International Journal of Information, Engineering & Technology

Volume 11, Issue 7, PP 55-60, ISSN: 2360-9194, April, 2022
Double Blind Peer Reviewed International Research Journal
arcnjournals@gmail.com
Journal Series: Global Academic Research Consortium (garc)

Investigating the Effects of Weather on the Performance of Mono-crystalline and Polycrystalline Photovoltaic Systems in Maiduguri

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Abstract: *Various developing countries in the world view renewable energy sources as an inevitable necessity to reduce greenhouse gas emissions and dependence on fossil fuel energy. The main source of energy for electricity generation in Nigeria comes from fossil fuels, which greatly constrains the fossil fuel supply and contributes to adverse effects on the environment. For these reasons, the Nigerian government is working toward attaining energy independence and promoting efficient use of renewable energy resources.One of the main sources of renewable energy in a tropical climate such as Borno is solar photovoltaic energy. The photovoltaic systems have received a tremendous attention due to the role it played in sustainable energy production and energy saving in the past two decades. Photovoltaic (PV) module and array performance is difficult to predict due to variations in weather, air mass (AM), and non-linear performance characteristics of various module technologies. Photovoltaic (PV) technology harvests abundant, free sunlight to produce electricity via photonic effect. In effect, this solar Pv, performance were hindered by the weather. In view of this, the Researchers try to investigate the performance of the system in Maiduguri which was known for its harsh weather and characterize it according to the two types of Pv used. This research explores other influential factors such as ambient temperature, light intensity, wind cooling, and humidity that could contribute to the sudden drop in PV energy generation. These factors are especially important to the conditions in tropical weather locations. The researchers intend to implore the NI LabVIEW and CompactRIO soft wares which are proved to be the best approach for analyzing the tropical environmental impact of solar photovoltaic performance. The ruggedness and modularity of CompactRIO made it the most suitable platform for our application." A host program using LabVIEW will be designed to monitor data in real time and analyze the data in offline mode. The program will capture three main features of thermocouple data, environmental data, and PV generation data in real-time mode. These parameters are so much essential when it comes to the production of PV modules so as to derive the maximum efficiency from the finished goods.*

Key words: *Photovoltaic, solar power, weather effect, standalone pv system, renewable energy*

INTRODUCTION

Nowadays, energy-related aspects are becoming extremely important. They involve, for instance, a rational use of resources, the environmental impact related to the pollutants emission and the consumption of non-renewable resources. For these reasons there is an increasing worldwide interest in sustainable energy production and energy saving. Among the technologies that could play a role in the generation of sustainable and widespread energy, interesting solutions are represented by photovoltaic (PV) cells, wind generators,

biomass plants and fuel cells. In particular, photovoltaic systems can be considered one of the most widespread solutions with significant margins of improvement while ensuring the generation of energy with low environmental impact(Rajput & Sudhakar, 2013).

Photovoltaic (PV) module and array performance is difficult to predict due to variations in weather, air mass (AM), and non-linear performance characteristics of various module technologies. The International Electro technical Commission (IEC) has proposed PV rating standards (IEC 61853) that include characterizing module performance based on a matrix of various weather conditions, including high temperature conditions (HTC), STC, nominal operating cell temperature (NOCT), low temperature conditions (LTC) and low irradiance conditions (LIC)(Micheal, 2011). Temperature affects how electricity flows through an electrical circuit by changing the speed at which the electrons travel. This is due to an increase in resistance of the circuit that results from an increase in temperature. Likewise, resistance is decreased with decreasing temperatures.

Solar panels work best in certain weather conditions, but since the weather is always changing and as engineers are installing solar panels all over the world in different climate regions, most panels do not operate under ideal conditions. That is why it is important for researchers to understand how panels react to different weather conditions. With this knowledge, it can be designed in such a way as to improve the efficiency of solar panels that operate in non-optimal conditions.

Amongst the various renewable energy sources, photovoltaic (PV) technologies that convert sunlight directly to electricity have been gaining ground and popularity, especially in countries with high solar irradiation. The power generation of a photovoltaic (PV) system may be documented by a capacity test that quantifies the power output of the system at set conditions, such as an irradiance of 1000 W/m^2, an ambient temperature of 20°C, and a wind speed of 1 m/s. A longer test must be used to verify the system performance under a range of conditions. A year-long test sample weather and shading associated with all seasons. Temperature affects how electricity flows through an electrical circuit by changing the speed at which the electrons travel. This is due to an increase in resistance of the circuit that results from an increase in temperature as in the case of Maiduguri where temperature will raise to about 50^oC. Hence, there is the need to investigate the performance and effects of the two PV systems and keep a document on the effect of temperature on the photovoltaic power system in such a harsh and dusty city of Maiduguri.

Wilton (2011), carried out a joint effort research between the University of Hong Kong (HKU) and CLP, the electricity power generation and distribution service provider in Hong Kong with the objective of identifying and verifying the potential relationships between performance of the standalone PV power system, such as the state of charge of the battery and power output, and other environmental factors such as solar radiation, wind speed, and ambient temperature.

(George M.,2014) provide an overview of different PV technologies ranging from crystalline silicon (c-Si) to thin-film and concentrators by outlining a summary of the main outdoor evaluation performance parameters used to describe PV operation and performance and also an overview of the effects of different environmental and operational factors such as

solar irradiance, temperature, spectrum and degradation is also provided along with the results of previously published research efforts in this field. Finally, the installed PV and data acquisition infrastructure of a testing facility in Cyprus is presented and a thorough analysis of the climatic conditions and the performance of different grid-connected PV technologies that have been installed side-by-side and exposed to warm climatic conditions, typical of the Mediterranean region are given. The main environmental factors affecting PV performance considered in his research include solar irradiance, ambient temperature and solar spectrum.

In addition to the review of several factors affecting PV performance, the main results of the outdoor investigation carried out in Cyprus over a four-year period have been presented. In particular, useful information on the performance of different PV technologies installed side-by-side was obtained by investigating their seasonal performance and the effects of temperature, soiling and power rating. The outcome of the outdoor performance assessment also showed that these technologies have enormous potential in countries with high solar resource.

And to the best knowledge of the researcher, there is no any record with this regard in Maiduguri and the results could help academia and industry to enhance the knowledge on the performance of such standalone PV supply system under real operating conditions and help to improve similar designs in the future.

Many module failures and performance losses are the result of gradual accumulated damage resulting from long-term outdoor exposure in harsh environments, referred to as "weathering" (Dumbleton, 2012). Similarly, most PV modules were designed to operate at a certain temperature. The dusty weather of Maiduguri will reach about 50^{o}C. Thus, the two can affect the performance of the PV System.

The main aim of this research proposal is to find out the characteristic/ effects of Weather on the Performance of Photovoltaic (PV) Systems in Maiduguri, Borno State.

This aim can be achieved through the following objectives: Investigate the performance of the different types of solar panels/modules; Identify and verify potential relationships between performance of the standalone PV power system and other environmental factors such as solar radiation and ambient temperature; Identify and verify potential relationships between Solar Radiation , ambient temperature and Time characteristics; Identify and verify potential relationships between Panel efficiency and Time analysis with and without dust.

METHODOLOGY

Basically there are three types of research methods; namely: qualitative, quantitative and mixed methodology.

Qualitative research is a unique method that comprises micro and macro analysis of knowledge based on observation, comparism and interaction. It has a multiple approach to a problem and its data were non numerical and obtained from either structured or unstructured approach. Qualitative data which are in the form of words, pictures or words provide meaning to a research because it is subjective, process oriented, holistic and

interpretative and also tends to provide full description of the research ((Bryman, 2004)) by giving detailed explanations and generation of theory at all levels of analysis.

Qualitative research has the advantages of being subjective; providing complete description; good for early research; and it provide the researcher with first-hand information for he is the instrument for data gathering. Disadvantages include consuming a lot of time; and the data collected cannot be generalized.

Quantitative research on the other hand, is objective and involves measuring facts. Quantitative data are numerical and presented in either percentage or graphs. It has the advantages of being hard, objective, strong, and its data are generalised at a significant level. Similarly, (Rank, 2004) outlined the following disadvantages: it seldom captures the overall context; biasness may exist in respondents' response; validity of data may be questionable.

Mixed methodology is a hybrid of qualitative and quantitative research. According to (Rank, 2004), it has the advantages of providing additional insight; increased validity; further pushing of research; and it mutually supports each other's lacks. And has the disadvantages of higher cost and more time consuming.

In this research, "**NI LabVIEW** and **CompactRIO** proved to be the best approach for analysing the tropical environmental impact of solar photovoltaic performance. The ruggedness and modularity of CompactRIO made it the most suitable platform for our application" (M. Ya'acob Effendy, Universiti Putra)(Ya'acob, Hizam, & Mustaffa).
The researcher will set up 2-250W each of mono- and poly- PV pilot plant at the Power Laboratory of Ramat Polytechnic Maiduguri, Nigeria. The pilot plant will be made up of two units of concentrating PV (CPV) generator systems; one unit of tracking-flat PV (TF) generator systems; a thermometer with clock and; 1KVA inverter.
This research explores other influential factors such as ambient temperature, light intensity/visibility, wind cooling/heating, and humidity whose data will be obtain from the DAQ system as shown in fig 1 below that could contribute to the sudden drop in PV energy generation. These factors are especially important to the conditions in tropical weather locations.

DAQ and Monitoring System Setup
Similarly, DAQ and Monitoring Systems set up used in (Ya'acob, Hizam, & Mustaffa) for the solar PV monitoring system will be adopted in this research work with little modifications. The researcher will capture the power generated from the PV panels and the surface temperature of the PV and synchronize it with the environment data.
The CompactRIO module will be programmed in such a way as to automatically measure and log data in real time, normally from 6:00 a.m. until 6:00 p.m. every day. The system operates in a stand-alone mode and can constantly stream data to a PC connected to the CompactRIO module.

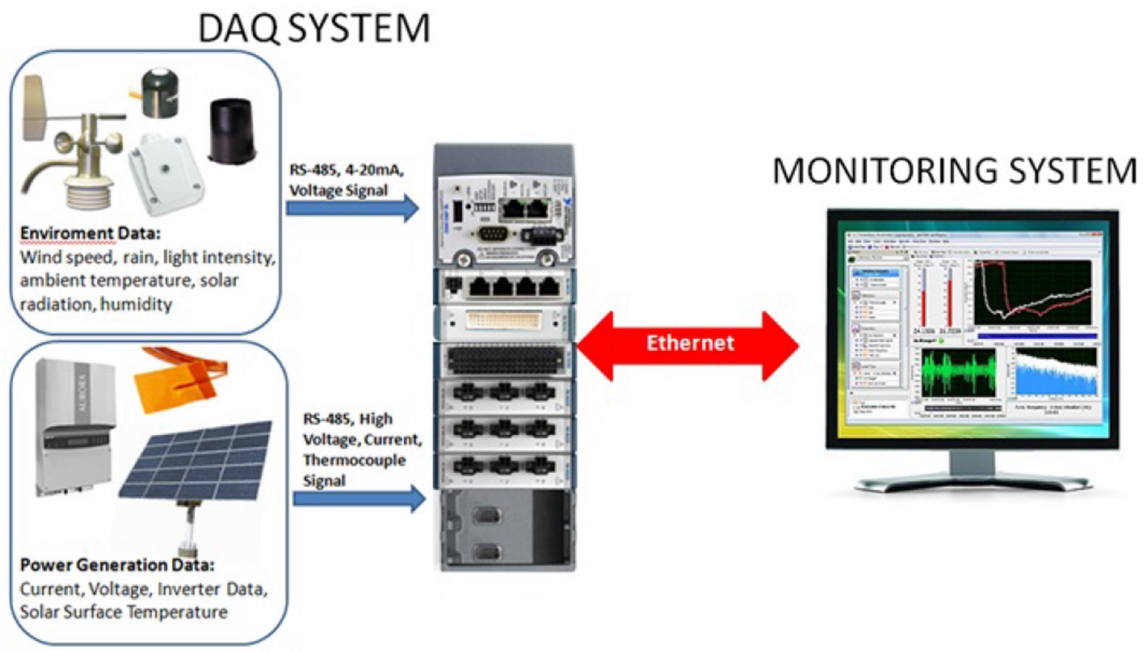

Figure 1. Solar Monitoring Station System Setup

SUMMARY OF THE FINDINGS

The study so far revealed that, for the two types of modules used, both exhibit a good and efficient outcome base on the parameters involved. However, the poly-crystalline panel shows a slightly better output especially when there is haze/dust. For the period under review, the temperature, relative humidity and output voltage was measured three times a day. That is, 10am, 2pm and 4pm.

The relationship between ambient temperature and the state of charge of the battery was very weak. In case of high temperature, the output of the PV will significantly decrease as temperature of the PV module was very high. Therefore, the temperature factor is not the dominating factor that influences the PV output in the typical environment of Maiduguri.

The wind speed in Maiduguri is quite strong and the exposed solar panel may be exposed to the wind chilling effect, a study on the relationship between wind speed and state of charge was also very weak, even weaker than that of ambient temperature. Hence, the wind speed was also not a dominating factor that affects the output of the PV system installed in Maiduguri.

The relationship between solar radiation and state of charge of the battery indicate that there is increment of the battery state of charge. State of charge was just one way to measure the PV output. However, it also depends on other factors such as the solar radiation, initial state of charge and loading demand.

The relationship between the inverter output and solar radiation recorded was very intelligible. When the battery was fully charged, the increment of the inverter was significant even when solar radiation was increasing. The peak of the solar radiation was

also the peak of the inverter output. The solar radiation was the dominating factor to the inverter output.

CONCLUSION

The collected data from the photo voltaic system in the electronics and Telecommunication Laboratory and the weather data from NAMA Maiduguri were used to investigate the relationship amongst various environmental factors such as solar radiation, wind speed, ambient temperature etc. The PV output of the system in terms of SOC and inverter output was the dominating factor that correlated to solar radiation. The direct solar radiation also plays a key role in the system output and efficiency of the system. The ambient temperature and wind speed were the less significant factors. It was discovered that, the major localised environmental effect affecting the system was the solar radiation. When the battery capacity was fully charged, one way to improve the system efficiency was to increases the battery capacity.

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