International Journal of Electronics
and Communication Engineering (IJECE)
ISSN (P): 2278-9901; ISSN (E): 2278-991X
Vol. 5, Issue 6, Oct - Nov 2016; 29-36

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

CLOSED-STRUCTURE MULTISIDED PV SYSTEMS FOR EVENLY DISTRIBUTED IRRADIANCE COLLECTION

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ABSTRACT

Though photovoltaics (PVs) are considered to lead the renewable energy sector, they have a shortcoming of not providing constant level power supply and this where this paper fits in to propose a possible solution. Gaussian-shaped outputs from solar panels are due to the way the available sun light is captured; and this directly depends on the positioning of solar panels. Techniques that have been applied, automated sun-tracking panels, have not been to the level of producing regulated outputs though acknowledgeable for improving output levels. This paper describes and develops a model that consists of making use of prism-shaped PV systems in order to ensure there is a same amount of PV area that faces the during the daytime. Also known as closed-structure- multisided (CSM) approach, it could sound obvious, yet the power dynamics and the accurate figures to quantitatively be determined and all this was deeply elaborated herein. As for the results, a cylindrical-shaped CSM PV system was qualified to provide the same level regulated power average as the average value of a single fixed-tilt PV panel of the same area and material.

KEYWORDS: Battery Charge and Discharge, CSM PV Systems, Multisided PV Approach, PV Regulated Output, Renewable Energy

INTRODUCTION

Background and Rationale

Further to the global move to renewable energy[1], photovoltaic (PV) systems have gained popularity given their ability to comply with both economic and environmental needs. They are thus, deemed to lead the renewable energy sector by year 2030 [2] given investments and research uptakes focussed at PVs[3], [4]. In building power supply, photovoltaics operate together with storage batteries and power regulators before the power is supplied to end-use by loads[5]. However, with techniques being used, one can collect an unevenly irradiance distributed, even with the implementation of deservedly trusted automatic-controlled PV systems that track the sun[6] and this restrains batteries to limited life spans. Backup batteries that normally operate within a defined range have their effectiveness affected by long time charge-discharge cycles and the ideal should be to find a system that can ensure evenly distributed power when the sun is on.

In space engineering, spacecraft should be primarily supplied with a relatively regulated power for the sake of limiting the complexity, reliance on backup batteries and thus of lunch costs calculated per mass. As for batteries, it has been established that deep discharges and overcharges are the main sources of short battery's lifespan and this can result in short space missions[7]. Consequently, for instance, costly NiH_2- based batteries with depth of discharge (DoD) ranging between 40 % and 60 % are to be deployed in a spacecraft built for long lifetime missions (a year and more). On the contrary, NiCd batteries are found suitable to short lifetime missions as a result of their low DoD (10 %-20 %) and of their short lifespan.

The open-structure-multisided (OSM) PV systems another chapter part of the current study, though providing a good average power output, they still lack the quality of supplying constant dc power that would grant less fluctuations in battery charge-discharge cycles and the long life span for the electronics involved in power regulation.

CORRECTIVE APPROACH

The closed-structure-multisided (CSM) PV systems were then thought of as a reliable solution since they can ensure the uniformly distributed irradiance over daytimes. The idea of using them in this research context was inspired from a work related to the study of PV system multisided topologies [8]. The model of topologies was adapted to CSM systems, extensively modelled and explored to suit solar energy-based supply on rooftops for home, industry and spacecraft applications. The CSM systems' performances were measured against the one for a single fixed tilt solar panel of the same surface area and composition. This implies that for a CSM with *n* sides, each side' s area is *n* times smaller than the area of a single fixed tilted solar panel considered as a reference.

In the process of model development, assumptions were also outlined for the purpose of proper and accurate assessment of the functioning of these particular topologies. From sunrise and sunset, the sun's apparent movement plan is perpendicular to the CSM's plan which receives irradiance along the day. The nominal irradiance released by the sun is 1 kW/m^2 and the PV systems' area is 1 m^2, same as for the reference panel.

CSM PV PROFILES

The profiles for CSM PV systems were based on the aforesaid PV topologies' model and the algorithm towards their establishment was developed as to cover a larger number of multisided PV systems than in the study of topologies; thus increasing the expectation of reliable results. The graphs of randomly but strategically topologies were selected and displayed in Figures 1 to 8.

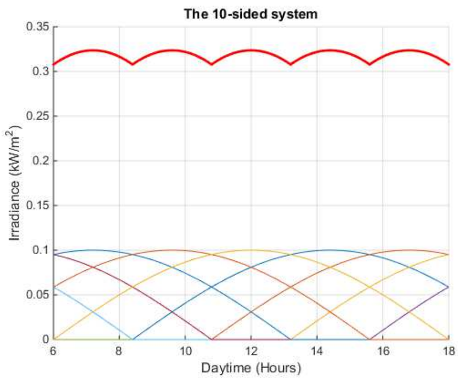

Figure 1: Ten-Sided CSM Irradiance Dynamics

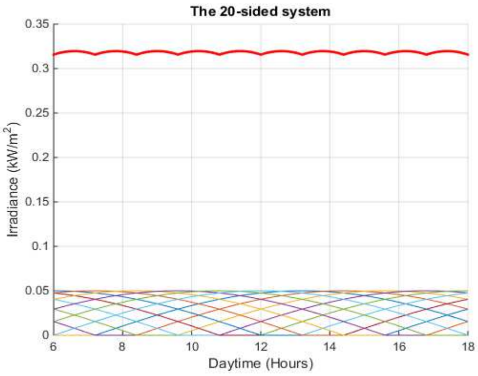

Figure 2: Twenty-Sided CSM Irradiance Dynamics

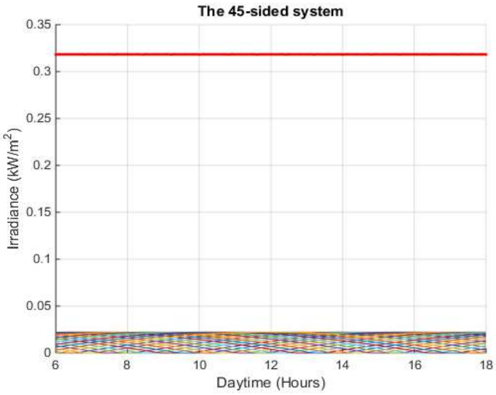

Figure 3: Forty-Five CSM Irradiance Dynamics

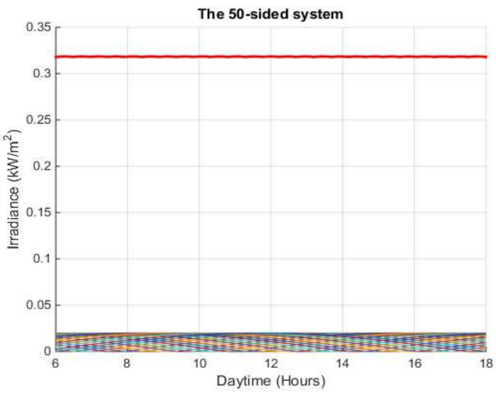

Figure 4: Fifty-Sided CSM Irradiance Dynamics

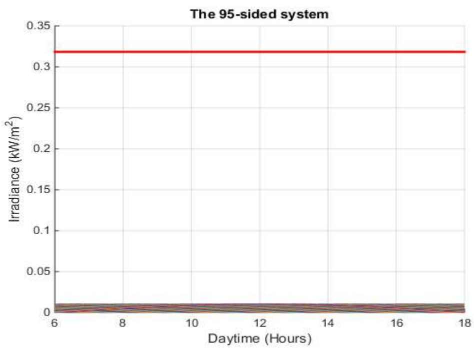

Figure 5: Ninety-Five CSM Irradaince Dynamics

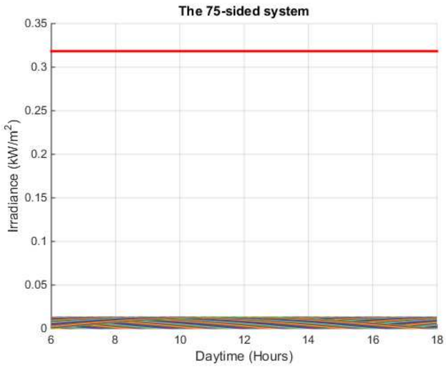

Figure 6: Seventy-Five CSM Irradiance Dynamics

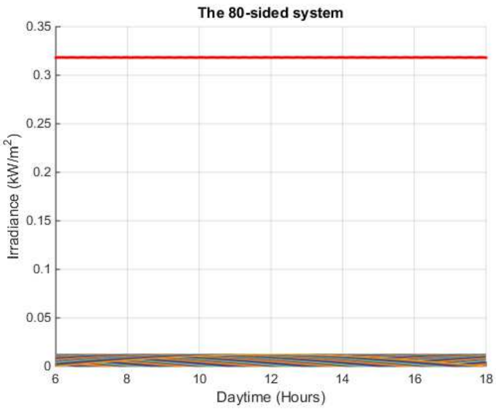

Figure 7: Eighty-Sided CSM Irradiance Dynamics

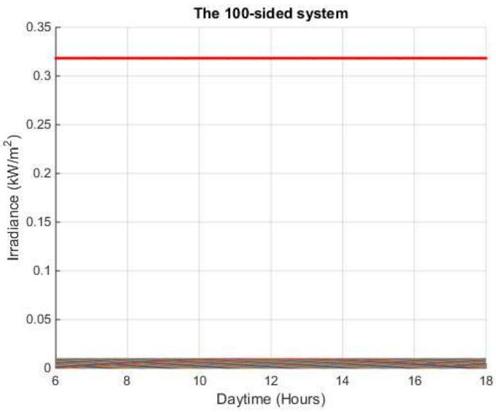

Figure 8: Hundred-Sided CSM Irradiance Dynamics

OBSERVATION

In general, the irradiance distribution over a daytime becomes constant and settles at an average value of 0.318 as the number of sides increase. This is further illustrated having a look at figures of strategically selected parameters including the average, the minima, the maxima and ripple values of the irradiance represented in Table 1 ; results that are graphically represented in Figures 9 to 13.

Table 1: Results Summary

Type	Max(Kw/M^2)	Min(Kw/M^2)	Average(Kw/M^2)	Ripple(Kw/M^2)	Ratio
One	1	0	0,31818	1	1
Two	0,5	0	0,3157	0,25	0,992206
Three	0,3333	0,2887	0,318	0,0223	1,007285
Four	0,3537	0,25	0,3177	0,0518	0,999057
Five	0,3236	0,3078	0,3182	0,0079	1,001574
Six	0,3333	0,2887	0,318	0,0223	0,999371
Seven	0,321	0,3129	0,3183	0,004	1,000943
Eight	0,3266	0,3018	0,3182	0,0124	0,999686
Nine	0,3199	0,3151	0,3183	0,0024	1,000314
Ten	0,3236	0,3078	0,3182	0,0079	0,999686
Fifteen	0,3189	0,3171	0,3183	0,0009	1,000314
Twenty	0,3196	0,3157	0,3183	0,002	1
Fourty-five	0,3184	0,3182	0,3183	0,000096	1
Fifty	0,3185	0,3179	0,3183	0,00031	1
Ninety-five	0,3183	0,3183	0,3183	0,00002	1
Hundred	0,3184	0,3182	0,3183	0,00008	1

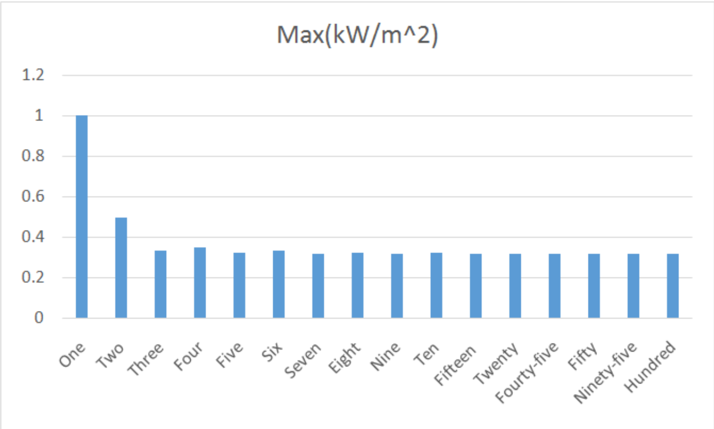

Figure 9: Comparison of Maxima Irradiance

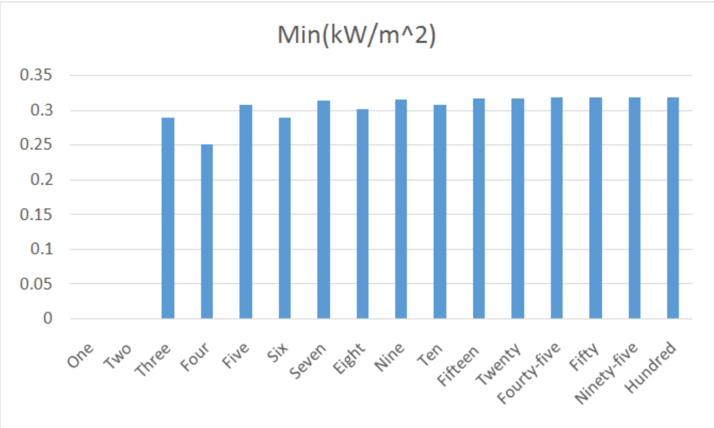

Figure 10: Comparison of Irradiance Minima Values

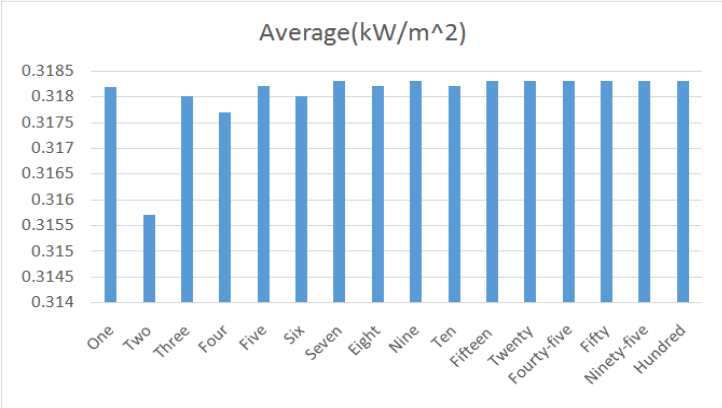

Figure 11: Comparison of Irradiance Average Values

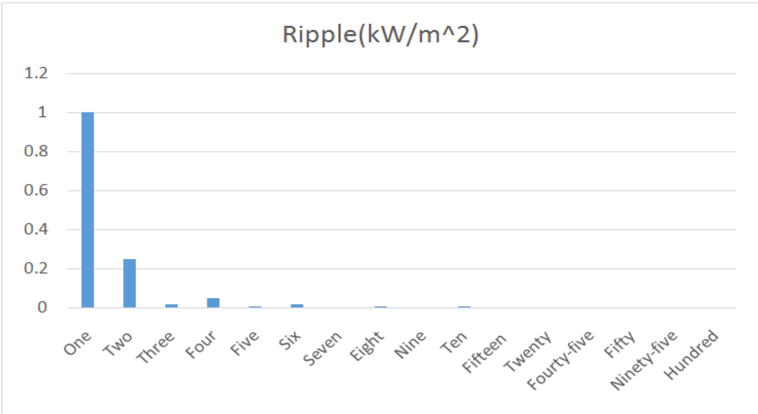

Figure 12: Comparison of Irradiance Ripple Values

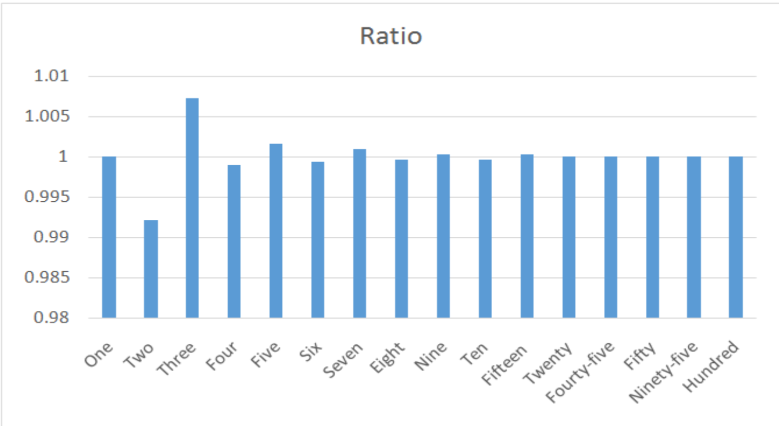

Figure 13: Comparison of Ratio (CSM/Fixed Tilt Panel)

CONCLUSIONS

A broad observation on the table 1 and comparison graphs lead to a conclusion that CSM PV systems have a better irradiance distribution as compared to the single-sided and fixed-tilt solar panel. As the number of sides increases, the CSM PV systems provide a more and more smoother irradiance of which the level equals the average of the single-sided PV systems of the same area. By deduction, this output is expected to be perfectly constant for cylindrical-shaped systems. With no fluctuations between minima and maxima values and with a ratio of 1 –with respect to the reference average irradiance, CSM PV systems are believed to guarantee that the output systems' electrical will in turn be constant. Looking closely to the number of sides, it is shown that systems with an odd number sides produce smoother irradiance distributions than systems with an even number of sides. A three-sided system has less ripple than the four sided and it remains so for the five and the six-sided, the seven and the eight-sided, the nine and the ten-sided systems. As for the efficient utilisation of sides, irrespective of the irradiance dynamics evenness, three-sided CSM systems, simple in design, are best candidates.

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AUTHOR'S DETAILS

Janvier Kamanzi holds BTECH and MTECH degrees in Electrical, Electronic and Computer Engineering respectively obtained in 2012 1nd 2014 at the Cape Peninsula University of Technology (CPUT), Cape Town, South Africa. He is currently studying towards a research-based D Eng specializing in renewable energy with focus on Photovoltaics' efficiency.

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