Study on the surface stress and the surrounding dust deposition of solar photovoltaic module

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Abstract: Northwest China is rich in solar energy resources and vast land resources, this unique advantage is the reason for the development of solar photovoltaic industry here. However, windy and sandy climate characteristics of northwest are brought hidden trouble to run efficiently and safety for solar photovoltaic modules. This topic through the numerical simulation method to simulate wind load condition of S275 type polycrystalline silicon photovoltaic modules in net wind field, dust particle are added on the basic, to analyze the various factors influencing the settlement of sand and dust around the photovoltaic modules, as well as provides a reference to the design standards for solar photovoltaic system suitable for northwest China climate and landscape environment.

1. Introduction

The solar photovoltaic component toward the development of lightweight, anti wind performance put forward a very high demand, at the same time, the rate of conversion of solar photovoltaic modules to high quantitative development, in order to ensure solar power plants in the desert dust in the environment of efficient and stable operation, analysis of dust in the desert environment of sand movement in gas-solid flow and settlement mechanism and the conditions of solar photovoltaic module surface is necessary[1]. With the rapid development of solar energy industry, more and more researches on the wind resistance performance of solar PV modules are presented. Raddu et al.[2] Studied the effect of wind on the solar flat plate collector. It is concluded that the drag coefficient is the largest when the wind blows from below. Dou Zhenzhen[3] of Chang'an University through the analysis method of wind tunnel test and numerical simulation on comparison of the solar photovoltaic component of wind load, wind angle, inclination, height, spacing and location factors of wind load, obtains the photovoltaic array of solar photovoltaic power plants in the mutual occlusion of the wind load produces certain effect. In the numerical simulation of wind blown sand flow, Hsu[4] studied the characteristics of wind sand flow under low wind speed. Li Yintang[5] calculated by Fluent software, the dust events occurred during the initial stage of the surface layer in different wind speed, particle size, volume fraction of space dust distribution, the results show that the numerical simulation and wind tunnel test is very similar. Based on the above research, this paper adopts the numerical simulation method of S275 type polycrystalline silicon solar PV module and wind load were analyzed in the gas-solid two-phase flow in the sand dust around the settlement, according to the simulation results, analysis of influence factors and the sedimentation of wind load.
2. Physical Model
Solar photovoltaic array is to meet the needs of practical application in high power and a plurality of solar photovoltaic modules connected together constitute the monomer in the array, this selection is shown in Table 1 will be six pieces of polysilicon components S-275D connection in the solar photovoltaic array unit together, simulation model is built according to the actual size 5952 * 1956 * 50mm.

The simulation of solar photovoltaic components due to different conditions, choose the conditions of mirror perpendicular to the surface of the calculation domain settings, can calculate the occlusion rate was 1.79% in the table size calculation and calculation of the domain model, meet the requirements.

| Calculation model | Calculation model | Calculation model | Calculation model | Blocking rate (%) |
|-------------------|-------------------|-------------------|-------------------|------------------|
| height (m)        | width (m)         | windward length (m) | leeward length (m) |                  |
| 13.692            | 47.616            | 13.667            | 39.095            | 1.79             |

In the solar photovoltaic installation, PV module under the ground along the distance should be 0.3 ~ 0.5m, so as not to be weed shelter and winter snow buried, this paper choose along the height from 0.5m, this distance is reflected in the calculation model of photovoltaic module and the lower edge of the bottom surface of the spacing of flow field.

3. Calculation Model

3.1 Modeling and Meshing
The ANSYS software is used to model and build the mesh. First set up a small area near the photovoltaic component model, the calculation model for cutting 5 plane through a small domain, the method is cut into 18 geometry, the area using tetrahedral mesh encryption to adapt to complex flow field of photovoltaic module. The external area is the use of mesh in Body sizing--Body of Influence function to generate the positive rate of growth from small area of hexahedral mesh body grid size to 1.05 gradient, can shorten the calculation time reduced the number of grid. The surface of the PV module needs to be encrypted locally, and the overall grid is shown in Figure 1, and the total number of grids is 2 million 60 thousand.

![Figure 1. Calculation model after mesh](image)

The calculation process is solved by Fluent pressure basis and the standard $k-\varepsilon$ model is adopted[6]. Using the Euler Euler method to establish the basic equations of wind sand flow, the mixed model numerical simulation model, follow the mass conservation equation, momentum conservation equation, energy conservation equation, discretized by the finite volume method calculation area.

3.2 Boundary Condition Transitivity

3.2.1 Net Wind Field Simulation Boundary Condition Setting
In the numerical simulation assuming fluid motion for incompressible unsteady flow, velocity boundary conditions using the entrance entrance conditions, fully developed flow boundary conditions with open boundary conditions, the computational domain top and sides and a photovoltaic component on surface adopt wall noodles no slip wall, the standard wall function is selected the function simulation of near wall flow.

3.2.2 The Boundary Conditions of the Simulation of the two Phase Flow
The dust particles added in the net wind field numerical simulation has been completed, and the air together constitute the sand two-phase flow, Euler -Mixtrue model is applied to simulate and analyze the above selected process of settlement of dust in the solar photovoltaic module and peripheral surface. The characteristics of the given boundary between Bagnold gravel, sand and dust were 1mm and 0.01 mm in dust deposition, widely used in sport research, in the process of simulation of dust particle size selection as a reference, the sand density is 2650 kg/m³, it was assumed that the following conditions are established:

1) if the air is an incompressible fluid, the density is always constant;
2) assume that dust particles for uniform quality, uniform particle size and sphere, without collision and other reactions, dust particles in the field of entrance along the height of the uniform distribution, the volume fraction of the initial conditions set the average volume fraction of the dust particles.

The 3D double precision should be calculated in the process of pressure based implicit solver; in sand two-phase flow need to set the Y -9.81 in the direction of acceleration of gravity; flow field solution using SIMPLE algorithm, two order upwind scheme use high precision; other parameters besides the settings are in accordance with the default value.

4. Simulation Results and Analysis

4.1 The Influence of Inclination Angle of Wind Farm on Distribution of Velocity Field
The installation of photovoltaic modules in actual project settings and the ground has certain angle, different installation angles will affect the photovoltaic component around the velocity field and surface pressure distribution, which affects the safety stability of PV module structure, so the analysis is very important for the installation angle of the PV modules.

The flow velocity is 10m / s, and the distribution of the velocity field on the symmetry plane of the PV module is 15 °, 30 °, 45 °, 60 °, 75 ° and 90 °, respectively. Comparison of field distribution can see installation speed when the different angle, flow and blunt obstacle of solar PV flow is similar to that of air on the surface structure of the windward side will have a block, the airflow from the outward appearance of radial expansion, blocking above will be on the rise and cross structure the following points, blocking will flow down to the ground, and the general flow around bluff body is different, the solar photovoltaic component along the ground and there is a certain distance (500mm), so the air separation will occur in the lower part, from below through air to roll up to form a small vortex.

Comparison of installation angle of 15 degrees to 90 degrees around the velocity field of PV modules, can be seen with the change of installation angle, the wind PV area is more and more big, the blocking effect of air is more and more big, performance in the PV downstream flow width becomes longer, the upstream PV module cyclotron eddy current with the increase of the angle end from the near to flow more and move up to 90 degrees maximum, basically symmetrical; air separation along the length is increased with the increase of PV installation angle decreases.

4.2 The Factors Affecting the Deposition of Dust around Solar PV Modules
In the foundation of calculation simulation has been completed in accordance with the net wind field, wind blown sand flow setting conditions of dust particles into phase, then the dust in the settlement around the solar photovoltaic component simulation, considering the effect of gravity in the simulation process, the dust particle density is set to 2650kg/m³.
4.2.1 Effect of Installation Inclination on Dust Deposition

The distribution of the velocity field around the PV module is affected by the inclination of the solar PV module, which affects the sedimentation of the sand particles. At the same time, due to the blocking of the surface of the PV module to the dust particles, the particles collide with the surface of the PV module and consume a part of kinetic energy.

![Image](a)
(a) The distribution of dust around the components at 0° installation angles

![Image](b)
(b) The distribution of dust around the components at 15° installation angles

![Image](c)
(c) The distribution of dust around the components at 30° installation angles

![Image](d)
(d) The distribution of dust around the components at 45° installation angles

![Image](e)
(e) The distribution of dust around the components at 60° installation angles

![Image](f)
(f) The distribution of dust around the components at 75° installation angles

![Image](g)
(g) The distribution of dust around the components at 90° installation angles

Figure 2. Volume fraction distribution around the photovoltaic modules at different installation angles

Figure 2 shows the fixed wind speed 10m/s, dust particle size 10um, entrance volume fraction 5e-05%, PV installation angle of 15°, 30°, 45°, 60°, 75° and 90° of PV components symmetrical surface dust volume fraction distribution. It can be seen from the figure, installation angle of PV modules around the sand volume fraction distribution, and volume fraction of large area, it can be considered a dust prone to subsidence of the area, which shows that the inclination angle is very significant influence on the sedimentation.

Comparison of the installation angle of photovoltaic modules around the dust distribution, because of the self gravity of PV modules and dust barrier role in the PV wind to ground will appear different degrees of settlement. 0° of dust only in the thickness of the photovoltaic components by very small obstacles, so in front of the PV module basically no settlement, 90° of PV module maximum of blocking effect of sand flow, the dust is not easy to be blocked by the photovoltaic component dust along the surface of the most obvious decline, settlement.

Because of the PV module below through air will roll up the formation of a small vortex, the airflow will drive the wind direction is hindered by the dust through settlement in the PV back to the
ground subsidence area will always appear dust, from 0° to 90° to the dorsal subsidence area from the photovoltaic component is getting closer. At 0°, the aeolian sand flows through a small perturbation of the PV module and then continues to flow in the horizontal direction until it is deposited in the far back due to gravity. At 90°, the wind direction to block the dust, the lower the direction of the settlement is also faster.

5. Conclusions
Wind load simulation results show that the wind farm:

With the increase of the inclination angle, the wind PV area is more and more big, the blocking effect of air is more and more big, performance in the PV downstream flow width becomes longer, the upstream PV module cyclotron eddy current with the increase of the angle from the end near the flow more and move up to 90° maximum, basically symmetrical; air separation along the length is increased with the increase of PV installation angle decreases.

Simulation results of wind sand two phase flow by Euler Mixture:
With the increase of installation angle, appear in the PV wind to the ground sedimentation area is more and more obvious, the photovoltaic component subsidence area from the back to the PV module is getting closer, dip the instructions to install more easily in the PV surrounding settlement.

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