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Optimization of Power Generations in Niger Delta

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Abstract
The importance of optimizing electricity generation, especially in the developing countries cannot be overemphasized because it helps to improve electricity access, economic development and energy sustainability. Nigeria is a developing country with an acute electricity problem. The country is blessed with rich renewable energy resources. However, most of these resources are yet to be exploited. A look at the energy sector in Nigeria suggests that for the country to be energy sufficient, it must embrace other energy sources in its energy mix. This study was aimed at investigating the cost of optimizing power generation in Niger Delta. The evaluations of combinations of different specific power source options were used to determine the least-cost energy pathway for the optimization of the region's power source. The optimization approach conducted was a sequential search for a possible option for power generation. The results show that grid is the best choice economically, because it attracts the least cost but the problem is that, the grid is not reliable and not efficient within the nation. From an environmental perspective there were significant benefits in using Hybrid Solar-Grid power. Some of the benefits include no carbon emission, no noise and environmental friendliness. It was observed that the use of generator requires very huge capital and it also has some environmental challenges such as carbon emission, noise, etc. From the results, Niger Delta could save 119,731kg of CO_2 emissions annually by removing backup generators and by optimizing Solar-Grid and wind power source.

Keywords: *Optimization, Power, Generation, Solar*
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1. Introduction

The Nigerian power sector for a very long time has been a nightmare, difficult, agonizing and devastating both to the government and the general population. A populace of around 170 million individuals with the greater part of them living without electric power supply (Akpan, 2015), absolutely presents a cataclysmic circumstance for financial and social improvement of the country and individuals. Decentralization of power sector in Nigeria has brought to the fore the need to investigate power generation alternatives for the improvement of power capacity, dependability, and accessibility. One of such alternatives is the change from generalized power generation to generation at the dispersion level. Installed generation is an arising idea in the power sector, which addresses great substitutes for power supply rather than the customary incorporated power generation idea, however this is moderately new as a feasible alternative in Nigeria.

Nigeria is a tremendous country with an aggregate of 923,768 sq km, of which 910,771 sq km (98.6% of complete territory) is land. The country comprises of six Geo-Political Zones partitioned into 36 states and the Federal Capital Territory (FCT). To give sufficient ability to guarantee that Nigeria is among the industrialized countries, three basic exercises should be successfully accomplished (Onohaebi and Omorogiuwa, 2014): (a) sufficient power should be created, (b) power should viably be sent to all parts of the country, and (c) power should be proficiently circulated to the customers.

Since improvement and populace development in any nation are profoundly powerful, these three exercises should likewise be painstakingly tended to in a dynamic, innovative and coherent way. Sufficient power supply is essential to any country's development, and power generation, transmission and dispersion are capital-escalated exercises requiring gigantic resources of both funds and capacity. In the common conditions in Nigeria where accessibility to fund is logically lessening, inventive and imaginative solutions are important to address the power supply issue.

Power supply in Nigeria traces all the way back to 1886 when two (2) little generating sets were introduced to serve the then Colony of Lagos. By an Act of Parliament in 1951, the Electricity Corporation of Nigeria (ECN) was set up, and in 1962, the Niger Dams Authority (NDA) was likewise settled for the advancement of Hydro Electric Power. In April 2005, Agips 450-MW plant came online in Kwale in Delta State. The NNPC and Joint Venture (JV) accomplices, Conoco Phillips and Agip gave $480 million to build the plant. Independent Power Producers as of now under development incorporate the 276-MW Siemens station in Afam, Exxon Mobils 388-MW plant in Bonny, ABBs 450-MW plant in Abuja, and Eskoms 388-MW plant in Enugu. A few state governments have additionally charged Oil producing companies to increase generation including Rivers State, which contracted Shell to extend the 700-MW Afam station. The Nigerian government additionally endorsed the development of four nuclear energy stations (Ukoko et al., 2014), with a consolidated limit of 1,234 MW to meet its generating objective of 6,500 MW in 2006. Likewise, fourteen hydroelectric and Natural Gas plants were gotten ready for kick-up, but unfortunately never moved beyond that point. Chinas EXIM Bank Su Zhong and Sino Hydro have focused on subsidizing the Mambilla (3,900-MW) and Zungeru (950-MW) hydroelectric ventures. Additionally, NNPC, in a JV with Chevron were to build a 780-MW gas-terminated warm plant in Ijede, Lagos State. The task was relied upon to be developed in three stages, with the initial two stages expected to have limit of 256 MW each (Momoh, 2001). The plant was required to be operational in 2007, but never started.

With the development in industrialisation and populace, there has been an expanding interest for electric energy in Nigeria. Generation of power in Nigeria is principally from three hydro-electric power stations, steam and gas warm stations. The greater part of these offices is being overseen by the Power Holding Company of Nigeria (PHCN), an administration possessed service organization that co-ordinates all exercises of the power sector from creation, transmission, appropriation, to marketing and sales (Ibe and Okedu, 2009). Agbauduta (2018) announced that Nigeria's monetary misfortunes from problematic influence generation and supply was put at an amazing N66 billion (comparable to $0.55 billion). He distinguished the absence of qualified maintenance engineers, non-accessibility of required extra parts and the unsteadiness of the public framework among different factors as being answerable for the poor performance of these power stations.

2. Materials and methods

2.1 Materials

This research is centered around all the Niger Delta States in Nigeria. Five (5) advancements were considered for this research and these are Grid Power, Solar Photovoltaic, Wind turbine, Wind Speed and Hydro Plant. Climate information are significant components for pre-feasibility investigation of inexhaustible renewable energy framework for a specific zone, hence, the information for solar and wind assets were gotten from the NASA Surface Meteorology and Solar Energy site. HOMER programming software was used to reproduce the model. HOMER programming was utilized to run the reproduction of this exploration on the grounds that HOMER takes into consideration greater adaptability of research purposes in power algorithm. HOMER program simplifies the task of assessing plan of power framework utilizing improvement calculations. In this exploration, the framework measuring was done utilizing HOMER-streamlining and reenactment programming device for parts of the numerical modeling was driven by HOMER. The outcomes from the improvement by the product were utilized as perspective (analysis). HOMER's improvement calculation computes the number of and what size of every segment to be utilized for the cross-breed framework at the least expense conceivable. The chosen information was utilized to determine the streamlining. The existence cycle costs and assessed power supply were determined for almost hundred distinctive crossover framework segment blends dependent on contrastingly measured PV exhibits, estimated wind turbines, hydro turbines and matrix framework.

2.2 Proposed method

This part presents the novel techniques created to be utilized in the optimization interaction. The proposed technique was the Best Technology Determination Method (BTDMD) and Electricity Demand Determination Methods (EDDM). This strategy was used because it has what it takes to decide the best power source innovation for an area and power demand of an area.

Best technology determination method (BTDM)

To decide the innovation for power sources establishments, Equations (1) – (6) were defined. In this manner, the relative power source capability of innovation in area I, Pij, has been shaped, as given in Equation (1).

$$\bar{P}_{ij} = \frac{P_{ij}}{\frac{1}{n}\sum_{i=1}^{n} P_{ij}} \quad (1)$$

where P_{ij} is the power source potential regarding the measure of solar radiation (for sun-oriented asset potential), or the wind speed (for wind asset potential), and so forth of innovation j in area I. It ought to be noticed that, i=1...n, and j=1...m where n is the quantity of areas, m is the quantity of technologies and 1n$\sum ni$ 1P_{ij} is the normal power source capability of innovation over all areas. Hence, Equation (1) gave the relative (standardized) capability of every innovation in a given area. This condition was developed such that it would permit examination of various energy assets. As Pij is unit less, it tends to be utilized to analyze the possibilities of various energy assets in every area, and correspondingly it tends to be utilized to decide the best area for every innovation (fundamentally the area having the most noteworthy measure of relative potential). To decide the best/most exceedingly terrible innovation/asset for every area, and best/most exceedingly terrible area for every innovation/asset, there is a need to frame a unique matrix. In this manner, PN matrix was framed as shown in Equation (2).

$$\text{PN} = \begin{matrix} \overline{P_{11}} & \overline{P_{12}} & \cdots & \overline{P_{1m}} \\ \overline{P_{21}} & \overline{P_{22}} & \cdots & \overline{P_{2m}} \\ \overline{P_{31}} & \overline{P_{32}} & & \overline{P_{3m}} \\ \vdots & \vdots & \cdots & \vdots \\ \overline{P_{n1}} & \overline{P_{n2}} & & \overline{P_{nm}} \end{matrix} \quad (2)$$

PN is the near likely framework, indicating relative possibilities of all technologies in all areas. PN was used to figure out which areas ought to be supported for every innovation and which advancements ought to be supported for every area. Model from Equation (2), the base of the relative force source possibilities recorded in line I, prompted the innovation with least potential (most exceedingly terrible innovation) in area I. Also, the base of the near RE possibilities recorded in section, prompted the most exceedingly terrible area for a given innovation as introduced in Equations (3) and (5) individually. By utilizing this grid, the accompanying arrangement of factors can be characterized.

$$WT_i = \min_j \{\overline{P_{ij}}\} \quad \forall i \quad (3)$$

$$WT_i = \max_j \{\overline{P_{ij}}\} \quad \forall i \quad (4)$$

$$WL_j = \min_i \{\overline{P_{ij}}\} \quad \forall j \quad (5)$$

$$WL_J = \max_i \{\overline{P_{ij}}\} \quad \forall i \quad (6)$$

where WTi and BTi are utilized to decide the most exceedingly terrible and best technologies (regarding potential) in area I, individually. Additionally, WLj and BLj are utilized to decide the most noticeably awful and best areas for innovation j. From Equation (2), the best and most exceedingly terrible areas/advancements can be resolved utilizing Equations (3) – (6).

Electricity demand determination method (EDDM)

Equation (7) was utilized to calculate the total predictable power requirement for the area of analysis.

$$\overline{PD_C} = \sum_{1=1}^{n} \overline{ED_i} \quad (7)$$

where EDi is the scaled assessed power requirement for area I in MW as demonstrated in Equation (8). To start with, the force supply for every area I, Psi ought to be acquired. From that point forward, the pinnacle interest for area I ought to be determined (assessed) by applying a straightforward addition; if the stock of area I is PS_i, the interest (the necessary inventory if the entrance level of that area was100%), would be ED_i. By utilizing ED_i of every area, the all-out pinnacle request dependent on the power access levels (PD-EA) can be determined, ∑ni=1ED_i. Notwithstanding, the nation's accounted for top interest, PDT, can be not quite the same as the absolute PD-EA (∑ni=1EDi). In such cases, a scaling factor is required to scale the PD-EAs so ED_i could be acquired and the all-out assessed power (PDe) would coordinate with PDT, or give an exceptionally close estimate to it. Nonetheless, it ought to be noticed that scaling factor is required to change for every country or area. The connected conditions of the ideas referenced above, are given underneath:

$$\overline{ED_i} = FxDE_i \quad (8)$$

where F is a scaling factor (the proportion of the absolute power required to add up to assessed power interest of the area of investigation), and it is determined as follows:

$$F = \frac{PD_T}{\sum_{i=1}^{n} ED_I} \quad (9)$$

where Product Development Technology (PDT) addresses the complete power requirement of the area of investigation, n∑i=1 Edi is the assessed absolute interest for the area of examination where Edi is the assessed requirement for area i when the entrance level is at 100%, and it is determined as follows:

$$ED_i = \frac{100\ x\ PS_i}{a_i} \quad (10)$$

where PS_i is the power supply to each location i, and a_i represents the electricity access level 0–100% in location i.

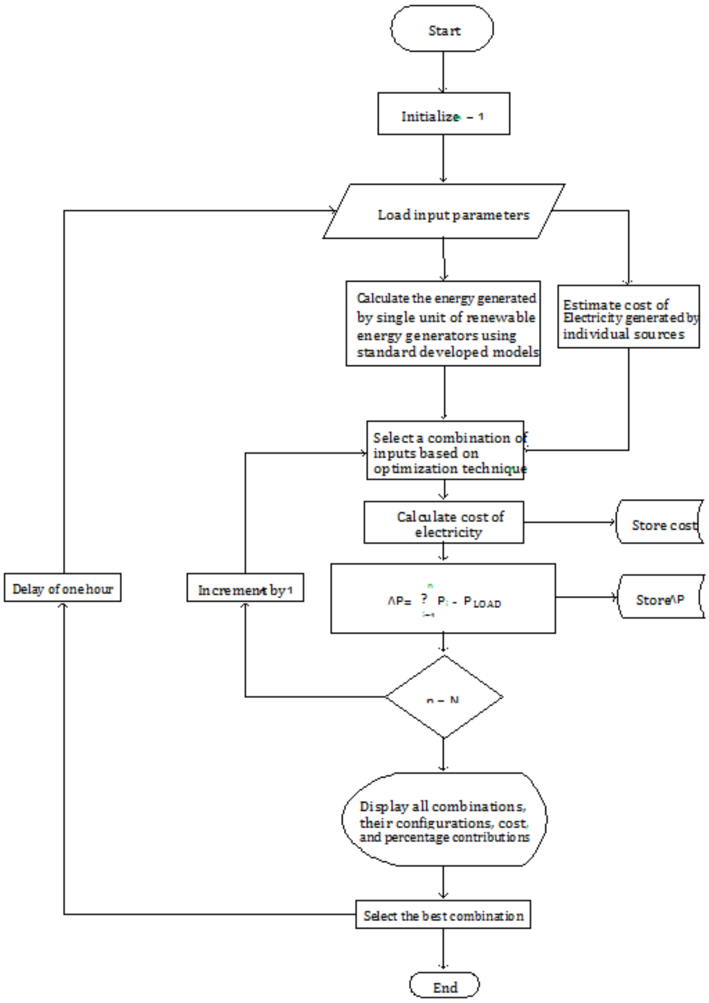


Fig. 1: Flow chart diagram of the proposed system structure for power generation.

3. Results and discussion

3.1 Result

The solar, wind and water resources for Niger Delta are summarized in Table 1, while the HOMER output for solar, wind speed and water flow profile for Niger Delta are shown in Fig. 2, 3 and 4.

Table 1: Wind, solar and water resource for Niger Delta

Month	Clearness index	Average radiation ($kWh/m^2/day$)	Wind speed (m/s)	Water discharge (m^3/s)
Jan.	0.605	5.680	2.100	40.251
Feb.	0.578	5.570	2.1200	42.541
Mar.	0.537	5.250	2.458	44.144
Apr	0.503	4.414	2.147	44.215
May	0.487	4.940	2.547	42.214
June	0.458	4.124	1.248	45.124
Jul	0.415	3.184	2.458	40.254
Aug	0.382	4.187	1.472	41.241
Sep	0.406	4.251	1.242	48.121
Oct	0.457	5.124	2.000	50.415

Nov	0.537	5.387	1.478	50.254
Dec	0.539	4.125	2.144	47.124
Scaled annual average		4.680	1.954	44.658

Source: Nigerian Metrological Agency

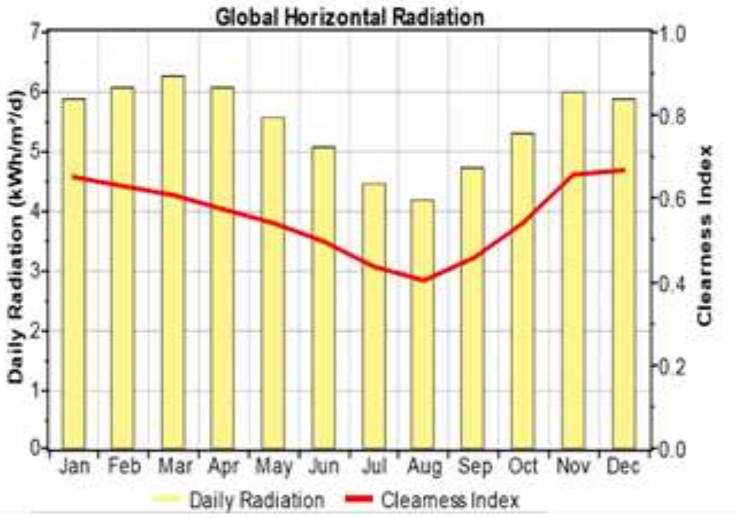


Fig. 2: HOMER output for solar profile for Niger Delta

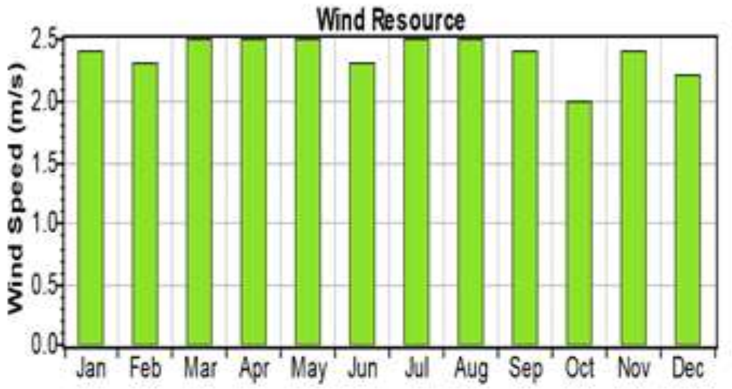


Fig. 3: HOMER output for wind speed profile for Niger Delta

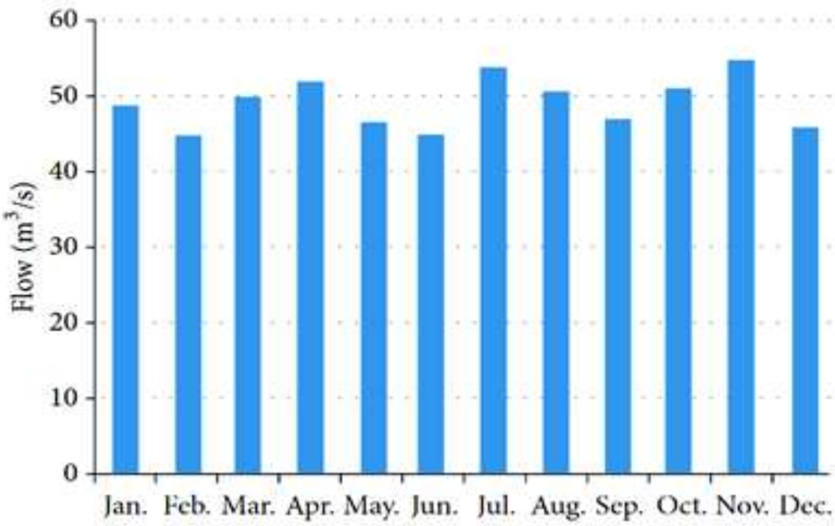
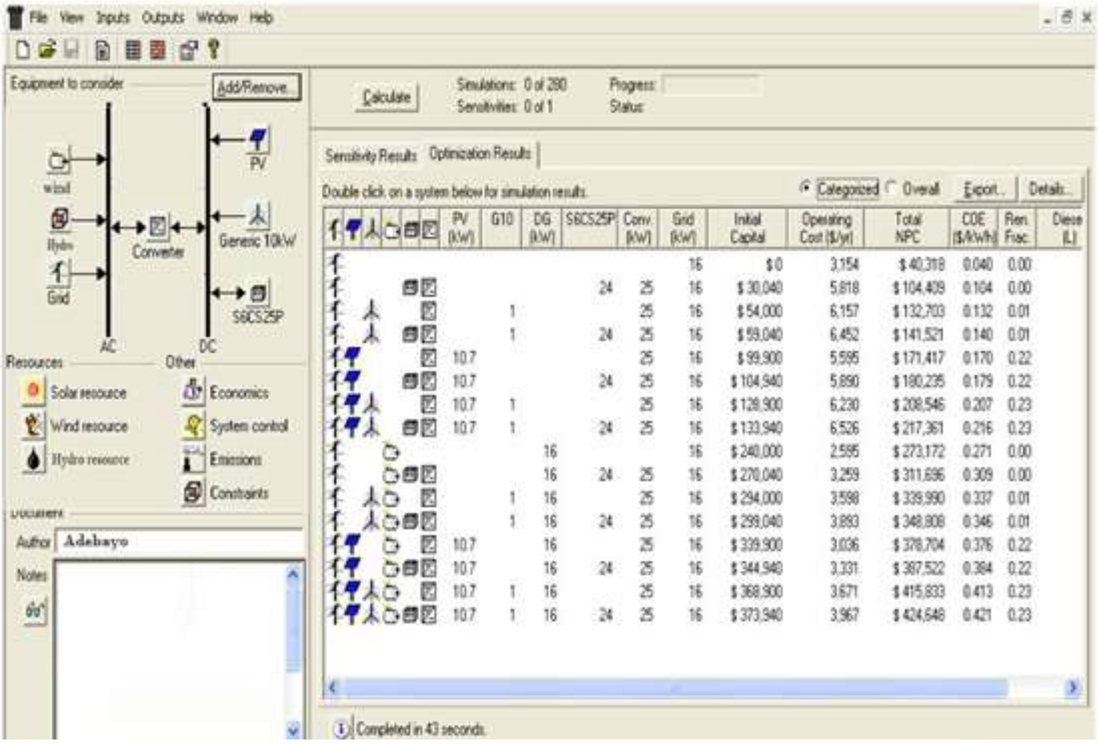


Fig. 4: Average water flow per month

3.2 Optimization of power system for Niger Delta

Fig. 5 shows the aftereffects of the proposed lattice associated cross breed PV-wind energy framework and hydro framework under a similar burden request profile for a recreation period of 1year in the examined areas in Nigeria. Applying the streamlining Model condition inferred, the best energy arrangement was resolved for some random area. Various kinds of conceivable single-source frameworks and cross breed framework blends were mimicked with their costing and estimating contrasted and a PV/wind/matrix/diesel/battery framework.



PV (kW)	G10	DG (kW)	S6CS25P	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)
					16	$ 0	3,154	$ 40,318	0.040	0.00	
			24	25	16	$ 30,040	5,818	$ 104,409	0.104	0.00	
	1			25	16	$ 54,000	6,157	$ 132,703	0.132	0.01	
	1		24	25	16	$ 59,040	6,452	$ 141,521	0.140	0.01	
10.7				25	16	$ 99,900	5,595	$ 171,417	0.170	0.22	
10.7			24	25	16	$ 104,940	5,890	$ 180,235	0.179	0.22	
10.7	1			25	16	$ 128,900	6,230	$ 208,546	0.207	0.23	
10.7	1		24	25	16	$ 133,940	6,526	$ 217,361	0.216	0.23	
		16			16	$ 240,000	2,595	$ 273,172	0.271	0.00	
		16	24	25	16	$ 270,040	3,259	$ 311,696	0.309	0.00	
	1	16		25	16	$ 294,000	3,598	$ 339,990	0.337	0.01	
	1	16	24	25	16	$ 299,040	3,893	$ 348,808	0.346	0.01	
10.7		16		25	16	$ 339,900	3,036	$ 378,704	0.376	0.22	
10.7		16	24	25	16	$ 344,940	3,331	$ 387,522	0.384	0.22	
10.7	1	16		25	16	$ 368,900	3,671	$ 415,833	0.413	0.23	
10.7	1	16	24	25	16	$ 373,940	3,967	$ 424,648	0.421	0.23	

Fig. 5: Optimization of power system for Niger Delta

The proposed power system consists of the following:

i. A generic 1,000 MW wind turbine

A generic 1,000MW sort wind electric generator that gives 48V DC was taken for this framework. It converts wind energy into electrical energy. Accessibility of energy from the wind turbine relies extraordinarily upon wind varieties. Wind turbine rating is for the most part a lot higher contrasted with the normal electrical burden. As yield cost of one unit is viewed as ₦29m while substitution and support costs are taken as ₦25m each year.

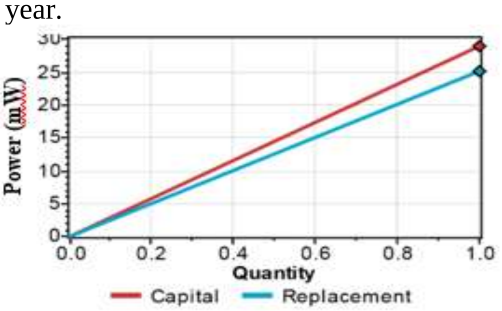


Fig. 6: A Generic 1,000MW cost curve

ii. A 1,000 MW photovoltaic array

Solar powered PV modules are associated in series equal. At the point when the sun rays strike the Solar PV boards, it produces power. The Solar PV power at the site is higher than the wind power. A 1000 kW sunlight-based energy framework's establishment and substitution costs are accepted inexact as $17000 and $16000, separately (Fig. 4). The lifetime of the PV clusters are taken as 20 years and no global positioning framework is remembered for the PV.

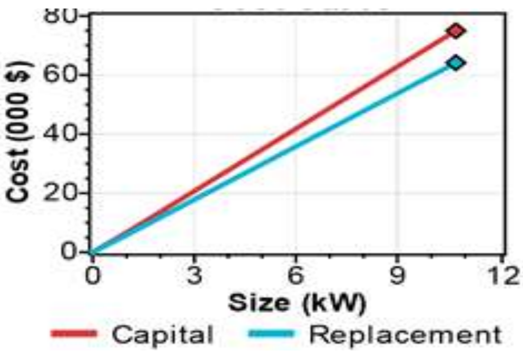


Fig. 7: Cost curve of PV

6CS25P sort Batteries are taken for this framework. The battery pack comprises of 6V, 1,156Ah, 9,645kWh batteries associated in arrangement/equal setup. Cost of one battery is ₦1210 with a substitution cost of $1200 (Fig. 8).

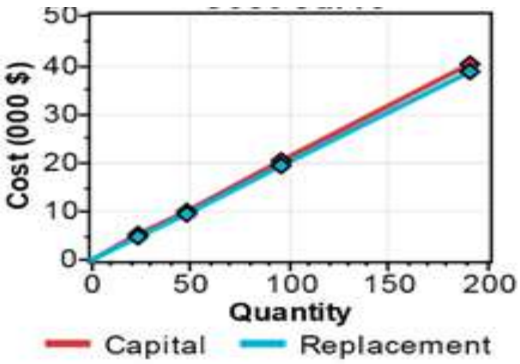


Fig. 8: Cost curve of battery

iii. A 1,200 MW hydro power plant

Fundamentally, the power generated at a hydroelectric power plant results from the dynamic energy that delivered the power acquired from the mass of water that falls through the tallness, the differential of head of water from the channel point, and the head of water over the turbine. The interaction of transformation includes a pressure driven turbine which changes over the active energy of the streaming water into mechanical work that produce a force. A dynamo at that point changes over the force accordingly delivered into power. A 1200 MW hydropower plant establishment costs are accepted rough as ₦28000 (Fig. 9). The lifetime of the force plant are taken as 20 years.

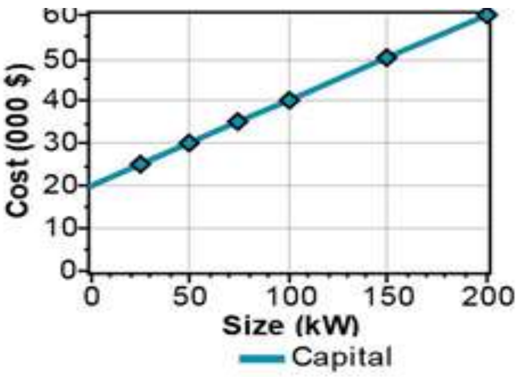


Fig. 9: Cost Hydro plant

3.3. Simulation results of different generators for monthly average electric production

Table 2 summarises the results obtained from different generators for monthly average electric production.

Table 2: Results of different generators for monthly average electric production

Month	Solar Electric Production (Mw)	Wind Electric Production (Mw)	Water Electric Production (Mw)
Jan.	680	200	451
Feb.	570	470	441
Mar.	250	458	444
Apr	414	471	415
May	940	547	414
June	124	248	524
Jul	784	458	454
Aug	587	472	785
Sep	651	242	812
Oct	724	457	515
Nov	487	478	554
Dec	425	441	724

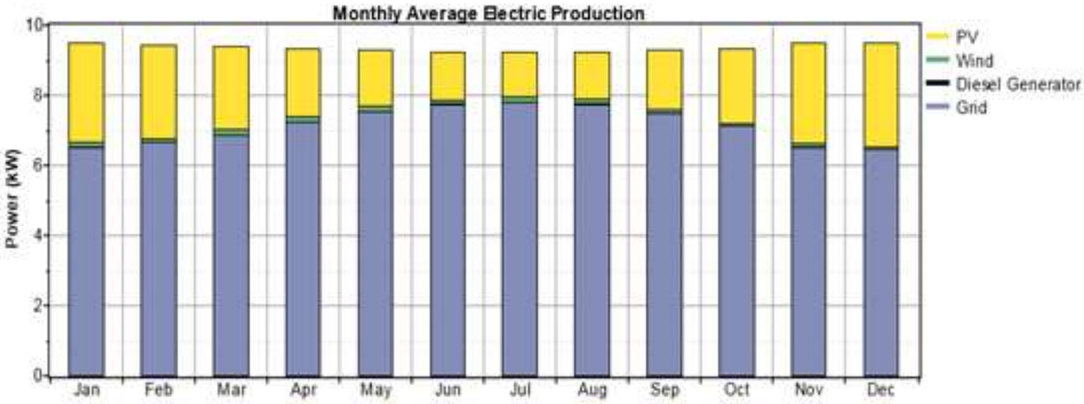


Fig. 10: Grid, PV, Wind and Hydro Monthly Average Electric Production for Niger Delta

Table 3. Comparison of Simulation results of Economic Cost for Niger Delta

Parameter	Grid	Wind-Grid	PV-Grid	Hydro-Grid	PV/Wind Grid	Wind / Hydro	PV/Hydro Grid	PV/Wind/ Diesel-Grid
Initial cost (m ₦)	90,045	59,040	104,940	270,040	133,94	299,040	344,940	373,940
Operating cost (m ₦)	13,565	10,987	15,987	20,650	21,756	13,534	13,875	10,534
Levelized cost (m ₦) ($/kWh)	0.645	0.756	0.969	0.765	0.643	0.764	0.875	0.342
Total NPC	103,611	70,038	₦120,928	₦290,691	155,679	₦312,575	358,816	₦384,747

4. Discussion

Systems located in Niger Delta were optimized. The Simulations provide information concerning the electricity production, economic costs and environmental characteristics of each system, such as the CO_2 emissions. A thorough study of the system's key performance indices (Okundamiya et al 2013) indicates that the renewable energy will be more economical when its potential is fully tapped. This is obvious owing to the dependence of renewable resources on climatic conditions (Falayi and Rabiu, 2005). The larger percentage contribution of renewable sources throughout the studied locations is a reflection of the vast resource availability and the economic and technical viability of the renewable resources for a sustainable electricity supply to Niger Delta states (Adejumobi, et al 2013). There is about 11% variation of the grid power contribution in the Niger Delta (Celik, (2002). This variation is compensated for through renewable energy sources. Renewable energy contribution varies from about 84.3% ~~in~~ to about 94.4% across Niger Delta states (Falayi and Rabiu, 2005). Solar power is estimated to contribute higher percentage (of about 67%) than twice the corresponding wind potential (28.6% and 27.5%) within the Niger Delta. There is a significant variation of solar energy potential of about 50% to the total energy contribution within the region (Kela et al 2001).

The contribution of solar energy is largely limited by the sharp decrease in the annual average solar energy around the raining season (Okundamiya et al 2013). As a result, a larger fraction of wind energy is required to compensate for the available grid electricity supply. The performance of solar conversion system is almost evenly distributed with peak values of about 50% (Kela et al 2001). This corresponds to about 4526 hours of operating the hydro plant annually for the energy demand to be effectively satisfied. The implementation of the proposed system would eliminate the need for the fossil fuel led generators and reduce the dependence of the load on the erratic grid supply from about 47% presently to as low as about 4.9%. This would in turn translate to a reduction in the pollutant emissions released into the atmosphere as a result of the consumption of electricity produced by generators. By comparison with the current practise, the implementation of the proposed system indicates that an average performance improvement of over 300% could be achieved in the operation and maintenance cost of Power Generations in Niger Delta.

4. Conclusions

The results obtained show that grid is the best choice economically because it attracts the least cost but the problem is that the grid is not reliable and not efficient within the nation. From an environmental perspective there are significant benefits in using Hybrid Solar-Grid power. It was observed that the use of generators is out of place looking at the huge amount of money involved and its environmental disadvantages. From the results obtained, Niger Delta could save 119,731kg of CO_2 emissions annually by removing backup generators and by using Solar-Grid as a power source. In general, the hybrid Solar-Grid power system offered a better performance to provide power supply than the grid only system. The simulation results demonstrate that utilizing renewable generators such as a hybrid (PV/wind) generator reduces the greenhouse gases (CO_2 and NO_x) emitted to the environment. The results also demonstrate that renewable energy technologies, including solar Photovoltaic and wind systems, have the potential of supplying electricity to the Niger Delta region in a cost-effective manner. Grid would have been the best option but due to its unreliability in Nigeria, coupled with its high environmental impact, PV-Grid system is likely to be the best option which is reliable and has the least environmental impact. However, it is important to note that there is no general least-cost option for powering the region at different states. It all depends on climatic conditions and available renewable energy resources.

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