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Simulation of Wind Effect on Solar Panels

Mateus Manuel Neto[1,3], Pham Van Thang[1], Luu Thi Lan Anh[1], Pham Phi Hung[2], Nguyen Ngoc Trung[1], Vo Thach Son[1]*

[1] Hanoi University of Science and Technology - No. 1, Dai Co Viet Str., Hai Ba Trung, Ha Noi, Viet Nam
[2]Vietnam Metrology Institute - No. 8 Hoang Quoc Viet, Cau Giay, Hanoi, Viet Nam
[3]Agostinho Neto University - Avenida 4 de Fevereiro 7 Luanda, Angola
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Abstract

The design and installation of photovoltaics system depend on the location climate condition. In this study, we investigate to effect of wind as velocity, inclined angle of solar panels,...to the solar cell system in Angola through the using the Computational Fluid Dynamic (CFD) software ANSYS Fluent. The simulated using solar cells system has power of 300W consist of 25 solar panels with dimension of each panel is 1.96m in length, 0.99m in width and 0.046m in depth. Panels are placed with 5 rows and 5 columns, where these solar panels are designed to be placed within a 0.002m gap between them. Results show that inclined angle of solar panels β = 30º within velocity of wind 9m/s and horizontal wind direction (attack angle α equal zero degree). The lower left corner in the direction of the wind is the largest distortion of about 0.685mm. The equivalent stress is found maximum at vertical bar of support of solar panel. The maximum value is about 7.46x104Pa. This value is lower than the limit stress of aluminum alloy (7.1x109Pa).

Keywords: c-Si solar cells, Angola, CFD, ANSYS Fluent, Wind velocity

1. Introduction

Today, solar cells is extensively using enlarged because of technology improvement of solar cell fabrication and cost reduction. Solar cell system does not only be used with large power but be used with small power, and may be used with all topographic if where have sun light [1] .

Angola is a country of the Africa, has a large area, but no country grid. The usage of the solar cells in this country has many potential, special features in the rural village [2] .

A wind action determines the most important load in the design of the support systems of the solar panels. Wind speed, or wind flow velocity, is an atmospheric quantity; it is caused by air moving from high pressure to low pressure, usually due to changes in temperature[3].

The wind loads also represent a factor of stability or instability for the operation of the solar panels, bearing in mind that the support structure of the solar panel should withstand all loads of winds, regardless of their location, over the roof, in lighting poles, or on the ground. Wherever they are located, on flat roofs, pitched roofs or ground level, the wind represents the main action that determines the design of support systems for solar panels[4].

Determination of wind forces on the support systems of solar panels is the subject of many research studies. In the last decade, numerous studies were performed in order to determine the pressure distributions and the size of wind forces on solar panels located on flat and pitched roofs, building envelope or at ground level. Design of the anchor systems must be done so that the extreme values of wind will not affect the integrity of the solar panels. The main problem in design of the anchor systems is to determine the correct uplift forces as well as the pressure field, in order to find solutions to reduce them [3]–[6] .

For solar panels located at ground level, the assessment of the wind loads proves to be an easier task than for panels installed on the roof top. Air flow is influenced by the presence of solar panels and the terrain roughness. In order to determine the average wind speed and the velocity profile, the influence of orography and roughness factors specific for the terrain type, is fundamental. Particularly in urban and suburban areas where the turbulence of the wind is increased because of the increased roughness of the boundary layer is important to find how it influences the interaction between the air flow field and the structures immersed in it.

* Corresponding author: Tel.: (+84) 947001597
Email: thang.phamvan@hust.edu.vn

In this section, we evaluate the influence of the winds on the solar panels located at ground level, taking into account, the characteristics of the Angola rural areas. Given the large surface area the aerodynamic forces acting simultaneously on solar modules could cause serious mechanical problems to the systems. Therefore, a good understanding of the wind flow and its interaction with the arrayed sets of panels is of interest to minimize the potential damages. Thus, we use Computational Fluid Dynamics (CDF) tool in ANSYS software to examine the effects of wind actions on the PV panels. The goal of simulations of the interaction between wind and the solar panels is to estimate the complex wind flow and pressures that act upon their surface.

2. Experimental

The processes to simulate the fluids flow problem by using CFD tool in ANSYS software include basic steps below:

Identify computational domain

The characteristics of solar panels is presented in table 1. The solar panel array consist of 25 solar panels with dimension of each panel is 1.96m in length, 0.99m in width and 0.046m in depth. Panels are placed with 5 rows and 5 columns, where these solar panels are designed to be placed within a 0.002m gap between them. Thus, the solar panels has 9.808m in length, 4.958m in width and 0.046m in depth. The solar panels are mounted at 3m or 5m height from ground level and tilted at a different slope. The solar cells assemblies are typically covered with glass and mounted in an aluminum alloy frame. In our calculation, Young's Modulus of glass is $7x10^9$Pa and of aluminum alloy is $7.1x10^9$Pa. The ambient temperature is 25^{o}C and the atmospheric pressure is 1atm.

Table 1. Characteristics of solar panels

No	Panel Solar Characteristics	
1	Voltage, V	: 24
2	Power Panel, W	: 300
3	Module Panel, Pcs	: 72
4	Quantities	: 25
5	Dimensions of each panel	: 1.96 x 0.99 x 0.046 m (L x W x D)
6	Weight of each panel	: 22.68 Kg

Figure 1 is geometry for simulation of wind action on solar panels.

According to the sunlight conditions in Angola, solar panels should be placed at angles situated between 20º and 40º from the ground level. Scientific literature recommends that solar panels should be facing the North direction with small deviations to North-East and North-West. Therefore, five inclination angle of the solar panels (20°; 25º; 30°; 35°; and 40 °) have been analyzed with the computer code ANSYS.

The computational domain is presented in figure 2. The dimension of computational domain depends on the minimal height of solar panel from the ground (H). The H is chose as 0.6m.

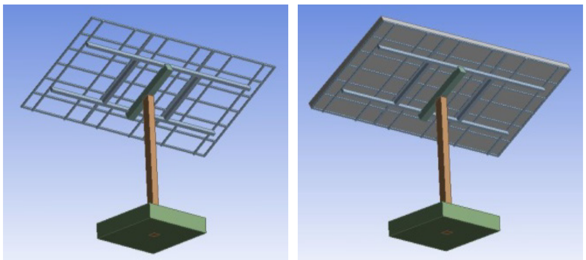

Fig 1. Generated model of solar panels

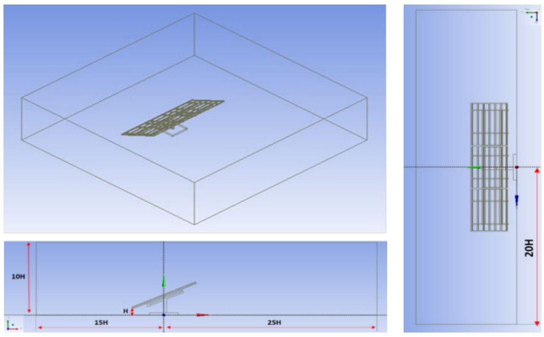

Fig 2. Computational domain

Mesh computational domain

ANSYS meshing is used to mesh computational domain shown in figure 3. The mesh is composed of $0.6*10^6$ structural elements. Near solar panels and support, the mesh is generated with very fine quality due to the aim to carry out the distribution of pressure on the solar panels and the support.

Set up numerical conditions

The *k-ε* turbulent model was chose due to the robustness, economy and reasonable accuracy for a wide range of turbulent flows explain its popularity in industrial flow simulations. It is a semi-empirical model, and the derivation of the model equations relies on phenomenological considerations and empiricism. The standard *k-ε* model is a semi-empirical model based on model transport equations for the turbulence kinetic energy and its dissipation rate "ε". The model transport equation for "*k*" is derived from the exact equation, while the model transport equation for "ε" was obtained using physical reasoning and bears little resemblance to its mathematically exact counterpart.

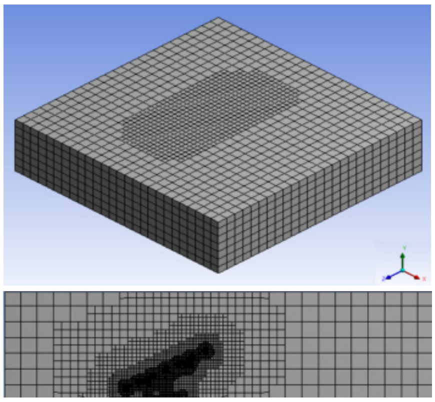

Fig 3. Mesh of computational domain

The boundary conditions show in table 2.

Table 2. Boundary conditions

Boundary	Conditions
Inlet	Velocity - Inlet
Bottom of computational domain	Wall
Solar panel and support systems	Wall
Other side of computational domain (except inlet and bottom)	Pressure - Outlet

Solve occurring problems

Following the step before, a steady problem of fluid flow need to estimate using CFD tool in ANSYS software. The number of iteration is found out that, from the 1000th iteration, the results of CFD problem are considered as stable.

3. Results and disscution

Effect of wind actions on solar panels

Effect of inclined angles

This section the effect of five different inclined angle of solar panels (β = 20; 25; 30; 35 and 40°) within velocity of wind 3m/s and horizontal wind direction (attack angle α equal zero degree) were investegated.

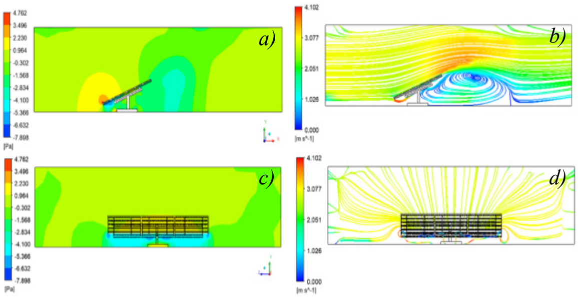

Fig. 4. Distribution of pressure and streamline of fluid flow around solar panels at center *XY* (a, b), *YZ* (c, d) plan - Wind velocity 3m/s, atttack angle 0° and inclined angle 20°

The maximum pressure is found at leading edge position where the wind is first contact to solar panel. This position is also called stagnation point. At this position, pressure is maximum (figure 4a) but velocity is minimum (figure 4b). Behind solar panel, a vortex in centered *XY* plan is observed. However, in centered *YZ* plan, no remarkable phenomenon is found (figure 4c, d). These remarks are similitude when inclined angle of solar panels increases from 20 to 40 degrees.

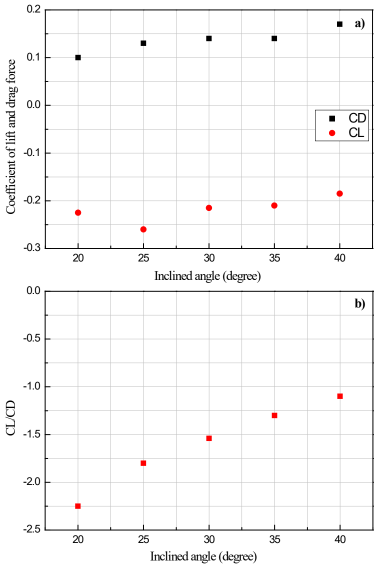

Fig.5. Effect of inclined angle of PV to aerodynamic characteristics: a) Coefficient of lift and drag force and b) Aerodynamic quality

According to the calculated results as shown in figure 5, the wind affects a negative lift to solar panels. It means that the solar panels adhere with ground. When the solar panels is inclined with increased angle, the lift and drag forces vary with a little difference but aerodynamic quality (CL/CD) increases in the absolutely value. The wind acts on the solar panel with a minimum force, and solar panels have less damage by wind.

The variable of aerodynamic characteristics of solar panel is negligible. So, we choose the solar panels installed with inclined angle of 30°. This is also accordant with sunlight conditions in Angola.

Effect of wind velocity

The value of wind velocity is exposed in this section within 30° inclined of solar panels and horizontal wind direction (attack angle α equal zero degree).

According to the calculated results as shown in figure 6, the wind affects a negative lift to solar panels. It means that the solar panels adhere with ground. When the velocity of wind increases from 3 to 6 m/s, the lift force increases but the drag forces decreases. For wind velocity from 6 to 15m/s, lift and drag forces vary with a very small difference (figure 6a). The aerodynamic quality of solar panels was increasing with wind velocity from 3 to 15m/s.

The variable of aerodynamic characteristics of solar panel is negligible. So, the 9m/s of wind velocity is chosen to estimate the simulation about direction of wind.

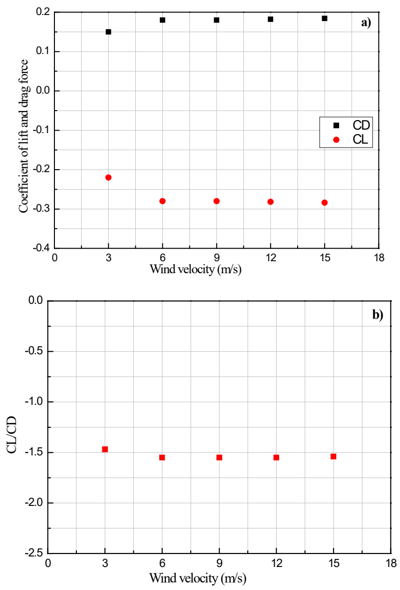

Fig.6. Effect of inclined angle of PV to aerodynamic characteristics: a) Coefficient of lift and drag force and b) Aerodynamic quality

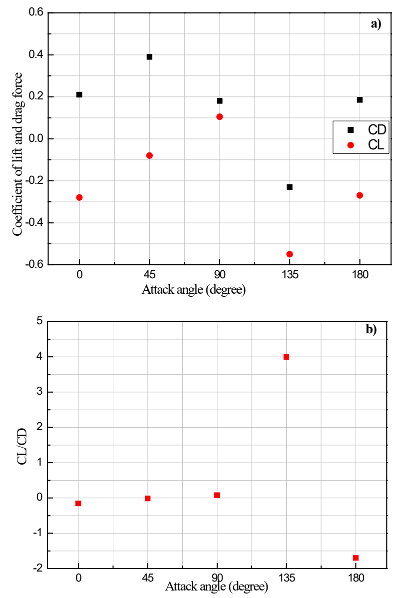

Fig.7. Effect of inclined angle of PV to aerodynamic characteristics: a) Coefficient of lift and drag force and b) Aerodynamic quality

Effect of wind direction

The effect of wind direction (attack angle α = 0; 45; 90; 135 and 180°) within velocity of wind 9m/s and 30° inclined solar panels were investegated.

According to figure 7, wind direction has strong effect to aerodynamic characteristics of solar panels. At horizontal wind (both in 0° and 180° of attack angle), coefficient of lift, drag and aerodynamic quality is around -0.26, 0.17 and -1.60 respectively. At vertical wind (90° attack angle), the drag force is approximately like 0.17 but lift force is positive. This positive value of lift force causes the solar panels to be pulled out of its fixed position.

At 45° direction of wind, the lift force is negative but aerodynamic quality of solar panels is smallest. At 135° direction of wind, both lift force and drag force are negative. It seems that the solar panels could not keep its fixed position.

Strength analysis of solar panels

For strength analysis of solar panels, the horizontal wind flow with 9m/s velocity, 0° attack angle and 30° inclined solar panels are chosen. First, the CFD problem for this case is solved to find out distribution of pressure on full surface of solar panels. Then, this distribution of pressure is used as load acting on structure of solar panels. Finally, the strength analysis of solar panel is solved to estimate the strength of solar panels using ANSYS software.

The mesh for strength analysis is presented in figure 8. This mesh includes 48,672 unstructured elements.

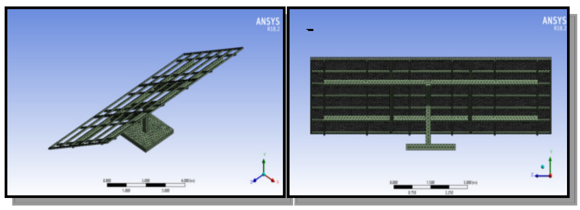

Fig.8. Mesh of strength analysis problem

Total deformation of solar panel is presented in figure 9. The solar panels are deformed at four corners. The lower left corner in the direction of the wind is the largest distortion of about 0.685mm.

Figure 10 displays the equivalent stress is found maximum at vertical bar of support of solar panel. The maximum value is about $7.46\text{x}10^4$Pa. This value is lower than the limit stress of aluminum alloy ($7.1\text{x}10^9$Pa). Thus, we could conclude that solar panels are durable with wind velocity 9m/s, attack angle 0° and 30° inclined angle of solar panels.

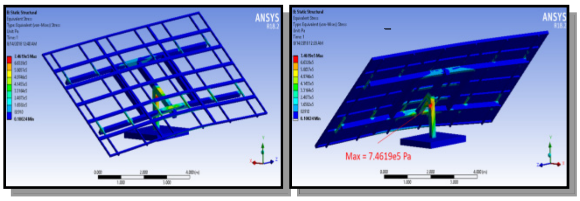

Fig.9. Total deformation - Wind velocity 9m/s; Attack angle 0° and Inclined angle 30°

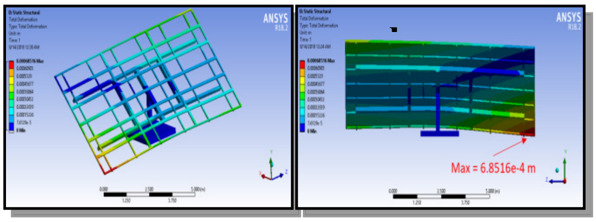

Fig10. Equivalent Stress - Wind velocity 9m/s; Attack angle 0° and Inclined angle 30°

4. Conclusion

From all the analyzed cases it has been pointed out that, the inclined angle of solar panels β = 30° within velocity of wind 9m/s and horizontal wind direction (attack angle α equal zero degree) is the best choice of system. The lower left corner in the direction of the wind is the largest distortion of about 0.685mm. The equivalent stress is found maximum at vertical bar of support of solar panel. The maximum value is about 7.46×10^4Pa. This value is lower than the limit stress of aluminum alloy (7.1×10^9Pa).

Acknowledgments

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References

[1] A. Goodrich et al., ‘A wafer-based monocrystalline silicon photovoltaics road map: utilizing known technology improvement opportunities for further reductions in manufacturing costs. Sol Energy Mater Sol Cells (2013) 110–35.

[2] Web, ‘www.angolaenergia2025.com/en/conteudo/grid-expansion’.

[3] Z. Zhang, ‘Influence of Special Weather on Output of PV System’, IOP Conf. Ser. Earth Environ. Sci., 108 (2018) 1-7.

[4] O. O. Osarumen, H. A. Emeka, N. N. Ekere, P. O. Olagbegi, ‘A review of photovoltaic module technologies for increased performance in tropical climate’, Renew. Sustain. Energy Rev., 75 (2017) 1225–1238.

[5] G. V. Kudav, Y. M. Panta, and M. Yatsco, ‘Design and testing of wind deflectors for roof-mounted solar panels’, WIT Trans. Eng. Sci., 74 (2012) 15-27.

[6] S. Hsu et al., Simulated Wind Action on Photovoltaic Module by Non-uniform Dynamic Mechanical Load and Mean Extended Wind Load, Energy Procedia, 130 (2017) 94–101.