Design of Solar Mount using High Density Polyethylene

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Abstract:

The limited fossil fuel resources and higher energy demand has led to the requirement of commissioning solar PV plants to a great extent. Renewable energy sources like solar which is free of cost, eco-friendly, sustainable and unlimited has problem of land requirement which will always be an expensive commodity. Thus, to overcome this problem, an innovative idea of installing solar power plants on the rooftops of the homes and buildings with portable solar module mount can be an attractive option. This work highlights the concept of solar PV plant with portable mount and deals with solar photovoltaic design, development using numerical analysis. Portable components are made up of HDPE which show superior performance and are cost effective. CFD analysis is executed on the structure for the study of flow and assessment of wind pressure on the developed model using Indian environmental conditions. The CFD results have been compared and validated with the analytical calculations obtained through IS 875 codes part 3 for wind pressure. Also, Structural FE analysis is carried out to ensure structural stability for the given environmental conditions.

Keywords: Solar, PV, CFD, Polymer, HDPE

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Introduction:

The increasing demand for sustainable and renewable energy sources has propelled the widespread adoption of solar energy systems. Solar photovoltaic (PV) technology has emerged as a prominent solution for harnessing clean and abundant solar energy to meet our electricity needs. A crucial element in the efficient operation of solar PV systems is the solar mount or mounting structure that supports and positions the PV panels. Traditionally, these mounts have been constructed using materials like metals and alloys, but recent advancements have led to the exploration of polymer-based designs, offering innovative possibilities for solar energy infrastructure.

Polymer materials, renowned for their lightweight, durable, and corrosion-resistant properties, present a compelling alternative for solar mount design. This paradigm shift leverages the benefits of polymers, which include ease of manufacturing, reduced environmental impact, and design flexibility. This design approach aligns with the overarching goal of sustainable energy generation by not only utilizing renewable solar power but also incorporating eco-friendly and recyclable materials in the system.

In this context, this study focuses on the design of a solar mount using polymer materials. By integrating polymers into the mount's structure, we aim to explore novel avenues for optimizing the efficiency and cost-effectiveness of solar PV installations. The design process encompasses various aspects, including load-bearing capabilities, structural integrity, thermal expansion considerations, and resistance to environmental factors such as UV radiation and moisture.

The utilization of polymers in solar mount design introduces exciting possibilities for customization and adaptability. Polymer-based mounts can be engineered to accommodate different panel sizes, orientations, and installation scenarios, thus catering to a wide range of solar energy applications. Moreover, the inherent insulating properties of certain polymers can contribute to improved temperature management and potentially enhance the overall performance of the PV panels.

This paper will delve into the fundamental principles of polymer material selection, structural design, and engineering considerations for solar mounts. It will also address challenges and limitations associated with polymer-based designs, including load-bearing capacities and long-term durability. Comparative analyses between traditional metal mounts and polymer-based mounts will be conducted to assess the viability and competitiveness of the proposed approach.

Literature Survey:

In India, there are many infrastructures with huge rooftop space and thus this technique serves as a complementary advantage. In addition to all positive aspects, proper design consideration such as wind, water stability, temperature limit, snow load, cyclone, and typhoon, etc. should be considered. Also, proper azimuth tilt and angle as per geographical location should be considered. It is found to produce 1.2 times the current production of PV on lands[11] studied the power generation effectiveness of the floating solar PV plant and analyzed the capacity of a floating solar PV system with respect to terrestrial solar PV system. It was estimated that floating PV system is almost increased by 2% in comparison with the land-based PV system[8]. Authors studied different cases for various wind angle of attack on standalone ground-mounted solar panels [7] and concluded that panel length has a major impact on solar panels. Also, the spacing factor is an important factor for designing a solar farm. First row panels are subjected to higher wind loads when panel length increases[10]. Qazi A et al [5] showed that Solar PV system performance is enhanced due to its open design which facilitates natural ventilation. A 3D CFD model describing the performance of the system is developed and compared with the experimental data [5]. McLaren J. et al [6] concluded the angle of attack of wind on surface plays an important role to study the mean pressure distribution. It was observed that pressure was maximum at 0° and 180°. Gadhavi Aksh G et al. [29] studied variations of lift and drag force with the change in the angle of attack. It was found that at 30°, the lift force is higher than the drag force. Solar systems can raise a householder’s awareness of energy consumption by means of a monitoring facility provided with the installation. This enhanced awareness of energy use could encourage further energy efficiency [29].

This type of behavioral change is advantageous to the adoption of solar as it increases the compatibility of the systems with current energy consumption trends. Solar energy is the main natural source of all form of energy. Energy received direct from the sun radiation is solar energy. In case of wind, which is essentially air in motion, carries with it kinetic energy. The amount of energy contained in the wind at any given instant is proportional to the wind speed at that instant. The temperature of the wind also influences the energy content of the wind but it is not important in the context of wind-based production system[24]. Consumer's attitude towards technology adoption become significant at least in marketing sense, because any time they are introduced to products which require us to change our current mode of behavior (to be energy conscious and using less energy). The technology adoption cycle is used a marketing model to deal with the introduction of a new high technology product. Solar system can raise awareness of householder's energy consumptions by means of a monitoring system. However, despite the positive characteristics, solar systems remain unattractive to individual householder as a home improvement and incompatible with personal priorities [27]. Nevertheless, even if the costs reduced and information was made more widely available, it is not clear whether adoption levels would increase. Several international studies done on the price elasticity of electricity have shown that it is inelastic. There are further hurdles to widespread adoption in the form of issues with the long pay-back periods, high capital costs and a lack of confidence in the long-term performance [30].

Different types of loads acting on solar structure in this review paper studies different types of loads acting on solar structure and their analysis. Also studied if the structure is not designed considering all loading factors then it can lead to breakage of structure which intern will affect the power generation [24]. Design and analysis of solar panel support structure in the paper studies Support structure by considering environmental effects like wind load, height of structure, structural load the analysis can be done by creating the model in software and then analysis in different software and is also considered that verify that the location is important for solar panel mounting structure it also affects the performance and life span of that structure [22]. Design and stability analysis of solar panel support structure subjected to the wind force and made in mind steel in this paper the design of solar panel support structure and the effect of wind force on its structural stability is discussed in this paper the measures for preventing the overturning of structure are also discussed they used CAD modelling software CREO 2.O test model of solar panel support 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[23]. 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. Studies design and analysis of solar structural and mounting for solar panel in this studies discussed the solar mounting system and their various types and also studied material selection which material can be suitable for solar mounting structure for including all environmental effects also studied material properties and cost of materials They concluded that 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 [22].

Numerical investigation of impact of various wind loads on the structural stability and strength of solar panel supporting structure. In this study, Finite Element Method (FEM) was established to investigate the impact of various wind loads on the structural reliability and strength of solar panel supporting structures. also studied Wind loads were also calculated by mathematical approach. They concluded that solar panel structure was significantly affected by wind loads applied on the surface of solar PV module. The wind speeds of 20 m/s, 25 m/s, 30 m/s, 35 m/s and 40 m/s were used for the analysis of solar panel supporting structure. The results obtained from the FEM analysis that total deformation and maximum equivalent stresses were increased by increasing the wind loads [24]. Analysis of solar panel support structure in this study, the analysis of two different design approaches of solar panel support structures is presented. Also studied the analysis in three different ways such as Loading calculation, Analysis of the structure, identification of structure critical point also studied Finite Element Method (FEM) is used to calculate the stresses acting on the supporting structure there are two types of solar panel mounting structure fix and adjustable are studied in this paper. They concluded that fixed solar array support structures have sophisticated design that needs to be analyzed and often improved in order to withstand the wind load. The same applies of course to adjustable designs to an even greater extend. The stresses on different members of the structure are studied and also studied comparison of fixed and adjustable support structure [25].

One of the largest areas of innovation within solar involves mounting system. Probably the most competitive solar product market (still it' 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 increasing 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.

Proposed Model:

3D Cad Modelling of Main Part which will be the base of the structure. Ballast rocks that will hold the structure in place and Solar Panels are as Follows. All the above-mentioned components were designed and modelled in the CAD platform. The assembly of the MMS was also done in the same software. The model was designed for a 17-degree tilt – and number of panels as per requirement.

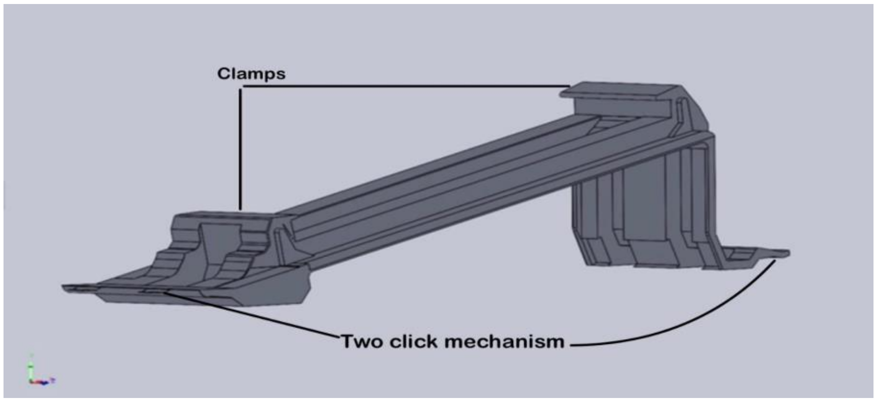

Fig. 1. CAD Model of the Main Part

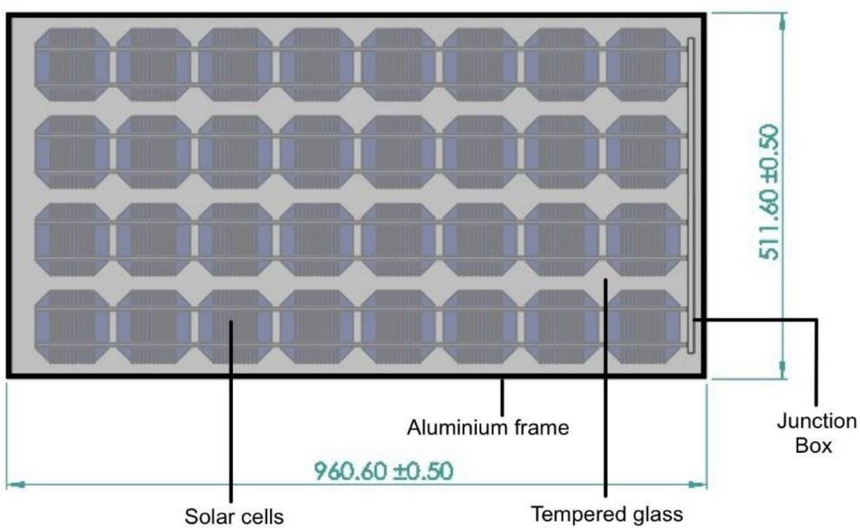

Fig. 2. CAD Model of Solar Panel Used

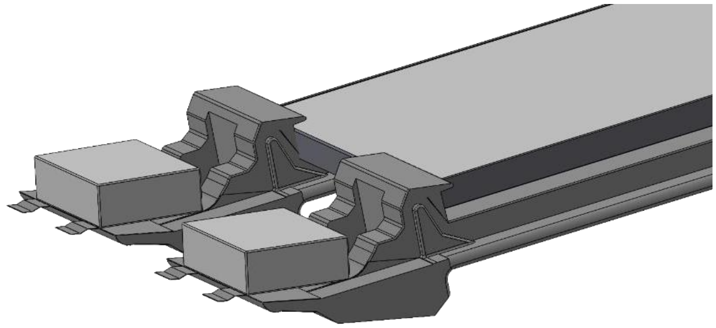

Fig. 3. CAD Model of Ballast Rocks Supporting the Base Part

The main part supporting the solar panel is shown in the Fig 1. Two of the main parts together hold the solar panel in place. The dimension of the part can be altered depending on the size of the desired solar panels. The Fig 2 shows the dimension of the solar panel used for the analysis. The panel taken into consideration is made by Luminous and is a monocrystalline type of solar panel with 445 watts. Overturning of the structure is caused due to the lateral forces. When structures are subjected to lateral forces such as wind force and seismic forces, they undergo deflection in the lateral direction and lateral sway is also observed in one direction of the structure. This causes structure to experience overturning. The various types of lateral forces acting are as follows, 1) wind loads, 2) seismic loads, 3) earthquake loads, etc. In our case it’s the wind and thus the ballast rock for both ends will support the structure as well as the panels and hold it in place. The ballast rock along with the main part is shown in the Fig. 3.

Results and Discussions:

As shown in Table 1, the maximum Lift generated force due to wind flow for downwind Condition is 101541 N and for upwind Condition is 101707 N and hence accordingly, analysis for the same load condition needs to carry out for respective load conditions. It is clear enough from CFD analysis that high pressure is observed for upwind condition due to high variation in flow and hence a certainty factor should be taken into account to calculate design wind Pressure. Also, various velocity and streamline plots were also studied for flow assessment and pressure variation.

Forces on component were defined as per IS 800 for wind loading. Analysis was for different load cases i.e., upwind and downwind.

After the computational fluid dynamics, the result obtained are showed in the Table 1. The table demonstrate the different parameters selected for the study, which include total pressure, average velocity, force and torque.

Table 1: Output Obtained After Analysis

Name	Unit	Value	Progress	Criteria	Delta

Total Pressure	Pa	101593	100	1633.89268	43.2400556
Average Velocity	m/s	8.873	100	0.168241028	0.145105795
Force	N	10.691	100	8.08413891	0.526266368
Torque	N*m	-0.203	100	3.29336235	0.89324343

The outputs selected are calculated using flow simulation. These results are shown in the cut plots depicted in Fig. 4, Fig. 5 and Fig. 6. The Fig. 4 shows the maximum and minimum velocity areas for the downwind condition. This is done with the wind velocity of 10 m/s taken as reference. This data was obtained from the daily wind speed data by the meteorological department of India for Mumbai. The cut plot of the assembly shows the maximum velocity to be 14 m/s and minimum velocity of around 0 m/s at the opposite end from the point of contact between the wind and the assembly. Similarly, the Fig. 6 also shows the velocity difference for downwind condition in the form of streamlines. A streamline is a path traced out by a massless particle as it moves with the flow. This helps to visualize the flow of wind or streamline along the body selected for examination. The Fig. 5 shows the pressure gradient along the assembly under the application of wind speed of 10 m/s. The maximum pressure due to wind speed of 10 m/s is 101541 Pa and minimum pressure of 101293 Pa.

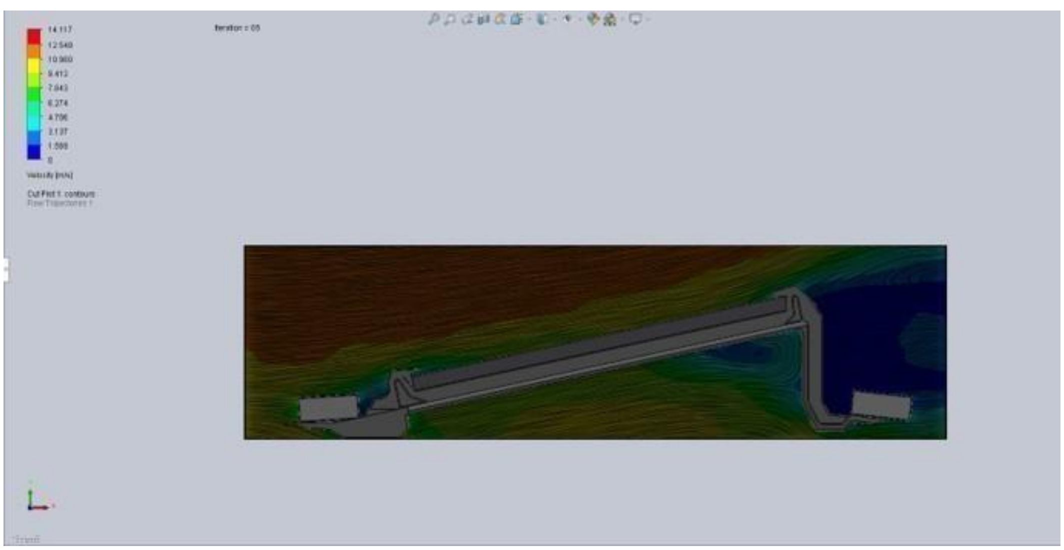

Fig. 4. Velocity Plot

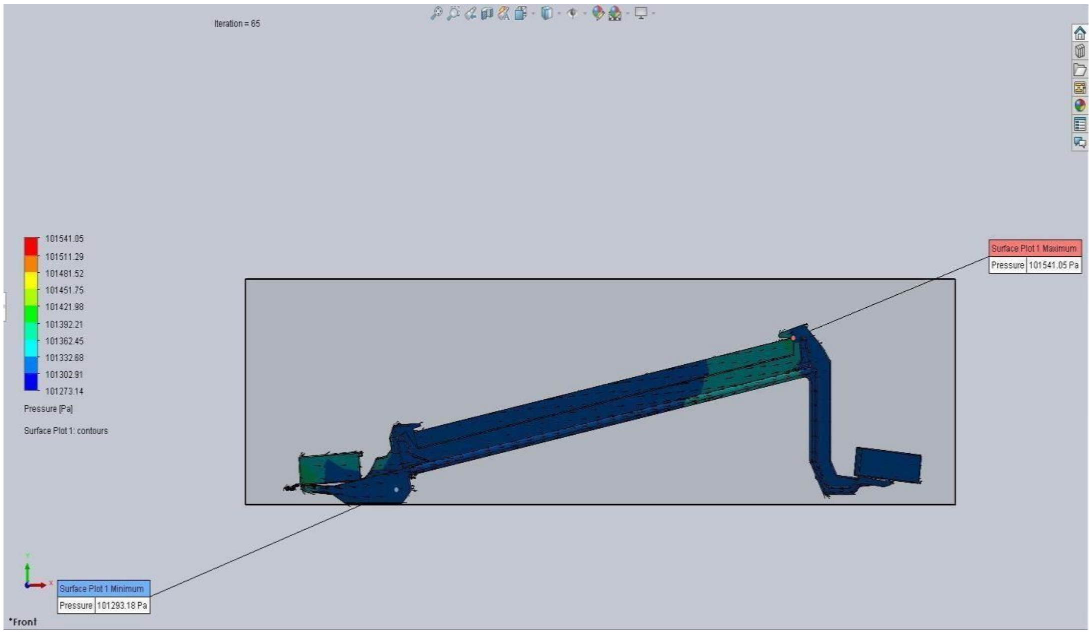

Fig. 5. Pressure Plot

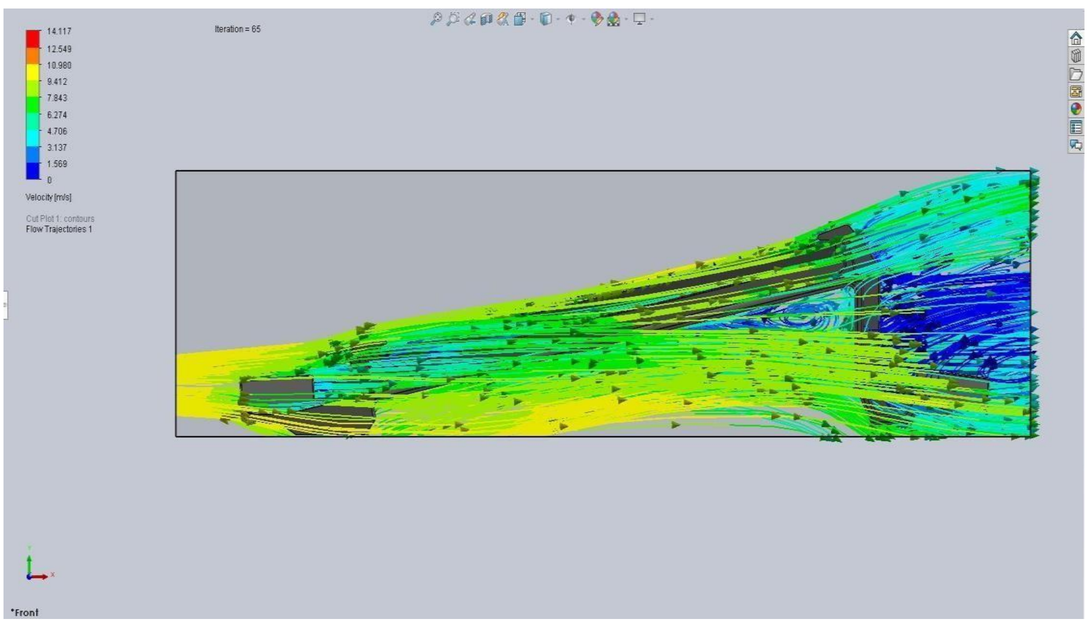

Fig. 6. Streamlines Plot

Conclusion:

Computational Fluid Dynamics Software was a useful method to simulate the fluid flow behavior (air/wind) with the relevant governing equation. In CFD Software, the finer mesh size could provide the accurate result. The smaller the mesh size, the higher the number of elements. The increase in the number of elements allowed the CFD software simulation to more accurate results. The analysis depicts the maximum and minimum force, pressure and the velocity the assembly selected will undergo. The design is optimized for easy assembly, dismantle and transportation.

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