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Loss Of Load Probability Analysis For Cellular Network Transceiver Base Station Solar Pv Power System

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***Abstract*—In this paper, loss of load probability analysis for cellular network transceiver base station solar PV power system is presented. The daily load demand for the case study cellular network transceiver base station is 48252 Wh/day. The daily load demand and the solar radiation data are used in PVSyst to select the requisite PV system components sizes and also to determine the loss of load probability and loss of load duration. Particularly, the study focused on providing detailed insight into the exact day and time that loss of load will occur in each month based on PVSsyst simulation results. The results showed that there is a total annual average loss of load probability (LOLP) of 9% with a total annual loss of load duration of 792 hours per year. The results show that the loss of load occurred on 30th of January and it lasted for 10 hours, from about 2 am to 12 noon. Also, the results show that the loss of load occurred on two consecutive days in March, namely, on 12th and 13th of March and it lasted for 31 hours, from about 6 am on 12th of March to 1pm on 13th of March. Furthermore, the highest loss of load duration occurred in the month of July with about 169 hours of no power supply to the load. This amounts to about 7.041667 days of power outage. The idea presented in this paper can be employed to determine the exact time that loss of load can occur all through the year. This will help in power system planning.**

Keywords— Loss Of Load Probability, Solar PV Power System Cellular Network, Daily Load Demand, Transceiver Base Station, PVSsyst Software

1. INTRODUCTION

Cellular network is the fundamental technology employed in mobile phones and other wireless networking and personal communication systems [1,2,3,4,5,6,7,8,9,10]. Basically, cellular network consist of at least a fixed-location transceiver base station which provides connectivity to the various communication devices that are with the coverage area of the base station [11,12,13,14,15,16,17]. Notably, the coverage area is divided into different cells, where neighboring cell are designed to operate at different frequencies [18,19,20,21,22,23,24,25,26]. In practice, the base station is usually a critical equipment in cellular networks because the failure of the base station amounts to the failure communication for the devices that are within the coverage area of the base station [27,28,29,30,31]. One of the dominant causes of failure of the cellular network base station is electric power failure.

In some cases, the base stations are located in remote areas that do not have access to the electric power from the national grid. In other cases, the national grid do not supply power regularly, or the power supplied from the grid are not good enough to power the base station equipment. In such cases, alternative power supply is required. One of the performance measures of such PV power system is the loss of load probability (LOLP). The LOLP defines the fraction of time that the load demand could not be satisfied over a given period. In this paper, the loss of load probability for a cellular network transceiver base station powered by a standalone PV power system is presented. The study seek to estimate the exact day in a year and the exact time and duration in each of those days when power failure will be experienced at the base station. The study is essential for power generation planning and load shading management system at the base station. The mathematical details are presented along with numerical example based on a case study transceiver base station. The analysis is simulated using PVSyst software.

2 METHODOLOGY

When the power source fails to generate enough power to meet the load demand, there will be a power failure or loss of load. Loss of Load Probability (LOLP) gives a measure of power failure incidence and the fraction of the period which the power failure occurred due to insufficient power generation from the power source. Generally, LOLP can be computed from the knowledge of the daily energy yield of the power source and the daily energy demand. In this paper, the power source is a PV solar power system. For PV solar power system, over a period of N days, the daily PV energy yield (E_{pvd}) for day j (where j = 1, 2, 3…N) is computed as follows;

$$E_{pvd(j)} = (A_{pv})(G_{av(j)})(\eta_{pv})((\eta_{wire})(\eta_{inv})) \quad (1)$$

Where, A_{PV} represents the PV-array area; G_{av} represents the solar radiation incident on the PV-array for day j; represents the PV array efficiency which is about 18.54% or 0.185; η_{wire} represents the wire efficiency (0.95); and η_{inv} represents the efficiency (0.9). Let the daily load demand for day j be denoted as $E_{L(j)}$, then energy difference $E_{d(j)}$ on day j is computed as;

$$E_{d(j)} = E_{pv(j)} - E_{L(j)} \quad (2)$$

The annual energy difference, $E_{Y(j)}$ is computed as;

$$E_{Y(j)} = \sum_{j=1}^{j=365}(E_{pv(j)} - E_{L(j)}) \quad (3)$$

When $E_{d(j)}$ is positive, then there is Energy Excess ($EX_{d(j)}$). The excess energy is used to charge the battery bank, hence the Energy Excess ($EX_{d(j)}$) is stored in battery bank.

$$EX_{d(j)}) = E_{d(j)} \quad \text{for} \quad E_{pv(j)} \geq E_{L(j)} \quad (4)$$

When $E_{d(j)}$ is negative, then there is Energy Deficit ($ED_{d(j)}$). The energy stored in the battery bank is then used to supply the energy to the load.

$$ED_{d(i)}) = E_{d(j)} \text{ for } E_{pv(j)} < E_{L(j)} \quad (5)$$

Loss of Load Probability (LOLP) over a period of one year is the ratio of total annual energy deficit to the total annual energy demand, where,

$$\text{LOLP} = \frac{\sum_{j=1}^{365}(ED_{d(i)})}{\sum_{j=1}^{365}(E_{L(j)})} \quad (6)$$

Loss of Load Probability (LOLP) over a period of N days is the ratio of total energy deficit to the total energy demand over the period of N days, where,

$$\text{LOLP} = \frac{\sum_{j=1}^{N}(ED_{d(i)})}{\sum_{j=1}^{N}(E_{L(j)})} \quad (7)$$

Also, Loss of Load Probability (LOLP) can be computed in terms of the ratio of the total power failure time over a given period to the total time in the period. For instance, the ratio of the total power failure hours in a year to the total number of hours in a year gives the LOLP in a year.

$$\text{LOLP} = \frac{\textit{Power failure time}}{\textit{Total period of time}} \quad (8)$$

The load demand for the cellular network transceiver base station is given Table 1 with a daily load of 48252 Wh/day. The solar radiation and ambient temperature data for the study site are given in Table 2. The scatter plot of the daily solar radiation data on the horizontal plane for study site is shown in Figure 2.

3. RESULTS AND DISCUSSION

The load demand and solar radiation data are used in PVSyst to select the requisite PV system components sizes and also determine the loss of load probability and loss of load duration. The schematic diagram of the PV power system is given in Figure 3, the simulation parameters are presented in Figure 4 and the results on energy use and loss of load are presented in Table 3 while the graph plot of the results on the monthly loss of load duration is presented in Figure 5. The results in Table 3 shows that there is a total annual average loss of load probability (LOLP) of 9% with a total annual loss of load duration of 792 hours per year. In essence, out of the 8760 hours in a year, there is no energy supplied to the load for a total of 792 hours in a year. This amounts to annual $\text{LOLP} = \left(\left(\frac{792}{8760}\right)100\%\right) = 9.04109589\,\% \approx 9\,\%$, as shown in Table 3.

Table 1 The load demand for the cellular network transceiver base station

S/N	THE EQUIPMENT	QTY	POWER RATING (W)	DURATION (h)	ENERGY DEMAND/DAY (Wh)
1	Base Transceiver System (BTS)	2	50	24	2160
2	Air Conditioner	2	1120	12	26856
3	Security light	3	160	12	5760
4	Fluorescent lamp	4	30	0.3	36
5	Aviation warning light	5	160	12	9600
6	Incandescent bulb	3	60	12	2160
7	Connecting Microwave	1	70	24	1680
	Total Daily Energy Demand (Wh)				**48252**

Table 2 The solar radiation and ambient temperature data for the study site

Meteo File NG_SOUTH_SOUTH_AKWA_IBO_SYN.MET, Monthly accumulations

Close Print Export Change Plane

Meteo for SOUTH SOUTH AKWA IBOM, Synthetic data

Plane: tilt 30°, azimuth 0°, Albedo 0.20

Interval beginning	GlobHor kWh/m².mth	GlobInc kWh/m².mth	T Amb °C
January	165.2	184.9	26.00
February	149.2	153.8	26.40
March	160.9	151.9	26.30
April	151.5	132.2	26.40
May	141.1	112.1	26.30
June	112.5	93.4	25.60
July	102.3	84.7	24.80
August	117.8	101.5	24.40
September	109.5	100.8	24.70
October	132.1	129.8	25.10
November	149.1	162.3	25.40
December	159.0	180.5	25.70
Year	1650.2	1587.9	25.59

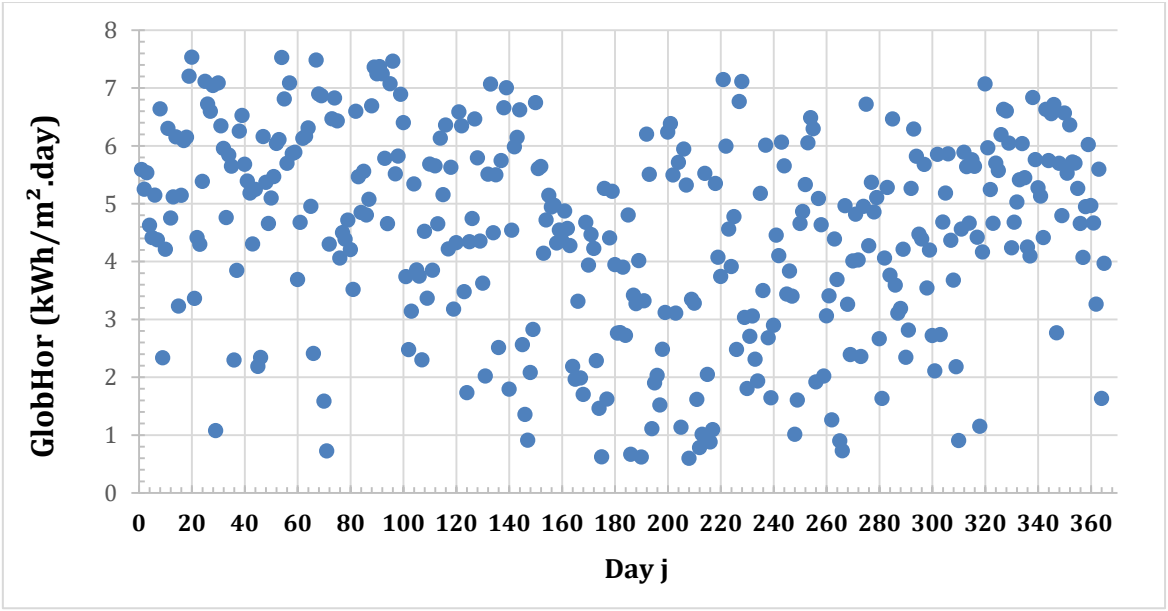

Figure 2 Scatter plot of the daily solar radiation data on the horizontal plane

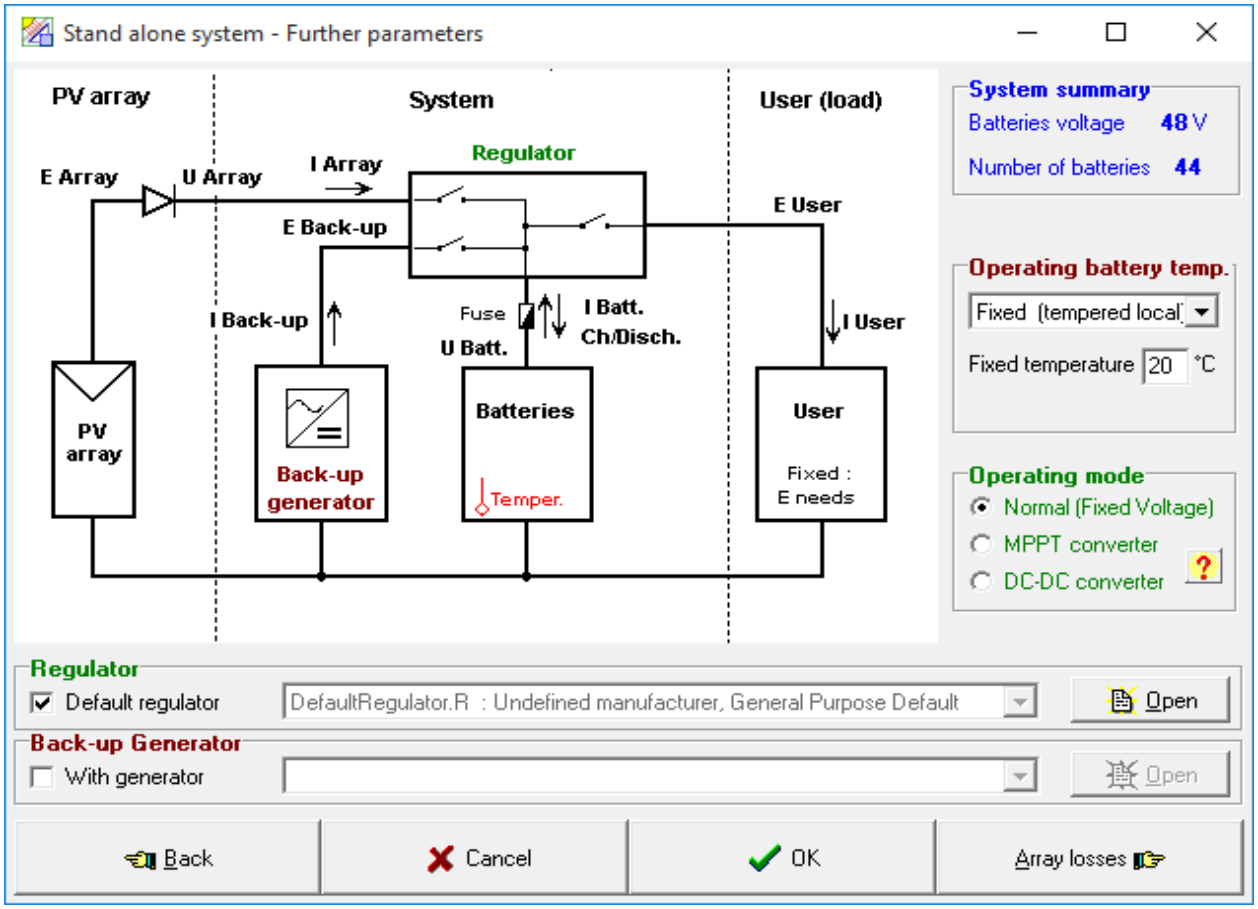

Figure 3 The schematic diagram of the PV Power Syste

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Stand Alone System: Simulation parameters

Project : LOLP BASE STATION

Geographical Site		**SOUTH SOUTH AKWA IBOM**	**Country**	**Nigeria**
Situation	Latitude	5.0°N	Longitude	5.0°E
Time defined as	Legal Time	Time zone UT+1	Altitude	56 m
	Albedo	0.20		

Meteo data : SOUTH SOUTH AKWA IBOM from NASA-SSE, Synthetic Hourly data

Simulation variant : New simulation variant

Simulation date 31/05/21 08h00

Simulation parameters

Collector Plane Orientation	Tilt	0°	Azimuth	0°

PV Array Characteristics

PV module	Si-poly	Model	**Quick Tile D4-FrPf/43**		
		Manufacturer	Sesol		
Number of PV modules		In series	9 modules	In parallel	43 strings
Total number of PV modules		Nb. modules	387	Unit Nom. Power	48 Wp
Array global power		Nominal (STC)	**19 kWp**	At operating cond.	17 kWp (50°C)
Array operating characteristics (50°C)		U mpp	57 V	I mpp	291 A
Total area		Module area	**200 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.	3.3 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	2.5 %
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	48 V	Nominal Capacity	1100 Ah
	Nb. of units	4 in series x 11 in parallel		
	Temperature	Fixed (20°C)		
Regulator	Model	General Purpose Default		
	Technology	Undefined	Temp coeff.	-5.0 mV/°C/elem.
Battery Management Thresholds	Charging	54.7/52.3 V	Discharging	47.0/50.4 V
	Back-Up Genset Command	47.3/51.6 V		

User's needs :	Daily household consumers	Constant over the year
	average	48 kWh/Day

Figure 4 The simulation parameters

Table 3 The results on energy use and loss of load

New simulation variant

Energy Use

	EArray kWh	E Load kWh	E User kWh	SolFrac	T LOL Hour	Pr LOL %
January	1882	1496	1476	0.987	10	1.3
February	1701	1351	1326	0.982	12	1.8
March	1838	1496	1432	0.958	31	4.2
April	1784	1448	1437	0.992	5	0.7
May	1661	1496	1332	0.890	81	10.9
June	1377	1448	1238	0.855	104	14.5
July	1277	1496	1156	0.773	169	22.8
August	1436	1496	1163	0.778	165	22.2
September	1374	1448	1223	0.845	112	15.6
October	1653	1496	1393	0.931	51	6.9
November	1710	1448	1367	0.944	40	5.6
December	1839	1496	1477	0.988	9	1.3
Year	19532	17612	16020	0.910	792	9.0

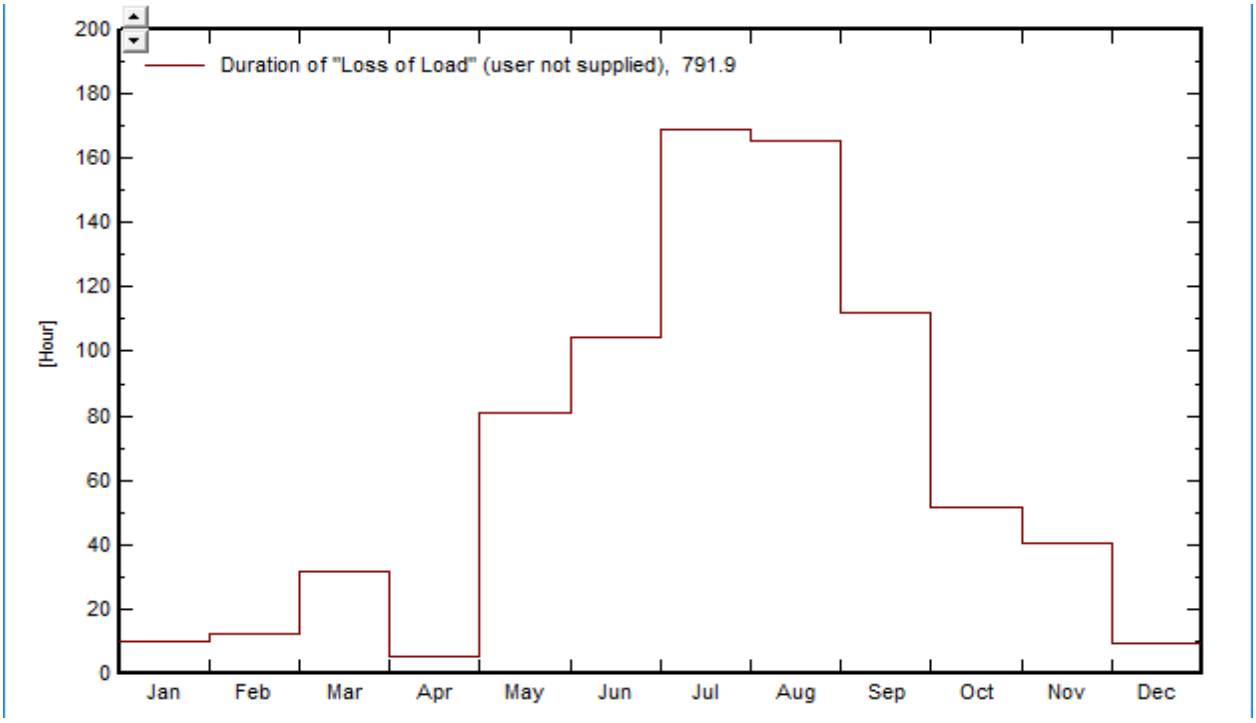

Figure 5 The Monthly Loss of Load Duration

The bar chart of the energy demand (load) and energy supplied by the PV to the load for the month of January are presented in Figure 6. Also, the graph plot of exact day loss of load occurred in the month of January is shown in Figure 7 while the graph plot showing of the exact time and duration of loss of load in the month of January is given in Figure 8. The results in Figure 6, Figure 7 and Figure 8 show that the loss of load occurred on 30th of January and it lasted for 10 hours, from about 2 am to 12 noon.

The bar chart of the energy demand (load) and energy supplied by the PV to the load for the month of March are presented in Figure 9. Also, the graph plot of exact day loss of load occurred in the month of March is shown in Figure10 while the graph plot showing of the exact time and duration of loss of load in the month of March is given in Figure 11. The results in Figure 9, Figure 10 and Figure 11 show that the loss of load occurred on two consecutive days in March, namely, on 12th and 13th of March and it lasted for 31 hours, from about 6 am on 12th of March to

1pm on 13th of March. Similar approach can be used to evaluate the details of the loss of load probability for the rest of the months. The highest loss of load duration occurred in the month of July with about 169 hours of no power supply to the load. This amounts to about 7.041667 days of power outage.

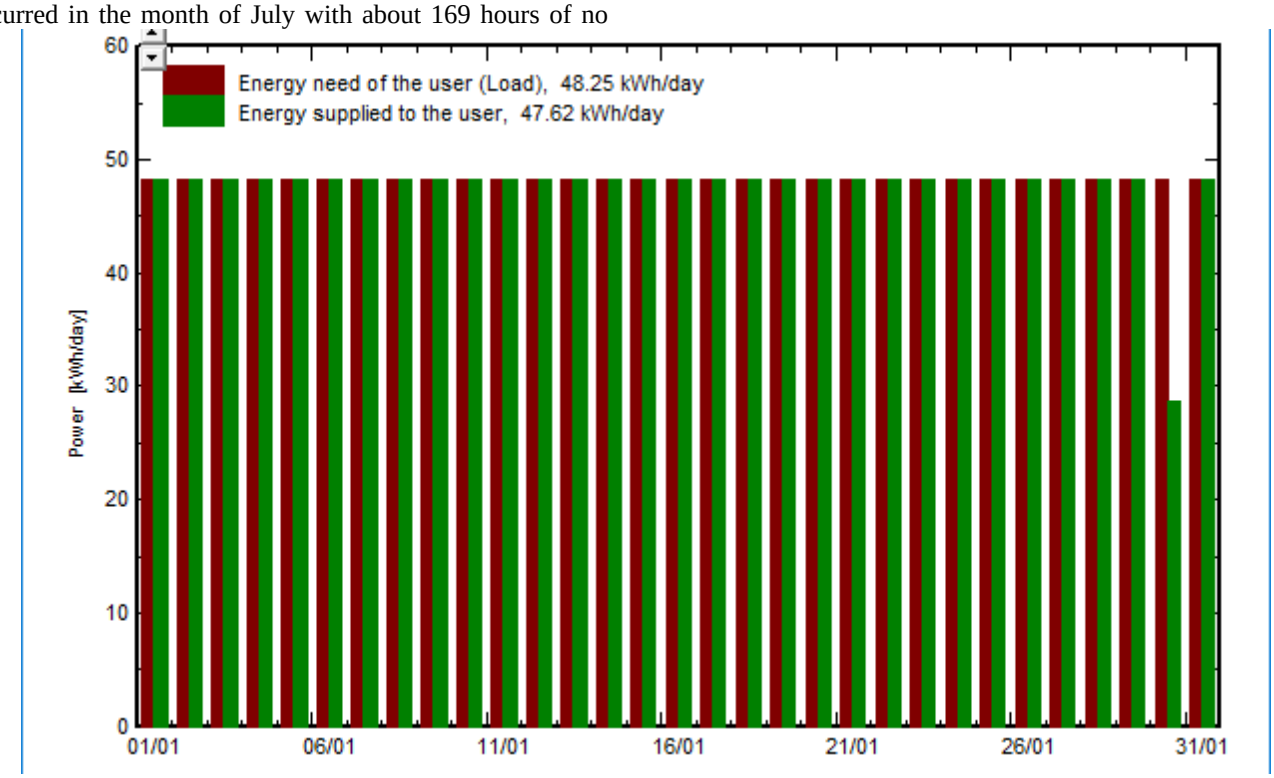

Figure 6 The energy demand (load) and energy supplied by the PV to the load for the month of January

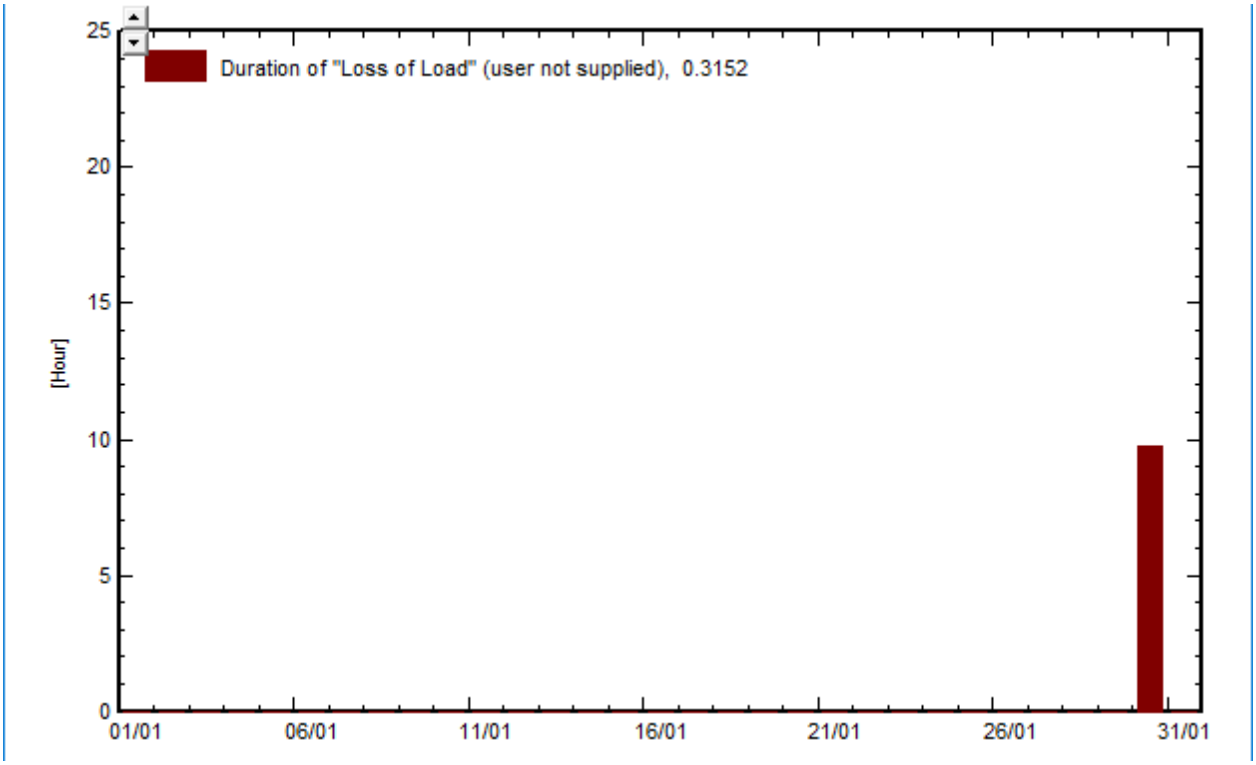

Figure 7 The plot of exact day loss of load occurred in the month of January

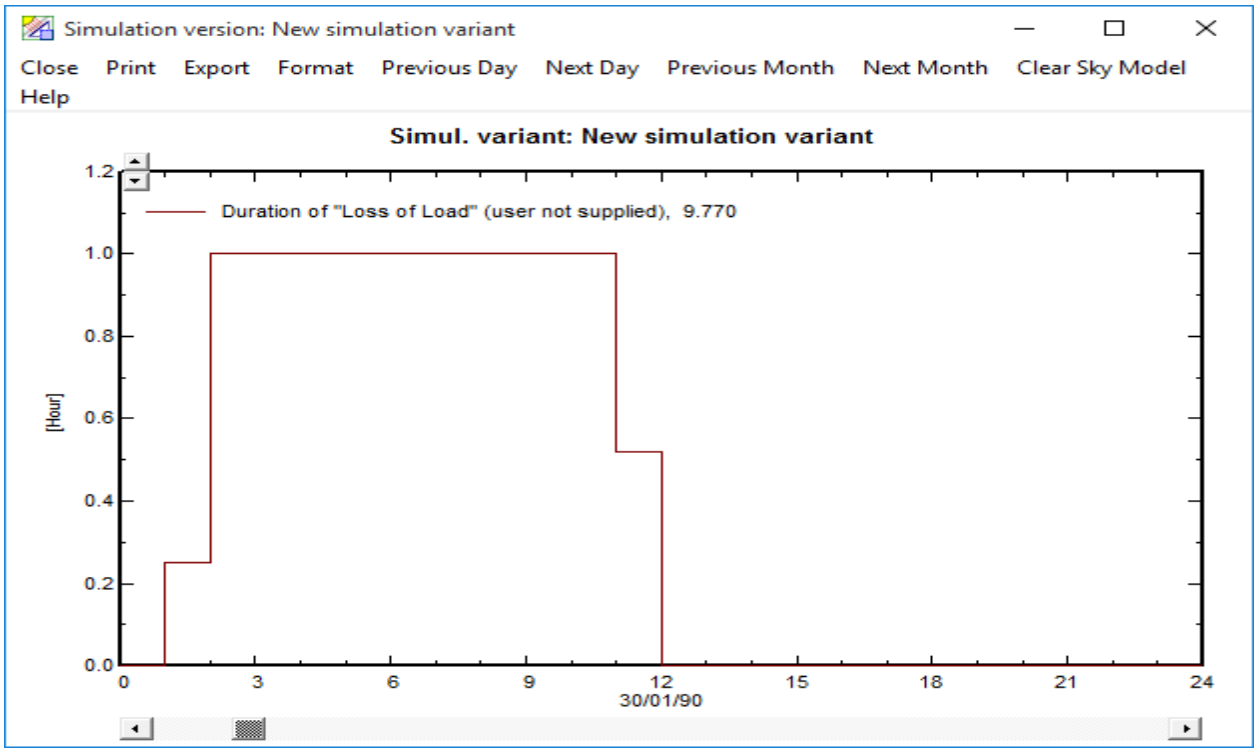

Figure 8 The plot of the exact time and duration of loss of load in the month of January

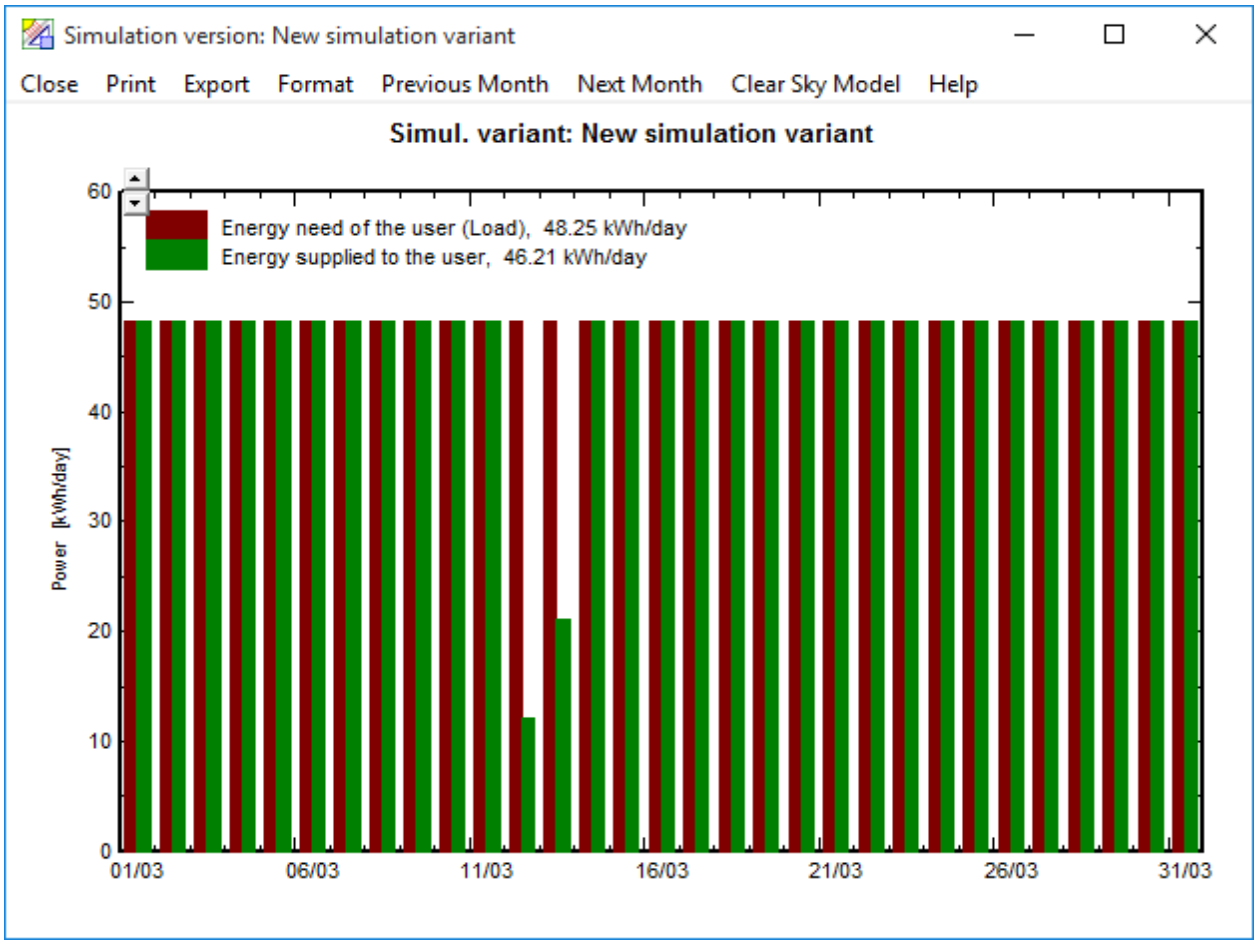

Figure 9 The energy demand (load) and energy supplied by the PV to the load for the month of March

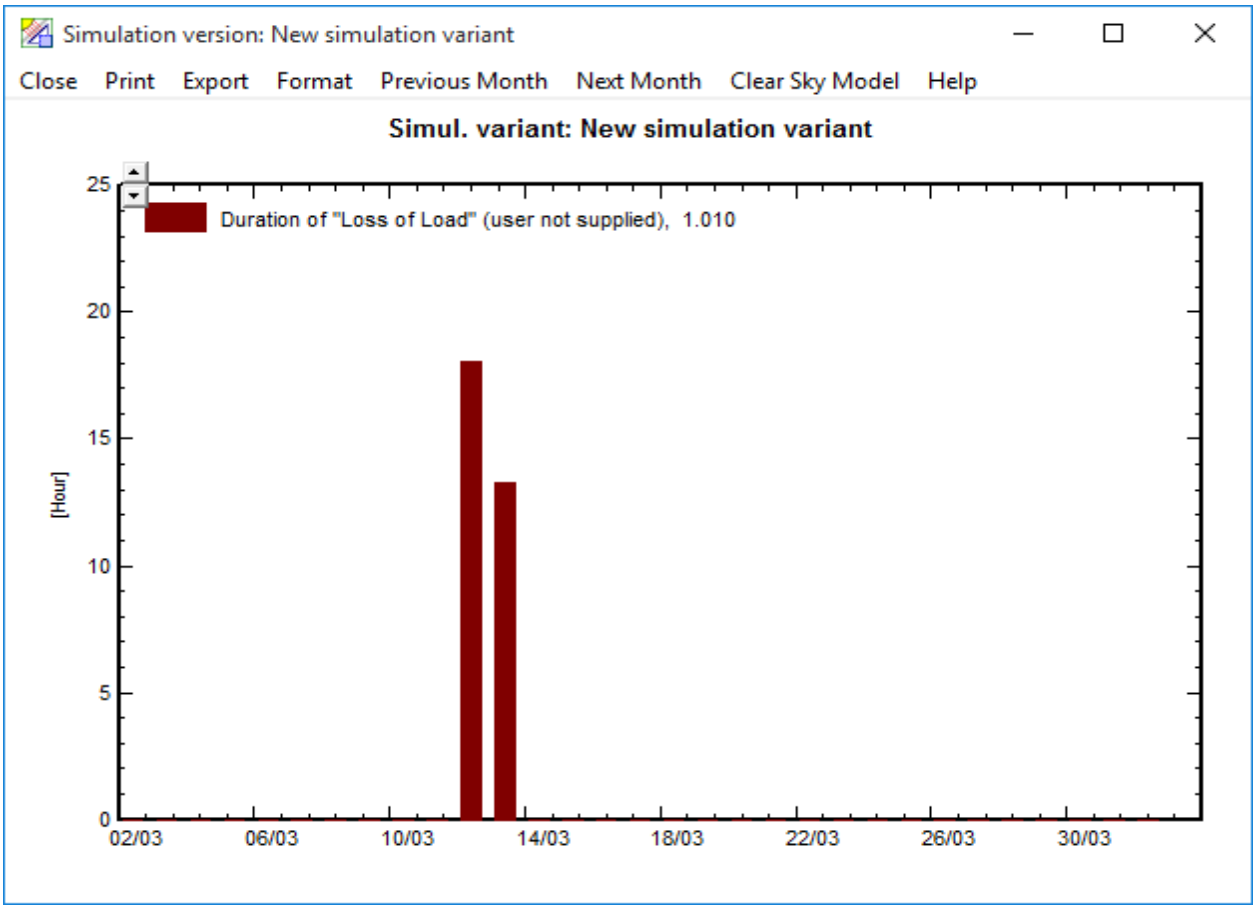

Figure 10 The plot of exact day loss of load occurred in the month of March

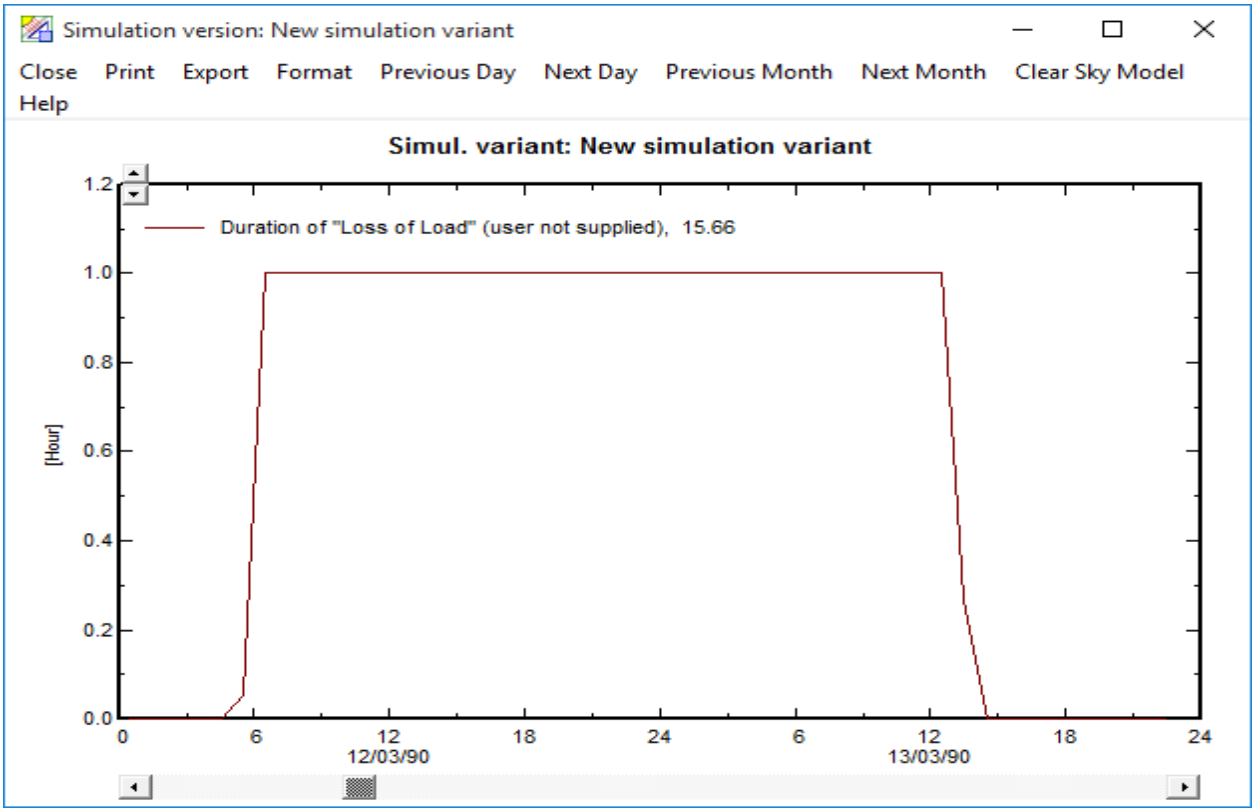

Figure 11 The plot of the exact time and duration of loss of load in the month of March

4. CONCLUSION

Analysis of the loss of load probability and loss of load duration for a standalone PV power system is presented. The study used a cellular network transceiver base station as the load. The study seeks to provide detailed insight into the exact day and time the loss of load will occur in each month based on the PVSsyst simulation results. The results of the monthly and annual loss of load probability and loss of load duration are presented. Also, the exact day and time the loss of load occurred in the months of January and March are presented. Similar approach can be employed to determine the exact time the loss of load can occur all through the year. This will help in power system planning.

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