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Analysis of solar power public street lighting optimization with Pvsyst software in a residential complex area

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***Abstract*—The duration of street light illumination on solar-powered public street lighting is often short-lived (decreased T_{lol}) due to exposure to near shading (loss irradiance) of 8.89% in residential complexes. Therefore, optimization of PV panels and battery components through PVsyst software simulation analysis is required. The simulation results after optimization showed that the PV array obtained 205 wp and a battery capacity of 62 ah (2 days of autonomy), resulting in a decrease in T_{lol} of 765 hours. While the Performance Ratio (PR) is 67.6%, there is an increase of 7.7%, and the sulfuric ratio is 93.6%, there is an increase in the energy supplied to users by 12.74% or 33.36 kWh.**

***Keywords*—public street lighting; PVsyst software; PV array; the sulfuric ratio; energy supplied to users**

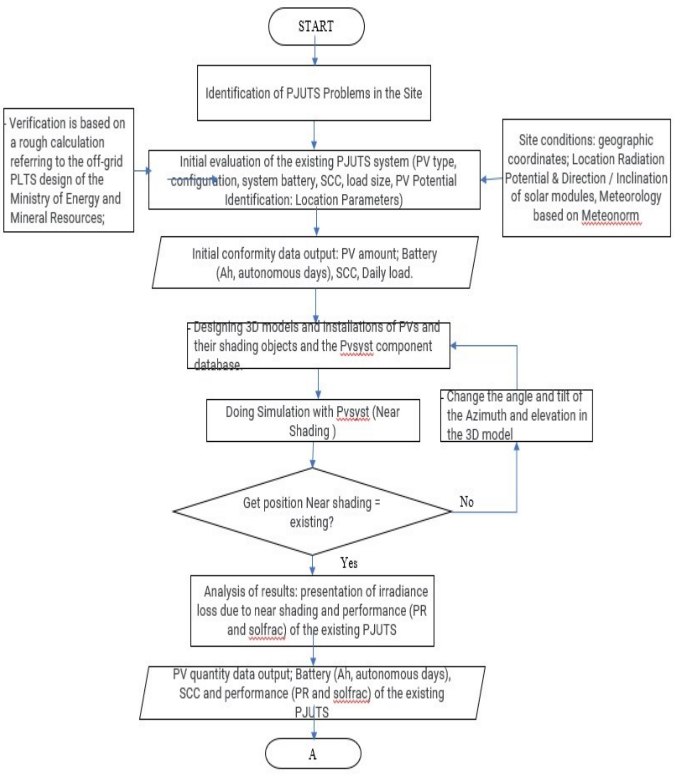
I. Introduction

SOLAR Public Street Lighting (SPSL) in residential areas in South Jakarta designs to operate for 12 hours (6.00 p.m. - 6.00 a.m.). However, the reality on the ground is that there are constraints on the point of light that need to increase for the duration of the lighting, especially at the point of exposure to shading. Often shading constraints are difficult to avoid and affect performance to be shorter. Some research that optimizes Solar Public Street Lighting, namely reference [1]–[5], optimizes the slope angle by shifting the azimuth position of the PV panel arrangement, then references [6]–[9], also optimizes the PV panel tilt parameters PV (tilt panel) and battery. Reference [10], [11] also optimizes Street Lighting sizing by simulating with PVsyst through performance ratio and Solar Fraction. Reference [12]–[14] uses an optimization method by maximizing the height of the pile. Reference [15] offers optimization with a smart SPSL design (reliable and economical) equipped with centralized damage monitoring and integration with IoT[16], [17]. Based on some of the optimization research above, this study applies optimization of the sizing component of the size of the PV panel and battery in the focus area of shading exposure analysis with PVsyst simulation, using performance parameters ratio and Solar Fraction in Solar Public Street Lighting in a residential area in South Jakarta, Indonesia.

II. Research Method

A. Optimization and Simulation Flowchart

Contains the method and stages of this research using experimental research, which refers to the quantitative method of analyzing the PV power requirements and battery capacity in Solar Public Street Lighting (SPSL) through a simulation approach with the PVSyst Software. Figure 1 is a flowchart of research regarding optimization simulation.



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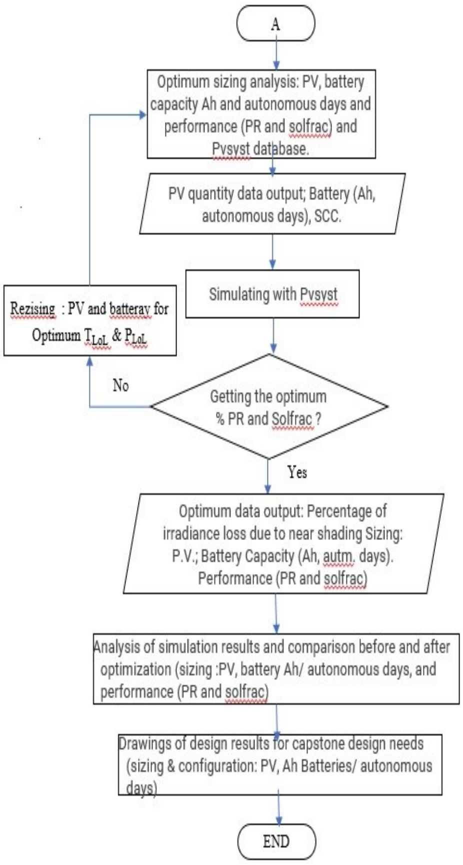

Fig. 1. Optimization simulation flowchart

Explanation of each stage [18] namely:

1) Identifying SPSL problems at the SPSL Site in the Site studied, there are several obstacles, namely the duration of the service time for the lights on, which is not sufficient from the expected time, especially in areas exposed to near shading;

2) SPSL power generation potential At this stage, the resource potential of PV panels is mapped so that the amount of electric power determines whether its availability meets demand with Site location, unique location characteristics, especially exposure to shading (near), with Meteonorm data on the PVsyst software [18].

3) At this stage, it is intended to map and determine the PLTS generation capability from its installed capacity. The PV parameters analyzed are location parameters, including radiation potential from several sources, namely Meteoronorm (sunlight intensity data).

4) Analyze the components of the SPSL system, namely analysis of technical data specifications for existing SPSL devices: PV modules, SCC, batteries, and lights.

5) Analyze the PV module, including PV system type, cell module direction, and PV array installation: PV size, building, building position against sunlight (UV), side resistance data, and others.

6) Identify exposure Shading (near) At this stage, analysis carries out partial shading, which affects only a portion of the field. Exposure to shading will reduce the Wattpeak of the PV array [19]; shading is simulated through: - In PVSyst with near shading simulation and constructed in a three-dimensional (3-D) plane, as shown in Figure 1.

7) Analysis of PV panels and SPSL batteries After a good shading near simulation analysis has been carried out on the PVsyst, it compares to the capstone design equipment, and the results and conclusions obtained for optimizing the amount of PV and battery required.

B. Load Data and Load Operating Hours

The total energy requirement is calculated (E_{load}), where SPSL LED lamp power is 60 W. Then the total daily energy requirement (Wh) is 720 Wh with a turn on time of 12 hours from 18.00 to 06.00. he total daily energy requirement = 720 Wh.

C. Calculate peak power and Solar modules.

The data needed is the local daily average irradiation, is 4.833 kWh/m2/day. From the total daily energy requirement (kWh) in point B, power can be calculated the peak of PLTS follows: wp = 0,931099 = 1 module.

D. Calculate the required effective Area of the solar module.

The effective Area is the specific Area intended for placement of solar modules. Module efficiency = 16% (module efficiency on the market = 14%-18%). Area = (186.2197/16%) = 1163.873 m^2.

E. Calculating the Number of Modules

The number of modules is calculated as follows. PV rating of the module unit = 720 4,833 x 75% = 198.63 available in the market => = 200 Wp/module.

F. Calculating Energy Requirements from Batteries

The battery requirement is calculated as follows: $C_b = (720\ x\ 2)/\ (90\%\ x\ 24\ x\ 90\%) = 74\ Ah$. The number of autonomy days is taken as a value of 2.

G. Calculating Power & Current Capacity of Solar Charge Regulator (SCR)

Solar SCR Capacity and Current are calculated as follows: Total SCR power > Solar Module peak power = Total SCR power > 200 Watt = Total SCR Current > (200/24)= 8.33 Amperes 24 = 0.83 = 1 SCR unit With SCR power = 360 Watts/SCR.

H. Days of autonomy

Autonomous Day (Days of Autonomy) is a day that can be supplied by battery without the help of another generator. The greater the target of the day of autonomy, then the battery life or lifetime of the battery will be longer (operating on The lower the DoD, the higher the battery cycle life, see Appendix 4). DoD and battery efficiency are assumed to be 80% each [20].

I. Simulation Parameters

1) Daily solar radiation.

This data was obtained based on simulated meteonorm data on PVSyst 7.3.1. Figure 2. below shows that the annual local daily average irradiation is 4.833 kWh/m2 /day.

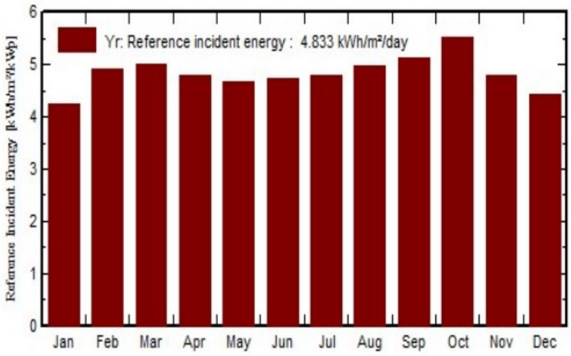

Fig. 2. Daily average irradiation

2) Facing Direction and Tilt Angle of the Solar Panel

The location of SPSL is in South Jakarta at 6° 15'37" S 106° 50' 03" E, as shown in figure 3.

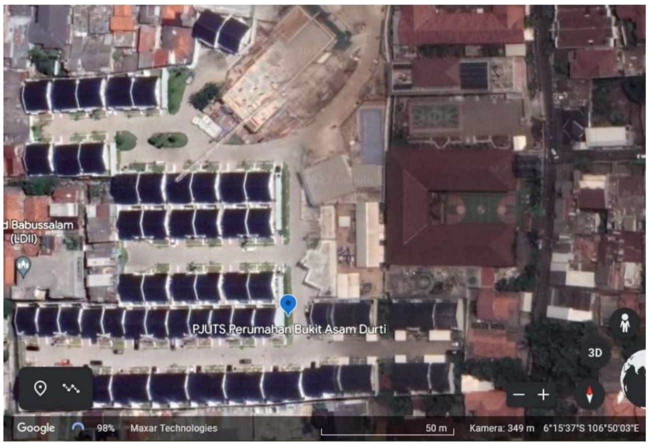

Fig. 3. View of the location of SPSL

To absorb the maximum energy from the Sun, the orientation plane is determined beforehand, which aims to determine the direction or front of the panel Sun, as shown in Figure 4, to obtain input data for the simulation, which includes determining the tilt of the sun panel and the azimuth or rotation angle to the Sun's movement [1].

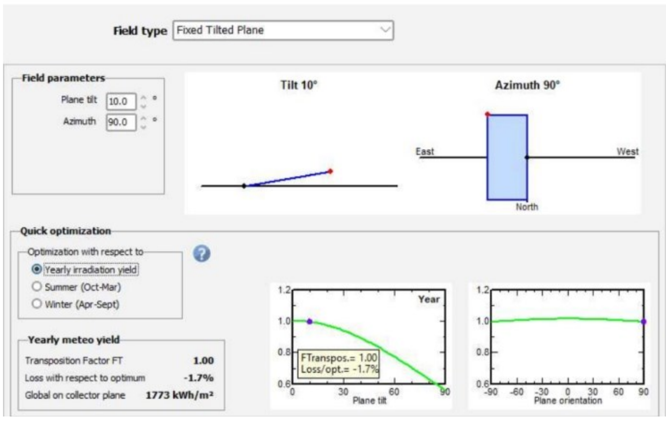

Fig. 4. Determination of the angle of placement of solar panels

Optional designs include placing the solar panels with the following condition of the existing building in the field. Figure 4. shows the simulation results of plane orientation where data obtains that a plane slope of 10° with azimuth 90° will produce a global collector plane potential of 1773 kWh/m². Geographical conditions of the building adjust into an oriented placement design plane PVsyst, with a tilt of 10° (tilt of solar panels) and azimuth of 90° (tilt of building based on north direction).

III. RESULT AND DISCUSSION

A. Near shading conditions

Near shading conditions Three-dimensional (3D) perspective of the near shading PV-Field and its surroundings are shown in Figure 5, then its relation to ISO-Shading conditions the diagram is shown in Figure 6.

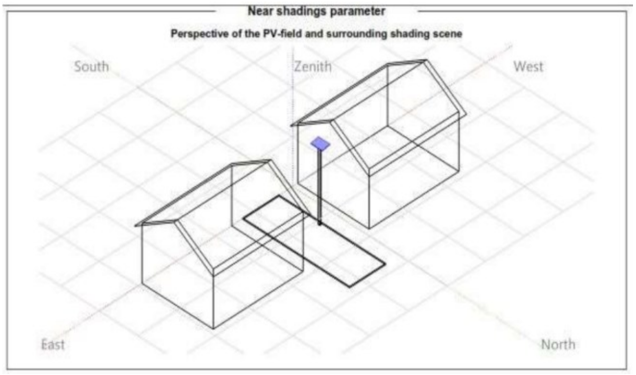

Fig. 5. Three Dimensions (3D) from the near shading simulation.

In Figure 5, you can see a simulation of the percentage of near shading: 1%; 5%; 10%; 20%; and 40%, with the following conditions:

a) *On the X axis is the azimuth, namely from 0° – 150°; 0° – 160°; 0° – 170°; and 0° – 180°;*

b) *On the Y axis is Sun Height ranging from 0o– 50°; ; 0°– 55°; ; 0°– 57°; ; 0°– 60°; and 0°– 65°;.*

c) *On the X axis is the azimuth, namely from (-65°) – (-115)°; (-65°) – (-120)°; (-65°) – (-120)°; (-60°) – (-120)°; and (-60°) – (-125)°;*

d) *On the Y axis is Sun Height ranging from 0° – 10°; 0°– 15°; 0°-17°; 0°– 20°; and 0° – 22°;*

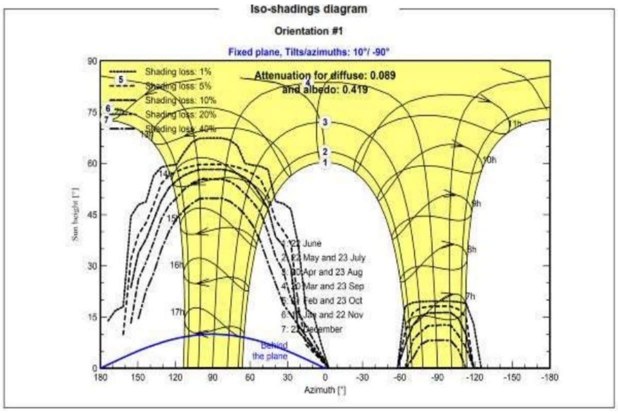

Fig. 6. ISO Shading Diagram SPSL Simulation Results

The Near Shading simulation on SPSL is shown in Figure 6, where the Pvsyst software identifies the shading percentage on the ISO-Shading diagram according to the perspective of the PV-Field and the surrounding shading scene.

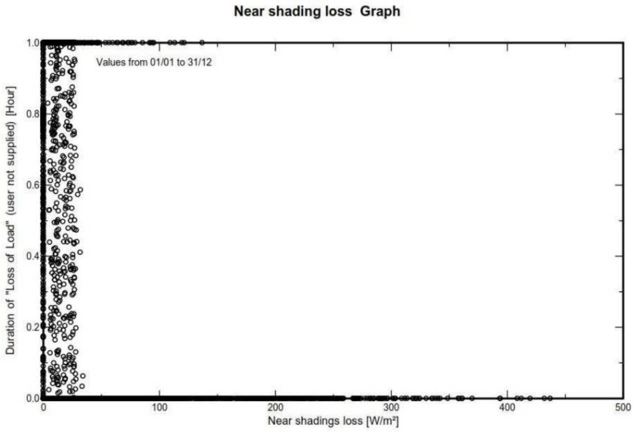

Fig. 7. Near Shading Loss Simulation Results

Figure 7. shows a Near Shading loss of 8760 points (number of hours within a year), where the highest near shading loss value is 436.9908 W/m².

B. Current Near Shading Loss chart

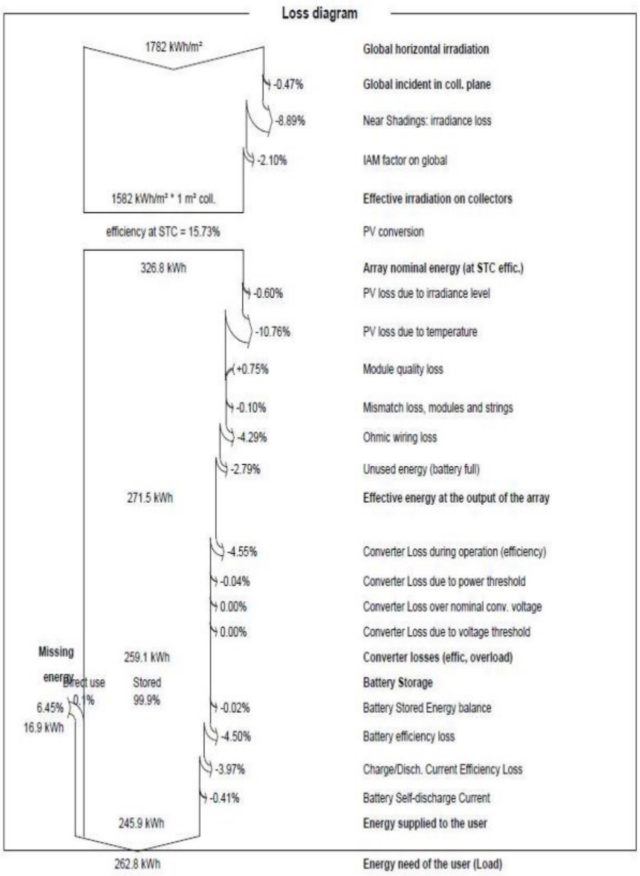

Fig. 8. Loss Diagram Simulation Results after Optimization

In Figure 8, the loss diagram shows that there are three irradiance losses, namely Global incident in the collection plane by 0.47%; IAM Factor Global of 2.10%; and near shading loss occupies the most significant position in irradiance loss, namely by -8.89%. Then the conversion value from irradiance loss to loss of electrical energy is shown in table I.

TABLE I
A SIMULATION RESULT OF LOSS IRRADIANCE AND CONVERSION TO LOSS OF ELECTRICAL ENERGY

Item	Parameters	Simulation before	Simulation After	Satuan
A	Global Horizotal Irradiation (GHI) =	1.782	1.782	(kWh/m²)
B		0,47%	0,47%	
	Global Incident in collection plane = Loss Irr_1	= 8,37	8,37	(kWh/m²)
		1773,326	1773,32601	(kWh/m²)
		1,69	1,69	kWh
C		8,89%	8,89%	
	Near Shadings (Irradiance Loss) = Loss Irr_2	= 157,74	157,74	(kWh/m²)
		1615,59	1615,59	(kWh/m²)
		31,75	31,75	kWh
D		2,10%	2,10%	
	IAM Factor Global (Irradiance Loss) = Loss Irr3	=33,93	33,93	(kWh/m²)
		1581,66	1581,66	(kWh/m²)
E	loss energi pendekatan	6,83	6,83	kWh
F	Efficiency at STC =	15,32%	15,73%	
G	module area (Px L) = 1,324 0,992 =	1,313	1,313	m²
H	Effective Irradiation on Collector =	1.582	1.582	kWh/m²*1m² collection
I	Array Nominal energy (at STC effiency) =	318,4	326,8	kWh

Calculation details in table I shows that the amount of Irradiance loss is considered the same in the conditions before and after optimization due to the treatment of the same near shading conditions (near shading conditions are difficult to avoid) shown in steps A-C. Then at point H, Effective Irradiation on Collector is obtained of 1,582 kWh/m2 *1m2 collections. The PV conversion is 15.73% (efficiency at STC); then, Array Nominal energy (at STC efficiency) = 326.8 kWh. Nominal Array Calculation energy after deducting the effect of irradiance loss as follows: H Effective Irradiation on Collector = 1.582 kWh/m2 *1m2 collection F PV Conversion = 15.73% Array Nominal energy (at STC efficiency) = I = 1582 x 15.73% x 1.313 = 326.8 kWh From the simulation results and calculations, the loss due to near shading is: Irradiance loss = 157.74 kWh/m2 or equivalent to 31.75 kWh.

C. Component Resizing

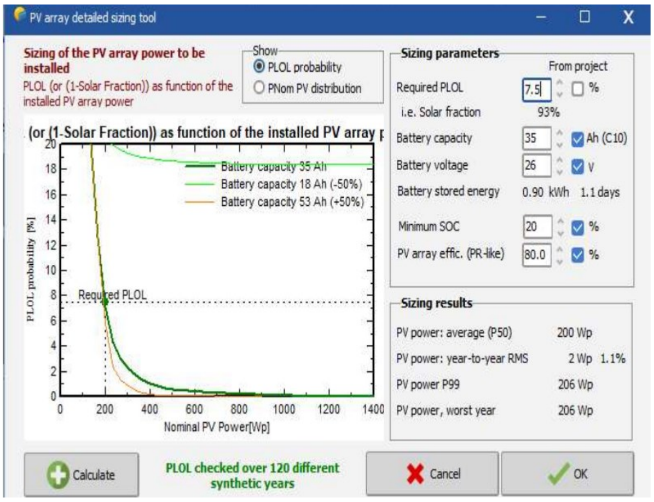

Fig. 9. PVArray detailed sizing tool on existing Pvsyst conditions

Figure 9 shows the existing PV Power sizing condition of 200Wp, so the PLoL (Power Loss of Load) probability value is set at 7.5%, and the battery has a capacity of 35 Ah (C10), with 1-day autonomy.

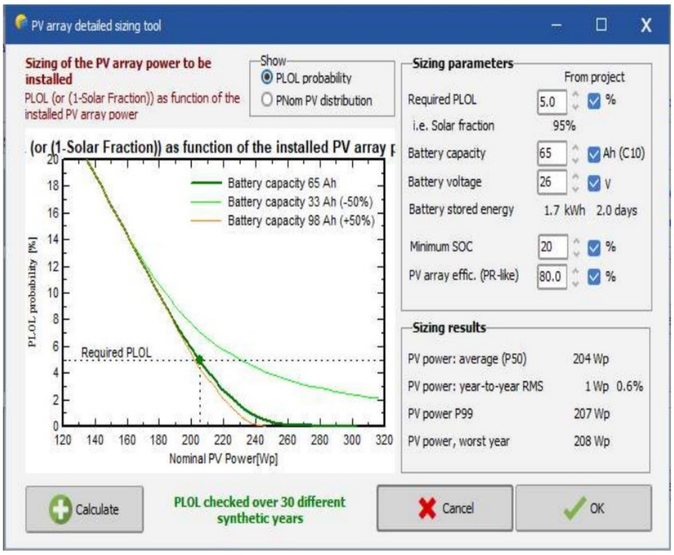

Fig.10. PV Array detailed sizing tool on Pvsyst optimization conditions.

Figure 10 shows that by sizing the PV Power of 204 Wp, will get the PLoL (Power Loss of Load) probability: set to 5% and the battery with a capacity of 65 Ah (C10), with an autonomy of 2 days. However, according to what is on the market, 205 Wp is taken.

Then a summary of the optimization results of component sizing is made, as shown in Table II below.

Table II shows that the optimal sizing for the PV array is 205 Wp (where the existing is 200 Wp), and the battery capacity is 62 Ah (existing is 32 Ah).

TABLE II
COMPONENT SIZING OPTIMIZATION RESULTS AND PERFORMANCE SUMMARY

No.	Comp.	Sizing Component		Explanation	
		Before	After	Diff.	Effect.
1.	PV array	200Wp	205Wp	5	Added 5Wp
	Battery	31 Ah	62 Ah	31	Reduction 31Ah
	TLo_Y early (Hour)	2396	765	-1631	Lost Hours Reduction Service
2.a	$PR \Rightarrow \left(=\frac{Yf}{Yr}\right)$	59,9%	67,7%		
	Yf (kWh/k Wp/Day)	2,91	3,29	7,8%	Increase Ratic Performance
	Yr $\left(\frac{kWh}{\frac{m2}{Day}}\right)$	4,86	4,86		
2.b	SolFrac (Euser/E load	80,86%	93,55%		
	Eload (kWh)	262,8	262,8	12,69 %	Increased power that can be supplied to the load
	Euser (kWh)	212,51	245,86		
	Emiss (kWh)	50,29	16,94		

D. Performance of Public Street Lighting after optimization

The SPSL performance after optimization is based on the performance parameters Ratio, solar fraction ratio, and T_{LoL} seen from the PVSyst simulation results in table III.

TABLE III
POST OPTIMIZATION SPSL PERFORMANCE SIMULATION

Month	EArray (kWh)	E_Load (kWh)	E_User (kWh)
January	21.06	22.32	19.26
February	21.49	20.16	19.18
March	22.99	22.32	20.33
April	22.60	21.60	20.48
May	23.08	22.32	21.17
June	22.66	21.60	20.64
July	23.20	22.32	21.22
August	24.35	22.32	21.58
September	23.01	21.60	20.67
October	24.06	22.32	22.22
November	21.28	21.60	19.26
December	21.73	22.32	19.85
Year	271.52	262.80	245.86

Month	E_Miss (kWh)	Yr (kWh/m²/ day)	PR ratio
January	3.063	4.33	0.700
February	0.976	4.95	0.676
March	1.994	4.90	0.652
April	1.121	4.89	0.680
May	1.155	4.69	0.710
June	0.957	4.70	0.714
July	1.098	4.77	0.701
August	0.740	4.98	0.683
September	0.927	5.22	0.644
October	0.096	5.55	0.630
November	2.339	4.80	0.653
December	2.472	4.54	0.688
Year	16.939	4.86	0.676
Month	SolFrac ratio	Pr_LOL %	T_LOL Hour
January	0.863	16.01	119
February	0.952	4.33	29
March	0.911	13.32	99
April	0.948	6.96	50
May	0.948	9.60	71
June	0.956	4.93	36
July	0.951	6.87	51
August	0.967	7.02	52
September	0.957	7.73	56
October	0.996	0.82	6
November	0.892	12.61	91
December	0.889	14.04	104
Year	0.936	8.73	765

Performance Ratio (PR) Based on table III and according to formula 1, the Performance Ratio is as follows: PR existing = (2.91/4.86) x100 % = 59.9 % meanwhile, the conditions after optimization are (3.29/4.86) x 100 % = 67.6% Meanwhile, based on the simulation results in table 2 it shows that the performance ratio (PR) in the existing condition is 59 .9%. That means that about 40.1% of the total energy generated by the PV modules is lost, or 40.1% is not supplied to the load and battery bank. At the same time, the performance ratio (PR) in the condition after resizing the components is 67.6 %. That means that after optimization, there is an increase in PR of 7.7%.

Solar Fraction Ratio based Performance Ratio is as follows: $SolFrac$ existing = (212.5/262.8) x 100 % = 80.86 %. As for the conditions after optimization, namely: $SolFrac$ conditions after optimization = (245.86/262.8) x 100 % = 93.6%. table 1 shows the ratio of Solar Fraction (SolFrac) at the conditions existing is 80.86%. That means that the energy supplied by the SPSL system fulfills 80.86% of the load requirements. Meanwhile, the performance ratio of Solar Fraction in the post-resizing condition of the components is 93.6%, meaning that the energy supplied by the SPSL system fulfills 93.6% of the load requirements. That means that after optimization, there is an increase in the energy distributed for user use by 12.74%, or the equivalent of 33.36 kWh.

Load loss duration indicator (T_{LoL}) The distribution and duration of the load loss periods in one year gives in table 2 and table 1 on the existing condition of the annual load loss duration or period (annual T_{LoL}), which is a total of 2396 hours (power outage duration) or equivalent to a yearly P_{LoL} loss of 27.3%. Meanwhile, after optimization and resizing the components, the Total Loss of Load (Pr_{LOL}) in a year is 8.73%. Equivalent to an annual TLOL of 765 hours, i.e., a total of 765 hours of power outage per year. So that after optimizing the resizing of the components, the duration increases service hours to 1631 hours per year.

Conclusion

The simulation results in the yearly loss diagram show the loss near shading of 8.89% Loss Irradiance. With conversion calculations, the loss due to near shading in Loss Irradiance is 157.74 kWh/m2, equivalent to 31.75 kWh. The results of resizing the components, which include the PV array and battery, then the results obtained before optimizing the capacity of the 200 Wp PV array with a battery capacity of 31 Ah (1-day autonomy), resulting in "duration lost hours of service" (TLoL) of 2396 Hours. After optimizing, the PV array's capacity of 205 Wp with battery capacity 62 Ah (2 days auto) results in a drop to TLoL of 765 Hours. Analysis of the performance of the SPSL system shows that the Performance Ratio (PR) in the existing condition is 59.9% (energy loss 40.1% of the total energy). While the performance ratio (PR) in the post-resizing state of the components is 67.6 %, this means that after optimization, there is an increase in PR of 7.7%. In comparison, the Solar Fraction Ratio (SolFrac) analysis in the existing conditions is 80.86 %, which means that the SPSL system's energy fulfills 80.86% of load requirements. While the performance ratio of Solar Fraction in the post-resizing conditions component is 93.6%, this means that after optimization, there is an increase in the energy distributed for user use is 12.74% or the equivalent of 33.36 kWh. These results indicate that the analysis of the simulation results succeeded in reducing the irradiance loss due to the shading effect from 8.89% to 1.19%. The impact is quite significant.

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