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Using Design of Experiments Approach to analysis Factors Effecting on the PV Cells

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ABSTRACT

Many factors affect the performance of a PV module. In this experiment, we will use the factorial experimental design method to investigate these factors. Several factors are studied in this experiment such as phase change martial type, PCM-thickness, fin length thickness, fin count and the wind speed. A factorial design is often used by scientists wishing to understand the effect of two or more independent variables upon a single dependent variable so applying factorial design in PV parameters will give us the most significant parameter on the temperature of the cells. The statistical results showed that the most significant factors affected on the temperature of the cells are PCM-thickness and wind speed.

KEYWORDS: *PV cells; Performance; DOE; Wind speed; Fin*

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INTRODUCTION

Energy has appeared as a critical economic issue and the top priority for all countries. Unsustainable energy supply and high demand have serious impacts on everything from household budgets to international relations, Due to this fact world must find alternative energy recourses to cover world consumption such as renewable energy sources like solar energy. The sun is the mother of all the energy resources which has a great potential, the proportion of the sun's rays which reaches the earth's surface is more than enough to provide for 10,000 times more than the current global energy consumption.

A solar cell or photovoltaic cell is a device which generates electricity directly from visible light. But the main issue is the efficiency is low, So, the solar cell costs expensive according to other energy resources products. Several factors affect solar cell efficiency. [1]Photovoltaic (PV) modules are one of the most effective, sustainable, and ecofriendly systems. Only a small portion of solar irradiation incident to these modules is converted into electricity. The rest of the irradiation is converted into heat, which overheats the PV module and reduces its performance, there are Several factors affect solar cell efficiency, these effects are cell temperature, MPPT (maximum power point tracking), Dust effect and energy conversion efficiency. The changing of these factors improves solar cell efficiency for more reliable applications [2]

Silicon is the most semiconductor material used as it forms the basis for an integrated circuit (IC). Is the most mature technology hence most PV cells are also silicon-based in the tow martial available type of PV cells mainly mono-crystalline and poly-crystalline. The process of direct conversion is carried out in a variety of solar cells. The efficiency of the conversion of solar energy into electric energy is strongly dependent on the type of solar cell and operating conditions. PV cells convert a certain wavelength of the incoming irradiation that contributes to the direct conversion of light into electricity, while the rest is dissipated as heat. Only 15-20% of incident solar energy is converted into electricity. The remaining part of the solar energy is converted into heat, which causes heating of the solar cells in PV panels. The surface of the PV panel can be heated up to 40 C^o above ambient temperature.

Literature review

Dincer and Meral (2011) they reviewed almost all factors affecting efficiency of PV panels Firstly, an overview of the PV cells/panels and PV electricity generation systems are presented. Then, the effects of PV cell technology and ambient conditions are described. The selection criterion of required equipment such as battery and power electronic controllers also presented. Power quality requirements for the grid-connected systems are also mentioned[3].

Fardila et al. (2016) have recently shown that there are many alterable and unalterable factors that can govern a PV module's efficiency. Dust is one of the location-dependent environmental factors that falls under the unalterable factors group. It can degrade the efficiency of a PV panel by

causing physical damages, by attenuating the incoming solar radiation and by causing temperature rise, which results in changes in panel's electrical characteristics. Degree of degradation depends mainly on the deposition density, which is governed by various factors. Dust accumulation of 20 g/m2 on a PV panel reduces short circuit current, open circuit voltage and efficiency by 15–21%, 2–6% and 15–35% respectively. This work reviews, elaborates and summarizes the effects of dust on solar panel efficiency and the factors governing dust deposition on PV panel[4].

Stropnik and Stritih (2016) they present how to increase electrical efficiency and power output of photovoltaic (PV) panel with the use of a phase change material (PCM). The focus of the work is in experimental setup and simulation heat extraction from the PV panel with the use of TRNSYS software. A modification of PV panel Canadian Solar CS6P-M was made with a phase change material RT28HC. The actual data of cell temperature of a PV panel with and without PCM were given and compared. A simulation of both PV panels in TRNSYS software was performed, followed by the comparison of results with the simulation and experimental actual data. The experimental results show that the maximum temperature difference on the surface of PV panel without PCM was 35.6 C higher than on a panel with PCM in a period of one day. Referring to experimental results the calculation of the maximum and average increase of electrical efficiency was made for PV-PCM panel with TRNSYS software. Results of simulation show that the electricity production of PV-PCM panel for a city of Ljubljana was higher for 7.3% in a period of one year.[5]

Sohail R. Reddy et al (2015). they summarized various cooling methods and reported results over the last five year, with emphasis on thermal management and efficiency using single phase flow-based cooling techniques. Various air-cooled and water-cooled, including natural and forced convection and immersion techniques, have been discussed. All of the reported methods were compared on their ability to reduce module temperature and increase efficiency. The reviewed results shown that PV system's efficiency and performance in real world could be significant improved by adopting appropriate cooling technologies. It can be seen that a rigorous comparison is extremely difficult due to the irregularity or the different conditions present at testing from different authors. For this reason, it is imperative that a non-dimensional model be developed in the future. Such a model would allow for a fair comparison of various sized PV–T systems at different flow rates and ambient conditions. This will allow for a shorter development time of credible thermal management system for a specific geographical location[6].

Experimental description

This experimental was done under specific condition:

- tow type of phase change material (Paraffin RT20, Salt hydrate CaCl2 6H2O)
- Initial temperature: 55 C°
- Ambient temperature: 40 C°
- Simulation of finite elements for heat transfer process of 2 hours and 45 minutes.
- Finite step: 5 mm
- Finite time interval: 0.01 second
- Total runs: 32 RUNS

Statistical Analysis

Factorial experiment is experiment that investigate the effect of two or more factors or input parameter on the output response of a process. factorial experiment design or simply factorial design is a systematic method for formulating the steps needed to successfully implement a factorial experiment. estimating the effects of various factors on the output of a process with a minimal number of observations is crucial to being able to optimize the output of the process.

In a factorial experiment, the effect of varying the levels of the various factors affecting the process output are investigated. Each complete trial or replication of the experiment considers all the possible combination of the varying levels of this factor. Effective factorial design ensure that the least number of experiments runs are conducted to generate a maximum amount of information about how input variables affect the output of process.

The 2^k design is particularly useful in the early stages of experimental work, when many factors are likely to be investigated. It provides the smallest number of runs for which k factors can be studied in a complete factorial design. Because there are only two levels for each factor, we must assume that the response is approximately linear over the range of the factor levels chosen.[7]

In this study a full factorial design had used to investigate the significance of five factors that are mostly concerned with solar PV cells. one response had analyzed which is temperature of the PV cells. A 2^5full factorial had used in order to specify the most significant factors of the five factors of interest, Table 1 below shows the main parameters of this study.

Table 1: Description of parameters levels.

Parameters	Level 1	Level 2
PCM Type	Paraffin RT20	Salt hydrate CaCl2 6H2O
Fin length	2.5 cm	10 cm
PCM thickness	1.5 cm	3 cm
Fin count	4 fins	16 fins
Wind speed	1 m/s	5 m/s

Results

The results of simulation analysis could discover effect of different factors on the temperature of the PV cells responses. one response has been studied which is temperature of the PV cells. phase change martial type, PCM-thickness, fin length thickness, fin count and the wind speed are considered as variables to understand their influences on the mentioned responses. To be more effective, the simulation results were gained based on the design of experiment approach (DOE). The (DOE) was conducted using a full factorial method to show their direct effects, their interactions, and the optimization design for the system.

from table 2, Which is the Factorial Table it tells us the effect for each factor, and we can also see the different interaction effect between these factors, also in the table we can see the value of P-value. which is represent how much the factor is significant, when the P-Value for the factors is small that's mean that factor is significant.

Figure 1 and Figure 2 show normal plots of the standardized effect for temperature of the PV cells. Furthermore, it illustrates the interactions between factors for each response. In same figure, it is clearly observed that the highly weighted factors which play a key role in cooling PV cells are PCM-thickness, and wind speed, on the high-level values of the studied parameters.

The independent variables (factors) might interact with each other. It happens when the influence of one factor depends on the value of another factor. Figure 3 showed that the interaction effect on temperature of cells. It was clearly noted that (PCM type*PCMthickness), (Fin length*PCMthickness) and (PCM type *Fin length) respectively have the greatest interaction effect between each other.

Table 2: The results of simulation analysis.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	15	198.881	13.259	6654.85	0.000
Linear	5	195.731	39.146	19648.34	0.000
pcm_type	1	4.121	4.121	2068.27	0.000
Fin length	1	17.302	17.302	8684.51	0.000
PCM_thickness	1	1.476	1.476	740.77	0.000
Fin_count	1	0.000	0.000	0.00	1.000
Wind_Speed	1	172.832	172.832	86748.13	0.000
2-Way Interactions	10	3.150	0.315	158.10	0.000
pcm_type*Fin length	1	1.538	1.538	772.00	0.000
pcm_type*PCM_thickness	1	0.035	0.035	17.32	0.001
pcm_type*Fin_count	1	0.000	0.000	0.00	1.000
pcm_type*Wind_Speed	1	0.001	0.001	0.69	0.420
Fin length*PCM_thickness	1	0.532	0.532	266.83	0.000
Fin length*Fin_count	1	0.000	0.000	0.00	1.000
Fin length*Wind_Speed	1	1.044	1.044	523.80	0.000
PCM_thickness*Fin_count	1	0.000	0.000	0.00	1.000
PCM_thickness*Wind_Speed	1	0.001	0.001	0.38	0.544
Fin_count*Wind_Speed	1	0.000	0.000	0.00	1.000
Error	16	0.032	0.002		
Total	31	198.913			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0446356	99.98%	99.97%	99.94%

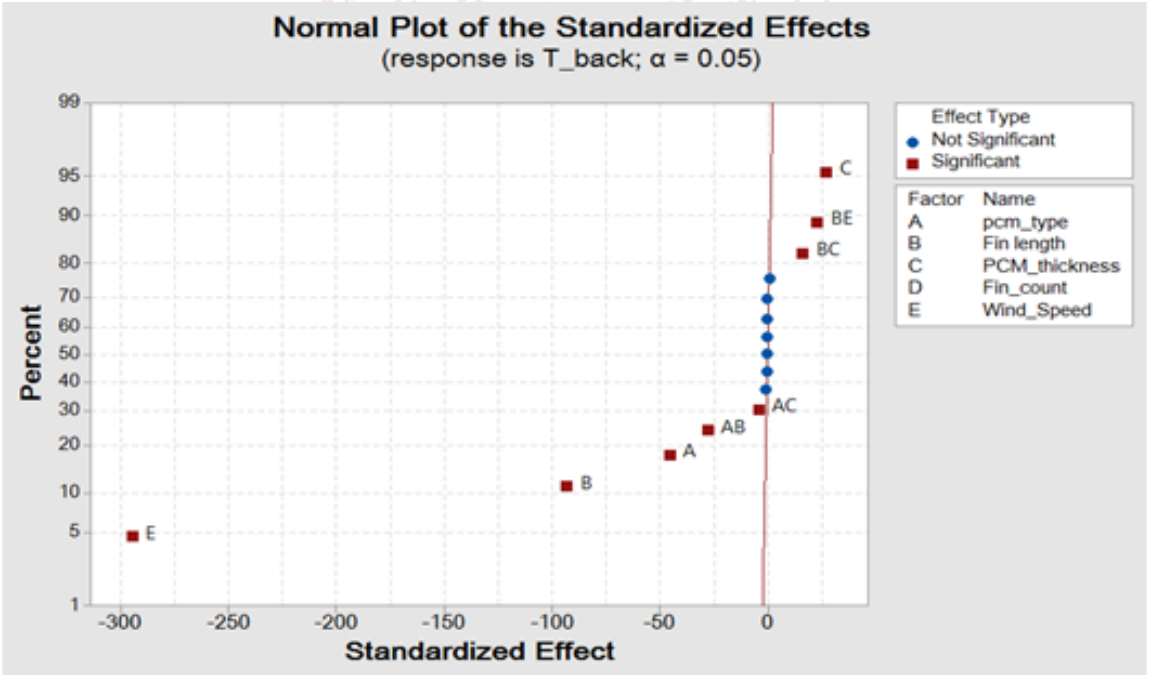

Figure 1: Normal plots of the standardized effects for temperature of the PV cells

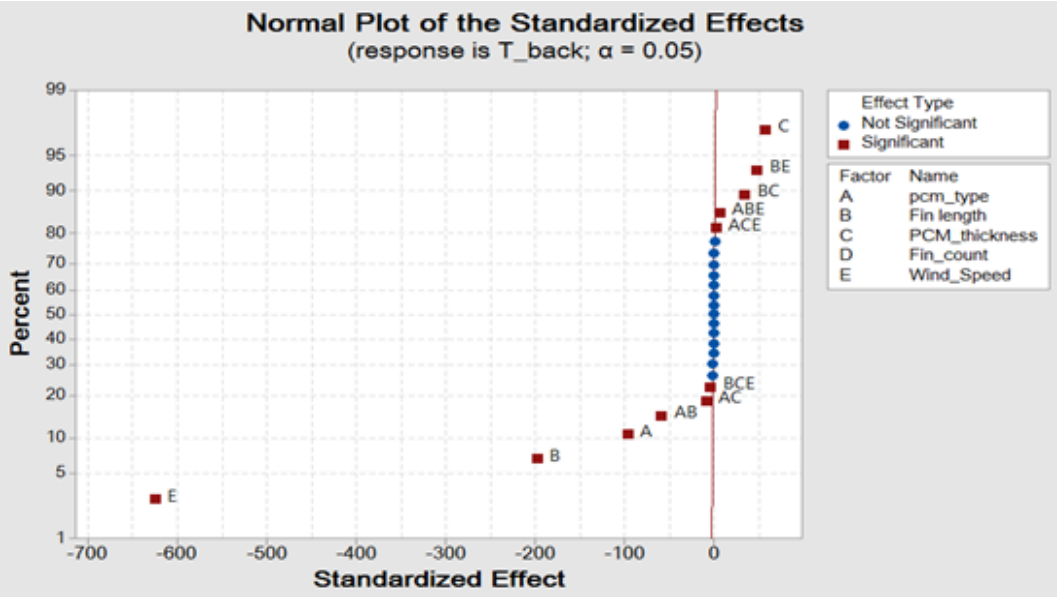

Figure 2. Normal probability plot for Three-way interaction

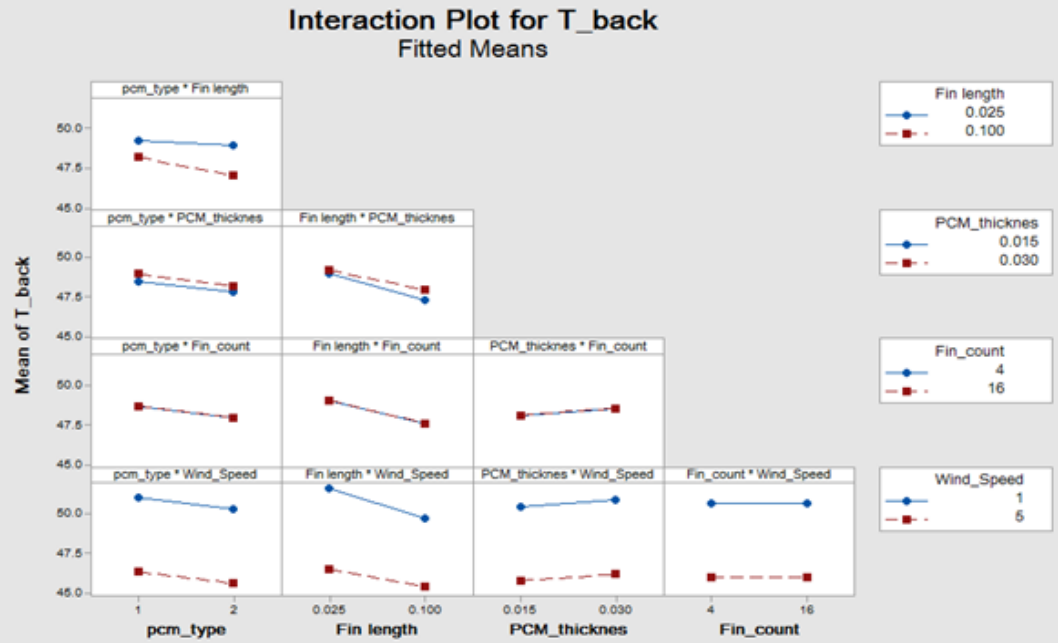

Figure 3.Interaction plot for PV cell temperature

Conclusion

Refer to Minitab output, main effects plot and interaction plot for efficiency the following statements are determined:

- The wind speed has the largest effect on the cell temperature while the Fin length and PCM-type a fewer effect respectively.
- In tow way interaction, there is a small significance compared interaction to the main effects. For example, the PCM-thickness and Fin length interaction was less than the fin length and wind speed interaction.
- Three-way interaction is not significant as shown in Figure 2.

References

[1] Mehrtash, M., Quesada, G., Dutil, Y., & Rousse, D. (2012). Performance evaluation of sun tracking photovoltaic systems in Canada.

[2] Makki, Adham, Siddig Omer, and Hisham Sabir. "Advancements in hybrid photovoltaic systems for enhanced solar cells performance." Renewable and sustainable energy reviews 41 (2015): 658-684.

[3] Meral, Mehmet Emin, and FurkanDincer. "A review of the factors affecting operation and efficiency of photovoltaic based electricity generation systems." Renewable and Sustainable Energy Reviews 15.5 (2011): 2176-2184.

[4] Zaihidee, FardilaMohd, et al. "Dust as an unalterable deteriorative factor affecting PV panel's efficiency: Why and how." Renewable and Sustainable Energy Reviews 65 (2016): 1267-1278.

[5] Stritih, Uroš. "Increasing the efficiency of PV panel with the use of PCM." Renewable Energy 97 (2016): 671-679.

[6] Reddy, Sohail R., Mohammad A. Ebadian, and Cheng-Xian Lin. "A review of PV–T systems: Thermal management and efficiency with single phase cooling." International Journal of Heat and Mass Transfer 91 (2015): 861-871.

[7] (D. C. Montgomery and G. C. Runger, "Applied Statistics and Probabilityfor Engineers", 5 th edition, John Wiley & Sons, pp.571, 2011.)