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RELIABILITY EVALUATION OF ELECTRIC POWER GENERATION PLTS SYSTEM ON PUBLIC STREET LIGHTING TARAKAN CITY

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Abstract
Public street lighting (PJU) is a lighting lamp that is public (for the common good) and is usually installed on the road. Solar Public Street Lighting (PJU-TS) is a public street lighting where the electrical power for the lights is supplied by a Stand Alone system that uses solar energy. In this study, measurements of sunlight, lamplight intensity, and lamppost height were carried out on 24 PJU-TS units spread across 4 sub-districts in Tarakan city. Furthermore, simulating PJU-TS using Matlab Simulink to determine the level of reliability based on the use or usage of batteries in PJU-TS. Based on the regulation of the Minister of Transportation of the Republic of Indonesia Number PM 27/2018 concerning Street Lighting Equipment that the lighting level of PJU-TS lamps is 3-6 lux and based on recommendations from the Reliability Standard Power Plant that the reliability value is at least 80%. The results of this research simulation that PJU-TS that meets the standards of the Minister of Transportation of the Republic of Indonesia Number PM 27/2018 amounted to 3 units of 3-6 lux, 40 W lamps, lamp working hours 11 hours 14 minutes, 300 WP solar modules, solar charge controller current 15.72 A, 40 Ah batteries, battery working hours 13.72-18.68 hours, percentage of Ah battery usage 46.42% - 95%. In addition to meeting the standards of the Minister of Transportation of the Republic of Indonesia Number PM 27/2018, the results of this simulation also meet the Reliability Standard Power Plant recommendations with reliability exceeding 80%, namely 81.27% - 100%. Meanwhile, 21 units of PJU-TS do not meet the standards of the Minister of Transportation of the Republic of Indonesia Number PM 27/2018 concerning Street Lighting Equipment and Reliability Standard Power Plant recommendations.

Keywords:
Public street lighting; matlab; simulink; reliability

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1. Introduction

This modern era cannot be separated from the existence of energy. All of it is a support for our daily lives that allows our lives to be easier, more practical and efficient. One of the renewable energies is solar energy where many consumer communities have used it. Indonesia, as a tropical country with an average of 12 hours of sunshine per day, has tremendous potential for solar energy. According to the National Energy General Plan (RUEN), Indonesia has an estimated solar energy potential of 207,898 MW (4.80 kWh/m2/day), equivalent to 112,000 GWp. One of the uses of electricity that is widely used by people today is as a source of lighting. The increasing level of community mobility makes all activities require lighting, including highways or public roads. Public street lighting is lighting that is public (for the common good) and is usually installed on roads or in certain places such as parks, and other public places. Public Street Lighting (PJU). PJU (Public Street Lighting) Solar Power is a public street lighting where the electrical power for the lights is supplied by an independent system obtained from solar energy. The reliability of electrical power generation in the PLTS system plays an important role in meeting

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the needs for Public Street Lighting (PJU). A good level of reliability determines the continuity of the PLTS system's electrical power distribution on Public Street Lighting (PJU).

2. Experimental Section

A. Place and Time of Research

This research will be carried out at points where the PLTS system is installed on public street lighting in the city of Tarakan. This research was carried out for approximately 6 months.

B. PJU-TS reliability

In this study, calculation analysis is carried out with the data that has been obtained, then simulate PJU-TS using matlab simulink to determine the level of reliability based on the use or use of batteries in PJU-TS. Based on the regulation of the Minister of Transportation of the Republic of Indonesia Number PM 27/2018 concerning Street Lighting Equipment that the lighting level of PJU-TS lamps is 3-6 lux and based on recommendations from the Reliability Standard Power Plant that the reliability value is at least 80%. If the equipment works at least 80%, it can be said to be reliable because the equipment works in minimum conditions so that a good capacity is if the equipment works at least 80%, with a maximum reliability value of 100% if the power plant equipment works in conditions of 80% of the power plant capacity. The theory in this research follows the title of the discussion to be researched, and references are obtained from journals, books, and others.

C. Solar Public Street Lighting (PJU-TS)

Solar public street lighting uses solar cell panels that function to receive sunlight and then convert it into electrical energy through the photovoltaic process. Photovoltaic systems produce output power only when the photovoltaic modules are illuminated by the sun, therefore photovoltaic systems use energy storage mechanisms so that electrical energy is always available when the sun is no longer shining (at night). The battery is a component used for storing the electrical energy produced by the photovoltaic array. In addition to being a storage medium for electrical energy, batteries are also used for system voltage regulation and current sources that can exceed the capabilities of photovoltaic arrays. The formula used is as follows:

Calculating Ornament Handlebar Angle [1]

$$T = \sqrt{h^2 + c^2}$$

$$\cos^{-1} \varphi = \frac{h}{T}$$

With:

T = Distance of lights to the center of the road

h = Pole height

c = horizontal distance of the lamp to the center of the road

φ = Angle of inclination of the handlebar ornament

Calculating light intensity (i in candela/cd)

$$I = \frac{\phi}{\omega}$$

Then :

$$k = \frac{\Phi}{p} \text{ dan } \Phi = k \; x \; p$$

With:

I = Light intensity in candela (cd)

ϕ = Light flux in lumens (lm)

$\boldsymbol{\omega}$ = Angle of space in sterdian (sr)

Calculating Illumination Intensity

$$Ep = \frac{k\ x\ W\ x \cos\beta}{\omega\ x\ r^2}$$

With:

Ep = Illumination Intensity

K = Efficacy of light

W = Lamp power

Cos β = Angle of inclination of the handlebar ornament

$\boldsymbol{\omega}$ = Angle of space in sterdian (sr)

r = distance from light source to point P (m)

Calculating Solar Module Capacity: [2]

Module capacity (W) = Im x Vm

With:

Im = Panel maximum current

Vm = Maximum voltage of the panel

The size or rating for the flow control device in and out of the battery in Amperes is :

$$Icc = \frac{Pmaks}{FF\ x\ Voc}\ x\ (100\% +\ \eta\ baterai)$$

With:

icc = solar charge controller rating current (amperes)

Pmax = many solar panels x Pnom (watts)

Calculate the battery capacity as follows:

$$\frac{Eload}{\eta v}$$

With:

Eload = Quantity of energy

η = Battery Efficiency

v = Battery voltage

D. Research Procedure

Data is obtained by direct observation and conducting interviews with the parties concerned. After obtaining the data, then the calculation analysis is carried out using the data that has been obtained after that the simulation is carried out using Matlab Simulink based on Reliability Standard Power Plant. f the equipment works at least 80%, it can be said to be reliable because the equipment works in minimum conditions so that a good capacity is if the equipment works at least 80%, with a maximum reliability value of 100% if the power plant equipment works in conditions of 80% of the power plant capacity.

3. Result and Discussion

There are 24 PJU-TS locations in 4 sub-districts of Tarakan city that have been installed by the Ministry of Energy and Mineral Resources and managed by the Tarakan city Transportation Office. In the east Tarakan sub-district there are 6 streetlights, in the middle Tarakan sub-district there are 4 streetlights, in the west Tarakan sub-district there are 6 streetlights, in the north Tarakan sub-district there are 8 streetlights. Based on the Road Classification according to the regulation of the Minister of Transportation of the Republic of Indonesia Number PM 27/2018 concerning Street Lighting Equipment at the PJU-TS location point in Tarakan city including Environmental roads. Based on the Road Classification according to the regulation of the Minister of Transportation of the Republic of Indonesia Number PM 27/2018 concerning Street Lighting Equipment at the PJU-TS location point of Tarakan city including Environmental roads. Environmental roads are public roads that serve environmental transportation with short distance travel characteristics, and low average speeds. The requirement for strong lighting (illumination) that must be produced for Environmental roads is 3-6 lux.

A. Solar Public Street Lighting Data

Calculating Ornament Handlebar Angle

With:

Pole height (h) = 7 m

Horizontal distance from the lamp to the center of the road (C) = 5 m

$$T = \sqrt{h^2 + c^2}$$

$$= \sqrt{7^2 + 5^2}$$

$$= 8{,}602\ meter$$

Then :

$$\cos\varphi = \frac{h}{t}$$

$$= \frac{7}{8{,}602}$$

$$= 0{,}813$$

$$\varphi = cos^{-1} 0{,}813$$

$$\varphi = 35{,}609°$$

Calculating light intensity (i in candela/cd)

I $= \frac{\Phi}{\omega}$ or $\boldsymbol{\omega} = 4\pi$

With :

$k = \frac{\Phi}{p}$ dan $\Phi = k\ x\ p$

$$i = \frac{k\ x\ p}{\omega}$$

$$= \frac{100\ x\ 40}{4\pi}$$

$$= \frac{4000}{4\pi}$$

$= 318{,}30$ cd

Calculating Illumination Intensity

With :

h = 7 m

W = 40 W

r^2 = $\sqrt{7^2 + 5^2}$ = 8,602

= $8{,}602^2$ = 74

r^2 = 74

cos β = 0,813

$\boldsymbol{\omega}$ = 4$\boldsymbol{\pi}$

4$\boldsymbol{\pi}$ = 4 x 3,14

$\boldsymbol{\omega}$ = 12,56

$$Ep = \frac{k\ x\ W\ x \cos\beta}{\omega\ x\ r^2}$$

$$= \frac{100\ x\ 40\ x\ 0{,}813}{12{,}56\ x\ 74}$$

$$= \frac{3.252}{929{,}44}$$

$= 3{,}49\ lux$

Solar Panels

The specifications of solar panels used in solar public street lighting in Tarakan city can be seen in Table 1. As follows:

Table 1. Solar Panel Specifications

Description	**Specification**
Type	*polycrystalline*
Module Power (Pnom)	300W
Max voltage (Vm)	36,41 V
Max current (Im)	8,24 A
No-load voltage (Voc)	45,20 V
Short circuit current (Isc)	8,73 A
Module dimensions	1956 mm x 982 mm

To find the value of the module capacity by multiplying the maximum current of the panel with the maximum voltage of the panel.

Module capacity (W) = Im x Vm

$= 8,24\ x\ 36{,}41$

$= 300\ W$

Solar Charge Controller

Table 2. Specifications of Solar Charge Controller

Description	**Specification**
Type	*Switching Regulator MPPT*
PV Module Input Voltage	Max. 45 VDC
Max Charge Current	15 A
Battery Input Voltage	Max. 29,4 VDC
Upper Limit Voltage	12,6 V - 13,8 V (12 V System) 27.6 V – 29,4 V (24 V System)

The size or rating for the flow control device in and out of the battery in Amperes is :

Icc = $\frac{Pmaks}{FF \: x \: Voc} \: x \: (100\% + \: \eta_b \text{ baterai})$

$= \frac{300}{0{,}76 \: x \: 45{,}20} \: x \: (100\% + 80\%)$

$= \frac{300}{34{,}35}$ x 1,8

= 15,72 A

Battery

Table 3 Battery Specifications

Description	Specification
Type	*Battery LifePO4* (*Lithium -ion ferrouse phosphate*)
Voltage	25,6 V
Current Capacity	40 AH
Battery Efficiency	80 %

Calculating the capacity of the battery used:

$\frac{Eload}{\eta_b v} = \frac{768 \: wh}{80\% x \: 24 \: V}$

= 40 Ah

B. Modeling PJU-TS Using Matlab Simulink Based on Field Data

Simulink modeling with lighting intensity using measurement results measured using measuring instruments

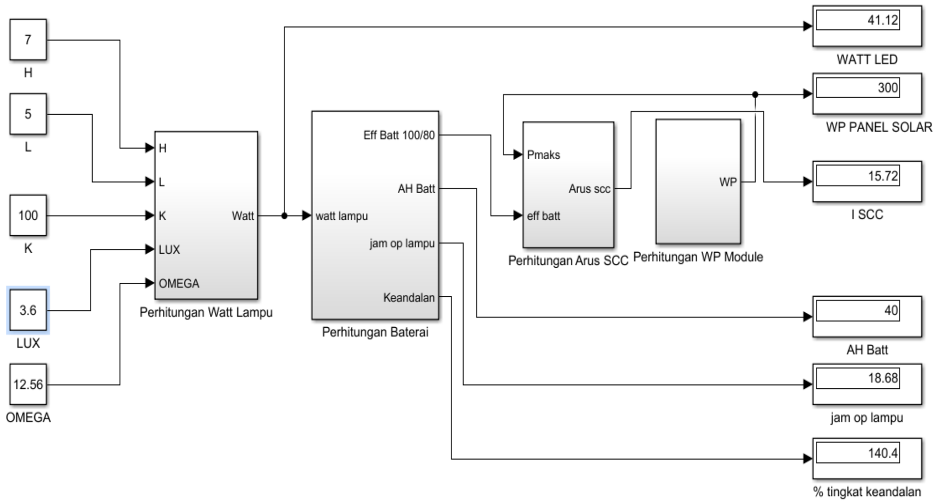
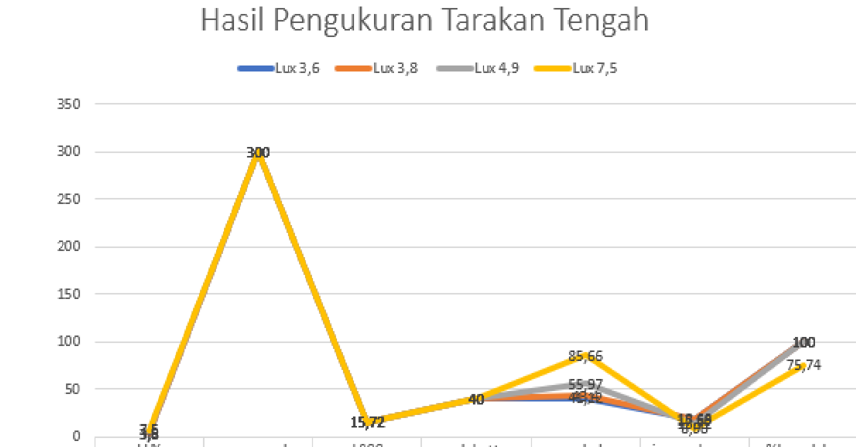
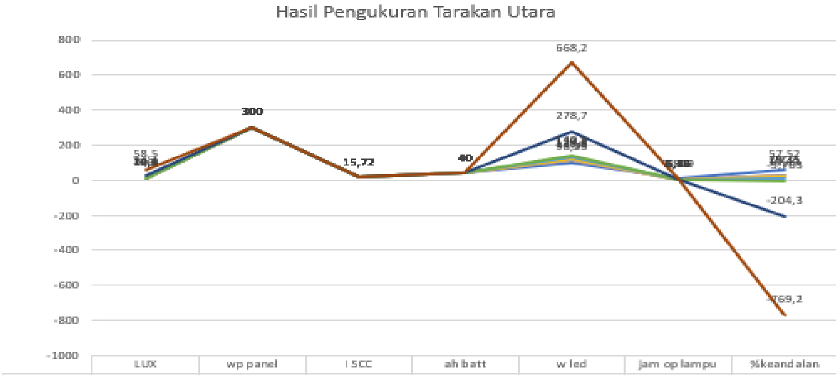


Figure 1. Subsystem modeling results based on measurement results



	LUX	wp panel	I SCC	ah batt	w led	jam op lampu	%keandalan
Lux 3,6	3,6	300	15,72	40	41,12	18,68	100
Lux 3,8	3,8	300	15,72	40	43,4	17,69	100
Lux 4,9	4,9	300	15,72	40	55,97	13,72	100
Lux 7,5	7,5	300	15,72	40	85,66	8,96	75,74

Figure 2. Graph of Modeling Results for the Central Tarakan subsystem



	LUX	wp panel	I SCC	ah batt	w led	jam op lampu	%keandalan
Lux 8,6	8,6	300	15,72	40	98,23	7,819	57,52
Lux 10,3	10,3	300	15,72	40	117,6	6,52	29,35
Lux 10,4	10,4	300	15,72	40	118,8	6,46	27,7
Lux 10,9	10,9	300	15,72	40	124,5	6,16	19,41
Lux 11,4	11,4	300	15,72	40	130,2	5,89	11,13
Lux 12,3	12,3	300	15,72	40	140,5	5,46	-3,783
Lux 24,4	24,4	300	15,72	40	278,7	2,75	-204,3
Lux 58,5	58,5	300	15,72	40	668,2	1,14	-769,2

Lux 8,6 Lux 10,3 Lux 10,4 Lux 10,9 Lux 11,4 Lux 12,3 Lux 24,4 Lux 58,5

Figure 3. Graph of Modeling Results for the North Tarakan subsystem

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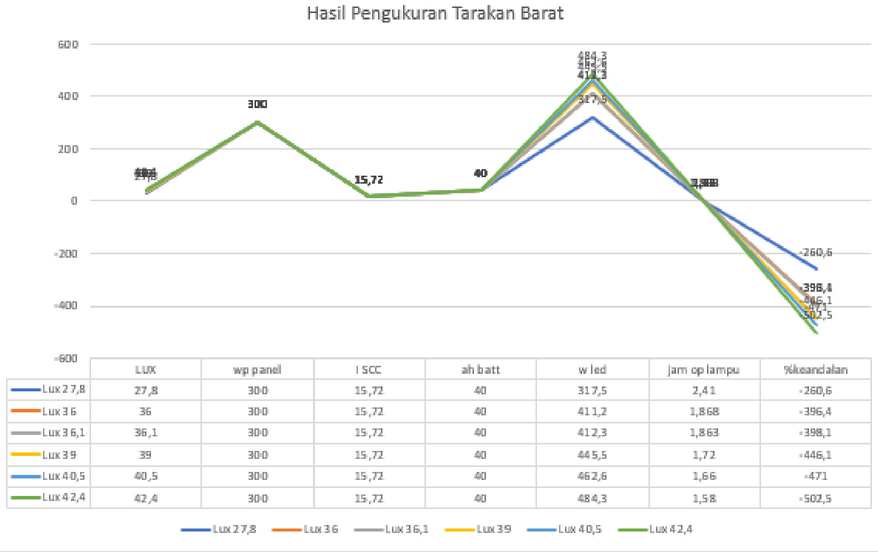
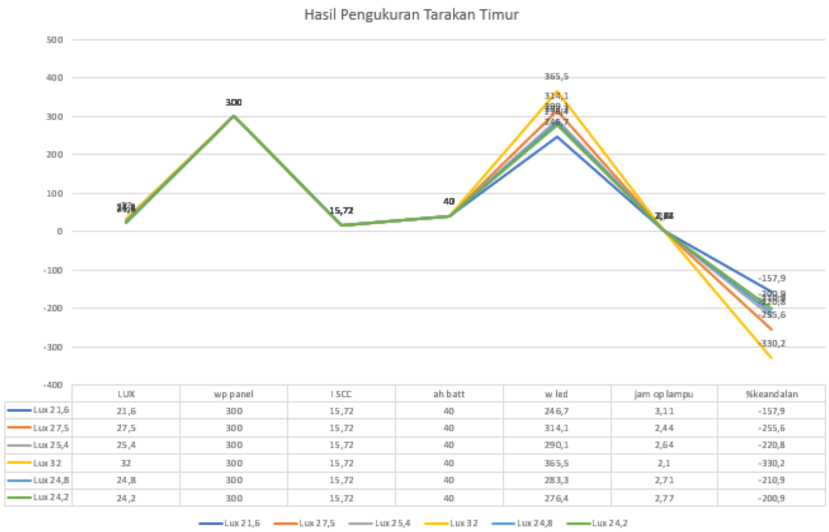


	LUX	wp panel	I SCC	ah batt	w led	jam op lampu	%keandalan
Lux 27,8	27,8	300	15,72	40	317,5	2,41	-260,6
Lux 36	36	300	15,72	40	411,2	1,868	-396,4
Lux 36,1	36,1	300	15,72	40	412,3	1,863	-398,1
Lux 39	39	300	15,72	40	445,5	1,72	-446,1
Lux 40,5	40,5	300	15,72	40	462,6	1,66	-471
Lux 42,4	42,4	300	15,72	40	484,3	1,58	-502,5

Figure 4. Graph of Modeling Results for the West Tarakan subsystem



	LUX	wp panel	I SCC	ah batt	w led	jam op lampu	%keandalan
Lux 21,6	21,6	300	15,72	40	246,7	3,11	-157,9
Lux 27,5	27,5	300	15,72	40	314,1	2,44	-255,6
Lux 25,4	25,4	300	15,72	40	290,1	2,64	-220,8
Lux 32	32	300	15,72	40	365,5	2,1	-330,2
Lux 24,8	24,8	300	15,72	40	283,3	2,71	-210,9
Lux 24,2	24,2	300	15,72	40	276,4	2,77	-200,9

Figure 5. Graph of Modeling Results for the East Tarakan subsystem

Table 4. Battery Usage and Reliability

NO.	Battery Usage (%)	Working hours Lamp	Reliability (%)
1.	46,42 %	11 hours 14 minutes	100 %
2.	50 %	12 hours	100 %
3.	60 %	14 hours 4 minutes	100 %
4.	65 %	15 hours 6 minutes	100 %
5.	70 %	16 hours 8 minutes	100 %
6.	75 %	18 hours	100 %
7.	80 %	19 hours 2 minutes	100 %
8.	85 %	20 hours 4 minutes	93,7 %
9.	90 %	21 hours 6 minutes	87,51 %
10.	95 %	22 hours 8 minutes	81,27 %
11.	100 %	24 hours	75 %

From the table above it can be seen that the amount of usage or use of the battery can affect the working hours of the battery and the level of reliability of the battery. The use of a good battery if the battery works at least 80% of its capacity so that it affects the capacity and lifetimenya or battery life.

Based on mathematical modeling using Matlab Simulink that the field data of lamp working hours is 11 hours 14 minutes, it is known that the battery usage is only 46.42% with the remaining battery usage of 53.58% and a reliability level of 100%.

4. Conclusion

Based on the results of research conducted by simulating PJU-TS using Matlab Simulink that PJU-TS that meets the standards of the Minister of Transportation of the Republic of Indonesia Number PM 27/2018 totals 3 units of Solar Public Street Lighting (PJU-TS) with a lighting level of 3-6 lux resulting in a lamp wattage of 40 W, lamp working hours of 11 hours 14 minutes, solar module 300 WP, solar charge controller current 15.72 A, battery 40 Ah, battery working hours 13.72-18.68 hours, percentage of battery Ah usage 46.42% - 95%.%. In addition to meeting the standards of the Minister of Transportation of the Republic of Indonesia Number PM 27/2018, the results of this simulation also meet the Reliability Standard Power Plant recommendations with reliability exceeding 80%, namely 81.27% - 100%. While the PJU-TS of 21 units does not meet the standards of the Minister of Transportation of the Republic of Indonesia Number PM 27/2018 concerning Street Lighting Equipment and Reliability Standard Power Plant recommendations.

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