On Determination of Parameters Dynamic Resistances of Photovoltaic Panels under the Shading Effects

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ABSTRACT

The paper proposes studies the determination of parameters dynamic resistances of photovoltaic panels under the shading effects. We are calculated series resistance, shunt resistance as well as dynamic resistance of photovoltaic panels by technique single I-V curve method under shading in style in full cells, the half cells and one fourth of cell. The find the effects shading in style of mono-crystalline, poly- crystalline and amorphous silicon modules.

The experiments we are used to photovoltaic panels non-commercial and commercial and measured I-V Curves under dark condition and illumination. The compression parameters of series resistance, shunt resistance and dynamic resistance.

The results as show as we are used photovoltaic panels non- commercial and without bypass diode. The parameters of series resistance, shunt resistance and dynamic resistance unequal when the shading condition in style in full cells, the half cells until one fourth of cell. As a result of current-voltage and power output different a significant. On the other hand, we are used photovoltaic panels commercial without or included bypass diode. As a result of current-voltage and power output nearly under shading in style. Also we are important parameters in solar cells before the assembly photovoltaic panel because it a very impact power output and efficient of photovoltaic panels.

Keyword: Shading effects, Photovoltaic panels, parameters dynamic resistances

1. INTRODUCTION

At present, the 10-year Alternative Energy Development Plan (AEDP 2012-2021) is set in Thailand as a goal to promote the alternative energy usage to 25% of the domestic final energy consumption within 2021[1]. Therefore, the usage of solar energy is supported by the AEDP policy and Provincial Electricity Authority has been regulated to purchase electricity from the projects of Community Solar Farms and Solar PV Rooftop since 2013. The total installed capacity is 1,000 MWp including 800 MWp power generation from solar farms, 100 MWp installed capacity in houses, 100 MWp installed capacity in business and factories. As a result, the study of factors affecting capacity of solar power generation is needed. This research is aimed at studying the relation of current, voltage and electric power which are reduced from hard shading and soft shading of single crystalline solar cells, poly crystalline solar cells, and thin film solar film in proportion to the growing shading area of both commercial and non-commercial solar cells. The objective of the study is to find the relation of the internal parameter of solar cells and electric current, voltage and power.

2. Related theories and principles

2.1 Electric and solar equivalent circuits

The structures and parts of solar equivalent circuits can be illustrated with electric circuits. There are many models to show the specification of solar cells. Single Diode Model is a simple model to describe the features and parameters of the systems, including power supply, parallel resistance (R_{sh}) and series resistance (R_s) [2] and when the electric equivalent circuit of each cell is connected in series to become a module, the electric equivalent can be drawn as shown in Figure 1.

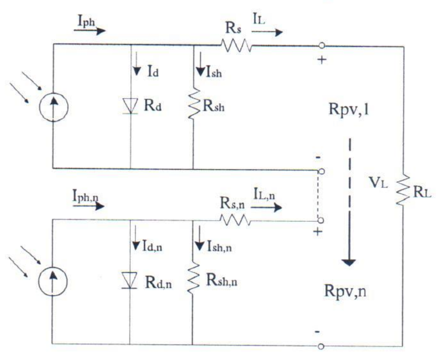


Fig.1 equivalent circuits of module

The total photon current module can be written as in the equation 1.

$$I_{ph,T} = I_{ph,1} + I_{ph,2} + ... + I_{ph,n} \quad (1)$$

When n is the number of cells, the total internal resistive $\left(R_{pv,T}\right)$ can be written as in the equations 2-4.

$$R_{pv,T} = R_{pv,1} + R_{pv,2} + ... + R_{pv,n} \quad (2)$$

Whereas

$$R_{pv,n} = \frac{R_{L,n}.R_{p,n}}{\left(R_{s,n} + R_{L,n} + R_{p,n}\right)} \quad ; R_p = \frac{R_d.R_{sh}}{\left(R_d + R_{sh}\right)} \quad (3)$$

The result is

$$R_{pv,T} = \sum_{i=1}^{n} \frac{R_{L,i}.R_{p,i}}{\left(R_{s,i} + R_{L,i} + R_{p,i}\right)} \quad (4)$$

The dynamic resistance R_d is calculated from the relation of the voltage V_{MPP} and current I_{MPP} at a maximum power point.

$$R_d = \frac{V_{MPP}}{I_{Mpp}} \quad (5)$$

An equation for the efficiency of the solar cell can be derived with the MPP-performance P_{MPP}, the cell area A_C,and the irradiance on the solar cell G :

$$\%\eta = \frac{P_{MPP}}{G.A_c} \times 100 \quad (6)$$

2.2 Shading

Ubisse and Sebitosi [3] mention that currents generated by cells are in direct proportion to light absorption of cells. The reduction of light is caused by insufficient sunlight, resulting from partial shading or full shading of cells. The shading reduces the cells' capacity to generate currents. The reduction of current in a cell leads to much reduction of the output stream in a series string. Different shadings depends on the environment. Soft shading occurs nearby buildings, utility poles, or electricity posts. When cells are under soft shading, 10% of rays is absorbed (ray diffraction). Hard shading makes cells unable to absorb either direct light or diffracted light. Hard shading is found when there are bird droppings or stains. Hard shading which makes cells less able or disable to generate currents is called resistive load of cells.

Naracha, Thongpron, and Teerasak [4] studied shading of solar cells. According to the findings, if the internal resistive load in each cell does not equal i.e. $R_{pv,1} \neq R_{pv,2} \neq ... \neq R_{pv,n}$ the total internal impedance load when shading ($Z_{shad,T}$) can happen from 2 cases [3].

Case 1: $R_{shad,T} > R_{pv,T}$ means that power loss was more than 50% of maximum power of solar cells.

Case 2: $R_{shad,T} < R_{pv,T}$ means that power loss was less than 50% of maximum power of solar cells.

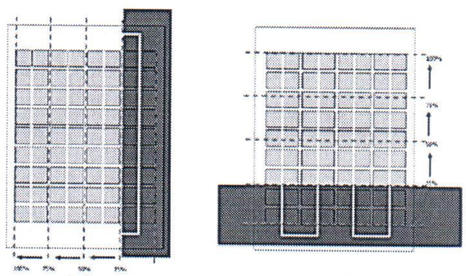
3. Experiment

The experiment was conducted when the temperature was constant and similar , at Rajamangala University of Technology Lanna Tak during September. The solar cells were installed outdoors with glaring sunlight and the irradiance is at least 800 W/m^2. The panels were arrayed on the floors and the shading were tested with single crystalline solar cell, poly crystalline solar cell, and thin film solar cell. The cells in commercial and non-commercial panels were assembled in series array as shown in Table 1.

Table 1. Description of modules under test

Non-commercial silicon solar cell modules			
Module type	Mono-crystalline	Poly-crystalline	Thin film
Manufacturers	Solar power	No name	No name
Cell area (m^2)	0.036	0.153	0.099
Rating	P_{max} = 5 W V_{oc} = 6 V	P_{max} = 20 W V_{oc} = 21.6 V I_{sc} = 1.24 A	P_{max} = 7.7 W V_{oc} = 24.5 V I_{sc} = 0.49 A
commercial silicon solar cell modules			
Module type	Mono-crystalline	Poly-crystalline	Thin film
Manufacturers	Solartron	Gain Solar	sharp
Cell area (m^2)	0.391	0.904	1.341
Rating	P_{max} = 50 W V_{oc} = 21.50 V I_{sc} = 3.25 A	P_{max} = 140 W V_{oc} = 22.3V I_{sc} = 8.3 A	P_{max}= 121 W V_{oc} = 45 V I_{sc} = 2.69 A

In the hard shad testing, black polypropylene board fixed tightly on the solar cell panels to increase 25%, 50% and 75% shading on the vertical and horizontal panel area. In Figure 2, PROVA 210 Solar Module Analyzer was used to measure electric current, voltage and power of the solar cell panels.



(a) (b)

Fig.2 Shading scenarios: (a) vertical, (b) horizontal.

In the soft shad testing, white plastic boards with 3-level transparency of light, 0.3, 0.6, and 0.9 mm thick were fixed at 5 meters above the panels to simulate the shading of clouds or buildings. The different levels of the plastic boards increased more shading 25%, 50%, 75% and 100% at a time of the vertical and horizontal panel area. In Figure 3, PROVA 210 Solar Module Analyzer was used to measure electric current, voltage and power of the solar cell panels.

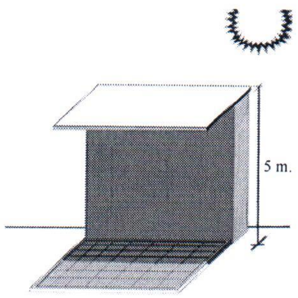


Fig.3 Soft shading scenarios.

The hard shade and soft shade of all commercial and non-commercial panels were tested as illustrated in the test diagram in Figure 4.

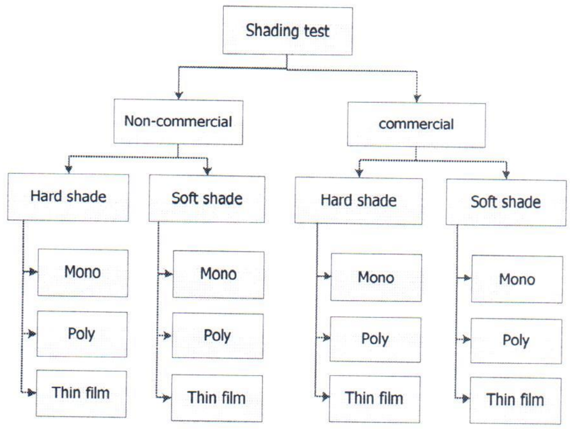


Fig.4 Shading test diagram.

4. Results and discussion

The commercial and non-commercial solar cells panels were experimented on vertical and horizontal shading of the mono crystalline solar cell, poly crystalline solar cell, and thin film solar cell. The Im, Vm and Pm were measured with Solar Analyzer to find Rd and n from the relation of the equations (5) and (6) respectively. The findings are presented in Table 2 and Table 3.

In Table 2 and Table 3, it was found that the dynamic resistance R_d of the hard shade was highly increased where the efficiency η was reduced proportionally and significantly. The reason was that the solar cells were shaded and unable

Table 2. Shading scenarios of non-commercial module

Shading scenarios			Non-commercial					
			Mono-crystalline		Poly-crystalline		Thin film	
			R_d (Ω)	%η	R_d (Ω)	%η	R_d (Ω)	%η
Hard	vertical	No	14.783	10.066	13.210	12.908	42.850	22.222
		25%	94.253	1.843	12.622	12.836	60.719	14.692
		50%	1,482.759	0.085	2,771.267	0.062	87.287	9.647
		75%	3,870.968	0.012	5,391.489	0.024	175.556	4.457
	horizontal	No	14.390	9.176	14.383	14.449	43.046	21.075
		25%	611.290	0.330	2,695.513	0.084	83.700	10.469
		50%	1,501.292	0.077	6,395.122	0.021	80.300	10.068
		75%	2,416.185	0.025	9,128.713	0.008	4,386.581	0.135
Soft Lv.1	vertical	No	14.061	10.747	12.443	13.663	39.281	8.207
		25%	20.818	7.763	15.070	11.622	43.378	7.320
		50%	19.737	7.411	19.238	9.587	49.027	6.438
		75%	19.466	7.063	18.372	9.536	53.268	6.078
		100%	17.863	6.989	20.095	8.497	62.299	5.168
	horizontal	No	14.061	10.747	12.443	13.663	39.281	8.207
		25%	18.905	7.341	21.220	9.614	52.665	6.521
		50%	17.954	6.941	20.378	10.020	47.849	6.850
		75%	19.453	6.494	19.606	8.870	78.018	4.463
		100%	18.674	6.469	19.194	8.546	65.679	4.765

Table 3. Shading scenarios of commercial module

Shading scenarios			commercial					
			Mono-crystalline		Poly-crystalline		Thin film	
			R_d (Ω)	η	R_d (Ω)	η	R_d (Ω)	η
Hard	vertical	No	5.668	13.390	1.846	13.459	15.634	8.548
		25%	940.415	0.102	2,047.337	0.018	19.869	7.777
		50%	2,515.498	0.027	1,710.526	0.012	29.002	4.567
		75%	4,407.143	0.010	2,714.286	0.004	55.068	2.205
	horizontal	No	5.064	12.525	1.862	14.615	15.998	9.662
		25%	1,383.415	0.060	1,147.518	0.029	30.438	4.682
		50%	3,259.615	0.017	2,633.124	0.008	41.168	1.677
		75%	5,930.818	0.005	2,339.950	0.005	17,526.31	0.001
Soft Lv.1	vertical	No	5.181	12.877	1.883	14.723	14.444	10.326
		25%	6.979	10.133	2.488	12.042	14.825	9.741
		50%	6.686	9.910	2.473	12.156	17.142	8.481
		75%	6.533	9.483	3.780	9.395	18.910	7.757
		100%	6.431	8.839	3.303	9.510	17.091	7.828
	horizontal	No	5.181	12.877	1.873	13.893	13.500	10.734
		25%	6.695	10.027	2.645	12.243	15.611	9.182
		50%	6.380	9.873	3.050	11.296	17.194	8.512
		75%	6.742	9.252	2.522	11.606	18.266	8.100
		100%	6.967	8.649	2.586	11.511	17.931	8.005

to generate power supply so they became load. The power was transferred from regular solar cells to loading solar cells. As a result, the total power of the panels was lower and the solar cells might get damaged. Regarding the soft shade, the dynamic resistance R_d was found nearly similar and the efficiency η was not reduced differently. The shaded solar cells were still able to generate electric power. When the thick of soft shade was increased to level 2 and 3, the behaviors of soft shade were still similar to level 1 although the electric power were reduced according to the thick of shading.

In addition, it was observed that the vertical and horizontal arrays of the commercial and non-commercial panels were different. With the bypass diode installation of the commercial solar cell panels, the vertical shading or one string, the current flow in the solar cells were still nearly similar to regular currents because the currents would not flow through the shaded strings. However, the horizontal shading which was partly shading on each string in the solar cells resulted in the total power of the horizontal shading was more than the vertical shading. On the other hand, the non-commercial panels did not have the bypass diode installation, the total power of the vertical and horizontal shading reduced in a similar level.

5. Conclusion

The results of the experiment to determine the parameter dynamic resistance of photovoltaic panels revealed the shading effects. In Community Solar Farm Project or Solar PV Rooftop Project, therefore, the installation of solar panels should be commercial to enable them to generate the electric power effectively. Moreover, the installation should avoid shading behaviours, especially hard shade. If the soft shade such as the shading of buildings or electricity poles cannot be avoided, the vertical array of the panels is a better option for obtaining higher power than the horizontal array.

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