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Design and analysis of mounting structures of Solar Panels mounted on industrial sheds.

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ABSTRACT

This Paper seeks the Design of a new mounting structures for Solar Panels mounted on industrial sheds with the Analysis of these mounting structures and the comparison of new and already available Mounting structures in the market on the basis of design, material of structure, static structural analysis and wind load handling capacity. Presently solar energy conversion is widely used to generate heat and produce electricity. It was found that solar thermal is getting remarkable popularity in industrial applications. Solar thermals are an alternative to generate electricity, process chemicals or even space heating. Therefore it is very important to ensure the proper mounting of solar panels on industrial sheds as proper mounting helps in improving efficiency of the system , avoid the damage to the solar panels from the wind loads and various other parameters.

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1. INTRODUCTION

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The use of non-renewable source of energy like coal, oil, gas in generation of electricity are getting scarce and has led to the emission of pollutants to atmosphere which has resulted in global warming. The results of a recent review of literature concluded that as greenhouse emitters begin to be held liable for resulting in climate change, a high value for liability mitigation would provide powerful incentives for development of renewable energy technologies like solar energy.

The main objective of our project is to optimal design of mounting structures to replace the usually using that from decades or usage of the different material which will be compatible with the material used for structure today. In this study we are bringing forth the design challenges involved in finding optimized solutions to effectively resist the forces of wind and gravity on a solar panel structure. Also the various research is done on the proper selection of material compatible for mounting structure. As a sponsored project, our motive is to provide them design of mountings structure in a such way that it should having enough strength with minimum material usage in order to optimal the cost of mounting structure that will directly affect reducing cost of installation of solar panel on industrial sheds and hence increasing profit of company.

With the number of solar parks and rooftop installations increasing, people are becoming more concerned about the aesthetics and maintenance of the array structure. Owners and operators are looking to solar as a Architects desire solar systems that blend in with the rest of the building and surrounding area.

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- fortably, 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 metal of choice for solar.

1.1.1 TYPES OF ROOF MOUNTS

A. **Flush Mount** is the first type of roof mount that we will cover. They are inexpensive and simple option suitable for most roof mounted solar panel installations. They are generally not adjustable, and as the name suggest, they are designed to lay flush with the roof surface on which they are mounted. The solar panels are generally secured using metal clips that hold the panel in place, leaving about 2-4 inches of space between the roof and the bottom of panel. This allows the plenty of airflow along the underside of the panel, which keeps the panel cool and operating at maximum efficiency. If a panel overheats, its efficiency drops and so does its life. These mounts are great for homeowners, less so for business owners. Roof

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mounts aim to protect your roof as well the solar panels. Flush mounts are ideal for reducing the dead load on your roof .they work for any type of system, are suitable for high wind areas, there is room for flexibility in the panel slope and orientation and they provide minimal interference with roof drains.

B. **Ballasted Mountsare** similar to flush mounts, but use weights to hold the solar panels in place on your roof. This design can save labor time and cost, but presents an additional challenge of getting the weights onto the roof, which can be quite substantial when dealing with larger systems. Ballasted mounts do not require roof penetration, are faster and cheaper to install and allow for a panel tilt of up to 20 degrees for optimal solar exposure. However, this mounts increase the load on your roof, has lower power density, and is less suitable for high-wind areas. They are limited by certain site conditions like roof slope and building height.

C. **Hybrid Mounts,** which you guess are a combination of flush mount and ballasted mounts. They use some structural elements of both mounts to accommodated some roofs that can‟ t support either. Hybrid mounts, require minimal roof penetration, can be fast to install (depending on the model) and allows for custom design optimization based on factors loke load bearing and wind. These mounts expensive and can take up more space on your roof, leaving less room for your system.

D. **Mounting Rack Material**

Mounting rack can be made of different materials. The majority of manufactures of mounting racks use aluminum. It is not only low weight - thus decreasing weight pressure on the roof, pole tracking system – but also corrosive-resistive, strong and compatible to the solar module frames of many manufactures that are mostly made of Aluminum.

Another choice can be mounting structures made of stainless steel. Although stainless steel racks are very strong and resistant against environmental impacts such as hail, snow, rain etc. and can last for ages, they are nevertheless an expensive investment. Wood-made mounting rack are cheap and easy to work, but are weak in consistence and bound to fail quickly particularly in wet environments. Plastic made mounting racks are also cheap, but not optimal choice in terms of statics and life time. Like wood-made mounting racks, they may burn or even break if pressure on the solar panels is to high.

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2. METHODOLOGY

2.1 DESIGN METHODOLOGY

a. Adaptive Design of theMembers.
b. Theoretical Checking of individual members for structuralsafety.
c. Modeling and Analysis of the panel structure forStrength.
d. Optimization of Panel member‟ sstrength.

2.2 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.

2.3 MATERIAL

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

2.4 SOFTWARE

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

3. 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

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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.
  1) 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

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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.

- 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 design.

4. 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

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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 aluminumin hot dip galvanized state along with steel for better protection against rust formation.
Aluminum ideal for rooftop weight limitations Existing rooftops 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 rooftops that simply cannot handle the high weight of a steel frame structure. Aluminum extrusions deliver superior design flexibility, high strength-to-weight ratio, excellent 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 on carports, commercial buildings and home rooftops.

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 it‟ s 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

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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***

4.1 ROOF TOP VARIOUS DESIGNS AVILABLE

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

Out of all the system it was found that shared Rail system is ideal as a mounting structure for solar panels. It‟ s kind of similar to Rail less in the sense your minimizing penetrations and you‟ re middle rail with that penetration row, but you have a standard rail that is holding up the whole system.

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4.1.1 PREVIOUS DESIGNS:

1. **Squared extruded structure**

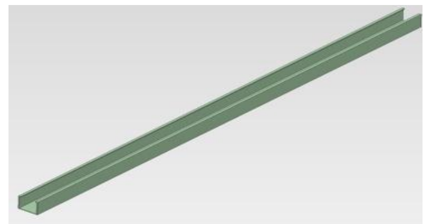

Figure 4.1 Square Constructed Structure

Specification:
Length = Width = Height=

2. **Modified Taper extruded structure**

a. Increased height

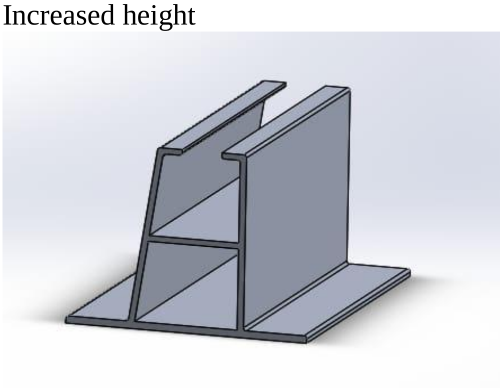

Figure 4.2Increased Height Structure

Specification:
Length= Width= Height=

b. Increased width

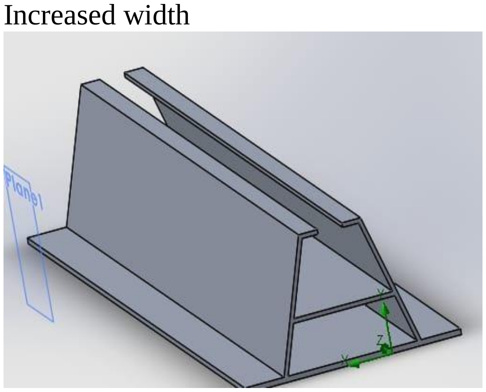

Figure 4.3 Increased Width Structure
Specification: Length=

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Width= Height=

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Due to this wind force, the structure experience as overturning effect. This overturning couple is expressed as

4.1.2 NEW DESIGN:

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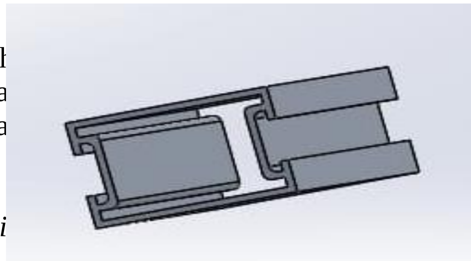
$C = F_{wind} * h$

This overturning couple imparts a reaction force at the base of the structure. This reaction force can be calculated by using the following expression.

$$F_R = \text{–}$$



Th cal plane. In this model we have considered either left or right ha ne. So, the reaction force F_R is expected to distribute in all the ba rtion.

Fi

Specification:
Length= Width= Height=

Theoretical analysis of wind load:

Formulation of generalized stability condition of structure for wind force

The arrangement of solar panels in structure is similar to double sloped roof trusses, for which the expression for wind pressure is given by:

$P_{wind} = 0.6*V^2$ (1)

Therefore, Wind Pressure* Effective area of panel

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SPECIFICATIONS OF MODEL

1. Length of shed, l = 4m
2. Width of roof, b = 2m
3. Total area of sloped roof, A = $8m^2$
4. Total mass of structure , m = 425kg
5. Total height of the structure, h = 3.123m Distance between the primary touching points of the base legs, x = 1m

4.2 ASSUMPTIONS:

I. The structure is symmetric about any vertical plane.
II. The wind load is acting in horizontal direction.
III. Depth/thickness of panel is ignored.

F_{wind}

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$= P_{wind}$

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* A_e

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(2)

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IV. Wind load is acting with a constant velocity.
V. Structure is placed is horizontal position.

A_e = Total area of sloped roof * Sine of angle of inclination

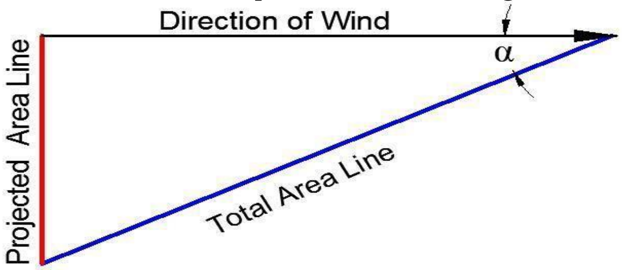

Figure 4.5 Wind Direction

From figure 4.5,

Sine α =

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VI. The wind force is acting at the tip of the structure.

5. CALCULATIONS, RESULTS & ANAYLIS

$U_{pwind} = 0.6*V^2$

Design velocity, V is taken from the standard table

Therefore, Projected area line = sine α * Total area line $A_e = A \times \text{sine}\ \alpha$ (3)

Substituting equation (3) in (2)

$F_{wind} = P_{wind} * A * \text{Sine}\ \alpha$ (4)

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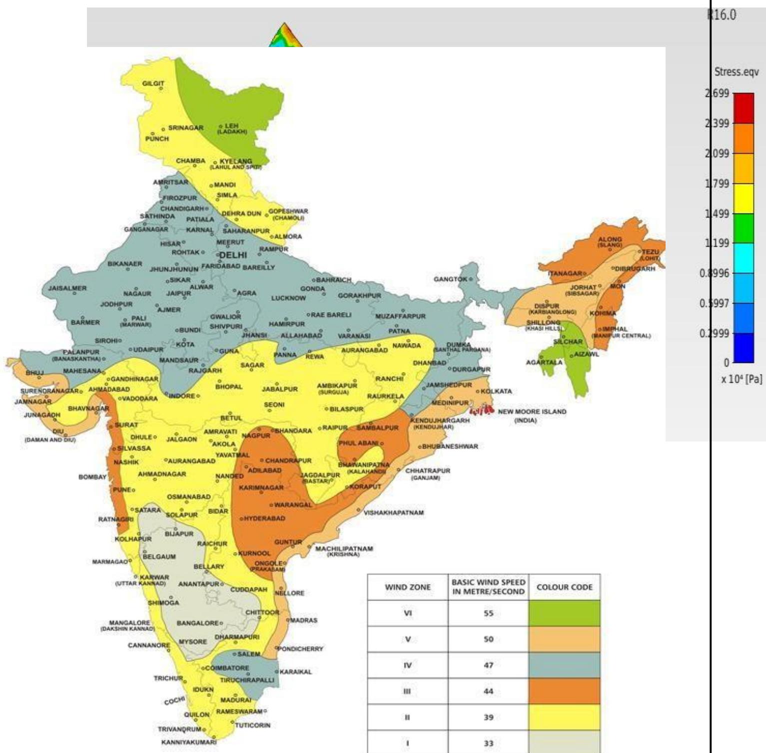

Figure 5.1 Wind velocity with regions code

Therefore,

V = Basic wind speed of zone II = 39m/sec $P_{wind} = 0.6 * V^2$

Therefore,

$P_{wind} = 912.6\ N/m^2$ Wind force,

$F_{wind} = P_{wind} * A * \text{Sine } \alpha$

Here, the angle of inclination is considered as 5º Therefore, $F_{wind} = 636.3066$ N

Overturing couple, $C = F_{wind} * h$

(The value of „h" is taken from the table) Overturning Couple = 363.36 N/m

Reaction force $F_R = C/x$ N $F_R = 363.36$ N

Weight of the structure, W = m * g N Therefore, Weight = 4170 N

Applying stability condition, $W \geq 2 * F_R$

$4170 \geq (2 * 363.36)$

$4170 \geq 726.66$

The condition is satisfied.

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

5.1 ANALYSIS OF STRUCTURE ON ANSYS

Assume force: 2N

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Figure 5.1.1 Stress analysis of mounting structure Maximum stress=2.391

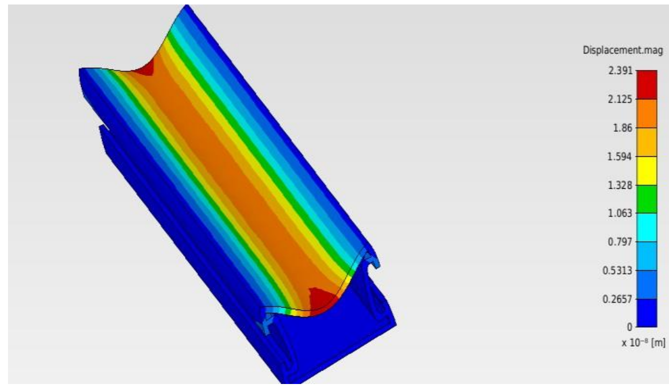

Figure 5.1.2Displacement analysis of mounting structure Maximum displacement=2.699

ADVANTAGES OF NEW DESIGN:

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

5.2 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

5.3 CONCLUSION

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- 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 constant‟ s regions velocity and different boundry conditions.
- The material used for the modified design is appropriate for all the surrounding conditions and cost friendly,

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