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Evaluation of Wind Loads on Solar Panel Attached to Building Roofs

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***Abstract*— Solar energy has been widely accepted as a source of energy in the last few years owing to its numerous advantages over conventional energy sources. The most important fact is that it is environment friendly. Solar panels are majorly placed on building roof tops or on flat barren terrain. They do not produce any pollutants in the process of generating energy and, hence, is considered as a clean source. However, the other side of the coin is that, solar panels are expensive and are often vulnerable to wind forces which are fundamental atmospheric phenomena caused by air moving from high to low pressure due to change in temperature. Information about wind load on solar panels is rarely discussed in the Indian standard codes, which makes the study of wind forces an essential exercise. This paper deals with computational fluid dynamics analysis that is carried out to approximately determine the flow and formulate an equation that shall provide us with the wind movement and other characteristics of the wind flow. For the purpose of analysis, a building with a suitable dimension was chosen and proper symmetrical arrangement of solar panels on top of building where carried out. ANSYS fluent was used for simulation. The results revealed sufficient suction wind pressure surrounding solar panel which may cause uplift.**

Keywords— Wind Load, Wind Pressure, Solar Panels, Computational Fluid Dynamic, ANSYS.

I. INTRODUCTION

Solar energy is a sustainable alternative to conventional energy from an environment perspective. In recent years, solar energy has been widely accepted as a source of energy. Present technologies that convert solar radiation into solar energy employ photovoltaic cells mounted on a panel. A lot of research on solar panels has been carried out in past decade, so as to, make it cost effective and highly efficient. Main hindrance to implement solar energy is its initial capital. Cost of supporting structure required for solar panels holds significant portion of initial cost. Therefore, optimization of the supporting structure is very important to bring down the cost.

Design of supporting structure is governed by wind load. As accurate designs are not available in design codes, possibility of unsafe design is very high. Evaluation of wind induced forces on solar panels is hence very important. Wind forces are governed by various factors like inclination angle, height, type of terrain etc. Researchers have made efforts to develop relations between different codes. Main objective of such studies is to analyse data and provide more safe and economical design. Due to poor design or non-availability of designs, many cases of damaged solar panels have been observed upon exposure to strong winds.

Computational fluid dynamics involves numerical analysis and data structure to analyse wind flow. The volume occupied by fluid is divided into mesh. Mesh can be uniform or non-uniform, structured or non-structured. Boundary conditions involve specifying the fluid behaviour and properties at all bounding surfaces of the domain. Wind causes a time dependent load which can observed as a mean and fluctuating component attached to it. Wind exerts dynamics oscillations due to fluctuating component.

Fluent is using the control volume method to solve the continuity equation and 3D Reynolds-Averaged Navier–Stokes equations.

II. LITERATURE SURVEY

Study by Jones Westin, Sweden (2011) suggested there is difference between wind actions in open range deployment and roof mounted because of turbulence and wind stream direction act by building. Uplift forces caused by wind action are balanced by attaching ballast to the photovoltaic mounting system. Such practice needs economical and safe guidelines so that uneconomical dimension doesn't cause construction infeasible [1].

Study by A Mihailidis, K Panagiotidis and K Agouridas suggested use of different approaches for supporting structure these helped in achieving the maximum overall efficiency. First was load calculation and to determine pressure distribution. Second was analysis of the structure [2].

In this particular paper from zeinub samani (2016) reveals wind load govern the design of supporting structures of solar panels and constitutes about 50% of the total cost approximately [3].

Study by bitsuamlaka demonstrated that sheltering effects is caused by upwind solar panels substantially reduced the wind load on the adjacent solar panel [4].

Mehrdal shademan study carried simulations at different azimuth and inclination angle with Reynolds numbers equal to 2×10^6 .It was observed drag coefficient for the downstream sets of panels reached a minimum [5].

Guideline from franke (2007) provides us methodology for CFD simulation of flows in the urban environment. It focuses on two categories errors and uncertainties in modeling the physics and numerical errors [6].

III. MODELLING OF WIND FLOW AROUND BUILDING

For analysis purpose, building of 6 stories is considered with dimension 80 m length, 20 m breadth and height 18m. Building is general building with mean probable design life

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of structure is 50 years. Terrain category 3 is considered which implies numerous closely spaced obstructions having the size of building structures up to 10m in height. Wind speed consider for analysis purpose is 39 m/s. The solar panel inclination is kept constant at 25degree.

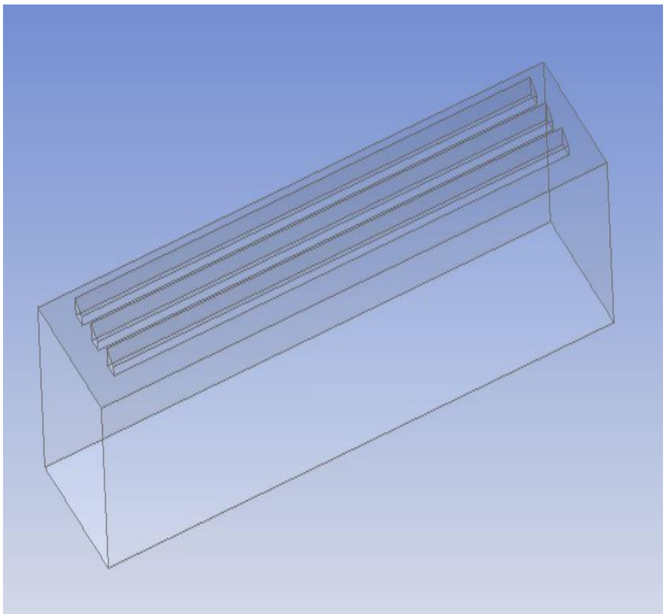

Figure 1. Representation of building

The dimensions of the computational fluid domain is carried from Franke (2007) modelling the Silsoe Cube guildelines. Its as shown in figure 2.Wall boundary conditions,top boundary conditions and inflow and outflow boundary condition are taken from franke guidelines. Dimesions are mensioned in table below.

Table 1. Measurements of fluid domain.

5H	90m
15H	270m
6H	108m

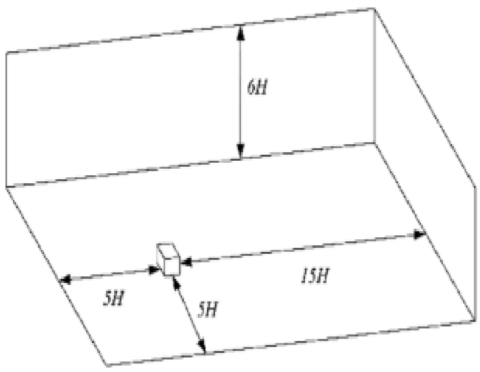

Figure 2. Representation of fluid domain

Meshing enables the solver to convert the problem into solvable by discretizing the problem domain i.e. using nodes and elements. In the current research work, tetraheadral type of mesh element is used. Fine mesh is done to obtain accurate results as shown in the figure. Meshing is decided based on the Aspect ratio, othogonal quality and skewness. The values of some of which are shown in the table.

Table 2. Details of mesh.

Nodes	28056
elements	144064
skewness	1.3061×10^{-10}(avg)

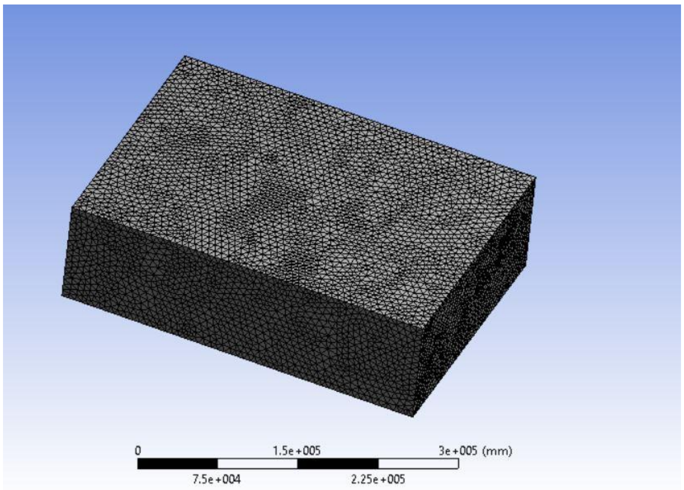

Figure 3. Meshing of Computational domain

With help of user defined function in Ansys fluent the turbulence energy and turbulence dissipation rate is varied. Boundary layer velocity profile is created.Wind is passed through A to B for first case and from B to A for the second case. A and B are respective inlets and outlets as shown in figure 4.

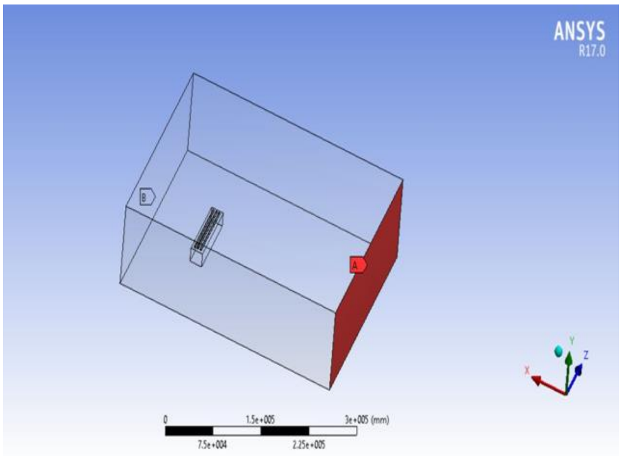

Figure 4. Inlet and outlet for wind flow

IV. RESULTS AND ANALYSIS

Wind is passed through computational domain from inlet. Inlet is varied and two cases are observed. First case wind is made to pass through solar panels facing wind direction and in second case wind is pass through opposite direction that is from behind the solar panels.

Velocity streamlines

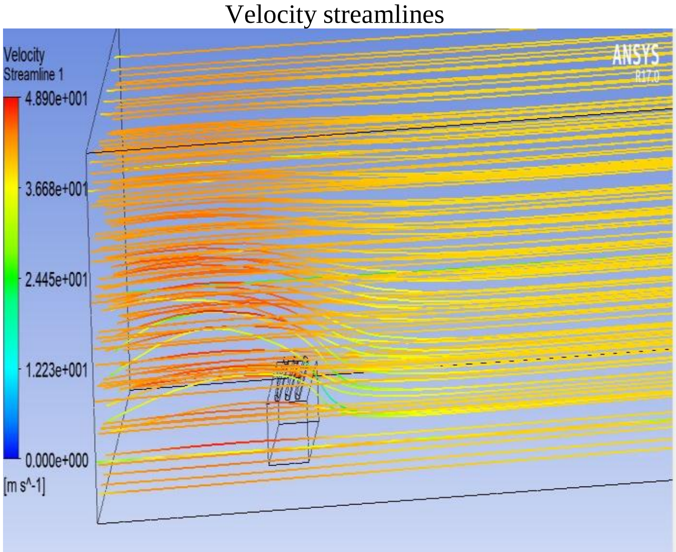

Figure 5. Velocity streamline around building case 1

Velocity stream around solar panels and building periphery is observed in both cases and shown in figure 5 and 6 respectively. When wind flows through solar panels facing wind direction there is huge increase in pressure as shown in figure 5.Red streamline indicates pressure has substantially increased. Vortex is seen but not so prominent.

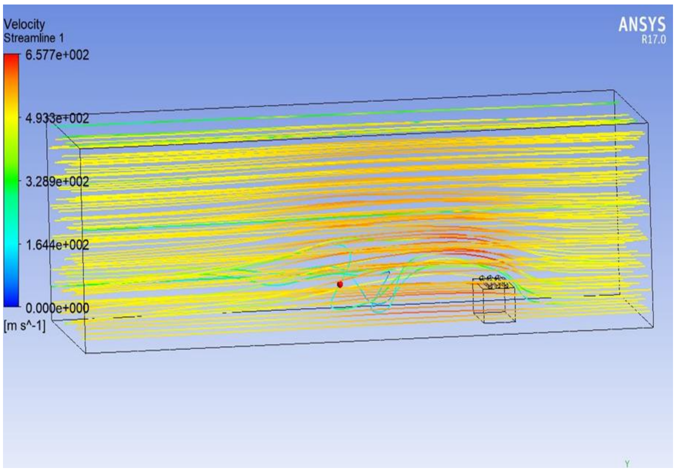

Figure 6. Velocity streamline around building case 2

In above case where wind flows from behind the solar panels negative pressure is observed. Vortex is clearly visible in leeward side of building. Streamline turn red that indicates pressure has increase. Blue stream lines indicate pressure has drop down substantially.

Velocity contour

Velocity contours around solar panels and building periphery is observed in both cases and shown in figure 7 and 8 respectively.

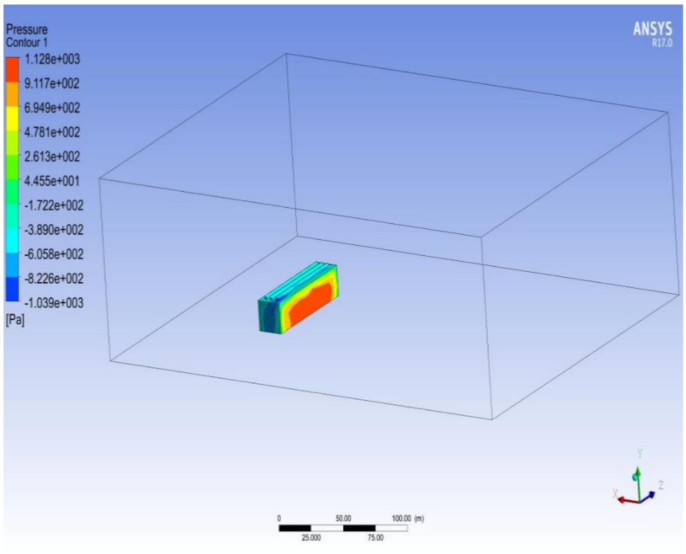

Figure 7. Pressure contour on building and solar panels case 1.

When wind flows through solar panels facing wind direction there is increase in pressure on face of building. Red indicates increase in pressure on face of the building. Low pressure is seen on side faces of the building. And negative pressure is seen on solar panels.

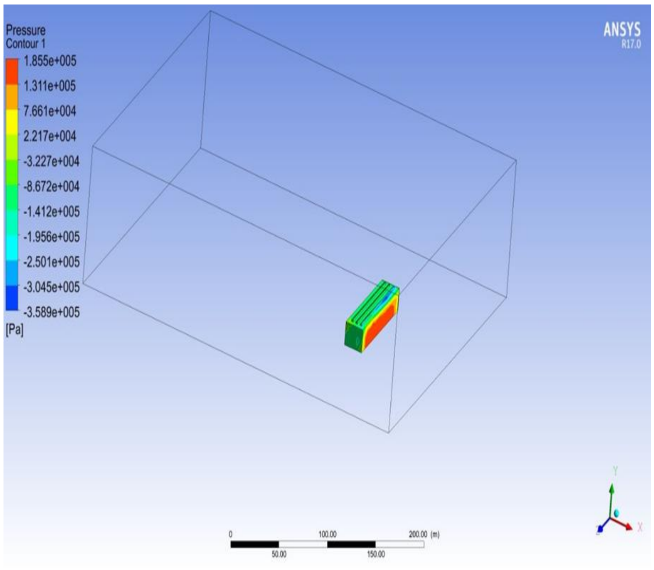

Figure 8. Pressure contour on building and solar panels case 2.

In above case, where wind flows from behind the solar panels. Increase in pressure on face of building. Red indicates increase in pressure on face of the building. Low pressure is seen on side faces of the building but not so prominent as seen in figure 7. And negative pressure is seen on solar panels. But blue color on edges indicates increase in negative pressure on edges.

V. CONCLUSION

- Solar panel placed on roof of a building is subjected to considerable amount of negative pressure.

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- Values from analysis trend to show similar pattern which are discussed in IS code 875 part 3 for mono slope roof.
- Wind direction plays important role in design as we have seen vast diversity in results for windward facing solar panels and opposite case.
- The results reveal sufficient suction wind pressure surrounding solar panel which may cause uplift.
- Numerical modelling can be an alternative approach time consuming wind tunnel experiment to assess the wind characteristics.
- Critical location of the solar panels can be studied.

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