SENSITIVITY ANALYSIS OF HYBRIDIZED WIND/PV ENERGY SYSTEM FOR POWERING TELECOMMUNICATION MAST IN LAGOS SOUTH-WEST NIGERIA

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ABSTRACTS

Power delivery micro-grid of hybridized wind and solar system installations keep growing worldwide. There is a great economic advantage in the use of cleaner renewable energy for power generation in the telecommunication industries, especially in remote areas. This studyanalyses the effect of three wind speed fluctuationsor levels on a hybridizedwind energy system's electricity production for a typical three (3) BTS telecommunication mast using Hybrid Optimization Model for Energy Resources (HOMER)PRO software in Lagos south-western Nigeria as a case study. The economic implication of energy at the different wind speed levels investigated was also derived. From the obtained results, a wind speed of 4, 4.22, and 5 m/s gave an annual electric production of 39,950, 39,050, and 39,250 kWh and energy cost of 195, 192, and ₦175, respectively. This result is useful for the techno-economic operation of hybridized wind/solar system powered by three (3) BTS telecommunication masts.

Keywords: Micro-grid, Hybridized, Renewable energy, Homer, masts, telecommunication.

1. Introduction

A hybridized energy system is akind of system where there is a combined use of two or more energy forms. The resulting overall system from a hybridized system is expected to have a more economical and practical approach(Aberilla *et al.*, 2020). Micro-grids are primarily low voltage distribution networks that use any combination of generation, load, and storage technologies and can operate in a grid mode(Jethava, 2018). Despite the economic and environmental advantages in the use of renewable energy,the intermittent feature is a major drawback in producing this energy steadily(Jahangir *et al.*, 2020). Integration of hybridized renewable energy systems (HRES) with micro-grid to supply telecommunication masts with electricity is a sustainable solution.

Today, the use of wind and solar energyis on the rise. The use of these renewable energy lowers CO_2emissions and eventually the greenhouse effect. The renewable sources available can be used to fulfill the increasing demand for energy with clean energy. Solar and wind alone ~~can~~inherently fluctuate and sometimes lead to low generation and storage for applications,however, renewable energy can still be used as a backup to electromechanical generators.Renewable energycould become a significant source of electricity in years to come because wind and solar energy are abundantly available in many parts of the world. Presently 3% of the world's electrical energy is consumed by information and communications technology(ICT) causing approximately 2% of the CO_2 emissions in the world(Ayang *et al.*, 2016). Telecommunication companies are working on increasing their coverage in Nigeria. As a response to the increase in mobile penetration level in Nigeria which stands at 57.3% in the year 2011 and 65% in the year 2012 (Kanishka, 2014). An increase in telecommunication coverage will lead to an increase in energy demandthat will contribute to more emissionsof greenhouse gasses if powered with synthetic energy.

Hybrid Optimization Model for Energy Resources (HOMER) PRO is a hybrid optimization-modeling tool for rapid assessment for the least cost solution for clean reliable power. HOMER PRO makes use of conventional resources, renewable resources, and storage facility. It is an excellent tool for modeling and gaining insight into each of these resources or any system where ~~you~~ there is need for clean and reliable power. The HOMER PRO software is designed to model all the major components and technologies across ~~this~~ segment range of loads. It evaluates technically and financially the options for off-grid power systems. This is achieved with an approach that combines simulation, optimization and sensitivity (Suresh, Muralidhar and Kiranmayi, 2020). The consideration of a large number of technology developmental options to account for energy resource availability and other variables is available in HOMER software (Dustin *et al.* 2015). The design, optimization, and sensitivity analysis of the micro-grid in HOMER software do not consider only the system requirement but also some uncertain factors such as load and resources variation (Mohd Noor *et al.,* 2016 and Saheed-koussa, 2011)In related literature, Mohd *et al.*, (2016) carriedout feasibility analysis of a stand-alone renewable energy supply for Celcom telecommunication tower in Malaysia using HOMER PRO software. The potential and possibility of adopting solar energy was addressed. Homer was used to design and analyze the system. From the obtained results, a total of 78% of the energy was generated from solar energy sources, while 22% of the energy was produced from generator energy. 78% of the solar energy produced is 9,372 kWh/yr, while 22% of energy from diesel generator is 2,682 kWh/yr. A sensitivity analysis of a PV-diesel hybrid system using HOMER PRO software carried out byJethava, (2018) evaluated technically and financially the options for off-grid power systems. The project gives a model of micro-grid with sensitivity analysis of solar, diesel, generator, converter, load and battery using HOMER PRO software. In addition,Kumar *et al.*, (2016) worked on optimal design configuration using HOMER PRO software presented an ideato design, simulate and analyze stand-alone hybrid renewable energy resources for ATM machine in remote areas. Analysis for power systems for rural electrification in Algeria by(Saheb-koussa *et al.*, (2011)showed that a per unit (kWh) cost of energy for different number of households on four sites varies from 1.49, 2.46, 1.84 and 4.1 USD to 1.19, 2.16,1.33, and 1.52 USD respectively.

The aim of this research is to model and analyze the effect of wind fluctuation on a hybridizedwind/pvenergy system for a GLO telecom mast in South-West Nigeria with the use of HOMER PRO software. Here.

The specific objectives are to:

1. optimize to obtain the energy system configuration with the lowest cost.
2. carry out analysis and gain more insight on the optimal system performance.

2. Materials and Method

2.1 Description Study area

Location of telecommunication towers in requires a complete adherence to the government approved regulation. These responsibilities and standards are under the jurisdiction of Nigerian Communications Commission (NCC), and National Environmental Standards and Regulations Enforcement Agency (NESREA). The emission of radio-frequencies (RF) by the mast is a major guide in the location of telecommunication towers. South-west region as shown in Figure 2, consist of various telecommunication masts of different telecommunication providers. These providers are MTN, GLO, Etisalat, Airtel and Vodacom. Other factors determining the location of these provider's mast in Nigeria are terrain height of the area and surrounding topography, heights and density of the buildings and structures within the area and, proximity to adjacent radio base stations and their signal coverage.

The position Location of the mast and data source generation on the map with position location at cell mid-point latitude 6.25, cell mid-point longitude 3.75 shown in Figure 1.

Figure 1 position location of mast

Data Sources

2.2.1 Solar resources

The solar resource based on NASA surface meteorology and solar energy data based on monthly average insolation was of 4.74 kWh/m^2/day shown in Figure 2.

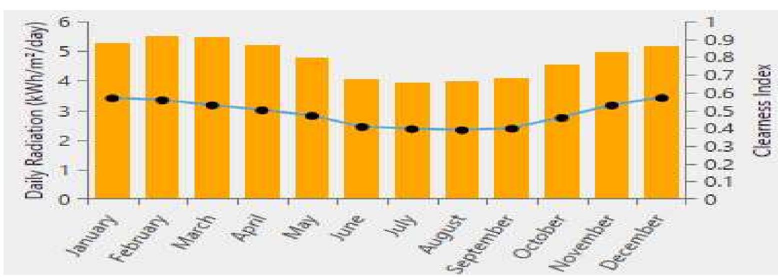

Figure 2: Solar resource (source NASA database)

2.2.2 Wind resources

Based on NASA prediction of worldwide energy resource (POWER) database, monthly average wind speed at the chosen location of the mast was 4.22 m/s shown in Figure 3. The average simulation load obtained at GLO terminal site was 2.27 kW with peak load of 2.72kW using rectifier's reading at the GLO terminal site in Lagos shown in Figure 4.

Figure 3: Wind resource *[source NASA database]*

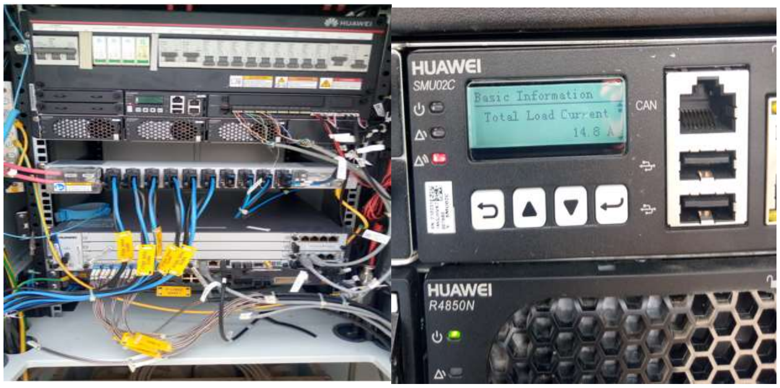

Figure 4:GLO Cabinet Base Band unit.

2.3 Method

HOMERPRO software developed in the US by the National Renewable Energy Laboratory that is capable of modeling and carrying out technical and economic analysis was utilized to model and analyze the energy system. This software combines simulation, optimization, and sensitivity analysis. Its simulation by default uses hourly power to provide energy required to model the components of the system. Components and loads were selected to calculate the energy balance of theHOMER PRO software.

Thehybridized renewable wind turbine consists of solar PV panels andinverter. The solar resource used in this study was based on NASA surface meteorology and solar energy data base. In this modeling two 3kVA wind turbines and chosen a of 5 kW converter were used.

2.4 Theoretical analysis

HOMER calculates the hub height wind speed using the equation (1)(Homer, 2009):

$$U_{hub} = U_{anem}\left[{}^{Z_{hub}}/_{Z_{anem}}\right]^{\alpha} \quad (1)$$

Where:

U_{hub}= the wind speed at hub height of the wind turbine [m/s]

U_{anem} = the wind speed at hub height of the anemometer [m/s]

Z_{hub} = the hub height of the wind turbine [m]

Z_{anem} = the nanometer height [m]

α = the power law exponent.

HOMER multiplies the power value predicted by the power curve by the air density ratio to adjust to actual conditions, as in the equation 2(Homer, 2009).

$$P_{WTG} = (\rho/\rho_o)P_{WTG,STP} \quad (2)$$

Where:

P_{WTG}= the wind turbine power output [kW]

$P_{WTG,STP}$ = the wind turbine power output at standard temperature and pressure [kW]

ρ = the actual air density [kg/m^3]

ρ_o = the air density at standard temperature and pressure (1.225 kg/m^3)

The output of PV array in HOMER PRO is directly proportional to the solar radiation incident upon it. Homer calculates the output of PV array using the equation(3)below(Homer, 2009).

$$P_{PV} = f_{PV}Y_{PV}\left[G_T/G_{T,STC}\right] \quad (3)$$

Where:

f_{PV}=the PV derating factor [%]

Y_{PV}= the rated capacity of the of the PV array

G_T = the solar radiation incident on the PV array in current time step.

$G_{T,STC}$ = The solar radiation incident on the PV array in the incident radiation at standard test conditions.

Homer calculates the clearness index based on the average radiation, the month and the latitude. The clearness index is calculated in HOMER PRO using the formulae $KT = \frac{H_{ave}}{H_{0,ave}}$

Where:

H_{ave}= the average of the monthly radiation

To minimize the total net present cost, the annualized cost of each component with any miscellaneous costs were added together resulting to the total annualized cost of the system. This value is very important because HOMER used it to calculate the total net present cost and the cost of energy. The total net present cost was obtained with equation 4.

$$C_{NPC} = \frac{C_{ann.tot}}{CRF\ (i,Rproj)} \quad (4)$$

Where:

$C_{ann.tot}$ = the total annualized cost

i = the annual real interest rate (the discount rate)

$Rproj$= the project lifetime and CRF is the capital recovery factor.

According to Panneerselva in engineering economics, the capital recovery factor (CRF)was determined with equation 5.

$$CRF(i,N) = \frac{i(1+i)^N}{i(1+i)^N-1} \quad (5)$$

Where:

i = the annual real interest rate
N = the number of years.

Equation 6 was used to calculate the cost of energy COE

$$COE = \frac{C_{ann,tot}}{E_{prim}+E_{def}+E_{grid,sales}} \quad (6)$$

Where:

$C_{ann,tot}$ = the total annualized cost
E_{prim} and E_{def} are the total amounts of primary and deferrable load, respectively, per year,
$E_{grid,sales}$ = the amount of energy sold to the grid per year.

3.0 Resultsand discussions

The optimal system configuration for the energy requirement is given in the table 1 which showed the lowest cost system design.

Table 1: Optimal system configuration energy requirement

Architecture						Cost				System	
PV (kW)	G3	Gen25 (kW)	1kWh LA	Converter (kW)	Dispatch	COE (₦)	NPC (₦)	Operating cost (₦/yr)	Initial capital (₦)	Ren Frac (%)	Total Fuel (L/yr)
26.4	3	25.0	69	3.66	LF	₦200.02	₦51.4M	₦1.84M	₦27.6M	92.8	580
44.2	3		123	2.88	CC	₦202.72	₦52.1M	₦1.39M	₦34.1M	100	0
32.9		25.0	76	3.97	LF	₦207.86	₦53.4M	₦2.14M	₦25.7M	90.9	729
65.9			136	3.43	CC	₦224.85	₦57.8M	₦1.61M	₦37.0M	100	0
	11	25.0	88	14.1	CC	₦315.53	₦81.1M	₦3.48M	₦36.1M	34.0	4,249

The results showed that wind speed chosen as the model to gauge the effects of uncertainty or changes in the model inputs for 4, 4.22, and 5 m/s annual electric production are 39,950 kWh, 39,050 kWh, and 39,250kWh respectively. And the costs of their energy are N195, N192, and at N175. As the hybrid energy system power output varies so also the cost of generating this power changes with the changes in the sensitive variables.

4.0 Conclusion

HOMER result gives the base system with an initial capital of 6 million and NPC of 166 million, while the current system has an initial capital of 27.6 million and NPC of 51.4 million. We can see that the initial capital for the current system is higher than of the base system, the current system will save a lot of running cost and in the long run which makes it cost effective.

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