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Harnessing Available Renewable Energy Sources (RES) into Power Generation for Education Institutions

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Abstract: The unavailability of constant power supply at the University of Port Harcourt campuses has been a bottleneck faced especially at Choba campus of the university. Renewable energy sources (RES) such as solar and biomass energy are available sources which can be harnessed to provide electric power for the campus. This research work in the verge of improving electric power for the University campus therefore deemed it necessary to harness the RES available by presenting a hybrid generating system. A solar PV/Biogas power system to be incorporated to the available Grid/Diesel power system. This renewable energy system takes into consideration the amount of solar radiation within the university campus in developing the solar PV system and also the amount of human waste (sewage sludge) made available in the university hostels occupied by students within the campus into biogas generation which in turn generate electricity. The university electricity load was the basis for determining the renewable energy system capacity. This hybrid energy system incorporation as calculated was simulated in HOMER (Hybrid Optimization Model for Electrical Renewables) software as the result of the system performance shows that 17% of the total electricity generated by the system came from the renewable energy systems of solar and biogas. This study approach of harnessing these available renewable resources creates room for technology advancement in providing solution to the ever-rising electricity demand of the university campus.

Keywords: Renewable Energy Sources, Integrating Hybrid Solar and Biomass Systems, Solar Energy Sources, Biomass Energy Sources.

1. Introduction

Power generation in Nigeria heavily depends on hydrocarbons as fuel such as diesel and petrol among others [1]. The power generation is characterized with emission of greenhouse gases (GHG) which are harmful to our environment and pose a serious threat to it.
Renewable energy systems tend to be gaining more popularity as it sources tagged renewable energy sources (RES) include six important resources namely; direct solar energy, biomass, geothermal, hydropower, ocean energy and wind energy [2]. These sources of energy are preferred since they provide clean, safe and low emission operation when compared with the hydrocarbons. Solar PV (photovoltaic) and biogas systems are viable. The solar PV system comprises of PV cells which acts to trap sunlight in form of light energy and offer conversion to electrical energy [3]. The output from the solar PV system will be regulated by the insolation, which is the rate of light energy penetration from the sun at a specific location. According to [4], the insolation value is higher at regions close to equator than at other regions. This is why

PV systems tend to have more performance in Africa. The climate conditions of any region are also key factors as during warmer months (dry season), the insolation is greater than in cold months (rainy season).

Biogas as another RES is gotten from the breakdown of organic matter by microorganisms which oxygen is absent [5]. This product composed in large portion methane, while the rest is mixed with carbon dioxide and few hydrogen sulphide and moisture traces. The biogas quality and composition depend on the organic material chosen [6]. The hydrogen sulphide (H_2S) quantity present is a key factor in the process of decomposition. The reason is because a little amount can greatly slow down or prevent the process of degradation. Biogas is usually generated using anaerobic digesters built to contain the biomass on which microbes act till decomposition occurs [7]. During the decomposition of organic matter, biogas is generated which in turn, is tapped out. Once the gas has been generated, it is channeled to a bio-generator which produces electricity.

Educational institutions are littered around Nigeria with most of the institutions starting small and growing to large institutions. The city Port Harcourt as the capital and largest city of Rivers State in southern Nigeria is host to one important university [8]. University of Port Harcourt located in the city of Port Harcourt, Rivers State in southern Nigeria as one of the top ranked universities in Nigeria [9]. The institution of higher learning had three campuses namely; Choba, Delta and Abuja campuses. This institution established more than forty (40) years ago had witnessed remarkable expansion in terms of human and infrastructural development. However, the ratio of power supply to this expansion is inconsistent since the electric power received by the university cannot match up with the increase in demand for power. In order to supplement and improve this electric power supplied by the power distribution company, the university invested in installing a diesel generator to carter for their ever-growing power need. The quest for more power cannot be eliminated as human and infrastructure continue increasing. This ever-increasing need of the institution for electricity had been of concern to the university community as every department and sections tends to make way for its power alternatives by procuring and utilizing diesel generator. This had created nuisance as inherent noise generation and carbon pollution had become an ugly site to behold. The institution has potential for direct solar energy and biomass energy sources and as such facilities can be put in place to harness these sources for electricity generation.

2. Methods

In a way to bring about increase in the amount of electric power generated, the solar PV and Biogas systems are integrated into the already existing Grid-Diesel generator. The system utilizes the RES of solar energy and biomass (sewage sludge) towards providing more electric power for use by the university load. The system components are highlighted in figure 2.1

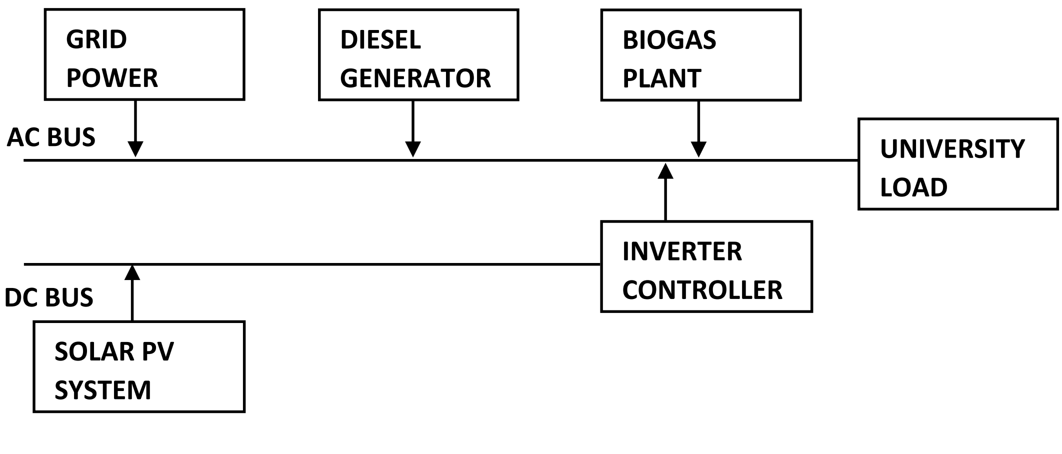

Figure 2.1: Block diagram of a hybrid solar PV/Biogas/Diesel/Grid system for power generation

The figure 2.1 shows the block diagram of the proposed system incorporated to the already available system. The renewable system which provides DC (direct current) will have the inverter introduced in order to properly provide the required AC (alternating current) for the university load consumption. The system flowchart and algorithm are presented in fig 2.2

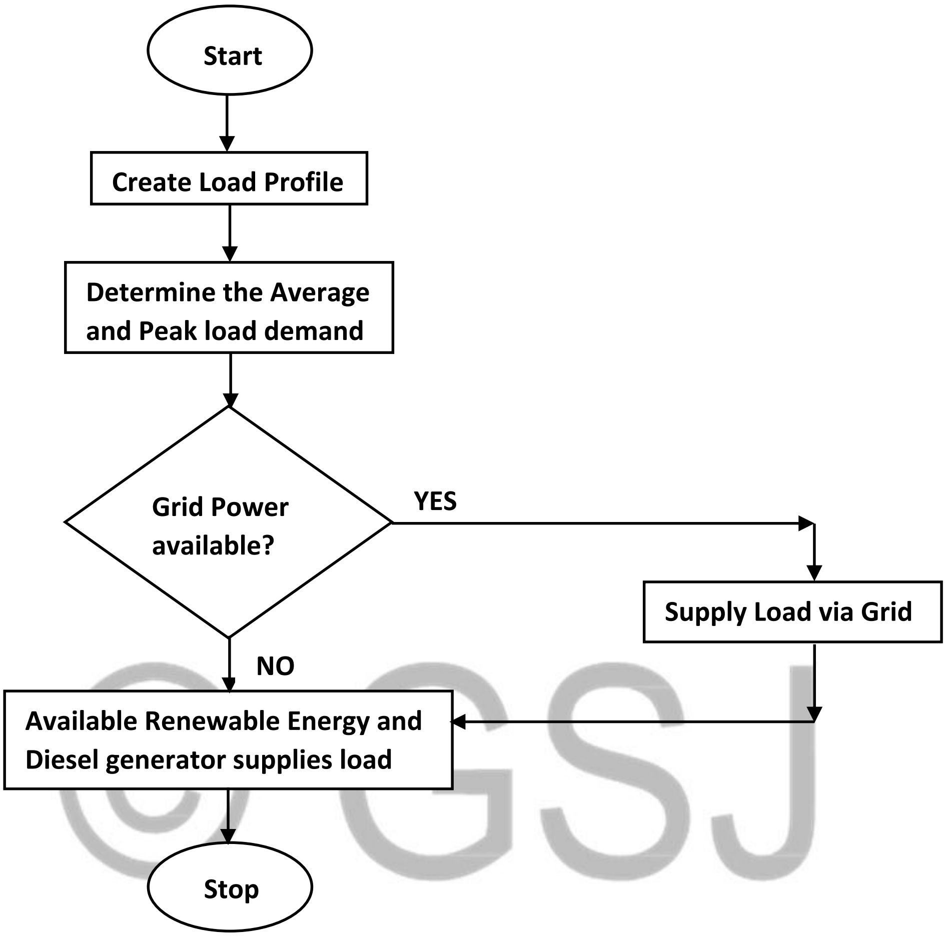

Figure 3.2: System flowchart

Having presented the proposed system and its flow chart, we have to determine the various parameters needed in defining the proposed system operation. The solar PV system requirements are calculated based on the university campus load requirements data collected. Also, the amount of biomass available is calculated and used in determining the quantity of biogas to be generated for power generation. First is to give a breakdown of the university load requirements as basic input for selecting a particular system generating capacity. Thereafter, the various components that made up the system parameters for operation are calculated.
The hourly rundown of load consumption of the university campus is presented in table 2.1. It was observed that midnight hours (0-6 hours) had the lowest load consumption, morning hours (7-11 hours) followed with little increase as the afternoon period (11-15 hours) had the highest load power consumption rate which drops towards the evening time (15-24 hours)

Table 2.1: University Hourly Load Profile

Hours	Load (W)	Hours	Load (W)	Hours	Load (W)
0.00 – 1.00	594423	8.00 – 9.00	680156	16.00 – 17.00	731597

1.00 – 2.00	577273	9.00 – 10.00	680156	17.00 – 18.00	691588
2.00 – 3.00	525835	10.00 – 11.00	680156	18.00 – 19.00	754459
3.00 – 4.00	537266	11.00 – 12.00	914496	19.00 – 20.00	754459
4.00 – 5.00	617285	12.00 – 13.00	914496	20.00 – 21.00	731597
5.00 – 6.00	565844	13.00 – 14.00	948790	21.00 – 22.00	748744
6.00 – 7.00	645863	14.00 – 15.00	908780	22.00 – 23.00	780121
7.00 – 8.00	680156	15.00 – 16.00	743028	23.00 – 24.00	737312

Source: Works department, University of Port Harcourt

a) The average load of the system is determined using the equation:

$$L_{av} = \frac{L_{tot}}{H_{tot}} \tag{2.1}$$

Where L_{av} is the average load
L_{tot} is the total load
H_{tot} is the total hours

b) The peak load is the maximum power requirement of the load in a profile.

The solar resource available in Choba, the university campus location showing the solar energy radiation in kWh/m^2/day received monthly from the sun is presented in table 2.2. This table values indicates that solar energy inflow value is greater during the dry than in rainy season.

Table 2.2: Solar radiation of Choba [10]

Month	**Solar radiation (kWh/m^2/day)**
January	4.879
February	4.901
March	4.830
April	4.626
May	4.284
June	3.888
July	3.465
August	3.803
September	4.224
October	4.317
November	4.752
December	4.848

Source: National Renewable Energy Laboratory (NREL) database

Table 2.3: Parameter values for the solar PV panels

Parameter	**Value**
Model	Evergreen ES-A-200
Peak power	200 W
Maximum power voltage (V_{mp})	18.1 V
Maximum power current (I_{mp})	11.05 A
Cell type	Monocrystalline silicon
Aperture area	1.93 m^2
Factor of efficiency (η_{pv})	0.8

The appropriate PV size for the load demand is given by:

$$P_{pv} = \frac{Average\ Energy\ demand\ (\frac{kWh}{d})}{Equivalent\ Sunlight\ hours\ (EHS) \times \eta_{pv}} \tag{2.2}$$

Where η_{pv} is the PV rated factor of efficiency

Solar PVs are arranged in parallel and series configuration so as to attain maximum output from the system. From the total PV sizing, the total number of panels T_{pv} can be determined.

$$T_{pv} = N_s \times P_p \quad (2.3)$$

$$N_s = \frac{V_s}{V_{mp}} \quad (2.4)$$

$$N_p = \frac{P_{pv}}{V_s \times I_{mp}} \quad (2.5)$$

Where N_s is the number of panels in series
N_p is the number of panels in parallel
V_s is the PV operating voltage

The total area of land required for installing solar panels is calculated from each individual panel area.

The biogas plant will utilize biogas generated from biomass for electricity generation. In determining its parameters for operation, these processes follow:

1) Determine the carbon content of the waste
2) Evaluate the methane content
3) Calculate the energy equivalent of methane generated

The estimated population of students capable of generating sewage and residing at the various hostels in the university campus in Choba is shown in table 2.4

Table 2.4: Population of hostels in the University Choba campus

Hostel	**Population**
Block A	250
Block B	250
Block C	250
Extension	250
Medical	200
Total	1200

The amount of waste excreted per day for individual is 135 – 270g [11].
Wet waste is composed of 65% water content and 35% solid content [12].
Using Buswell equation to estimate the products from the anaerobic breakdown, the water chemical composition is given by [12] as:
Carbon – C – 450
Hydrogen – H – 2050
Oxygen – O – 950
Nitrogen – N – 12
Sulphur – S – 1
Also from the periodic table,
C – 12
H – 1
O – 16
N – 14
S – 32
Biomass to biogas is calculated thus;

a) Percentage of biodegradable carbon content (C_{bg}) in human waste is assumed to be 70% from Buswell equation [12]
b) Amount converted from carbon to biogas (C_{bg}) is given by:
$$T_{c-b} = T_{carbon} \times C_{bg}$$
c) Weight of methane-carbon present in the biogas, W_{m-c}
$$W_{m-c} = T_{c-b} \times M_p$$
Where M_p = Buswell methane percentage = 53% [12]

d) Weight of methane present in the methane (W_m) is:

$$W_m = W_{m-c} \times \frac{16}{12} \tag{2.6}$$

The system components comprising the solar PV, Biogas plant, Diesel generator, Grid system and Battery system are integrated in HOMER software as shown in figure 2.5.

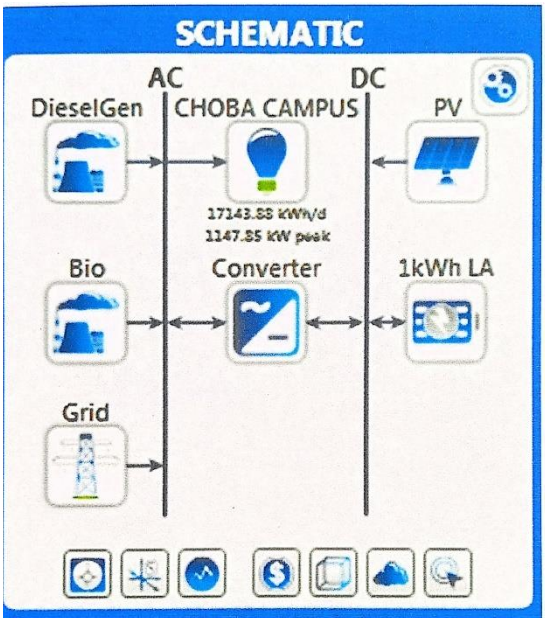

Figure 2.5: Biogas/PV/Diesel/Grid System integration in HOMER

Integrating the components on the schematic diagram of figure 2.5 shown, the various data for each component was inputted into the HOMER software. The university campus load requirement represented as Choba campus in the schematic was supplied with the data on table 2.1. the solar PV was provided also with the biogas resource data of figure 2.4. the batteries (1 kWh LA) which are incorporated alongside with the solar PV to supply more dc voltage attracted the converter required in converting the dc voltage into ac voltage. The grid is set at intermittency rate as diesel generator which is more like a backup source should be powered alongside the renewable energy systems of solar and biogas whenever the grid is unavailable. For essence of simplicity, figure 2.6 shows flowchart of the system simulation.

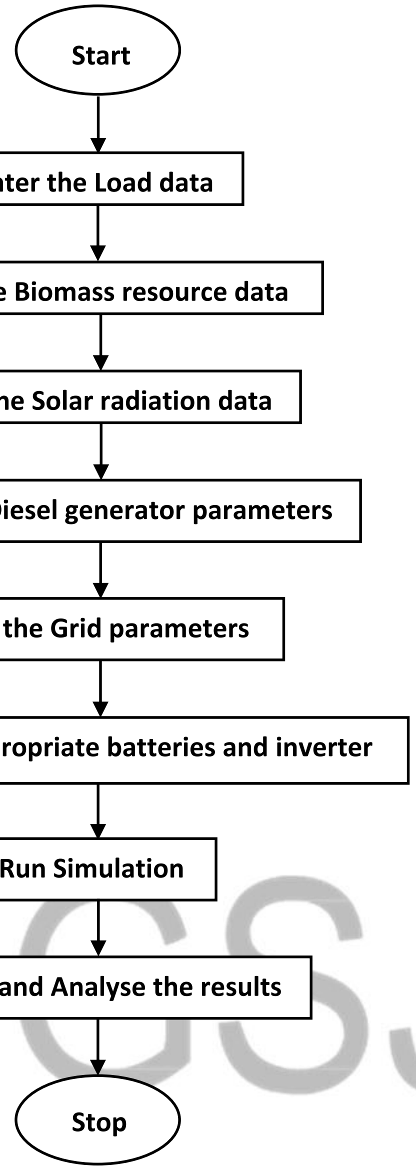

Figure 2.6: Simulation Flowchart of the system

Having examined, calculated and presented the various parameters required for modeling and simulating the proposed system in HOMER, the simulation was done and results interpreted as the system gains are highlighted.

3. Results

Table 3.1: The feasible solutions

						PV (kW)	DieselGen (kW)	Bio (kW)	Uni.System	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)
						500	1,000	500	2	1,000	CC	$5.74	$2.60B	$32.3M	$262M	16
						500	1,000	500	2	1,000	LF	$6.59	$2.98B	$37.6M	$262M	17

After the simulations, two feasible solutions were found. The first is the optimal system comprising a 500kW PV system, 1 MW diesel generator, a 500 kW biogas generator, 2 x

100kW UET Reflex batteries and a converter. The renewable fraction for the system configuration is 16% as depicted in table 3.1.

Note that the battery system was introduced for proper operation of the solar PV system as there may be period whereby the power generated might fall short of the required amount. However, the batteries add to the system cost as the batteries comprises of two 100 kW battery packs.

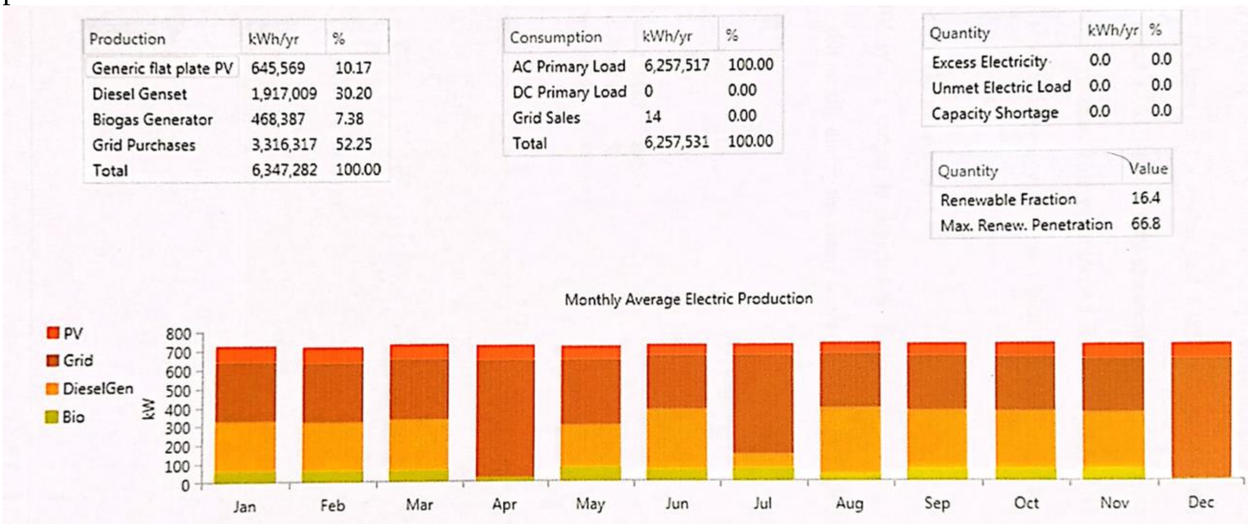

Figure 3.1: System Electrical Output

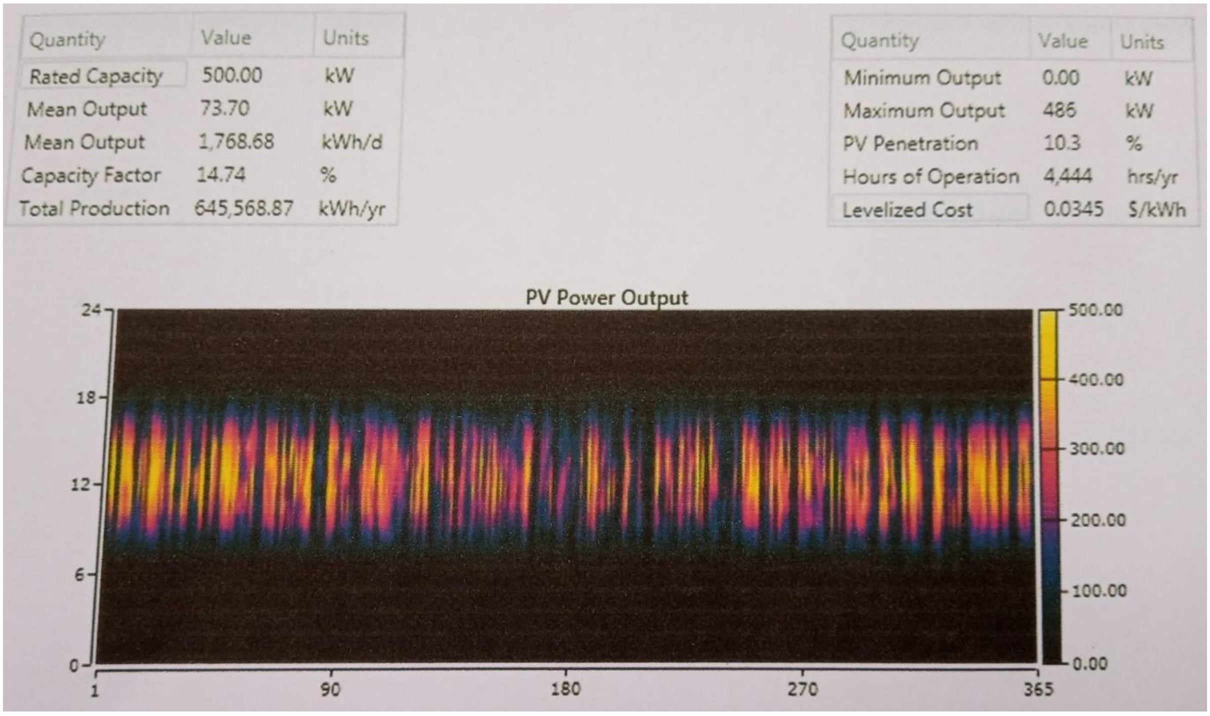

Figure 3.2: The PV Output

The system electrical input from the various energy sources as depicted in figure 3.1 indicates that 52.3% of the total electricity demand was provided from the grid, 30.2% from the diesel generator, 10.17% from the PV system and 7.38% is supplied by the biogas generator. This indicates that about 17.55% of the total electrical energy of the system was supplied by the renewable energy systems. This value had shown remarkable input of the renewable energy systems contributing to more electrical energy production.

The solar PV system output is depicted in figure 3.2. the figure shows that the PV penetration is felt mostly during the sunny hours (10 – 15 hours) each day.

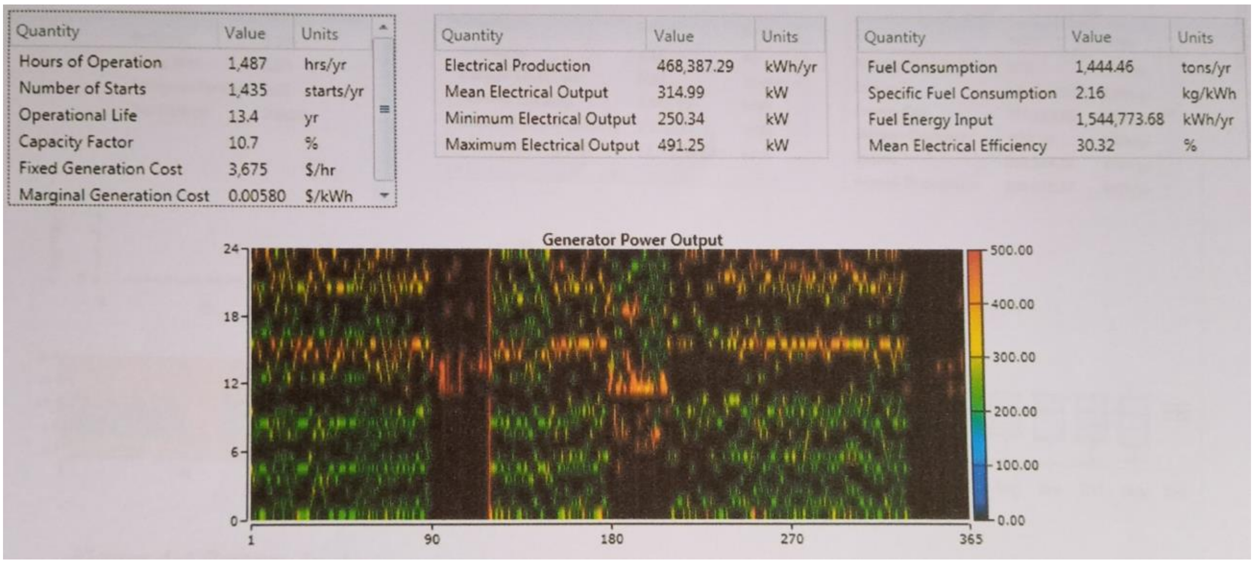

Figure 3.3: The Biogas Generator

The biogas generator operation details are depicted in figure 3.3 as it shows the hours of operation, number of starts, operational life, the quantity of fuel (biogas) consumed, etc.

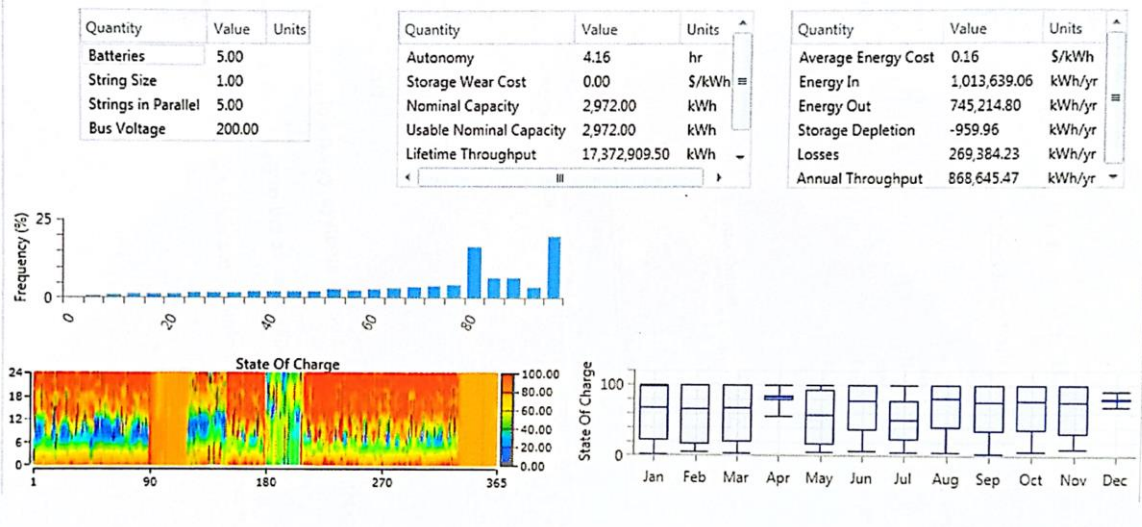

Figure 3.4: Battery Analysis

The batteries contribution to the system is highlighted on figure 3.4 as also the analysis of the batteries operation. The inverter operation analysis is presented in figure 3.5, showing the operation of conversion of dc voltage of the solar PV and batteries to ac voltage.

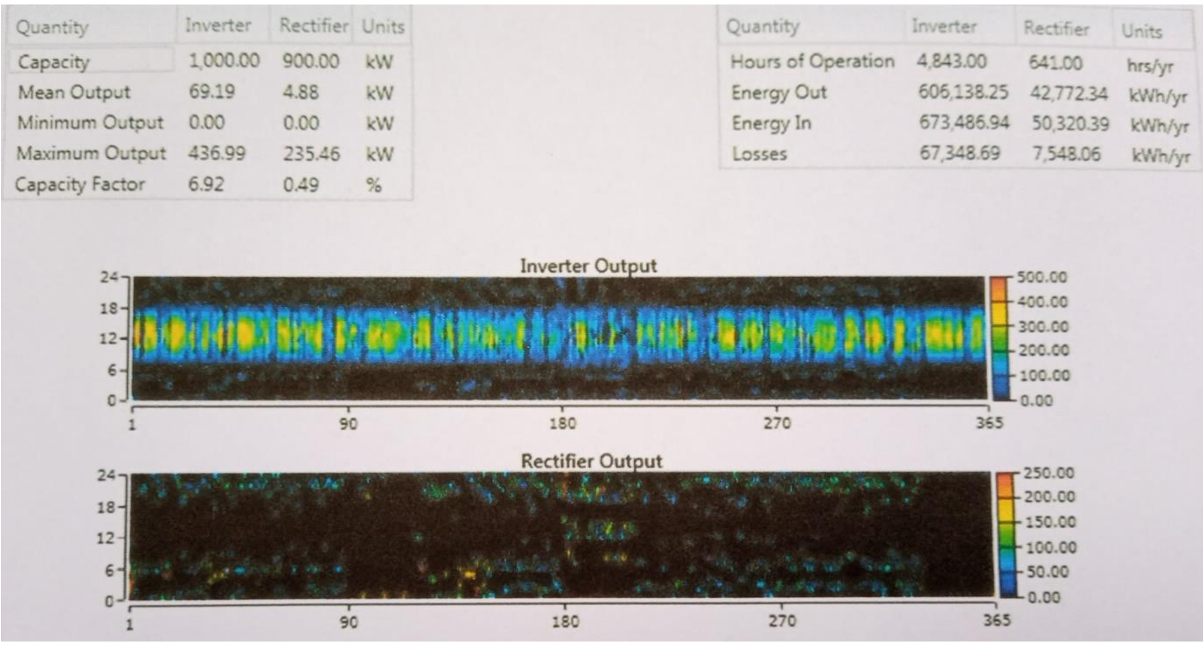

Figure 3.5: Converter Analysis

Also, other two available power systems (diesel generator and grid) which are included in HOMER simulations have their results presented.

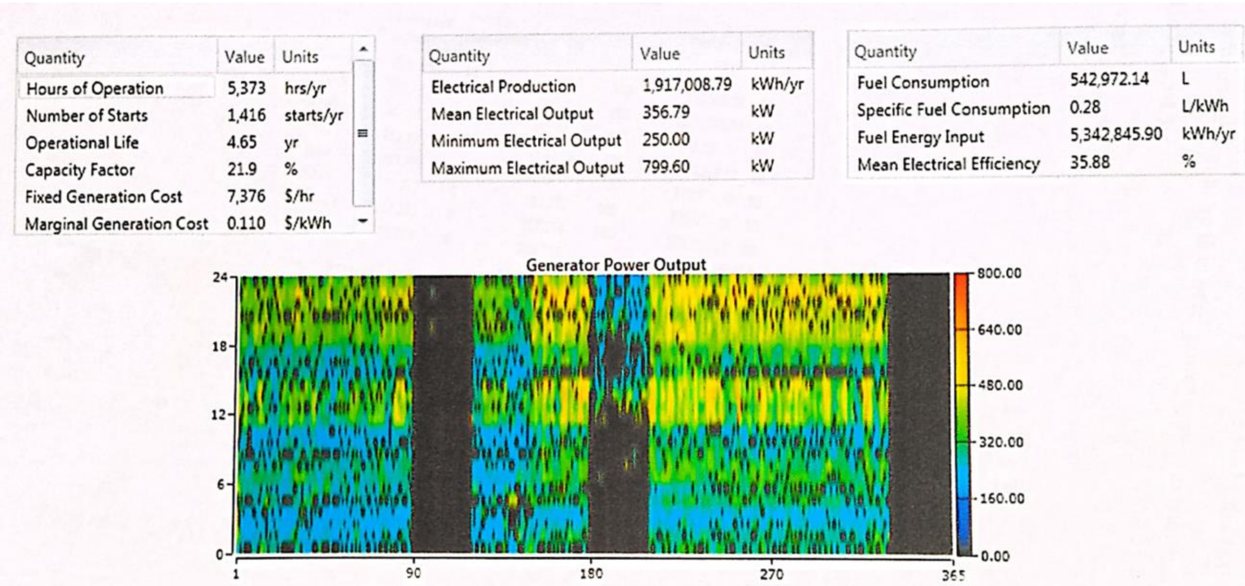

Figure 3.6: Diesel Generator Output

The figure 3.6 shows the diesel generator operation details showing the fuel quantity consumed, its hour of operation, etc. this generator assumed to be 1 MW currently installed at the university campus performs perform more than other power systems as shown.

Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Energy Purchased (kWh)	Peak Demand (kW)	Energy Charge ($)	Demand Charge ($)
February	215,088	14	215,074	350	$21,508.09	$0
March	241,432	0	241,432	350	$24,143.20	$0
April	451,565	0	451,565	800	$45,156.50	$0
May	262,875	0	262,875	400	$26,287.47	$0
June	207,270	0	207,270	300	$20,726.96	$0
July	389,272	0	389,272	600	$38,927.15	$0
August	217,232	0	217,232	300	$21,723.19	$0
September	206,739	0	206,739	300	$20,673.94	$0

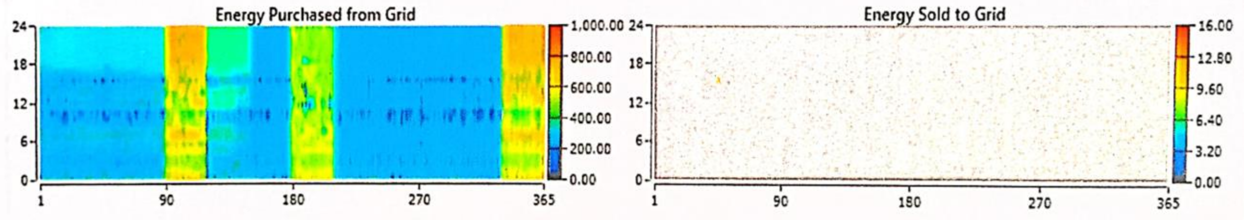

Figure 3.7: The Output of the Grid

4. Discussions

The impact of this system is very clear as the system will improve the amount of electric power generated thereby making sure that electric power is always available in the university campus. The campus offices will not have to be procuring generator set for their individual electric power thereby reducing the rate of noise and GHG pollution experienced in the university campus. This is as a result of reduced usage time of diesel generator by the renewable systems. The sewage waste used in biogas production after undergoing digestion may be sold as fertilizer to farmers thereby creating a source of revenue from municipal waste. The implementation of this power system will invariably increase the rate of RES harnessing in the state and country thereby encouraging other institutions, government parastatals to venture into RES utilization for electric power generation.

Every electric generation system has its uniqueness based on its design, operation or otherwise, the proposed RES energy system is a supplementary to an existing energy system though it could be used independently. It can compete favorably with similar systems available in their capabilities.

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