International Academic Journal of Information, Communication, Technology & Engineering
ISSN: 5741-2605 | Volume 8, Issue 8 | January, 2025 | pages 87 – 94
OTL: 222-3942-8342-542-879-1
Double Blind Peer Reviewed International Research Journal
https://accexgate.com
journalsaccexgate@gmail.com

Performance Analysis of Self Regulated PV System and the National Grid on the Economic Advancement of Small and Medium Businesses in Nigeria. A Case of Commercial Phone Charging Centers in Maiduguri

Abdullahi Mohammed Birma
Department of Electrical/Electronic Engineering, Ramat Polytechnic, Maiduguri

Abstract: *The use of mobile phones has become an integral part of daily life for most people in Nigeria. However, frequent battery depletion often forces individuals to seek charging points, many of which are commercial phone charging centers. These businesses face significant challenges, as the unreliable national grid compels them to rely heavily on petrol-powered generators. Unfortunately, this dependence on fossil fuel results in spending nearly 90% of their earnings on fuel costs, reducing profitability. This research aims to evaluate and compare the cost-effectiveness of installing a photovoltaic (PV) solar power system with the daily operational expenses of running a petrol generator. The study provides insights into adopting solar energy as a sustainable and economically viable solution for phone charging centers.*

Keywords: *Fossil Fuel, Charging Centers, National Grid, Pv Regulated Power System.*

INTRODUCTION

The traditional way of meeting the electricity demand of consumers all over the world consists of three stages: generation, transmission and distribution (Idowu1.*et al*, 2021). As the demand of consumers continues to rise, power utilities are expected to satisfactorily meet this demand.

The objective of every power utility is to supply electricity in a manner that is cost effective and reliable to customers. The benefit of good planning and maintaining of reliable electricity supply to customers is that there will be reduction in the price and interruptions of power supply to customers. Reliability is an important aspect in the planning and design of a distribution system that will function effectively in terms of cost with minimal interruptions to customer loads (Vishalini. *et al*, 2016). An electrical utility company in a deregulated environment has the main objective of increasing the market value of its services to customers. This can be achieved by supplying reliable electricity at lower operational and maintenance cost and the construction of new electricity infrastructures at lower cost. All these factors will help to bill the customers at a lower rate which will likely lead to customer satisfaction (Idowu1.*et al*, 2021). There are so many ways by which a utility company can achieve this objective. One of the effective ways is to employ the use of Distributed Generation (DG).

The overall performance of Nigeria power sector has not yield the expected result. The electricity demand has not been met satisfactorily. As a result, there has been an increased interest to generate electricity using distributed generators that will make the system a reliable one. The network needs to be improved to provide electricity that is reliable and economical to the customers. The integration of distributed generation units into the power network will lessen the duration of outage and the number of interruptions.

The generated electricity that is presently available in Nigeria is not adequate to meet customers demand due to electricity infrastructures that are old and not being properly maintained. As a result, power supply to industrial consumers as well as commercial and domestic customers are not stable. No doubt, the economic growth of the country is negatively impacted. The available generated electricity can only serve less than half of the country population. In order to bridge the gap, the independent power producers (IPP) have turned to the option of using distributed generation technologies (Hachimenum, 2017).

The option of alternative energy resources such as solar, wind, biomass and tidal has attracted energy sector to generate power in large scale. Solar and wind energy systems are being considered as promising power generation sources due to it availability and topological advantages in local power generations. However the drawback common to wind and solar options, is their unpredictable nature and on weather and climatic changes, and the variation of solar and wind energy may not match with the time distribution of demand. it is also prudent that, neither solar nor wind energy can provide continuous supply of energy due to seasonal and periodical variations, fortunately, the problem cause by variable nature of these resources can be over by integrating the two resources in proper combination. Solar generating system consists of PV array, battery bank, inverter, controller and other accessories and cables (Zhou *et al* 2010).

A lot of work has been done on modeling of solar generating system. Q. K. Hassan *et al*, (2011) examined the modeling of solar energy over a portion of a residential community of sandstone in the northwest of Canada. He calculated the actual daily incident solar radiation as function of latitude, day of year, and day light hours. The analysis of the model revealed that the solar energy might be able to support significant amount of the electrical energy needs over the community of interest during the period of April to September every year.

Jeyraj S. (2013) modeled a solar-PV generating system using MATAB/SIMULINK package. In his work, the solar irradiance and cell temperature are taken into consideration, the output current and power characteristics of the PV model are simulated and optimized using the proposed model. This enable the dynamics of PV power system to be easily simulated, analyzed and optimized

PV Array Models

There are various PV array models found in the literature based on the current voltage characteristics of photovoltaic modules. Some authors modeled the system considering the dynamic and static electrical characteristics of the system and some on one or two diode models. Borowy and Salameh (1996) modeled the PV module for average power output with detailed technical characteristics like module series resistance, number of cells, open circuit voltage, maximum voltage, short circuit current, maximum current etc... All the precise data of each manufacturer is difficult to find to use this model. Markvard (2000) modeled the output power from the PV generator in terms of area of a single module, instantaneous PV generator efficiency, global irradiance incidence on the tilted plane and number of modules. This model does not consider other technical factors like open circuit voltage, short circuit current, maximum current and maximum voltage of PV panels and assumes all the losses to be zero. He proposed the PV array model consisting of five parameters as series resistance, non linear temperature voltage effects, non linear effects of the photocurrent, PV module dimensionless coefficient and maximum power point tracking efficiency. In order to calculate the output power from PV modules, the dynamic behavior of the systems has to be calculated and this data is not available in all the technical datasheets of manufacturers. Lasnier and Ang (1990) defined the current voltage relationships based on the electrical characteristics of the PV panel as short circuit current, maximum current, maximum voltage, open circuit voltage. Although this is the simplest model based on maximum power point tracker (MPPT), it is not widely used and not tested for validity. Nikraz et al. (2003) used four parameters to model the electrical characteristics of the PV panel. The result showed that this model is validated for analysis of PV characteristic and best for single crystal and polycrystalline PV arrays.

MODELING OF BATTERY STORAGE SYSTEM

The harnessing of renewable energies presents, however, a further set of technical and economic problems. Unlike fossil and nuclear fuels, which are concentrated sources of energy that can be easily stored and transported renewable forms of energy are highly dilute and diffuse. Moreover, their supply can be extremely intermittent and unreliable, so batteries are required to even out irregularities in the solar and wind power distributions.

Bemardi and carpenter (1995) developed a mathematic model of lead-acid batteries by adding the oxygen recombination reaction. Nguyen et al (1990) presented a model analogous to the flooded type and examined the dynamic behavior of the cell during discharge with respect to cold cranking amperage and reserve capacity.

In general, these models are complex in terms of the expression and number of parameters employed. Furthermore, many of the parameters are determined through measurement of internal components or processes or by extensive experimentation consequently, these models tend to be used to assess the theoretical performance of battery designs and are not practical for simulating the performance of an arbitrary battery at arbitrary operating conditions.

Another common modeling approach is to develop an types of models to describe the power output of wind turbines, where the quadratic expressions are applied for the simulation (Alhusein *et al,*1993).

However, it is generally acknowledge that the hour-by-hour simulation programs require hour-by-hour wind speed data, which may not be available for many locations. In some other researches calculation of wind turbine power is based on electrical load, average wind speed and curve of the wind turbine (Nehrir,2000). Since the calculation based on actual wind speed and direction is time-consuming and sometimes impossible, average wind power curve cannot exactly represent wind turbine power output because the curves can only give the power output of the wind turbine as a function of the average wind sped ignoring instantaneous wind speed variations, and thereby will to some extent, undermine the performance of the wind turbine (Muljadi et al,2001). Nelson, Nehrir and Wang (2006) used combination of fuel cell stack, electrolysis and hydrogen storage tanks as an energy storage system for the hybrid PV and wind standalone systems. They presented the comparison with battery, fuel cell and electrolyze. The results showed that battery system is still superior to fuel and electrolyzed system even though fuel and electrolysis has zero capital cost. They studied the performance of a PV-wind hybrid system for hydrogen production. Although the results demonstrated feasible and reliable solution through hydrogen storage, the improvements on the fuel cell stacks assemble still remain to avoid hydrogen leak. Vanhanen and Lund (1995) used a hydrogen storage system model to improve the performance of the overall energy system. This model requires parameters to evaluate more than the equations and is complex to analyze. Wei, Hongxing and Zhaohong (2008) modeled the battery of the system considering several characteristics as current rate, charging efficiency, self-discharge rate, state of charge, floating charge voltage and battery life time. Although this model provides reliable output, it requires detail technical characteristics of the battery which results complexities. Moreover, the methodology for finding floating voltage is complex since it computes the different coefficients of the battery during charging and discharging mode using second degree polynomial equations. This model uses state of charge condition of the battery and does not require details technical characteristics to calculate the coefficients of battery as open circuit voltage, internal resistance and so on as Zhou et al. The result showed that this model is technically and economically viable. Based on the above literature review, fuel cell and electrolyser are not economically justified technology for the design of hybrid solar wind energy technology. Furthermore, proton exchange membrane and maintenance cost of such membranes are higher in fuel cells and storage of hydrogen is difficult as well. It justifies that battery storage should be used for less economical hybrid system and for the purposes of this study, battery state- of- charge(SOC) model used by Belfkira, Zhang and Barakat (2011) is considered, since it is both technically and financially justified and does not require complex calculations.

The installation of solar PV (SPV) is an environmentally friendly project. Solar energy is free and present in sufficient amounts in almost every part of the world. Moreover, the maintenance cost of solar PV is very low as compared with other conventional sources (Kamran,2018). Different types of the PV modules and system schemes were discussed that would help in planning the different renewable energy systems schemes in (Detrick and Mitchel,2005).

PROBLEM STATEMENT

The epileptic nature of power supply in Nigeria has resulted in people resorting to alternative power supply. The mostly used alternative power supply is the use of generator. With recent subsidy removal however, it makes the cost of fuelling unbearable for most people especially those that uses it for commercial purposes. As a result of that, most businesses have crashed out. This is because greater percentage of what they earned is lost to fuelling and servicing of the generators, thus, leaving them with noting rather than west of time, without any economic achievements. For, commercial battery charging centers that requires continues and uninterrupted power supply, cost of fuelling the generators always gulp about 90% of the generated revue. To overcome this scenario, a renewable energy such as solar power energy that is clean and eco friendly will be the solution to this and of which it has more economic long term benefits.

OBJECTIVE OF THE STUDY

(a) To collect data from different commercial phone battery charging centers in term of energy usage

(b)To analyze the collected data and determine the average energy usage by the commercial phone battery charging centers

(c) To compare the cost of running the energy usage in terms of fuelling a generator and the use of renewable solar energy in the long run.

METHODOLOGY

This research is to be carried out within the Maiduguri metropolis where average fuel consumption per day by commercial battery charging centers will be collected and the cost of running on generator over a period of time will be compared with cost of installing a renewable power source (solar) since the national grid is not stable to provide the much needed power for the smooth running of the business.

A data will also be collected from the commercial battery charging centers about the average load per day so as to ascertain the capacity of solar inverter that will serve purpose.

Data analysis will be conducted with using hardware which involves the use of the following:

1. Solar panel
2. Battery
3. Charge controller
4. Inverter
5. Flexeble cables
6. Power regular

RESULTS

The research shows that the commercial phone charging centers that combine the use of national grid and generators as sources of power supply for the operation of the business spends not less than an average of seven (7) hours on generators. The made it so difficult for them to achieve a significance gain as a substantial part of the money realized is spent fuelling the generator. The table below shows the significant average amount that can be spend on running the generator for a year as compared to installing a solar power source that can be used to cover the same need.

Table 1: Average cost of running generator for a year @ a cost of ₦1,200/liter

S/N	**ITEM**	**QTY**	**UNIT PRICE (₦)**	**TOTAL(₦)**
1	Average cost of fuelling the generator per day	3	1,200	3,600
2	Average cost of fuelling the generator per month	30	3,600	108,000
3	Average cost of fuelling the generator per year	12	108,000	1,296,000
4	Average cost of servicing the generator	12	5,000	60,000
5	Average cost of buying the generator	1	250,000	250,000
6	**GRAND TOTAL**			**₦1,606,000**

Table 2: Average cost of installing a 3KVA inverter

S/N	ITEMS	QTY	UNIT PRICE (₦)	TOTAL (₦)
1	Inverter	1	320,000	320,000
2	Solar plates	6	57,000	342,000
3	Tubular Battery	2	280,000	560,000
4	Cable (6mm^2)	12	6,000	72,000
5	Labor			30,000
6	**GRAND TOTAL**			**₦1,324,000**

DISCUSSION

Table 1 shows that an average sum of one million, six hundred and six thousand (₦1,606,000) can be spend in addition to the exorbitant monthly charges by the PHCN, the polluted noise environment, the unexpected power outage, and a lot of unexpected generated failure that one can face during the work. However, one million, three hundred and twenty four thousand is expected to be spent in installing a 3KVA inverter that is noiseless, more reliable and almost zero maintenance fees. With solar power source, one is in control of when to ON or OFF the power. He/she is also at liberty to use the power beyond the normal period usually spent while operating.

CONCLUSION

The study unequivocally demonstrated the economic viability and sustainability of adopting solar power as an alternative energy source for commercial phone charging centers. Despite the initial investment required for installation, the long-term benefits of reduced operational costs, increased reliability, and minimal maintenance requirements far outweighed the expenses associated with generator usage. By harnessing solar energy, entrepreneurs were able to optimize their business operations, enhance profitability, and contribute to a cleaner environment.

EFERENCES

Adamu Communication Center. (2024). Maiduguri, Borno State.

Al-Ansar Communication. (2024). Maiduguri, Borno State.

Belfkira, R., Zhang, L., & Barakat, G. (2011). Optimal sizing study of hybrid wind/PV/diesel power generation unit.

Bernard, D. M., & Carpenter, M. K. (1995). A mathematical model of the oxygen-recombination lead-acid cell. *Journal of the Electrochemical Society*, *142*(8), 2631-2641.

Borowy, B. S., & Salameh, Z. M. (1996). Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system. *IEEE Transactions on Energy Conversion*, *11*(2), 357-373.

Detrick, A., & Mitchel, L. (2005). Performance evaluation standards for photovoltaic modules and systems. In *Conference Record of the Thirty-First IEEE Photovoltaic Specialists Conference* (pp. 609-617). Lake Buena Vista, FL, USA.

Hachimenum, E. (2017). Distributed generation in Nigeria: Post-privatized power sector—challenges and prospects.

Hassan, Q. K., Coops, N. C., & Chen, Z. (2011). Solar energy modeling over a residential community in the city of Calgary, Alberta, Canada.

Idowu, S. O., Abolarinwa, J. O., & Adewale, R. A. (2021). Reliability improvement study of a distributed network with distributed generation.

Jeyraz, S. (2013). Photovoltaic module modeling using MATLAB/Simulink.

Kamran, M. (2018). Current status and future success of renewable energy in Pakistan. *Renewable and Sustainable Energy Reviews*, *82*, 609-617.

Lasnier, F., & Ang, T. S. (1990). Sensitivity of solar photovoltaic panel efficiency to weather and dust over West Africa: Comparative experimental study between Niamey (Niger) and Abidjan (Côte d'Ivoire).

Markvard, A. (2000). Techno-economic analysis of a PV/biomass/fuel cell energy system considering different fuel cell system initial capital costs.

Muljadi, E., & Butterfield, C. P. (2001). Pitch-controlled variable-speed wind turbine generation. *IEEE Transactions on Industry Applications*, *37*(1), 240-249.

Nelson, J. L., Nehrir, M. H., & Wang, C. (2006). Unit sizing and cost analysis of stand-alone hybrid wind/PV/fuel cell power generation systems. *Renewable Energy*, *31*(10), 1641-1656.

Nehrir, M. H. (2000). An approach to evaluate the general performance of standalone wind/photovoltaic generating systems. *IEEE Transactions on Energy Conversion*, *15*(4), 433-439.

Nguyen, T. V., & White, R. E. (1990). The effects of separator design on the discharge performance of a starved lead-acid cell. *Journal of the Electrochemical Society*, *137*(10), 2998-3004.

Nikraz, H., Murthy, S., & Yap, S. W. (2003). Electrical hazard analysis during assembly, integration, and testing of solar arrays.

Vanhanen, M., & Lund, T. (1995). Feasibility study of a metal hydride hydrogen store for a self-sufficient solar hydrogen energy system.

Vishalini, D., Perumal, R., & Santhakumar, S. (2016). Reliability improvement study of a distributed network.

Wei, H., Hongxing, Y., & Zhaohong, X. (2008). Battery behavior prediction and battery working states analysis of a hybrid solar–wind power generation system.

Yang, H. S., Lu, L., & Zhou, W. (2007). A novel optimization sizing model for hybrid solar-wind power generation system. *Solar Energy*, *81*(1), 76-84.

Zhou, W., Yang, H. S., & Fang, Z. H. (2010). Current states of research on optimum sizing of standalone hybrid solar-wind power generation.