

Wind Load Analysis of Solar Panel System using ANSYS

¹Ayush Gardia, ²Sudhir Singh Rajput

¹Research Scholar, ²Head of Department

¹Mechanical Engineering,

¹ Raipur Institute of Technology, Raipur, Chhattisgarh, India.

Abstract: Solar panels are exposed to high speed winds in coastal and tropical regions which causes damage to PV cells. In order to mitigate effects of wind load it becomes essential to mount air deflectors. The present work investigates the effect of flat and curved air deflectors under real time wind flow conditions on solar panel support structure. The CAD model of solar panel support structure is developed using Creo design software and CFD analysis is conducted using ANSYS CFX. The comparative analysis of three design configurations i.e. solar panel without deflector, with flat deflector and with curved deflectors is made on the basis of drag force, lift force generated. The usage of deflectors resulted in significant reduction of drag force and lift force generated on solar panel.

Keywords: ANSYS CFX , CFD, Solar Panel System.

• Introduction

The wind subjects the solar PV modules, and the PV mounting system to excessive force and the wind load influences how close the solar PV panels must be mounted to the edges of the roof. The higher the wind load, the larger the distance to the roof edge (paraphet wall) should be chosen. The wind loading can be enormous, but there are particularly robust solar PV panels, which are designed for large wind and snow load and adverse weather conditions. The solar panel support structure should be properly mounted and possess sufficient strength as to withstand wind loads.

• literature review

Chih-Kuang Lin et al. [1] used FEA approach to find the effects of self-weight and wind loads on structural deformation and misalignment of solar radiation. They contemplate distribution of stress and deformation with wind speed seven and twelve with varied processing directions as well as gravity. The result shows that this CAE technique is applicable for coming up with a reliable and economical trailing electrical phenomenon system. Highly stressed regions are settled at bushing and needle bearing von-mises criterion there's no structural failure for given electrical phenomenon system.

AlyMousaadAly et al. [2] built testing models of large civil engineering structures at geometric scale 1:500 to 1:100. They were manufacturing Associate in Nursing mechanics model of solar battery subjected to wind load and mounted on ground. Testing can be carried out experimentally (in boundary layer wind tunnel) and numerically (by computational fluid dynamics) at different geometric scale. The result shows that for very small size solar panels are having different mean loads as they are located very close to ground.

Alex Mathew et. al. [3] Worked on style and stability analysis of solar battery support structure created out from soft-cast steel. They conducted this work as a vicinity of project of Mahindra Reva Ltd. Named as “solar 2 car”. The result shows that the solar panel support structure can able to sustain a wind load with velocity 55 km/hr. They calculated required amount of weight to withstand wind load for different wind zones without any holding arrangements and then after optimization can be done for easy assembly, dismantle and transportation

Georgeta Vasies et al. [4] given Numerical simulations for analysis of wind action on star panels settled on flat roofs with and while not parapets. Numerical simulations are performed in ANSYS CFX, for an incidence wind angle of 45°.they are watching that Oblique direction of wind generating high intensity of uplift forces in the corner areas of the flat roof, forces which bring an additional load on support systems of solar panels. Presence of

the parapet facilitate mitigate the wind hundreds, and average pressure is up to 18.6% lower that for solar panels placed on flat roof without parapet.

Girma T. Bitsuamlaka et al. [5] presented the aerodynamic features of ground-mounted solar panels under atmospheric boundary layer. They did four different test cases to determine the wind effects on stand-alone ground mounted solar panels differing from one another by wind angle of attack and number of panels. They verified that there is reduction in wind loads on the adjacent solar panel when they are arranged in tandem. After that they were conclude that „the solar panels experienced the highest overall wind loads for wind angle of attack.

• PROPOSED WORK

The objective of this project is to analyse the effect of real time wind flow of varying magnitudes on drag force and lift force developed on solar panels without deflectors and with curved and flat deflectors. The analysis is conducted using techniques of Computational Fluid Dynamics (CFD). The CAD model is developed in Creo 2.0 design software and analysis is conducted using ANSYS CFX software. The pressure plot, drag force and lift force are determined from CFD analysis.

• methodology

The CAD model of solar panel support structure is developed using Creo 2.0 software which is sketch based, feature based, parametric 3d modelling software developed by PTC and has properties of parent child relationship and bidirectional associativity. The CAD model is developed using extrude, revolve, sweep and pattern tool. The blades developed after extrusion is assembled using coincident constraint, axis pattern and angle offset. This CAD model is saved and converted into. iges format to be exported in ANSYS software.

Table 1: Dimensions of solar panel support structure [6]

B	2.48m
W	7.29m
H	1.65m

The CAD model of solar panel is developed as per dimensions shown in table 1 above. Three different CAD models are developed. The first without air deflector, 2nd with flat air deflector and 3rd with curved air deflector.

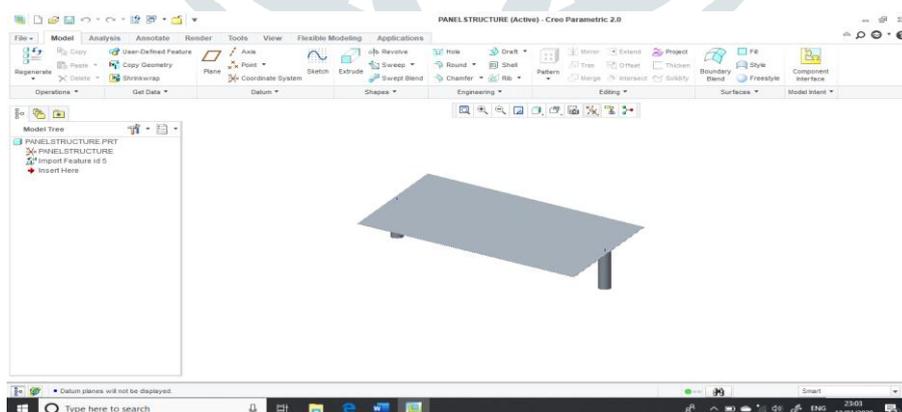


Figure 1: Solar panel structure without deflector

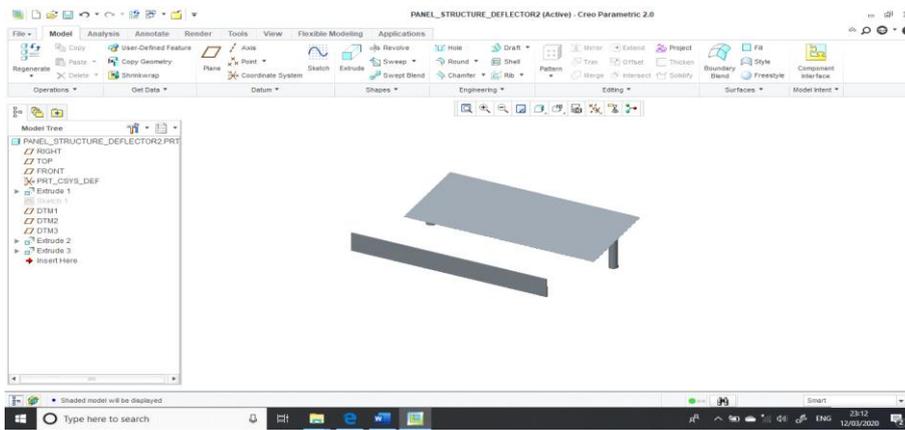


Figure 2: Solar panel structure with flat deflector

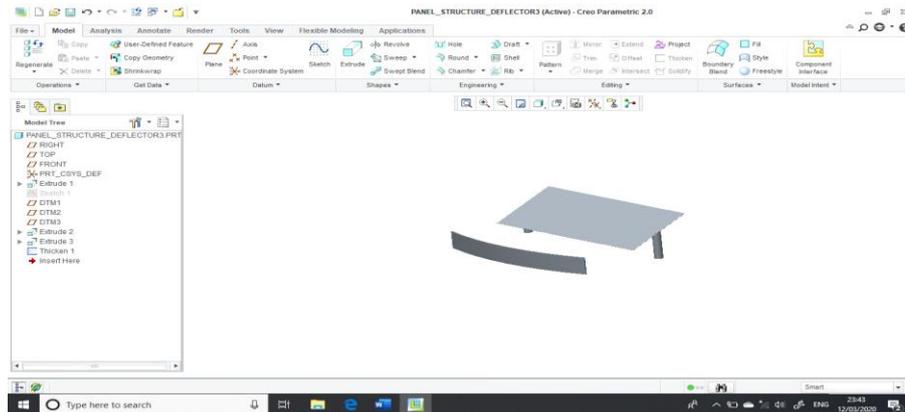


Figure 3: Solar panel structure with curved deflector

The distance between flat and curved deflector and solar panel structure is 3.5m from vertical support member and height of deflector is 700mm from base. The CAD model developed in Creo is imported in ANSYS design modeler. Here it is checked for geometric errors like hard edges, hard angles and other data losses.

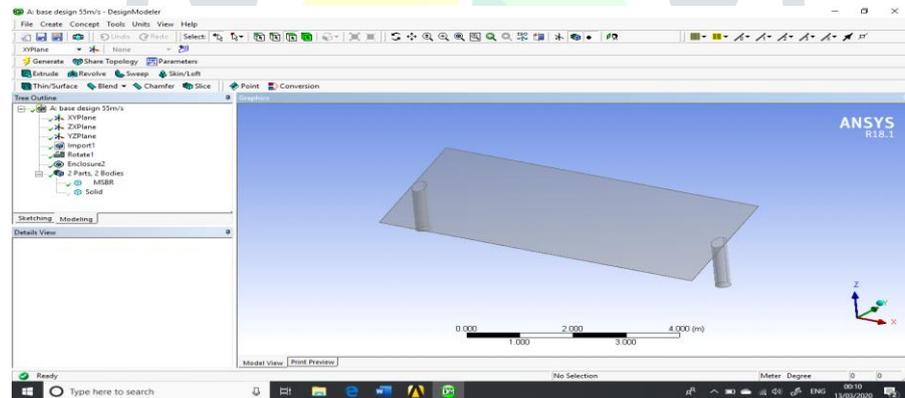


Figure 4: Imported CAD model of solar panel in ANSYS design modeler

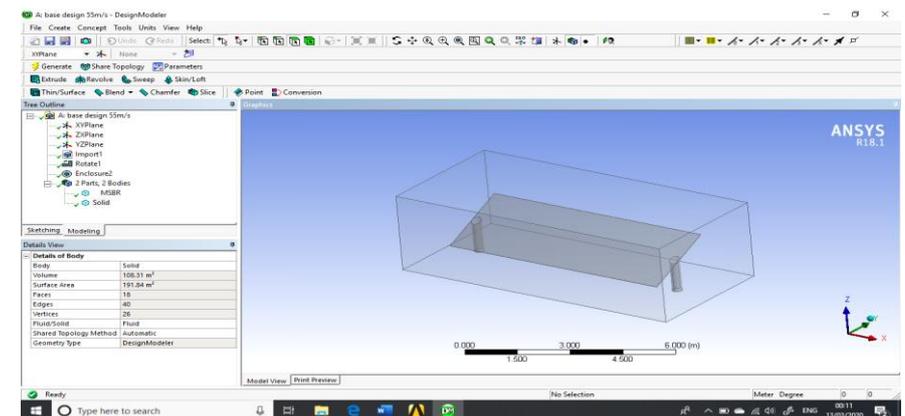


Figure 5: Enclosure modelling for solar panel

The solar panel is enclosed using cubical enclosure as shown in figure 5 above. The enclosure has dimensions as $2\text{m} * 2\text{m} * 1.1\text{m}$. The model is meshed using tetrahedral elements of fine sizing and curvature size function. The relevance center is set to medium, span angle center set to fine, smoothing set to medium.

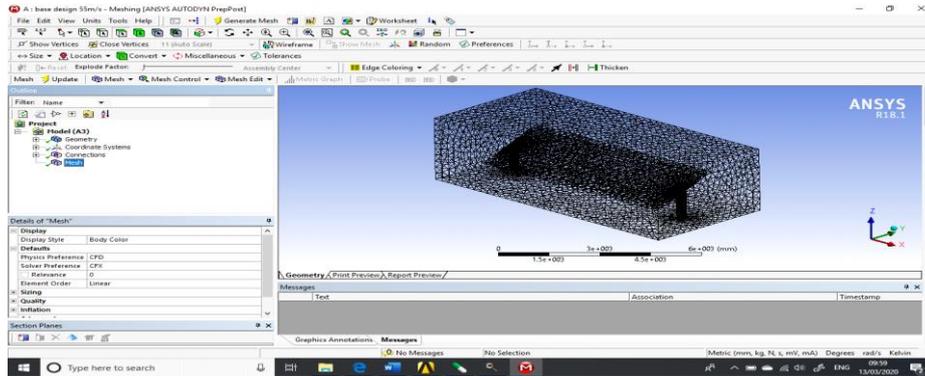


Figure 6: Meshing CAD model of enclosure with solar panel in ANSYS

Number of nodes generated is 23704 and number of elements generated is 118485. Domain is defined as fluid with isothermal energy condition and reference pressure set to 1 atm. RNG k-epsilon turbulence model is set for analysis which is 2 equation model and helps in fast computation and useful in prediction of simpler fluid flows. The inlet boundary conditions are defined as per meteorological data of India. Three different air inlet velocities are 55m/s, 47m/s and 39m/s respectively for all the three CAD models. The top face and 2 side faces are applied with opening boundary conditions as shown below.

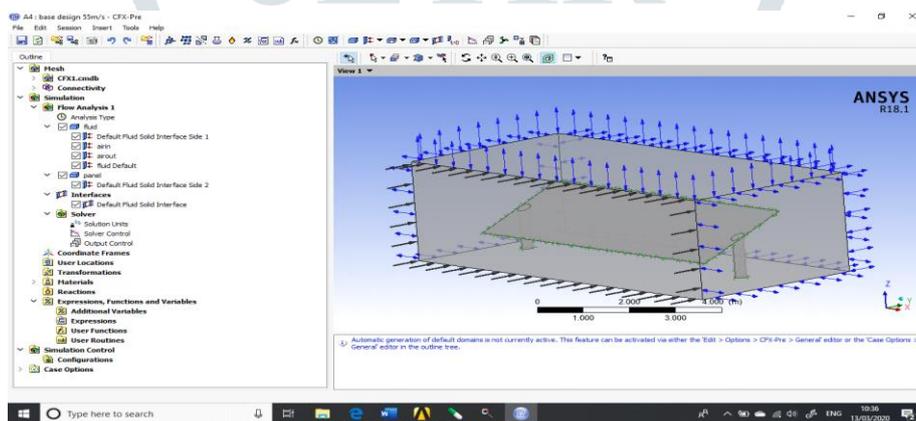


Figure 7: Loads and Boundary conditions

Solver settings are defined using RMS residual values set to $1e-4$ and iterations to 200, advection scheme high resolution upwind, turbulence numeric set to 1st order, length scale option to conservative.

RESULTS AND DISCUSSION

The contour plot for solar panel without any deflector shows maximum pressure in frontal and bottom portion of panel with magnitude of 2231Pa as shown by red coloured region which reduces as we move away from bottom region with magnitude of 1022Pa as shown by green colour.

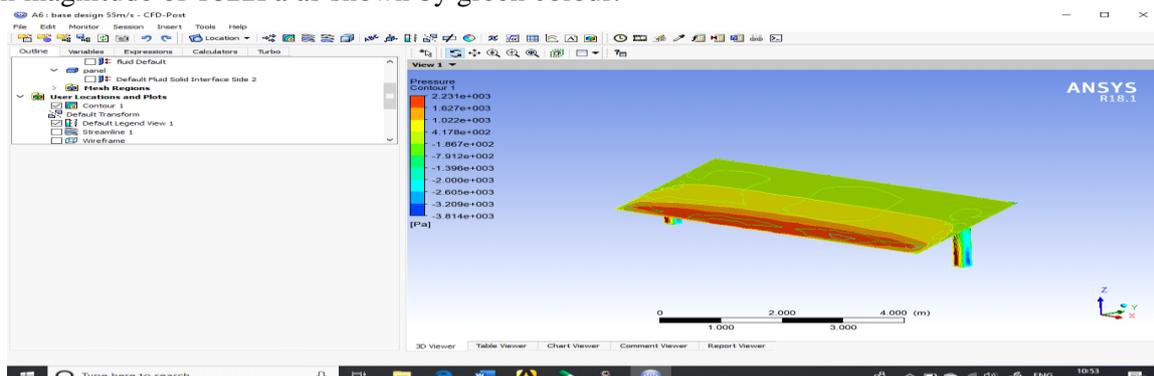


Figure 8: Pressure contour on solar panel at 55m/s

The velocity field is plotted in figure 8 below. The velocity is high just above solar panel with magnitude of 41 m/s which and almost null behind the panel as shown by dark blue coloured region.

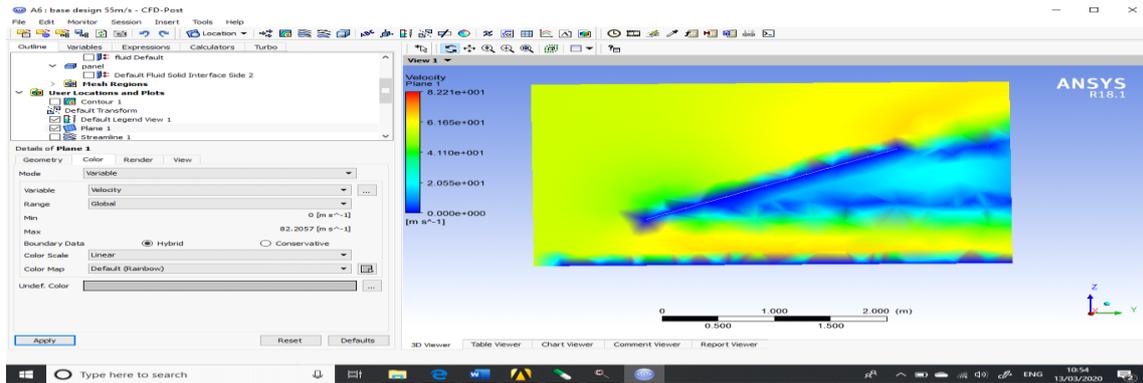


Figure 9: Velocity contour on region above solar panel at 55m/s

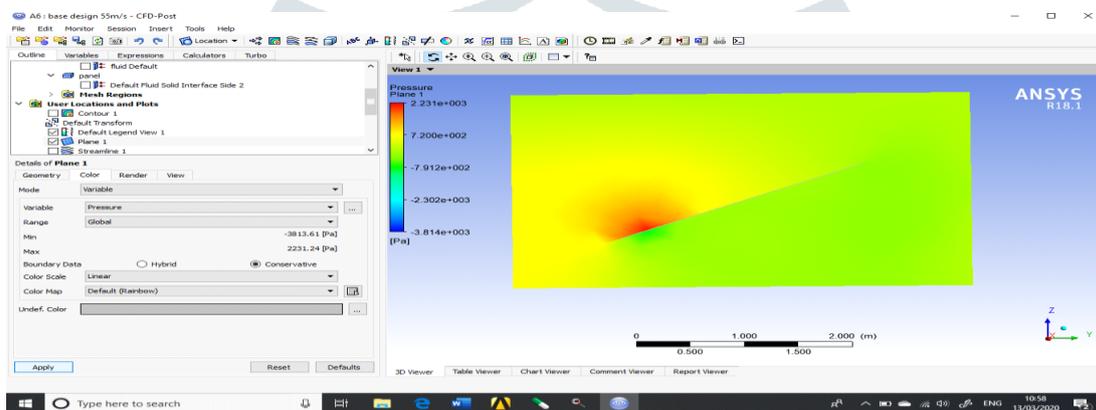


Figure 10: Pressure field on region above solar panel at 55m

The pressure field plot for solar panel is shown in figure 10 above. The plot shows high pressure in the region near lower portion of panel depicted by red coloured zone with magnitude of 2231Pa.

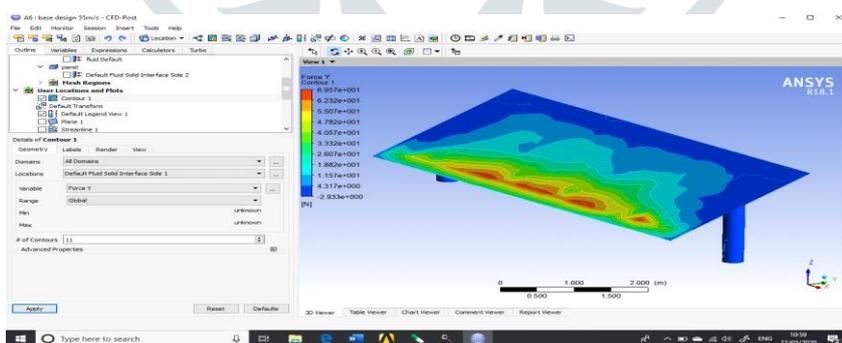


Figure 11: Drag force acting on solar panel

The drag force generated from air flow is shown in figure 11 above. The plot shows higher magnitude of 69.57N near bottom lower portion which reduces as we move away from it as shown by dark green colour and yellow colour.

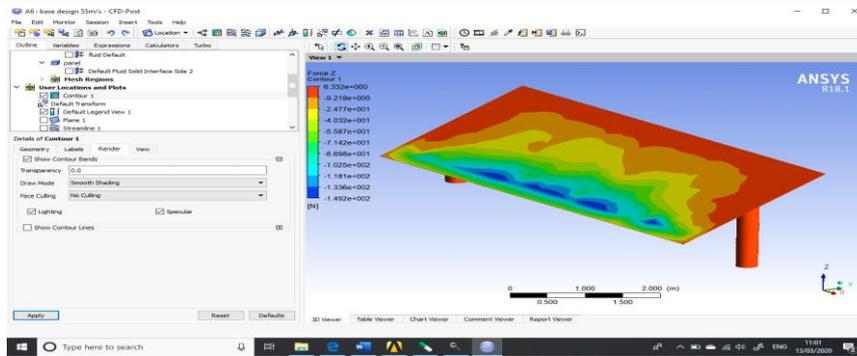


Figure 12: Lift force acting on solar panel

The CFD results have shown that maximum lift is generated on top most portion of solar panel with magnitude of 6.33N as shown by dark red coloured region and decreases as we move away from it. Similar analysis is conducted on solar panel with flat deflectors and curved shaped deflectors subjected to same wind speeds i.e. 39m/s, 47m/s and 55m/s.

Figure 13: Lift force comparison at 39m/s

The lift force comparison at 39m/s chart is shown in figure 13 above shows that maximum lift force generated on solar panel is experienced without air deflector followed by flat deflector and curved deflector. The minimum lift force is observed for solar panel with curved deflector design.

Figure 14: Drag force comparison at 39m/s

The drag force comparison at 39m/s chart is shown in figure 14 above shows that maximum drag force generated on solar panel is experienced without air deflector followed by flat deflector and curved deflector. The minimum drag force is observed for solar panel with curved deflector design.

• CONCLUSION

The CFD analysis is conducted on solar panel structure using k-epsilon turbulence model to determine the effect of wind flow on drag force and lift force generated. The design of solar panel support structures is further analyzed using air deflectors in front of it. The detailed conclusion are as follows:

- The magnitude of pressure generated on solar panel structure without deflector is high as compared to solar panel structure with deflector.
- Two variable k-epsilon turbulence model gave reasonably fluid flow predictions.
- The incorporation of wall as air deflectors led to deflection of incoming air and passage over solar panel. This led to reduction of pressure, drag and lift force generated on solar panel.
- The magnitude of drag force generated on solar panel structure without deflector is high as compared to solar panel structure with deflector.
- The magnitude of lift force generated on solar panel structure without deflector is high as compared to solar panel structure with deflector.

References

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