Comparitive Studies of Futuristic Optimisezed and Regular Solar Panels with Windload Effects on Solar Farms, Solar Panels at High Altitude for Free Green Solar Energy

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Abstract:

Solar energy is one of the most promising green and eco-friendly renewable energy out of the wind and other non-conventional energies. In nature, we have abundance of solar energy, due to this there is a significant attention on capturing the solar energy by photovoltaic systems in recent years. Photovoltaic energy conversion is most harnessing renewable energies for different communities especially in developing countries like India. The efficiency decrease is not only due to the shadows of buildings, but also due to birds, lack of sunlight and also wind effect on solar panels which will decrease efficiency and damage the total panels or array of panels. In this work, two different analyses are carried out with changing wind velocities and angle. The aerodynamic effects on the panels were investigated by varying the orientation of panels from 0 to 180 degrees and two different wind speeds of 5m/s and 25m/s. Initial angle of 0 degrees which is normal to the flow direction is solved for two different wind speeds of 5 m/s and 25 m/s and followed by changing the orientation of panels from 0 to 180 degree inclination to investigate the aerodynamic effects on the panels. Depending on the results obtained a futuristic panel design will be proposed which can generate optimum power and also aerodynamically effective. This current study indicates that the pressure distribution on the front face of the solar panels, which are aptly suitable to design optimized solar panel shapes.

Keywords: Solar Panel, Aero Dynamics, Urban Environment, Optimization, Free green solar energy.

Introduction

Towards the green energy approach over the past few years, commercial ground mounted solar farms installation have expanded not only in urban areas but also into agricultural and rural communities where open land is more. The farmers can give their land for producing clean and pollution free green solar energy. A solar farm is a photovoltaic power station in which solar panels are arrayed in decentralized manner supplying the power to power grid. Solar farms may be associated with both residential community-scale solar and utility-scale solar. Recently people are thinking about community scale solar, in which solar array is a large ground mount installation that occupies one or more acres. Utility scale solar is the largest scale (1 to 5 MW) solar installation. The main difference between community solar scale and utility solar scale is that the power generated in utility scale is not utilized at the host site. The produced 1 MW of power in utility sector can supply power to 200 households. Even though the cost of the solar farm depends on the location and availability of sunlight, it will cost around 100 crore rupees. India installed the world’s largest solar farm at Pavagada which was completed in 2015 with 2050 MW power generation capacity which can supply power to thousands of households.

Solar energy can potentially replace all types of renewable energy sources, but there are some major constraints for development of solar energy in India. The constraints are solar resource assessment, wind resource assessment, wind and solar farm distribution and atmospheric conditions like hurricanes, tornadoes with wind speeds up to 200 miles per hour. It is very important to know about how the solar energy system holds up in extreme wind events that may knock out the parts of the electric grid. Normally, solar farms are highly rigid to damage from stormy wind conditions. In most cases wind causes damages to solar system, failures might happen because of weakness in racking or the roof where we place the system. When wind flows across the array of the panels, it flows between the small spaces of the panels causing a lifting of the panels that leads to damage of the total solar farm. This wind flow is capable of damaging panels from their mounts, or the mounts from ground or roof. Another cause of damage is flying debris. Different types of debris that can be blown in storm can make damage to the solar array of panels.

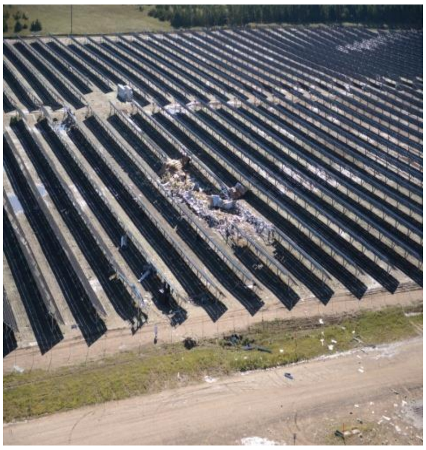

Figure 1. Camp Ripley received damage 60 acre solar field, during a big storm and tornado Sept 7, 2016.

Objectives and Hypothesis

The main objective of this work is to find a solution to the problem of ground mounted and roof mounted solar panels that are dislocated due to aerodynamic loads. The effects of forces caused due to air flow are accurately predicted in all directions by using CFD (computational Fluid Dynamics). A full scale model is used with a control domain to produce results accurately. It is hypothesized that doing CFD analysis and analyzing the data, a most accurate and reliable data can be obtained on aerodynamic forces so that uncertainties can be reduced.

Damage of solar panels: The solar panels modules and mounting structures will be affected by the wind as follows.

1. Velocity of the wind: Usually there is huge variation in wind velocities form one region to another region. Normally there is 10 to 60 km/hr of wind speed and at the coastal regions the range will be around 60 to 90 km/hr. Similarly at the time of hurricanes the speed may rise to more than 90km/hr.

2. Direction of the Wind: Normally Wind direction is always changing from one direction to another direction. Since we place the solar panels at the top of the building or on the ground, wind may flow in either direction. Wind may flow in the direction of inclination of panel and sometimes opposite to that.

3. Size of the building and the presence of the protective wall: The speed of wind is varied due to increase in latitude means that there is more speed at the top. Protective wall around the building prevents the air to go into the backward position and causes lift in the upward direction.

4. Position of the building in the environment.

5. Inclination of the solar panels to the sides of the building i.e. either oblique or parallel.

6. Angle of tilt of the solar panels: The tilt angle of solar panels normally 12 to 18 degrees. It may change from season to season. Tilt angle is important for maximum exposure of sunlight on the panels.

7. location of the panels to the roof edges.

There are many research objectives to be considered while doing a project.

To obtain the aerodynamic loads on an arrayed ground mounted solar panels in a solar farm and the aerodynamic load effects on roof mounted solar panels. To examine the effects of pressure, velocity and turbulence in all cases. To obtain forces acting on individual solar panel to access most probable damage caused by aerodynamic load. To optimize shape of solar panel to reduce the wind forces.

Methodology

Numerical modeling program was adopted to calculate the pressure distribution on solar panels [1]. The numerical results of CFD ANSYS simulation and the pressure coefficient distribution are similar when compared to full scale measurements. [2].In the past years many people have done research on the wind effect on solar panels. Numerical studies and scaled wind tunnel test on array of PV panels were done by researchers [3, 4, 5, and 6]. Among the many parameters which influence the drag forces and lift forces, wind directions are the ones which will affect most of these forces. There are many parameters that can change the entire effect of wind on panels.

CFD ANSYS is a software tool to optimize the conditions of products and control even before making of the first prototype. Fig.1 shows the overview of the CFD modeling. There are several steps to examine the outcomes of the effect of wind on solar panels. The initial step is problem identification and the subsequent steps are preprocessing, solving and post processing. [7].

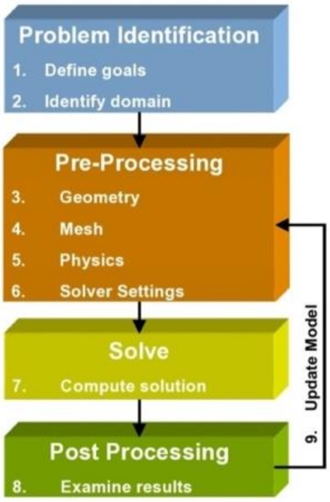

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Fig.2 Overview of the CFD modeling.

Results

The computational domain is used to simulate the scenarios possible to appear in real time scenario and such following scenarios are considered. The following are the cases which are published in my previous papers [8, 9].

Wind direction is normal to the Panel Plane with 5 and 25 m/s speed for rectangular and optimized panels at ground mounted.

Wind direction is reverse normal to the Panel Plane with 5 and 25 m/s speed for rectangular and optimized panels at ground mounted.

Wind direction is normal to the Panel Plane with 5 and 25 m/s speed for rectangular and optimized panels at roof mounted.

Wind direction is reverse normal to the Panel Plane with 5 and 25 m/s speed for rectangular and optimized panels at roof mounted.

Table.1 Comparing the Drag forces between Rectangular and Hexagonal solar panels at wind velocity 5m/s

Comparing of wind effects on solar Panels mounted at 5 Storey building at Velocity 5m/s				
	Rectangular Solar Panels		**Optimized Hexagonal solar panels**	
Wind Angle	**ϴ=0° (Front Side)**	**ϴ=180° (Back Side)**	**ϴ=0° (Front Side)**	**ϴ=180° (Back Side)**
PANEL NO	**Force F(-Z) N**	**Force F(Z)N**	**Force F(-Z) N**	**Force F(Z)N**
PANEL 1	204.355	106.249	74.641	56.963
PANEL 2	191.083	98.393	80.724	56.921
PANEL 3	183.415	124.031	71.53	57.943

Table.2 Comparing the Drag forces between Rectangular and Hexagonal solar panels at wind velocity 25m/s

Comparing of wind effects on solar Panels mounted at 5 Storey building at Velocity 25m/s				
	Rectangular Solar Panels		**Optimized Hexagonal solar panels**	
Wind Angle	**ϴ=0° (Front Side)**	**ϴ=180° (Back Side)**	**ϴ=0° (Front Side)**	**ϴ=180° (Back Side)**
PANEL NO	**Force F(-Z) N**	**Force F(Z)N**	**Force F(-Z) N**	**Force F(Z)N**
PANEL 1	1048.461	355.516	505.248	280.93
PANEL 2	1307.698	720.88	904.305	502.811
PANEL 3	1137.764	944.868	469.716	307.695

Table.3 Comparing the Lift forces between Rectangular and Hexagonal solar panels at wind velocity 5m/s

Comparing of wind effects on solar Panels mounted at 5 Storey building at Velocity 5m/s				
	Rectangular Solar Panels		**Optimized Hexagonal solar panels**	
Wind Angle	**ϴ=0° (Front Side)**	**ϴ=180° (Back Side)**	**ϴ=0° (Front Side)**	**ϴ=180° (Back Side)**
PANEL NO	**Force F(Y) N**	**Force F(Y)N**	**Force F(Y) N**	**Force F(Y)N**
PANEL 1	412.576	211.943	237.637	174.459
PANEL 2	385.285	196.039	258.404	174.535
PANEL 3	369.217	248.29	229.846	177.834

Table.4 Comparing the Lift forces between Rectangular and Hexagonal solar panels at wind velocity 25m/s

Comparing of wind effects on solar Panels mounted at 5 Storey building at Velocity 25m/s				
	Rectangular Solar Panels		**Optimized Hexagonal solar panels**	
Wind Angle	**ϴ=0° (Front Side)**	**ϴ=180° (Back Side)**	**ϴ=0° (Front Side)**	**ϴ=180° (Back Side)**
PANEL NO	**Force F(Y) N**	**Force F(Y)N**	**Force F(Y) N**	**Force F(Y)N**
PANEL 1	4817.519	906.98	1037.084	648.869
PANEL 2	4517.555	2692.649	895.045	1376.16
PANEL 3	3933.78	865.799	919.814	1891.854

Above tables show the drag and lift forces between the rectangular solar panel and hexagonal solar panels when they are mounted at 5 storey building at velocities 5m/s and 25m/s. At overall glance, the drag and lift forces are less for hexagonal solar panel due to the shape of the panels. From Table.1, drag forces on rectangular solar panel is more than 50% as compared with drag forces on the hexagonal solar panel when the wind flows with 0° to the panels at 5m/s velocity. Furthermore the drag force is more than 50% high in case of rectangular solar panels as compared with hexagonal solar panels when wind flows 180° to the panels at 5m/s. The change of wind speed from 5m/s to 25m/s doesn't affect the outcome (see table2). But the magnitude of the drag force is more in case of wind velocity 25m/s which is almost 5times more as compared with velocity 5m/s. From these we can say that optimized hexagonal solar panels will affect less amount of drag force due to the hexagonal shape of the panels. Due to heavy amount of drag force it can be observed that dislocation and damage of the panels occurred.

From Table.3shows that lift force is more in case of rectangular solar panels as compared with hexagonal solar panels. But in case of the 180° wind flow at 25m/s, lift force is little bit more in hexagonal solar panels which can be observed in the Table.4. This is the unpredicted behavior of the turbulence flow. Overall for the roof mounted solar panels, the drag and lift forces are less in hexagonal as compared with the rectangular solar panels. So, hexagonal solar panels are preferable for households and commercial purpose. Due to low cost, we can use maximum active area of solar radiation exposure and less amount of silicon wafer is wasted. The hexagonal solar panel can be used easily on rooftops of the building for both house using and commercial purpose. The low ratio of perimeter to area reduces the sampling bias and tessellate to form a continuous grid. Also hexagons are preferable when they are connecting the small panels into big panels. Hexagons are also better for capturing the solar radiation duo to large working area and hexagons grid will have less amount of distortion due to the curvature. Hexagonal panels have drag coefficient of 1.83which is less than the drag coefficient of a square 1.92 due to the shape of the plane.

Table.5 Comparing the Drag forces between Rectangular and Hexagonal solar panels at wind velocity 5m/s mounted at ground.

Comparing of wind effects on solar farm mounted at ground at Velocity of 5m/s					
Shape of the panel		**Rectangular Solar Panels**		**Optimized Hexagonal solar panels**	
ROWS	**Wind Angle**	**Ɵ=0° (Front Side)**	**Ɵ=180° (Back Side)**	**Ɵ=0° (Front Side)**	**Ɵ=180° (Back Side)**
	PANEL NO	**Force F(-Z) N**	**Force F(Z) N**	**Force F(-Z) N**	**Force F(Z)N**
ROW-1	PANEL 1	180.34	176.5408	57.73	46.33
	PANEL 2	182.17	171.9558	59.27	52.03
	PANEL 3	179.67	174.2058	58.59	53.35
	PANEL 4	182.57	174.6558	56.86	53.49
	PANEL 5	181.24	174.0558	60.48	53.5
	PANEL 6	181.37	175.7308	58.97	52.68
	PANEL 7	181.72	175.2692	58.47	46.12
ROW-2	PANEL 8	181.57	175.3442	22.12	38.45
	PANEL 9	181.86	178.1992	23.42	47.02
	PANEL 10	181.72	178.2692	23.68	47.69
	PANEL 11	181.26	178.4992	23.14	47.26
	PANEL 12	183.42	178.9192	23.95	48.12
	PANEL 13	188.82	176.2192	23.78	46.43
	PANEL 14	180.71	180.2742	22.95	39.05
ROW-3	PANEL 15	179.83	180.7142	21.35	27.49
	PANEL 16	182.44	180.9092	20.33	31.11
	PANEL 17	180.42	181.9192	21.1	31.89
	PANEL 18	178.53	182.8642	21.4	32.87
	PANEL 19	179.29	182.4842	20.19	32.99
	PANEL 20	178.53	182.8642	21.28	28.42

	PANEL 21	180.41	183.4242	21.28	28.42
ROW-4	PANEL 22	173.44	186.9092	20.96	55.6
	PANEL 23	176.43	185.4142	21.59	57.35
	PANEL 24	176.36	185.4492	21.87	57.29
	PANEL 25	176.16	185.5492	21.58	56.82
	PANEL 26	176.73	186.7642	20.74	56.57
	PANEL 27	175.86	187.1992	21.32	57.18
	PANEL 28	176.38	186.9392	21.5	55.61

Table.6 Comparing the Drag forces between Rectangular and Hexagonal solar panels at wind velocity 25m/s mounted at ground

Comparing of wind effects on solar farm mounted at ground at Velocity of 25m/s					
Shape of the panel		**Rectangular Solar Panels**		**Optimized Hexagonal solar panels**	
ROWS	**Wind Angle**	**ϴ=0° (Front Side)**	**ϴ=180° (Back Side)**	**ϴ=0° (Front Side)**	**ϴ=180° (Back Side)**
	PANEL NO	**Force F(-Z) N**	**Force F(Z) N**	**Force F(-Z) N**	**Force F(Z)N**
ROW-1	PANEL 1	2151.7	1241.45	1445.62	473.725
	PANEL 2	2092.88	1265.63	1479.42	530.815
	PANEL 3	2205.83	1223.93	1434.23	455.965
	PANEL 4	2170.74	1252.8	1431.33	473.4
	PANEL 5	2080.44	1240.4	1508.07	462.2
	PANEL 6	2147.52	1246.39	1464.62	487.195
	PANEL 7	2145.79	1256.22	1460.66	490.11
ROW-2	PANEL 8	1137.92	1131.27	547.23	409.635
	PANEL 9	1183.56	1034.92	576.83	334.46
	PANEL 10	1100.00	1056.62	571.62	1184.23
	PANEL 11	1222.66	1105.45	572.47	1174.54
	PANEL 12	1156.16	1090.02	591.85	1188.53
	PANEL 13	1220.54	1091.31	579.86	1153.46
	PANEL 14	1209.21	1052.99	567.55	963.42
ROW-3	PANEL 15	1189.67	914.7	526.35	675.15
	PANEL 16	1214.3	907.45	493.62	766.46
	PANEL 17	1158.3	899.13	514.42	793.23
	PANEL 18	1173.99	941.01	524.67	815.78
	PANEL 19	1207.59	869.18	496.94	810.27
	PANEL 20	1150.35	882.12	522.16	698.81
	PANEL 21	1190.51	972.86	522.16	698.81
ROW-4	PANEL 22	1020.93	2043.24	512.3	1386.63
	PANEL 23	1100.19	2097.22	523.16	1430.75
	PANEL 24	1090.38	2066.68	546.59	1431.64
	PANEL 25	1070.18	2035.38	531.33	1416.71
	PANEL 26	1150.17	2139.29	512.65	1412.66
	PANEL 27	1100.54	2065.4	527.74	1422.64
	PANEL 28	1080.96	2065.16	530.07	1393.46

Table.7 Comparing the Lift forces between Rectangular and Hexagonal solar panels at wind velocity 5m/s mounted at ground

Comparing of wind effects on solar farm mounted at ground at Velocity 5m/s					
Shape of the panel		**Rectangular Solar Panels**		**Optimized Hexagonal solar panels**	
ROWS	**Wind Angle**	**Ө=0° (Front Side)**	**Ө=180° (Back Side)**	**Ө=0° (Front Side)**	**Ө=180° (Back Side)**
	PANEL NO	**Force F(Y) N**	**Force F(Y) N**	**Force F(Y) N**	**Force F(Y)N**
ROW-1	PANEL 1	551.29	555.927	173.54	138.53
	PANEL 2	557.71	555.67	178.89	159.64
	PANEL 3	551.68	551.02	176.25	163.19
	PANEL 4	557.31	557.54	170.94	163.86
	PANEL 5	552.79	552.38	182.64	163.77
	PANEL 6	556.13	555.98	176.74	160.94
	PANEL 7	555.09	556.21	176.18	137.54
ROW-2	PANEL 8	555.7	555.86	58.94	113.92
	PANEL 9	556.54	556.72	62.89	143.31
	PANEL 10	556.1	556.08	64.29	145.77
	PANEL 11	555	554.86	62.98	144.46
	PANEL 12	561.58	561.52	64.85	147.38
	PANEL 13	559.99	559.81	64.56	141.36
	PANEL 14	553.25	553.73	61.63	115.3
ROW-3	PANEL 15	550.71	550.4	57.21	77.15
	PANEL 16	558.33	558.5	54.89	90.18
	PANEL 17	556.42	556.41	57.19	92.91
	PANEL 18	544.66	544.53	58.37	95.56
	PANEL 19	548.5	549	54.78	96.01
	PANEL 20	545.39	546	56.11	95.38
	PANEL 21	552.13	552	57.29	80.35
ROW-4	PANEL 22	536.17	536	56.24	171.03
	PANEL 23	539.91	540	59.06	177.38
	PANEL 24	545.75	546	59.88	176.39
	PANEL 25	539.25	539	58.98	175.03
	PANEL 26	541.95	542	56.31	174.52
	PANEL 27	539.45	539	58.02	175.63
	PANEL 28	539.96	540	57.45	171.04

Table.8 Comparing the Lift forces between Rectangular and Hexagonal solar panels at wind velocity 25m/s mounted at ground

Comparing of wind effects on solar farm mounted at ground at Velocity 25m/s					
Shape of the panel		**Rectangular Solar Panels**		**Optimized Hexagonal solar panels**	
ROWS	**Wind Angle**	**Ө=0° (Front Side)**	**Ө=180° (Back Side)**	**Ө=0° (Front Side)**	**Ө=180° (Back Side)**

	PANEL NO	Force F(Y) N	Force F(Y) N	Force F(Y) N	Force F(Y)N
ROW-1	PANEL 1	6555.39	3731.56	4370.18	3433.92
	PANEL 2	6378.60	3794.7	4480.54	3977.03
	PANEL 3	6662.22	3658.96	4300.25	4065.00
	PANEL 4	6592.41	3733.14	4310.16	4074.75
	PANEL 5	6386.31	3718.69	4570.47	4074.37
	PANEL 6	6468.91	3716.81	4400.64	4010.83
	PANEL 7	6358.52	3768.66	4410.72	3421.63
ROW-2	PANEL 8	3405.12	3383.26	1470.31	2823.71
	PANEL 9	3539.01	3089.72	1550.39	3566.30
	PANEL 10	3224.07	3119.11	1560.29	3639.81
	PANEL 11	3661.71	3302.57	1520.41	3610.66
	PANEL 12	3460.39	3265.81	1610.07	3658.00
	PANEL 13	3620.80	3243.09	1580.91	3532.51
	PANEL 14	3578.53	3127.6	1530.78	2864.02
ROW-3	PANEL 15	3549.41	2742.35	1420.06	1912.43
	PANEL 16	3547.94	2724.02	1340.59	2238.60
	PANEL 17	3509.77	2705.41	1410.14	2329.48
	PANEL 18	3446.03	2817.74	1440.06	2391.00
	PANEL 19	3605.53	2602.59	1360.15	2379.8
	PANEL 20	3417.22	2642.39	1390.05	2315.62
	PANEL 21	3545.22	2925.33	1420.74	1994.85
ROW-4	PANEL 22	3068.8	6210.82	1380.66	4277.63
	PANEL 23	3273.29	6415.11	1440.21	4435.55
	PANEL 24	3310.28	6267.61	1510.58	4417.85
	PANEL 25	3197.51	6220.87	1470.94	4375.21
	PANEL 26	3402.20	6473.71	1400.32	4317.69
	PANEL 27	3269.66	6255.42	1450.16	4386.89
	PANEL 28	3225.86	6316.42	1430.92	4289.59

Here we are comparing the drag and lift forces for ground mounted rectangular and hexagonal solar panels at velocities 5m/s and 25m/s. Optimized solar panels are the futuristic panels with respect to efficiency and with standing for the wind at all locations. The above tables clearly say that hexagonal panels are the best panels compared with the rectangular panel.

Conclusion

By using Computational Fluid Dynamics, the present work examines the effects of the wind loads on the Solar panels. Multiple scenarios are simulated to evaluate the forces on the behavior of loads on ground mounted solar farms and roof mounted solar panels. A 28 panel array of ground mounted solar farm is simulated for the conditions of 5 and 25 m/s speeds from front and behind. Data obtained shows that in the ground mounted scenario for 5m/s & 25m/s, maximum forces occurred from panel 1 to panel 7 on front face of the solar panel. Based on the results obtained, it is noted that for traditional shaped solar panels the pressure distribution on the front face of the solar panels is very high. Thus there is a need to design optimized solar panel shape. An array of 28 panels is simulated in full scale conditions. The forces are reduced on this model when compared with the traditional model at maximum velocity. The maximum force occurred on panel 1 to panel 7 for traditional model is 6500 N and the forces occurred on the optimized solar panel is 4100 N in case of 25 m/s speed when the direction of wind is normal to the panel. It is recommended that for rigorous flow scenarios, the optimized solar panel design is adequately suitable in cyclone prone areas and shore regions.. A 3 Panel array of roof mounted solar panel is simulated considering active roof concept. For 5 m/s and 25 m/s front and behind flow is simulated. For 25 m/s the maximum load is occurring on Panel 1 with 1100N force for traditional solar panels and a force of 925N is occurring on Panel 2 for optimized solar Panel. Observation of the behavior of loads on roof mounted solar panels with traditional and optimized panel design is also recommended. This scenario is considered to investigate the suitability of optimized solar panel in urban environment.

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