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Numerical Simulation of a Ground-Supported Solar Panel PV Array Subjected to Periodic Flow

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Abstract. Detailed numerical modeling and research were conducted to assess the influence of wind loads on various solar arrays using commercial software such as Ansys. A large amount of damage has been recorded from solar arrays and mounting frames worldwide owing to strong winds. This paper exemplifies the analysis of displacement and stresses of the structure due to strong wind flow and wind load around the solar panel. Since the solar panels are located in the same panel array at the same spacing, we assume that periodic flow conditions can be applied in the flow direction. The model displays a flow field with a free flow velocity of 10 m/s , 25 m/s, and 50 m/s and calculates the resulting structural stresses and displacements. This model uses two other studies. Initially, Turbulent Flow, a kε physical interface, is used to resolve turbulence around the solar panel. The other uses the Solid Structure physical interface to resolve structural stresses and displacements. Fluid Structure Interaction, Fixed Geometry Multiple physical coupling features are used to connect the boundary load of a fluid flow to a solid region in the fluid region. It corresponds to unidirectional fluid structure interaction analysis..

Keywords: Solar panel, Photovoltaic, Ground-supported Solar panel, Optimum Design.

Introduction

Given the growing worry for global warming, plenty of the nation's economies are switching quickly to renewable energy sources, particularly solar energy. In the previous several years, solar power has become a world leader for power generation [1-3]. With solar panels growing quickly across wide regions in past years, the mechanical safety of solar panels and the assembly method is primarily at issue, since the enormous investment may be involved. Solar arrays are subject to several hazards, including high-wind disruption, and are susceptible to major risks to solar systems. Turbulent strong wind damages the solar array as well as the mounting mechanism extensively, unless it is correctly constructed [3]. The distinct geometry of the structures leads in different wind load effects; thus, each is distinct in design [4].

Previous study shows that solar panels have azimuth angle angles ranging from 22o to 48o that provide sufficient solar panel sunlight. For various areas in Iraq tilt angles of around 30o are optimal. In an earlier study [5] effective techniques for installing solar panels on the rooftops have been put up. The location of the site and the angle of orientation from the sun is crucial to specify here. Latest study [6] has shown that tests in wind tunnels can assess wind elevation on photovoltaic models satisfactorily. This report also addressed the influence of guidance panels in different experimental configuration of photovoltaic arrays for the decrease of lifting forces. A much recent research has demonstrated the utility of Numerical simulations data connecting the CFD findings to the wind tunnel testing data for roofed photovoltaic solar arrays [7 - 9].

On nearly any flat, asphalt, gravel, or rubber surface, the solar panel racks may be placed. Wind velocity and wind speed leading to aerodynamics or wind loads on the racks are the main factors of the ground-mounted panel racks. General data maps of the wind [2] assist in the year-round determination of the velocity range, direction, and angle of attack in Iraq. The wind velocities and directions / angle of assaults may also be estimated by using maps with generic wind data from various continents and nations [4]. The use of high ballast is typically required for wind loads to offset such effects. However, the ballast weight may exceed the structural load permissible on the roof. Efficient wind deflection devices can thereby minimize the usage of ballast, or preferably eliminate it.

The effectiveness of wind tunnel experiment and CFD testing for solar photovoltaic arrays on the ground has been shown in a recent research [6]. The current study describes the schematic of wind deflectors through the use of CFD as well as wind tunnel capabilities to reduce wind forces on solar panels, particularly the lift and drag forces. The computing analysis includes CFD software for one-quarter and full-scale models ANSYS Fluent in the iterative mode [7,9]. These findings have been confirmed by wind tunnel testing. The CFD simulation used for the 30° inclined freestanding PV array, which is susceptible to a variable wind rate from the front of the array to the back of the array at the interval of fifteen degrees, also estimated wind subjected angles resulting to maximum pressure over arrays [9-11].

In this paper, a solar frame installation systems that is explored and studied under severe wind charges by using COMSOL Multiphysics. The force coefficients across solar frames from CFD simulations were used to estimate the wind load considered in the current investigation. Solar panel mounting system involves a system consisting of solar cells laminated in a silicone sheet, as panels, encased in an aluminum box, and a variety of PV boxes mounted atop a steel channel truss frame.

The difference between this research and the research in [8-11], which are in the field of numerical analysis, is that these research used the ANSYS program, the well-known software for most mechanical and thermal engineering researchers, and that our research used another program which is COMSOL Multiphysics. In this software, it is possible to create all mechanical designs within the software with the introduction of all variable's parameters, and constants, in addition to that, it is possible to change the arithmetic equations that are used in the numerical calculation. This software depends on the finite element analysis and therefore it is possible for researchers to experiment with this software and compare the results with what is available. In addition to all this, the turbulent flow-structural interaction was used as the fluid will affect the solid part.

Figure 1. The solar farm's geometry shows a repeating range that produces periodic flow [2].

FE Model Configuration

The structural behavior of the solar-mounting systems is investigated utilizing COMSOL Multiphysics (Turbulent flow K-epsilon and Structural) for normal forward wind occurrences at one tilt angle of 30°, equivalent to severe wind pressure forces with a baseline wind speed of 10 m/s. Mechanical behavior under wind stress is investigated for solar mounted on a single mounting frame configuration with three distinct wind speed ranges of 10 m/s, 25 m/s, and 50 m/s, totaling three instances. Figure 2 illustrates a particular solar panel with a COMSOL Multiphysics-modeled supporting structure. Figures 2 (a) and (b) depict the wind incidence direction over the solar panel and supporting frame, respectively. Figure 2 illustrates (1 x 2) m2 solar PV panels modeled is 10 mm in thick silicone sheets encased in an aluminum container with acceptable cross-sectional dimensions.

Modeling and Simulation

It's vital to consider all components, not only photovoltaic processes through which the sun captures and transforms energy into electricity when developing solar panels. The panel components, such as dynamic loading, must also be included in a thorough study of the system. The flow field must be calculated for the measurement of the wind load, i.e. the stresses of the flow on the structure. Because of the regular characteristics of solar farms, regular flows may be predicted.

Flow Field Analysis of the Solar Panel Design

In the beginning, the solar cells were exposed to a strong wind force, because the purpose of this research is to expose the solar cells to a strong force in order to study some of the variables that occur on the panel. In the end, these results can be used to reach the most accurate designs. In the beginning, it was assumed that When exposed to winds of 10 m/s or about 40 km/h and this in turn is a strong wind force and from this we want to evaluate the proposed design and therefore we can then read the results regarding the mechanical part of the panel. Because this can be classified as a moderate storm, depending on the Beaufort Scale. So we have to look at the flow of air (liquid) through the shape of the plate and see how the plate reacts to the force of the wind.

We may suppose that in this design there are sufficient solar panels upstream and downstream of the underlined panel to be suitable to periodic flow circumstances. Once the stream of the flow is predicted, the structural deformation induced by strong winds may be further analyzed. Only one panel of the underlined periodical region is shaped of the geometry to further minimize the computer load as can be seen in Figure 2. And, we may reduce computing time utilizing simpler physical structure when simulating the flow behavior and periodic fluid flow. The supports at the rear of the panel may not be used in this geometry because the supports are tiny compared with other geometries and they are positioned.

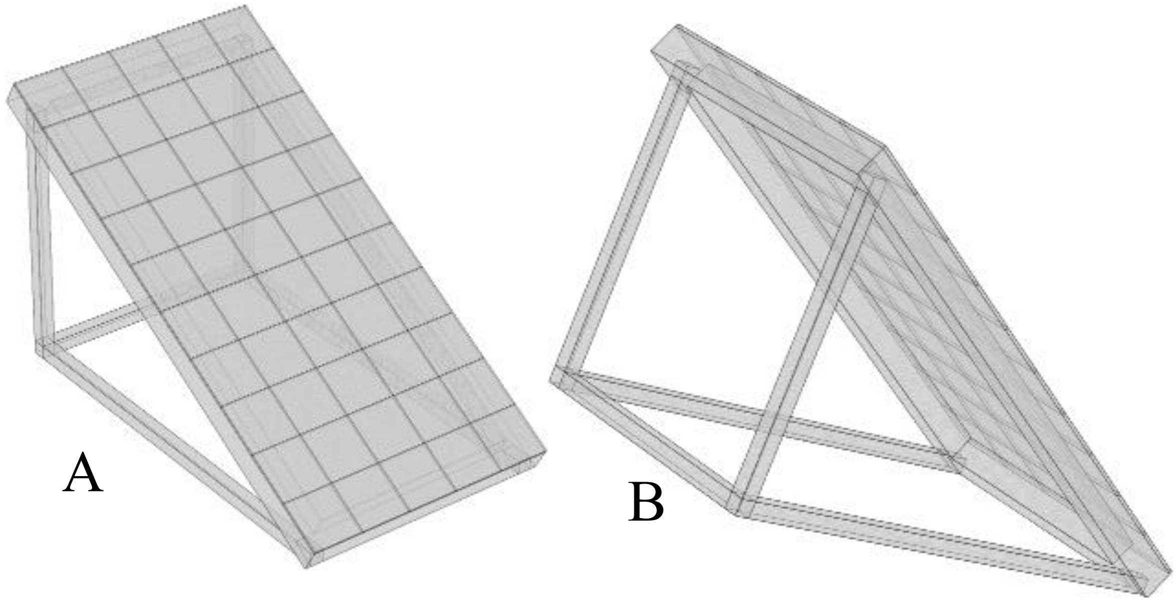

Figure 2: A) The shape of the solar panel used for the modeling of structural machinery shows the supports included: B) Back side perspective of geometry of solar panels utilized in the modeling of fluid flow.

A periodic flow is produced by the introduction of fluid flow into a geometry which repetitively consists of several of the same components (Figure1). The system's physical geometry needs to be repeated and it needs to be repetition for a specific amount of time before a regular flow pattern develops. Such a flux pattern typically happens in a solar farm in which hundreds of similar panel layouts exist. A regular flow field may be modeled in COMSOL Multiphysics, which includes an outlet flow from one frontier to another, using the CFD module.

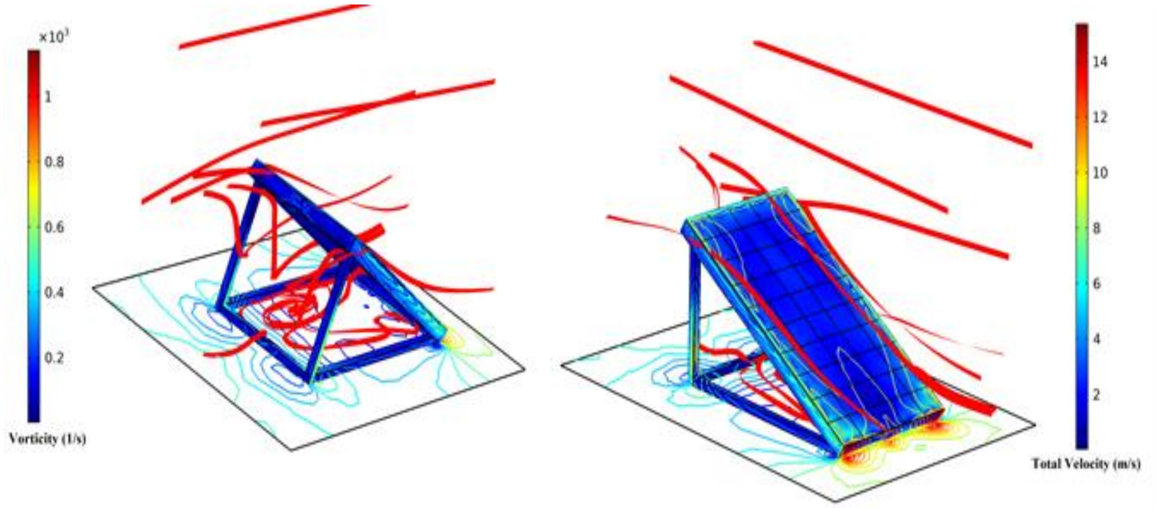

Figure 3. Velocity streamlines characterized by the turbulent, freestream-standardized film energy and speed components down the panel.

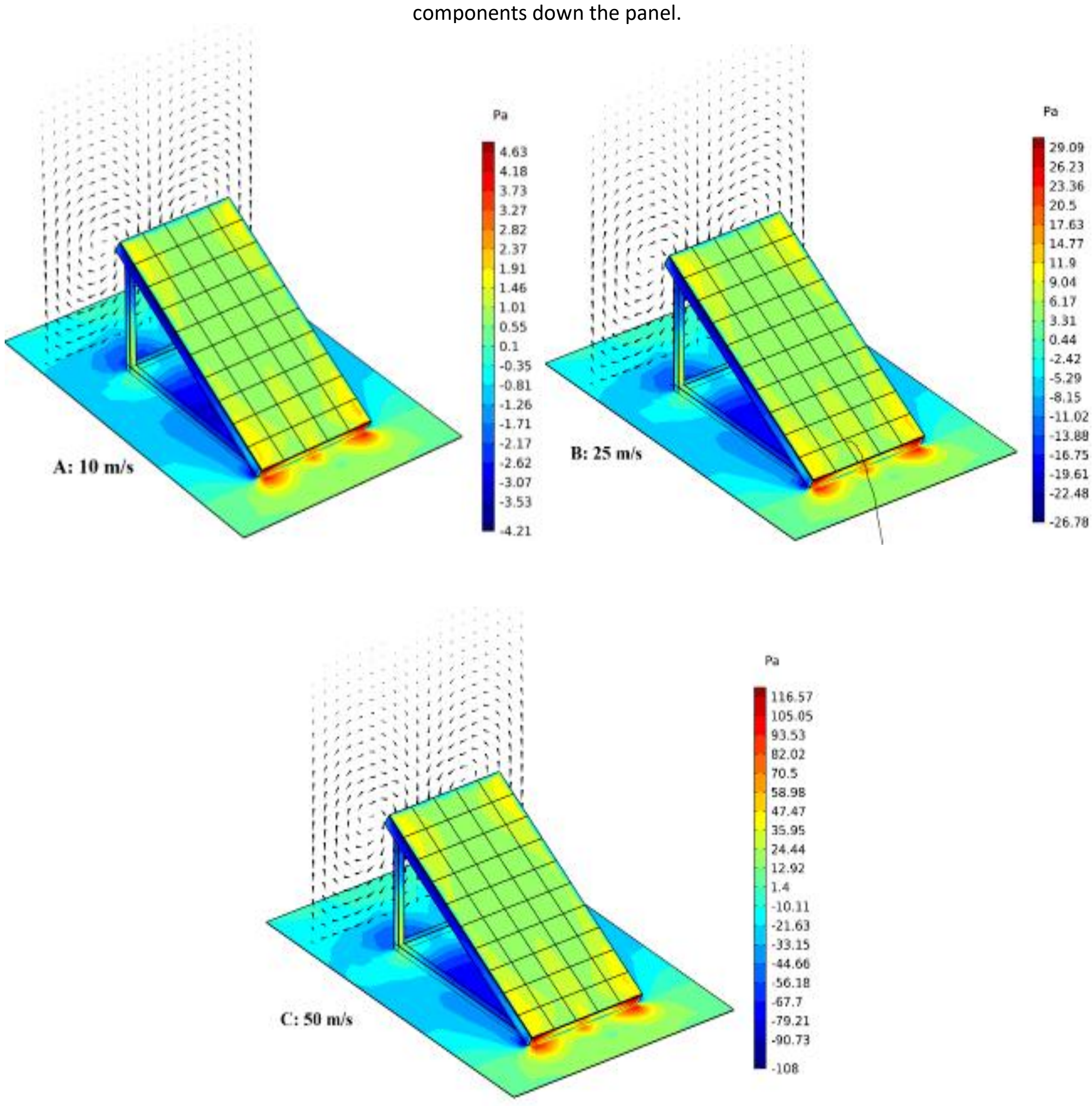

Figure 4. The contours of surface pressure and the speed components of the plane are 6 cm behind the panel

within the flow field. The number of necessary mesh elements is dramatically decreased when these components are ignored. Following is the geometry utilized in the simulation fluid-flow section. Figure 3 represents a simulation once can observe the area of circulation between the array panels. The flow is slower with a quicker recirculation area turbulence towards the top of the panel. The upper right corner of the panel has the greatest winds and pressures. This indicates the panel surface pressure and is visible in the following model as demonstrates in Figure 4.

Figure 3 represents the total wind speed on the board, as well as the distribution of wind force on the surface of the board in addition to the speed distribution around the board. From the figure it can be seen that the wind flow is slower with a faster turbulence in the recirculation region towards the top of the plate. The upper right corner of the plate has the greatest winds and pressures. This indicates pressure on the surface and bottom of the plate is clearly visible as shown in Figure 4.

Figure 3 and 4 indicate that the wind force on the solar panel, and that in the upper right corner of the panel, the highest pressure applied to the PV panel is about 5 Pa when the wind speed is about 10 m/s and 30 Pa when the speed is set Wind at 25 m/s and finally 116 Pa when the wind speed is 50 m/s. It's all like a storm that can give great information about board design to get the optimum design in many weather conditions. Through this information, it is possible to reconsider the design of the panels that are exposed to periodic air movement, especially the solar panels that are used in vacant areas or agricultural areas, which are usually many in number and are described in the form of arrays, and therefore any wind, regardless of its strength, can form winds of a periodical nature.

Mechanical Findings

Furthermore, we use the entire geometry of the solar panel to calculate the structures of the panel caused by fluid load. The following displacement (Figure 5 (A and B)) appears whenever designers apply the fluid load to the photovoltaic panels.

The largest movement takes place in the center of the panel, as suggested by earlier simulations. But this is relatively minor displacement (only about 0.4 mm). Due to this modest movement, the solar panels surrounding the range are supposed to aid to shield the panel from the total wind force of 10 m/s. The endurance of solar panel designs must also be enhanced, as the solar power industry increases, and solar panels become more energy efficient and economical. Further analyzes and optimization to establish whether high winds such as violent storms of up to 117 kph can survive the design of the aforementioned solar panel. PV technology throughout the world will address these and other issues as the photovoltaic sector continues to develop tremendously.

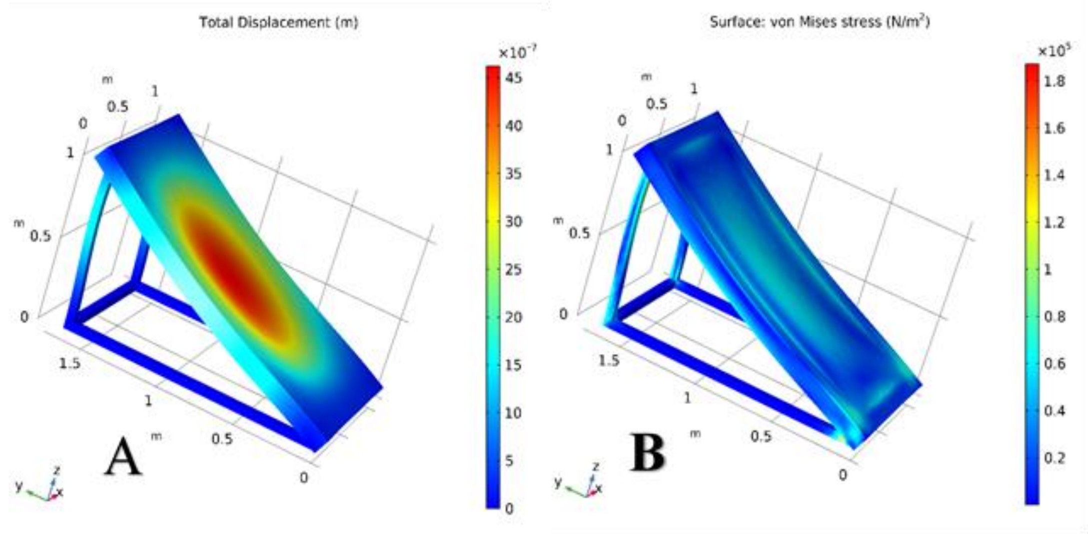

Figure 5. Due to the fluid flow load structural deformation of the solar panel, where A) the total displacement (m) due to the fluid force; B) the total stress (von Mises stress (N/m2))

Conclusion

COMSOL Multiphysics was used to evaluate the array mounting frame possibilities. Composites consisting of the framework for structural steel assemblies, the case of panel aluminum panels and the PV panel for silicone examined here. Wind speed has been found to have a significant impact on the pressure distribution on solar arrays in all of the situations studied. Because of the subjected flow that forms conical vortices on the surface of the solar array, suction values are higher for wind speed. These vortices appear symmetrically in pairs, one on each edge of the solar panel, and a region of strong suctions occurs in the middle of each vortex. The data obtained for each studied scenario were utilized to compare the pressures produced on each panel of the solar array.

References

[1] Spratley, W.A., 1998, Solar Rooftops as Distributed Resources, The Electricity Journal 11, pp. 40.

[2] Baetu, G., Teleman, C. E., Axinte, E., & Rosca, V. E. (2013). Numerical simulation of wind action on a solar panels array for different wind directions. Buletinul Institutului Politehnic Din Lasi. Sectia Constructii, Arhitectura, 59(4), 9.

[3] Kudav, G. V., Panta, Y. M., & Yatsco, M. (2012). Design and testing of wind deflectors for roof-mounted solar panels. WIT Transactions on Engineering Sciences, 74, 15-27.

[4] Sharif MA, Wahhab MS, Khalaf KS. Practical Performance Investigation of the Solar (PV) Panel System of the Electronic and Control Engineering Department – Kirkuk. 2nd International Multi-Disciplinary Conference: "Integrated Sciences and Technologies," 2021.

[5] Sharif MA. Modeling and Analysis of Electrical Performance of Solar Photovoltaic Cell. 2021

[6] Barkaszi, S.F. and Dunlop, J.P., 2001, Discussion of Strategies for Mounting Photovoltaic Arrays on Rooftops, Proceedings of Solar Forum 2001, Solar Energy: The Power to Choose, April 21-26, Washington D.C., pp. 6.

[7] Chung, K., Chang, K., Liu Y., 2008, Reduction of wind uplift of a solar collector model Journal of Wind Engineering and Industrial Aerodynamics, 96, pp. 1294.

[8] Agarwal, A., Irtaza, H., & Ahmad, M. J. (2021). Numerical analysis of the ground-mounted solar PV panel array mounting systems subjected to basic wind for optimum design. Canadian Journal of Civil Engineering, 48(6), 656-668.

[9] Yatsco, M. 2011, Numerical Analysis and Wind Tunnel Validation of Wind Deflectors for Rooftop Solar Panel Racks. Master's Thesis, School of Graduate Studies & Research, Youngstown State University, Youngstown, Ohio, USA.

[10] Meroney, R.N., Neff, D.E., 2010, Wind effects on roof-mounted solar photovoltaic arrays: CFD and wind-tunnel evaluation, The Fifth Computational Wind Engineering (CWE2010), Chapel Hill, North Carolina, May 23-27.

[11] Agarwal, A., Irtaza, H., and Zameel, A. 2017. "Numerical study of lift and drag coefficients on a ground-mounted photo-voltaic solar panel", Materials Today: Proceedings, Vol. 4. pp. 9822–9827.