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David Wafula Wekesa, Ph.D.
Director, Centre for Renewable Energy
Machakos University
P. O. Box 136 90100, Machakos, Kenya

Dear Dr. Wekesa,

RE: INVITATION TO AN INTERNATIONAL CONFERENCE ON SCIENCE, TECHNOLOGY AND INNOVATION FOR SUSTAINABLE DEVELOPMENT IN DRYLAND ENVIRONMENTS

Umma University in Kajiado County, South Eastern Kenya University (SEKU) in Kitui County, Lukenya University in Makueni County and Machakos University in Machakos County, together with other partners, are jointly organizing an international Conference entitled *"Science, Technology and Innovation for Sustainable Development in Dryland Environments"* to be held on 19th-23rd November 2018. The theme of the conference is *"Harnessing Dryland Natural Resources for Sustainable Livelihoods in the Era of Climate Change*". The conference will be two-phased with a two day pre-conference training workshop on 19th-20th November 2018 at SEKU and the main conference on 21st-23rd November 2018 at Umma University. The conference will provide an excellent platform for the academia from around the world to engage with the industry, innovators, policy makers, value chain developers, farmers, and service providers among others so that higher education in Africa contributes to solving the problems of natural resources governance in the era of climate change. We are therefore pleased to invite you to attend the pre-conference training workshop at SEKU Main Campus in Kitui on 19th-20th November 2018 and the Main conference at Umma University on 21st to 23rd November 2018. Please note that you will be responsible for your travel and accommodation arrangements and conference registration fee.

Yours Sincerely,

DR. ALI ADAN ALI
FOR THE: VICE-CHANCELLOR

Comparative Study of the Performance Behaviour of Solar PV Modules in Kitui County

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Abstract

Solar energy technology is an emerging alternative energy source to meet specific demands around the world. The research will identify and focus on performance behavior of Solar PV modules at selected sites whose geographical parameters such as latitude, insolation, altitude and other installation design factors will be identified. The current–voltage and power–voltage characteristics at STC will be measured and recorded for each module at the Centre for Renewable Energy at Machakos University before installation for a period of six months. Daily climate parameters such as ambient temperature, humidity, air mass, wind speed and rainfall data will be recorded alongside the daily maximum current, voltage and power output of each PV module for the set period. The data collect will be analyzed to indicate whether the climatic, geographical and ambient variations in the region have a significant effect on the performance ratio of PV module types. Hopefully, the findings of this research will give a comparative and predictive performance behavior for PV modules in the corresponding climatic region that can guide manufacturers, suppliers, consumers and potentially open a path to developing a third standard for PV Modules Testing standards for different regions in Kenya.
Keywords: Solar PV; Performance behaviour; STC; Solar module; Climate

1. Introduction

Analysis of the Sustainable Development Goals isolates, sustainable energy (SDG 7) and combating climate change (SDG13) as critical to transformational challenges facing developing nations – Kenya included. Sustainable energy for all (SE4ALL) estimates one billion people in the world without access to energy and 2.9 billion relying on unclean energy sources in developing nations. Over 90% of Kenyan rural households still rely on kerosene lamps for lighting despite being classified as a high adopter of micro-solar home system kits and solar lanterns. The local kerosene tin lamps still exist in the 21st Century as the main lighting alternative in-case of blackouts, extra-demand or to complement existing clean sources of lighting technology (KICC, 2014).

Kenya is endowed with high solar insolation averaging at 4.5kWh/m2/day because of its location along the equator and thus it has a higher potential for solar PV energy production than many other nations in Africa and the world. As a means of promoting private sector involvement in solar PV, the government has created an opportunity for local and international investors under the Feed in Tariff (FiT) and other energy regulations driven by the Energy Regulatory Commission. The aim is to enhance national energy security as well as the promoting entrepreneurship in clean energy which in turn enhances connectivity using energy resources that sustains the environment and curb climate change. Immense opportunities exist in the off-grid solar market and solar lighting products (SHS and Pico Systems) as the demand rises sparked by devolution and international energy access to green funds and urbanization. Stand alone and off grid solar PVs have dominated institutional alternative lighting solutions mainly supported by government and donors as solar lantern and solar home systems widely used in rural households.

Two decades ago institutional solar PV market segment accounted for approximately two-third of installed capacity. However, recently there is an observed increase in the market for standalone SHS, and solar lighting products (SLP) (KICC, 2014). The falling global prices of PV modules from above USD 5 per watt in 2000 to as low as USD 0.5 per watt in 2014, has led to the national solar market increase by more than 100 percent (Muok et. al. 2015). Government and donors continue to play a major role in promoting solar PV as an alternative energy solution for Kenya. However, a private market has gradually emerged since the 1980s and has rapidly grown with the continued reduction in PV System prices leading to a genuine boom period in the late 1990s. By 2000, the installed PV capacity had risen to about 3.9 MWp and a decade later to between 8 and 10 MWp according to the comprehensive market review undertaken by GTZ in Kenya in 2009 (UNEP, 2014). Although information about subsequent developments in installed PV capacity has been sporadic, Ondraczek (2014) estimated that at least 320,000 SHS were in operation in 2010 supplied majorly through the private solar market. Similarly, Ramboll (2012) claimed a figure of 16 MWp as of 2012 and Tobias Cossen of GIZ a figure of 20 MWp in November 2013 (UNEP, 2014). The total potential for photovoltaic installations is estimated at 23,046 TWh/year (RECP, n.d.)

As the solar PV market continues to expand in Kenya, a key concern is the knowledge gap in the effect of extreme climatic condition on performance of solar products in the country. As alluded to above, while Kenya enjoys high insolation rates, output from the same PV generator (module) will vary in different climates, weather and environments due to an array of factors including technical, infrastructural and or human. Research has shown that insolation levels, ambient and cell temperature, wind speed and air mass, affect the performance levels of solar PV modules (Chikate & Sadawarte, 2015). The Koppen-Geiger climate classification indicates that Kenya, being part of the African Plate has 3 main climates zones namely Tropical, Arid and Temperate which vary in temperature, humidity, airmass and rainfall (Peel, Finlayson, & Mcmahon, 2007). In addition, the geographical and installation design aspects vary from one zone to another including latitude, altitude, insolation levels, tilt angle and orientation needed, pollution levels, season and cloud cover.

This study has identified Kitui, Kenya (1.37°S 38.01°E 1154m) where two modules types (mono-Si and p-Si) types will be installed. Kitui is in the Eastern region of Kenya with its climate classified as Tropical (Aw). The daily average high temperature varies between 24 – 27 °C with the hottest months being Feb & March (27/17 °C). Data will collect data on five main climatic parameters namely daily temperature, rainfall, humidity, airmass and wind speeds. In addition, we will record other environmental factors such as altitude, latitude, tilt and orientation of modules, insolation and dusting of panels and their effect on the maximum current, voltage and power of each module type in this region. The outcomes will be generalized using a suitable mathematical model for all other regions in Kenya

2. Methodology

2.1 Study site

The selected site sits on extensive Mwingi/Kitui plateau adjoining coastal belt to the south and north-eastern zones to the east and north. The site is located on latitude 1^0 22/S and on longitude $38^0$02/E. It is at a height of 3433 ft AMSL.

2.2 Design of the Study

The main objective of this research is to collect data and analyze the performance behavior of mono-Si and p-Si PV modules in Kitui's climatic, geographic and environmental conditions as well as the rest of Kenya. The current-voltage and power-voltage characteristics at STC will be measured either at IEET or SERC using appropriate references and calibrations. In the case where, equipment is unavailable, the manufacturer set values at STC will be recorded before testing commences to give a baseline for comparison with outdoor values.

For this study daily climate data will be recorded focusing on ambient temperature, daily precipitation, humidity levels, air mass and wind speed. Corresponding module performance, daily maximum voltage, daily maximum current and daily maximum power output will be recorded and analyzed against the climatic and ambient factors. Factors such as soiling and shading due to dust, leaves and bird droppings will also be considered in the analysis of the data collected.

Kenya Metrological Department (KMD) will provide historical climatic data for the selected stations which will allow the calculation of a theoretical output for Kitui. The data will be collaborated with daily data collected by Meteoblue. This will not factor in the effect of dust, soiling and other forms of shading. To have a predictive analysis, the theoretical performance output will be compared to the experimental and actual performance output which will not only factor in the impact of climatic elements but the level of shading in each station. This comparison will yield the performance ratio for the site and will be extrapolated for other regions using a generalized mathematical model.
High or low will be determined by STC and PTC of Solar PV modules. This means that: for temperature, 20-25 degrees will be considered average; for wind, 1m/s will be considered average and for air mass, which will determine humidity, 1.5AM will be considered average.

2.3 Materials & Instruments

The station set up in Kitui will include two sets of materials – PV System Components and weather stations instruments and sensors. We will use 10W – 12V mono-Si and p-Si PV modules together with other components including 2 Lead-gel batteries 12 V/7.2 Ah, 2 Charge regulators with deep discharge protection and 2 inverters MCI150 – 12 V DC/230 V AC and others.

2.4 Expected Data Output & Analysis

We will collect two sets of data. I-V and P-V data will be recorded hourly, daily and accumulated monthly. As well, weather parameters – T, RH and wind speed - variations will be recorded hourly, daily and monthly. These parameters will be compared against the I-V and P-V curves of the two modules and used to calculate performance ratios (Wp STC and possibly Wp measured if we are able to measure I-V and PV characteristics at STC). The tables below will be used to record data for analysis and calculation of monthly PR.

Table 1: Power Output table

Module Make/Type	Wp (Rated) (W)	Wp (STC Measured) (W)	Exposure (Months)	Wp (Outdoor Measured)
mono-Si #XYZ	10	1.5 AM	September	1000 W/m^2
poly-Si #XYZ	10	1.6 AM	October	1020 W/m^2

Table 2: I-V and P-V monthly data averages

Module Make/Type	Isc	Voc	Imp	Vmp	Prated	Pmax	Wh
mono-Si #XYZ	0.01	12.6	0.04	13.4	30.0	200	1200
poly-Si #XYZ	0.02	11.9	0.06	12.9	40.0	190	1050

Data will be collected and recorded hourly, daily and monthly averages determined to be used in the performance ratio calculation for each module.

2.5 Conclusion

Comparative performance testing of different PV modules in outdoor climate of Indonesia has been validated for Keseveni site in Kitui county. The mono-crystalline (m-Si) was the best performance both under STC condition and outdoor exposure condition (in terms of module efficiency and overall power production). Poly-crystalline (p-Si) has a good performance in STC conditions, but did not show a good performance in outdoor test condition. Meanwhile, micro-morph silicon (uc-Si) has a not good performance in STC conditions, but showed a good performance under outdoor test condition. The output power of the PV module depends on solar irradiation and temperature. The increase in solar irradiation leads to higher output power of PV module. The micro-morph silicon (thin-film) has the lowest temperature coefficient compared with the crystalline silicon modules, such as mono-crystalline and poly-crystalline. Therefore, it has more in energy production.