



EXPERIMENTAL MODEL FOR FIELD ADOPTABILITY OF A PHOTOVOLTAIC – WIND HYBRID ENERGY SYSTEM FOR A SUSTAINABLE DC – AC VOLTAGE GENERATOR

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Abstract

Energy is generally required for motive power, electricity and heat .The commonly conventional source of energy for any utilization in Nigeria is the fossil fuel that is carbon based (CB) in nature and finite in supply. Generation of electrical energy from the conventional source (fossil fuels)

has generated more problems than solution for man. The

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problems include environmental

INTRODUCTION

Energy in an electrical form is essential and has formed a dependable base for almost every modern human endeavor. This trend is compelling scientists and engineers to be looking vigorously into every possible means of electrical energy generation that would not impart more negatively on our planet earth as the continually utilization of the conventional fossil fuels is sending catastrophic result on our earth planet with other attendant problems of corruption along the chain of exploration, transportation, refining, sales and communal clashes over the ownership of oil field amongst others [1]. So the fight against global warming arising from

degradation leading to loss of biodiversity, finite nature of crude reserve, insecurity, corruption of all forms, high cost of processing and economic instability. Similarly, our experience of COVID -19 pandemic and the series of protects where movement of persons and products are being placed on restriction are pointers for scientists and engineers to look into an alternative, renewable, reliable and sustainable energy source(s). The energy from the photovoltaic and wind systems is renewable and respectively electromagnetic and mechanical in nature. For the maximum extraction of energy and its conversion from these two different sources, an optimum operating condition should be established as the energy from these sources is not constant at all times due to unavoidable natural phenomena. Variation in the day and night as a consequence of the earth's rotation affects the intensity of sunshine and wind speed and the earth's revolution that brings about seasonal variation that is responsible for the change in the direction of wind speed. In this work, the dc output voltages of a photovoltaic and wind energy system was cascaded and fed via a rectifying circuit for regulation and stabilization. The coupled dc output voltage was also fed via a maximum power point tracking (MPPT) inverter for de - rectification with the sole aim of obtaining an ac voltage. The halogen lamps and fan used here represent the sun and wind source respectively. The resultant voltage obtained is a multiple of the sum of the two separate voltages from the two energy sources used in this experiment at the optimum operating conditions - highest optical irradiation, maximum wind speed at zero degree position of light source to photo (solar) cell and fan to wind energy generator. It is recommended that for the field implementation of a photovoltaic - wind hybrid energy for the generation of a dc - ac voltage, an automated mechanism for tracking maximum solar intensity radiation, wind speed and position of both the sun and wind direction with respect to the solar cell and wind electric

*generator respectively efficient electric power
be installed for extraction.*

The use of hydrocarbon based fuels for which the world leaders are taking as a priority must be fought by the use of renewable energy resources like solar or wind and both.

The sun and wind are naturally occurring sources of energy that can be readily, easily and reliably converted into direct current (dc) or alternating current (ac) electricity.

The hybrid photovoltaic (solar) wind energy resource has no adverse effect on our environment. It can be installed and operated non - stop in the regions with abundant solar and wind resources even in cloudy session of the days or at night time when solar irradiation is minimal or hampered [2]. Hence, the deployment of this novel technology will give a fantastic, continuous, dependable and reliable electric power that will create a departure from the conventional hydrocarbon based derivable electrical energy generation.

So, the non-availability of solar power for a complete day at the same location and the random effect of wind at all-time [3] are obvious reasons and justification for the deployment of the hybrid power system where each can complement the other [4].

Another justification for this laboratory implementation is the low values of the peak voltages obtained from the solar and wind alone system as reported in [1,5] and the unreliability arising from voltage fluctuations, frequency fluctuations and harmonics associated with irradiation changes of a solar power system configuration . Similar experience can be observed for a wind power system configuration where fluctuations in wind speed make the entire system unreliable [6].

The goal of this research is to cascade the outputs of the stand-alone solar and wind power systems as a complementary system for availability, stability and reliability of electrical power generation at the optimum conditions established in [1,5,] where the effect of solar irradiation and tilt angle dependency of the electric output parameters of a solar cell and the effect of wind speed and relative position of wind source on the voltage current characteristic of a wind power system were studied.

It also explored the conversion of the as obtained resultant voltage that is dc in nature to an ac form using the well acclaimed and robust inverter technology system relying on the full assurance that the ac form does not allow for much energy losses compared to the dc form of electric power transmission.

THEORY

The theory is expected to spell out the underlying principles upon which solar and wind electric powers are extracted from incident solar radiation and wind propelled generators respectively.

The sun as a source of solar energy is a natural nuclear fusion reactor whereby hydrogen atoms are pressed to form a helium nuclide with the release of a huge amount of energy. It releases tiny packets of energy termed photons that travel several miles to the earth approximately 510 seconds and when these photons that are electromagnetic in nature are absorbed by solar cells that are solid state electronic device, electrons are dislodged leading to the creation of holes and electric field is established.

The estimation of the amount of electrical energy in KWh that can be generated by a photovoltaic system [7] is defined by

$$E = A_t \eta H_{g\lambda} PR \quad 1$$

Where; E = Energy in KWh, A_t = Total solar panel area, η = Solar panel efficiency, $H_{g\lambda}$ = Annual average solar radiation on tilted panels without shading, PR = Performance Ratio

Wind energy is a converted form of solar energy which is produced by the nuclear fusion of hydrogen (H) into helium (He) in its core.

Wind results from the movement of air due to atmospheric pressure gradient and it flows from regions of higher pressure to region of lower pressure and as such has an associated energy called kinetic (mechanical) energy [8] defined by:

$$E_k = \frac{1}{2} m \bar{u}^2 \quad 2$$

This kinetic (mechanical) energy impacts a force of rotation on a turbine or wind electric generator that finally produces electrical energy through induced magnetism.

The wind power, P_w , can be obtained from equation (2) as

$$P_w = \frac{dE_k}{dt} = \frac{1}{2} \dot{m} \bar{u}^2 \quad 3$$

Where m = mass of air, \bar{u} = mean wind speed, \dot{m} = wind mass flow rate.

The wind mass flow rate, \dot{m} , can be defined as:

$$\dot{m} = \rho A \bar{u} \quad 4$$

Hence, equation (3) becomes

$$P_w = \frac{1}{2} \rho A \bar{u}^3 \quad 5$$

The mechanical power [7] of a wind turbine is

$$P_w = \frac{1}{2} C_p \rho A \bar{u}^3 \quad 6$$

Where C_p is the power coefficient (0.593, also known as Betz's constant).

The algebraic sum of equations 1 and 6 will give the solar - wind hybrid total energy in KWh as

$$E_T = A_t H_{g\lambda} PR + \frac{1}{2} C_p \rho A \bar{u}^3 \quad 7$$

Equation 7 reveals that the total output energy of a solar wind hybrid power system depends directly on the total surface area of the solar panel, solar incidence radiation conversion efficiency, wind speed and position of both solar panel to optical incidence radiation and wind electric generator to wind direction.

This hybrid system as an integrated energy source is designed and expected to produce non-intermittent electric voltage as opposed to the either solar or wind alone system.

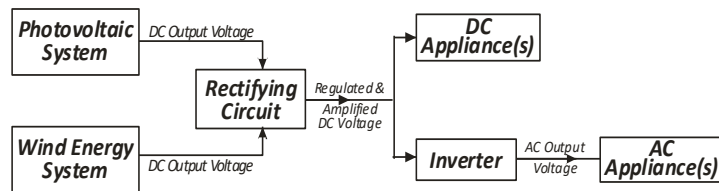


Figure 1: Block Diagram of the Voltage Flow for the Photovoltaic Wind Hybrid DC-AC Electricity Generation System

MATERIALS AND METHOD

The material requirements for this laboratory implementation are a complete photovoltaic (solar) energy system (figure 2), Wind energy device (Figure 3), digital light (lux) meter, digital anemometer, diode, an inverter, digital multimeter and an oscilloscope.

The method of the measurement of output voltage of the two separate energy system, light irradiance and wind speed have been fully described in [1,5].

The separate open circuit voltages obtained from the two energy sources are fed into the rectifying section of the experimental set up and the resultants single regulated and stabilized dc voltage was measured using the digital multimeter. In order to convert the dc output voltage into an ac voltage, a maximum power point tracking (MPPT) is used to de-rectify the dc voltage.

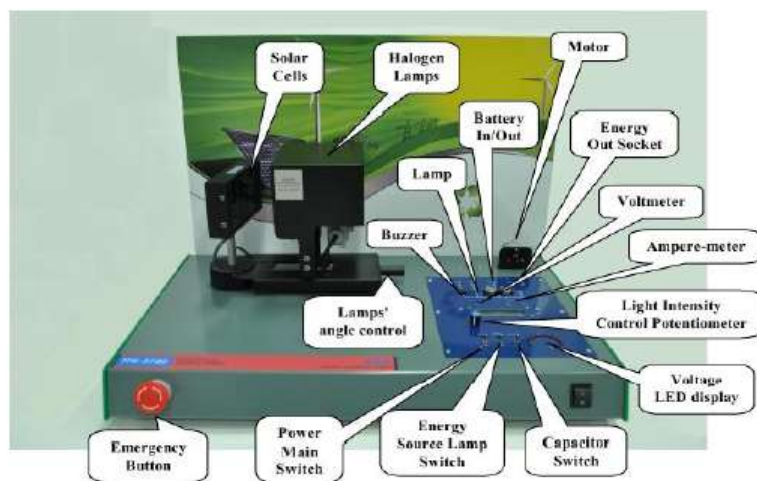


Figure 2: Solar Energy Training Device (TPS-3720)

Source: [9]

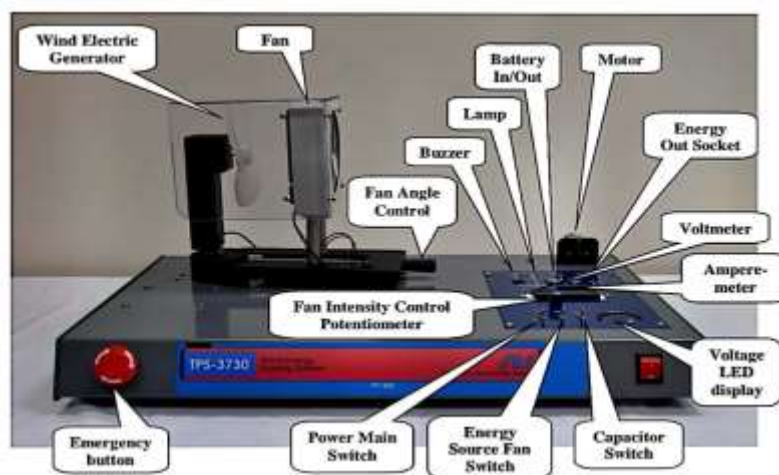


FIGURE 3: Wind Energy Training Device (TPS - 3730)

Source: [9]

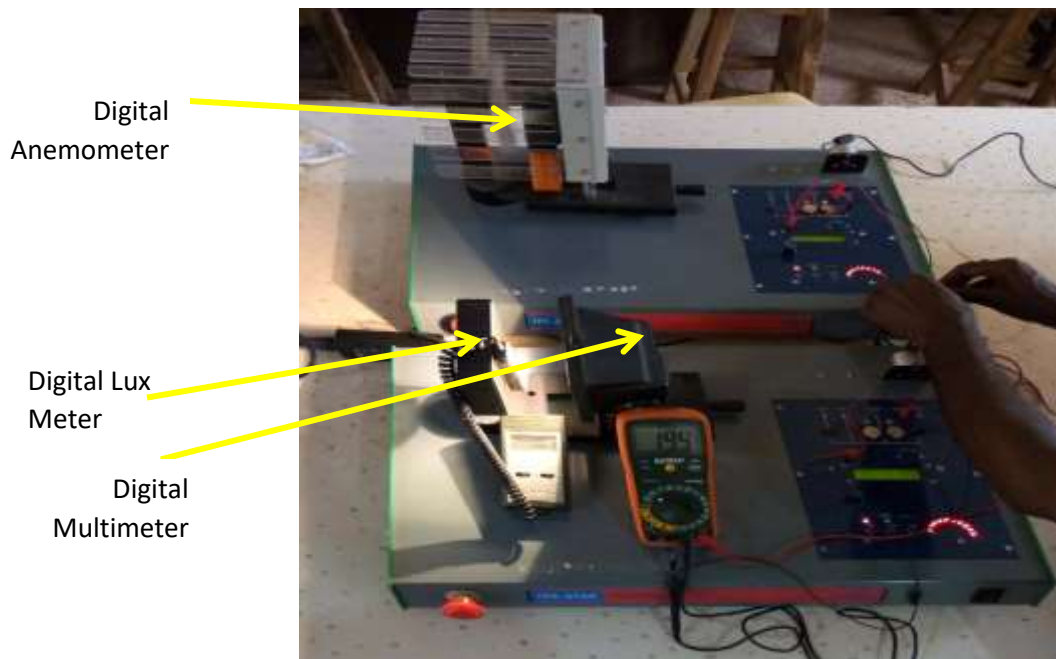


Figure 4: Experimental Setup of the Photovoltaic-Wind Energy Hybrid Electricity System

RESULTS AND DISCUSSION

TABLE 1: Peak Output Voltages of Stand-Alone and Hybridized System

Levels	Stand-Alone Systems				Hybrid System
	Photovoltaic System		Wind System		Resultant Voltage (V)
	Light Intensity (lx)	Voltage (V)	Fan Speed (m/s)	Voltage (V)	
1	42	5.06	4.65	3.56	7.00
2	103	5.19	5.00	3.94	19.40
3	116	5.22	6.56	6.46	20.20

Table 1 is the presentation of the measured open circuit voltage from the photovoltaic machine(TPS - 3720), wind energy device(TPS-3730) and their combined (hybridized) voltage at the peak and optimum operating conditions – zeroed angular position at which the light energy source (lamp) and wind energy source(fan) were immovable.

The level of intensity considered using the potentiometer are 3, 4 and 5 but recorded as 1, 2 and 3 since levels 1 and 2 gave a very insignificant optical irradiance and wind speed.

It is observed that the generated voltage from the three scenarios - photovoltaic, wind and hybrid systems increases with both increasing optical irradiance and rotational kinetic (mechanical) energy from the lamp and fan respectively.

From the table, the hybridized voltage at level 1 was less than the sum of the combined photo - and wind - generated voltage contrary to levels 2 and 3 for which the hybridized or resultant voltages are far very greater than the sum of the two separate voltages. These results suggest that for optimum performance, the solar cell and wind electric generator (wind turbine) should as a necessity be interfaced at a normal position to the source incidence energy such that peak values can be obtained.

Figure 5 is a plot of the as obtained voltage of the separate system, photovoltaic (red colour) wind (blue colour) and hybrid (green colour) against level of intensity of light and wind speed.

There exists an intercept of the photovoltaic system and wind system and large voltages attained beyond this intercept for the hybrid system.

The results so obtained showed that photovoltaic wind hybrid system is not only complementary but guarantees a sufficient voltage amplification at the highest light intensity striking the solar (photovoltaic panel), maximum speed of the fan (wind source) impeding on the wind electric generator and above all the irradiance and wind should be a normal to the solar cells surface and wind electric generator (wind turbine) respectively. The voltage at the output of the rectifying circuit is dc in nature and can be de-rectified or inverted using the maximum power point tracking (MPPT) inverter technology to get AC voltage and subsequent hybrid ac power for heavy loads.

The success of this off grid implementation has provided a platform for field implementation of a solar-wind hybrid power system.

The deployment of inverter technology indeed is necessary for in most cases the need for this kind of hybrid electricity is for power availability for loads or appliances are AC dependent.

It is also very important to mention here that the successful deployment and installation of a solar wind hybrid system will help to electrify not only our rural communities but would create an answer for the ongoing discussion of the departure from fossil fuels source of electricity with its attendant established problems.

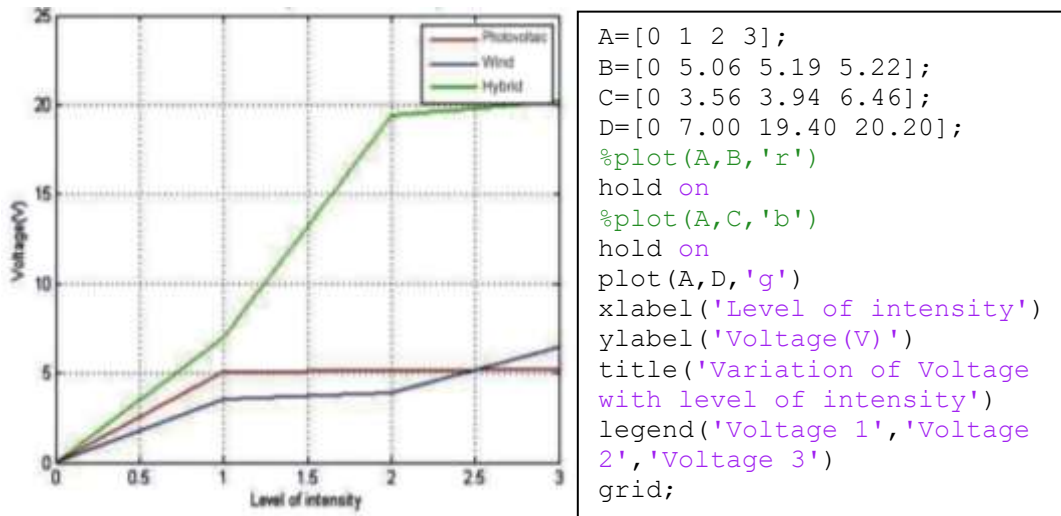


Figure 5: Plots of the Variation of the Peak Output Voltages of the Stand – Alone and Hybrid Systems with the intensity of light and wind speed

CONCLUSION

The implementation of a hybrid energy system for electric energy generation technology as proposed in this work using the photovoltaic and wind energy that are renewable is successfully achieved with the measurable output voltage of tremendous magnitude compared to the sum of the individual voltage obtained from the two energy sources at the established optimum operating conditions.

So, this laboratory implementation has provided a strong model for the field implementation of a robust hybrid solar – wind electric power generation technology that can guarantee the clamour for the departure from the conventional electricity generation using hydrocarbon based resource.

This experimental model has also reviewed that the effect of the position of solar cell, solar intensity, wind speed and the relative position of the solar cell and wind electric generator when properly determined at the

maximum operating conditions, can guarantee a sufficiently high voltage for continuous availability of electric power days and night.

The model also has provided a path way for researcher and industrialist in the field of photovoltaic-wind hybrid electricity generation technology.

REFERENCES

- K.M. Omatola, F. Egbunu, "Measurement and Analysis of the Voltage Current Characteristic of a Model Wind Power System", International Research Journal of Engineering and Technology, Vol.07 Issue 7, pp **3478 – 3483, 2020.**
- J – Y. Li, P – h. Guo,"Preliminary Investigation of a Novel Solar Wind Energy Extraction System", Proc. IMEechE, J. Power and Energy, Vol. 226 Part A,pp **73 – 85,2011.**
- Austin Wasonga, Michael Saulo, Victor Odhiambo, "Solar – Wind Hybrid Energy System for New Engineering Complex – Technical University of Mombasa", International Journal of Energy and Power Engineering, Vol. 4, No.1 - 2, pp **73 – 80, 2015.**
- Manfred Stiebler,"Wind Energy Systems for Electric Power, Einsteinufer 11, D – 10587, **Berlin German.**
- K.M. Omatola, V.I. Sule," An Experimental Analysis of Illumination Intensity and Tilt Angel Dependency of Photovoltaic Cell Electric Output Parameters", International Journal of Scientific Research in Physics and Applied Sciences, Vol. 8, Issue 2, pp **15 – 21, 2020.**
- Payal Pisudde, Ganesh Wakte, "Design and Implementation of Solar – Wind Hybrid System Generation", International Journal of Engineering and Technology, Vol.6, Issue 4,pp **1687 – 1690,2019.**
- Alphesh Desai, Indrajit Mukhopadhyay,"Theoretical Analysis of a Solar PV – Wind Hybrid Power System for Energy Generation in Kutch Region", International Conference on Smart Power Internet Energy Systems ,IOP Publishing,322,012006,pp **1 – 9,2019.**
8. Wei Tong, "Fundamentals of Wind Energy", WIT, Transactions on State of the Art in Science and Engineering, WIT Press, Vol.1 – **46, 2010.**
9. Skill 'G' Nigeria Limited. "Science and Technology Education Training Manual". *Gregory University Press*, Uturu, Abia State, Nigeria, pp **75 – 80, 2009.**