Original Research Article

Centric Data Analytics Framework for Solar Energy Efficiency in the rural settings

Abstract

Climate change periodically, and one of its natural causes is solar variation. Solar energy generation is now gaining more attention in developed nations, and its usefulness is becoming acceptable in rural settings. This research focused on Centric Data Analytics Framework for Solar Energy Efficiency called DAFSEE to solve power supply deficiency *in resource-limited settings in Kwara State. Statistically,* resource-limited regions feature a low population with a shortfall of social amenities. Significantly, households in urban areas have more electricity consumption than rural ones, making solar energy more relevant. The researcher then determined the efficiency of solar energy in the selected regions over time using an experimental study using cloud computing to create a dataset in six geo-locations in Kwara State. A predictive model was adopted and yielded 98.99% from the recurring analytics of the installed solar cells. The outcome of this study suggested best practices to sustain renewable energy in the area across all seasons. The study provides a starting point to distil policy implications for a centric analytics framework of improving rural electrification relevant for collective resource-limited settings across Nigeria.

Keywords: Centric Data, Energy Efficiency, Solar Energy, Solar Cells

Introduction

Climate change results from natural phenomena and the nature that affect the changes that cannot be eliminated but can be studied [1]. Many researchers have published many research works on the trends of environmental change that have influenced solar energy. These environmental changes now are categorized into two, climate change and solar radiation [2]. People living in some Local Government Areas (LGA) in Kwara State, Nigeria, have been facing down trends of electrification credit facilities in the seventeen (17) LGA(s) in the State. The bottleneck in the line of grid expansion poses significant challenges in rural settings because of the rapidly growing population. Rural Settlement all over Nigeria suffers from an overwhelming deficit in access to reliable electricity [3]. The use of non-renewable energy resources is significantly low in a low resource settings compared with mega-cities [4]. While the impact of using renewable resources for producing electricity is increasing in developed countries [5].

The problem in mind according to the researcher is that; the radiant energy from sunlight has proven not efficient in the research domain, provided that household energy consumption is high compared with available energy generated from solar cells. however, the shortfall of energy consumption affects social life in the rural settings, and this determines the needful to decide on the quantity of energy required for the sustainability the livelihood. This study is viable for future analytics and assists renewable vendors and stakeholders in deciding on electrification capacity that would fit rural settlements. This Possibilities to provide an alternative to shortfall grid supply will be visible and accepted in the results followed by stakeholders. To analyse whether the DAFSEE result is efficient and can generate sufficient solar radian (energy), therefore can improve the sustainability of rural electrification using mini and micro sub-stations if adequately implemented in the villages.

However, this research is to study the efficiency of solar energy in a low-resource setting over time then determine how rural sentiment can rely on solar energy as an alternative to the grid system and predict sustainability and efficiency using a research design model.

Solar panels are becoming more popular across the globe. The people living in low-resource settings could see the long-time benefit due to poor user experience and lack of technical know-how [2], [5]. The research charged with the responsibility to determine factors hindrance the sustainability with the approach of real-time monitoring of radiant energy in some regions n Kwara State. This required forensic analysis through laboratory experiments in the research study and a couple of supervised ethics to yield results.

2.0 Literature Review

The solar panels produce Direct Current DC through radiation of energy from sunlight. The form of fuel is then converted into electrical energy and stored the point in an accumulator [5]. Centric data analytics is now gaining global acceptance when industries and organisations look inward to how digitalisation is used and transformed the business products line. Data capturing is one of the essential requirements for potential solar areas; most data span 30–40 years, and using unit root and Johansen co-integration tests with low data points provides low statistical testing power [6]. In the scenario, where are looking at the extended analysis using total factor productivity in African manufacturing to examine the relationship with infrastructure in the six Local Government Areas in Kwara State [7]. Looking at the author's overview for a recent review of support mechanisms for renewable electricity, the World Bank uses several criteria to support electrification projects. These include cost-effectiveness to connect, distance to a grid, affordability and population density.

However, as the example of Villages around Abuja, Nigeria, shows, the real value of supplying efficient solar energy at a locality with off-grid technology lies in its ability to draw on local resources and help develop local potential [7].

2.67 million Households in Kwara State, according to the 2006 censor, do not have access to electricity, resulting in an overall electrification rate of about 33 per cent. The access rate for a household in urban settle suffers inadequate grid supply of about 3-5 hours on up-line within 24 hours, and this declined state of the economy. The access deficit is even further pronounced in rural areas in all seventeen local governments in the Kwara State, such as Offa, Irepodun, Oyun, Asa and others, as shown in table 1. In addition, considering energy consumption deviation and patterns, household access to electricity varies considerably in the rural areas (villages and hamlets) of over one million people residing in the targeted 6 LGA [8].

Selected six Local Government Area on Study		
Asa	Isin	Offa
Oyun	Irepodun	Oke Ero

Table 1: Selected LGA study

The off-grid substation for electrification in the rural setting is not coming up in Kwara compared with States like Lagos, Lokoja, Kogi, Port Harcourt, Enugu and others. Still, only a few individual residences in urban areas have adopted renewable energy as an alternative source. The solar radiation is very high and varies across all local governments in the target State. The researchers take advantage of the variance to determine the possibilities for efficient use of photovoltaic technology to produce electrification in the sub-regions under each local government [9]. These sub-regions are target areas, and the study utilised the region when required to implement off-grid supply or be used as a natural alternative to the grid supply. Utilising the energy stored in batteries is a prime factor that determines the efficiency of solar in the target region.

Uganda tops African countries with well-developed electricity regulatory frameworks - ERI 2020 report Nigeria remains Nigeria remain the lowest bottom in the electric power frameworks. The energy requirement will increase by 200% from FY 2015 to FY 2030 9 [10]. Therefore, to meet these growing demands, the exploitation of renewable energy sources like solar and wind is crucial. So far, only 45,917 MW of renewable energy have been installed and utilised. The Business vendors in Nigeria will likely target about installation worth 175 GW of renewable energy by the end of 2022 [9]. The employment of these renewable energy sources has become Increasingly substantial, attractive and cost-effective. But the erratic nature and dependence on climatic changes hinder properly utilising these resources. Due to the reliance on variable sunshine hours and changing wind speeds, these resources do not produce productive the energy throughout the year [11] But, mixing two or more energy resources can mitigate these problems.

Fig.1 shows the block diagram of a hybrid renewable energy system. In this system, solar energy is the input, and a battery is the backup energy source during the non-availability of power. A diesel generator can serve the load if solar and wind energy is unavailable. It can also do the load during peak hours.

Many renewable energy systems have been installed in the last decade, resulting in new technologies that can challenge conventional energy systems. In the past few years, a series of work on renewable energy has been carried out, including developing efficient converters, maximum power point trackers (MPPT), improved batteries and optimal design and control of renewable energy systems [4].

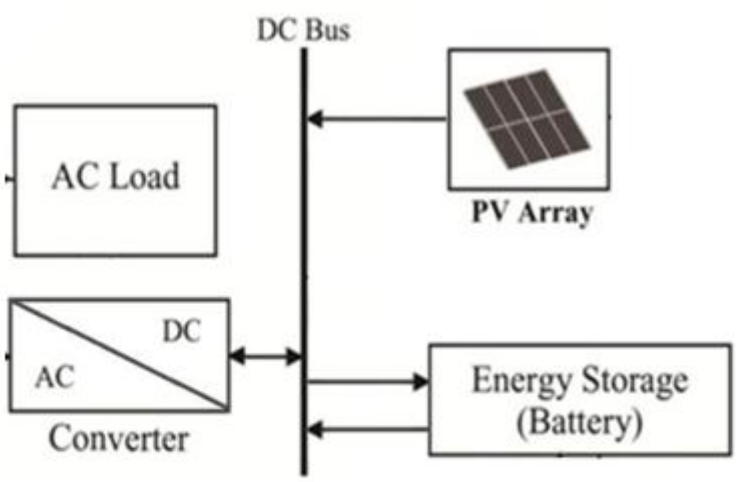

Figure 1. Concept of Solar energy system

2. Pre-feasibility analysis of solar energy systems

The climatic conditions determine the availability of solar energy resources at that specific location. Pre-feasibility studies depend upon climatic data such as wind speed, solar irradiance and load demand for that particular location. To calculate a system's performance, then appropriate weather data is needed. The weather conditions may vary from one place to other. The advantage of hybrid energy systems is inherent in exploiting several sources simultaneously, raising the system's overall efficiency.

The weather patterns at different locations play an important role in designing and implementing the solar-wind hybrid energy system. Many researchers consider the metrological station data for pre-feasibility study, design and optimization of renewable energy systems. The feasibility and performance studies confirmed studied to evaluate options of hybrid PV- wind energy systems; an approach castigated to inspect the feasibility of hybrid PV-wind energy systems using artificially collected solar radiation and wind speed data [5].

3. Photovoltaic system

Solar energy is an abundant source of renewable energy on earth. It is a non-polluting, freely available renewable energy source; therefore, it helps reduce greenhouse gas emissions [8],[9]. Solar energy utilizes either solar photovoltaic (SPV) or solar-thermal technologies. In a solar PV system, solar radiation from the sun is converted into electricity using solar photovoltaic cells. The most commonly used materials for PV cells are mono and poly-crystalline silicon. The solar energy that utilized in off-grid or grid-interactive mode to serve electricity. Solar PV technology devices name used in different areas such as rooftop solar plants, telecommunication, transportation, refrigeration and most specifically in remote and rural electrification.

An off-grid solar PV system detailed in Fig 2 shows that the SPV system consists of solar panels comprising many solar cells, a charge controller, battery bank and inverter to serve the AC load. MPPT trackers extract maximum power from the solar panels [11],[12]. The charge controller is significant for battery management and prevents the battery from overcharging and over-discharging. The inverter converts DC power into AC power to supply the AC load.

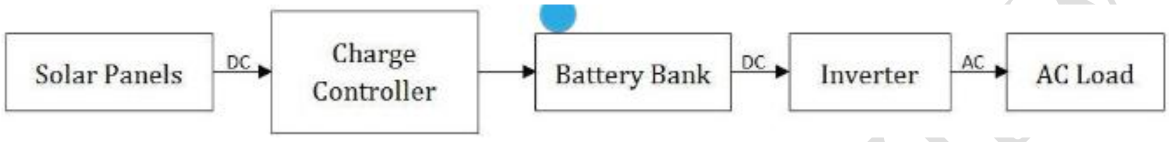

Figure 2. Block diagram of off-grid solar PV system

To harness maximum output from the wind energy systems, then a proper site selection is required to do feasibility studies such as technical viability and economic feasibility need to be performed [11],[13]. Researchers have also proposed several modelling techniques for wind energy conversion systems (WECS). [7][14], presented the horizontal furling method for small wind turbines and compared the two control methods, tip speed ratio and hill-climbing, for maximum power output extraction.

4. Centric Analytic framework results and findings

The study presents the Centric Analytic framework (CAF) in Fig.1. The model system has been designed and modelled in Optimization Model for Electric Renewable (HOMER) platform. The modelling method includes site identification, load identification and resource assessment, technology selection, system constraints, optimization and economic analysis [10],[15].

At first, the geographical details of the proposed site remain the central collected. The energy demand of the selected area is estimated further after calculating energy demand, the potential assessment and technology selection of renewable energy sources in the proposed and investigated. Then, the mathematical model of system components, including renewable energy sources like solar and wind, load demand, energy storage system and converters, is developed. Finally, the model is optimized to evolve an optimal model for energy supply in the study site.

The study occurred in Offa and Ijagbo, Kwara, with a latitude and longitude of 8.1393° N and 4.7174° E, respectively. In this study, the approximate measured average annual consumption recorded 282.76kWh/day with a peak load of 39.65kW. Fig. 3 shows the monthly average load profile. Fig. 4 shows the yearly daily average solar radiation and clearness index for the proposed location and is estimated to be 5.34 kWh/m2 and 0.619, respectively. The average wind speed is about 4.73 m/s measured at 50m Anemometer height.

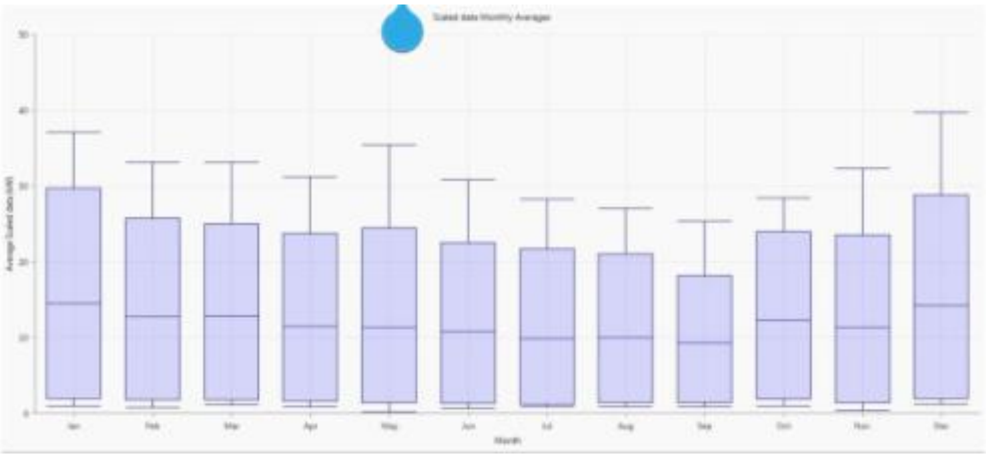

Figure 3. Average monthly load demand

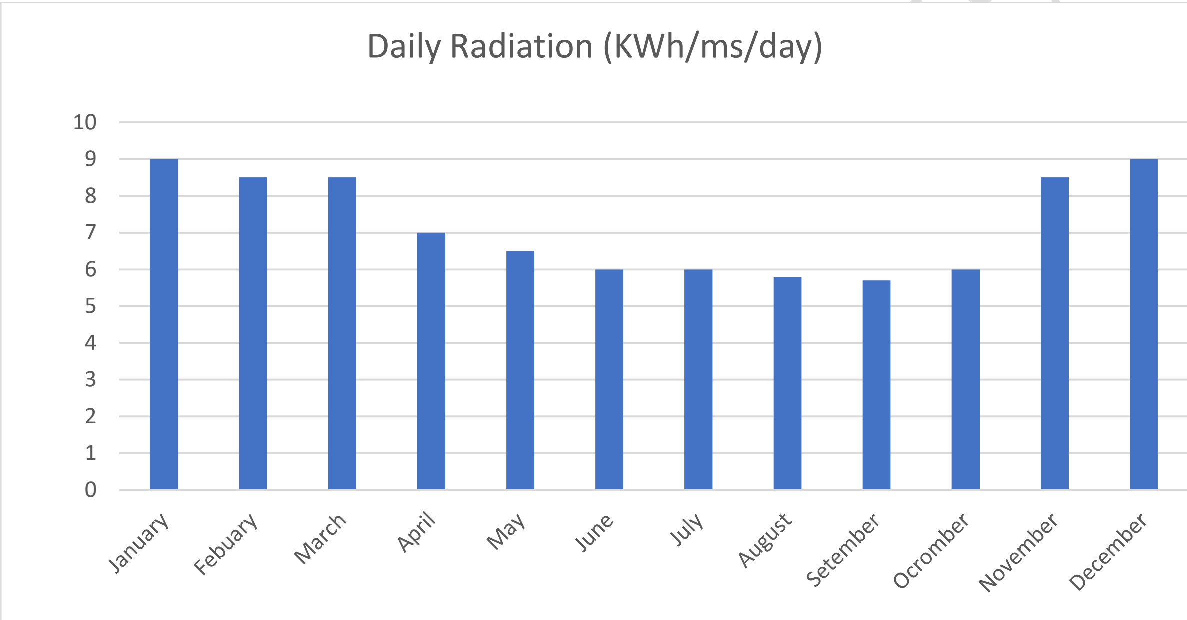

Figure 4. Average daily solar radiation and clearness index

Table 2 represents the overall architecture of the system. A PV array of 50kW, then solar of 10kW, was used for power generation.

Table 2. The system architecture of the proposed system

PV	GenericflatplatePV	50kW
WindTurbine	Generic10 kW	2
Generator	10kW	20kW
Battery	TrojanIND23-4V	96 strings
Converter	SystemConverter	40kW
DispatchStrategy	CycleCharging	

The selection and sizing of different components of a hybrid renewable energy system will be carried-out using HOMER software [15]. Thousands of simulations are carried out by

the software and result in the best possible design for the system in terms of feasibility and optimal economic cost. For the PV capacity of 50kW, two wind turbines of 10kW each, 20kW
diesel generator, 40kW converter and 96 batteries, the Total Net Present Cost (TNPC), Cost of Energy (COE) and operating cost are $3,98,881, $0.299/kWh and $6,117
respectively. Fig. 5 shows the monthly average electricity production. Table 3 shows the Net Present Cost (NPC) cash flow summary by component type. The total NPC of the proposed system is $3,98,881, including all the capital costs, replacement costs and O&M costs.

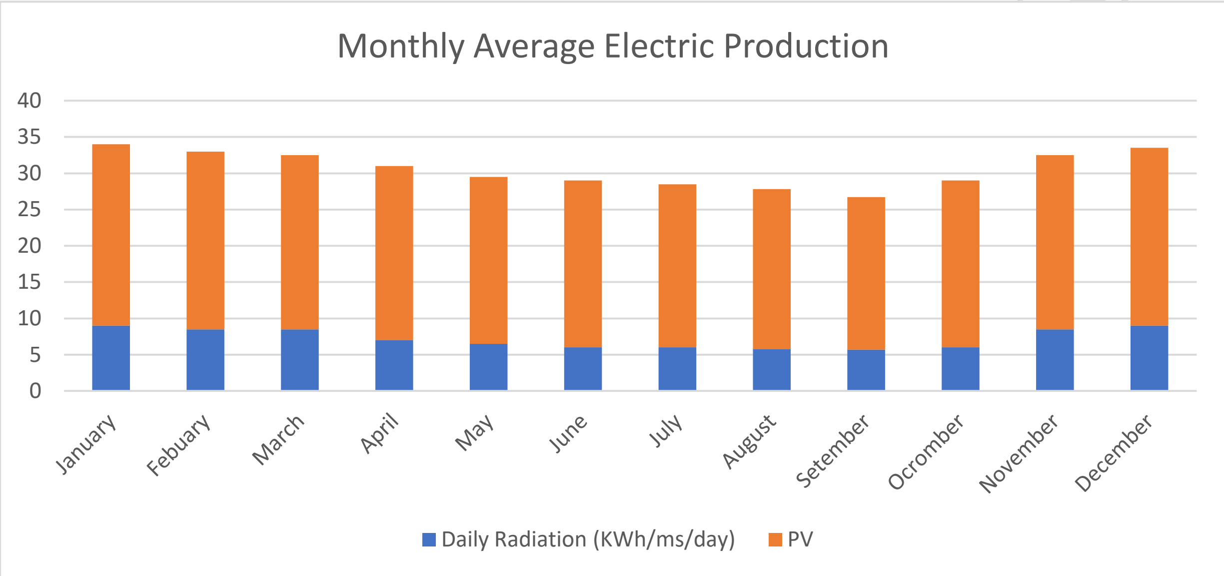

Figure 5. Monthly average electricity production of renewable energy system

Table 3. Net present cost by component type

Component	Capital ($)	Replacement ($	O&M ($)	Fuel (L)	Salvage ($)	Total ($)
GenericflatplatePV	2,50,000	0	6,464	0	0	2,56,464
Generic10 kW	2,000	6,695	388	0	-3,773	32,310
10 kWGenset	6,000	1,481	6,694	54,708	-538	68,345
TrojanIND23-4V	28,800	9,887	0	0	-4,577	34,110
Converter	6,000	2,037	0	0	-383	7,653
System	3,19,800	20,100	13	54	-9,272	3,98,881

6. Challenges and future scope

Currently, the research identifies the use of coal to generate electricity in Off/Ijagbo despite being limited, non-renewable and emitting enormous CO2 that contributes to global warming. So using renewable energy resources alone or mixing them with some other aid to generate power can reduce CO_2 emissions[16],[17]. Still, there are several challenges to the employment of renewable energy systems. Some probable solutions are:

ü HRES have much accomplished in the last couple of years. Even though there are still specific challenges regarding their efficiency and optimal performance. Renewable energy sources demand cutting-edge technology to harness maximum helpful power.

ü The significant impediment to using solar photovoltaics is its poor efficiency. It's enhanced by using efficient materials for the fabrication of solar cells.

ü The grid interconnection power quality of the renewable energy systems is of significant concern and needs cooperative R&D.

ü The switching losses associated with power electronic converters should be minimal.

ü The capital cost of renewable energy sources is a significant problem that needs serious attention. The affordable usage can eventually allow residential and industrial consumers to use such systems.

Future, leading-edge technology development is required to boost the overall efficiency of hybrid energy systems. The widespread use of hybrid renewable energy systems will circumvent the energy issues and ensures a clean and bright future for subsequent generations.

7. Conclusion

In this paper, a Centric Data framework with the constituent of solar
for a rural site is designed and implemented to suit the research objectives. The proposed system's economic analysis enables the window reality of the adaptive prototype model. However, the issues in terms of efficiency, power quality, stability and economic feasibility have hampered the use of these resources. Future R&D efforts can conquer these issues by implementing renewable energy systems. Hybrid renewable energy sources have immense potential to meet the country's increasing energy demands and create a sustainable future.

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