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Techno-Economic Evaluation Of Grid-Connected 10 KW Solar Photovoltaic Power System For A Household In Rivers State

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***Abstract*— In this work, techno-economic evaluation of grid-connected 10 kW solar photovoltaic (PV) power system for a household in Rivers State is presented. The solar PV installation site is located at latitude of 4.5 °N , longitude of 7.0° E and altitude of 15 m and the site has 1489.9 kWh/m^2 total global solar irradiation on the horizontal plane in a year. The solar power system consist of 76 units of 285 Wp Si-poly PV modules and 15 kW Siemens inverter. The technical analysis results show that the total energy yeild for a year is 22604 kWh, the total load demand for a year is 83957 kWh, the total energy supplied to the user for a year is 21298 kWh, the total energy supplied to the grid for a year is 1305.7 kWh and the mean solar fraction for a year 0.269. this means that means that 26.9 % of the energy supplied to the load is supplied from the solar power while 73.1 5 are suplied from the grid. According to the economic analysis, the PV module cost is 850 Naira per Wp power while the inverter cost is 880 Naira per Wp power. Also, 22 % tax is adopted with 25 years life cycle time. The results show that the unit cost of the energy is 261 Naira per kWh while the total yearly cost of the energy is 5,906,039 Naira.**

***Keywords*— Techno-Economic, Grid-Connected Solar Power, Photovoltaic System , unit cost of the energy**

1. INTRODUCTION

In recent years, there has been increasing adoption of solar power system across Nigeria [1.2]. This has been occasioned by the poor power supply from the grid [3,4,5] and the fact that a good number of Nigerians do not have access to the grid [6,7]. However, nowadays, the need for affordable clean solar energy is driving researchers and designers to carefully select the system components in the design of solar power system [8,9]. Accordingly, in this work, PVSyst simulation software is used to conduct a technical and economic analysis of a grid connected solar power system [10,11,12]. Notably, the technical analysis is used to select the system components sizes and also to determine the energy yield, energy consumptions, losses and other performance parameters [13,14] while the economic analysis is used to determine the cost of implementation and maintenance of the system and also to determine the unit cost of the energy [15,16,17. The details of the technical and economic analysis are performed using PVsyst software.

2. METHODOLOGY

The focus in this work is to evaluate a grid-connected solar PV system designed for a household in Rivers State Nigeria. The geo-location of the solar PV installation site for the extraction of the meteorological dataset is latitude 4.5 °N , longitude 7.0° E and altitude of 15 m, as shown in Figure 1. The geo-location data are used to PVSyst software meteorological data download tool to download the global solar irradiation on the horizontal plane and the ambient temperature from NASA weather data portal. The downloaded monthly mean of the meteorological data of the solar PV installation site is shown in Figure 2.The dataset shows that the annual mean ambient temperature is 26.14 °C while the total of the monthly mean global solar irradiation on the horizontal plane in a year is 1489.9 kWh/m^2. The optimal tilt angle for the PV array and the corresponding transposition factor are determined using the PVSyst PV orientation tool. According to the PVsyst software, the optimal tilt angle for the PV array at installation site is 15 ° with a transposition factor of 1.02, as shown in Figure 3. That means the irradiation hitting the PV array on the optimal tilt angle is about 102% of the one on the horizontal plane (which amounts to total of the monthly mean global solar irradiation on the tilted plane as 1,519.698 1489.9 kWh/m^2).

The schematic diagram of the grid-connected solar (GCS) power system is shown in Figure 4. According to the schematic diagram, the main components of the GCS power system are the electrical load, the inverter and the PV array. The electrical load is captured as the daily load demand in Figure 5 and it consists of a constant 10 kW power that runs for 24 hours every day and this amounts to 240 kWh energy demand per day or average energy demand of 7200 kWh.month.

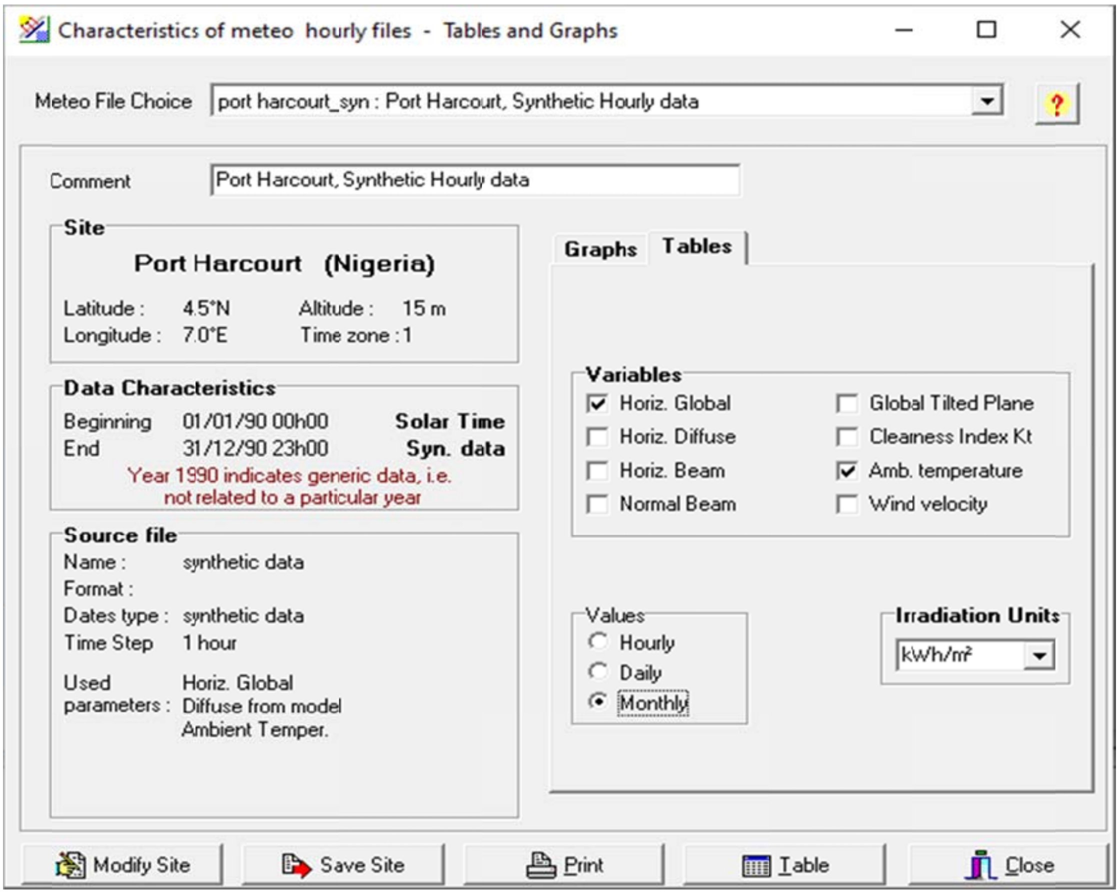
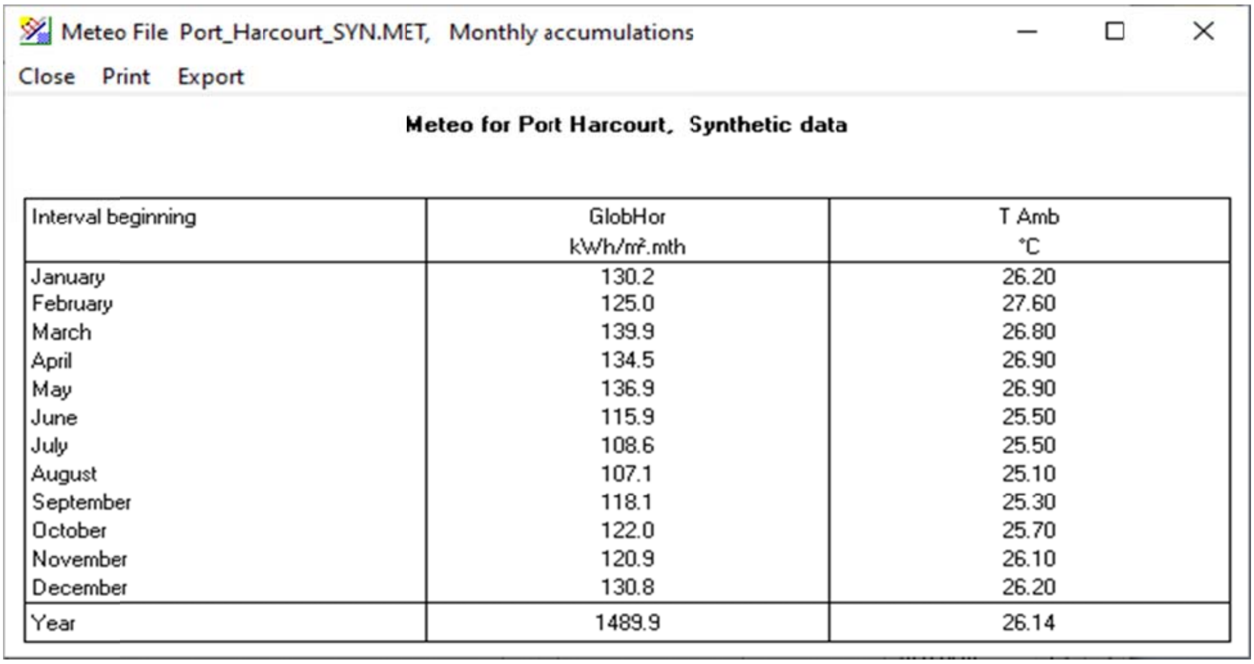


Figure 1 The geo-location of the solar PV installation site for the extraction of the meteorological dataset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Meteo for Port Harcourt, Synthetic data

Interval beginning	GlobHor kWh/m².mth	T Amb °C
January	130.2	26.20
February	125.0	27.60
March	139.9	26.80
April	134.5	26.90
May	136.9	26.90
June	115.9	25.50
July	108.6	25.50
August	107.1	25.10
September	118.1	25.30
October	122.0	25.70
November	120.9	26.10
December	130.8	26.20
Year	1489.9	26.14

Figure 1 The meteorological data of the solar PV installation site

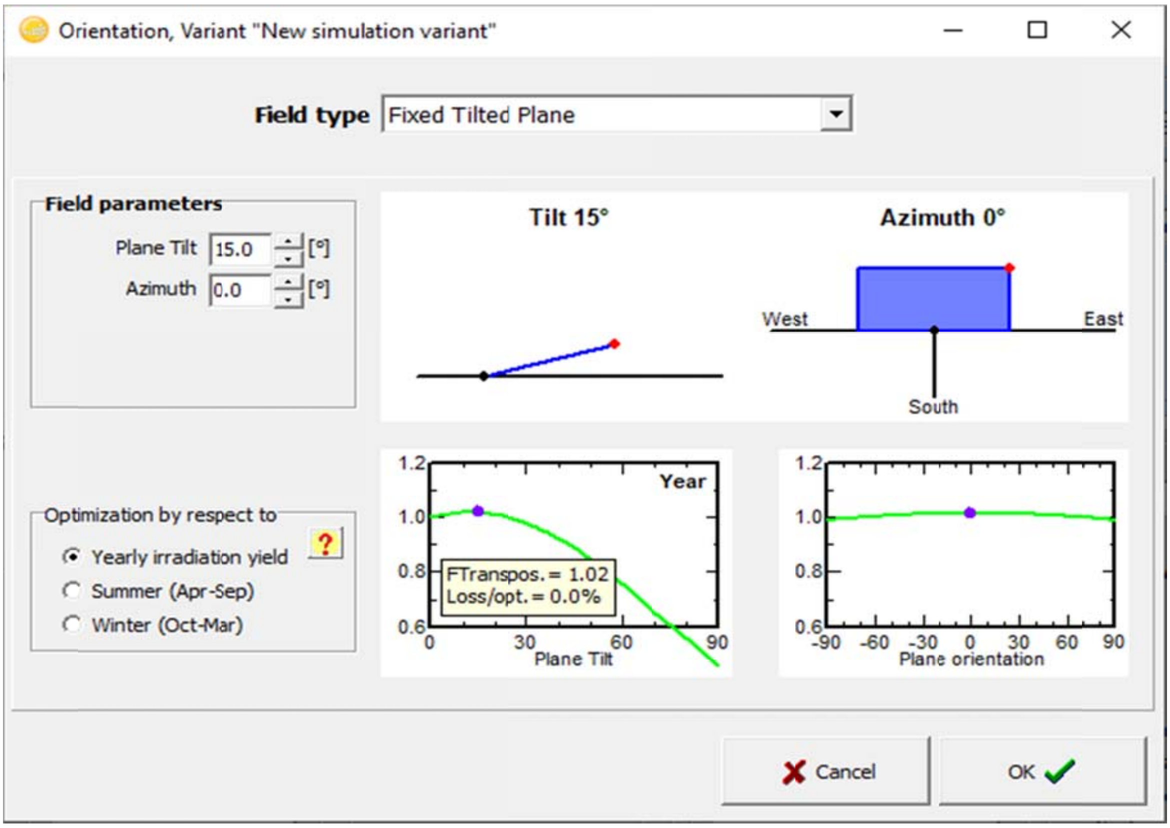

Figure 3 The visualization of optimal tilt angle for the PV array and the corresponding transposition factor

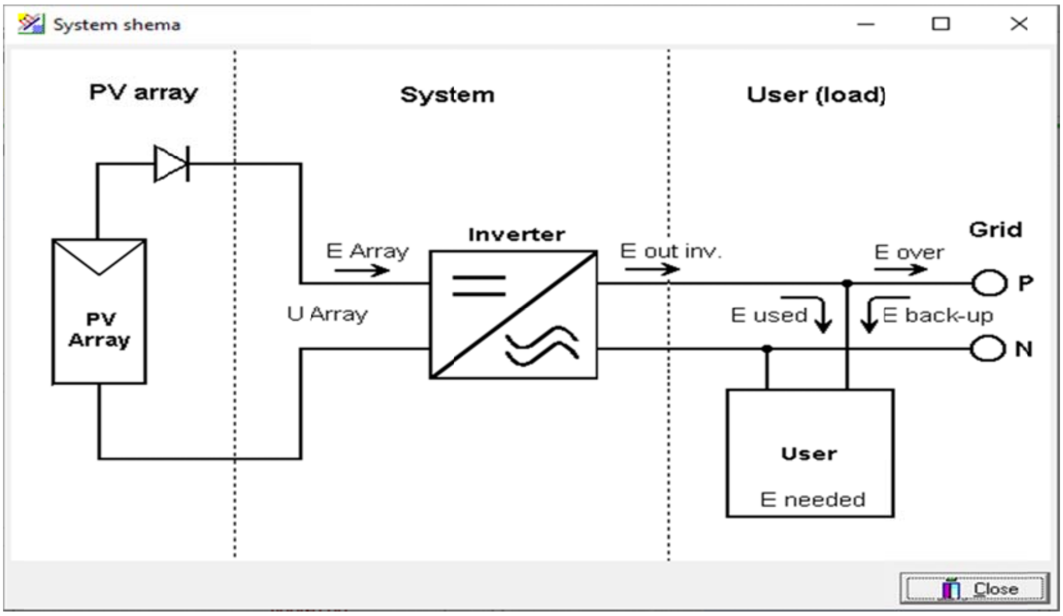

Figure 4 The schematic diagram of the grid-connected solar power system

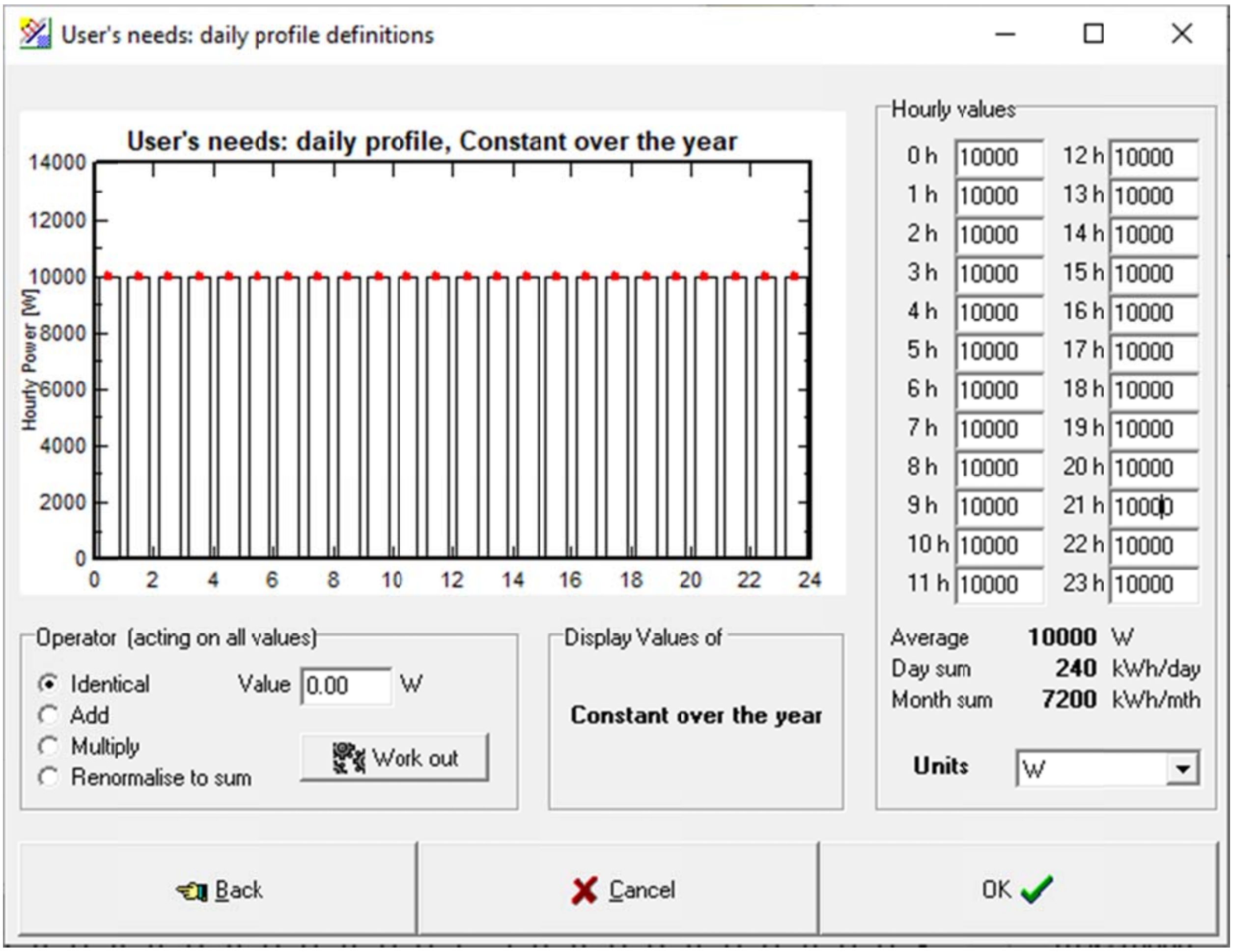

Figure 5 The daily load demand profile for the GCS power system

3. RESULTS AND DISCUSSION

The design and evaluation of the grid-connected solar (GCS) power system is conducted using PVsyst software. The sizing of the PV array and inverter are conducted using the PVSyst's system components selection dialogue window, as shown in Figure 6. According to the PVsyst dialogue window in Figure 6, the 15 kW Siemens inverter, model Sinvert 20 is used and its details are presented in Figure 7. In addition, from the PVsyst dialogue window in Figure 6, the 285 Wp Si-poly PV module manufactured by ASE with model number as ASE-300-DG-FT- (285) 17 is used and its details are presented in Figure 8. In all, a total of 76 PV modules are used whereby 38 PV modules are connected in series and there are two sets of such 38 PV modules that are connected in parallel, as shown in Figure 8

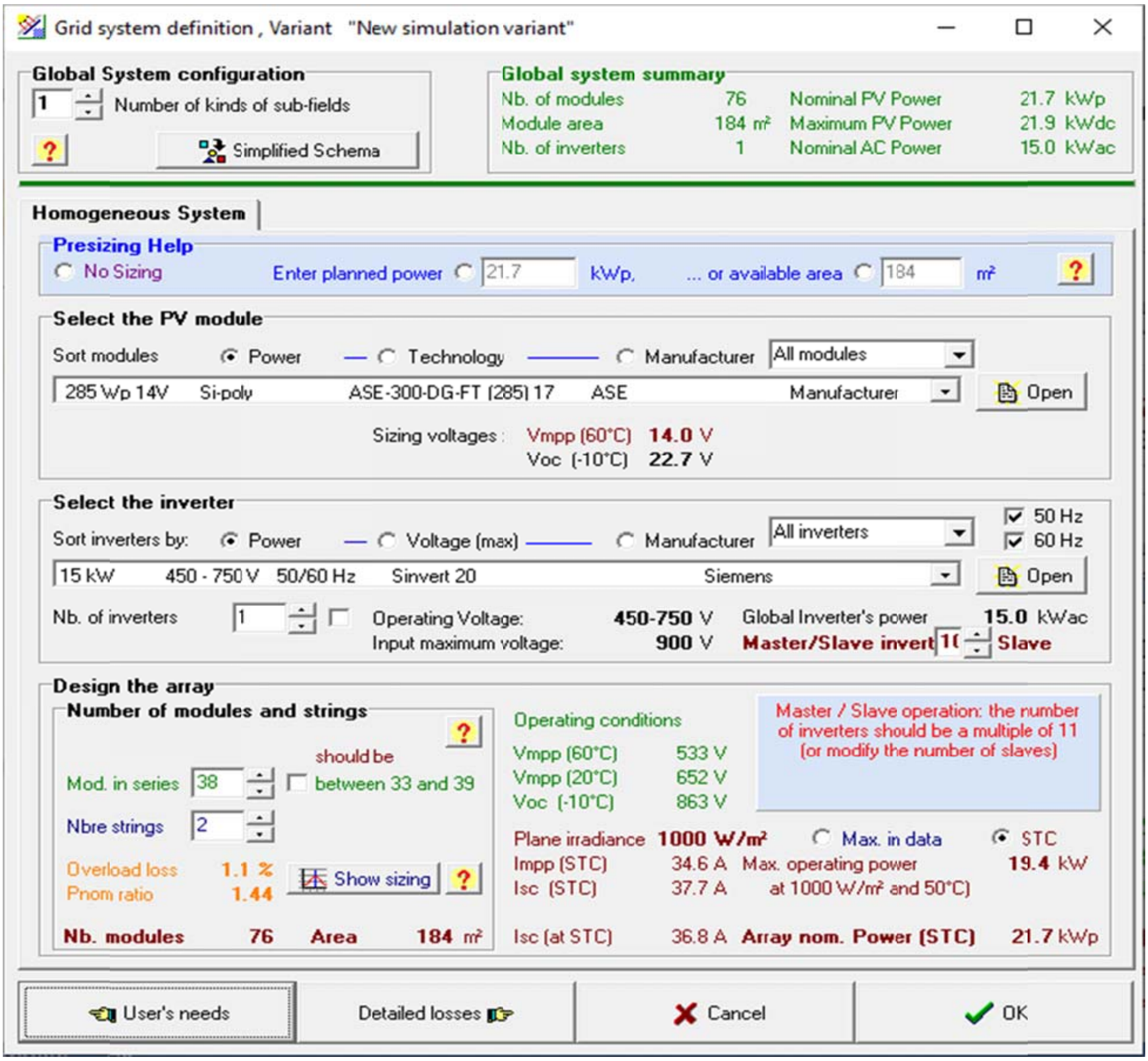

Figure 6 The PVSyst's system components selection dialogue window for the GCS power system

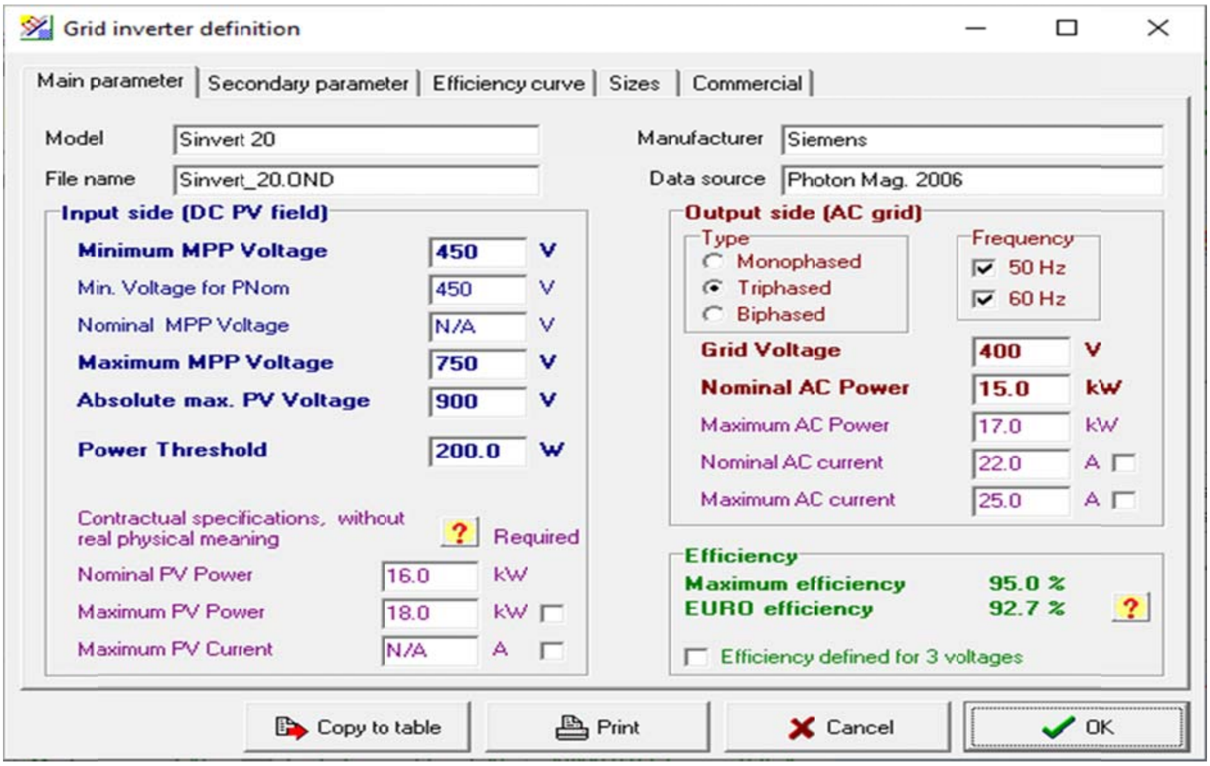

Figure 7 The details of the 15 kW Siemens inverter, model Sinvert 20 used in the GCS power system design

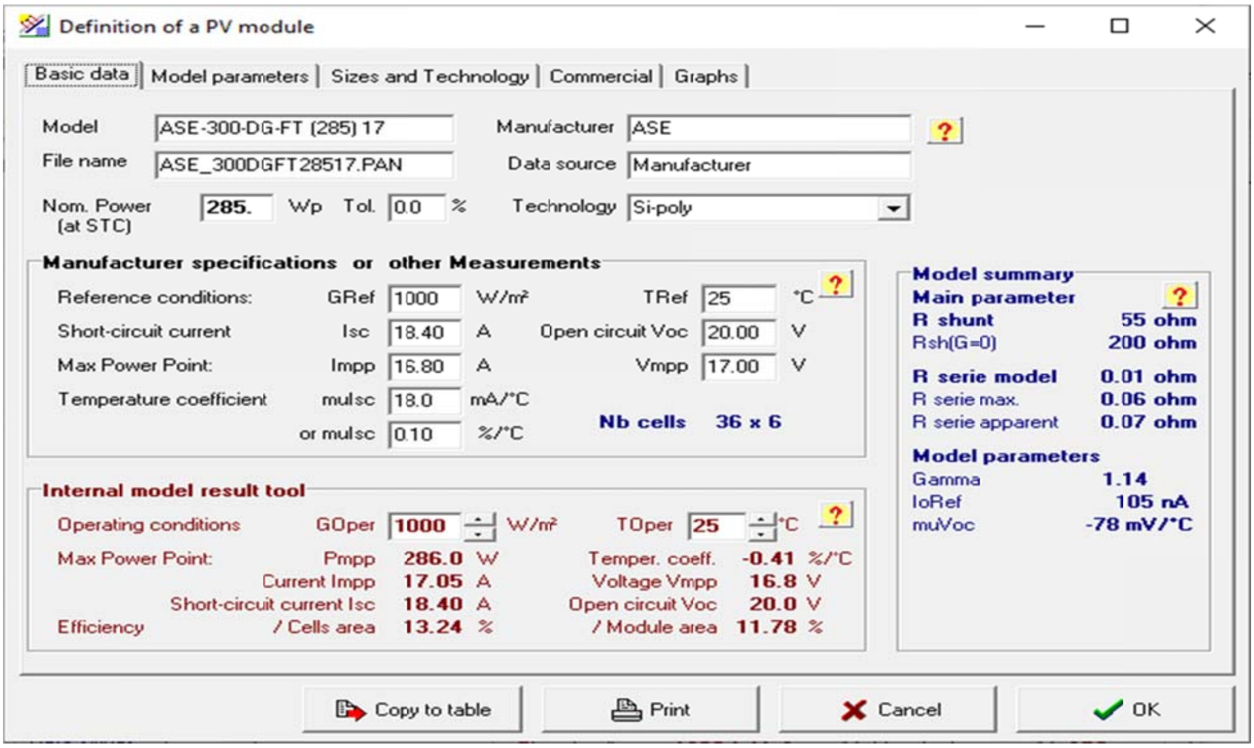

Figure 8 The details of the 285 Wp Si-poly PV module manufactured by ASE with model number as ASE-300-DG-FT- (285) 17

The main results on the technical evaluation of the GCS power system are presented in Figure 9 and the results show the monthly available solar energy yeild (E Avail), the energy demand of the load (E Load), the energy supplied to the load or user (E User), the energy supplied to the grid (E Grid and the solar fraction (SolFrac) which is the fraction of the load demand that is supplied from the soalr power. According to the results, the total E Avail for a year is 22604 kWh, the total E Load for a year is 83957 kWh, the total E User for a year is 21298 kWh, the total E Grid for a year is 1305.7 kWh and the mean SolFrac for a year 0.269. Essentially, solar fraction is the ratio of E User to E Load (21298/83957 = 0.253677478) and E avail is the susm of E user and E Grid, that is 21298 + 1305.7 =

22603.7 kWh. Also, solar fraction of 0.269 means that 26.9 % of the energy supplied to the load is supplied from the solar power while 73.1 5 are suplied from the grid.

The key input dataset for the economic evaluation of the GCS power system are presented in Figure 10 while the main results on the economic evaluation are presented in Figure 111. According to the economic analysis input dataset in Figure 10, the cost of the PV module is 850 Naira per Wp power while the inverter cost is 880 Naira per Wp power. Also, 22 % tax is adopted with 25 years life cycle time. The results show that the unit cost of the energy is 261 Naira per kWh. Meanwhile, the energy used by the load is 21.3 MWh per year while the energy sold to the grid is 1.3 MWh per year. The total yearly cost of the energy is 5,906,039 Naira.

Simulation variant : New simulation variant

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New simulation variant
Energy use and User's needs

	E Avail kWh	E Load kWh	E User kWh	E Gridl kWh	SolFrac
January	2072	7131	1916	156.3	0.291
February	1929	6441	1798	130.8	0.299
March	2123	7131	1953	170.1	0.298
April	1988	6901	1859	129.1	0.288
May	1989	7131	1934	54.8	0.279
June	1678	6901	1650	28.0	0.243
July	1566	7131	1526	39.7	0.220
August	1567	7131	1514	52.9	0.220
September	1793	6901	1693	99.9	0.260
October	1889	7131	1782	106.6	0.265
November	1898	6901	1765	132.9	0.275
December	2112	7131	1907	204.7	0.296
Year	22604	83957	21298	1305.7	0.269

Figure 9 The main results on the technical evaluation of the GCS power system

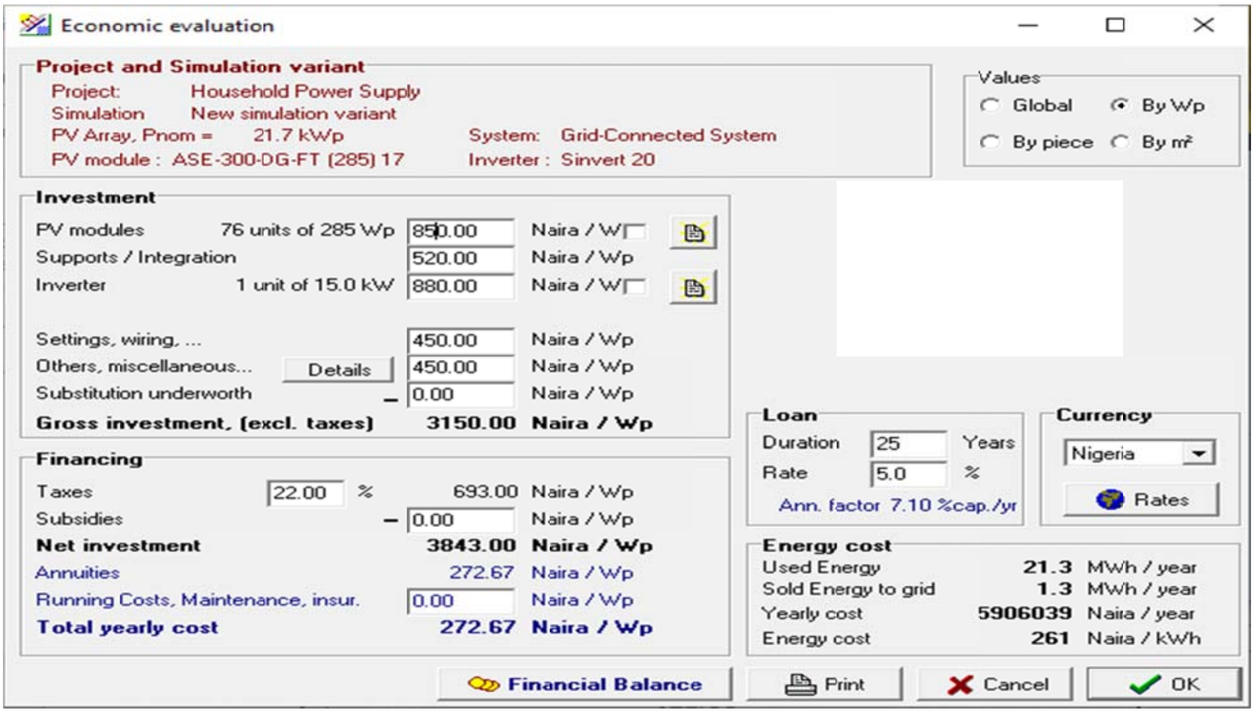
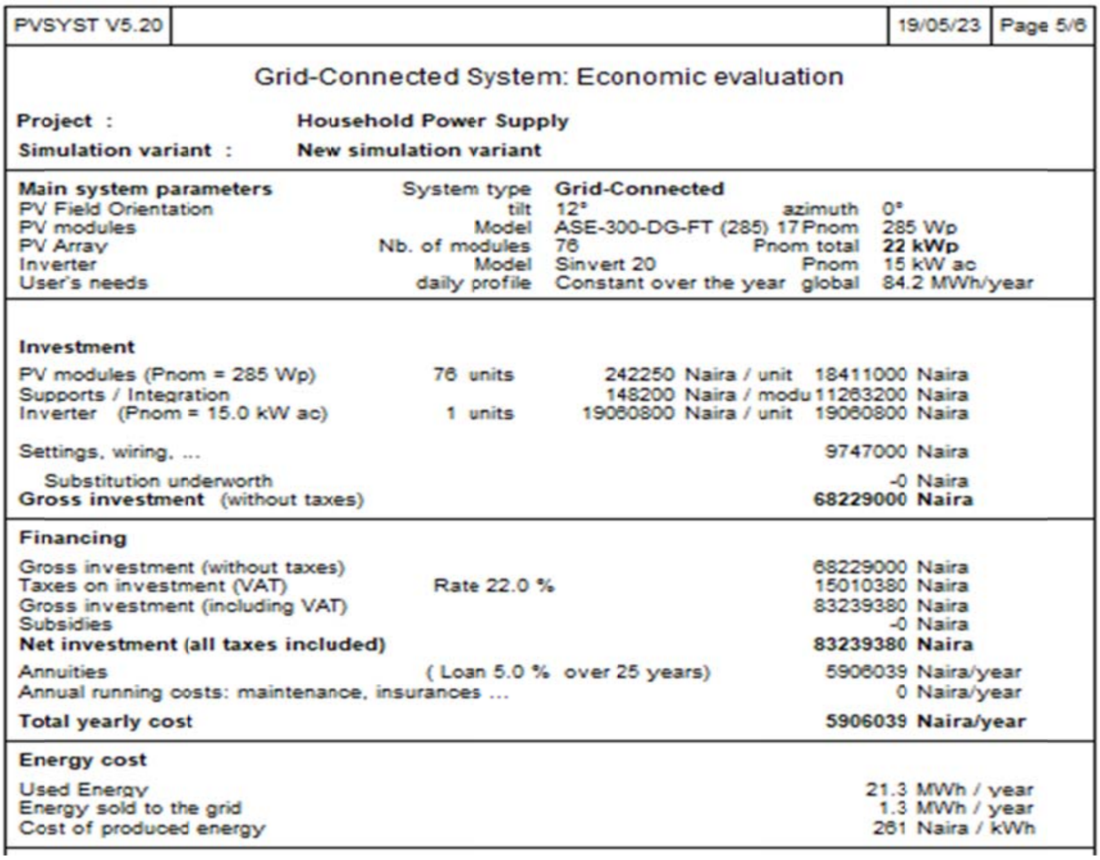


Figure 10 The key input dataset for the economic evaluation of the GCS power system



PVSYST V5.20		19/05/23	Page 5/6

Grid-Connected System: Economic evaluation

Project : **Household Power Supply**
Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	12°	azimuth	0°
PV modules	Model	ASE-300-DG-FT (285) 17	Pnom	285 Wp
PV Array	Nb. of modules	76	Pnom total	**22 kWp**
Inverter	Model	Sinvert 20	Pnom	15 kW ac
User's needs	daily profile	Constant over the year	global	84.2 MWh/year

Investment

PV modules (Pnom = 285 Wp)	76 units	242250 Naira / unit	18411000 Naira
Supports / Integration		148200 Naira / modu	11263200 Naira
Inverter (Pnom = 15.0 kW ac)	1 units	19060800 Naira / unit	19060800 Naira
Settings, wiring, ...			9747000 Naira
Substitution underworth			-0 Naira
Gross investment (without taxes)			**68229000 Naira**

Financing

Gross investment (without taxes)		68229000 Naira
Taxes on investment (VAT)	Rate 22.0 %	15010380 Naira
Gross investment (including VAT)		83239380 Naira
Subsidies		-0 Naira
Net investment (all taxes included)		**83239380 Naira**
Annuities	(Loan 5.0 % over 25 years)	5906039 Naira/year
Annual running costs: maintenance, insurances ...		0 Naira/year
Total yearly cost		**5906039 Naira/year**

Energy cost

Used Energy	21.3 MWh / year
Energy sold to the grid	1.3 MWh / year
Cost of produced energy	261 Naira / kWh

Figure 11 The main results on the economic evaluation of the GCS power system

4. CONCLUSION

Techno economic evaluation of a grid connected solar power system is conducted using PVSyst simulation software. The work involved sizing of the PV array and the inverter, and also to determine the lifecycle cost of the system based on the prevailing cost of the components. The system is designed based on solar radiation data of a site in River State and with a constant 10 kW daily load demand. In all, the results obtained from the simulation show that unit cost of energy is less than 300 Naira per kWh.

REFERENCES

1. Ugulu, A. I. (2019). Barriers and motivations for solar photovoltaic (PV) adoption in urban Nigeria. *International Journal of Sustainable Energy Planning and Management*, *21*.
2. Agbo, E. P., Edet, C. O., Magu, T. O., Njok, A. O., Ekpo, C. M., & Louis, H. (2021). Solar energy: A panacea for the electricity generation crisis in Nigeria. *Heliyon*, *7*(5).
3. Babatunde, O. M., Ayegbusi, C. O., Babatunde, D. E., Oluseyi, P. O., & Somefun, T. E. (2020). Electricity supply in Nigeria: Cost comparison between grid power tariff and fossil-powered generator. *International Journal of Energy Economics and Policy*, *10*(2), 160-164.
4. Olukan, T. A., Santos, S., Al Ghaferi, A. A., & Chiesa, M. (2022). Development of a solar nano-grid for meeting the electricity supply shortage in developing countries (Nigeria as a case study). *Renewable Energy*, *181*, 640-652.
5. Akinbomi, J. G., Ezeilo, L. C., Fagbuyi, O., & Onyebueke, L. (2021). Optimal microgrid power supply system for Nigerian detached communities: Environmental impact and energy cost criteria. *Nigerian Journal of Technology*, *40*(3), 491-500.
6. Babatunde, O. M., Ayegbusi, C. O., Babatunde, D. E., Oluseyi, P. O., & Somefun, T. E. (2020). Electricity supply in Nigeria: Cost comparison between grid power tariff and fossil-powered generator. *International Journal of Energy Economics and Policy*, *10*(2), 160-164.
7. Oladigbolu, J. O., Ramli, M. A., & Al-Turki, Y. A. (2020). Feasibility study and comparative analysis of hybrid renewable power system for off-grid rural electrification in a typical remote village located in Nigeria. *IEEE Access*, *8*, 171643-171663.
8. Bogdanov, D., Ram, M., Aghahosseini, A., Gulagi, A., Oyewo, A. S., Child, M., ... & Breyer, C. (2021). Low-cost renewable electricity as the key driver of the global energy transition towards sustainability. *Energy*, *227*, 120467.
9. Adewuyi, A. (2020). Challenges and prospects of renewable energy in Nigeria: A case of bioethanol and biodiesel production. *Energy Reports*, *6*, 77-88.
10. Elsaid Ayousha, A. F. (2021). *Design and economic analysis of a grid-connected photovoltaic system for different types of solar panels in Saudi Arabia using pvsyst software* (Doctoral dissertation, Universiti Tun Hussein Malaysia).
11. Mohamed, N. S. S., Sulaiman, S. I., & Rahim, S. R. A. (2022, August). Design of ground-mounted grid-connected photovoltaic system with bifacial modules using PVsyst software. In *Journal of Physics: Conference Series* (Vol. 2312, No. 1, p. 012058). IOP Publishing.
12. Dellosa, J. T., Panes, M. J. C., & Espina, R. U. (2021, September). Techno-Economic Analysis of a 5 MWp Solar Photovoltaic System in the Philippines. In *2021 IEEE International Conference on Environment and Electrical Engineering and 2021 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)* (pp. 1-6). IEEE.
13. Razmjoo, A., Kaigutha, L. G., Rad, M. V., Marzband, M., Davarpanah, A., & Denai, M. (2021). A Technical analysis investigating energy sustainability utilizing reliable renewable energy sources to reduce CO2 emissions in a high potential area. *Renewable Energy*, *164*, 46-57.
14. Majed, A. R., Gueymard, C. A., Al-Khayat, M., Ismail, A., Lee, J. A., & Al-Duaj, H. (2020). Performance evaluation of a utility-scale dual-technology photovoltaic power plant at the Shagaya Renewable Energy Park in Kuwait. *Renewable and Sustainable Energy Reviews*, *133*, 110139.
15. Khan, S. U. D., Wazeer, I., Almutairi, Z., & Alanazi, M. (2022). Techno-economic analysis of solar photovoltaic powered electrical energy storage (EES) system. *Alexandria Engineering Journal*, *61*(9), 6739-6753.
16. Ashtiani, M. N., Toopshekan, A., Astaraei, F. R., Yousefi, H., & Maleki, A. (2020). Techno-economic analysis of a grid-connected PV/battery system using the teaching-learning-based optimization algorithm. *Solar Energy*, *203*, 69-82.
17. Javed, H., Muqeet, H. A., Shehzad, M., Jamil, M., Khan, A. A., & Guerrero, J. M. (2021). Optimal energy management of a campus microgrid considering financial and economic analysis with demand response strategies. *Energies*, *14*(24), 8501.