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Comparative Analysis and Simulation of a Hybrid PV/Diesel Generator/Grid System for the Faculty of Engineering Main Building, Rivers State University, Port Harcourt Nigeria.

*Sigalo, Marvin Barivure[1], Nugha, Barivare Tee[2], Rilwan Usman[3]
Centre for Electrical Power System Research, Dept. Of Elecetrical Engineering, River State University Port Harcourt
Dept. Of Elecetrical Engineering, Modibbo Adama University Technology Yola
Corresponding Author: Sigalo, Marvin Barivure

Abstract: The hybrid power system (HPS) is considered an effective option in terms of low cost of power generation, reduced noise and gas emission, improved and reliable power supply using PV as the main power source and having diesel generator or the grid as a back-up power sources. An economic feasibility study and a complete design of hybrid system consisting of photovoltaic system (PV), a diesel generator and the grid as back-up, for the faculty of engineering of the Rivers State University main building using Homer software, has been presented in this paper. Other scenarios where also analysed in this paper to ascertain which one of them is appropriate, which was found to be PV/grid based on COE and other environmental factors. A simulation program was developed to optimize the sizes of the different components. Specifications of the hybrid components are then determined according to the optimized values. Solar radiation data are first considered, cost of different components, hourly solar radiation obtained from the solar GHI, temperatures and other design considerations are inputs of the Homer simulation program.

Keywords: *Hybrid PV Systems, Diesel Generator, Grid System, Solar Radiation.*

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I. INTRODUCTION

Energy requirement has become a prerequisite to enhance income, improved life quality for individuals no matter their locations (Bahta, 2013). Frequent electricity outages, cost, poor, unreliable and unsecure supply of electricity has thus become a common trend with the Nigerian power distribution companies today. Developing countries in the line of a growing economy are in a much demand for electricity, to facilitate their industrial growth, sustainable economic growth of such countries, as electricity is the pivot of every growing economy. Hence, the quest for a better supply and availability of electricity has led to the need for a renewable energy.

Harnessing an abundance renewable energy sources using versatile hybrid power systems can offer the best, low-cost and reliable energy service with reduced emissions and pollution and provide continuous power supply, increased operational life, and an alternative efficient means of power (Othman., 2005)

THE HYBRID SYSTEM (TECHNOLOGY)

The hybrid system incorporates multiple energy sources which are renewable energy (photovoltaic energy or solar energy), diesel generator, and battery storage system. It combines one or more resources of renewable energy such as solar, wind, micro/mini-hydropower and biomass with other technologies such as batteries, diesel generator and the grid. It offers a clean and efficient power that will in many cases be more cost-effective than a standalone diesel generating set (Othman., 2005)

Therefore, the renewable energy options have increasingly become the preferred-solution to an inadequate power system. In this paper, the hybrid system is modeled using the HOMER (hybrid optimization model for electric energy renewable)software.

THE COMPONENT OF THE HYBRID SYSTEM

The hybrid power station (HPS) consists of a solar photovoltaic array or module and solar regulator with a specified minimum power capacity with a specified temperature and insulation, a lead acid battery storage system, with a specified minimum storage capacity. A diesel generator, usually of an equal sized at an equal rating with the inverter (Othman., 2005).

This acts alongside with the battery storage system as a backup. The system controller, which interfaces with the diesel generator through interconnections with the diesel generator control system which enables automatic operation and selection of power sources.

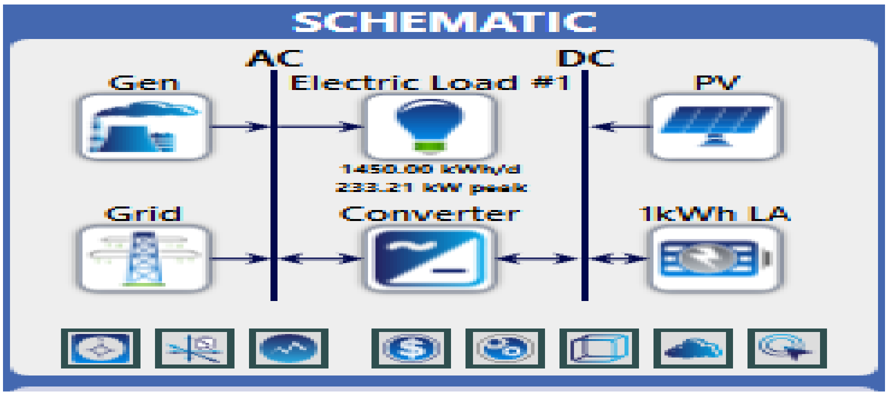


Fig1: The Homer Schematic of The Hybrid System

SIGNIFICANCE AND MOTIVATION OF STUDY

Electricity is the pivot of every growing economy. In Nigeria today, there is constant increase in our population, and as such much demand is placed on electrical energy.On the contrary, the Nigerian power sector over the years is characterised by constant power outages and therefore creating and ill effect on our economy. In achieving a suitable and constant power supply, the hybrid PV/Diesel-generator/Grid/Battery system should be considered, where there will be reduced burning of fossil fuel, reduced emission of dangerous gases which is responsible for the depletion of the ozone layer therefore causing global warming, it also offers clean, effective, cheap, very easy to maintain and a more reliable power sector.

II. RESEARCH METHODOLOGY AND RESULT ANALYSIS

ELECTRICAL LOAD ASSESMENT FOR THE FACULTY OF ENGINEERING MAIN BUILDING.

Table 1: Appliances used in The Faculty Building and Their Wattage.

Component	Size	Wattage
Lighting bulb (Energy saving bulb.)		30
Fan		75
Computers (Desktop)		200
A.C	1.5/2hp	1119/1492
T.V set.	32 Inches plasma	80
Photocopier		250

Building Capacity. Number of offices = 122, Number of Classrooms = 12, Number of conference rooms = 2. Faculty Reception =1, Library =1, Rest Rooms=12.

Table 2: Number of Appliances in Offices, Classrooms, Receptions, Library, Rest Rooms.

S/N	Location	Lighting Points	Fans	Sockets	Computers	A.C
1	Office	4	1	3	1	122(1.5hp) each
2	Class Rooms	9	4	2	_	12(2hp) each
3	Conference Rooms	6	4	4	_	3(2hp) each
4	Reception	6	1	4	_	1(2hp) each
5	Library	12	8	8	1	2(2hp) each

Exceptions:
T.V randomly distributed in faculty=22
Photocopier =30.

LOAD CALCULATION.

Load calculation for the main faculty building, which comprises of 122 offices, 12 class rooms, 2 conference rooms, 1 reception, 1 library, 12 rest rooms from table 1.0, and table 1.1are presented below;

Lighting Points:
Locations of lighting point × number of lighting points...........1.1
(122 × 4) + (12 × 9) + (2 × 6) + (1 × 6) + (1 × 12) (12 × 4) = 674 points.
Rating of each bulb = 30watts.
Lighting point × wattage...1.1.2
⇒(674 × 30) = 20.220kw
Therefore, the power consumption by lighting point in kW = 20.22kw.

Fan
Location of fan × number of fan......................... ....1.2
⇒(122 × 1) + (12 × 4) + (2 × 4) + (1 × 1) + (1 × 8) = 187
Fan rating = 75w
Total number of fan × fan rating...1.2.1
∴(187 × 75) = 14025w = 14.025kw
Power consumed = 14.025kw

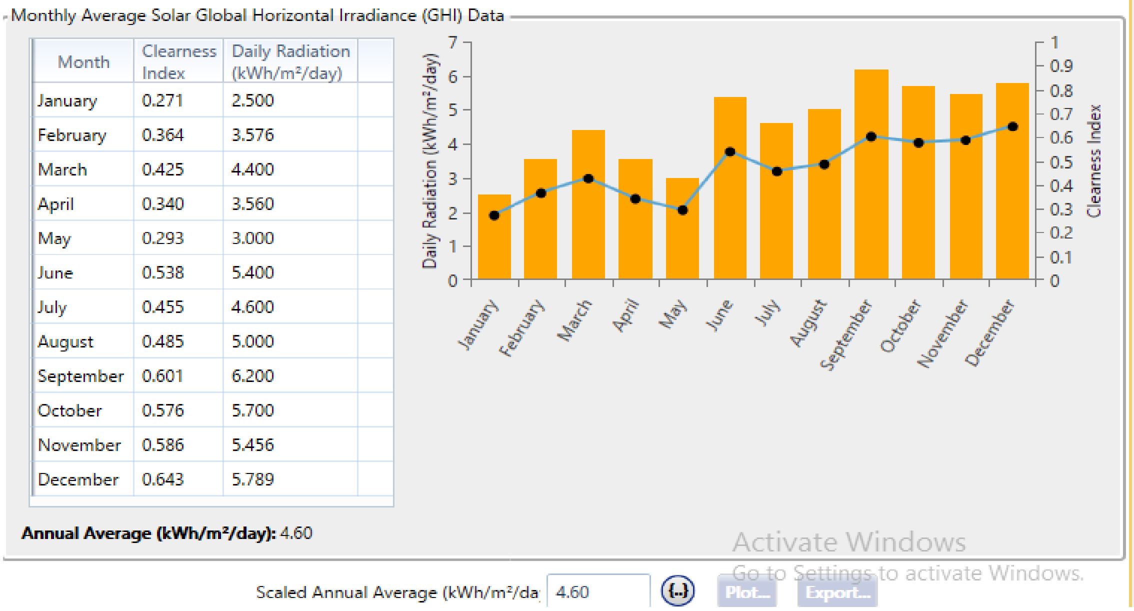
Air Conditioners
Total = 140
For 1.5hp (1hp = 746watts)
⇒1.5 × 746 = 1119watts
∴122 × 1119 = 136,518w
⇒For 1.5hp
We therefore have that 136.518kw is the power consumed by 1.5hp air conditioners
For 2hp
1 hp = 746 watts
∴2 × 746 = 1492watts
∴18 × 1492 = 26,856watts
⇒In kilowatts
Power consumed = 26.856kw.
Hence, total power consumed by air conditioner is;
Summation of 1.5hp and 2hp a.c. .i.e.
1.5hp a.c + 2hp a.c..1.3
⇒(136.518 + 26.856) kW = 163.374kw

Computers
Total numbers = 123
Rating = 200w
Power consumed by the desktop computers
Total number of computers × ratings of computers.................1.4
⇒123 × 200 = 24600w
In Kilowatts, power consumption = 24.6kw
TV Sets
Total numbers = 22
The ratings = 80w
Total number of television × ratings of televisions.................1.5
∴Power consumption in watts = 22 × 80 = 1760w
In kilowatts = 1.76kw
Photocopiers
⇒Total numbers = 30
Power rating = 250w
Number of photocopiers × ratings...1.6
Power consumed = 30 × 250 = 7500w
In kilowatts = 7.5kw
Therefore,the maximum power consumed or the load of the entire main faculty building is calculated by the simple algebraic sum of all individual loads i.e. (20.22 + 14.025 + 163.374 + 24.6 + 1.76 + 7.5) = 231.479kw.
It is very important to note that the size of the solar panel depends on this value of the faculty building power consumption, which is 231.479kw.

Simulation Result and Analysis.

In this research paper, the economic analysis is done base on the life cycle costing method where all types of costs for different components (initial costs, maintenance costs, fuel, operational costs, and replacement costs, etc) are considered. Cost of energy, (COE) which is the cost required to produce 1kwh, is the indicator used in the optimization process. It is the ratio between the total annual cost and the total annual energy required by the load. Different economic factors that affect the value of money over the life of the project also are considered. The life cycle period of the project is considered for 25years. It is the life cycle of the component that has maximum life time.

Analysis of the Photovoltaic System (PV) Data.



Month	Clearness Index	Daily Radiation (kWh/m²/day)
January	0.271	2.500
February	0.364	3.576
March	0.425	4.400
April	0.340	3.560
May	0.293	3.000
June	0.538	5.400
July	0.455	4.600
August	0.485	5.000
September	0.601	6.200
October	0.576	5.700
November	0.586	5.456
December	0.643	5.789

Fig 2: Monthly Average Solar GHI.

Analysis of the available hourly PV data for a year, shows that yearly average daily solar radiation on a horizontal surface (GHI), amount to 4.60kwh/m^2/day. This is as shown in fig 2 above.

Simulation Results.

The result of the simulation program shows that the lowest cost of energy (COE) obtained is 0.03856$/kwh achieved at 46.71% PV contribution and 0.099-hour autonomy days (AD) as shown on table 3 below. This result further indicates that the total NPC (Net present cost) is $287,327.10 and having an operating cost of $22,133.

Table 3: Optimization Table.

Export... Optimization Cases: Left Double Click on a particular system to see its detailed Simulation Results. Categorized Overall

Architecture								Cost			
PV (kW)	PV-MPPT (kW)	Gen (kW)	1kWh LA	Grid (kW)	Converter (kW)	Efficiency1	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)
200	150			999,999	150		CC	$0.0383	$285,702	$22,055	$585.00
200	150	260		999,999	150		CC	$0.0384	$285,796	$22,053	$708.16
200	150		10	999,999	150		CC	$0.0385	$287,233	$22,135	$1,085
200	150	260	10	999,999	150		CC	$0.0386	$287,327	$22,133	$1,208
				999,999			CC	$0.0800	$547,352	$42,340	$0.00
		260		999,999			CC	$0.0800	$547,446	$42,338	$123.16

The contribution of the PV modules, and the grid as modelled by Homer depending on which of the power sources of either grid or the generating set was available and more optimal when combined with the PV, as at the time in supplying the load in months of the year.

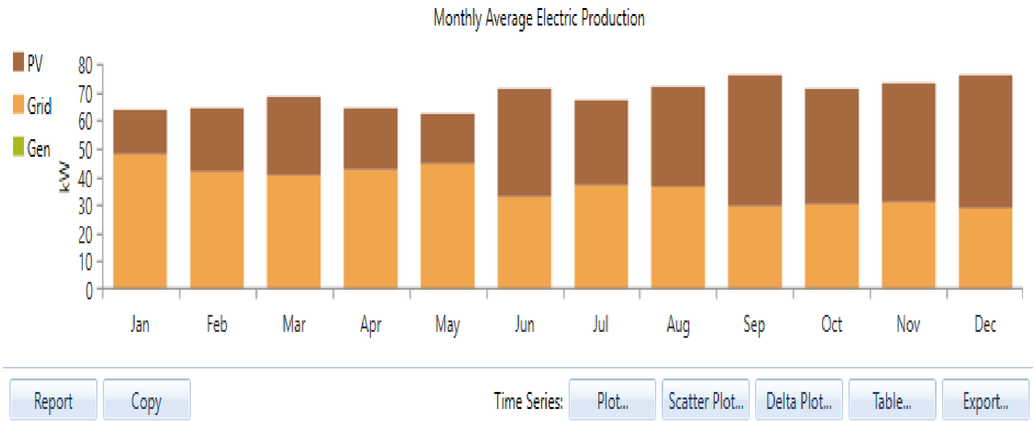


Fig 3: Monthly Average Electric Production.

It is very clear that the PV power supply, are much more produced from June to December depending on the solar global horizontal irradiance (GHI) earlier shown on figure 2.
The figure below shows the renewable penetration time series plot by Homer.

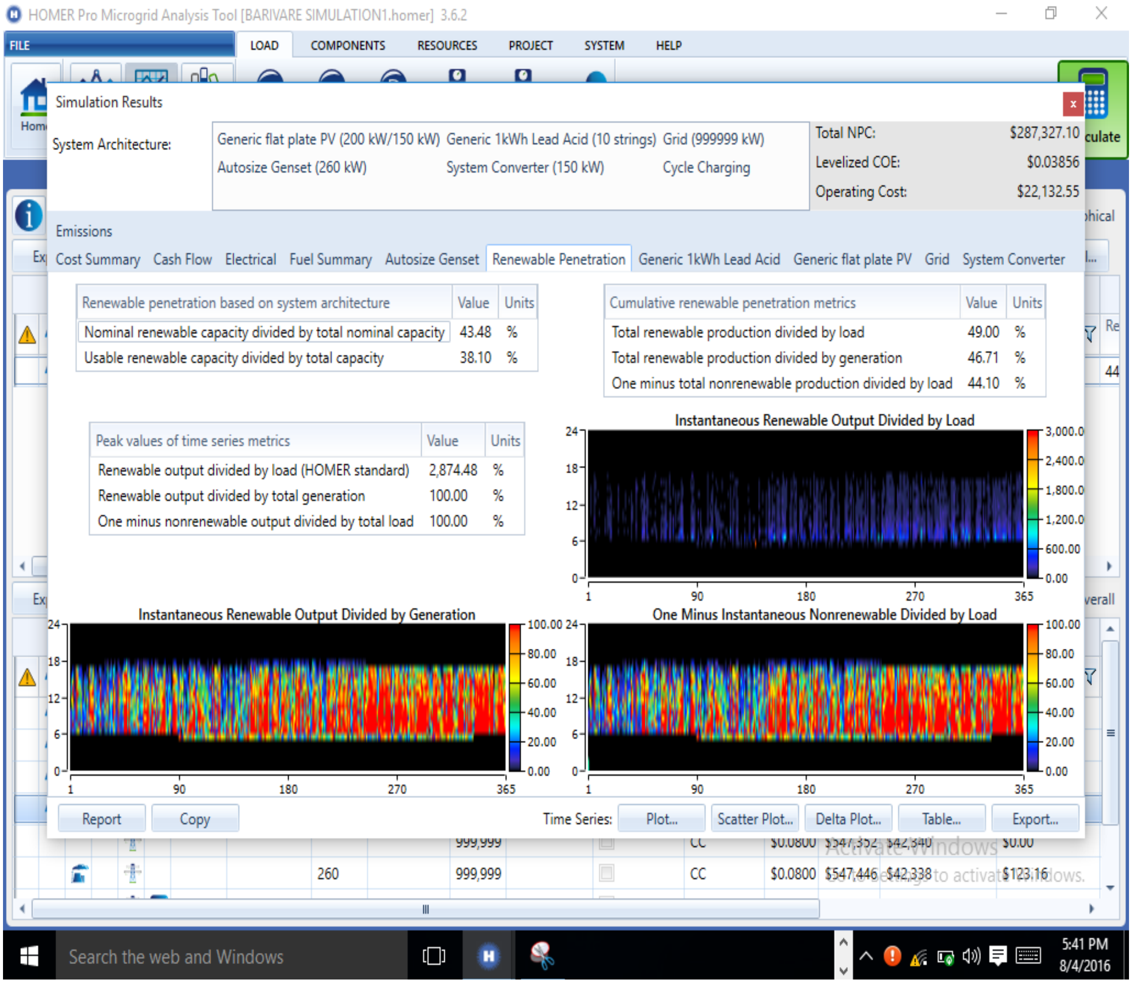
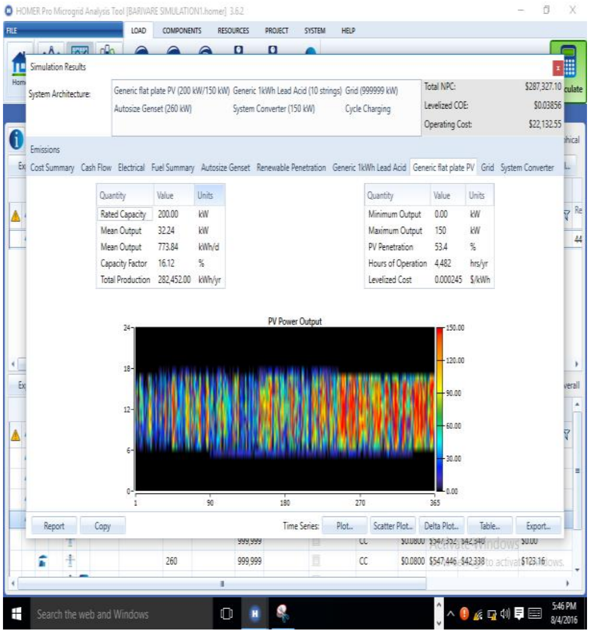


Figure 4: Renewable Penetration.



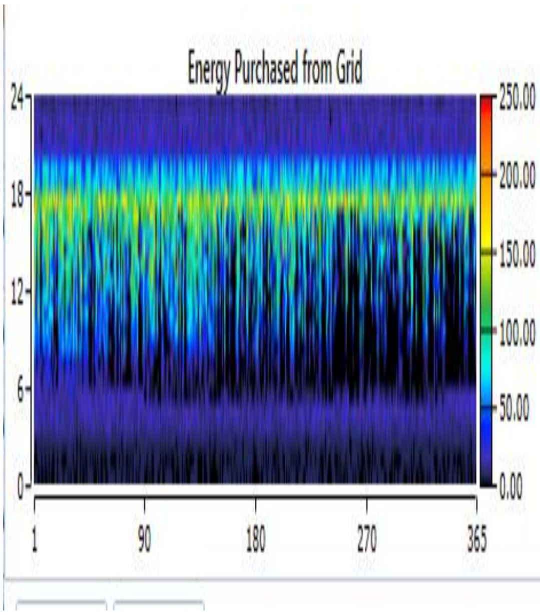


Fig5: PV output Power.Fig 6: Energy purchased from the Grid

The time series plot shown above indicate the energy purchased from the grid. The system converter has information such as the capacity, the mean output, the minimum output, the maximum output capacity factor for both inverter and rectifier respectively

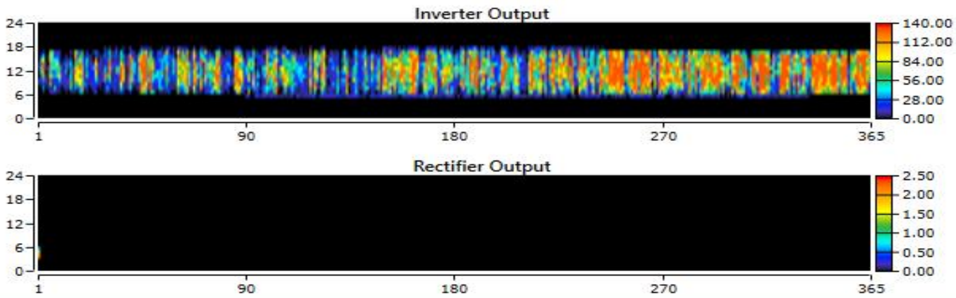
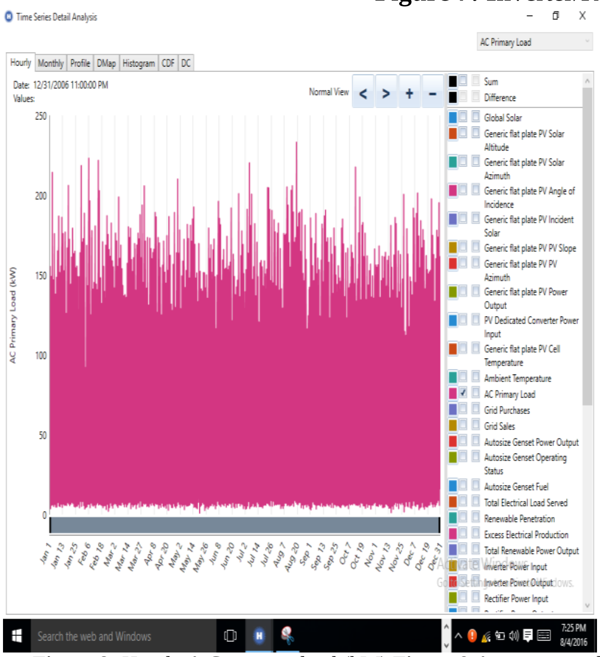


Figure 7: Inverter/Rectifier Output.



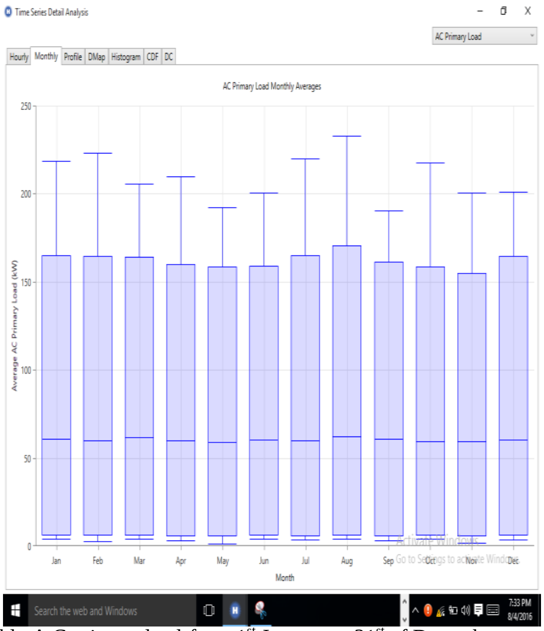


Figure 8; Hourly A.C primary load (kW) **Figure 9**:Average monthly A.C primary load from 1st January to 31st of December.

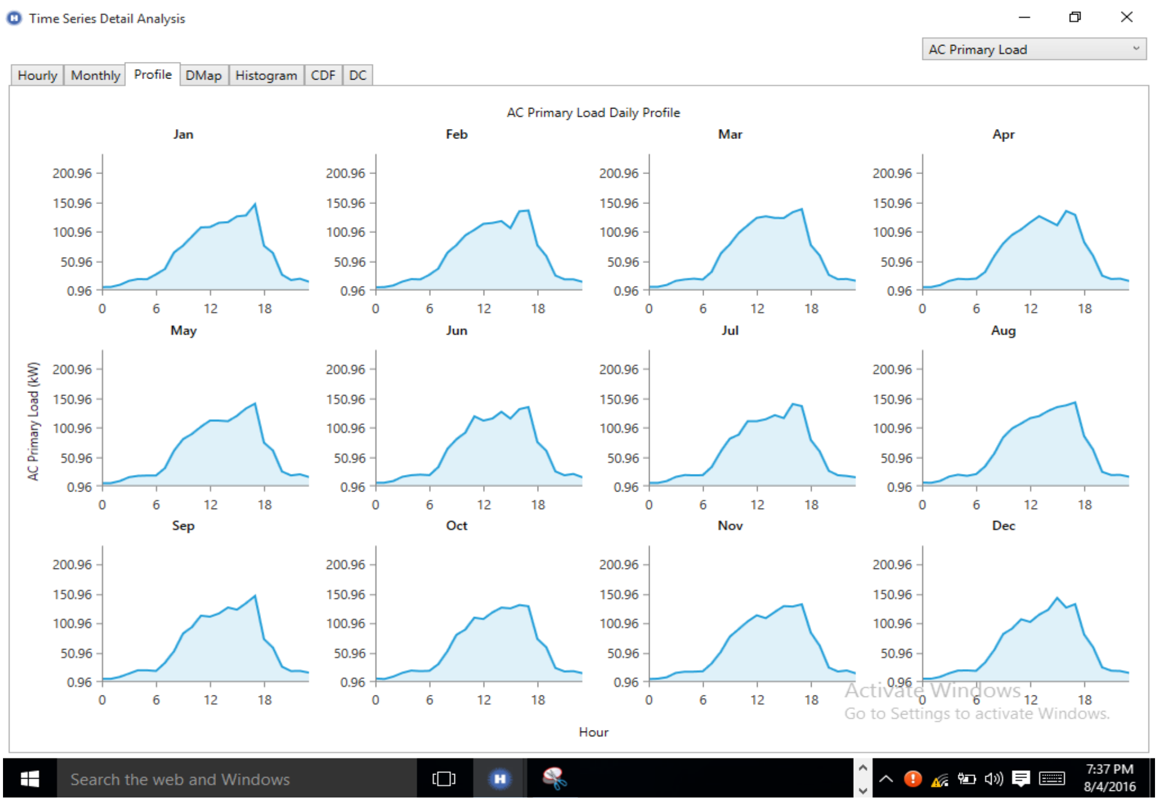


Figure 10: Monthly daily profile for A.C primary load.

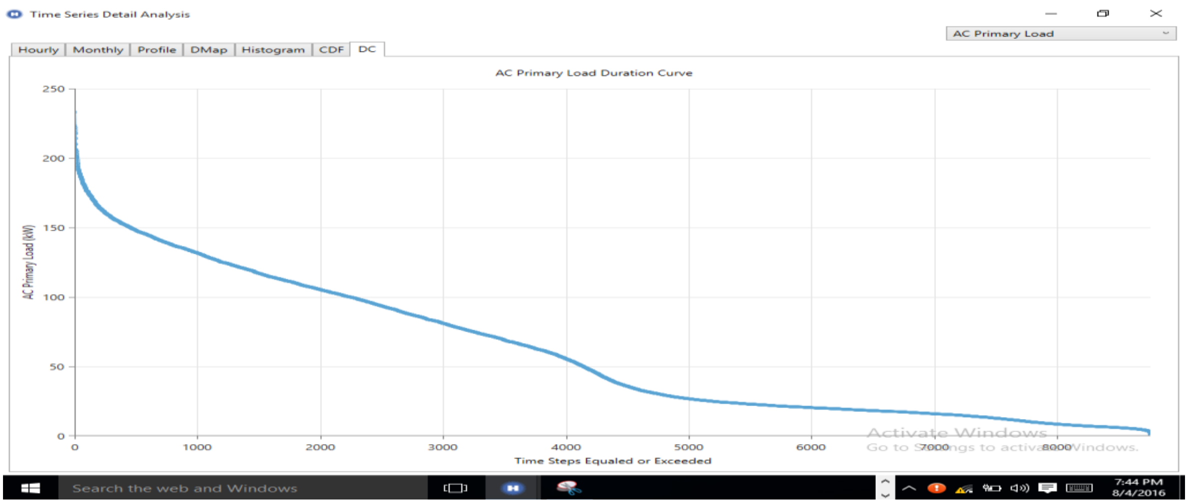


Figure 11 The A.C primary load duration curve.

III. CONCLUSION

It has been shown that the hybrid power system (HPS), is more cost efficient, providing a reduced emission of greenhouse gases, efficient use of energy with respect to the percentage excess electricity produced, the percentage unmet electrical load, and the percentagecapacity shortage, having reliability of supply, than a standalone diesel generator having much gases emission and reduced noise pollution, high cost of energy (COE). Certain scenarios where considered in this project, which include, standalone diesel generator, the hybrid power system of either PV/grid or PV/diesel generator, which the most cost efficient one was found to be the hybrid PV/grid as modelled by Homer and having a cost of energy (COE) of $0.0386 as a result of the solar GHI which was found to be 4.60kwh/m^2/day, and having an autonomy day AD of 0.099 hour with 46.71% of PV contribution due to the solar GHI available, and also having the grid contribution of 53.29%. Homer does a comparison between the hybrid PV/grid and PV/diesel generator where in all cases the PV is the standby power source and having either grid or the diesel generating set as back-up power sources. Hence, this led to the achievement of the project.

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