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EVALUATION OF ELECTRIC POWER SUPPLY FOR IMPROVED ALTERNATIVE POWER OPERATION: A CASE OF FEDERAL OCEAN TERMINAL ONNE-PORT

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ABSTRACT

The study examined the electric power supply to Onne Federal Ocean Terminal, Port Harcourt. Currently, the facility is autonomously operated by a diesel generator. The operational of diesel generator is huge and also not environmental friendly. The proposed hybrid diesel generator, PV and grid integration system impacted significantly in mitigating the high operation and maintenance cost as well as greenhouse gas emission associated with diesel generator. HOMER 3.11.2 software was used to simulate the system for three (3) scenarios[diesel generator and solar PV system, diesel generator and grid system, finally, diesel generator, solar PV was connected to the grid system] The result obtained shows that for base case when only diesel generator was used. [Cost of energy COE=N0.296], [net present cost NPC=N123M],[operating cost OC=N5.46M], [fuel cost FC=N3.80M,]. Also the GHG emission [CO2=13,271,421Kg/yr, CO=83,656kg/yr, Unburned Hydrocarbon =3,650kg/yr, Particle matters=507kg/yr, Sulphur dioxide=26811kg/yr, Nitrogen oxides=78586kg/yr]. However, after optimization of the hybrid system, diesel generator/solarPV/grid system gives the best cost reduction. [Cost of energy COE=N0.107], [net present cost NPC=N46.2M],[operating cost OC=N1.28M] , [fuel cost FC=N83,999,]. The GHG emission was reduced [CO2=7,356,091Kg/yr, CO=1.848kg/yr, Unburned Hydrocarbon= 80.6kg/yr, Particle matters =11.2kg/yr, Sulphur dioxide=31.213kg/yr, Nitrogen oxides= 16.711 kg/yr].

Key Words: Renewable Energy, Diesel Generator, Converter, Battery and Solar PV

1.0 Introduction

The prominence of stable electric power supply cannot be overemphasized as it is the prerequisite requirement in determining the socio-economic development of any society (Gupta, 2016).

In Nigeria, most industrial and commercial areas are connected to electric utility grid that is unreliable. Thereby, making the needed power supply to drive economic growth in that area epileptic. In most cases, diesel generators are autonomously used as main or backup power supply which is highly expensive to run and maintain, causes noise pollution and emit high amount of greenhouse gas. It is therefore pertinent to alleviate the excessive cost of diesel power generation using renewable energy system. This work is proposing an integration of grid, solar renewable energy to the existing diesel generator at Onne-Port Federal Ocean Terminal. It will not only reduce the high operational cost associated with diesel generator but will also improve supply to the port in a way and manner that is environmentally friendly.

1.1 Statement of Problem

High operation and maintenance cost, noise pollution and greenhouse gas emission associated with diesel fuel generator are of major concern to the management of Onne Port authority. The installed capacity of generator used in the facility 3x2000KVA. Thus, it is imperative to reduce GHG emission, noise pollution, diesel fuel consumption by integrating a renewable energy technology that is environmental friendly for power generation at Onne-port authority.

1.2 Aim of the Study

This research work is aimed at designing a hybrid PV/Generator/grid system for Federal Ocean Terminal (Onne-port) with the integration of the existing diesel generator. This system will optimize the electric power supply to the study case for improved performance.

1.3 Objectives of the Study

The objectives are:

i. To obtain necessary data from Federal Ocean Terminal, Onne-Port for analysis.
ii. To design a hybrid PV/Generator/grid system for Federal Ocean Terminal, Onne-Port using HOMER software.
iii. To reduce the high operational cost associated with diesel fuel generator
iv. To reduce the effect of greenhouse gas emission associated with fossil fuel generation (diesel)
v. To reduce the net present cost (NPC) and cost of energy (COE)

2.0 Literature Review

Liu (2015) in his work conversed the cost-effectiveness and environmental impact of a hybrid PV/Wind/Grid model. The result obtained shows that the 100kwh/day energy demand was achieved using the proposed renewable resources. It was further reviewed that when the energy demand skyrocketed the grid supply was introduced. Also, it was noted that the energy production from the wind turbine surpasses both PV and the grid. The hybrid grid-tide system was found to be cost-effective and reduces carbon emissions compared to grid supply.

Grip (2013), in their study noted that the hybrid power system has capability to regulate the supply of power from any of the generating units making up the hybrid power system in use with the aim to power a particular load. For example, a hybrid power system consisting of both renewable and non-renewable power generating units, the system will be able to determine when each of the generating unit will supply power to the load.

Purkus and Barth (2012) the major invention of the hybrid power system in each of the generating units at a particular time has the capability to sustain the load. It should be noted that cost saving does not involve using the most expensive solar panels, gas turbine or diesel generators but in ensuring that no matter the generating unit in use, they should be able to stand the required load. By adequate coordination, the power system will be more reliable, safe and operate at a low running cost.

Okedu and Uhunmwagho (2015) in their study on hybrid PV, gas turbine system reduced the high rate of fuel consumption. Thereby mitigating GHG emission and high electricity cost. It was further stated that this could be achieved with the use of renewable energy.

Sinha (2018). The hybrid power system helps to ensure availability of power owning to the fact that each of the generating units can independently supply power. In addition, it was noted that the independency of supply in the hybrid power system helps to eliminate the need to make separate arrangement for spinning reserves as in most conventional power generation.

Vojdani (2018) the hybrid power system in focus in this study is a power system that has two or more generating units to power a particular load. It could include a combination of different power generating unit like the PV, wind turbine, gas turbine, steam turbine, diesel generator, hydro power plant.

Hawkes and Leach (2012) noted that through the use of energy mix, a hybrid power system ensures adequate availability of supply. The vital components of a hybrid power system are gas turbine, solar panels, inverters and the solar trackers. The PV power system only depends on the sunlight to supply power but the gas turbine can be fired to supply at any time of the day, making it more reliable and flexible for use.

Wagner and Pick (2014) in their work computed the energy yield ratio and a cumulative energy demand for two wind turbines of capacity 1.5 and 0.5 MW respectively. The study was carried out in three different locations namely; coastal, near the coast, and inland. Based on the findings, it was reviewed that the energy payback time would be 3-7 months and with an energy yield ratio of 38-70.

Crawford (2019) in his work proposed a methodology known as hybrid embodied energy analysis approach to examine the energy life span and GHG emissions for 850 kW and 3.0 MW wind turbines respectively. Furthermore, the impact of turbine size on the yield ratio was examined. Based on the result on the findings it was noted that the method used in earlier research examining the energy life span was incomplete due to some limitations and errors in the quantifying key parameters.

Murphy and Niitsuma (2016) noted the use of fiscal policy, carbon tax and monetization as a compensation mechanism in reducing the high cost of geothermal electricity. It was further noted that counties like Japan, Indonesia and the Philippines have supportive government policies.

3.0 Methodology

3.1 Preliminary Data

Table1: Load Data

Load ID	Name	kW Rating
1	Chevron	180.25
2	Exxon Mobil	249.90
3	Exxon Mobil Quayside	187.85
4	Intels Building	183.25
5	Tower Light	124.95
6	Barroid/Crossbow	166.60

7	Snepco	378
8	Usan Mobil	239.70
9	Water Treatment Plant	187.85
10	Tower light	158.10
11	Jetty Tower Light	124.95
12	FMC	600
Total Loads		**2781.40**

3.2 Mathematical Model

I. PV Generator Array Output

$$P_{pv} = Y_{pv} * f_{pv}\left(\frac{\bar{G}_T}{\bar{G}_{T,STC}}\right)\left[1 + \alpha_p\left(T_c - T_{c,STC}\right)\right] \quad (1)$$

Where
P_{pv}: Output of the PV Array
Y_{pv}: Rated capacity of the PV array [kW]
f_{pv}: PV derating factor [%]
$\overline{G}_T$: Solar radiation incident on the PV array in the current time step [kW/m^2]
$\overline{G}_{T,STC}$: Incident radiation at standard test conditions [1 kW/m^2]
α_p: Temperature Coefficient of Power [%/°C]
T_c: PV cell temperature in the current time step [°C]
$T_{c,STC}$: PV cell temperature under standard test conditions [25°C]

II. PV Operating Temperature

$$\boldsymbol{T_c} = \frac{T_a + (T_{c,NOCT} - T_{a,NOC}) * \left(\frac{G_T}{G_{T,NOCT}}\right) * \left[1 - \frac{h_{mp,STC}(1-\alpha_{pTC,STC})}{\tau\alpha}\right]}{1 + (T_{c,NOCT} - T_{a,NOC}) * \left(\frac{G_T}{G_{T,NOCT}}\right) * \left(\frac{\alpha_p h_{mp,STC}}{\tau\alpha}\right)} \quad (2)$$

Where
$\eta_{mp,\,STC}$: The maximum power point efficiency under standard test conditions [%]
α_P : The temperature coefficient of power [%/°C]
$T_{c,\,STC}$: The cell temperature under standard test conditions [25°C]
$T_{C,\,NOCT}$: The nominal operating cell temperature [°C]
$T_{a,\,NOCT}$: the ambient temperature at which the NOCT is defined [20°C]
$T_{G,\,NOCT}$: the solar radiation at which the NOCT is defined [0.8 kW/m^2]
G_T: the solar radiation striking the PV array [kW/m^2]

III. Battery Bank Capacity Watt-hour

$$BB_{Wh} = \frac{(Wh_{AD})*(DOA)*(BM_{Temp})}{DL} \quad (3)$$

Where
Wh_{AD}: average daily [Wh]
DOA: days of autonomy
BM_{Temp}: battery temperature multiplier [1.19]
DL: Discharge limit [0.50]

IV. Operating Cost

$$C_{operating} = C_{ann,tot} - C_{ann,cap} \quad (4)$$

where
$C_{ann,tot}$: The total annualized, cost (N/yr)
$C_{ann,\ cap}$: The total annualized capital cost (N/yr)

V. Annualized Cost

$$C_{ann} = CRF\ (i, R_{proj}) \times C_{NPC} \quad (5)$$

Where;
$CNPC_{tot}$:The total net present cost (₦)
i:The annual real discount rate (%)
R_{Proj} : The Project Lifetime (yr)
CRF () :A function returning the capital recovery factor

VI. Net Present Cost

$$NPC = \left(CC + \sum_{i-1}^{N} \frac{(RC + O\&MC + FC - SV)}{(1+i)^N}\right) \quad (6)$$

Where;
CC: Capital cost
RC: Replacement Cost
O&MC: Operating and maintenance cost
FC: Fuel Cost
SV: Salvage Cost
i: Interest rate
N: Number of years (Project life time).

3.2 Model Simulation

Figure 1-4 shows the simulation for four (4) different models respectively.

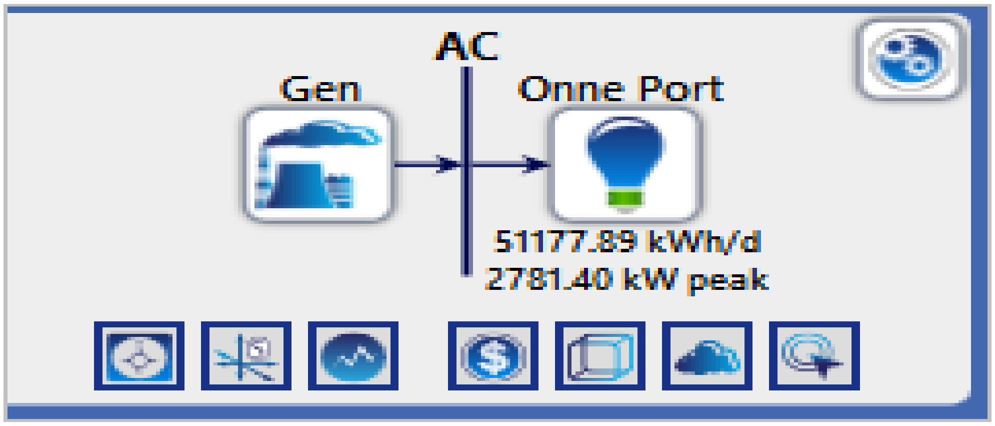

Figure 1: System Model with Only Diesel Generator

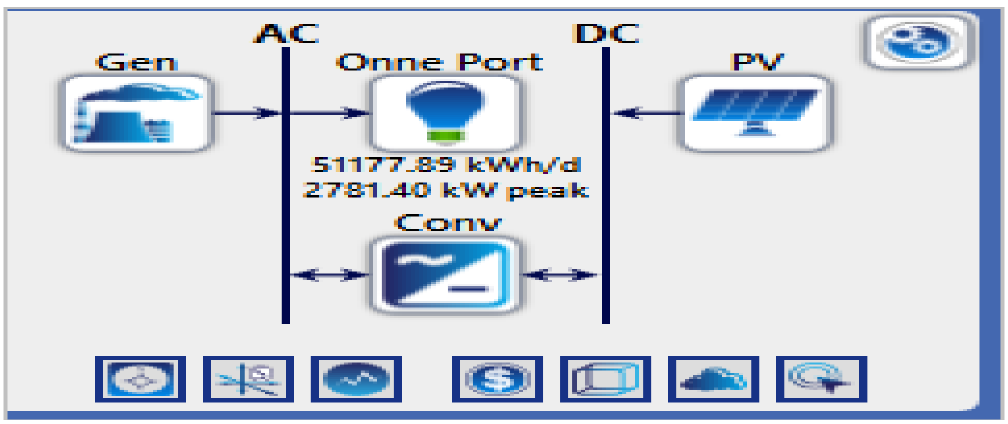

Figure 2: System Model with Diesel Generator and PV

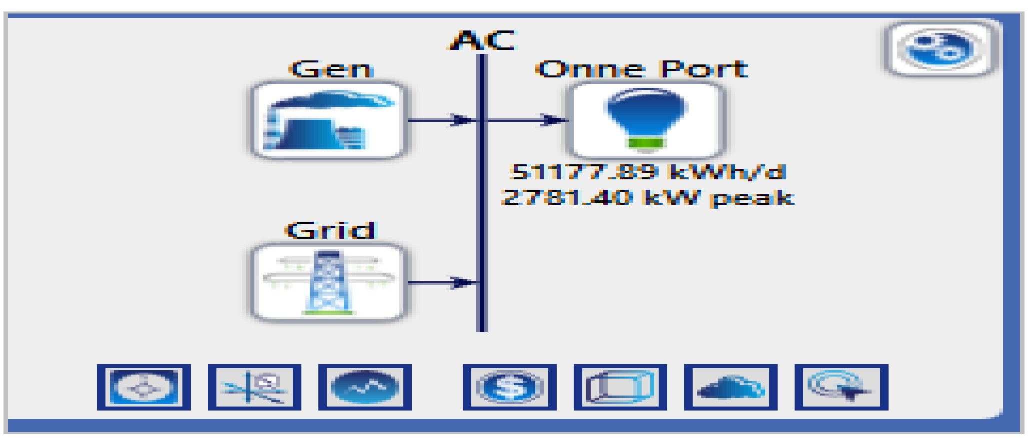

Figure 3: System Model with Diesel Generator and Grid

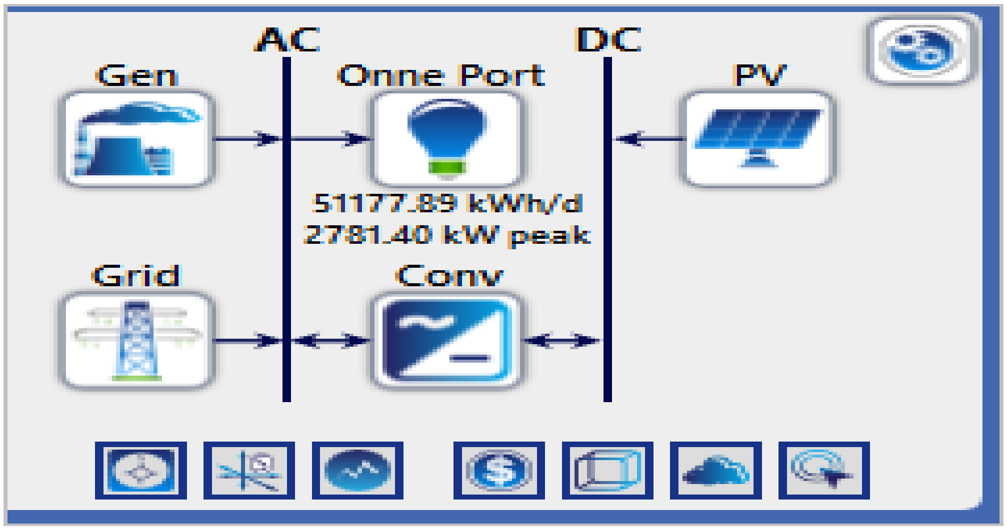

Figure 4: System Model with Only Diesel Generator and PV connected to Grid

4.2 Result Presentation

The simulation result is represented for four system models performed in HOMER software environment.

Table 2: Diesel Generator Only

Production	kWh/yr	%	Consumption	kWh/yr	%
Diesel Generator	18,697,929	100	AC Load	18,697,929	100
PV Generator	0	0	Grid Sales	0	0
Grid Purchases	0	0	**Total**	18,697,929	100
Total	18,697,929	100	**Excess Production**	0	0

Table 3: Diesel Generator and PV

Production	kWh/yr	%	Consumption	kWh/yr	%
Diesel Generator	10,914,145	46.0	AC Load	18,697,929	100
PV Generator	12,787,687	54.0	Grid Sales	0	0
Grid Purchases	0	0	**Total**	18,697,929	100
Total	23,701,832	100	**Excess Production**	4,613,178	19.5

Table 4: Diesel Generator and Grid

Production	kWh/yr	%	Consumption	kWh/yr	%
Diesel Generator	2,828,750	15.1	AC Load	18,697,929	100
PV Generator	0	0	Grid Sales	0	0
Grid Purchases	15,851,179	84.9	**Total**	18,697,929	100
Total	18,697,929	100	**Excess Production**	0	0

Table 5: Diesel Generator and PV connected with Grid

Production	kWh/yr	%	Consumption	kWh/yr	%
Diesel Generator	365,025	1.83	AC Load	18,697,929	96.6

PV Generator	8,376,145	42.1	Grid Sales	662,455	3.42
Grid Purchases	11,175,507	56.1	**Total**	19,342,384	100
Total	19,916,676	100	**Excess Production**	163,668	0.822

Table 6: Economic Analysis

System Architecture	Cost of Energy (N)	Net Present Cost (N)	Operating Cost (N)	Fuel Cost (N)	Total Fuel Consumed (L)
Gen	0.296	123M	5.46M	3.80M	5,070,044
Gen + PV	0.265	110M	3.81M	2.30M	3,064,097
Gen + Grid	0.159	65.9M	2.89M	650,951	867,934
Gen +PV + Grid	0.170	46.2M	1.28M	83,999	111,999

Table 7: Comparison of Gas Emission

Pollutant	Unit	Gen	Gen + PV	Gen + Grid	Gen + PV +Grid
Carbon dioxide	Kg/yr	13,271,421	8,020,627	12,289,863	7,356,091
Carbon monoxide	Kg/yr	83,656	50,558	14,321	1.848
Unburned Hydrocarbon	Kg/yr	3,650	2,206	625	80.6
Particle matters	Kg/yr	507	305	86.8	11.2
Sulphur dioxide	Kg/yr	26,811	16,204	48,022	31.213
Nitrogen oxides	Kg/yr	78,586	47,494	34,694	16.711

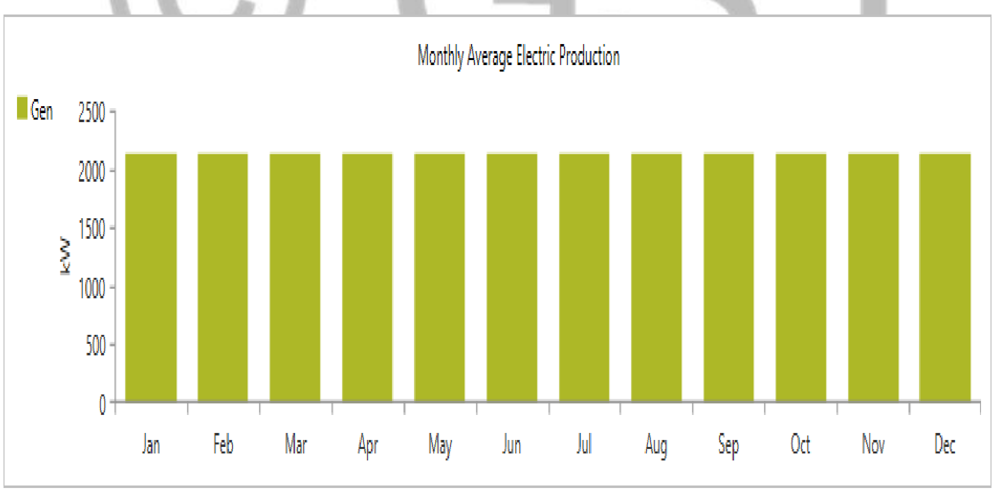

Figure 1: Monthly Average Electric Production for Diesel Generator

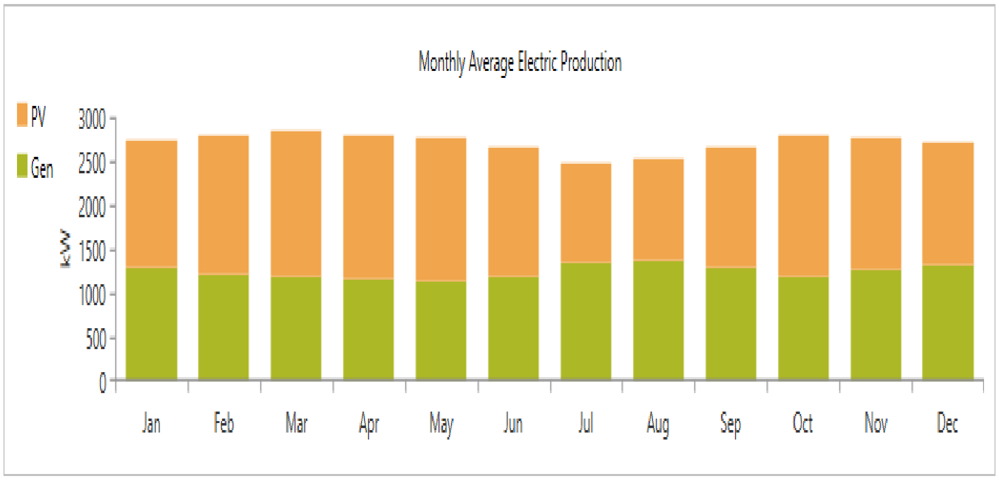

Figure 2: Monthly Average Electric Production for Diesel and PV generator

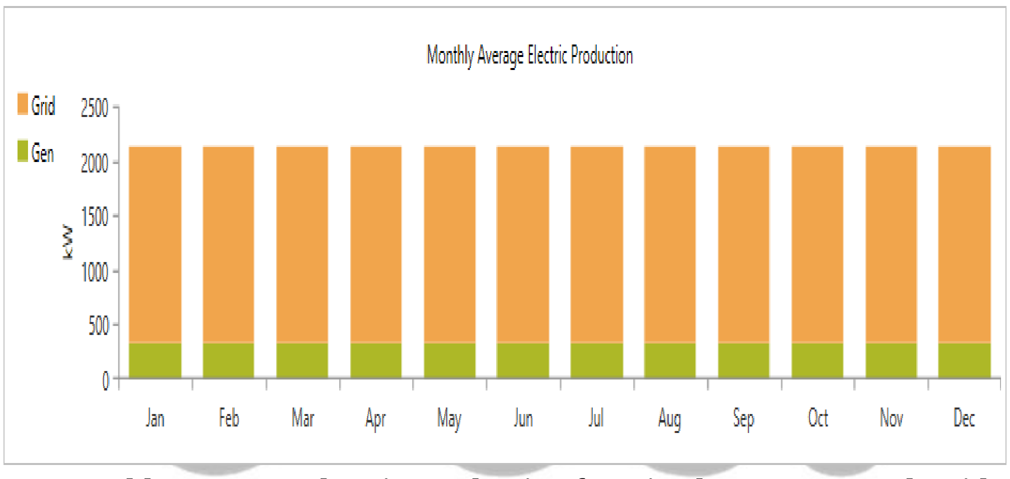

Figure 3: Monthly Average Electric Production for Diesel Generator and Grid Supply

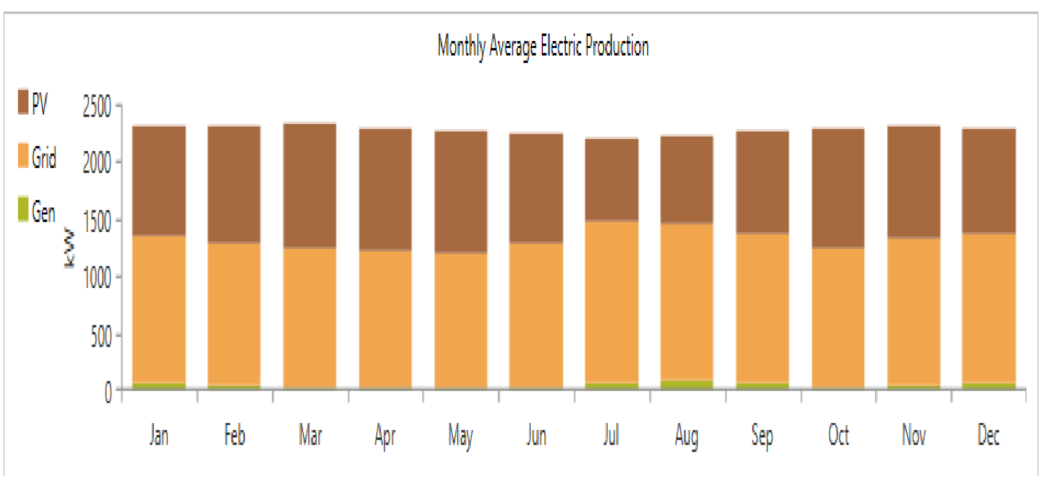

Figure 4: Monthly Average Electric Production for Diesel -PV Generator and Grid Supply

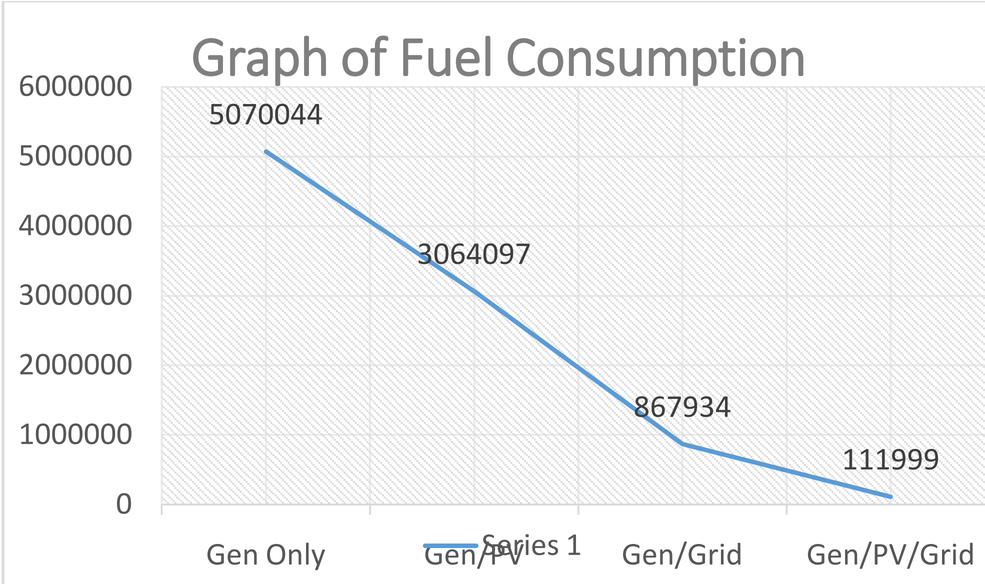

Figure 5: Graph of Fuel Consumption

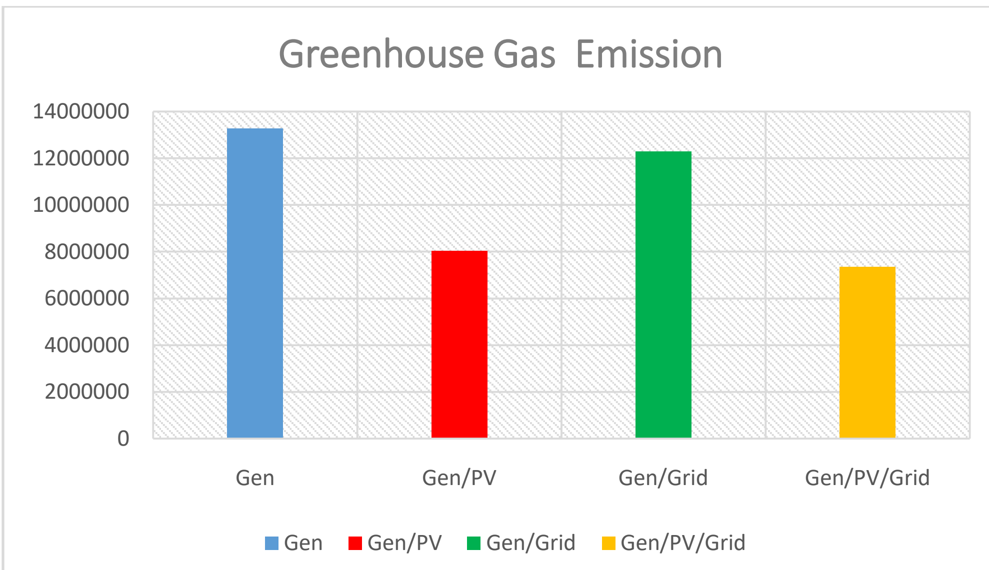

Figure 6: Graph of Generator Greenhouse Gas Emission

4.2 Result Discussion

Table 2 shows the base case electrical energy production when only diesel generator is used. The total energy consumed by AC primary loads is 18,697,929kWh and the total energy produced by diesel generator is 18,697,929kWh.

Table 3 shows the electrical energy production when combined with PV generator. The total energy consumed by AC primary loads is 18,697,929 kWh. The total electrical energy produced is 23,701,832 kWh. The fraction of energy produced by the diesel generator is 10,914,145 kWh (46.0%) and PV generators is 12,787,687 kWh (54.0%) respectively. A quick look at table 3 shows that 4,613,178kWh of energy was produced in excess.

Table 4 shows the electrical production when combined with grid. The total energy consumed by AC primary loads is 18,697,929 kWh. The fraction of energy produced by the diesel generator is 2,828,750 kWh (15.1%) and from grid is 15,851,179 kWh (84.9%).

Table 5 shows the electrical production when combined with PV and grid. The total energy consumed by AC primary loads is 18,697,929 kWh. The total energy produced by the system architecture is 19,916,676 kWh. The fraction of energy produced by diesel generator is 365,025 kWh [1.83%], PV generator is 8,376,145kWh [42.1%] and from grid is 11,175,507 kWh (56.1%) respectively. In addition, 163,668 kWh of energy is produce in excess.

Table 6 shows the fuel consumption of the diesel generator. A quick look at table 4.5 shows that 5,070,044 litres of diesel is consumed by the generator when only in use. Similarly, 3,064,097 litres of diesel is consumed by the generator when combined with PV system. Furthermore, 867,934 litres of diesel is consumed by the generator when combined with grid system. Finally, 111,999 litres of diesel is consumed by the diesel generator when combined with PV and grid system.

Table 7 shows comparison of greenhouse gas emission. A cursory look at table 4.6 shows that the optimal reduction in greenhouse emission is giving by the diesel generator / PV / grid system. (CO2=7,356,091Kg/yr, CO=1.848kg/yr, Unburned Hydrocarbon=80.6kg/yr, Particle matters= 11.2kg/yr, Sulphur dioxide= 31.213kg/yr, Nitrogen oxides=16.711kg/yr] compared to the other systems.

Similarly, figure 1-4 shows the monthly average electric power production for different system models. A quick at the monthly average electric power production shows that for diesel generator/PV model, 46% of the power was produce by diesel generator while 54% by PV. Similarly, for diesel generator/grid model 15.1% was produce by diesel generator while 84.9 % by grid. Finally, for diesel generator/PV/grid model 1.83% was produce by diesel generator while 42.1% by PV and 56.1% by grid.

Finally, figure 5 and 6 shows the generator fuel consumption and greenhouse gas emission. A quick look at the figure 5 and 6 shows that diesel generator/PV/grid model gives the optimal solution for fuel consumption and greenhouse gas emission respectively.

5.0 Conclusion

The goal of the study is to design a hybrid renewable energy technology that will improve electric power supply to Federal Ocean Terminal, Onne-Port. Four different energy technologies were simulated using hybrid optimization model for electric renewable (HOMER) software. The setup with the least net present cost is taken as the most optimized which is the diesel generator, PV and grid combination. Based on the finding, it is concluded that the hybrid renewable technology is economical in reducing operating cost and reduced greenhouse emissions associated with the use of the diesel generating plants.

Reference

Crawford, R. (2019). Life cycle Energy and greenhouse emissions analysis of wind turbines and the effect of size on energy yield. Renewable and Sustainable Energy Reviews, 13(9), 2653-2660

Gipe, P. (2013). Wind energy comes of age (Vol. 4): Wiley

Gupta, B.R. (2016). *Power system analysis and design*. Wheeler publishing Allahabard.

Hawkes, A., and Leach, M. (2012). Cost-effective operating strategy for residential micro combined heat and power. Energy, 32(5), 711-723.

Liu, D. (2005). Costs of Electricity. Nuclear Energy: Principles, Practices, and Prospects, 559-577.

Murphy, H., & Niitsuma, H. (2016). Strategies for compensating for higher costs of geothermal electricity with environmental benefits. Geothermics, 28(6), 693-711.

Okedu, K.E and Uhumwangho R (2014) Optimization of renewable energy using HOMER. *International Journal of Renewable Energy Research.* 4(2)421-427

Purkus, A., and Barth, V. (2012). Geothermal power production in future electricity markets—a scenario analysis for Germany. Energy Policy, 39(1), 349-357.

Sinha, A. (2018). Modelling the economics of combined wind/hydro/diesel power systems. Energy conversion and management, 34(7), 577-585

Vojdani, A. (2018). Smart integration. Power and Energy Magazine, IEEE, 6(6), 71-79.

Wagner, H.J., & Pick, E. (2016). Energy yield ratio and cumulative energy demand for wind energy converters. Energy, 29(12), 2289-2295.