ENTREPRENEURSHIP EDUCATION: AN IMPERATIVE FOR SUSTAINABLE DEVELOPMENT IN NIGERIA

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Abstract
This paper examined the major factors that affect the solar photovoltaic arrays such as neighbouring buildings around, rain, weather conditions, obstacles such as TV antennas, vents, chimneys, trees, power lines, and birds or their litters on the array, etc. The study found that an effect of shadows is degradation in power and this could cause damage on the surface of the solar panel which is called "Hot spot". It was also found that the configurations such as series, parallel and series-parallel of these solar panels under shadow varies when determining the power loss. The power output of the solar panels when there was no shadow and when there was shadow was investigated and it was discovered that shading is a major factor that must be considered when installing a solar photovoltaic array. From the results of the experiment, the study concluded that the series-parallel connection of solar panels is better than other types of connection.
Key words: *Hot spot, Photovoltaic (PV) array, Shadow, Solar.*

Introduction

Owing to Global warming and increasing prizes of fossil fuels, more attention has been drawn towards the usage of renewable energy sources particularly solar energy because of its various advantages (Cole & Skerrett, 1995). Researches have been conducted over the last few decades and the outcomes of those researches have brought about the use of Solar Photovoltaic (PV) panels to generate electricity.

Solar Photovoltaic (PV) panel is a power source having non linear internal resistance and an array which is formed by series-parallel combination of Solar Photovoltaic (PV) modules to attain a desired voltage and current level. A typical analysis considered that a shaded cell retains its original cell characteristics; excepting the diode photocurrent which is dependent on incident illumination. (Herrmann, Wiesner & Waassen, 1997). Later studies according to Quaschning and Hanitsch, (1996a) and Meyer and Dyk (2005) investigated additional changes in the single-cell parameters of a shaded cell such as fill factor and shunt resistance. It is observed that, recent photovoltaic (PV) technology which includes covering buildings rooftops and walls with photovoltaic (PV) arrays causes partial shading on the inter-connected arrays due to shades from clouds, trees and nearby building (Casadei, Grandi & Rossi, 2006).

Studying the shading effect is an interesting exercise. The exercise could however pose some multi-parameter and multi-objective challenges and problems. Nnadi (2012) claims that the shading effects depend on the space between collectors, their dimensions, their types, the tilt angles, the time of the year and day and the latitude. Shade is a natural enemy of solar panels. It reduces performance of the solar panel and if the shade is too much, it could make a system unviable (Ramaprabha & Mathur, 2012).

The effects of shadows may lead to power loss. Ramaprabha and Mathur (2012) posit that the rate of the power loss is dependent on the shadow geometry and the solar array geometry. The power lose also depend on whether series or parallel cells are shadowed; and how many are shadowed. The

shadowing can cause serious problems for the power-conditioning system. One of the effects of shadows is degradation in power and it could cause damage on the surface of the solar panel which is called "Hot spot" (Quaschning & Hanitsch, 1996b).

According to Passias and Kallback (1984), when solar arrays (photovoltaic (PV) or thermal) are arranged in multiple rows of panels, all but the first row suffer a reduction in power output even when the rows are sufficiently spaced. In any solar power system where a number of collectors (photovoltaic or thermal) of different kinds are used to collect solar energy, the shading of collectors by their neighbours would likely occur during some period of the day, especially near sunrise and sunsets (Appelbaum & Bany, 1979).

A major challenge in using a solar Photovoltaic source containing a number of cells in series is how to deal with its non-linear internal resistance. The problem according to Passias and Kallback (1984), gets more complex when the array receives non-uniform insulations. Cells under shade absorb a large amount of electric power generated by the cells that are receiving high insulation and then convert it into heat. This heat may damage the low illuminated cells under certain conditions. To relieve the stress on shaded cells, bypass diodes are added across the modules.

The most obvious effect of a shadow is a reduction in power output from the solar array. The amount of power loss according to Silvestre and Chouder (2007), is a function of the size and shape of the shadow, the geometrical and electrical layout of the cells in the array, and how the shadow falls across the particular solar cell array. The impacts of partial shading on the PV array performance has been widely discussed by Herrmann, Wiesner and Waassen (1997), Kaushika and Gautam, (2003), Klenk, Keller, Weber, Marckmann, Boueke, Nussbaumer, Fath, and Burkhart (2002) and Woyte, Nijs, and Belmans (2003).

Materials and Method

On a solar photovoltaic arrays of four polycrystalline solar panels (each of 80watts and 5amps) tilted at 10° considering the latitude of Nigeria two piece of cardboard papers were placed on one of the modules in such a way that the whole module was shaded completely leaving other modules vulnerable to the sun radiation. These solar photovoltaic arrays were configured using various connections such as Series, Parallel and Series-Parallel connections.

Apparatus Used in this Experiment

The following apparatus were used to perform the experiment on the effect of shading.

1. Battery:
   It is used as the source of power from which a number of connected electric cells were used to produce a direct current through the conversion of chemical energy into electrical energy. Four Sealed lead-acid batteries of 12volts, 7Ah were used.
2. Solar Photovoltaic:
   Solar Photovoltaic panel is used as a source of power with non-linear internal resistance and an array which is formed by series-parallel combination of Solar Photovoltaic modules to attain a desired voltage and current level.
3. Multimetre:
   This was used to in measure the voltage and current generated by the PV modules.
4. Electric Cables:
   These are insulated conductors used to carry electricity from one point to another. Electric cables of low resistance were used as the connectors.
5. Cardboard Paper:
   Used to form an artificial shade (red in colour).

Procedure 1
Solar PV in Series Connection When Shaded:

1. The solar PV modules were connected in series.
2. A piece of card board was then placed on one of the modules in such a way that the whole module was covered.
3. Battery bank (four 12v, 7Ah batteries) was connected together in series.
4. Then, the circuit was connected as shown in Figure 1 and readings were taken for both voltage (V) and current (I) generated.
5. The same experiment was repeated for un-shaded panels.

Figure 1 shows the connection of the solar PV in series configuration. Readings were taken and the results presented in Figure 4.

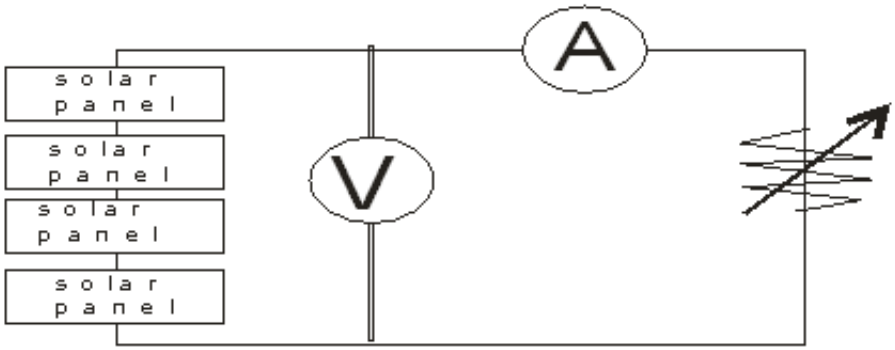

Figure 1: *Series Connection of Solar Panel*

Procedure 2
Solar PV in Parallel Connection When Shaded:

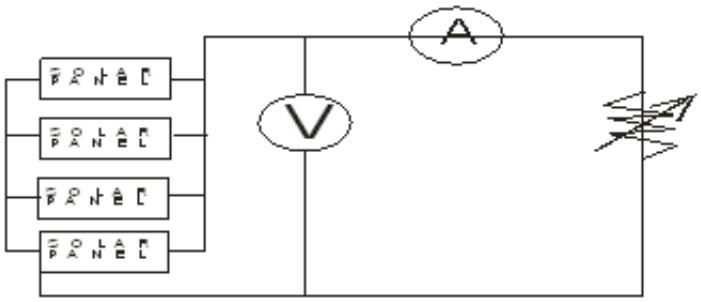

Figure 2: Parallel Connection of Solar Panel

Circuit connection was carried out as shown in Figure 2 and readings were taken for shaded and not shaded solar panels. The results obtained are shown in Figure 5.

Procedure 3
Solar PV in Two Series And Two Parallel Connections When Shaded:

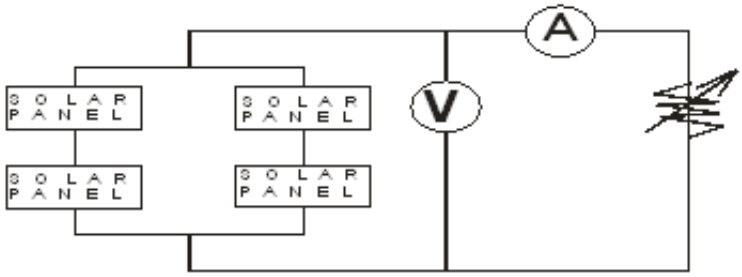

Figure 3: Series-Parallel connection of solar panel

Circuit connection was carried out as shown in Figure 3 and readings were taken for shaded and not shaded solar panels. The results obtained are given in Figure 6.

Results and Discussion

The following results were gotten from the experiment on shading effect on solar PV which was carried out in the month of October.

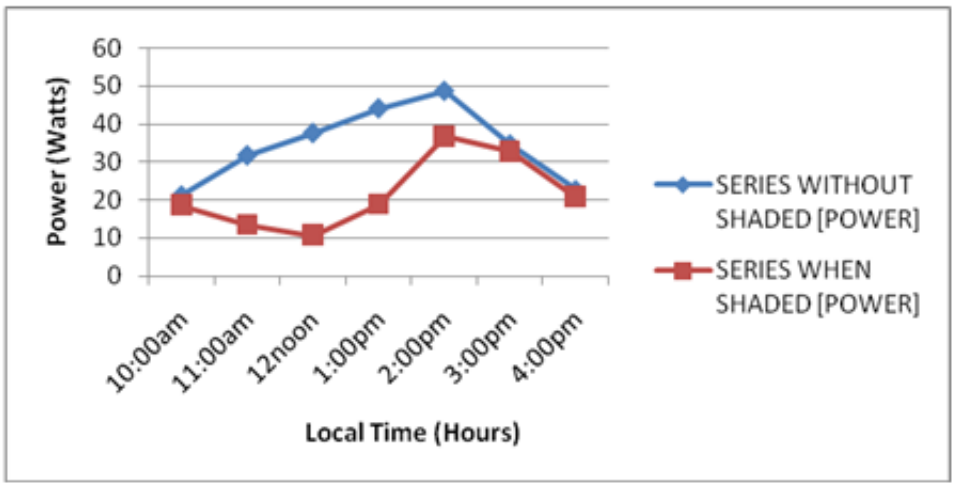

Figure 4: Graph of Power output at various time for series connection

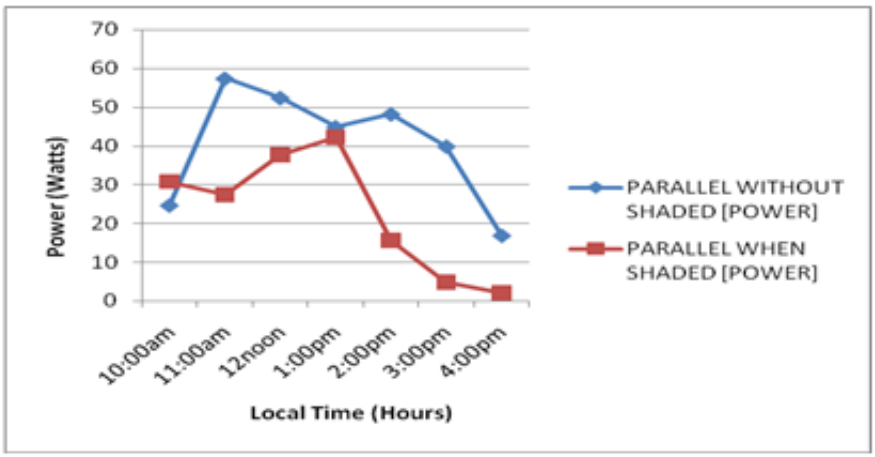

***Figure 5:*Graph of Power against time in parallel connection**

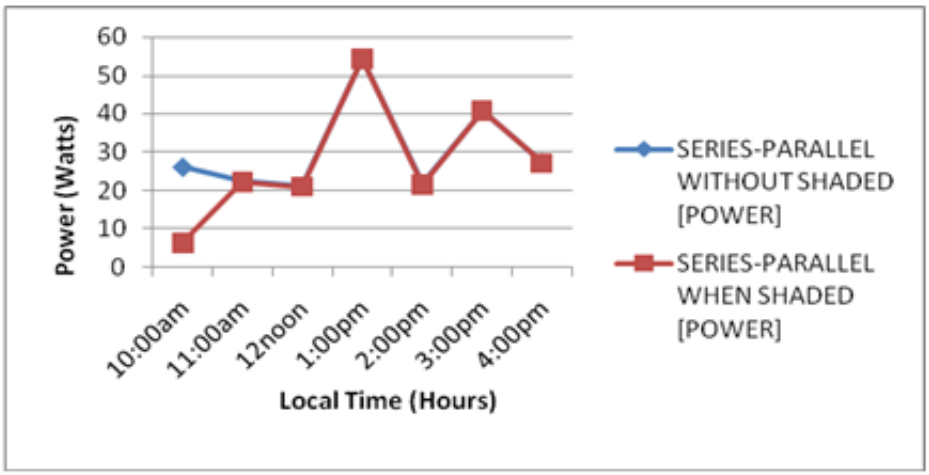

Figure 6:**Graph of series - parallel connections**

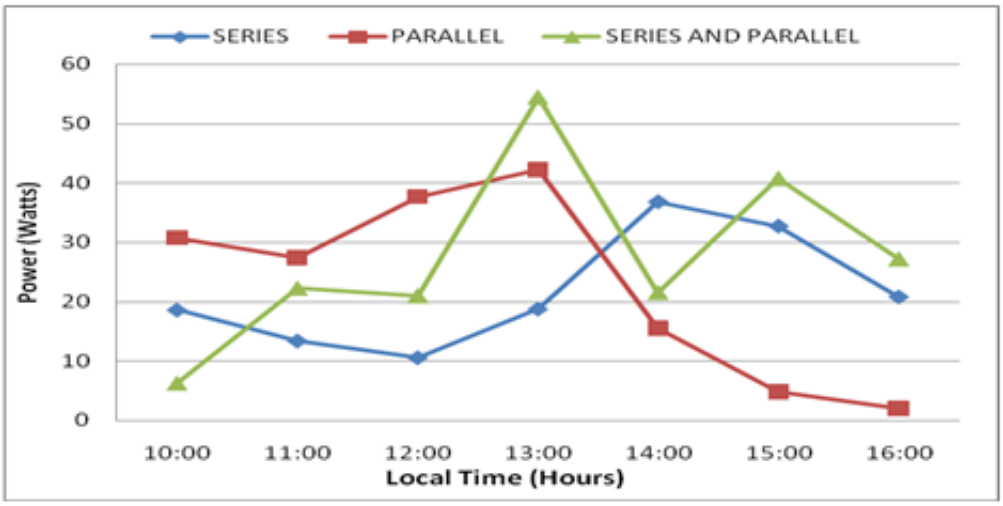

Figure 7:**Comparism of shaded PV power output at various times for Series, Parallel and Series/Parallel connections**

Discussion of Results

From the data obtained in the experiment, we observed that there was irregular current supply due to weather conditions in the month of October. This shows that the level of regularity of power generation in each months of the year is determined by the level of sun radiation. Also, the effects of the shading on solar power output were considered and numbers of different parameters affecting them were identified. A generic graph-curve of the shading effects was analyzed and it was used to investigate the effect of the three types of connection, i.e. series, parallel and series-parallel (when it was shaded and not shaded).

"Figure 4", shows that partial shading of only one solar panel reduces its power output. This is because all the panels were brought together in a series connection. The weakest panel brings the others down to its reduced power level. This means; whether a half of a panel (or even two) was shaded, the power decrease will be the same and that will be proportional to the percentage of area shaded – almost to zero power. "Figure 4" also shows that when a full panel is shaded, it can use energy produced by other panels and trigger the solar panel to protect itself. The solar panel will route the power around that series connection.

However, if the solar panels were connected in parallel as it was shown in Figure 5, shading one panel by itself will cause the current to decrease. The other three panels are unaffected and can produce the same amount of 12volts at a lower current. This is the primary advantage of wiring solar panels in parallel. An interesting result that was obtained from Figures 6 and 7 indicates that, series-parallel arrangement gives better power even when shaded. If compared to other connections earlier discussed, one can conclude that, series-parallel has highest power ratio for both when shaded and when not shaded. Therefore, to utilise maximum power, series-parallel is recommended to be used; particularly when higher voltage is required.

Summary, Finding and Conclusions

In this work, the series connection, parallel connection and series-parallel connection were studied and compared under shaded and non shaded conditions. It was found that series-parallel connection was dominant under shaded condition. This shows that the series-parallel connection is the best possible configuration. One of the conclusions of this study is that series connection of solar cells in an array is essential if one intends to get a utilisable voltage practically. As there is a substantial power loss due to non-uniform illumination of a series connection. It is also concluded that care should be taken so that all the cells connected in series receive the same illumination under different patterns of shading. Such a care will give a better protection to the array and at the same time the total energy output will also be higher.

The effects of shading on a series-parallel solar cell array leads to the following conclusions:

- Solar panels in parallel are less affected by shading if compared with solar panels in series. That is, shading is never a good idea and it can damage the panels or shorten their life spans.
- Where possible, it is best to avoid any shading on solar photovoltaic panels. It is also our conclusion that it is possible to change the wiring configuration of solar photovoltaic panels to lessen the negative effects. The most common method of lessening the effects on solar photovoltaic panels is to connect bypass diodes in parallel to the solar cells in the panel. When the solar photovoltaic panel is not shaded, the diode is "blocked". It is also concluded that, when the solar photovoltaic panels are shaded, the change in voltage in the weaker cells causes the diode to conduct the current instead, thereby bypassing the weaker cells altogether. This is discovered to have the advantage of restricting the loss in power output to the shaded cells.

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