Simulation and Analysis of the Wind Effects on the Solar Panels in the Solar Power Station

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***Abstract*— Because of global warming due to environmental pollutants, expanding the use of clean energies has gained a special place in all countries. In the meantime, solar energy is one of the most available renewable energies, which despite many researches in this field, still needs to be further investigated and overcome the shortcomings. One of the phenomena that has caused irreparable damage to solar power plants all over the world is the destruction of them due to strong winds. In this regard and in order to protect the solar panels which are produced with great difficulty, a small example of a solar power plant has been simulated in this research by Islamic Azad University, Central Tehran Branch, and the effects of wind on the solar panels have been studied and important results were obtained. Following this research, a new glass, frame and structure was designed to protect the solar panels, which they increase the resistance of the solar power plant against the wind. During this new design, the structure, frame and glass used in the solar panels can withstand wind speed up to 126 km/h. With this wind speed and in the case that the panel is installed at 30 degrees to the ground (the most critical situation), the pressure on the panel surface will be equal to 104234 pascals, and the amount of panel surface and frame bending caused by this pressure are respectively 1.1 mm and 0.2 mm and these changes do not harm our panels. Therefore, these seemingly simple changes can prevent many damages in solar power plants around the world.**

Keywords— Solar Panel, Solar Power Station, Wind Effects on the Solar Panels

I. INTRODUCTION

Considering that using of renewable energies helps to protect the environment and causes to manage environmental pollutants, the study about preserving and maintaining these systems is so important. One of the most popular renewable energies is solar energy. In general, protecting from solar cells and panels to preventing possible damage and to increasing their efficiency are divided into three below categories.

The first category is protection during the production of solar cells and panels, and there are various solutions to increase the quality and efficiency during production. V. Parra and his colleagues have studied on the trends in crystalline silicon growth on 2013 that the result of this study was a higher efficiency of the photovoltaic cells and reducing in costs of production [1]. Y. C. Wu V. and his colleagues have studied on the effect of seed arrangements on the quality of n-type mono-like silicon grown by directional solidification on 2016 and as a result, the seed junction with large tilt angles had little effect on the defect generation, and the best tilt angle ranged from 10° to 30°. Except for the area near the 0° tilt angle, the best life time of the wafer after gettering could be greater than 3ms [2]. Fang Zhang and his colleagues have studied on the designing functional Σ13 grain boundaries at seed junctions for high-quality cast quasi-single crystalline silicon on 2019 and they found in this study that the generation of dislocation clusters and sub-GBs from the seed junctions is significantly suppressed owing to the low energy barrier potential of the Σ13 GB. Although some twins could generate from the vertical Σ13 GB, they will not give a bad influence on the ingot quality. The efficiency of solar cells was with an average value of 20.1% in industrial circles [3]. As a result, the silicon block loss that was from 12.3% to 43.9% in different crucible and solar cell sizes decreased from 10.1% to 23.7%. These changes caused to improve the quality of the solar cells and increase the grade of them. Besides, by using 4,000,000kg silicon as this production line's row material, the polycrystalline solar cells' production efficiency that was from 744MW to 927MW during 218 to 293 working days increased from 913MW to 1048MW during 297 to 302 working days [4].

The second category is the protection of solar cells against the rising temperature of the panels' surfaces exposed to the sun, which despite the increase in thermal efficiency, causes a decrease in the solar cells' life time and a decrease in electrical efficiency, and today many manufacturers compete about this issue [5]. Zhang and his colleagues believe that photovoltaic-thermal modules are able to collect and convert a higher percentage of solar energy compared to solar panels and collectors in an identical absorption area that this matter causes to heat and power production with a low cost and high efficiency [6], and it has less payback period in comparison with photovoltaic systems and collectors [7,8]. M. Eftekhari Yazdi and his colleagues have studied during 2013-2014 about the behavior of thermosyphon solar water heaters and their effects on the thermal and electrical efficiencies as well as on the solar cells' life time [9-12]. H. Eskandarzadeh and his colleagues have investigated in 2015 about the combination of solar water heater and thermal photovoltaic solar panel in order to increasing the solar cells' life time [13]. A. Soleymani Ashtiani and his colleagues have studied during the years 2018 to 2022 about inserting a direct contact water basin was installed under the solar panels in order to increase the solar cells' life time and electrical and thermal efficiency of photovoltaic panels. During this research, the average voltage increased from 80% to 91% and the average amperage increased from 71% to 84%. Besides, the output (hot water with a temperature of about 99 degrees Celsius) was used as a solar water heater [17-14].

The third category is the protection of solar cells and panels against natural disasters that the most common of them is strong winds. C. Burgess and his colleagues have described an example of this incident in their own research [18]. Also, G. Robinson and his colleagues have studied about Weather Impacts on Solar PV Operations, Summary of the Current Body of Knowledge and Implications for Further Investigation [19]. Besides, as it mentioned in Figure 1, many projects around the world have been destroyed by strong winds. So, the simulation and analysis of the effects of wind on solar power plants has been done in this research and a new design has been developed.

A) Derecho event

B) Hurricane Maria

C) Solar Energy Association of Ukraine

D) Solar Power Plant in Mansa - Hindustan

Fig. 1. Sample of Wind Effects on the Solar Panels in the Solar Power Station

II. Methods and Principles

Considering that the mechanical resistance of solar cells cannot be changed in the production process, to preventing solar power stations from being damaged during strong winds and storms, it is necessary to have a structure, frame and glass around the solar panel which are able to withstand the strongest wind that may occur according to the reports of the Meteorological Organization of that region.

As it has been mentioned in figures 2 to 5, in most solar power plants around the world, one of these structures is generally used that each of them has its own advantages.

Fig. 2. A Common Structure of Solar Power Station with Use of DRIVIN PILES

Advantages of DRIVIN PILES mounting are as below:

- Used on various soils and sloping areas, except rocky
- Reduce the cost of installation work and ensure the fastest installation through the use of special equipment
- Create a reliable, stable structure with high load-bearing capacity
- The most economical type of foundation

Fig. 3. A Common Structure of Solar Power Station with Use of GEO SCREWS

Advantages of GEO SCREWS mounting are as below:

- Used for installation on soft soils
- Economic in comparison with concrete foundation
- Provide a minimum of work to level the site
- Quick and easy to install unlike a concrete foundation

Fig. 4. A Common Structure of Solar Power Station with Use of CONCRETED IN GROUND (BORED PILES)

Advantages of CONCRETED IN GROUND (BORED PILES) mounting are as below:

- Applied on all soils
- Do not cause dynamic impact on the soil
- Have a large load-bearing capacity
- During installation there is no high noise level, installation at night is possible.

Fig. 5. A Common Structure of Solar Power Station with Use of CONCRETE BLOCKS

Advantages of CONCRETE BLOCKS mounting are as below:

- Require minimal site preparation
- Mounted on rocky terrain where it is impossible to drive piles
- Easily dismantled and moved if necessary
- Resistant to temperature changes and groundwater
- Suitable for reuse

Also, the glass with the specifications of Table No. 1 is used in the most solar power plants around the world in accordance with UL 1703 Static Load (Global PV Module Testing Standard) [20].

Composition (%)	Clay	Solar Panel Waste Glass
SiO_2*	63.91 ± 1.21 **	72.33 ± 2.84
Al_2O_3*	16.89 ± 0.24	1.90 ± 0.01
Fe_2O_3*	6.38 ± 0.24	0.03 ± 0.00
CaO*	1.88 ± 0.03	8.98 ± 0.28
MgO*	1.82 ± 0.27	2.62 ± 0.09
SO_3*	0.13 ± 0.01	0.29 ± 0.08
Na_2O*	0.03 ± 0.00	12.87 ± 0.32
K_2O*	2.93 ± 0.09	0.04 ± 0.01
LOI	6.03 ± 0.91	0.94 ± 0.02
* Detected by X-ray fluorescence analysis ** Mean ± standard deviation (n=3)		

Table 1. Chemical Composition of Clay and Solar Panel Waste Glass [20]

As it was mentioned in Figure 1, none of the solar power plants that they used the aforementioned structures and glass have survived strong winds and irreparable damage has been done to these power plants. Therefore, in order to prevent such damages, it is necessary to use other type of glass, frame and structure which have sufficient mechanical resistance during strong winds. This subject has been studied in this research.

III. Results

After the initial simulation of a solar power plant and its analysis based on the environmental conditions which are according to the Table number 2, and also, after many trials and errors and finding the weakness of the frames and structures which are used in the most of the solar power stations in the world, a frame and a structure were designed according to the Figures No. 6 and 7.

Thermodynamic parameters	Static Pressure: 101325.00 Pa Temperature: 293.20 K
Velocity parameters	Velocity in X direction: 35.000 m/s OR 126 km/h Velocity in Y direction: 0 m/s Velocity in Z direction: 0 m/s
Turbulence parameters	Intensity: 0.10 % Length: 0.019 m

Table 2. Ambient Condition

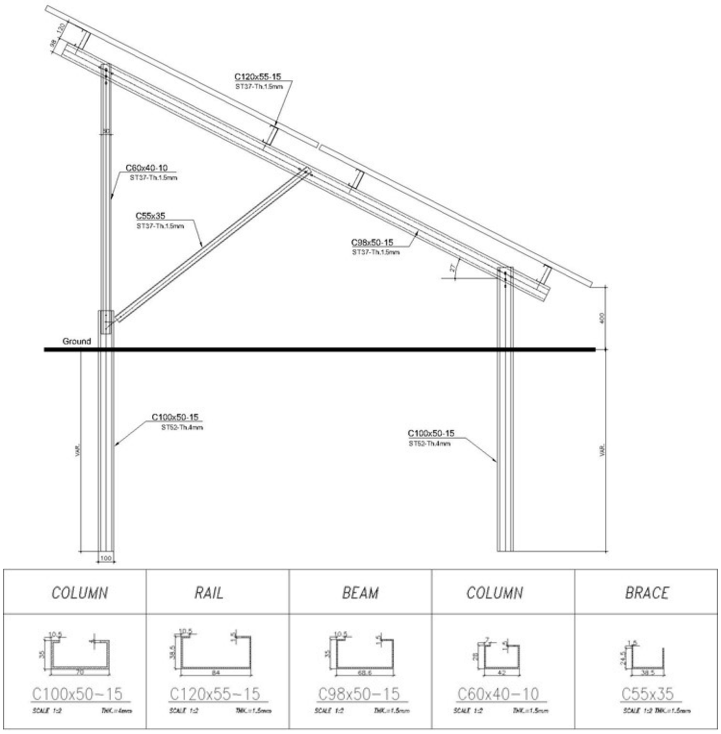

Fig. 6. Solar Structure Technical Data

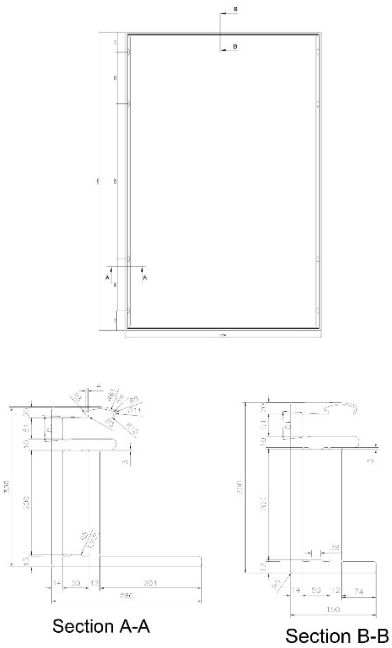

Fig. 7. Solar Frame Technical Data

Also, the specifications of the glass used on the solar panels in this study were changed according to Table No. 3.

Glass Chemical Analysis	
Content	W %
SiO_2	69-73.5
Na_2O	12.5-14.5
K_2O	0.005-0.03
CaO	8~11
MgO	2.5-4.5
Al_2O_3	0.8-1.3
Fe_2O_3	0.012≥
SO_3	0.2-0.5
Glass Surface Properties	
Coating Surface	Texture 0.4 -1µm
Pattern Surface	40 µm
Coating Analysis	SiO_2 or TiO_2
Coating Thickness	100-200 nm
Optical Properties	
Light Transmission	≥94 % (400 -1100 nm)
Mechanical / Thermal Properties	
Bending Strength	90 MPa
Tensile Strength	42 MPa
Pressure Resistance	700-900 MPa
Falling Ball Resistant (Impact) Test	Steel ball (227gr) to fall at height of 1 Meter to the center area, not broken
General Bow	<2%
Thermal Resistant Impact Test	250°C
Tempered Fragmentation per 50mm×50mm	≥ 40
Coefficient of Linear Thermal Expansion	$9*10^{-6}$ °C
Tempering Temperature	500-650°C
Density	2500 Kg/m^3
Dimension / Appearance	
Thickness	3.2±0.2mm
Cut Corners	Chamfer / max. 3mm
Edge	C-Shape
Round bubble Diameter	< 0.5 mm (No Metering)
	0.5≤ D < 1.5 mm (in $5m^2$ area)
	1.5≤ D ≤ 2 mm (in $3m^2$ area)
	>2 mm (Not Allowed)
Line bubble	L<1.5 mm, W≤ 0.5 mm (No Metering)
	L<1.5 mm, 0.5≤ W≤ 1 mm (in ≤$6m^2$ area)
	1.5≤ L< 3 mm, W≤1 mm (in ≤$4m^2$ area)
	3≤ L<5 mm, W≤0.5 mm (in ≤$3m^2$ area)
	3≤ L<5 mm, 0.5≤W≤1 mm (in ≤$2m^2$ area)
	L≥5 mm (Not Allowed)
Micro Bubble	Allow ≤3 cm^3

Table 3. Solar Glass Technical Data

As it has been mentioned in Figures 8 to 10, the mentioned structure, frame and glass in solar power plants can withstand wind speed up to 126 km/h. With this wind speed and in the case that the panel is installed at 30 degrees to the ground (the most critical situation), the pressure on the panel surface will be equal to 104234 pascals, and the amount of panel surface and frame bending caused by this pressure are respectively 1.1 mm and 0.2 mm and these changes do not harm our panels. Also, the M10 bolt used in this design can withstand these conditions well. Therefore, these seemingly simple changes can prevent many damages in solar power plants around the world.

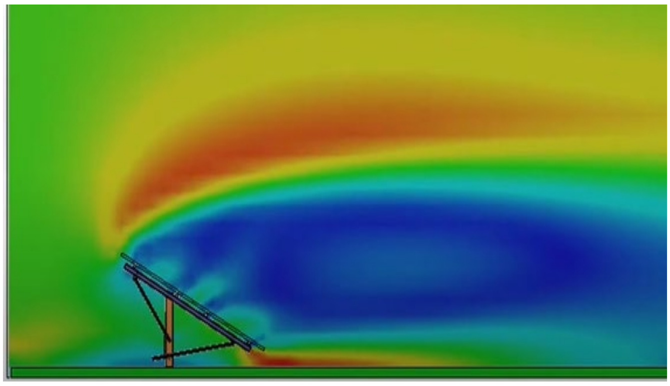

Fig. 8. Wind Velocity

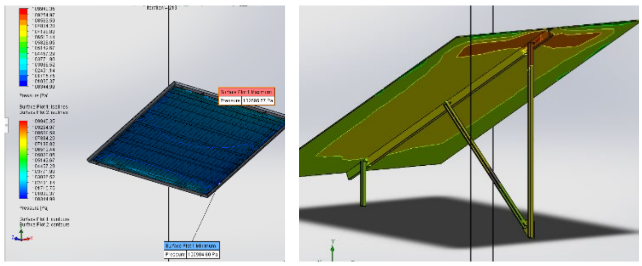

Fig. 9. Wind Effects on the Solar Panels

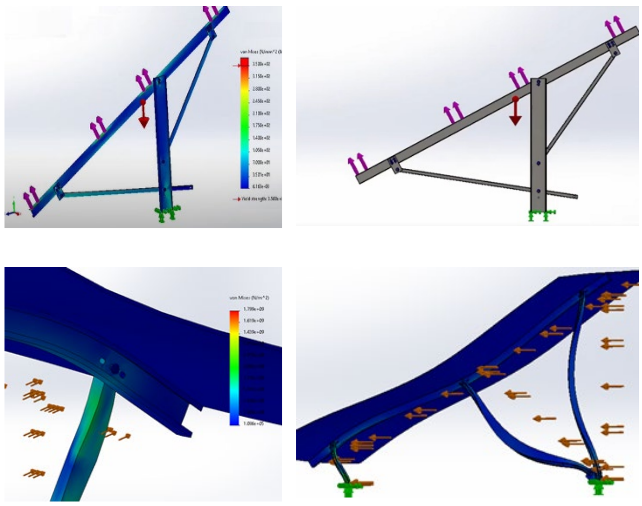

Fig. 10. Wind Effects on the Solar Panel and its Structure Bending

Therefore, the specifications of each installed solar panel in the studied power plant will be in accordance with Table No. 4.

Cell Type	M10, Half Cell, Topcon
Glass Type	Single Glass 3.2mm OR Double Glass 2.0mm
Structure Material	6063 Aluminum
Frame Material	ST37
Final Weight of Panel, Glass and Frame	24.5 Kg
Final Dimension of Panel, Glass and Frame	1728 x 1134 x 30 mm

Table 4. Final Solar Panel Information in the Solar Power Station

IV. Acknowledgement

This article is the result of authors studies of this research and all property and intellectual rights belong to Islamic Azad University, Central Tehran Branch, and every direct or indirect using from information of this research without the written consent from the responsible author and Islamic Azad University, Central Tehran Branch, has legal prosecution.

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