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Analysis of Temperature effects on Photovoltaic Modules: case of the city of Maradi

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Abstract: *The objective of this analysis is to determine the extent of temperature effects on the energy production of photovoltaic modules in the city of MARADI, Niger Republic. The Analysis is based on three main electrical parameters of PV modules' energy production namely maximum power, short circuit current and the open circuit voltage of the photovoltaic modules.*

Key words: *Photovoltaic module, PV open circuit voltage, PV short circuit current, temperature effect of PV*

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I. Introduction

The photovoltaic solar energy results from the direct transformation of a part of the sun rays into electrical energy. This conversion of energy is made by means of a photovoltaic (PV) cell based on a physical phenomenon called photovoltaic effect, which results in producing an electric strength when the surface of this cell is exposed to the light. The generated voltage can vary according to the material used in the manufacturing of the cell [1]. Generally, the PV unit cell produces very low electrical power (of the order of 0.6 - 0.8V PN junction voltage), with regard to the needs of most domestic or industrial applications. Hence, several dozens of unit cells are usually cascaded in order to achieve the nominal voltage of the PV module as well as the power rating. In addition, to increase the operating voltage of the PV system as well as the available power, the modules are connected in series and or parallel.

The modelling of the behavior of a PV cell appeals to the properties of the solar radiation and those of the semiconductors [2]. In the literature, the current-voltage (I/V) characteristics curve is often employed in the performance evaluation of the PV cell. Interestingly, the I/V curve of the PV cell is influenced by various climatic conditions, especially temperature [3]. Thus, although power generation from PV system represents great asset to the countries of the Sahelean region of Africa in view of the ample solar irradiance, this temperature effect on PV modules due to high atmospheric temperature gradient in this region pose a substantial threat to the optimal performance of PV power systems. This could adversely affect access to sustainable power supply to the rural areas and thereby restricting the attainment of the Sustainable Development Goals (SDGs) in these countries. I order to drive solar PV power investments in this region of the world, therefore, adequate information on the performance of the PV system with respect to the environmental conditions of the zone would be a vital resource. This would enhance proper sizing and the choice of the photovoltaic modules to be deployed. This is because, the performance characteristics of PV modules found on data manufacturers' sheets are measured in the Standard Test Conditions (STC) of atmospheric pressure of 1,5 AM, irradiance of 1000 W/m ² at a temperature of 25 °C. These conditions which are artificially created in the laboratory cannot be attainable on real ground environment where modules are installed. So, PV modules are subjected on-site to many factors of degradation caused by climatic and environmental parameters, such as temperature, wind and relative humidity. All these factors of degradation of the PV modules affect the performance of the PV module as well as resulting into economic losses of investment which often turn out to be enormous. It is thus important to know well the impact of these climatic conditions on the degradation of the PV module, so as to allow for the implementation of beneficial PV power plants based on optimal technical and economic evaluation [4].

1.2 PV Cell Technologies

Industrially, semiconductor technologies are the most widely used in the manufacture of PV cells. Among all semiconductors, silicon (Si) is mostly used because of its good properties and natural abundance. According to the labor union of the renewable energies (2013), about 80 % of PV cells in the market today are of silicon. Aside from Si, other semiconductors used are Gallium Arsenide of (GaAs), Cadmium Telluride of

(CdTe) and the Copper-Indium-Disélénium (CIS). The Schematic representation of a unit PV cell is as shown in Figure 1.

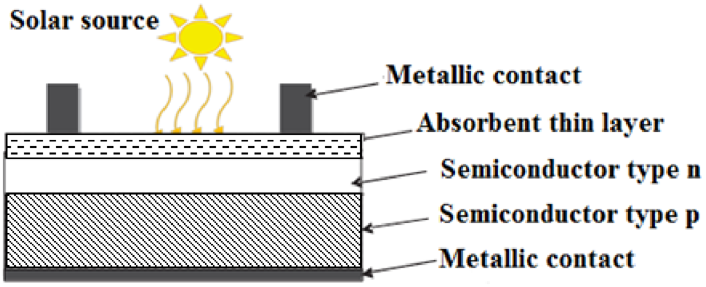

Figure 1: Representation of the structure of a simple photovoltaic cell.

The photovoltaic module is constituted by cells connected in series/parallel mode. The cells(units) are coated with Ethylène-Vinil Acetate (EVA) material. The front panel of the module is generally covered with glass while the back side covered with composite tedlar/alu material and is generally fragile. The frame structure is generally made from aluminum or aluminum anodized with a visserie in stainless material. The Typical range of efficiencies of Mono-crystal Si PV cell is between 18% to 22%, while the Polycrystalline type ranges from 10% to 13%. The amorphous type has the least efficiency range of 5% to 10%.

1.3 Parameters influencing the performances of the PV modules:

The energy production of a PV module is directly related to three main electric parameters namely; the maximum power (P), the short circuit current (Isc) and open circuit voltage (Vco). This energy produced by the PV module depends fundamentally on weather conditions and more particularly the solar irradiance and the ambient temperature. The reduction in output power due to irradiance (low radiations, angular specter) and also the ambient temperature can reach 10 % and 15 % respectively [7,8] . The Figure 2 represents the main parameters influencing the Vco, Isc and P.

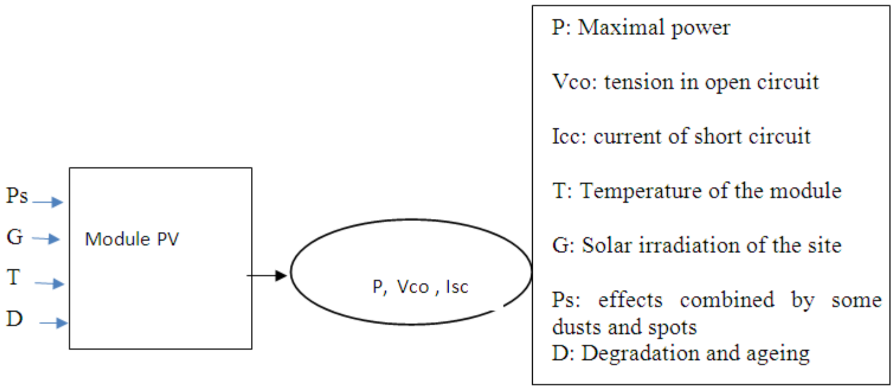

Figure 2: Schematic showing parameters influencing the Vco, Isc and P

The combined effects of dust, by the spot, and even by the possible shades on modules PV will be neglected. Indeed, the studied modules will be considered as subjected to a weekly cleaning; this reduces the impact of the dust and the spots on their performance. Also modules will be considered being installed in height on the roof, they are thus little influenced by the shade of trees. The degradation of modules bound to weather will be also untidy. Because these modules are considered as new and dating less than 10 months what is enough short with regard to the life expectancy of a module PV which is of 25 years to neglect the effect of the ageing of modules on their performances.

1.4 Influence of Irradiance on PV performance

The solar irradiance is the quantity of sun rays received by unit area. Figures 3 and 4 shows the I/V characteristics of the PV module inclined to 25 ° for diverse values of the irradianc4 [9].

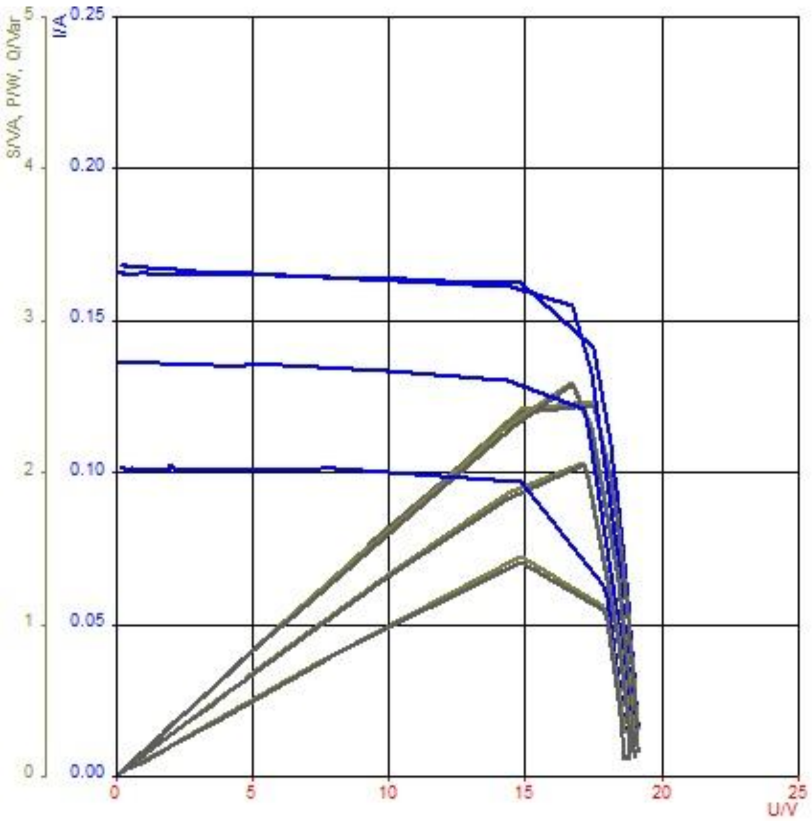

Figure 3: Characteristic (I/V) of a module for various values of the illumination.

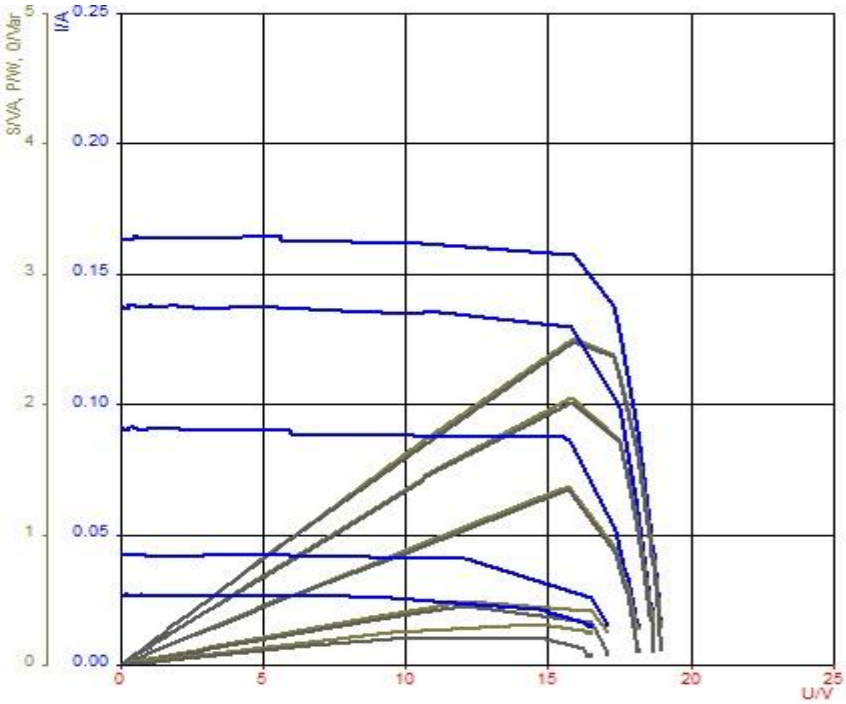

Figure 4: Characteristic (PV) of a module for various values of the illumination

It will be noticed that the light decrease of the tension of the circuit opened further to the decrease of the luminous flux. So we notice that the current is directly proportional in the irradiation at these levels of illumination.

1.5 Influence of Temperature on PV performance:

Ambient Temperature is a very important parameter in the behavior of cells PV. Figure 3 describes the behavior of the module under a fixed illumination of 1W/m^2, and in temperatures between 0°C and 75°C. We noticed that the current increases with the temperature. on the other hand, the Vco decreases, which results in decrease of the available maximal power.

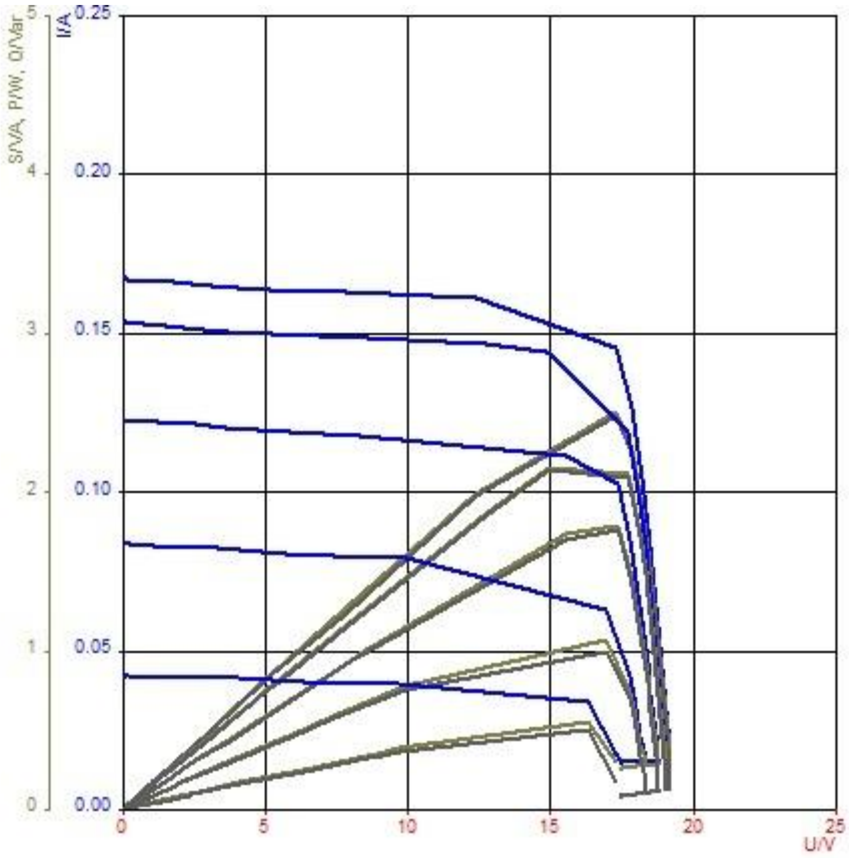

Figure 5: Characteristic(I/V) of a module for various values of temperature, Characteristic (PV) of a module for various values of temperature. [10]

II. Materials and Methods

2.1 Data collection

The temperature of the city of Maradi from 1990 till 1999 were collected as shown in Table 1.
Table 1:

	January	February	Mars	April	May	June	July	August	September	October	November	December	Year
Mini	6,3	6,5	12,7	13	17	17,8	16	17,4	17,5	12	8,4	6	6
Maxi	41	45,5	46,8	47,5	46,6	46	42	36,4	40,5	46	43,5	40	47,5
average	23,65	26	29,75	30,25	31,8	31,9	29	26,9	29	29	25,95	23	26,75

2.2 Simulation:

The simulation program called was employed to simulate the corresponding Isc, Voc and Pmax using the temperature data collected [11]. This program was developed from the coefficients of temperature given in the data sheet of the SILLIA SeT2xxG 230 photovoltaic module used for this analysis as shown in Table 2.

Impact of the temperature of cells:		Values	
Isc		3,92 mA/K	
Voc		-133,3 mV/K	
Pm = Ipm*Vpm		-0,46 % /K	
Temperature of module in °C	Short circuit current Isc(A)	Open circuit tension Voc(V)	Maximal power Pmax(W)
Calculate : 20	7,9236	43,9485	277,61

III. Results and Discussions

3.1 Results

Using the coefficients of temperature of the module given in the data sheet of the photovoltaic module, the values of Icc, Vco and Pmax were simulated from temperature of -20°C to 70°C. the results obtained were as shown in Table 3.

Table 3: results obtained for temperature effects on Icc, Vco and Pmax

Temperature (°C)	**Short Circuit current (A)**	**Open Circuit Voltage (V)**	**Maximal power (W)**
-20	7,92	43,94	277,61
-10	7,9628	42,61	267,03
0	8,002	41,28	256,45
10	8,042	39,94	245,87
25	8,1	37,95	230
30	8,1196	37,28	224,71
35	8,1392	36,617	219,42
40	8,1588	35,95	214,13
45	8,1784	35,28	208,84
50	8,198	34,617	203,55
55	8,2176	33,951	198,26
60	8,2372	33,28	192,95
70	8,2764	31,9515	182,39

The temperature characteristic curve may therefore be presented as shown in Figures 6 to 8.

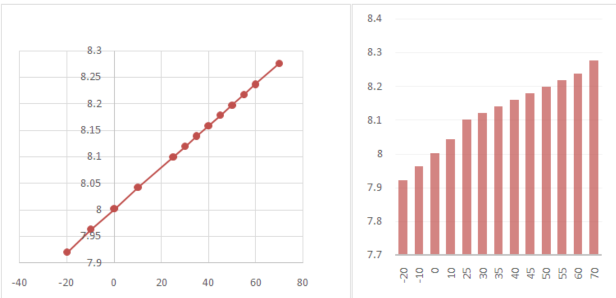

Figure6: Current-temperature Characteristics of the PV module

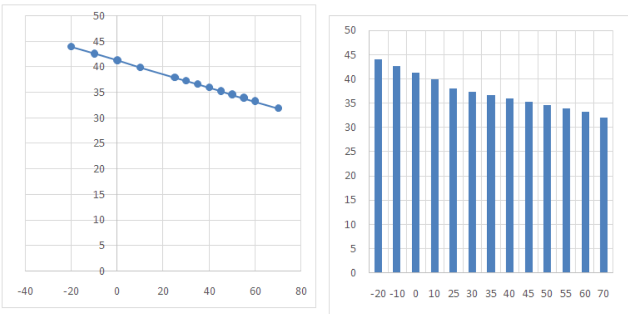

Figure7: Voltage-temperature Characteristics of the PV module

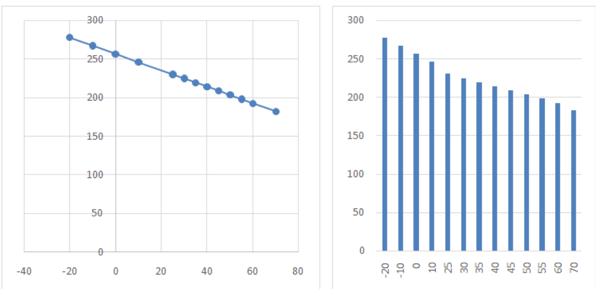

Figure8: Power -temperature Characteristic of the PV module

3.2 Discussion

The characteristics shown in Figures 6, 7 and 8 Show well the variation of the current, the Voltage and the power of the photovoltaic module with respect to temperature change. It could be seen that with the temperature increase, Vco dropped significantly, which also resulted in significant decrease in the available power. For the case of the city of Maradi with the temperature variation from 10, 4 to 47,5°C for the year, the power loss is approximately 37,03W (i.e. 208,84-245,87) for the Silla SeT2XXG 230Wc PV module, This loss is quite significant, especially for a large PV array. In other words an array of 100 PV modules will experience a power drop of 3703W, which could power substantial loads.

IV. Conclusion and Recommendations

This paper presented the effects of temperature variation on the performance of solar PV module in Maradi city of Niger republic. It was shown that the in view of large temperature excursion in of the city, significant power loss of about 37.03W could be experienced between the coldest month and the hottest month of the year.this showed that for large PV array system, the power loss cpould be very significant.

It was thus, recommended that proper sizing and installation of the PV panels should take into consideration this loss so as to ensure proper functioning of the system round the year.

- running of short circuit
- tension in open circuit
- the maximal power

What engenders as consequence the decrease of the efficiency on the module.

It is thus recommended as possible, to install solar panels in an airy place, to avoid the overheating.

Acknowledgement

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