Design and Analysis of Solar Panel with Tilting Arrangement

M. Krishnamoorthi[1], S. Seshagiri[2]

[1]Department of Mechanical Engineering, Govt. College of Tech. Coimbatore-641013, India

[2]Design Engineer, WEG Industries India Pvt. Ltd. Hosur-635109, India

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, Total deformation, Stress, Strain

1. Introduction

Solar energy is an inexhaustible resource. The sun produces vast amounts of renewable solar energy that can be collected and converted into heat and electricity. Today, people are more concerned about fossil fuel exhaustion and environmental problems caused by conventional power generation and renewable energy sources than ever before. Among the renewable resources, photovoltaic panels and wind generators are primary contenders. They have the advantage of being maintenance and pollution-free, but their installation cost is high and, in most applications, they require a power conditioner (dc/dc or dc/ac converter) for load interface. 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. Therefore, the average solar energy is not always maximized.

To increase the power generation on these solar panels, the panels should be oriented in the direction normal to the sun's position. In the paper Microcontroller based solar-tracking system and its implementation (Okan Bingol, Ahmet Altintas, Yusuf Oner) the solar panels are aligned in the direction normal to the sun by using the LDR sensors. In this system the LDR sensors tracks the sun's position and provides the information to the microcontroller and according to the information, microcontroller switches the stepper motor to tilt the solar panel. In this system power requirement to drive the stepper motor is continuous.

In order to reduce the power requirement to make the solar panel's position normal to the sun's position, we have designed Programmable Logic Controller based solar panel tilting system. Our system consists of solar panel, frame, tilting arrangement, PLC and inclinometer. The sun's positions on various timings are noted. According to the sun's position the program to tilt the solar panel is fed on the PLC. An inclinometer fixed parallel to solar panel checks the position of solar panel and it gives feedback to the PLC. According to the feedback PLC controls the tilting motion of the solar panel to the position normal to sun's position by the means of tilting arrangement. In this PLC based system the solar panel is tilted only once in an hour so power requirement for this system is not continuous.

Initially the solar panel is placed at 23 ½ (north south) degree due to the tilted position of earth at 23 ½ 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. The PLC controls the motor to provide power to the tilting mechanism to tilt the panel. The solar panel is tilted to nine degree in one minute for every fifty nine minutes (Table 1). Any changes to the existing PLC program can be modified by the human machine interface and it can be done by less skilled operators.

2. Method and Materials

Frame structures acts as supporting medium for solar panels, so designing of frame structure plays a major role to with stand against deformation. The assembled diagram of solar panel with frame and links is drawn by using pro-e software is shown in Fig 1. In this system the solar panel with frame structure is designed on C- channel and box channel. Various frame structures are designed using C- channel and box channel. The dimensional specification of C- channel and box channel is shown in table1 and Table 2. The Designing of various frame Structures is done by Using Pro-E Software. The Analysis of Designed frame Structures is done by Using Ansys Software. The frame structure is drawn based on the following dimensional specification:

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

Two materials such as structural steel and 6063 aluminum alloy are selected for designing of frame structures due to their properties and its wide application in construction industries. The following are frame sections drawn in two materials:

- 3*4 Section,
- 4*4 Section,
- 5*4 Section.

Solar panel tilting can be controlled by using PLC. This can be done by writing programs for 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 our project the sun's position at various timings are noted and it is programmed in PLC. Thus PLC is used to tilting the solar panel perpendicular to sun's position. An inclinometer 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. An inclinometer fixed behind the panel measures the angle of the panel and it gives the feedback to PLC. The PLC controls the motor to provide power to the mechanism to tilt the panel. In this thesis, our aim is to design and analysis the panel frame and amount of force required to tilting the solar panel in required position.

Table 1: Position of solar panel (view from north)

Time (24 hr format)	7	8	9	10	11	12
Position of panel (degree)	-45	-36	-27	-18	-09	00
Time (24 hr format)	13	14	15	16	17	
Position of panel (degree)	+09	+18	+27	+36	+45	

Table 2: Channels and its dimensions

Channels	*Height*	*Width*	*Thickness*
C- section	100 mm	45 mm	3.0 mm
Square section	120 mm	60 mm	4.5 mm

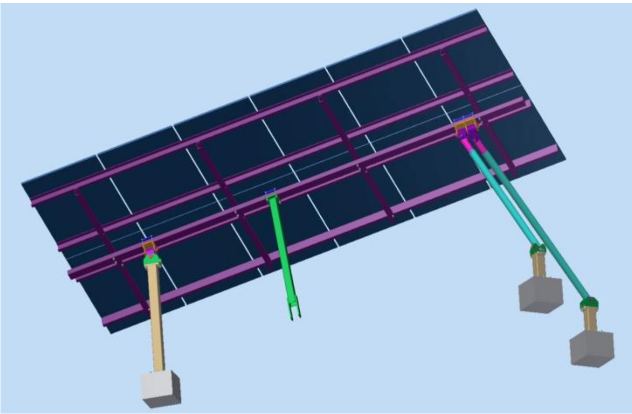

Figure 1: Assembled diagram of solar panel with frame and links

3. Calculations

1. The pressure that will be exerted on the solar panel frame due to the wind force can be calculated by as follows:
$F=\rho AV^2$
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/m^2.

From the case study of tamilnadu cyclones the maximum wind force attained is 280km/hr in dhanushkodi cyclone. The wind speed attained in the coastal areas will be higher than interior areas and so we have taken wind force range from 90 to 210 km/hr as an average value among various cyclones affected in tamilnadu to subject it on frame structure. The corresponding pressure to the wind force is calculated and shown in Table 3.

Table 3: Pressure force due to wind

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

2. The torque required to tilt the solar panel with frame structure is as follows:

- Total mass of tilting system = 620 kg (consider structural steel system)
- Link length =1.675 m
- Angular velocity of tilting is 45 ˚ in 5min.

Amount of Torque required for tilting the solar panel:
$T=mgr \sin\theta + I\alpha$
Where,
Moment of Inertia $I= mk^2$,
For rectangular object the radius of gyration can be obtained as,
$R_g^2= 1/3((W/2)^2+ (H/2)^2) = 3.7023$m,
$R_g = 1.9241$m
$\alpha = \theta/t^2 =45*(\pi/180)/5^2 = 0.0314$rad/m
On substituting the values in equation 1, we get,
$T= 7203.78 + (620*1.924^2*0.0314) = 7275.84$ N-m

3. Amount of Force required for tilting the panel:
$T = F r \cos\theta$
$7275.84 = F*1.675*\cos 45˚$
$F = 6145.13$ N

4. Analysis of Solar Panel Frame

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-12 Software. The following are the images of meshed various frame sections:

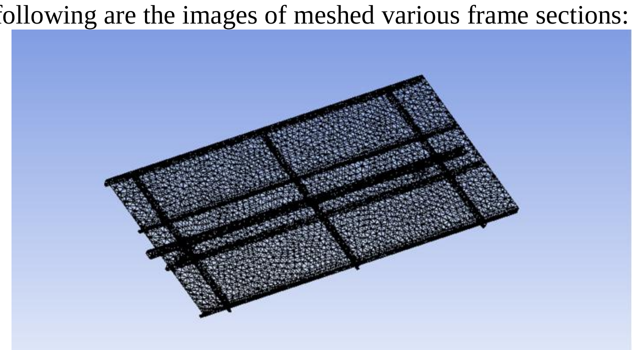

Figure 2: 3*4 frame section

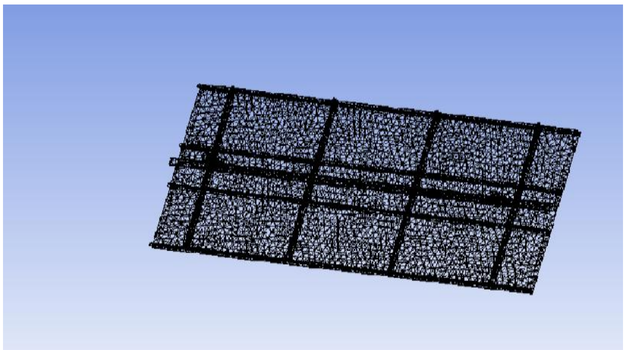

Figure 3: 4*4 frame section

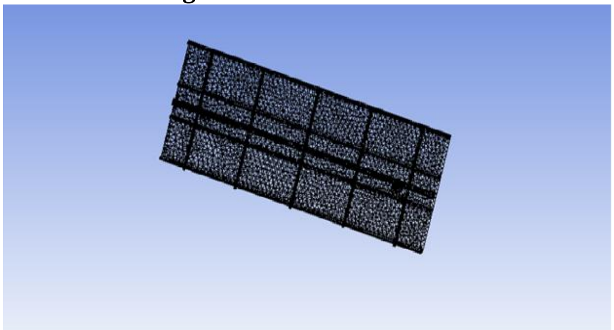

Figure 4: 5*4 frame section

5. Result and Discussion

We have designed various frame structures and analyzed by subjecting them against the maximum wind forces attained in Tamilnadu cyclones. From the results obtained from the analysis reports total deformation, stress, strain values for the corresponding frame structures against various wind force are obtained and various graphs are plotted. The graph plotted between wind force against total deformation (in mm), stress (in Pascal), strain corresponding to structural steel is shown in Fig 5(a, b, c) and for 6063 aluminum alloy is shown in Fig 6(a, b, c).

Here, SS-structural steel, AL-aluminium alloy, TD-total deformation, S1- 3*4 frame section, S2- 4*4 frame section, S3- 5*4 frame section.

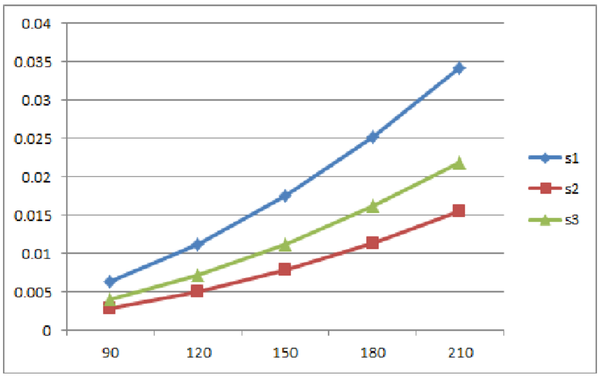

Figure 5 (a): Total deformation for structural steel

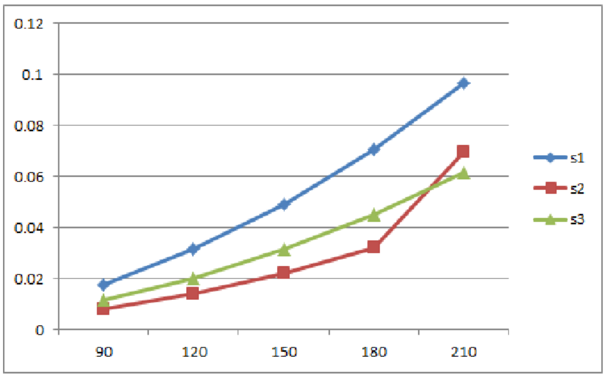

Figure 6 (a): Total deformation for 6063aluminium alloy

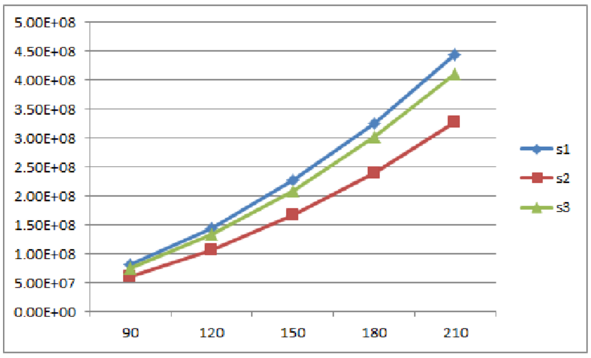

Figure 5 (b): Stress distribution for structural steel

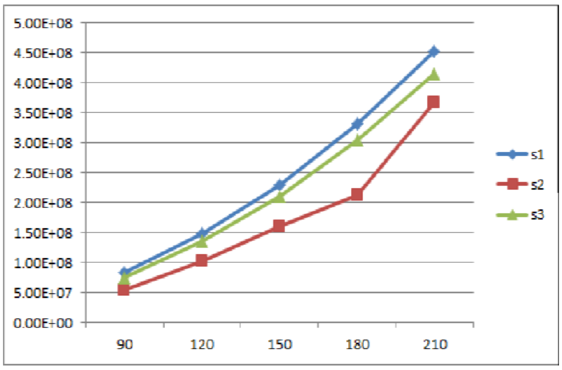

Figure 6 (b): Stress distribution for 6063aluminium alloy

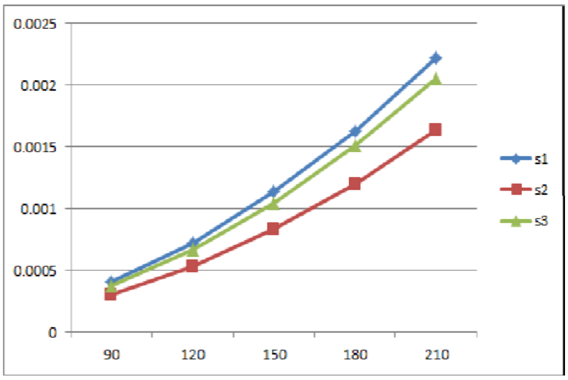

Figure 5 (c): Strain for structural steel

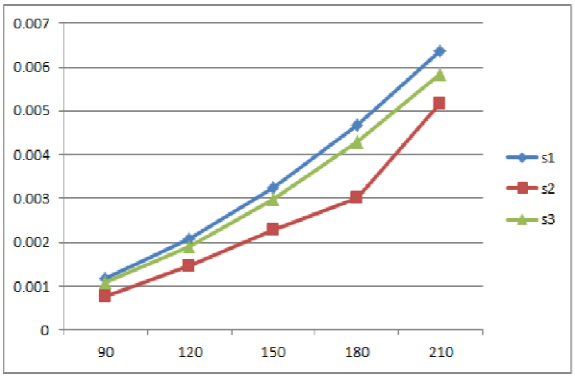

Figure 6 (c): Strain for 6063aluminium alloy

6. 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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