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Simulated Performance Analysis Of Standalone Photovoltaic Power System With Backup Generator For A Hospital In Akwa Ibom State

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Abstract*— In this paper, the simulated performance analysis of standalone photovoltaic power system with backup generator for a hospital in Akwa Ibom State is presented. The installation site geo-coordinates are 4.926045 (latitude) and 8.030304 (longitude) and the hospital has daily energy demand of 101.808 kWh.day. The system design specification has 2 days of power autonomy and maximum of 5% loss of load probability and DC line voltage of 24 V. A battery bank consisting of a total of 126 batteries each with 12 V and 150 Ah capacity is required. Also, PV array consisting of a total of 211PV modules each with 24V and 190 Wp power capacity is required.The PVSyst software simulation of the PV power system was conducted and the main simulation results show that the system has annual energy yield of 47.8 MWh/year, specific energy yield of 1193 kWhkWhp/year, solar fraction of 95.4 %, missing energy of 1736 kWh, loss of load of 4.7 % and unused energy of 7327 kWh/year. The PV system has yearly total of daily reference energy yield (Yr) of 1576 kWh/m^2.day, the normalized loss due to unused energy has annual mean of 0.257, the normalized loss (Lc) in the PV array has annual mean of 1.551, the normalized system loss (Ls) has annual mean of 0.333 while the system performance ratio (PR) is 0.564 or 56.4 %. The system loss diagram shows that battery loss is about 4.1 % of the total energy yield, energy loss due to unused energy is about 12 % of the total energy yield, while the highest loss of 19 % is the array loss which is the sum of thermal loss, loss due to PV module quality, dust and other factors associated with the PV module. Essentially, the PV system supplied 95.4 % (that is the solar fraction) of the required energy for the hospital while about 4.7 % (that is the loss of load) of the required energy are not met with the PV power system. However, the system performance is acceptable since the design specification allowed a maximum of 5 % loss of load with two days power autonomy. Also, with the backup generator in place, the missing 4.7% energy demand will be supplied from the backup generator.

Keywords*— *Performance Analysis, Standalone Photovoltaic Power System, Loss Of Load, Hospital PV Power, Backup Generator

1. INTRODUCTION

Increasingly, for effective service delivery, many health facilities in the remote parts of Nigeria are adopting solar power options [1,2,3]. This help them to stay connected in terms of internet connectivity as well as connected via the various wireless network services that are available in various parts of Nigeria. Notably, patients and their relatives are always eager to have some level of electric power availability in the health facilities to help them remotely connect and coordinate the health care service delivery and to respond promptly to emergency situation.

In any case, some of the health facilities in the remote areas have electric generators based on fossil fuel. However, with the present high cost of fossil fuel, majority of the health facilities are installing solar photovoltaic (PV) power as the main alternative power source with the fossil fuel electric power generators as the second option [4,5,6]. Consequently, in this paper, the simulated performance analysis of standalone photovoltaic power system with backup generator for a hospital is presented [7,8,9]. The study presented the sizing of the solar power system, as well as the normalized performance parameters [10, 11] and losses using the loss diagram in PVSyst software [12,13]. The analysis is done using PVSyst simulation software [14,15].

2. METHODOLOGY

The study considered a the Photovoltaic (PV) power supply for a hospital located at for Ituk Mbang, Akwa Ibom State with daily energy demand of 101.808 kWh.day, as shown in Table 1. The cut section of the Google map screenshot for the case study hospital at Ituk Mbang with geo-coordinate of 4.926045 (latitude) and 8.030304 (longitude) is shown in Figure 1. The time evolution plot of the daily solar irradiation on the plane of the PV module as captured from NASA portal using PVSyst software is shown in Figure 2. The PVSyst screenshot for the optimal tilt angle of the PV module for the case study site is shown in Figure 3. It shows that the 9° is optimal PV module tilt angle for the case study site and it yields transposition factor of 1.01 % on the titled plane of the PV module. Also, Figure 4 shows the PVSyst screenshot for the standalone photovoltaic power system with backup generator. The PV system key components sizing configuration in PVSyst software is shown in Figure 6.

Based on the system design specification settings on Figure 6, the system design specification has 2 days of power autonomy and maximum of 5% loss of load probability and DC line voltage of 24 V. A battery bank consisting of a total of 126 batteries each with 12 V and 150 Ah capacity is required. Also, PV array consisting of a total of 211PV modules each with 24V and 190 Wp power capacity is required.

Table 1 The daily energy demand profile for the case study a hospital located at for Ituk Mbang , Akwa Ibom State

Source [16]

S/N	Appliance Description	Qty.	Rated Power (Watts)	Number of Hours Operated	Total Power (Watts)	Total Wh per day	Total Kwh per day
1	Blood bank Fridge	2	50	24	100	2400	2.4
	Vaccine Fridge	2	80	12	160	1920	1.92
2	Microscope	2	15	6	30	180	0.18
3	Operating Lamp	1	125	4	125	500	0.5
4	Syringe Pumps	2	600	1	1200	1200	1.2
5	Air conditioners	2	746	6	1492	8952	8.952
6	Lighting	56	100	12	5600	67200	67.2
7	Hematology Mixer	1	28	4	28	112	0.112
8	Incubators	2	400	7	800	5600	5.6
9	Curing light	1	90	3	90	270	0.27
10	Microwave	1	700	3	700	2100	2.1
11	Medical Centrifuge	1	578	3	578	1734	1.734
12	Washing Machine	1	450	2	450	900	0.9
13	PC and Printer	2	120	6	240	1440	1.44
14	TV	2	50	10	100	1000	1
15	Drier	1	500	3	500	1500	1.5
16	Ceiling Fan	6	100	8	600	4800	4.8
Total					12793	101808	101.808
Average number of hours per day (hours)						7.958102	

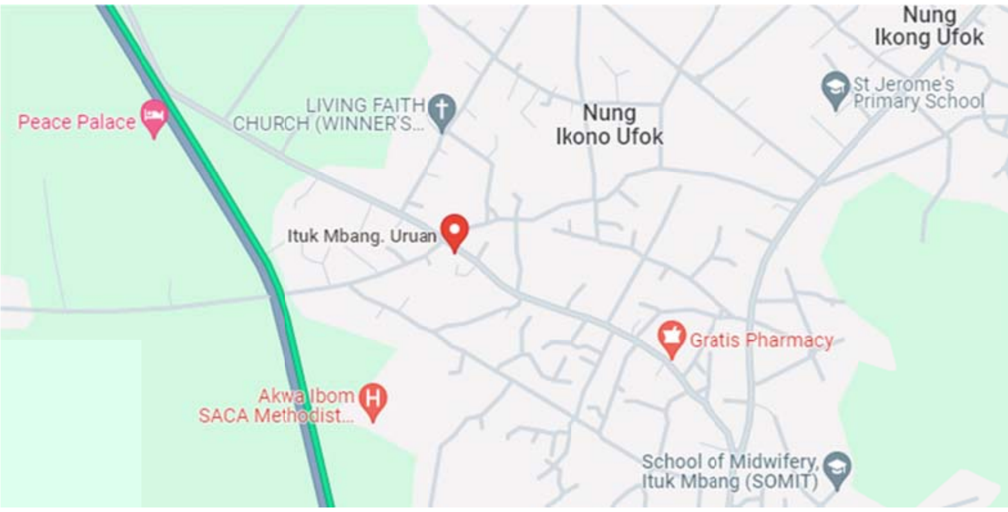

Figure 1 The cut section of the Google map screenshot for the case study hospital at Ituk Mbang with geo-coordinate of 4.926045 (latitude) and 8.030304 (longitude)

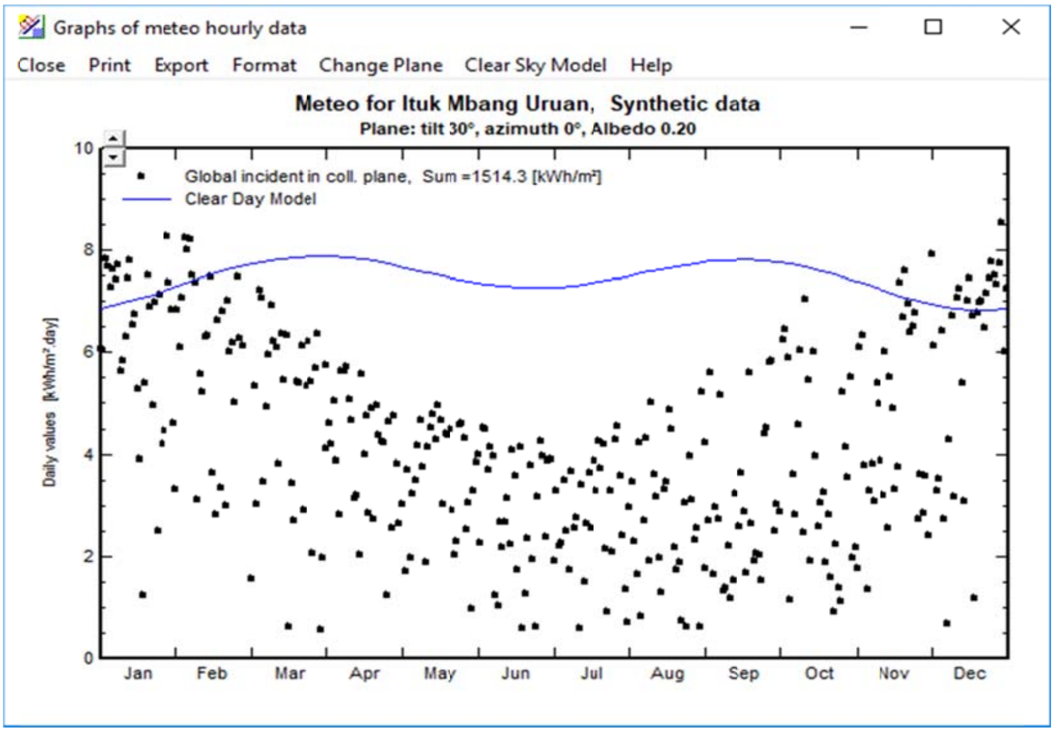

Figure 2 The time evolution plot of the daily solar irradiation on the plane of the PV module as captured from NASA portal using PVSyst software

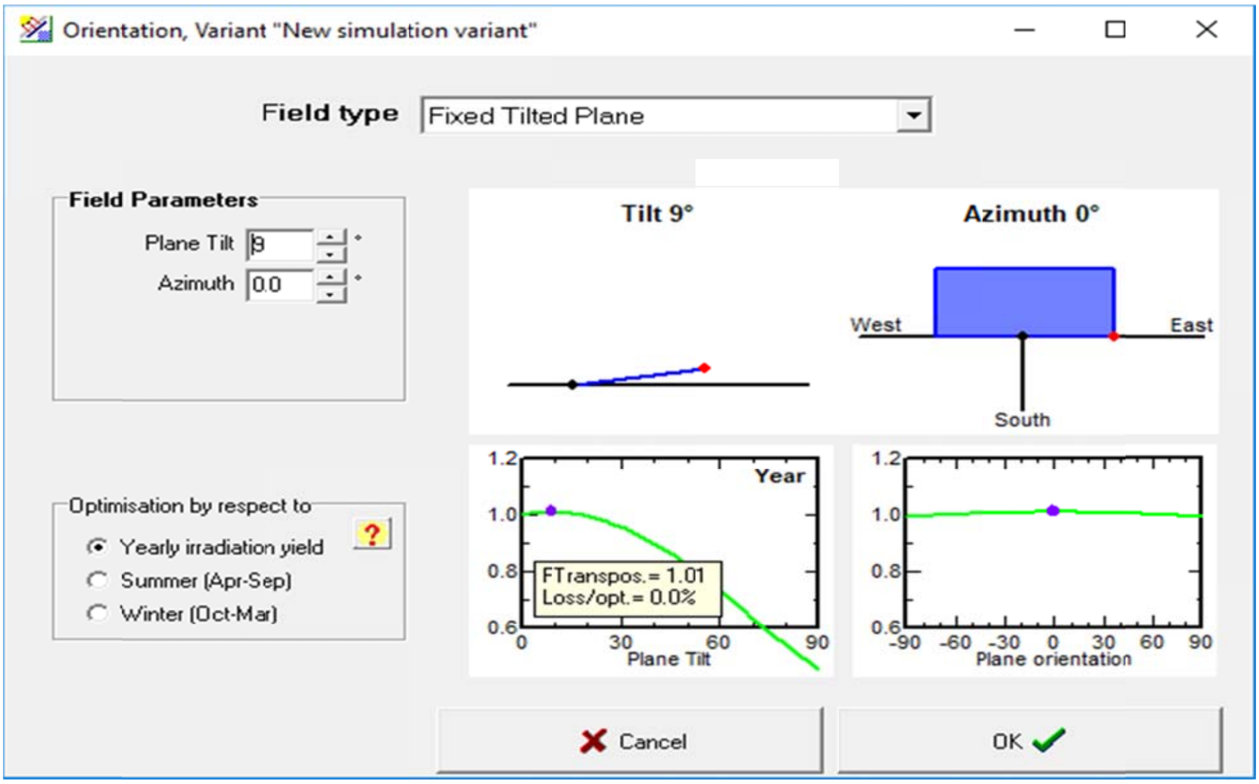

Figure 3 The PVSyst screenshot for the optimal tilt angle of the PV module for the case study site

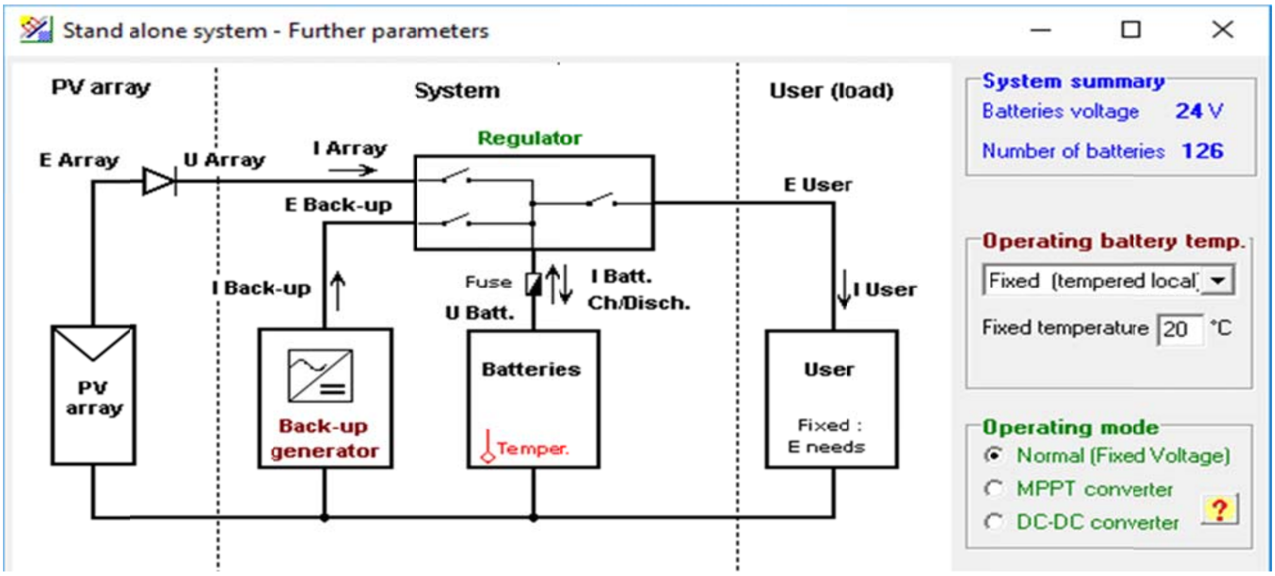

Figure 4 The PVSyst screenshot for the standalone photovoltaic power system with backup generator.

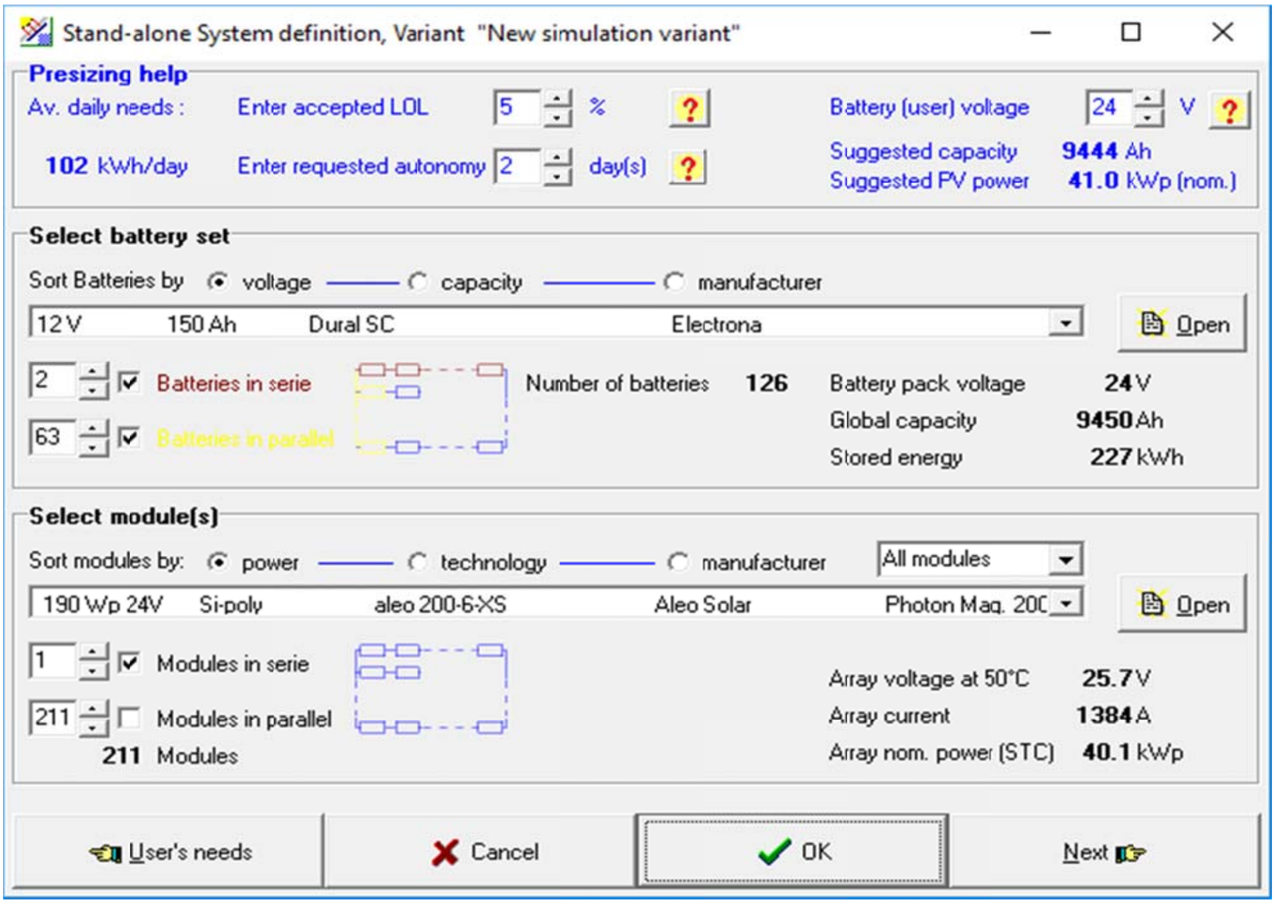

Figure 5 The PV system key components sizing configuration in PVSyst software

3. RESULTS AND DISCUSSION

Based on the system component sizing captured in Figure 5, the PVSyst software simulation of the PV power system was conducted and the main simulation parameters captured with the PVSyst software are presented in Figure 6. The screenshot of the PVSyst main results output page is shown in Figure 7. It shows that the system annual energy yield of 47.8 MWh/year, specific energy yield of 1193 kWhkWhp/year, solar fraction of 95.4 %, missing energy of 1736 kWh, loss of load of 4.7 % and unused energy of 7327 kWh/year. Essentially, the PV system supplied 95.4 % (that is the solar fraction) of the required energy for the hospital while about 4.7 % (that is the loss of load) of the required energy are not met with the PV power system. However, the system performance is acceptable since the design specification allowed a maximum of 5 % loss of load with two days power autonomy. Also, with the backup generator in place, the missing 4.7% energy demand will be supplied from the backup generator.

The normalized key performance parameters of the PV system are presented in Table 2. The results show that the yearly total of the daily reference energy yield (Yr) is 1576 kWh/m^2.day, the normalized loss due to unused energy has annual mean of 0.257, the normalized loss (Lc) in the PV array has annual mean of 1.551, the normalized system loss (Ls) has annual mean of 0.333 while the system performance ratio (PR) is 0.564 or 56.4 %.

The system loss diagram is presented in Figure 8. It shows that battery loss is about 4.1 % of the total energy yield, energy loss due to unused energy is about 12 % of the total energy yield, while the highest loss of 19 % is the array loss which is the sum of thermal loss , loss due to PV module quality, dust and other factors associated with the PV module

PVSYST V5.20			Page 1/4

Stand Alone System: Simulation parameters

Project : **Ituk Mbang Health Center**
Meteo data : Ituk Mbang Uruan From NASA-SSE, Synth Hourly Data

Simulation parameters

Collector Plane Orientation	Tilt	9°	Azimuth	0°
PV Array Characteristics				
PV module Si-poly	Model	**aleo 200-6-XS**		
	Manufacturer	Aleo Solar		
Number of PV modules	In series	1 modules	In parallel	211 strings
Total number of PV modules	Nb. modules	211	Unit Nom. Power	190 Wp
Array global power	Nominal (STC)	**40 kWp**	At operating cond.	36 kWp (50°C)
Array operating characteristics (50°C)	U mpp	26 V	I mpp	1384 A
Total area	Module area	**328 m²**		
PV Array loss factors				
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (G=800 W/m², Tamb=20°C, Wind velocity = 1m/s.)			NOCT	56 °C
Wiring Ohmic Loss	Global array res.	0.31 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	1.5 %
Module Mismatch Losses			Loss Fraction	4.0 % (fixed voltage)
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Parameter	0.05
System Parameter	System type	**Stand Alone System**		
Battery	Model	**Dural SC**		
	Manufacturer	Electrona		
Battery Pack Characteristics	Voltage	24 V	Nominal Capacity	9450 Ah
	Nb. of units	2 in series x 63 in parallel		
	Temperature	Fixed (20°C)		
Regulator	Model	General Purpose Default		
	Technology	Undefined	Temp coeff.	-5.0 mV/°C/elem.
Battery Management Thresholds	Charging	27.4/26.2 V	Discharging	23.5/25.2 V
	Back-Up Genset Command	23.6/25.8 V		
User's needs :	Daily household consumers	Constant over the year		
	average	102 kWh/Day		

Figure 6 The main simulation parameter captured with the PVSyst software

PVSYST V5.20			Page 3/4

Stand Alone System: Main results

Project : **Ituk Mbang Health Center**
Simulation variant : **No shading effects**

Main system parameters	System type	**Stand alone**		
PV Field Orientation	tilt	9°	azimuth	0°
PV Array	Nb. of modules	211	Pnom total	**40 kWp**
Battery	Model	Dural SC	Technology	vented, tubular
battery Pack	Nb. of units	126	Voltage / Capacity	**24 V / 9450 Ah**
User's needs	Daily household consumers	Constant over the year	global	37.4 MWh/year
Main simulation results				
System Production	**Available Energy**	**47.8 MWh/year**	Specific prod.	1193 kWh/kWp/year
	Used Energy	35.6 MWh/year	Excess (unused)	7327 kWh/year
	Performance Ratio PR	56.4 %	Solar Fraction SF	95.4 %
Loss of Load	Time Fraction	4.7 %	Missing Energy	1736 kWh

Figure 7 The screenshot of the PVSyst main results output page

Table 2 The normalized key performance parameters of the PV system

Simulation variant : New simulation variant

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Normalized Performance Coefficients

	Yr kWh/m².day	Lu	Yu kWh/kWp/d	Lc	Ya kWh/kWp/d	Ls	Yf kWh/kWp/d	PR
January	181.03	0.391	6.70	2.570	0.15	0.717	2.55	0.437
February	165.56	0.420	6.85	2.746	0.15	0.614	2.55	0.432
March	154.81	0.370	5.54	2.022	0.12	0.419	2.55	0.511
April	136.09	0.417	4.81	1.640	0.11	0.344	2.55	0.563
May	128.84	0.263	4.39	1.360	0.10	0.244	2.55	0.614
June	103.62	0.233	3.56	1.038	0.09	0.207	2.21	0.639
July	96.22	0.110	3.15	0.767	0.08	-0.025	2.36	0.761
August	94.48	0.070	3.11	0.750	0.08	0.147	2.15	0.706
September	97.27	0.042	3.29	0.745	0.08	0.158	2.34	0.721
October	113.72	0.231	3.87	1.197	0.09	0.183	2.29	0.624
November	133.66	0.265	4.79	1.551	0.11	0.352	2.55	0.573
December	170.71	0.282	6.30	2.304	0.14	0.650	2.55	0.464
Year	1576.00	0.257	4.69	1.551	0.11	0.333	2.43	0.564

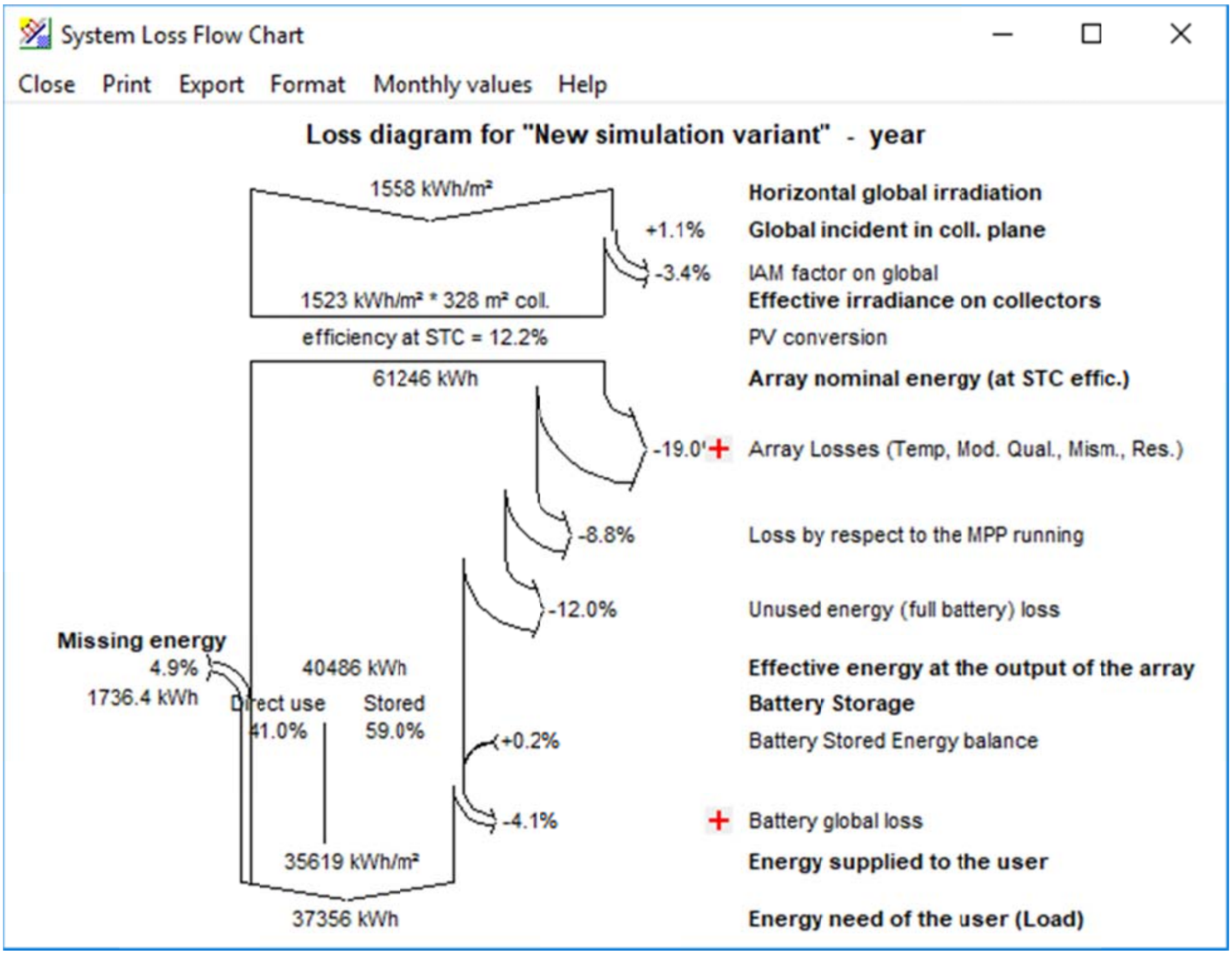

Figure 8 The system loss diagram

4. CONCLUSION

Simulation of solar power system for a health facility is presented. The PVSyst renewable energy system simulation software is employed for the simulation. The essence of the study is to evaluate the PV system performance for the health facility based on the specified energy demand of the health facility, the meteorological data of the site and the design specifications for the PV system.

The PV system considered in the study is a standalone system with battery bank and backup generator. The result show that about 95.3 % of the energy demand of the hospital is supplied from the PV power system while the missing energy of 4.7% is supplied from the backup generator.

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