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Comparative Optimal Daily Functionality of Industrial and Constructed Atmega328P Microcontrollers in Solar Energy Measurement System

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Abstract:- The embrace of solar energy by government and individuals for the installation and operation of public energy-enabled facilities is gradually dwindling in recent times for reasons that may not be entirely cost related especially with the recent past administration of the Anambra State governments preference for diesel powered street lights for eight years, the study was motivated to focus on the need for adequate measurement and evaluation of the output current, output voltage, temperature, and open circuit voltage of the solar energy system in the target area towards assessing the environment's suitability for household and commercial based rich energy generation, operations and sustainability. Adopting the Maximum Power Point Tracking (MPPT) technology, a brand new ATmega328P Microcontroller System denoted as CONST, was designed, constructed and implemented with the aid of Current sensor (ACS 712), Voltage sensor (Resistors 100Kohms), and Temperature sensor (LM35) Other materials used for the construction were Aluminum Heat Sink, Relay (5V), LCD, Vero circuit board, 1mm flexible wire, white medium size casing, solder, DC to DC Converter, and Buzzer sound alarm. The field measurement was implemented using two PV Solar Panels 280W, two 12V batteries (200AH and 70AH), two inverters (1KV and 12KV), two 100Watts bulbs as load, and one Multimeter. In order to achieve the objective of the study, the Constructed (CONST) ATmega328P microcontroller system and another but Industrial-Made (INDUSM) ATmega328P Microcontroller system were utilized to conduct the field measurement. Relevant data readings obtained were comparatively analyzed using graphs and the One Way ANOVA statistical tool. Output/results obtained showed that on day 1, under CONST System, when temperature is at 25ºC (day 1), 30ºC (day 2) and 33ºC (day 3) at 0800hour, maximum Current and Voltage output of 3.45A (day 1), 7.36A (day 2) & 4.93A (day 3) and 14.11V (day 1), V (day 2) & 13.21V (day 3) are observed. But under the INDUSM System, a maximum Current and Voltage of 6.6A (day 1) 8.1A (day 2) & 6.27A (day 3) and 10.3V (day 1), 10.4V (day 2) & 13V (day 3) are obtained at 0800hour as Temperature output reads 38ºC (day 1), 37ºC (day 2) & 36ºC (day 3). A higher output was however observed at 1200hour. Under the CONST System, when Temperature rises to 49ºC (day 1), 45ºC (day 2) & 51ºC (day 3), a maximum Current and Voltage output of 9.11A (day 1), 12.5A (day 2) & 10.73A (day 3) and 14.66V (day 1), 20.41V (day 2), & 14.47V (day 3) are recorded. This is a bit different from the observations under the INDUSM System where at 1200hour when Temperature rises to 44ºC (day 1), 57ºC (day 2) & 43ºC (day 3), a maximum Current and Voltage output of 13.2A (day 1), 11.6A (day 2) & 12.42A (day 3) and 13.9V (day 1), 13.4V (day 2) & 15.3V (day 3) are obtained.

Keywords:- *ATmega329P Microcontroller, Output Current, Output Voltage, Solar Energy Measurement System, Temperature.*

I. INTRODUCTION

Nearly every technological apparatus requires power for its optimal performance (1). However, (2) notes with regret that the electricity sector in Nigeria generates, transmits and distributes megawatts of electric power that is significantly less than what is needed to meet basic household and industrial needs. Despite twenty five generating plants taken over by six (6) generating companies (Gencos) with the capacity to generate 12,522 megawatts (MW) of electricity (against expected minimum of 40,000 MW required to meet household and industrial consumption in Nigeria) amid energy transmission and distribution operations presently being handled by one transmission company of Nigeria and 11 licensed distribution companies (Discos) respectively, an average of 3,827 MW was all that could be generated daily as at May, 2018 (2) and (3). This is more as the rising costs of fossil fuels (from N65 per litre in 2015 to N600 per litre as at May 2023 as well as Diesel from N130 per litre in 2015 to N750 per litre as at May 2023), and the consequent noisy activities of millions of generators across the country have gradually began to change the narrative about energy generation in Nigeria. The negligence of the rising rate of greenhouse gas (GHG) emissions in Nigeria by the Federal and State governments towards responding effectively to the deteriorating incidence of climatic changes and depletion of the ozone layer (4) is quite worrisome and considered a threat to the longitivity of human existence. (4) further laments that a 2015 government report lend credence to the above, showing that about 55% of the country's over 200 million inhabitants have no access to grid-connected electricity in Nigeria. These, perhaps, could be responsible for the growing emphasis on alternative renewable energy sources towards addressing these menaces considerably and reduce the unhealthy much reliance of Nigeria households, businesses and people on fossil-based energy generation activities in Nigeria.

In bid to meet the ailing energy demands by societies in Nigeria while taking advantage of advanced but improving technologies as well as promising potential energy applications, commendable attention has been re-intensified by individuals and the government on energies from renewable sources as the sunlight. Photovoltaics, the direct conversion from sunlight into electricity, promises to be a major energy technology in the future. This has also been referred to as solar energy. According to (5), energy from sunlight has the greatest potential to meet rising expectations for energy and the need for innovation of clean and eco-friendly technologies.

The observed shortfall in expectations coupled with the fact that the Sustainable Development Goals (SDGs) deadline for developing nations is fast approaching, and Nigeria seem to be striving to achieve them especially Goal 7 (affordable and clean energy for all), may have prompted the federal government earlier in August 2016 to initiate Power Purchase Agreements with fourteen new Solar Power Developers that had the potential of adding about 1,125MW to the national grid (6). (7) also strongly emphasizes that Nigeria's geographical location around the equator lies within a high sunshine belt that readily exposes the country to enormous radiation from the sun.

Concurring to the fact that energy from the sunlight consumed for illumination, most of the time, is more than necessary, (8) and (9) buttress on the need for effective measurement of light intensity of the environment and adequate control of the same to boost energy savings and storage. (10) further noted that in understanding a society's potential for solar power generation, the need for effective monitoring of the performance of existing solar installations, reliable and accurate measurements are considered very crucial). It is against this backdrop that this study maintains focus on measuring existing solar energy system installations through the open circuit voltage (V_{oc}), maximum current (Im), fill factor (ff), and efficiency of the solar panel for effective prediction of solar energy performances to assess the environment's suitability for household and commercial based rich solar energy generation, operations and sustainability. The remaining part of this research work are organized as follows: Section 2 reviews the various concepts portrayed in the work. Section 3 describes the research method and experimental approach deployed in the study. Section 4 discusses the findings and observations made, and Section 5 provides a summary and suggestions for future research considerations.

II. LITERATURE REVIEW

A. Solar Energy Measurement

Solar Energy otherwise referred to as the Photovoltaic (PV) system, one of the various renewable energy sources also comprising wind and biomass, has continued to witness commendable expansion at a geometric progression especially in developing countries like Nigeria due to attractive advantages it offers such as low polluting levels which is presently a global menace that is responsible for the rising global warming and green house levels as well as the abundance of solar energy. (11) are of the opinion that this perhaps is already making meaningful impact on the society by way of gradual cost reduction in PV technologies which no doubt has attracted and still attracts quality research and investments in the field.

It is however pertinent to state that the reliability and sustainability of the PV system depends on several factors among which are the long term functionality of the system and its maintenance through expertise supervisory role on the PV system installation. The attainment of this is often not without the observance of routine checks on the PV systems installation and this requires the exercise of measurement activities on relevant parameters of the PV system which directly or indirectly affects its functionality and sustainability. According to (12), it is essential to be able to estimate the production capacity of PV system when planning a PV installation. Supporting this, (13) stressed that a reasonable accurate knowledge of solar resource availability is of prime importance for solar Engineers in the development and designing of solar photovoltaic (PV)-based energy systems.

Accordingly, measurement is an important subsystem of a mechatronics system. Its main function is to collect the information on system status and to feed it to the micro-processor(s) for controlling the whole system. This system comprises the use of sensors, transducers and signal processing devices (14).

B. Maximum Power Point

Maximum Power Point (Pm or MPP) depicts the maximum power produced by a solar cell at at standard test condition (STC) (that is, solar radiance of 1000w/m^2 and cell temperature of 25^{0}C). Other than STC, the solar cell has maximum power (Pm) at different values of radiance and cell operating temperature. Notably, the cell can operate at different current and voltage combinations. But it can only produce maximum at a particular voltage and current combinations. (15) lend scholarly support to this describing the MPP as the sweet spot of the solar panel power output where the combination of the volts and amps results in the highest wattage (volts x amps = watts).

C. Solar Cell Parameters

The conversion of sunlight into electricity is determined by various parameters of a solar cell. The cell parameters are given by the manufacturers at the standard test conditions (STC). Under the STC, the corresponding solar radtation is equal to 1000w/m^2 and the cell temperature is equal to 25^{0}C.

➢ *The Solar Cell Parameters Considered in this Study are as follows:*

- *Voltage At Maximum Power Point (V_{mp})*
- *Current At Maximum Power Point (I_{mp})*
- *Open Circuit Voltage (V_{OC})*
- *Temperature*

➢ *Voltage at Maximum Power Point* (V_{mp})

This represents the voltage that the solar cell produces when operating at maximum power point. The maximum power voltage occurs when the differential of the power produced by the cell is zero (16).

➢ *Current at Maximum Power Point (I_{mp})*

Current at maximum power (I_{mp}) is the current (amps) that exists when the power output is at its greatest (17). Accordingly, this is the current which the solar cell will produce when operating at the maximum power point. Its values is always less than the short circuit current.

➢ *Open Circuit Voltage (V_{OC})*

This is the maximum voltage available from a solar cell, and this occurs when the current is zero. (17) viewed it as the number of volts the solar panel produces as outputs when no load is connected to it amid the positive and negative wires being joined together. It is open and not connected in order to form a complete electrical path.

D. Prior Related Studies

(18) in their study, adopted a 10Wp solar panel and used Arduino Atmega 2560 that is connected with voltage sensor, current sensor and temperature sensor to propose a real time monitoring system for the solar panel. This Arduino ATMega 2560 is further connected with ESP8266 Wifi module in a smartphone to display the measurements of current, voltage and power of solar panel and ambient temperatures through the Blynk app. The test was conducted for seven (7) days between 0800hours and 1600hours daily. The outcome of the experiment showed that this monitoring system concept has a good degree of accuracy with an average error rate of below 10%, thus implying that monitoring the performance of solar panels using a smartphone-based microcontroller can be done in real time even as it can be used for larger PV systems.

(19) conducted an investigative study to measure the solar energy using Arduino Board technology. During the 3 days measurement of the solar energy system, four parameters were deployed to achieve that purpose namely temperature measured using temperature sensor, light intensity measured using light dependent resistor (LDR) sensor, voltage using the voltage divider because the voltage generated by the solar panel are large for the Arduino as receiver and the current measured using the current sensor module that can sense the current generated by the solar panel. The project used polycrystalline type of the panel solar with 12V, 250mA, 3W as a source. The size of the panel was 145mm X 145mm. Simulation results obtained showed that at Sunrise position, the highest light intensity was 950 Lux at 1200hours, while the lowest light intensity was 830 Lux at 1700hours. They also found out that at the Upward position, the higher the light intensity, the higher the voltage value. Summarily, the solar panel in upward position records the highest voltage of 13.11V at 1000hours with light intensity peaking at 929 Lux and the lowest voltage recording 6.3V at 1700hours when light intensity peaked at 357 Lux. This outcome contradicted the outcome obtained at sunset position where the highest voltage recorded was 12.57V at 1300hours with light intensity at 964 Lux and the lowest voltage recording 11.19V at 0900hours with light intensity of 931 Lux. The study concluded that the best position of the solar panel energize was the sunrise position with the highest voltage value which is 14.75V at time 1100hours. The researchers noted that at this time the light intensity was 954 lux and the temperature was at 34.32℃.

(20) designed and constructed an Arduino-based solar parameter-measuring system which was found to be capable of measuring different solar PV parameters including the voltage, current, real time temperature, real time atmospheric pressure, and light intensity. The system comprised of both hardware circuit design and software programming for interfacing solar with the Arduino board. The hardware development involves the design of electronic components for the sensors interface between the solar panel to the Arduino UNO. A mono-crystalline 20W solar panel and 10W DC bulb were equally used. The hardware unit comprised of the voltage sensor, current sensor, light dependent resistor (LDR) sensor, pressure-temperature sensor and the Arduino Uno. The study found out that solar PV energy generation directly depends on the solar irradiance, temperature and air pressure.

(21) conducted a study to analyse the Solar Energy Parameters in Bida, Nigeria over a period of thirteen years (2000 – 2012). They however focused on Gunn-Bellani solar radiation, sunshine hour duration, relative humidity, rainfall, wind speed, maximum and minimum temperatures which data were analysed using both single-variable and multi-variable regression techniques of the Angstrom type to generate several regression equations (models). The study observed that the highest and lowest air temperatures are obtained in the months of March and December respectively. It also discovered that the highest and lowest values of the fraction of sunshine occurred in the month of November and August respectively.

(22) developed a measurement system of solar energy using Arduino Board technology that focused on the measurement of temperature, light intensity, voltage and current solar parameters using temperature sensor, light dependent resistor (LDR) sensor, voltage divider and current sensor module with emphasis on the sunrise, upward and sunset positions. The study found out that at sunrise position the highest and lowest power produced was 2.4W at 1600hours and 0.3W at 1700 hours respectively, just as the highest voltage recorded at the same position was 14.75V at

1100hours with light intensity was 945 Lux and the lowest voltage recorded was 9.17V at 1700hours with light intensity was 695 Lux. At upward position, the highest and lowest power produced was 1.7W at 1200hours, and 0.38W at 1700hours respectively, just as the highest voltage recorded was 13.11V at 1000hours with light intensity was 929 Lux and the lowest voltage recorded was 6.3V at 1700hours with light intensity was 357 Lux. The result obtained at sunset position showed that the highest and lower power produced was 1.63W at 1700hours and 1.21W at 0900hours respectively, just as the highest voltage recorded was 12.57V at 1300hours with light intensity was 964 Lux and the lowest voltage recorded was 11.19V at 0900hours with light intensity was 931 Lux.

For most scholars, voltage, current, power, temperature, and light intensity of a solar panel were measured using light dependent resistor (LDR) sensor, voltage divider and current sensor. However, the present readily deployed LM 35 as temperature sensor, ACS 712 as current and Resistor as voltage sensors. Although some of the scholars conducted their studies between 0800hours – 1600hours, this study covered a period of three days on hourly basis measurement from 0800hours – 1800hours. It is now the intent of this study to also fill the above gaps.

III. MATERIALS AND MEASUREMENT

➢ *The Constructed ATmega328P Microcontroller Solar Energy Measurement System Otherwise Referred to as CONST ATmega328P Microcontroller SEMS in this Study was Designed and Made using the following Materials:*

The measurement/field study was conducted for a total of three days using 280 Watt PV Panels between 0800hours and 1800hours; a time interval of eleven hours each study day using two 12V batteries, two ATmega328P microcontroller based-MPPT Charge controller boxes (one constructed, herein denoted as CONST and the other industrial made herein denoted as INDUSM), two Inverters, two 100Watts bulbs. The choice of the time range (0800hours – 1800hours) is judgmental. This enabled the Researcher to obtain a holistic actual daily irradiation from sunrise to sunset.

➢ *Accordingly, the Measurement Process went through the following Stages:*

First and foremost, when the energy from the sun fell on the PV module (280Watt panels) as photons, it generated electricity in direct current (DC) form. This electricity generated was passed to both charge controllers in use, herein known as maximum power point tracker (MPPT) technology. It was this charge controller that was used to charge the battery. Note that this charge controller controls the rate of charging of the battery to avoid overcharging, controls the rate of discharging of the battery assuming a DC load was in use and also converts excess voltage to current. However, this study did not use the DC load. As a result, two inverters (1KV and 12KV respectively) were connected to the batteries instead, to convert the direct current (DC) in the battery to alternating current (AC) which were fed to the AC load (two 100Watt bulbs, a total of 200Watts). It is pertinent to state that the use of the AC load is to enable the continuous discharging of the battery towards ensuring that a commendable flow of DC current from the PV module to the battery took place. And this process assures that reliable current and voltage values during the time interval of the measurement were obtained.

The current sensor (ACS 712), voltage sensor (Resistors 100kohms)) and the temperature sensor (LM 35), which were embedded in both MPPT technologies used, read the current, voltage and temperature and communicated them to both ATmega328P microcontroller systems that converted the analog readings received to discrete or digital signals for further processing. The values of the parameters were displayed on the liquid crystal display (LCD) screen. To this end, the entire system was powered by two 12V batteries, 200AH and 70AH respectively (for each MPPT Boxes) for effective functioning purpose. The Open circuit Voltage was measured with the aid of a digital Multimeter which obtained the Voc readings when no load was connected to the Panels.

IV. EXPERIMENTAL RESULTS

The data collated through the LCD screen were analysed by means of Tables and graphs for a concise appreciation of the trends and performance levels of the parameters of both ATmega328P microcontroller solar energy measurement system (the constructed or CONST ATmega328P microcontroller MPPT system and the Industrial-Made or INDUSM ATmega328P microcontroller MPPT system) which were evaluated at different time frame (0800hours – 1800hours) across three days (3rd March – 5th March, 2023) using 280watt Panels.

E. Day One, 3rd March, 2023 Tables and Graph Analyses

➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Current*

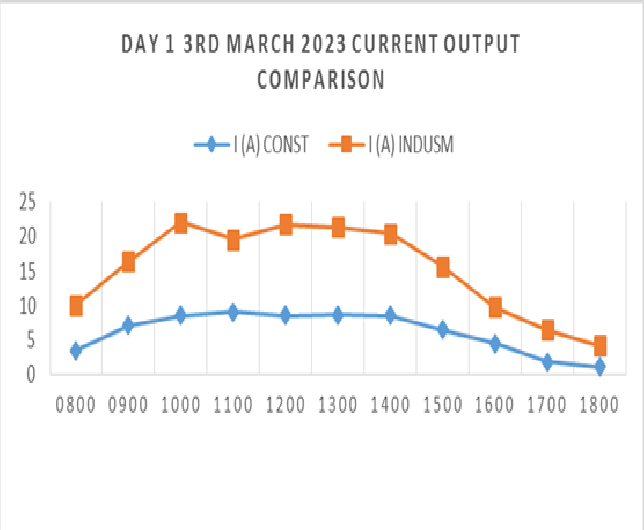

Fig 1 Day 1 3rd March 2023 Graph Comparison of Observed Current Output of CONST and INDUSM.

➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Voltage*

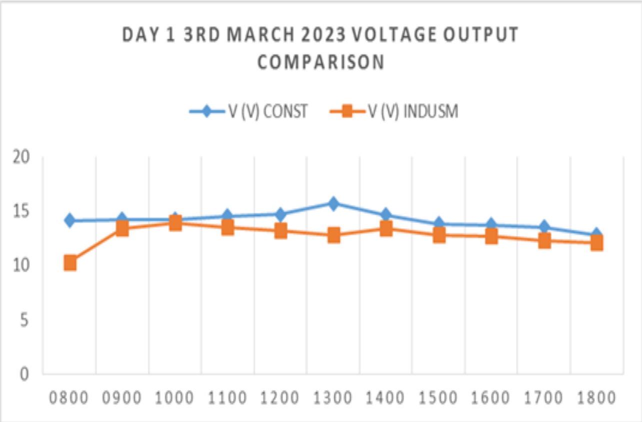

Fig 2 Day 1, 3rd March 2023 Graph Comparison of Observed Voltage Output of CONST and INDUSM.

➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Temperature*

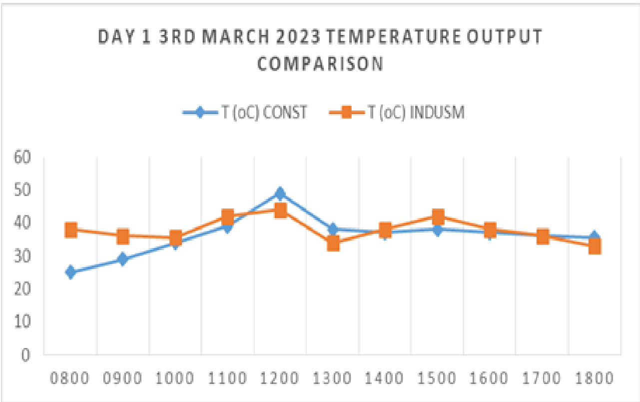

Fig 3 Day 1, 3rd March 2023 Graph Comparison of Observed Temperature Output of CONST and INDUSM Systems

➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Open Circuit Voltage*

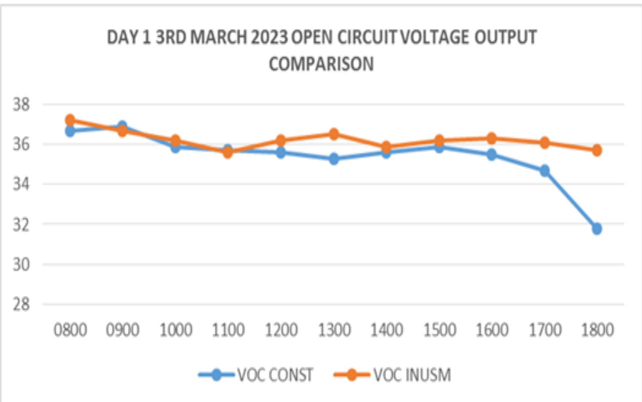

Fig 4 Day 1, 3rd March 2023 Graph Comparison of Observed Open Circuit Voltage Output of CONST and INDUSM Systems

➢ *Day 1 Results Comparison*

Using the Constructed (CONST) ATmega328P Microcontroller System, it was observed that as Temperature rises at 0800hours from 25°C to 49°C at 1200hours, Current and Voltage rises as well at 0800hours from 3.45A and 14.11V to maximum outputs of 9.11A and 14.66V at 1100hours and 1200hours respectively. Similarly, the INDUSM ATmega328P Microcontroller System's outputs showed that at 0800hours, Temperature rises from 38°C to 44°C at 1200hours. This leads to a consequent rise in Current and Voltage at 0800hours from 6.6A and 10.3V to a maximum outputs of 13.2A and 13.9V at 1200hours and 1000hours respectively. This means that as the temperature of the environment where the measurement was carried out rises, a corresponding rise is witnessed in the output of the Current and Voltage measured using the INDUSM System.

On the other hand, as Temperature begins to decrease at 1300hour from 38°C to 35.5°C at 1800hours under the CONST ATmega328P Microcontroller System, Current and Voltage equally witnesses a corresponding decrease at 1400hours from 8.52A and 14.55V to 1.13A and 12.3V at 1800hours. A similar situation was observed under the INDUSM ATmega328P Microcontroller System where the Temperature began to decrease at 1300hours from 34°C to 33°C at exactly 1800hours. This was observed to translate into a consequent decrease in Current and Voltage at 1400hours from 12.7A and 13V to 3.1A and 12.04V at 1800hours respectively. This means that decrease in the observed outputs of Temperature under both measurement Systems also leads to decrease in the outputs of Current and Voltage.

F. Day Two 4th March 2023 Tables and Graph Analyses

➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Current*

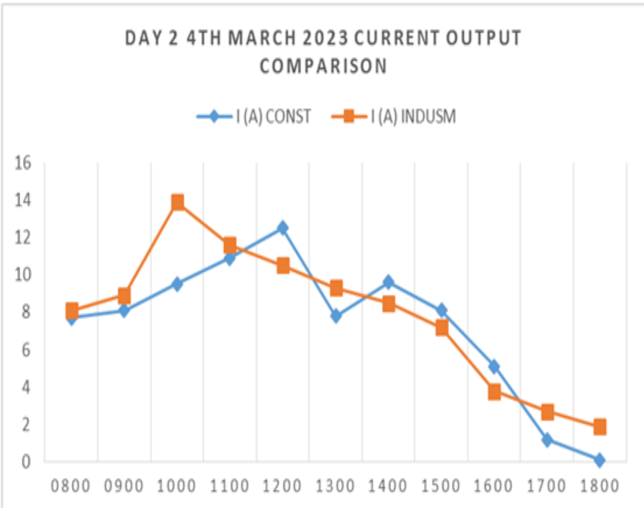

Fig 6 Day 2 4th March 2023 Graph Comparison of Observed Current Output of CONST and INDUSM Systems

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➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Voltage*

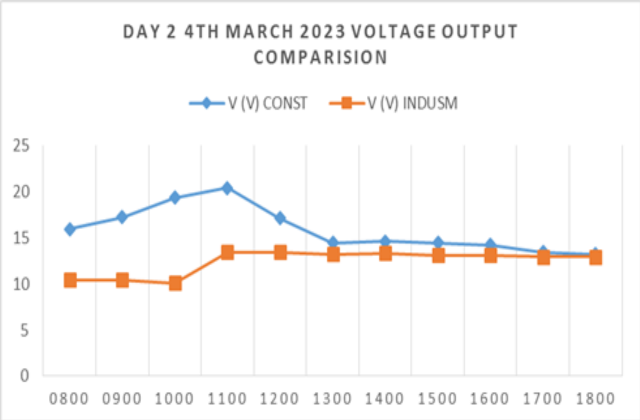

Fig 7 Day 2, 4th March 2023 Graph Comparison of Observed Voltage Output of CONST and INDUSM Systems

➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Temperature*

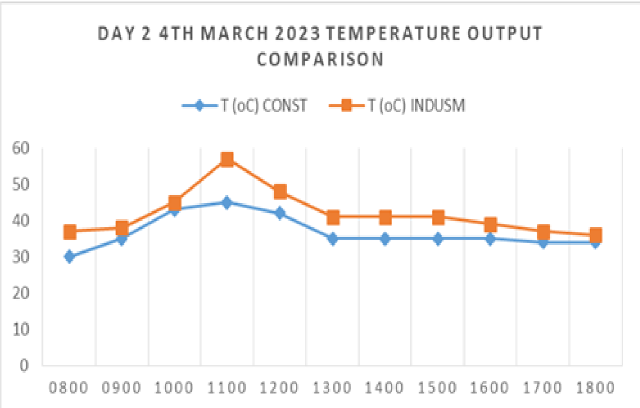

Fig 8 Day 2 4th March 2023 Graph Comparison of Observed Temperature Output of CONST and INDUSM Systems

➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Open Circuit Voltage*

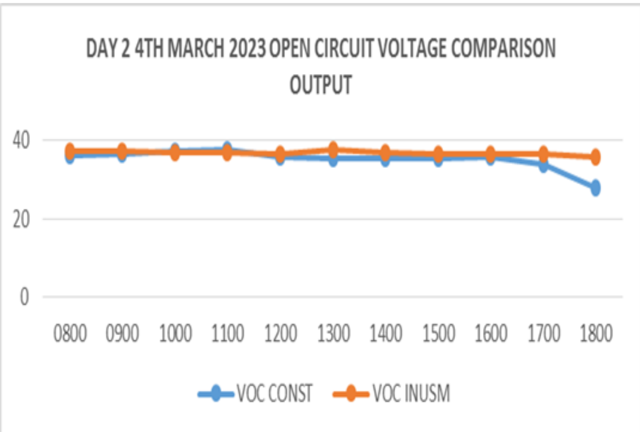

Fig 9 Day 2 4th March, 2023 Graph Comparison of Observed Open Circuit Voltage Output of CONST and INDUSM System.

➢ *Day 2 Results Comparison*

Using the Constructed (CONST) ATmega328P Microcontroller System, it was observed that as Temperature rises at 0800hours from 30ºC to 45ºC at 1100hours, Current and Voltage rises as well at 0800hours from 7.36A and 15.85V to maximum outputs of 12.5A and 20.41V at 1200hours and 1100hours respectively. In like manner, the INDUSM ATmega328P Microcontroller System's outputs showed that at 0800hour, Temperature rises from 37ºC to 57ºC at 1100hours. This leads to a consequent rise in Current and Voltage at 0800hours from 8.1A and 10.4V to maximum outputs of 11.6A and 13.4V at 1100hours and 1200hours respectively. This means that as the temperature of the environment where the measurement was carried out rises, a corresponding rise is witnessed in the output of the Current and Voltage measured using the INDUSM System.

On the other hand, as Temperature begins to decrease at 1200hours from 42ºC to 34ºC at 1800hours under the CONST ATmega328P Microcontroller System, Current and Voltage equally witnesses a corresponding decrease at 1300hours and 1200hours from 7.78A and 17.06V to 0.01A and 13.22V at 1800hours. A similar situation was observed under the INDUSM ATmega328P Microcontroller SEMS where the Temperature began to decrease at 1200hours from 48ºC to 36ºC at exactly 1800hours. This was observed to translate into a consequent decrease in Current and Voltage at 1200hours and 1300hours from 10.6A and 13.2V to 1.9A and 12.85V at 1800hours respectively. This means that decrease in the observed outputs of Temperature under both Measurement Systems also leads to decrease in the outputs of Current and Voltage.

G. Day Three 5th March 2023 Tables and Graph Analyses

➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Current*

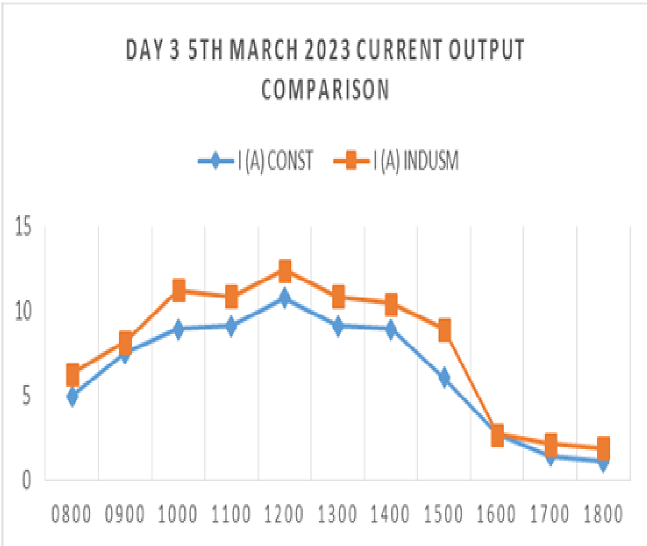

Fig 11 Day 3, 5th March 2023 Comparison of Observed Current Output of CONST and INDUSM

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➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Voltage*

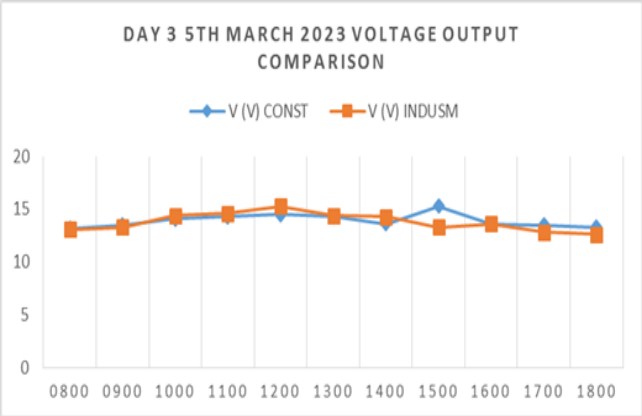

Fig 12 Day 3 5th March 2023 Graph Comparison of Observed Voltage Output of CONST and INDUSM Systems

➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Temperature*

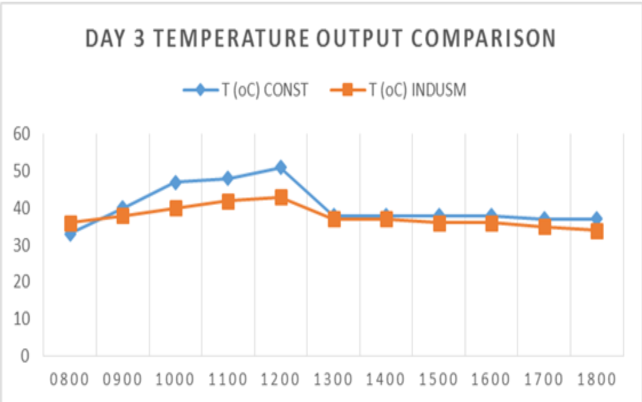

Fig 13 Day 3, 5th March 2023 Graph Comparison of Observed Temperature Output of CONST and INDUSM Systems

➢ *Comparison of CONST and INDUSM ATmega328P Microcontroller Systems Actual Readings of Open Circuit Voltage*

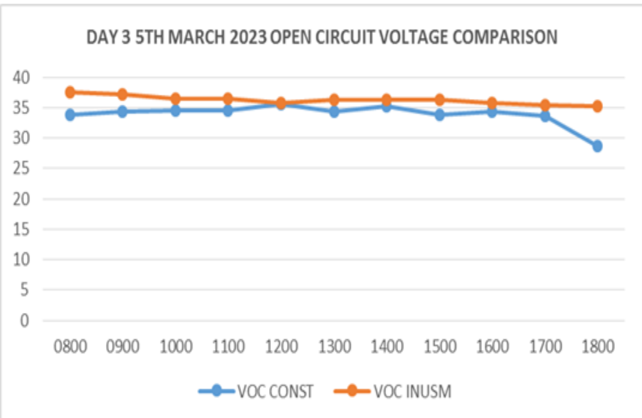

Fig 14 Day 3, 5th March 2023 Graph Comparison of Observed Open Circuit Voltage Output of CONST and INDUSM Systems

➢ *Day 3 Results Comparison*

Deploying the Constructed (CONST) ATmega328P Microcontroller System, it was observed that as Temperature rises at 0800hours from 33ºC to 51ºC at 1200hours, Current and Voltage rises as well at 0800hours from 4.93A and 13.21V to maximum outputs of 10.73A and 14.47V at 1200hours respectively. Similarly, the INDUSM ATmega328P Microcontroller System outputs showed that at 0800hours, Temperature rises from 36ºC to 43ºC at 1200hours. This leads to a consequent rise in Current and Voltage at 0800hours from 6.27A and 13V to maximum outputs of 12.42A and 15.3V at 1200hours respectively. This means that as the temperature of the environment where the measurement was carried out rises, a corresponding rise is witnessed in the output of the Current and Voltage measured using the INDUSM System.

On the other hand, as Temperature begins to decrease at 1300hours from 38ºC to 37.8ºC at 1800hours under the CONST ATmega328P Microcontroller System, Current and Voltage equally witnesses a corresponding decrease at 1300hours from 9.08A and 14.26V to 1.11A and 13.35V at 1800hours A similar situation was observed under the INDUSM ATmega328P Microcontroller System where the Temperature began to decrease at 1300hours from 37ºC to 34ºC at exactly 1800hours. This was observed to translate into a consequent decrease in Current and Voltage at 1300hours from 10.86A and 14.4V to 1.87A and 12.6V at 1800hours respectively. This means that decrease in the observed outputs of Temperature under both measurement Systems also lead to decrease in the outputs of Current and Voltage.

V. CONCLUSION AND RECOMMENDATIONS

The need to achieve a reliable solar energy generation and maximization in developing countries especially in Nigeria as a suitable responses to the unending energy generation and power supply crises cannot be overemphasized. While there may have been improvement in researches in this clean renewable energy source, the need for sustainability of the same upon implementation is hereby brought to the fore. This is the backdrop for the design and emergence of solar energy measurement system. While it may have become a culture among solar energy users and consumers to patronize international brand of such solar energy measurement system, the resolve of this Research work to design and construct similar contemporaries of local brand appears to have paid off, especially when the observations made from the output of its various sensors used, are mostly of no significant difference when closely compared with the measurement outputs obtained from existing and popular solar energy measurement systems of local brands which are already in use by most solar energy users and consumers in Nigeria. A state of similarity in the outputs obtained from both the CONST and the INDUSM Systems deployed, which also revealed that Current and Voltage maximum outputs during the three (3) days period of the measurement peaked mostly at 1200hour before it begins to decrease. From the observations made, it is important that households and solar energy consumers note that the time range between 0800hours-1200hours is considered the most sensitive and efficient time frame for storage of Current in the batteries.

REFERENCES

[1] J. Amajama, "Effect of Solar ILLuminance (or Intensity) on Solar (Photovoltaic) cell's output and the use of Converging lenses and X or Gamma rays to enhance output performance," International Journal of Engineering Research and General Science, vol. 4, issue 4, 2016, pp. 284 – 289. www.ijergs.org
[2] Wikipedia, "Electricity sector in Nigeria," Encyclopedia, May 5, 2020, Available at: https://en.wikipedia.org/wiki/Electricity_sector_in_Nigeria
[3] J.P. Casey, "Electrifying Nigeria: could solar power one million households?" Power Technology, January 20, 2020. Available at: https://www.power-technology.com/features/electrifying-nigeria-could-solar-power-one-million-households/
[4] E.P. Agbo, C.O. Edet, T.O. Magu, A.O. Njok, C.M. Ekpo, and H. Louis "Solar energy: A panacea for the electricity generation crisis in Nigeria," Heliyon, vol. 7, 2021, pp. 1 – 21.
[5] T.S. Senthil, and C.R. Kalaiselvi "New Materials for Thin Film Solar Cells," IntechOpen, 2019. Available at: www.intechopen.cpm
[6] Financial Nigeria, "Prospects of Solar Power in diversifying Nigeria's Energy Mix. Detail Commercial Solicitors,´ 2016. Available at: http://www.financialnigeria.com/prospects-of-solar-power-in-diversifying-nigeria-s-energy-mix-feature-67.html#sthash.903KeNfo.dpuf
[7] T.T. Onifade, "Renewable Energy in Nigeria: A Peep into Science, A Conclusion on Policy, International Journal for Innovations in Science, Business & Technology, vol. 1, 2015, pp. 49-72. Available at: http://wwhsdc.org/ijisbt/articles
[8] M.S. Ghassan, I. Hashimah, N. Debnath and A. Nadya, "Optimal Light Power Consumption Using LSDR Sensor. 2015 IEEE Int. Symposium on Rob. and Int. Sensors (IEEE IRIS2015), 2015, pp. 144-148.
[9] M.A. Özçelik "The Analysis of the Optical Measurement Sensitivity of the Phototransistor and LDR Sensors," Karaelmas Fen ve Mühendislik Dergisi, vol. 7, number 2, 2017, pp. 545-549. Available at: http://fbd.beun.edu.tr
[10] S.V. Dhole, A. Grover, S. Kumar and J. Kumar "Solar Energy Measurement System Using PIC," International Journal of Advanced Computing and Electronics Technology (IJACET), vol. 4, issue 2, 2017, pp. 10–13.
[11] M.A. Mejias, Y.G. Landera and L.L. Viltre, "Comparison of Maximum Power Point Tracking Techniques Used in Photovoltaic System," Journal of Engineering and Technology for Industrial Applications, vol. 7 number 27, 2021, pp. 4–12.
[12] L.Z. Urrutia, "Measurements and simulations of the performance of the PV systems at the University of Gävle," Master Thesis, Department of Building, Energy and Environmental Engineering, Faculty of Engineering and Sustainable Development, University of Gävle, 2017, pp. 1–66.
[13] G. Perveen, M. Rizwan and N. Goel, "Comparison of intelligent modeling techniques for forecasting solar energy and its application in solar PV based energy system," IET Energy System Integration, vol. 1, issue 1, 2019, pp. 34-51. doi: 10.1049/iet-esi.2018.0011, Available at: www.ietdl.org
[14] W. Setya, A. Ramadhana, H. Restu Putri, A. Santoso, A. Malik and M.M. Chusni, Design and development of measurement of measuring light resistance using Light Dependent Resistance (LDR) sensors, Journal of Physics: Conference Series 1402, 2019, pp. 1- 6.
[15] Stripe "How to Read Solar Panel Specifications," October, 2022. .https://www.solar4rvs.com.au/buying/buyer-guides/how-to-read-solar-panel-specifications/#:~:text=Current%20at%20maximum%20power%20(Imp,conditions%20in%20bulk%2Dcharge%20mode.
[16] C. Honsberg and S. Bowden, "Voltage at the maximum power point – Vmp,", October 2022b, Retrieved from: https://www.pveducation.org/pvcdrom/voltage-at-the-maximum-power-point-vmp
[17] A. Beaudet, "How Do I Read Solar Panel Specifications?, altestore, April 13, 2016. Available at: https://www.altestore.com/blog/2016/04/how-do-i-read-specifications-of-my-solar-panel/#.Y2eGzHbMLIU
[18] R.F. Gusa, L. Dinata, W. Sunanda and T.P. Handayani, "Monitoring System for Solar Panel Using Smartphone Based on Microcontroller," a conference paper presented at 2018 2nd International Conference on Green Energy and Applications, 2018, pp. 79–82.
[19] S.A. Jumaat and M.H. Othman, "Solar Energy Measurement Using Arduino, MATEC Web of Conferences 150, 01007, 2018. Available at: https://doi.org/10.1051/matecconf/201815001007
[20] I. Oladimeji, Y.B. Adediji, J.B. Akintola, M.A. Afolayan, O. Ogunbiyi, S.M. Ibrahim and S.Z. Olayinka, "Design and Construction of an Arduino - Based Solar Power Parameter-Measuring System with Data Logger, Arid Zone Journal of Engineering, Technology & Environment Azojete, vol. 16, issue 2, 2020, pp. 255-268. Available at: www.azojete.com.ng
[21] G.N. Okonkwo and A.O.C. Nwokoye, "Analysis of Solar Energy Parameters in Bida, Nigeria," European Scientific Journal, vol. 10, number 15, 2014, pp. 116–131.
[22] R.V. Pujari, "Solar Efficiency Measurement Using Arduino," International Research Journal of Engineering and Technology, vol. 7, issue 5, 2020, pp. 309 – 315