to 4*4 structural steel frame structure up to 210 km/hr due to its own weight. For wind force higher than 210km/hr the 5*4 structural steel structure can with stand successfully and so it can be selected when frame is subjected to wind force higher than 210 km/hr and beyond the wind force of 210 km/hr, 5*4 structural steel structure undergoes less deformation than 4*4 structural steel structure

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