International Journal of Future Generation Communication and Networking
Vol. 13, No. 2s, (2020), pp. 668–679

Design and Analysis of Solar Structural and Mountings for Solar Panel

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Abstract

This paper seeks the design of the structural components of a uni-pole design for solar panels connected to a water pump coupled directly without any power storage device. Agriculture is the most import sector for Indian growth of GDP. The higher running price and manufacturing cost is a threat to the farmers. So in such cases the renewable energy like solar will be effective source of power for them. The conclusion is that although the initial cost of solar water pumping system made is 2.14 times of the conventional diesel pumping system, initial cost. It's operating and maintenance costs and total life cycle cost are 8.7 times and 29.9 % lower than that of costs of conventional diesel pumping system. The use of conventional system also has given ride to the emission of greenhouse gasses which contributes to 8% to 12% of total emission. To alleviate this government of India has launched a solar pumping program for irrigation and drinking water with an ambition to target 1 million till 2020-2021 to five environmental and economical advantages.

Keywords— *Include at least 5 keywords or phrases*

I. INTRODUCTION

Solar operated water pumping system gives a huge advantage over conventional systems. The solar pump structure has to tolerate various environmental conditions like varying temperature, wind loads, corrosion of materials, etc. A solar pump system is considered to have 25 years of life span expectancy. so it becomes necessary to provide proper structural arrangement which denote deteriorate with time and age due or environmental conditions. The components should be manufactured adopting a process which is economical, providing aesthetic appearance and ergonomic factors consider. The pumping set is designed for a 3 HP pumping motor which is directly driven without use of a energy storage device. Each panel is assumed to produce 335 KW power so according to calculations 10 solar panels are required to run the setup under varying loads. Providing a good clearance so as to tackle the change in the amount of solar energy available according to seasons.

Each solar panel = 335 KW
Water pump = 3 HP
1 HP = 745.7 KW
10 solar panels produce = 3350 KW

The solar pump is used for irrigation purpose therefore it is a remote application. In conventional systems the transportation of fuel to site and its consumption increases the running cost and the conventional system also has considerable maintenance cost. This is a proof that solar water pumping system is a onetime investment giving a major advantage over conventional systems in terms of running cost and maintenance cost. The solar pumping system is a self-sufficient system as it produces its energy by its own without any external aid with the help of renewable resources.

The purpose is to reduce the harmful emissions which are a by-product of conventional system. This also helps to reduce the amount of fuel imported from foreign nations to operate these mechanical engines

ISSN: 2233-7857 IJFGCN

affecting environment and our currency altogether. The conventional systems also are noisy and operate at high vibrations. During the event of leakage it may also contaminate which will eventually affect the final crop harvested from the farm.

A. 1.1 SOLAR MOUNTING SYSTEM

Solar mounting system attaches the solar panels array to either the ground or rooftop for residential and commercial applications. For rooftop of industrial sheds installations, a variety of frame designs are used depending on whether the system is mounted on pitched or flat roof. These structures helps panels to rest com- portably, prevent from being damaged more importantly position them at precise tilt angle to harness maximum sun's energy. Mounting structures can be made for rooftops, ground mounting carports and sun tracker solutions which now have seen a lot of developments in terms of weight, material, adaptability and ease of installation. There have been many technological innovations that have led to reduced cost faster and better installation, high durability and with enhanced output.

Extruded Aluminum frame structures meet or exceed the strength and flexibility requirements while delivering a lower lifetime cost compared to steel frames, especially with a properly designed custom solution. Aluminum also provides a high level of aesthetic appeal through anodizing or powder coating to achieve the desired surface finish. And, an aluminum frame structure will remain free of rust and resistant to corrosion for the life of the structure.

Long life, simple design, easy installation, and greater aesthetic appeal over the life of the structure combined with lower lifetime cost makes aluminum the metals of choice for products.

B. MATERIAL

An overview of various materials used

1) Galvanized steel:

The process where the steel is coated with protective corrosion resistant zinc is known as galvanization. In case the coat gets scratched steel is still protected. The galvanization does not change mechanical properties of steel.

2) Hot dip galvanized steel:

Hot dip galvanizing is where an already formed part for example plate, round, perlin, etc. is dipped in zinc bath reaction takes place between steel and zinc during the time part is in zinc bath the thickness of zinc coating is influenced by number of factors, including surface of steel, the time steel is dipped in bath composition of steel as well as steel size and thickness.

One advantage of hot dip galvanized is that entire part is covered including edges welds etc. giving it an all round corrosion protection. The end product can be used outdoors in all different weather conditions. It is the most popular galvanizing method and is widely used in construction industry.

3) Pre galvanized steel:

Pre galvanized steel refers to steel which was pre galvanized while in sheet format, thus prior to further manufacturing pre galvanization is also known as mill galvanization due to the fact that the steel sheet is sent through the mill to be galvanized it is cut to size and recoiled.

4) Aluminium Alloy (Anodized):

Aluminium alloys are the alloys in which the aluminium is a predominant metal. The typical alloying elements are silicon, tin, copper, magnesium, manganese and zinc. Aluminium has special properties that make it an interesting material for many solar power companies. Light weight, high strength, proper corrosion properties, high surface reflectivity, excellent electrical and thermal conductivities as well as special optic properties of its anodic coating are such an interesting properties of aluminium that male it inseparable part of solar power systems.

5) PosMAC:

The material is the most sustainable of all above materials. The endurance factor is essential in building quality solar energy structures. To withstand exposure to wind , water and salt PosMac was invented as a revolutionary coating layer that significantly increases the resistance to corrosion.

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II. METHODOLOGY

C. DESIGN METHODOLOGY

a. Adaptive Design of the Members.
b. Theoretical Checking of individual members for structural safety.
c. Modeling and Analysis of the panel structure for Strength.
d. Optimization of Panel member strength.

1) ASSUMPTION

The Modeling and analysis of supporting structure is based on various assumptions:
a. The wind load is acting in horizontal direction.
b. Wind load is acting with a constant velocity.
c. Only wind force and weight of the panel are acting on the structure. Other forces are out of scope of this study.

2) MATERIAL

a. Aluminum
b. Galvanized Iron
c. Steel
d. posMAC

3) SOFTWARE

a. For Modeling Solid works.
b. For analysis ANSYS and CFD.

III. LITERATURE REVIEW

Alex Mathew & B. Biju et al. studied design and stability analysis of solar panel supporting structure subjected to wind force. In this study the arrangement of solar panels in structure is similar to double sloped roof trusses. Due to this wind force, the structure experiences an overturning effect. This overturning couple imparts a reaction force at the base of the structure. The structure is symmetric along any vertical plane. They used CAD modeling software CREO 2.0, the test model of solar panel supporting structure was created steel. They concluded that the design of solar panel supporting structure is done and the effects of wind force on its structure stability are analyzed. Due to the wind force, a reaction force is experienced on the structure and the structure will retain its stable state, only if this reaction force is compensated by the force due the self-weight of the structure. This structure will be used as the fuel stations to meet the energy requirement of solar cars, as it can be used for domestic purpose, commercial purpose.

Mihailidis et al. represented the analysis of two different design approaches of solar panel support structures which are 1) Fixed support structure design, 2) Adjustable support structure design. They did analysis according to the following steps.

Load calculation, 2) Analysis of the structure, which includes the creation of a Finite element model using ANSA as preprocessor. Loads calculated in the first step are applied to the model. As solver MSC Nastran is used. 3) Identification of the structure critical points. According to the results weak points are redesigned in order to increase theend.

Jinxin Cao et al. performed a wind tunnel experiment to evaluate wind loads on solar panels mounted on flat roofs. In order to find module force characteristics at different locations on the roof they use solar array which were fabricated with pressure taps. They consider two different cases 1) single array, 2) multi-array and find mean and peak module force co- efficient. They also find effect of mean module force co-efficient on design parameter of solar panel. They found effect of mean module force co-efficient on design parameters (tilt angle, height) of solar panel. The results show module force coefficient for single array cases is larger than multi array cases.

Chih-Kuang Lin et al. use FEA approach to find the effects of self weight and wind loads on structural deformation and misalignment of solar radiation.

Sayana M. et al. studied Buckling analysis of solar panel supporting structures. In this study buckling analysis is done by 1) Eigen value buckling analysis, 2) Non Linear buckling analysis. In this project

Finite element procedure is carrying out. In which the body is sub divided into small discrete regions known as finite elements. These elements are defined by nodes and interpolation functions. Governing equations are written for each element and these elements are assembled in to a global matrix. Loads and constraints are applied and the solution is then determined. ANSYS software which is finite element software has been used for this study. They concluded that the stability of a structure depends several factors such as sectional properties, sectional arrangements, modeling of the structure etc. From the results they concluded that the standard sections improve the stability of the structure, the arrangements of I, C, and L section affect the buckling behavior of the structure. Among these sections I section have more stability but it is not economical, and the C section is less stable during buckling. During loading such as due to the weight of the panel and the effect of wind, more stress occurring at the roof of the panel supporting structure, the L section is more suitable at the place of maximum stress.

1) Procedure

i. Market research & study of available system.
ii. Specify parameters &specification for design.
iii. Changes in designing and optimization by trial and error method.
iv. Material.
v. Mechanism.
vi. Attachments.
vii. Manufacturing process.
viii. Structure and shapes.
ix. Reaching optimum by trial and error method &comparison.
x. Checking for availability of components cost effectiveness.
xi. Proposing durability and effectiveness.
xii. Finalization of design from final results.
xiii. 2D draft, 3D design, with final practical coasting.

Solar Panels are being widely promoted by the Central government as it is very economical and eco-friendly. They need very less maintenance and their running cost is drastically reduced. Solar panels convert the freely available solar energy into the useful form electrical energy which is used to run the water pump and other accessories if any. The mountings which are required for the installation of Solar Panels are design and analyzed with all the considerations for its safety and avoiding accidental damage. Also, the amount of radiations which impinge on the solar panel according to the position of sun is to be studied. This will provide an optimum amount of energy at the output with an advantage of extended life. Various materials are also studied in varied conditions to obtain a sustainable and durable material. The four leg structure is to be designed.

IV. MATERIAL SELECTION AND DESIGN METHODOLOGY

When we decide to install solar plant, the most important thing of the solar plant is to choose the solar mounting structure material, and the material used for the structure affect the solar plant property, safety and solar plant life directly. A good mounting structure can not only wear the weight of solar modules, but can also withstand extreme weather conditions like storms and floods. A variety of materials ranging from wood to polymers have been used to create strong and durable mounting structure for solar panels. Stainless steel has been the popular choice in most cases. Give in the plant location and life cycle, stainless steel has traditionally been the most cost-effective option. However, recent trends show an increased utilization of aluminium hot dip galvanized state along with steel for better protection against rust formation.

Aluminum ideal for strength to weight ratio limitations Existing system typically were not designed to support the weight of a solar installation. But the low density of aluminum helps to make a solar installation feasible, especially on those field that simply cannot handle the high weight of a steel frame structure. Aluminum extrusions deliver superior design flexibility, high strength-to-weight ratio, excellent

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corrosion resistance and ease of handling and assembly – all of which are essential for a successful commercial rooftop installation. These characteristics make aluminum the metal choice for solar frame structures installed in agricultural applications like solar water pump.

Aluminum is "the green metal" and offers a number of advantages over steel for solar structures. An aluminum frame will outlast the life of the solar panel modules yet is cost competitive with steel structures that will rust out before the solar panels wear out. This frees you to design your solar installation for the life of the panels rather than the frame structure, giving you a significant competitive advantage. When its time to replace your solar structure, aluminum is 100 percent recyclable. But, environmental considerations start at the beginning of the process with the raw material used to extrude your components. Using recycled aluminum billet from Hydro reduces the environmental impact of your project by reducing the impact of sourcing and processing raw metal out of the ground.

Aluminum has a unique and unbeatable combination of properties that make it versatile, effective, and attractive for a vast array of applications:

Weight - Aluminum is light with a density one third that of steel (0.097 lbs/in3).

Strength - Aluminum is strong with a tensile strength of 10 to 100 KSI, depending on the alloy and manufacturing process. Extrusions of the right alloy and design are as strong as structural steel.

Elasticity -The Young's modulus for aluminum is a third that of steel (10,008 KSI). This means that the moment of inertia has to be three times as great for an aluminum extrusion to achieve the same deflection as a steel profile.

Formability - Aluminum has good formability, a characteristic that is used to the fullest extent in extruding, facilitating shaping and bending of extruded parts. Aluminum can also be cast, drawn, and milled.

Machining - Aluminum is very easy to machine. Ordinary machining equipment such as saws and drills can be used along with more sophisticated CNC equipment.

Joining - Aluminum can be joined using normal methods such as welding, soldering, adhesive bonding, and riveting. Additionally, Friction Stir Welding (FSW) is an alternative in certain applications.

Corrosion resistance - A thin layer of oxide is formed in contact with air, which provides very good protection against corrosion even in extremely corrosive environments. This layer can be further strengthened by surface treatments such as anodizing or powder coating. And corrosion resistance can be enhanced through alloy selection. Reflectivity - Aluminum is a good reflector of light and heat.

Thermal conductivity -Thermal conductivity is very good even when compared with copper. Furthermore, an aluminum conductor has only half the weight of an equivalent copper conductor. Electrical conductivity -When compared to copper, aluminum has good electrical conductivity. Linear expansion - Aluminum has a relatively high coefficient of linear expansion compared to other metals. Differences in expansion can be accommodated at the design stage, or in manufacturing.

Pure aluminum is only used in a limited way commercially. The majority of extrusions are made from aluminum alloyed with other elements. The most common elements used are magnesium (Mg), silicon (Si), manganese (Mn), zinc (Zn) and copper (Cu). Most aluminum extrusions are made from the alloy series listed below:

I. 1000 series Al
II. 3000 series Al + Mn
III. 5000 series Al + Mg
IV. 6000 series Al + Mg + Si
V. 7000 series Al + Zn + Mg

D. VARIOUS PARTS DESIGNS

1. Railed system
2. Rail-less system
3. Shared -Rail system

Here are some parts which are required for the solar pump mounting system. These are the important parts in the system. Namely perlin, rafter, springs clam, Unipole, U clamp, etc.

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Design is done on Solid works software. Figure of parts shows as below.

Figure 4.1 Part Rafter

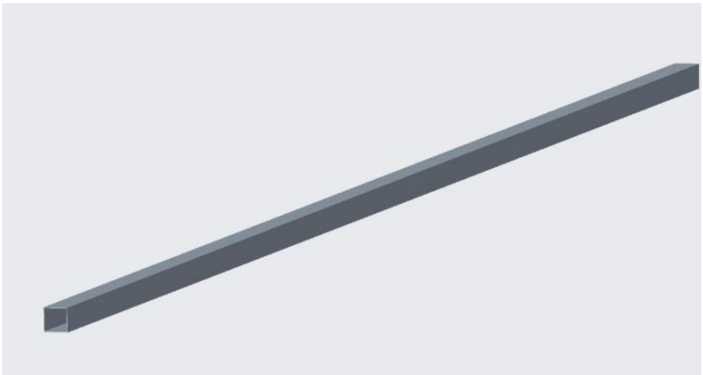

Figure 4.2 Part Perlin

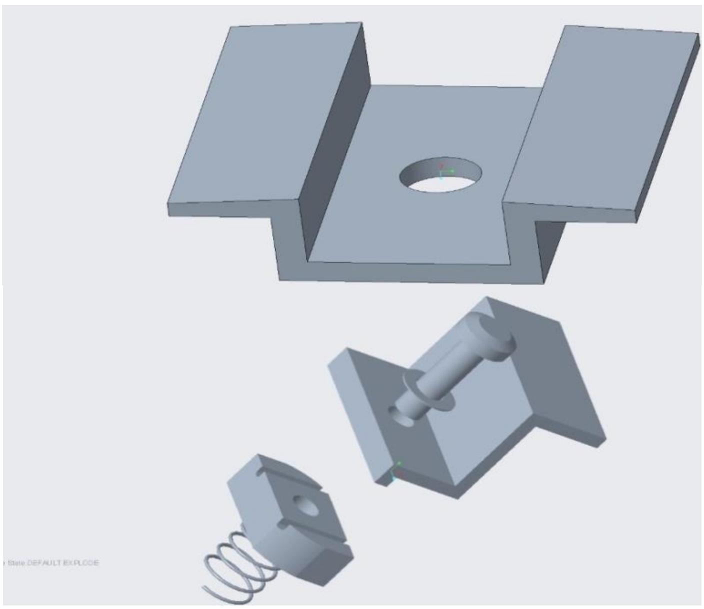

Figure 4.3 Part clamps

V. CALCULATIONS, RESULTS & ANAYLIS

The dead load includes loads that are relatively constant over time, including the weight of the structure itself, and immovable fixtures such as walls, plasterboard or carpet. The roof is also a dead load. Dead loads are also known as permanent or static loads.

The weight of solar panel is dominant dead load in design of solar mounting structure. This calculation of load is invariant hence can be calculated accurately. Clamps, bolts, weight is in negligible amount hence the clamping equipment's weight is neglected.

Weight of individual solar panel = 22kg
Dimension of solar panel = 2m * 1m* 0.04m
Number of solar panels used = 8
Area of solar panel = 2 m^2
Total area of solar panel = 16m^2
Dead load on the perlin and rafter is = weight one 1 solar panel * no. of solar panel = 8 * 22 = 176 kg
Taking 1kg = 9.81 N
The total dead load of solar panels is = 176 * 9.81 =1726.56 N
Considering factor of safety = 1.5
Load considering factor of safety =2589.84

A. Live load calculations:

Live load is a civil engineering term that refers to a load that can change over time. The weight of the load is variable or shifts locations, such as when people are walking around in a building. Anything in a building that is not fixed to the structure can result in a live load, since it can be moved around.

So the live load on solar panel is also needed to be considered for design calculations. Though it is not similar to that of other civil structure in which large loads of vehicle, man, machineries are considered but chances of putting object and hanging bags on solar panel structure for temporary purpose or chances of climbing of animals like monkeys, dogs, hens, etc. can't be neglected. In some critical situation like putting heavy object by taking support of solar structure can induce excess force on the solar structure.

Live load is considered as 20 N / m2.

B. Wind load calculations:

Area of solar panel = 2 m^2
Dimension of solar panel = 2m * 1m* 0.04m
Total area of solar panel array = 16m^2
Wind press on the structure is calculated by using following formula
P wind = 0.6 x V^2

To select basic velocity of air India wind zone map is studied. It shows maximum speed in the different region of the India. From map it shows maximum velocity of air in India can reach up to 33 m/sec to 50 m/s according to region. Considering the Maharashtra state the speed is varying less than 33 to 44 m/sec. the high velocity region is Kokan of Maharashtra and eastern part where velocity is in between 39-44 m/sec. Southern part of Maharashtra having max velocity less than 33 m/sec and remaining middle and northern part has 33-39m/sec. By analysing data, for satisfactory performance of structure in such critical condition of maximum air velocity mostly in storm, it is needed to design to withstand this air force. Hence we need to consider basic velocity of air for design of this critical situation. The basic velocity of air V,V = 45 m/sec

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Figure 5.1(a) Wind zone Map [3]

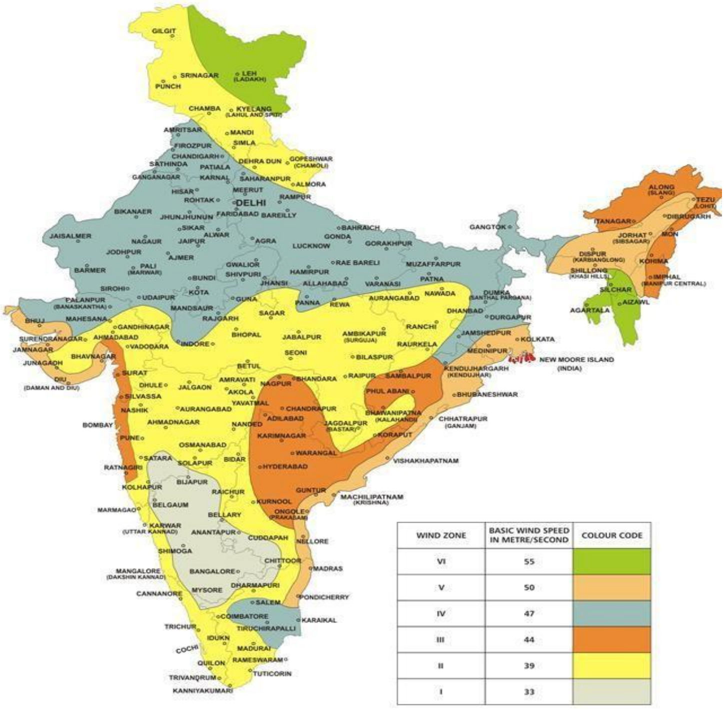

Figure 5.1(b) Wind velocity with regions code [4]

C. Design velocity

Design velocity, V can be calculate by using the equation

V= k1.k2.k3. Vb

k1 =Risk coefficient or probability factor. For all general building and structures with a wind velocity of 55m/s, it is 1. Various values are given in table.

k2 = Terrain, height and structure size factor. For terrain category 2 and class A structures, it is 1. A value of this coefficient is given in table.3 Category 2 terrain contains is contained with scattered obstructions having heights usually between 1.5m to 10m above ground surface. Class A are the

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structures and/or their components such as cladding, roofing etc. having maximum dimensions is less than 20m above ground surface.
k3 = Topography factor. Its value is taken as unity, if the slope of ground is < 3^0.
While calculating design velocity the $k_{2,}$ $k_3$are taken as unity.

Class of structure	Mean probable design life of structure (years)	k1 factor for Basic Wind Speed					
		33	39	44	47	50	55
All general buildings and structures.	50	1.0	1.0	1.0	1.0	1.0	1.0
Temporary shed, structures	5	0.82	0.76	0.73	0.71	0.70	1.67
Building and structures presenting a low degree of hazard to life and property in the event of failure.	25	0.94	0.92	0.91	0.9	0.9	0.89
Important buildings and structure such as hospitals, communication towers, etc.	100	1.05	1.06	1.07	1.07	1.08	1.08

Design velocity Vd = K1 * k2 * k3 * V
0.91* 1 *1 * 44
= 40.04approx 40
Wind pressure
Pwind = 0.6* vd2
960 N/ m2
Calculating projected area of solar panel and F wind acting on the solar panel

α (tilt angle)	Projected area Ae = A * sinα	F wind =Ae * Pwind (Vd =40m/sec)	Season
1	0.28	268.8	Summer
2	0.558	535.68	
3	0.837	803.52	
4	1.116	1071.36	
5	1.394	1338.24	
6	1.672	1605.12	
7	1.95	1872	
8	2.226	2136.96	
9	2.503	2402.88	
10	2.778	2666.88	Spring / autumn
13	**3.599**	**3455.04**	
15	4.141	3975.36	
18	**4.944**	**4746.24**	
20	5.472	5253.12	Winter
25	6.761	6490.56	
30	8	7680	
35	9.17	8803.2	
40	10.28	9868.8	
45	11.31	10857.6	

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From above chart we are selecting 13 degree 18 degree and 0 degree angles for annual functioning of solar panel. The selection of tilt is considered according to the geological location of Maharashtra (considering pune data as representing Maharashtra due to central location)

From above the maximum force that will be induced on solar panel structure due to wind load is 4746.24 N. this is a critical wind load condition for storm like situation.

D. Total load

Partial factor of safety for loads, for limit states

Limit state is a condition just before collapse. A structure designed by limit state should give proper strength and serviceability throughout its life. In limit state method, the limit state of collapse deals with the safety of structure and limit state of serviceability deals with the durability of structure.

Serviceability refers to the conditions under which a building is still considered useful. Should these limit states be exceeded, a structure that may still be structurally sound would nevertheless be considered unfit.

Comiatios	Limit state of strength			Limit state of Serviceability		
	DL	LL	WL	DL	LL	WL
DL+LL+WL	1.5	1.2	1.2	1.0	0.8	0.8
Load with FOS	2589.84	384	5695.488	1726.56	256	3996.99

The structure is able to withstand the wind load with the velocity of '39m/sec' & 5^{o} angle of Inclination. Therefore, The structure is stable.

E. ANALYSIS OF STRUCTURE ON ANSYS

Assume force: 2N

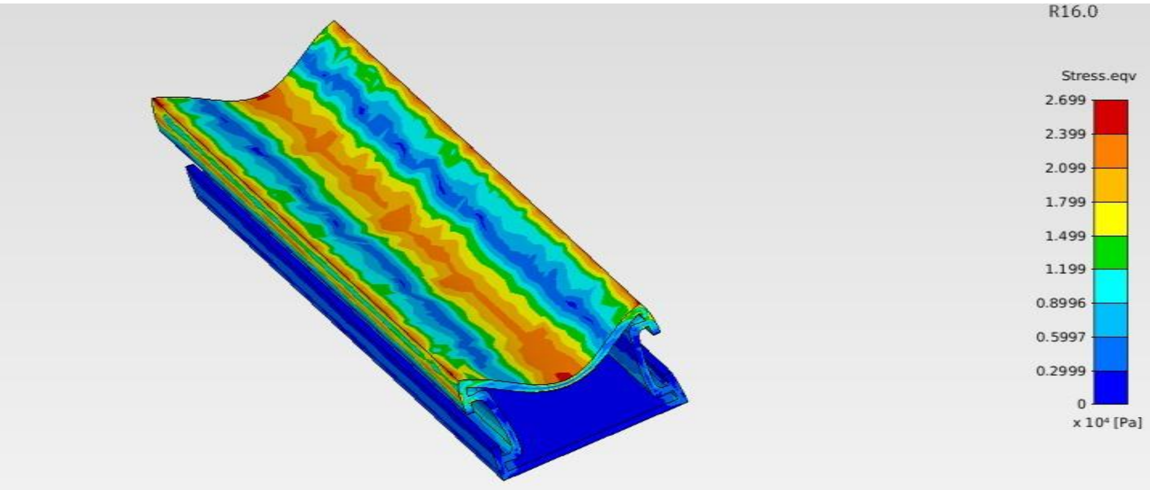

Figure 5.2.1 Stress analysis of mounting structure Maximum stress=2.391

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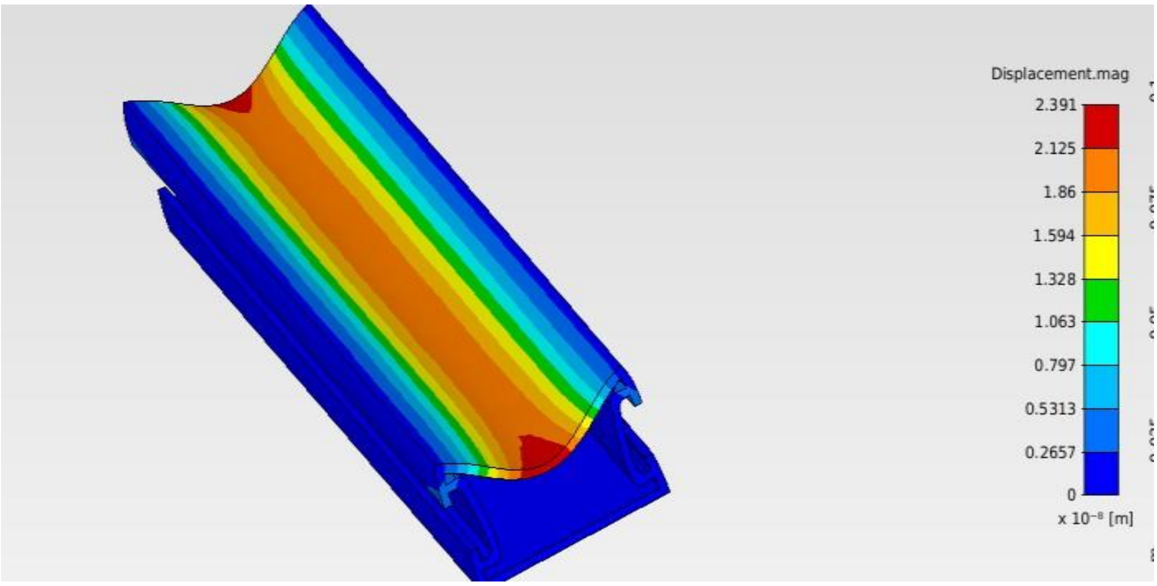

Figure 5.2.2Displacement analysis of mounting structure Maximum displacement=2.699

F. ADVANTAGES OF NEW DESIGN:

- Less penetration
- It improves efficiency
- Less material usage
- Decreased length

G. RESULT

- According to IBIS, despite using a more expensive raw material, when properly sourced, aluminium structures can have a lower installed cost than equivalent steel structures.
- Several factors influence this cost advantage, most notably faster installation time and reduced shipping cost relative to steel-based PV structures.
- Faster installation time and reduced shipping cost relative to steel- based PV structures.
- The maximum stress is applied at the end centers of the structure

VI. CONCLUSION

One of the largest areas of innovation within solar involves mounting system. Probably the most competitive solar product market (still it's just a drop in the bucket), mounting system are an important element of solar array, they secure solar panels to roof or ground. As per industry estimates, module mounting structures accounts for 9-15 percent of n total cost of solar power plant, depending on the size of the plant. In smaller plants, mounting structure make up about 9 percent of total project costs, while their share increase on large plants.

The modified solar mounting structure is based on the analysis of wind velocity considering constants regions velocity and different boundary conditions. The material used for the modified design is appropriate for all the surrounding conditions and cost friendly.

ACKNOWLEDGMENT

Authors would like to thanks Energica Pvt. Ltd. for funding this project and giving opportunity to accomplish project in company lab.

ISSN: 2233-7857 IJFGCN

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ISSN: 2233-7857 IJFGCN