PLANNING AN ON-GRID SOLAR ENERGY GENERATION SYSTEM FOR THE DWIMATAMA PIER AT TANJUNG EMAS PORT

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SURABAYA
2022

PERENCANAAN SISTEM PEMBANGKIT ENERGI SURYA ON-GRID UNTUK DERMAGA DWIMATAMA DI PELABUHAN TANJUNG EMAS

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PLANNING AN ON-GRID SOLAR ENERGY GENERATION SYSTEM FOR THE DWIMATAMA PIER AT TANJUNG EMAS PORT

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Bachelor of Engineering

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"I declare that this thesis entitled PLANNING AN ON-GRID SOLAR ENERGY GENERATION SYSTEM FOR THE DWIMATAMA PIER AT TANJUNG EMAS PORT is the result of my own research except as cited in the references. This thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

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ABSTRACT

Global warming is the gradual increase in the temperature of the Earth's atmosphere caused by increasing levels of pollutant gases such as carbon dioxide. Natural characteristics are expected to change as the Earth's surface temperature rises. By 2025, Indonesia's renewable energy use is expected to reach 23%. (Ministry of Energy and Mineral Resources, 2021). Existing critical sectors such as transportation and freight forwarding are being examined. For instance, vessels can reduce their carbon footprint by connecting to shore-connection facilities powering renewable energy sources in ports. The case study is the Dwimatama pier in Semarang's Tanjung Emas port. The city of Semarang receives approximately six hours of sunlight per day. With six-hour Semarang city irradiation could serve as a source of electrical energy in this region. The results of this study indicate that to generate electrical power from 1 MWp of solar radiation, a panel area of approximately 1 hectare is required for a solar panel area with a 20% efficiency. For the Semarang area, the panel's maximum output time is about 12 to 13 AM. Solar panels can fully power the vessel from 9 AM to 4 PM.

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ABSTRAK

Pemanasan global adalah peningkatan suhu atmosfer bumi secara bertahap yang disebabkan oleh meningkatnya kadar gas polutan seperti karbon dioksida. Karakteristik alam diperkirakan akan berubah seiring dengan naiknya suhu permukaan bumi. Pada tahun 2025, penggunaan energi terbarukan di Indonesia diperkirakan mencapai 23%. (Kementerian Energi dan Sumber Daya Mineral, 2021). Sektor-sektor penting yang ada seperti transportasi dan pengiriman barang sedang diperiksa. Misalnya, kapal dapat mengurangi jejak karbonnya dengan menghubungkan ke fasilitas sambungan pantai, yang dapat ditenagai oleh sumber energi terbarukan di pelabuhan. Kasus yang dikaji dalam penelitian ini adalah dermaga Dwimatama di Pelabuhan Tanjung Emas Semarang. Kota Semarang menerima kurang lebih enam jam sinar matahari per hari. Ini bisa menjadi sumber energi listrik di wilayah ini. Hasil penelitian ini menunjukkan bahwa untuk menghasilkan energi listrik dari radiasi matahari sebesar 1 MWp, diperlukan luas panel kurang lebih 1 hektar untuk luas panel surya dengan efisiensi 20%. Untuk wilayah Semarang, waktu keluaran maksimum panel adalah sekitar pukul 12 hingga 13 pagi. Panel surya dapat mentenagai kapal secara penuh untuk pukul 9 hingga pukul 16.

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LIST OF ABBREVIATIONS

DC	:	Direct Current
AC	:	Alternating Current
PV	:	Photovoltaic
kWH	:	Kilo Watt Hour
kW	:	Kilo Watt
MJ	:	Mega Joule
ha	:	Hectare
A	:	Ampere

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LIST OF SYMBOLS

t	:	*Peak itensity of the sun*
n	:	*Number of solar panels*
P	:	*Electric power*
V	:	*Voltage*
I	:	*Electric current*
$\cos \varphi$	:	*Power factor*
Hz	:	*Electrical frequency*

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Today, we are faced with a new challenge, global warming. Global warming is the rise in the Earth's atmospheric temperature caused by increased pollutant gases such as carbon dioxide (KBBI). According to a study from the IPCC, "most of the increase in global average temperatures since the mid-20th century is most likely due to increased concentrations of greenhouse gases due to human activity". Rising Earth's surface temperature is predicted to cause changes in natural characteristics. These changes can lead to natural events such as the disappearance of glaciers caused by rising sea surface temperatures that cause rising sea levels. The increasing intensity of extreme weather can disrupt agricultural products, decrease the area of human habitable areas, and change the lifestyle of living things to the extinction of living things. The greenhouse effect generally causes this problem. The greenhouse effect in the Earth's atmosphere has a greenhouse-like impact. The heat that the sun gives to the Earth provides warmth with impact on its surface. The results of heat are trapped by the Earth's atmosphere. The gas that causes this effect is gas emissions of fuels such as CO2. Carbon dioxide gas can provide the impact of holding the sun's heat trapped on the Earth's surface because it reflects existing heat so that the sun's heat is trapped on the Earth. This is why we are experiencing a process of warming the Earth.

From the above problems, we must start to fix our energy system. We must begin to reduce the use of fossil fuels as our energy sources that can impact the warming of the Earth, not to mention the source of fossil fuels that are limited and can be exhausted at any time. Therefore, we must change our fossil-dependent energy system, starting with something new, green, and environmentally friendly. Consequently, it is essential to develop clean and renewable energy sources. Clean energy sources, in addition to not producing greenhouse gases, also energy is not quickly depleted like fossil fuels. One renewable energy source that is relatively cheap today compared to fossil energy is solar energy.

In Indonesia itself, the use of renewable energy seems to be something we need to pay attention to. This amount is undoubtedly still left behind because Indonesia's total energy is only below 20% supplied by renewable energy. By 2025, the use of renewable energy in Indonesia is targeted to reach 23% (Ministry of Energy and Mineral Resources, 2021). The use of renewable energy in Indonesia, primarily to support the essential sector, must focus. They are existing important sectors such as the transportation and freight forwarding industries. Today is the era of globalization; people can easily buy goods from other regions. This can lead to an increase in the intensity of activity in this sector. The intensity of this activity will affect the rise in greenhouse gases caused by emissions from exhaust gases transporting goods. One of the main concerns is the emission of exhaust gases by vessels.

Moreover, the vessel is leaning and doing loading-unloading activities. At this stage, vessels' energy consumption is enormous, perhaps almost 100 percent power to move the vessel's crane. This vessel's loading and unloading activities cannot be completed in just a short time. Therefore, a new and environmentally friendly energy supply is needed. The green-port program is expected when loading and unloading activities by the vessel. Vessels do not need to use vessel generators to supply crane power.

Vessels can use shore-connection facilities that use renewable energy resources at the Port. In Indonesia, there is still minimal use of this shore-connection facility. The use of shore connection tends to be newly used in large ports and is usually newly used for container docks. PT. Pelindo III, as one of the Port holders located in a reasonably strategic area, has just installed a shore connection that accommodates new cargo vessels at Dwimatama Terminal, which is a TUKS dock to serve PT. Pupuk Indonesia Logistics. This facility's presence and increasing popularity is expected to reduce the potential of emission gas produced by vessels while the vessel is in port for the loading and unloading process. In the area of Tanjung Emas Port of Semarang, many areas have not been appropriately utilized or areas that have initially been used, but because of the existing rob flood make, some places around the Port can not be used properly. With this, it is very potential to utilize the area for solar panel fields to supply shore connection needs at Tanjung Emas Port. In addition, the length of sunlight irradiation in Semarang is approximately six hours per day. This can be used as a supplier of electrical energy sources in this region, considering the adequate time for electricity production by solar panels is four to five hours per day.

In Indonesia, shore-connection in the port still utilizes fossil energy resources. This happens because the electricity obtained on the shore connection uses the grid system. On-grid system in Indonesia, which own by PLN, PLN's on-shore electricity network is a power grid that gets power sources from various power plants, both owned by PLN and other parties. The percentage of power plants that still use fossil energy as their energy source is above 80% of the total power generation capacity, which reaches 69.6 Giga Watts (Government department of ESDM). This shows that shore-connection in Indonesia will have the same impact on environmental pollution. The shore-connection electricity in the port is still dominated by using fossil energy sources that will undoubtedly cause environmental pollution. Therefore, there is a need for development and research on shore-connection energy sources in ports that use renewable energy sources without emissions. Using a power source from photovoltaic cells as a shore-connection power source will be considered an excellent first step. Although it may be in its application can not be fully applied. Still, with the use of renewable energy sources, photovoltaic cells will reduce the use of fossil energy sources and gas emissions.

Therefore, a study is needed to analyze power flow for shore-connection supply with photovoltaic/solar cell power sources. Because in general, the shore-connection electricity supply at ports in Indonesia is supplied by an on-grid electricity network that uses AC electric current. At the same time, the use of photovoltaic cells will produce a DC electric current. These two types of electric current have differences, both in character and application. Therefore, the power flow analysis for shore-connection electricity supply is required by combining the two sources of electrical energy that have differences in the electric current provided. Also, because of the challenges of the times that need clean energy, local non-fossil power plants will be supplied around the port area.

1.2 Problem Statement

Looking from the background above, combining or replacing the shore-connection power flow that initially used the energy source from the Indonesia grid that uses AC electric current will be changed or combined with the power source from photovoltaic cells with DC power sources. There will be concerns about the feasibility of the power flow. The author gives two formulations of the problem that he discusses. First, How does the design shore connection electrical system schematic when using photovoltaic cells? Second, How does analytical power flow with photovoltaic in shore connection use system on grid?.

1.3 Research Objectives

The author has a two-thing research objective: looking at the problem statement above and designing a shore connection electrical system schematic using photovoltaic cells. Second, analyzing power flow with photovoltaic in shore connection use system on grid.

1.4 Scope of Research

The author creates a scope of research intending to limit the scope of study that the author is doing. First, the data generated is the result of software-based modeling. Second, the discussion is only for shore-connection cases at Tanjung Emas Port.

1.5 Research Benefit

This benefit is expected to be a reference for further research activities so that renewable energy can be used widely.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

At the moment, the world is faced with the problem of climate change. With this problem, every country in the world must participate in a decrease in the Earth's surface temperature of at least 1.5° Celsius. Therefore, the use of fossil fuels that certainly produce emissions must be limited and start using clean and renewable energy sources. Clean energy sources in Indonesia are actually many and very potential, ranging from water as a producer of electricity, geothermal, to sunlight, all in Indonesia. The use of photovoltaic cells in Indonesia is possible, especially in coastal areas. This is supported by several surveys conducted by the ESDM ministry on the latest energy maps in Indonesia, where Indonesia has tremendous potential compared to other regions in coastal areas. The use of electricity sources from photovoltaic cells can support port facilities located in Indonesia. Using the format of energy use mixed between on the grid and photovoltaic cell is expected to reduce the use of electricity from conventional fossil fuel power plants.

2.2 Related Studies

2.2.1 Radwan, M. E., Chen, J., Wan, Z., Zheng, T., Hua, C., & Huang, X (2019) Critical barriers to the introduction of shore power supply for green port development: the case of Djibouti container terminals

Research conducted by Muhammad discusses the problems/challenges of using shore connection as a support facility for green port programs in Djibouti. This research is motivated by the lack of literature studies on shore connection problems conducted in developing countries. If we look geographically, the developing countries have a fundamental difference compared to developed countries in general. In addition, the study also examines shore power technology from a policy perspective rather than its engineering complexity, which adds additional value to existing knowledge. This research shows that electricity needs, investment costs, and electricity costs are significant factors that hinder the development of shire-connection facilities in Djibouti's container terminals. Therefore, according to Muhammad, those who have power over the port and all relevant stakeholders should pay great attention to these factors. This research can also help policymakers and port authorities to make informed decisions and prioritize barriers according to their significance. The contribution of this research is mainly doubled.

2.2.2 Silaksanti, D., & Sudarmo, S. T. (2020). Cost and environmental benefit in the use of shore connection in BJTI port

The research conducted by Silaksanti and Sudarmo discusses the positive influence of environmental and economic impacts on the use of shore connection facilities at BJTI Port, Surabaya. According to this research, the utilization of shore connection facilities at the port can show positive results, especially in environmental aspects with reduced carbon emissions and air pollution by sulfur oxides (SOx). In addition, the use of shore-connection will be more effective if used for vessels with old technology or vessels with low-efficiency generator engines. This can be caused by fuel that was very inefficient or wasteful will be cut. Shore-connection is a facility that is also proven to save vessel fuel use so that vessel companies can save fuel costs. In addition, the study conducted by Silaksanti and Sudarmo also highlighted that the reduction in gas emissions from the use of shore-connection facilities would be much more significant if the port's power source came from renewable energy power plants. According to this research, the port can also analyze the potential of renewable energy utilized. This will have a positive impact because the port will be independent in providing energy and no longer rely on the local electricity grid relying on fossil fuels.

2.2.3 Harahap, P. (2020). Pengaruh temperatur permukaan panel surya terhadap daya yang dihasilkan dari berbagai jenis sel surya

The research conducted by Harahap discusses the effect of the surface temperature of solar panels on the power they produce. According to this research, solar panels can work optimally if the intensity of lux that hits the surface of solar panels is getting bigger. In addition, this research also shows the power generated by solar panels will be even greater if the surface temperature is low. According to the study, both of these factors significantly affect the effectiveness and efficiency of photovoltaic cells and vice versa.

2.3 Basic Theory

2.3.1 Tanjung Emas Port of Semarang

Tanjung Emas Port is a port located in Semarang, the center of government of Central Java province. The location of this port is quite strategic because it is only 15 minutes from the city center to reach this place. Tanjung Emas Port of Semarang is managed by PT. PELINDO III since 1985. Judging from its history, formerly this port is located in the Sam Po Kong Temple area, vessels enter through a river/canal that connects the Port with the city. In the past, this port was used by the Dutch as a trade center, especially the sugar export trade, because at that time, Central Java became the number 2 sugar producer in the world after Cuba

Fig. 1. Images of Tanjung Mas Port

Source: Google Earth

Currently, Tanjung Emas Port of Semarang to support its business has several facilities such as 5 Units of Vessel to Shore Crane Capacity of 35 tons, 19 Units of Rubber Tyred Gantry capacity of 35 tons, 2 Units of Luffing Crane Capacity of 20 tons, 3 Units of Reach Stacker Capacity of 45 Tons, 1 Unit of Top Loader Capacity of 36 Tons, 2 Units of Side Loader Capacity of 18 Tons, 1 Unit of Diesel Forklift Capacity 5 Tons, 1 Unit of Electric Forklift Capacity of 2.5 Tons, and 36 Units of Trailer Trucks

2.3.2 Shore Power Connection

Ashore power connection is a facility of the Port to provide electrical power from the mainland for vessel use. When loading and unloading the vessel, the goal is that the vessel does not need to start its engine to supply electricity for the vessel's needs simply by using the shore power connection facility. It is commonly used in some modes of transportation such as trucks that are usually used for camping using facilities like this by using electricity from camp sites and planes connected to the power grid at the airport.

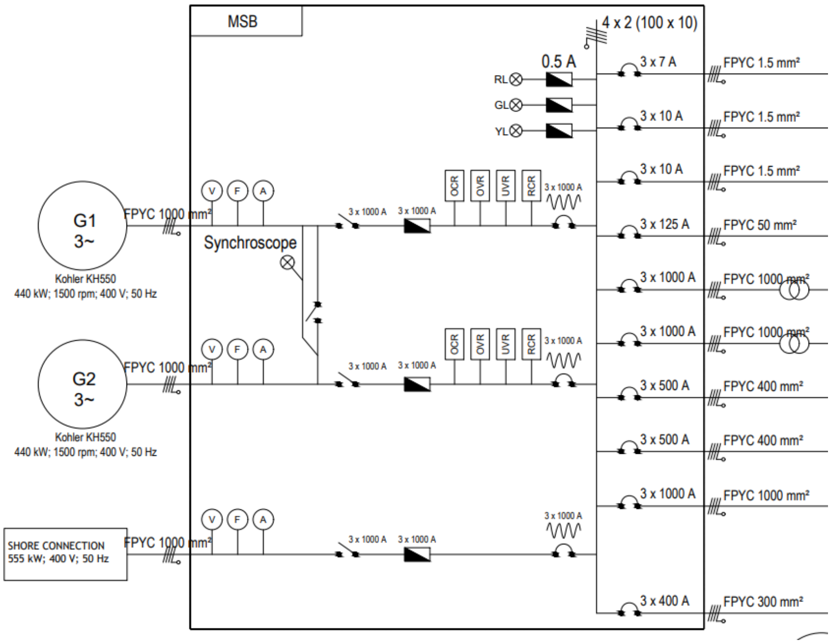


Fig. 1. 1 The Vessel's Shore Connection Diagram

The power source of shore power connection facilities is usually supplied by electricity service providers such as PLN or other energy sources such as new energy sources such as wind turbines or solar cells. The shore connection can save fuel consumption that is usually used to supply the vessel's electrical power when docked. In addition, the shore power connection facility can also reduce pollution caused by the combustion process of engines on vessels. As for using clean energy sources as shore power connection suppliers, it can be ascertained that gas emissions can reduce the loading and unloading process on vessels. We are currently paying more attention to the issue of climate change. Shore connection in the Tanjung Emas Port area of Semarang has been available with a 1-megawatt electric power (Doso Agung, Pelindo III principal director). This shore connection is available at the dwimatama terminal, explicitly operated to serve PT Pupuk Indonesia Logistik.

2.3.3 Vessel Power Requirements

The power needs of each vessel are different, following the vessel's dimensions and what facilities the vessel has. Therefore, this need must be met by the power supply of the Shore Connection. Give me is the power requirement of different types of vessels sailing in Europe

Table 1. 1 Power Requirements of Different Types of Vessels Sailing In Europe

Vessel Type	Average	Peak
Tanker	1400 kW	2700 kW
Cruise Vessel (<200 m)	4100 kW	7300 kW
Cruise Vessel (>200 m)	7500 kW	1100 kW
Ro-Ro	1500 kW	2000 kW
Container vessels (< 140 m)	170 kW	1000 kW
Container vessels (> 140 m)	1200 kW	8000 kW

Adapted: Patrik Ericsson & Ismir Fazlagic, 2008

2.3.4 Photovoltaic System

The photovoltaic system is an electrical power generation system that uses energy sources from the sun. This photovoltaic system combines several solar panels coupled with an inverter to create ac electric current because what is produced by photovoltaic cells is DC electric current. This electrical system can be used as a producer of clean electricity sources. This system also varies depending on the area of the system.

Photovoltaic (PV) systems consist of solar panels combined with inverters and other electrical and mechanical hardware that use energy from the sun to generate electricity. PV systems can vary significantly from small roofs or portable systems to large utility-scale generating plants.

Solar panel components

Solar panels are made of semiconductors. This material can make this cell have the ability to capture photons from sunlight and convert energy into electricity with the photovoltaic effect. Usually, dark-colored solar panels are intended to overcome the impact of reflection so that the results obtained are more efficient.

Solar panels can only generate electrical voltage when the solar cells get enough light. When this cell receives light, it can cause a 0.5 to 1 volt DC electrical voltage. This large voltage to make a power plant will be inadequate; therefore, some cells are arranged together in series to make a large enough voltage. Generally, one arrangement of solar modules contains 28 to 36 solar cells that can get a DC voltage of 12 Volts. In its use, this module is arranged in series or parallel to enlarge the voltage and current of its output

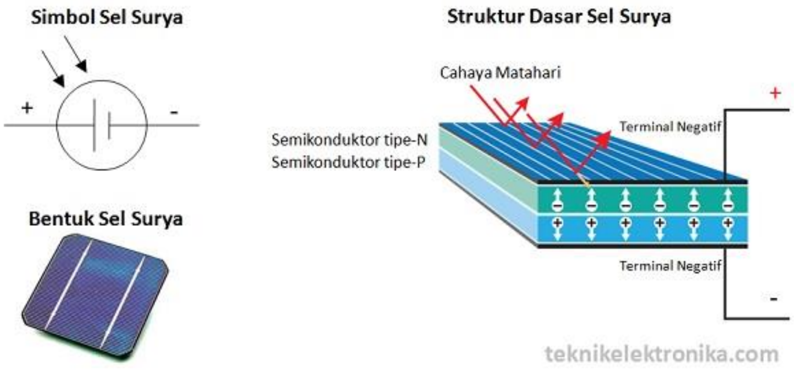


Fig. 1. 2 Solar Cell Base Structure

Source: https://teknikelektronika.com/

Solar Panel Parts

1. Substrate

The substrate is the material used in solar panels. This material is a material that supports all components of solar panels. The substrate material must have good electrical conductivity as it will also serve as a positive terminal contact of solar panels. Generally, the material used is metal or metal, such as aluminum or molybdenum. For dye-sensitized solar panels (DSSC) and organic solar panels, these substrates also serve as places of light entry.

2. Semiconductor materials

A semiconductor material is the core part of solar panels with a thin layer. The function of this semiconductor material is to absorb light from sunlight. The semiconductor part consists of a junction or combination of two semiconductor materials, namely p-type semiconductors and p-types, forming p-n connections. In addition to a substrate as positive contact, on the surface of semiconductor materials are usually overlaid transparent metal material as negative contact.

3. Anti-reflective coating

An anti-reflection material is a thin layer of material with a large optical refractive index between the semiconductor and the air that causes the light to be deflected towards the semiconductor, thus minimizing the reflected light. The function of this anti-reflective coating is to optimize the light absorbed by the semiconductor.

4. Encapsulation

Encapsulation is the part that serves to protect the solar module from rain or dirt.

How Photovoltaic Systems Work

The way this system works is that it starts with solar cells. The light obtained from sunlight containing photons falls on the solar cell in solar cells. Once the photon falls on the solar panels, it will create an electric current in the presence of a photovoltaic effect. Each solar panel can only produce a small amount of energy so we need several panels to have more energy. In using solar cells to produce electrical energy, the electricity generated is DC electricity. Therefore, for this electricity to be used for various needs, inverters are needed to convert DC to AC, where AC electricity is electricity that is commonly used in multiple aspects or included in the available electricity transmission system

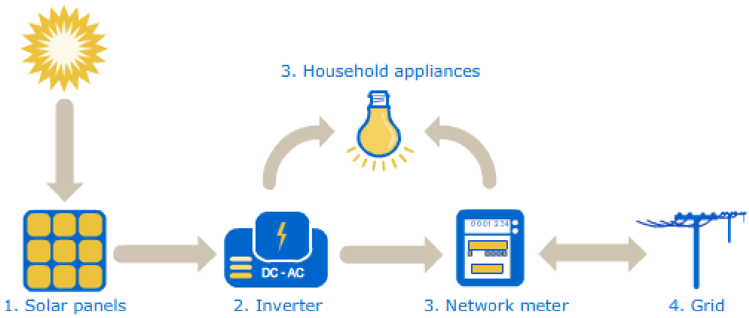


Fig. 1. 3 How Photovoltaic Systems Work

Source: https://factly.in/

Solar cells use sunlight consisting of very small particles called photons. When exposed to sunlight, photons that are particles of sunlight hit the semiconductor atoms of silicon solar cells, giving rise to energy large enough to separate electrons from their atomic structure. These separate, negatively charged electrons (-) will freely move in the conduction band region of the semiconductor material. The atom that loses the electron will be void in its structure, and the void is called a "hole" with a Positive charge (+).

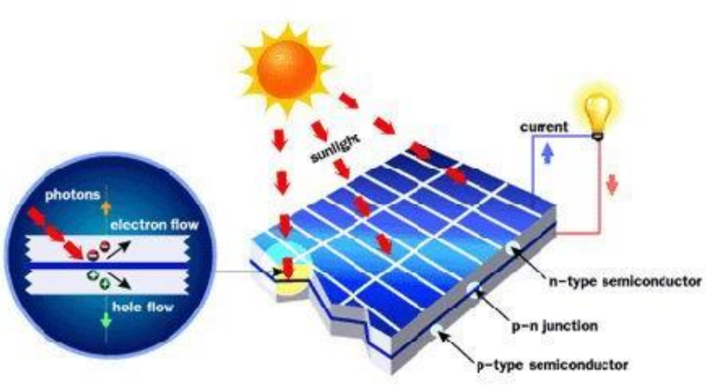


Fig. 1. 4 How Solar Cells Work

Source: teknologisurya.wordpress.com

Semiconductor regions with free electrons are negative and act as electron donors, and these semiconductor regions are called N-type semiconductors. While the semiconductor region with a hole is positive and acts as an electron acceptor called a P-type semiconductor.

At the intersection of the Positive and Negative (PN Junction) regions, it will give energy that encourages electrons and holes to move in opposite directions. The electron will move away from the Negative part while the hole will move away from the Positive region. When given a load in the form of lights and other electrical devices at this Positive and Negative Junction (PN Junction), it will cause an electric current.

2.3.5 Potential sources of electrical energy from photovoltaic cells in Semarang

Based on data collected from BMKG, the long of sunlight irradiation in the city of Semarang averaged at six hours of irradiation per day. This irradiation data can be interpreted as meeting the practical requirements for the place to be used as a producer of electricity from the sun. The ideal irradiation period that can produce electricity on solar panels is four to five hours per day. This is considered potent enough to be utilized potential sources of electrical energy from photovoltaic cells in this area. Photovoltaic cells are power generation systems that use energy sources from the sun as their energy source.

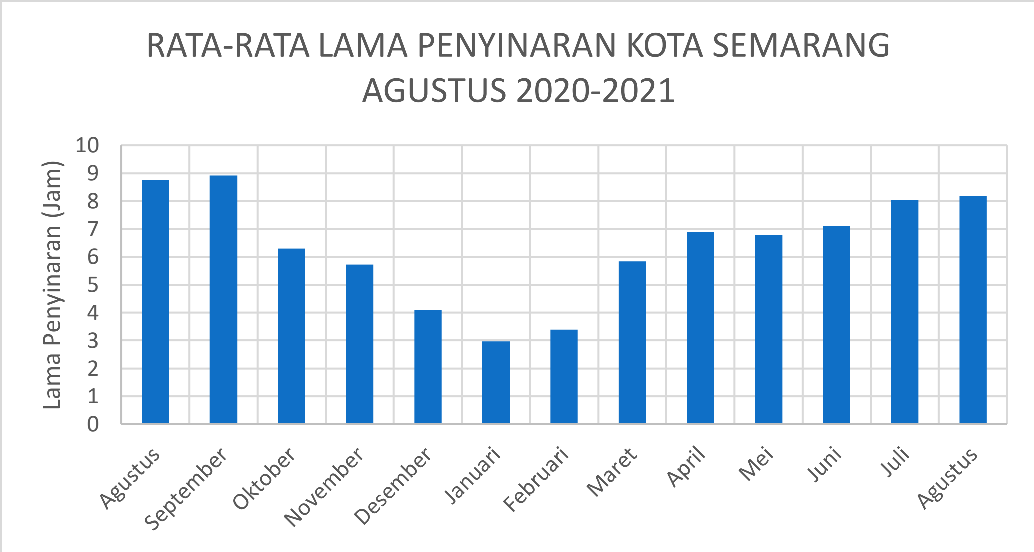


Fig. 1. 5 Trend Semarang's sun shines last year

Source: BMKG, 2021

From the table above, in January and February experienced a long decline in irradiation. This is because there is a fairly intense rainy season in the city area of Semarang. This makes the sky area of Semarang city covered by clouds. This cloud can reduce the length of irradiation in the city of Semarang. This results in a decrease in the efficiency of work in photovoltaic cells. When viewed from the length of irradiation, the reduction in efficiency when it rains can reach more than 30%. In the dry season, the average length of irradiation in Semarang is quite promising. Even on some days the sun can reach 10 hours of irradiation in the city of Semarang. This will have a good impact considering that a time like this can increase the oversupply of energy that we can use to be accommodated in the battery to be stored and later used to supply when there is a shortage of power supply.

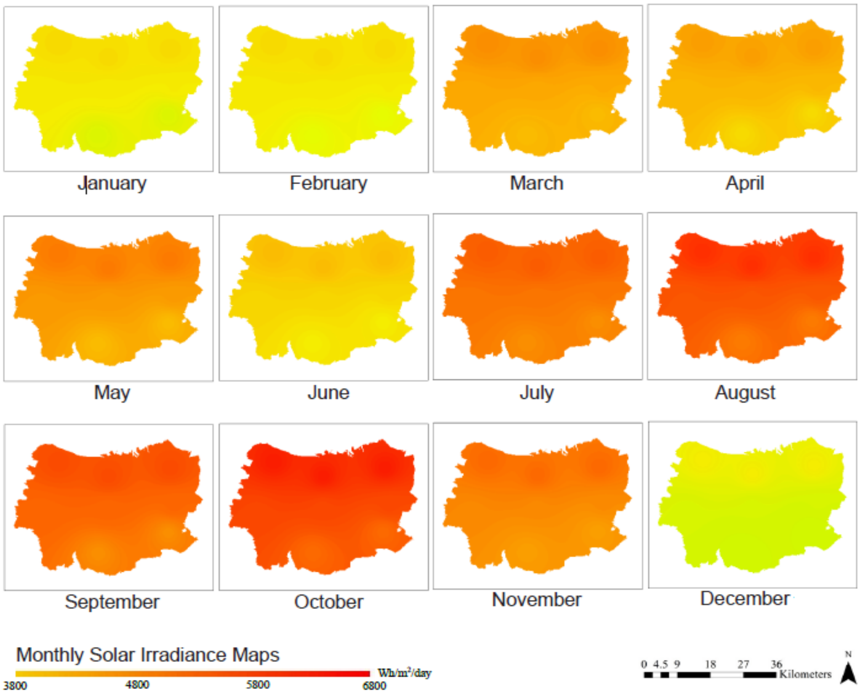


Fig. 1. 6 Monthly Solar Irradiance Map

Source: Djoko Adi Widodo, Purwanto Purwanto, Hermawan Hermawan 2021

Table 1. 2 Table of monthly solar irradiation potential

MONTH	kWH/M2/DAY
January	4.196
February	4.431
March	5.300
April	5.102
May	5.083
June	4.806
July	5.012
August	6.004
September	6.134
October	6.145
November	4.452
December	3.964

Source: Djoko Adi Widodo, Purwanto Purwanto, Hermawan Hermawan 2021

2.3.6 Calculation of Power Generated by Solar Panels

Below is a calculation formula of the value of electrical power capacity derived from solar cell panels:

$$PPV = t \times n \times P_{max}$$

Where:

PPV = Power generated by solar cells

t = Peak itensity of the sun

n = Number of solar panels

Pmax = Power capacity capable of generating one solar panel

2.3.7 Potential areas that can be utilized as solar panel fields

From the survey results of the area's location around Dwimatama pier, some places have the potential to be used as a place for solar panel fields. This area is an area that has not been utilized economically. The author chose the area where it is located if it is near the pier's location, which is planned to be supplied by solar panels. The author determined to set up the structure floating or on-shore from some locations.

1. The area of floating potential to be used as a solar field. This area is 107,582m^2 or 10.75ha.

Fig. 1. 7 Area floating solar panel

Source: Google Earth

2. The on-shore area utilized as a solar panel field is around the container area near the planned floating area. This area is still a stretch of grass that is not used

economically. So that if construction is held in this area does not cause excessive interest. The first planned area has an area of 102,358m^2 or 10.23ha. The planned second area has an area of 415,679m^2 or 41.5ha.

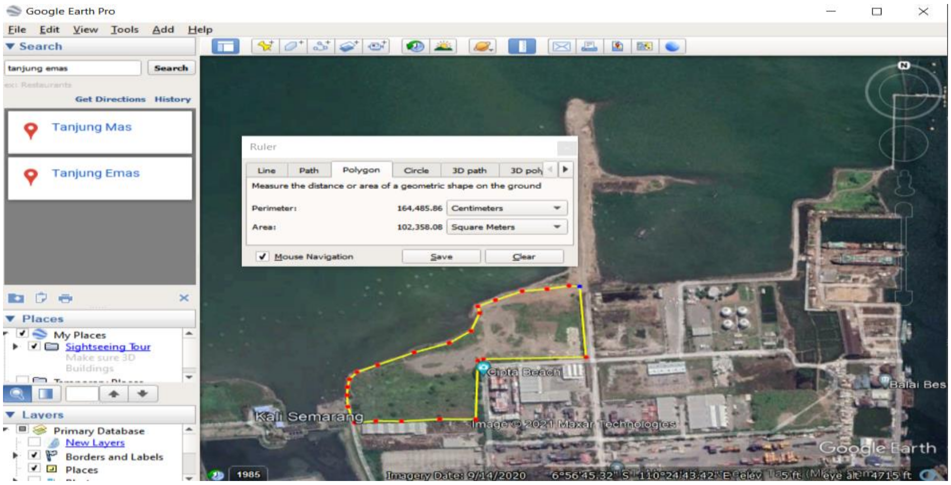


Fig. 1. 8 First Area on-shore solar panel

Source: Google Earth

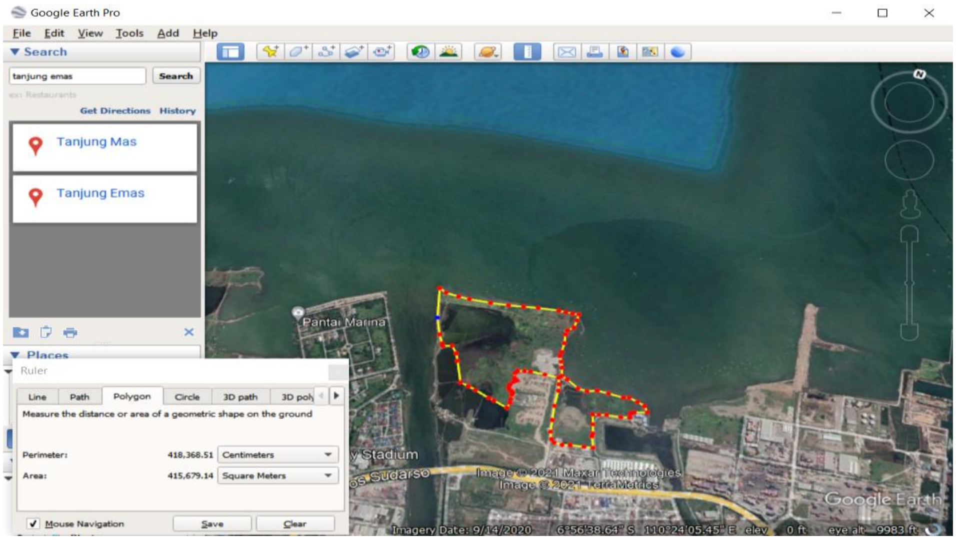


Fig. 1. 9 Second Area on-shore solar panel

Source: Google Earth

2.3.8 Electrical energy potential that can be generated from the scheme of the area

Based on existing areas and power potential generated from the data above. Calculations are calculated to calculate the total potential of electric energy generated in the region. In this way, we use existing potential data methods and existing PLTS data in Indonesia. PLTS data in Indonesia to find out the actual output power in PLTS in Indonesia

1. Based on Solargis Data

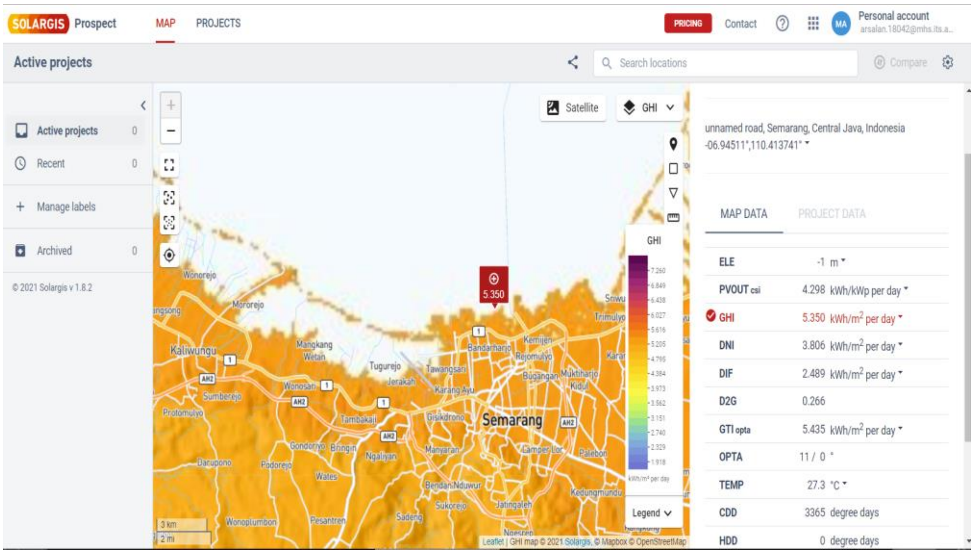


Fig. 1. 10 Electrical energy potential

Source: apps.solargis.com/prospect/

Table 1. 3 Calculation total output electrical energy

Potential Electric (kWH/M^2 per Day)	Floating area (kWH/M^2 per Day)	On-sore area #1 (kWH/M^2 per Day)	On-shore area #2 (kWH/M^2 per Day)
5.35	575,567.02	547,615.30	2,223,883.40

2. Based on solar power producers in Indonesia (PLTS Likupang)

Fig. 1. 11 Area PLTS Likupang

Source: Google Earth

Table 1. 4 Power output data of PLTS Likupang

Max	15	MW
Min	3	MW
Avrg	9	MW
Area (m^2)	202038.4	
MW/m^2	4.4546E-05	
MW/ha	0.445459873	

Table 1. 5 Power output data of planted area

Floating area MW/m^2 per Day	On-shore area #1 MW/m^2 per Day	On-shore area #2 MW/m^2 per Day
4.79	4.56	18.52

2.3.9 Electric Power Flow

Power flow studies reveal the performance and flow of power (real and reactive) for certain circumstances when the system is working at a steady state. Power flow study provides information on a load of transmission lines in the system. The voltage at each location for evaluation of power system performance regulation aims to determine the amount of power reactive power at various points on the power system that is in progress or expected for regular operation. The study of power flow is essential in planning and designing the expansion of electrical power systems and determining the best operation on existing networks. The power flow analysis is indispensable in the planning and development systems in the future. As consumers increase their electricity needs, there will always be changes in load, generating units, and transmission line changes (Ferry Jusmedy, 2007).

The power flow study here reveals the study of power flow on-shore power connection systems. In this power flow analysis, the things that need to be calculated are active power, reactive power in each bus, power loss, falling voltage, power flow on the system. Power studies have the difference between a one-phase load and a three-phase load, as in the following formula.

$$P = V \, x \, I \, x \cos \varphi$$

$$P = \sqrt{3} \, x \, V \, x \, I \, x \cos \varphi$$

Ideal and actual system conditions differ from electrical equipment, and the power provided by the source will not be the same once received by the load. Two factors, namely influence it:

- Impedance is the result of resistance, inductance, and capacitance. It can also be defined as a re resent of sinusoidal currents, which can also be caused by circuit connecting wires. Impedance is the cause of the loss of power (loss) in the circuit.
- The type of load, the kind of load on the circuit will also cause the inductive and capacitive load raised to affect the load factor so that the power provided by the power supply is different from the power received by the load.

2.3.10 Loss Standards, Drop Voltages, and Power Factors Based on IEC

Voltage fall is a problem caused by the loading of the electrical system. The authors used iec (International Electrotechnical Commission) benchmarks to determine eligibility in this study. IEC provides limitations on this. There are certain limits and rules for voltage reduction, and it is established that voltage reduction on electrical systems remains acceptable and within the tolerance range.

Power loss is also a sure thing in every electrical system. The authors used the iec (International Electrotechnical Commission) reference in this study. IEC regulates the amount of power loss defined in power efficiency from generation to load.

Table 1. 6 Drop Voltage Standard IEC

<table>
<tr><th>Type of installation</th><th>Lighting %</th><th>Other uses %</th></tr>
<tr><td>A - Low voltage installations supplied directly from a public low voltage distribution system</td><td>3</td><td>5</td></tr>
<tr><td>B - Low voltage installation supplied from private PV supply</td><td>6</td><td>8</td></tr>
<tr><td colspan="3">• As far as possible, it is recommended that voltage drops within the final circuits do not exceed those indicated in installation type A.
• When the main wiring systems of the installations are longer than 100 m, these voltage drops may be increased by 0,005 % per meter of wiring system beyond 100 m, without this supplement being greater than 0,5 %.
• Voltage drop is determined from the demand by the current-using equipment, applying diversity factors where applicable, or from the values of the design current of the circuits.</td></tr>
</table>

Adapted: IEC 60364

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

In the research methodology stage, the author explained about the research stage on "PLANNING AN ON-GRID SOLAR ENERGY GENERATION SYSTEM FOR THE DWIMATAMA PIER AT TANJUNG EMAS PORT" which began with the emergence of problems, review of related literature, data collection that supports. In this research, the author focuses on the development of shore connection facilities in the Port that the author will develop with the concept of combining renewable energy sources with energy sources installed in the facilities. Because of that, the author needs data to make the data collection step. The data collected include available shore connection capacity data, solar radiation data, and area data fitted with PV. After that, the author makes a model, simulates the flow of power, and then tests the existing rules. Whether the model that has been made is appropriate, the author makes a new model that the author has perfected and retested. After the model has been in accordance with existing requirements, the author conducts discussions and lays conclusions and suggestions about existing things based on the research results.

3.2 Research Flowchart

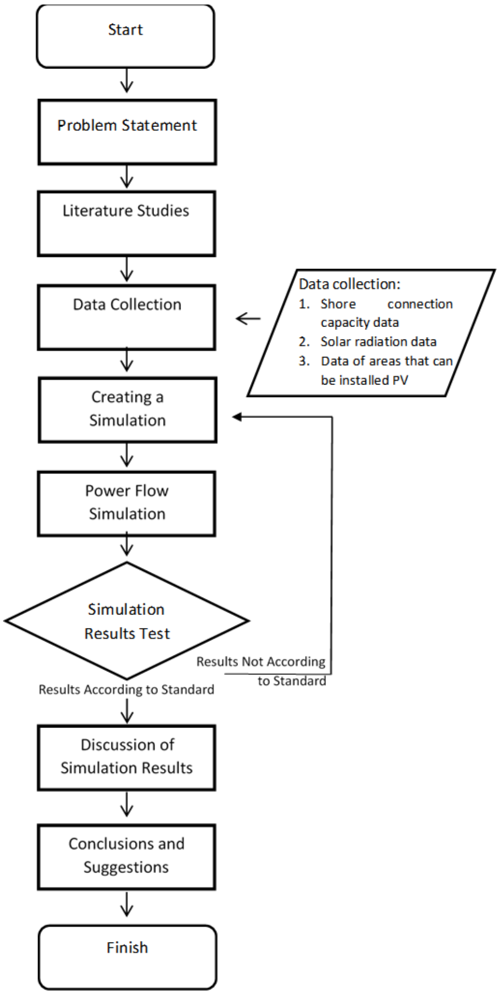


Fig. 2. 1 Research Methodology Flow Diagram

3.3 Problem Statement

Problem formulation is a problem that arises due to the occurrence of research. For this reason, the author conducted a study entitled " PLANNING AN ON-GRID SOLAR ENERGY GENERATION SYSTEM FOR THE DWIMATAMA PIER AT TANJUNG EMAS PORT." Therefore, there will be such problems. First, How does grid shore connection electrical system schematic design when using photovoltaic cells? Second, How does analytical power flow with photovoltaic in shore connection use system on grid?

3.4 Literature Studies

Literature studies is the process of collecting information and data related to research on related topics. The author takes literary sources from books, journals, final assignments, and articles in this study.

3.5 Data Collection

To support the green port concept, initial data and information is needed on related data to support the final task of utilizing photovoltaic cells used as shore connection resources. The authors need a variety of data as a support for this study, such as:

- Data shore connection owned by PT. Port of Indonesia III – Tanjung Emas Semarang branch and data wiring junction power and one-line diagram of afternoon connection
- Solar radiation data on Tanjung Emas Semarang area
- Optimal area data for solar panels to be fitted on Tanjung Emas Semarang area

3.6 Modeling

Modeling uses software by combining data that has been obtained before. After getting the data, the authors created a shore-connection system model using existing energy sources and renewable energy sources, using photovoltaic cells. After that, the author analyzed the power flow between existing shore-connection uses that use energy sources from grid and photovoltaic cell networks.

3.7 Simulation

In this process, simulations are carried out to compare existing conditions in the shore-connection system of the golden cape port with conditions that are expected to be operated using the newest energy, in this case, solar cells. As is well known the electricity that has been generated by solar cells is DC electricity so it needs to be changed to AC electricity which of course the electrical waves on the results of this change are not perfect.

3.8 Discussion Simulation Result

After the simulation process, the comparison process with the IEC and IEEE standards have made. If the simulated model does not have and meets the standards that have been determined, shrimp simulation is done by re-modeling with different variables.

3.9 Conclusion and Suggestions

This conclusion stage is carried out after the simulation data analysis results meet the relevant standards. This conclusion contains answers to answer the problem formulation and the purpose of this final task so that the author can provide advice related to things that have happened based on the results of the author's research.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this section, the author will discuss the study of power flow and voltage drop analysis on the electricity distribution system at the Dwimatama pier, Tanjung Emas Port, Semarang. Studying power and voltage drop analysis is accomplished in various ways. First, search data of the shore connection specifications that are the subject of this study. Second, research potential solar farm locations and its output. Third, search for information on solar cell system support tools. Fourth, using simulation software to create a single line diagram based on existing data. There are no modifications to the system's specifications or components. Fifth, conduct a power flow simulation to determine the active power, reactive power, and voltage drop across each bus and device in the system.

4.2 Shore Connection Specification

TUKS Pupuk Indonesia utilizes the shore connection at the Dwimatama pier in the Tanjung Emas Port area. As a result, all vessels docking at this pier are bulk carriers carrying fertilizer. On average, the vessels that call at this pier have two loading and unloading equipment types, including cranes and pumps. Both of these devices are extremely energy-intensive. As a result, a shore connection is used to eliminate the need for vessels to use an auxiliary engine to power these tools. The use of a shore connection can result in a 30-40% reduction in costs. The following are the specifications for the Dwimatama pier's shore connection. Specifications for shore connection at Dwimatama pier are as follows

Table 2. 1 Data of Dwimatama's Shore Connection

Voltage	400 V
Capacity	1000 KW
Frequency	50 Hz
Phase	3 Phase

Source: Pelindo Tanjung Emas

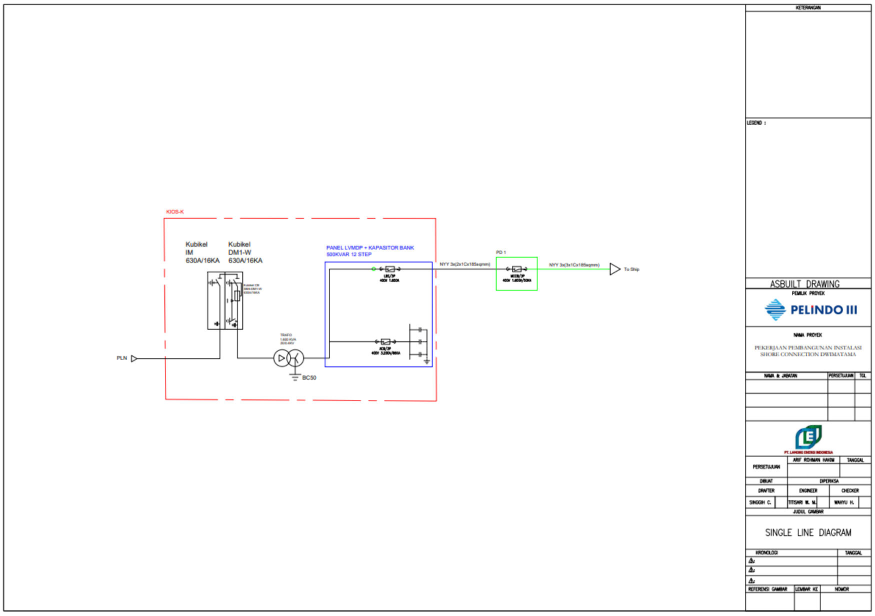


Fig. 3. 1 Single Line Diagram Shore Connection Dermaga Dwimatama

Source: Pelindo Tanjung Emas

Fig. 3. 2 MCB 3Fase for shore connection at Dwimatama Pier

Source: Private Document

Fig. 3. 3 Cubikel IM 630A/16KA & Cubikel DM1-W 630A/16KA

Source: Private Document

Fig. 3. 4 Capacitor bank 500kvar 12 step

Source: Private Document

4.3 Potential Solar Farm References

4.3.1 Data of area that planned for the placement of solar farm

Semarang is experiencing problems due to tidal flooding that has affected the city's coastal areas. This results in many areas that cannot be optimally utilized in the economic field. The existence of this phenomenon results in a large number of vacant spaces. The vacant area could install solar panels that will supply shore connection electricity. This leads the author to select the Cipta beach area due to its proximity to the Port area. So that the losses and installation costs are minimal

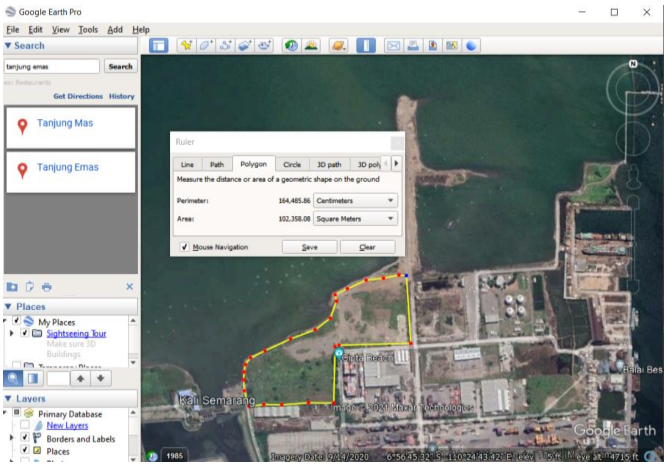


Fig. 3. 5 Planned area to be used as solar panel placement
Source: Google Earth

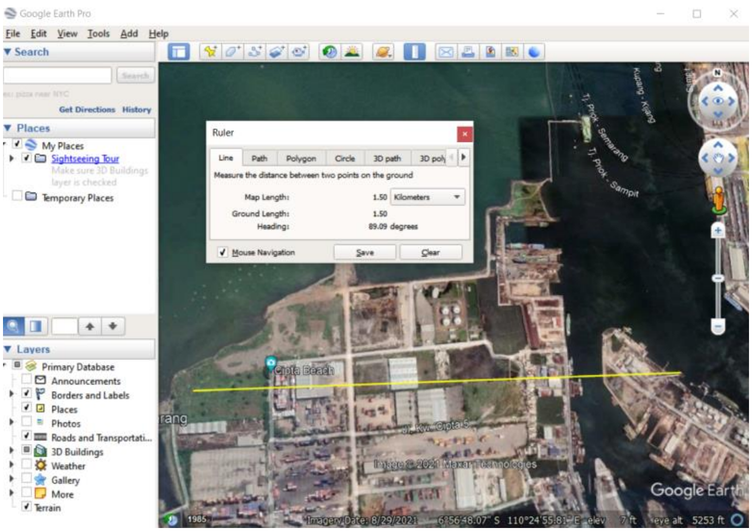


Fig. 3. 6 Planned area to be used as solar panel placement
Source: Google Earth

Table 2. 2 Area Used For Shore Connection

Area	102,358 m2 / 10.2 Ha
Distance	1.5 Km

Source: Google Earth

4.3.2 The potential energy that can be generated in the specified area

The author determines the area used for solar panel placement using the Solaris application. Following that, the author defines the amount of energy generated in the area being used. Considering installation and another factor, the author establishes a benchmark of 30% reduction in the area required for installation and another factor. Thus, an example utilizes only 70% of the available space out of the total area.

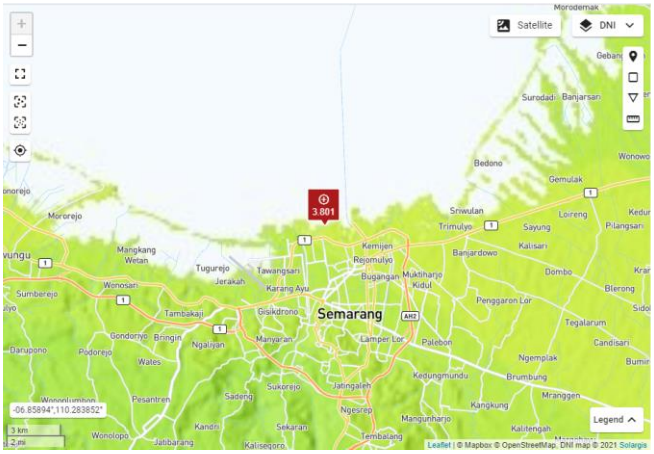


Fig. 3. 7 Solargis application display
Source: solargis.com

Table 2. 3 Data Total Solar potential

Type	Solargis data	Potential	
DNI	3.806	272702.18	kWh/m2 per day
DIF	2.489	178338.34	kWh/m2 per day

Source: solargis.com

These data indicate that the area can generate ±3.8 kWh/m2 of energy per day through DNI irradiation. Additionally, the data indicates that the energy generated by DIF irradiation is ±2.4 kWh/m2. The authors combine this data with the area that will be used. The total area harvested is approximately 10.2 hectares. Considering installation, maintenance, and other costs, the author determines that 30% of the area will be used for installation, maintenance, and additional charges. As a result, the maximum area used is

7 hectares or 71600 m2. The potential energy for DNI irradiation is 3.8 kWh/m2, multiplied by a surface area of 71600m2. Thus, the energy produced in a single day is approximately 272,080 kWh, producing 11,336 kW of power.

4.3.3 Projection to Indonesia Solar Power Plant

The author uses average data for solar power plants in Indonesia to compare the area and power generated in real terms on the Indonesian territory. The author searches for solar power plant data in Indonesia to project actual data generated by solar power plant in the Tanjung Emas Port area. The solar power plant Likupang on the island of Sulawesi is used as a comparison site. According to the cabinet secretariat, this PLTS can produce a maximum of 15MW/day.

Fig. 3. 8 Solar Power Plat Likupang seen from above

Source: setkab.go.id

Fig. 3. 9 Solar Power Plant Likupang seen from Satellite

Source: Google Earth

Table 2. 4 Likupang's Solar Power Plant Data

Maximum output	15	Mw/day
Minimum output	3	Mw/day
Mean	9	Mw/day
Luas area	20.2	Ha
Max mw/day	0.7	Mw/day/ha
Min mw/day	0.14	Mw/day/ha
Mean mw/day	0.4	Mw/day/ha

Source: Author

As shown in the table, solar power plant Likupang has a maximum output power of 15 Megawatts and requires approximately 20 hectares of photovoltaic area. This forces the authors to make a rough comparison in which one hectare can generate 0.7 Megawatts in a single day. Additionally, in the worst-case scenario, such as inclement weather, the area and power generated will be reduced to 1 hectare, which will generate 0.14 Megawatts in a single day.

The author attempts to create an artificial model using the planned area for solar panels based on Indonesia's solar power plant data and the area used. The creator of this model or projection did so by analyzing data from the established photovoltaic power plant. Developing this model aims to ascertain the approximate amount of electricity the area can generate.

Table 2. 5 Potential Power Data based on established solar power plant projections

Max MW/Day	5.32	MW/day
Min MW/Day	1	MW/day
Mean MW/DAY	3.19	MW/day

Source: Author

The table above is the result of calculations compared to the established solar power plant Likupang in Indonesia. Based on this data, it is estimated that the solar power plant that will be constructed will produce at least 1 Megawatt of electricity per day. Additionally, if the weather is clear and there are no other disturbances, the solar power plant can produce a maximum of 5.32 Megawatts of electricity in a single day.

4.4 Vessel Load Average to be Supplied

The Dwimatama pier is a special pier for urea. As a result, the vessels that dock at this dock share a common interest: fertilizer transportation. The vessels that lean against the pier are typically comparable in size and require comparable power consumption. The vessels leaning against the dock are also the vessels whose sizes have been determined, as this is the TUKS dock. The following table contains information about vessels and their power consumption.

Table 2. 6 Data on Vessel Power Consumption to be Supplied

Vessel Name	Average Load (kW)
Ibrahim Zahier	156.9
Pusri Indonesia 1	174
Soemantri Brojonegoro	121.3
Abusamah	147.3
Julianto Md	135.5

Source: Pelindo Tanjung Emas

As shown in Table 2.6, the Pusri Indonesia 1 vessel consumes the most energy. The vessel consumes an average of 174 kilowatts of electricity. The vessel with the lowest electrical power consumption is the Ibrahim Zahier, with an average power of 56kW. The vessels that will be supplied with the shore connection are identical; this is because the vessels operate out of the TUKS dock, which means that all vessels that dock there are similar.

4.5 One Megawatt Solar Power Plant Installation

4.5.1 Slope and Azimuth Angle

Solar cells are a technology that converts solar energy to electrical energy. The amount of energy obtained is highly dependent on the location and method of installation. Thus, by installing solar panels with the proper slope and azimuth angle, the intensity of solar radiation received by solar panels can be maximized. To determine the proper inclination angle for this solar panel installation, the author consults a journal that discusses the optimal tilt angle for solar panels in Semarang.

Table 2. 7 The angle of inclination of solar panels that can receive the highest average solar radiation each month

Month	Angle	Sun Radiance ($MJ/m^2/day$)
January	1	11.017
February	1	12.933
March	2	12.773
April	16	13.477
May	27	13.676
June	34	15.639
July	33	17.855
August	23	16.378
September	8	15.511
October	1	16.274
November	1	14.903
December	1	10.846

Adapted: Pangestuningtyas D.L, 2013

According to the journal data, each season has a unique optimal slope angle. This difference is most noticeable between October and March when the average inclination angle is 1°, and the average daily solar radiation is 13,128 $MJ/m^2/day$. Additionally, the average slope angle is 24° during the dry season, which runs from April to September. A panel tilted 24 degrees can receive a maximum average solar radiation of 15,284 MJ/m2/day during the dry season. Solar panels can receive significantly more radiation during the dry season than during the rainy season. This is because the dry season is sunnier than the rainy season.

In addition to the inclination angle, the solar panels receive solar radiation at an azimuth angle. The azimuth angle is created by orienting the solar panels clockwise regarding the north; it ranges from 0° to 360°. Additionally, the author utilizes a journal discussing the azimuth angle for the azimuth angle. The journal researched the azimuth angle using a solar panel tilt angle of 9 degrees; this value was determined using the average results in table 2.7 above. The average solar radiation with variations in azimuth angle produces the following results.

Table 2. 8 Average solar radiation results with variations in the azimuth angle of the photovoltaic module per month with a slope of 9° (MJ/m2/day)

Month	90°	120°	150°	180°	210°	240°	270°
January	11	10.8	10.8	10.7	10.8	10.9	11
February	12.9	12.8	12.7	12.7	12.7	12.8	12.9
March	12.7	12.7	12.7	12.7	12.7	12.7	12.7
April	13	13.2	13.3	13.4	13.4	13.2	13.1
May	12.6	12.9	13.2	13.3	13.2	13	12.7
June	13.6	14.1	14.5	14.7	14.6	14.2	13.8
July	15.6	16.1	16.6	16.8	16.6	16.3	15.7
August	15.4	15.7	16	16.1	16	15.8	15.5
September	15.3	15.4	15.5	15.5	15.5	15.4	15.3
October	16.2	16.1	16	16	16	16.1	16.2
November	14.8	14.6	14.5	14.4	14.5	14.6	14.8
December	10.8	10.7	10.6	10.5	10.6	10.7	10.8

Adapted: Pangestuningtyas D.L, 2013

According to table 2.8, the optimal azimuth angle for the Semarang metropolitan area is 180°. When the solar panels are installed at a 180° angle, the system receives an average of 13.9 MJ/m2/day of solar radiation, the highest value compared to the other values. The 180° angle refers to the orientation of the solar panels concerning the equator. This is consistent with Duffle - Beckmen's theory that the optimal azimuth angle for the southern hemisphere is 180°.

Solar panel installation has a significant impact on the results obtained by the panels. The slope angle and azimuth angle for solar panels are included in this installation. The optimal angle for installing fixed array solar panels is 180°, which means the panels should face north. Each month, the angle of the slope or the slope of the panel can vary. The optimal angle of panel installation during the rainy season is 1°. For the dry season, the optimal angle for panel installation is 24°. Because the author is designing a fixed and permanent power plant, the most optimal tilt angle for long-term use is 9° for the Semarang city area.

4.5.2 Solar Panel

The authors determine the solar panels to be installed to design them. The author chooses Suntech solar panels for this purpose. This choice was made due to the panel's long history of use in this industry. Additionally, this panel is reasonably priced and quite reliable, as it comes with a 25-year warranty. Authors use Suntech STP410 for this design

Fig. 3. 10 Suntech STP410 Solar Panel

Table 2. 9 Specifications of Suntech STP280 Solar Panels

STC	
VMP	31.5 V
IMP	12.98 A
VOC	37.45 V
ISC	13.88 A
Pmax	410 W
Module Eff	20 %
Operating Temp	-40°C + 85°C
NMOT	
Maximum Power NMOT	309.6 W
Optimum Operating Voltage	29.2 V
Optimum Operating Current	10.6 A
VOC	35.2 V
ISC	11.16 A

Adapted: suntech-power.com

4.5.3 Inverter

Solar panels generate DC electricity. As a result, an inverter is required to use solar panels as a power source. This inverter will convert the DC voltage from the solar panels into AC voltage. For designing a solar power plant connected to the grid, the author chose an ABB PVS800-MWS inverter. Because this inverter has a capacity of about a megawatt, it was chosen as the best option.

Fig. 3. 11 ABB PVS800 Inverter

Source: enfsolar.com

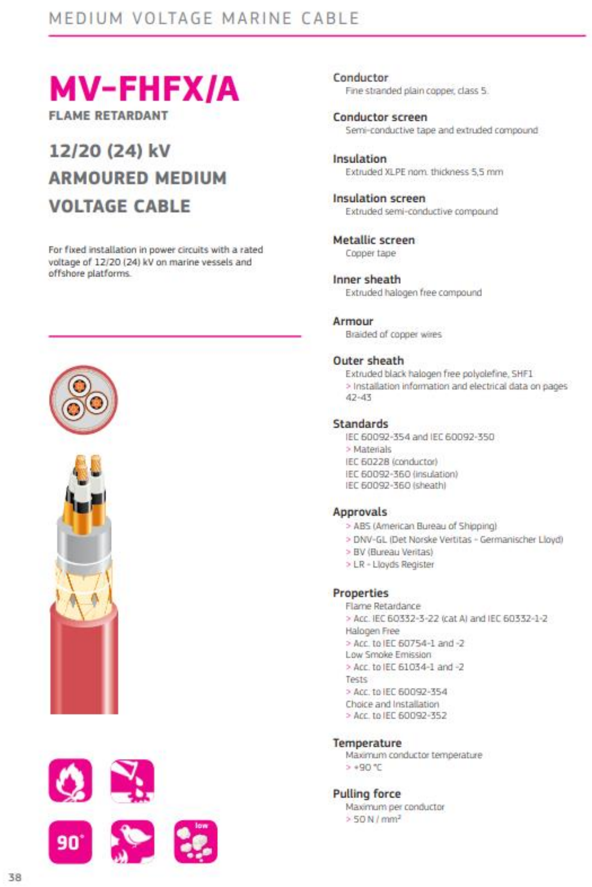
Table 2. 10 ABB PVS800 Inverter Specification

Input DC	
Maximum input power (PPV, max)	2 × 600 kW
DC voltage range, mpp (UDC, mpp)	450 to 825 V
Maximum DC voltage (UDC, max)	1100 V
Maximum DC current (IDC, max)	2 x 1145 A
Voltage ripple, PV voltage (UPV)	< 3%
Number of protected DC inputs	2 × 8 (+/-)
Number of mppt trackers	2
Output AC	
Nominal AC output power (PAC, N)	1000 kW
Nominal AC current (IAC, N)	28.9 A
Nominal output voltage (UAC,N)	20 kV
Output frequency	50/60 Hz
Harmonic distortion	< 3%

Source: enfsolar.com

4.5.4 Cable and Transmission System

Three different cable specifications are utilized in this proposed design. To begin, there is the direct current cable that connects the solar panel to the inverter. Second, a marine-grade ac cable connects the inverter to the station located near the Dwimatama Jetty. Thirdly, there is the submarine cable, which is used to lay cables at sea. This is necessary due to the cable's design, which involves pulling it through the sea to reduce the distance and minimize power and voltage drops.


MEDIUM VOLTAGE MARINE CABLE

MV-FHFX/A
FLAME RETARDANT
12/20 (24) kV
ARMOURED MEDIUM
VOLTAGE CABLE

For fixed installation in power circuits with a rated voltage of 12/20 (24) kV on marine vessels and offshore platforms.

Conductor
Fine stranded plain copper, class 5.

Conductor screen
Semi-conductive tape and extruded compound

Insulation
Extruded XLPE nom. thickness 5,5 mm

Insulation screen
Extruded semi-conductive compound

Metallic screen
Copper tape

Inner sheath
Extruded halogen free compound

Armour
Braided of copper wires

Outer sheath
Extruded black halogen free polyolefine, SHF1
> Installation information and electrical data on pages 42-43

Standards
IEC 60092-354 and IEC 60092-350
> Materials
IEC 60228 (conductor)
IEC 60092-360 (insulation)
IEC 60092-360 (sheath)

Approvals
> ABS (American Bureau of Shipping)
> DNV-GL (Det Norske Veritas - Germanischer Lloyd)
> BV (Bureau Veritas)
> LR - Lloyds Register

Properties
Flame Retardance
> Acc. IEC 60332-3-22 (cat A) and IEC 60332-1-2
Halogen Free
> Acc. to IEC 60754-1 and -2
Low Smoke Emission
> Acc. to IEC 61034-1 and -2
Tests
> Acc. to IEC 60092-354
Choice and Installation
> Acc. to IEC 60092-352

Temperature
Maximum conductor temperature
> +90 °C

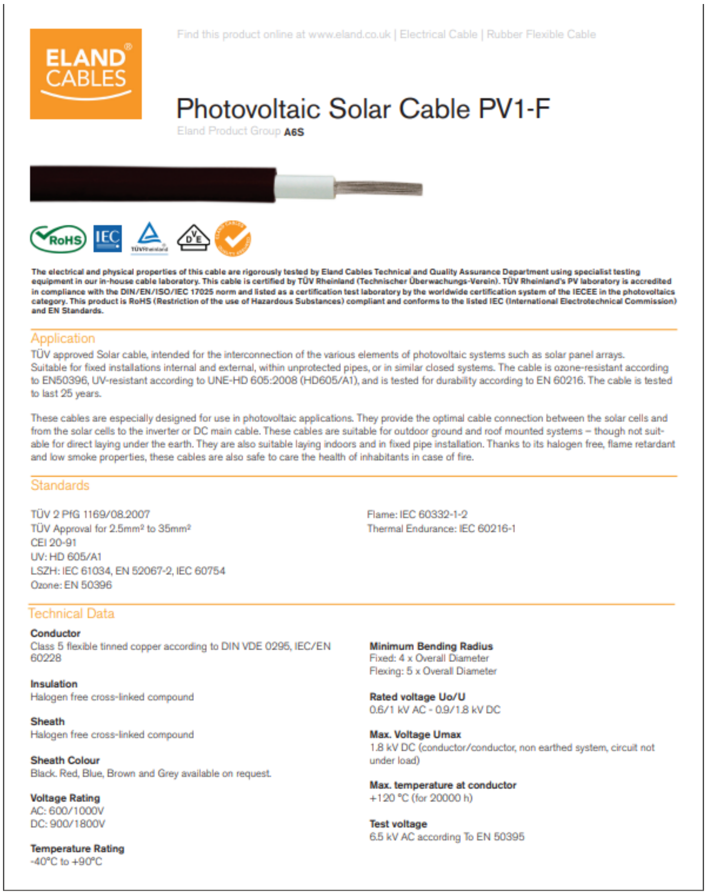
Pulling force
Maximum per conductor
> 50 N / mm²

90°

38

Fig. 3. 12 Marine Grade Cable

Source: prysmiangroup.com



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Photovoltaic Solar Cable PV1-F

Eland Product Group **A6S**

The electrical and physical properties of this cable are rigorously tested by Eland Cables Technical and Quality Assurance Department using specialist testing equipment in our in-house cable laboratory. This cable is certified by TÜV Rheinland (Technischer Überwachungs-Verein). TÜV Rheinland's PV laboratory is accredited in compliance with the DIN/EN/ISO/IEC 17025 norm and listed as a certification test laboratory by the worldwide certification system of the IECEE in the photovoltaics category. This product is RoHS (Restriction of the use of Hazardous Substances) compliant and conforms to the listed IEC (International Electrotechnical Commission) and EN Standards.

Application

TÜV approved Solar cable, intended for the interconnection of the various elements of photovoltaic systems such as solar panel arrays. Suitable for fixed installations internal and external, within unprotected pipes, or in similar closed systems. The cable is ozone-resistant according to EN50396, UV-resistant according to UNE-HD 605:2008 (HD605/A1), and is tested for durability according to EN 60216. The cable is tested to last 25 years.

These cables are especially designed for use in photovoltaic applications. They provide the optimal cable connection between the solar cells and from the solar cells to the inverter or DC main cable. These cables are suitable for outdoor ground and roof mounted systems – though not suitable for direct laying under the earth. They are also suitable laying indoors and in fixed pipe installation. Thanks to its halogen free, flame retardant and low smoke properties, these cables are also safe to care the health of inhabitants in case of fire.

Standards

TÜV 2 PfG 1169/08.2007
TÜV Approval for 2.5mm² to 35mm²
CEI 20-91
UV: HD 605/A1
LSZH: IEC 61034, EN 52067-2, IEC 60754
Ozone: EN 50396

Flame: IEC 60332-1-2
Thermal Endurance: IEC 60216-1

Technical Data

Conductor
Class 5 flexible tinned copper according to DIN VDE 0295, IEC/EN 60228

Insulation
Halogen free cross-linked compound

Sheath
Halogen free cross-linked compound

Sheath Colour
Black. Red, Blue, Brown and Grey available on request.

Voltage Rating
AC: 600/1000V
DC: 900/1800V

Temperature Rating
-40°C to +90°C

Minimum Bending Radius
Fixed: 4 x Overall Diameter
Flexing: 5 x Overall Diameter

Rated voltage Uo/U
0.6/1 kV AC - 0.9/1.8 kV DC

Max. Voltage Umax
1.8 kV DC (conductor/conductor, non earthed system, circuit not under load)

Max. temperature at conductor
+120 °C (for 20000 h)

Test voltage
6.5 kV AC according To EN 50395

Fig. 3. 13 DC Cable Proposed

Source: bhcdistributors.co.uk

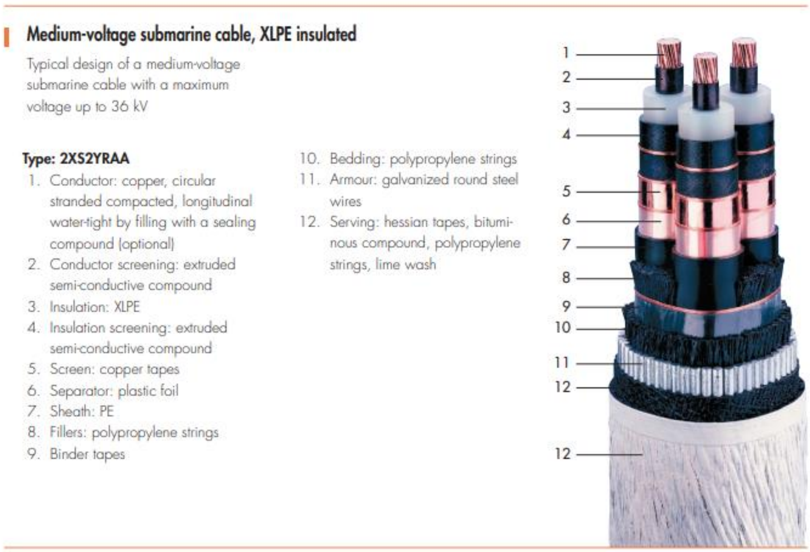

Fig. 3. 14 Under Sea Cable Proposed

Source: voltimum.de

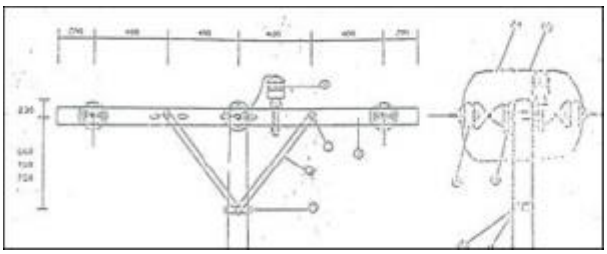

Fig. 3. 15 Air Transmission support Structure

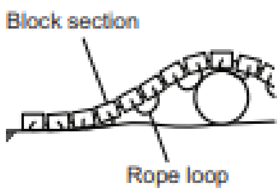

Fig. 3. 16 Handling construction under water cable

The cable used is a 4 x 2 x 150m2 DC cable. This cable is chosen because it can handle the required voltage and current. The other alternating current cable is a 3 X 35mm2 FPYC cable. This cable was selected because it can take the voltage and current that this system generates. Additionally, this cable is distributed via an air transmission system and under water transmission system. The air transmission system was chosen because it is less expensive than the underground transmission system, with a high capital cost. In addition, an underwater transmission system is also used in this design to connect transmissions that cross downstream of the river. In addition, the use of the transmission system is also due to minimizing power losses. If all use an air transmission system, the distribution distance will be very far, and much electrical power will be lost.

4.5.5 One-Line Diagram

The following diagram shows that on-grid solar power is expected to be installed at the dwimatama jetty. 21 series and 244 parallel arrays of 5124 solar panels make up this system. According to this real-world scenario, the Dwimatama Pier only has room for one vessel at any given time, so each load is simulated individually.

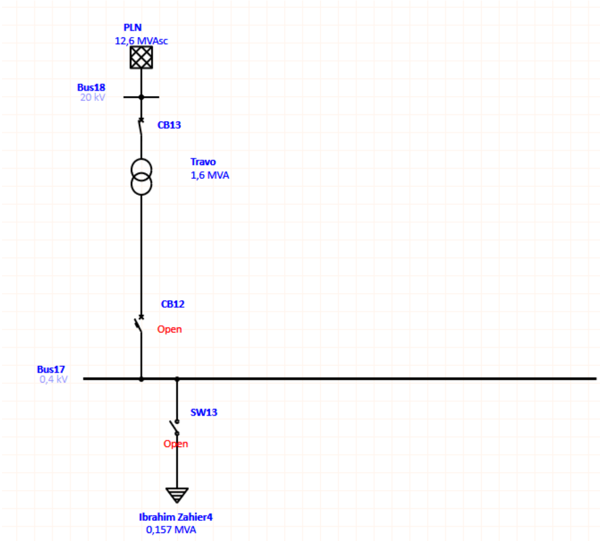

Fig. 3. 17 One Line Diagram Shore Connection Diagram Dwimatama Pier

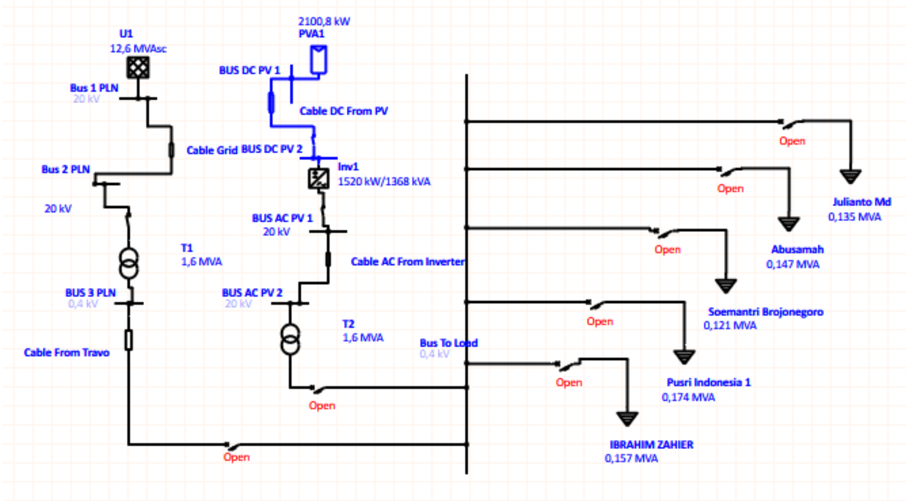

Fig. 3. 18 One Line Diagram Shore Connection Diagram Dwimatama Pier Planned

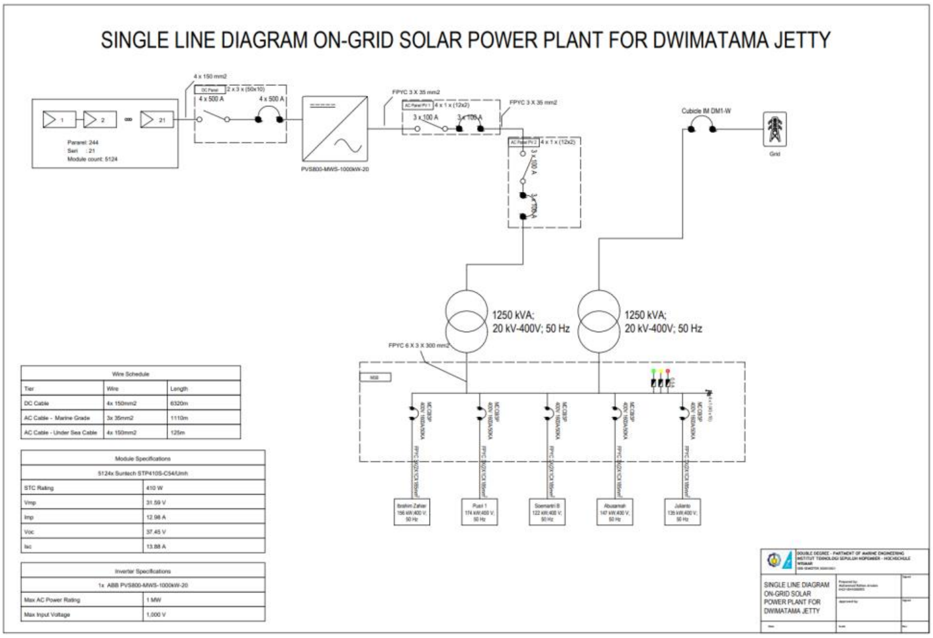

Fig. 3. 19 Single Line Diagram Proposed

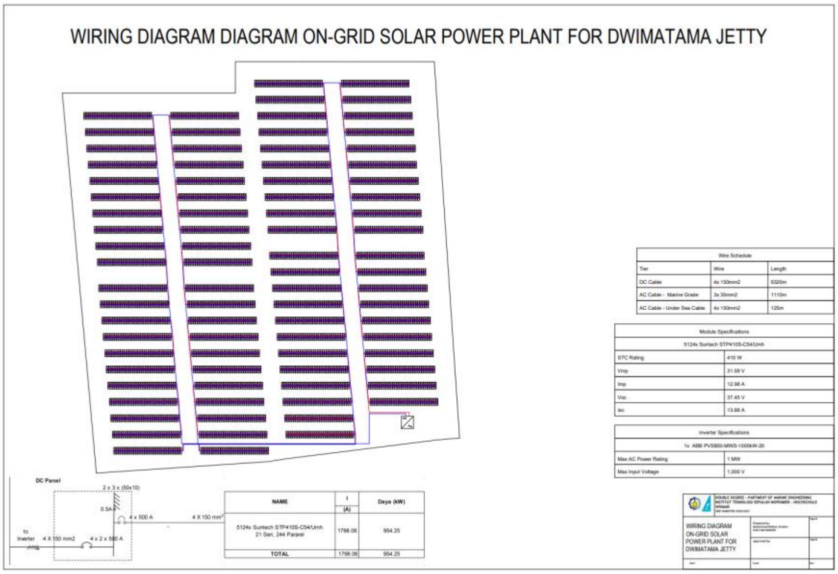

Fig. 3. 20 Wiring Diagram Proposed

4.5.6 Design Proposed

The proposed design entails the layout of the determined location and the construction of the solar panels. The solar farm was chosen for its location in the Semarang Cipta industrial area. Cipta industrial area was selected because it is close to the Dwimatama jetty, powered by solar energy, and connected to the grid via an on-grid system. Additionally, this area has a flat topology, making treatment before construction more effortless, and this area is also government-owned, which alleviates land acquisition constraints.

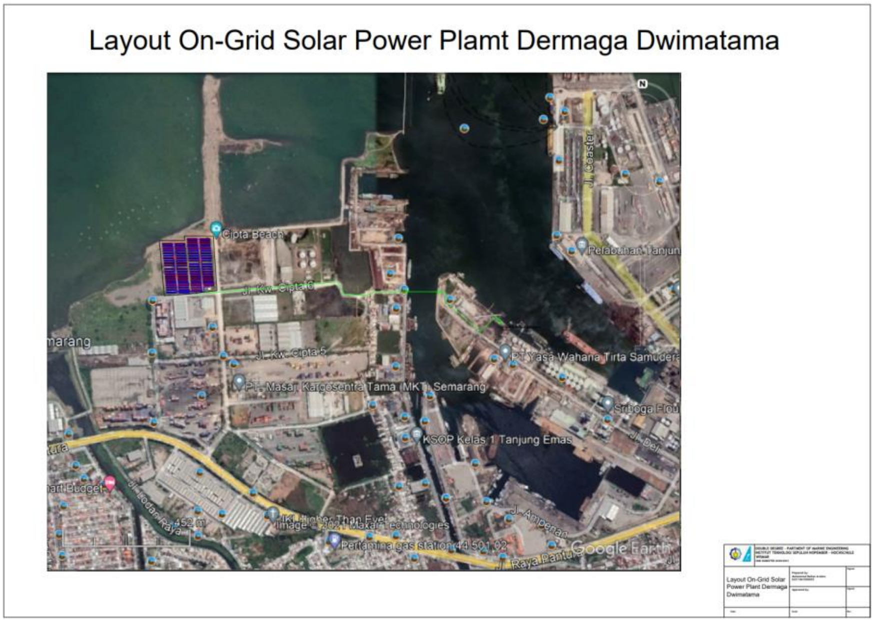

Fig. 3. 21 Proposed Solar Array Layout

The image below shows a three-dimensional layout of a solar array arrangement in the Cipta Industry Area. As indicated above, the dwimatama jetty at the Tanjong Emas Port, which serves as the TUKS for Pupuk Indonesia, is expected to be powered by an on-grid solar power plant. The distance between solar arrays is intended to be 5 meters. The designed distance of approximately 5 meters is intended to make maintenance on solar panels easier for technicians and to simplify actions in the event of a solar panel accident;. However, this is the least expected event, it must be carefully planned. The calculation indicates that 5124 panels were used in a series arrangement of 21 arrays and 244 panels in parallel. A total of 3,815 hectares is required to construct a solar farm based on this configuration (including solar arrays, inverters, and other supporting buildings). These calculations and designs may produce a maximum of 954kW of electricity with maximum irradiation of 470W/m2. The 470W/m2 irradiation value was obtained from the measurements by Arifin, Tamamy, and Amalia regarding the Solar Energy Potential in Semarang in 2018.

Fig. 3. 22 Proposed 3D Solar Array Layout

The solar panels are attached to the steel supports in the manner depicted in Figure 3.23, using clamps to prevent the panels from moving. The clamps are chosen following the Suntech product guide for solar panel construction. The choice of four clamps mounted on beams corresponds to panel c54 with a panel thickness of 30mm, where the panel type is the type of panel used in this solar farm. Figure 3.24 illustrates the solar panel configuration used in this proposed design. It is planned to have a 50cm high cement support during construction. The solar panel support steel will be mounted on a 50cm high cement beam. The support is designed to facilitate solar panel maintenance by allowing technicians easy access to the panels.

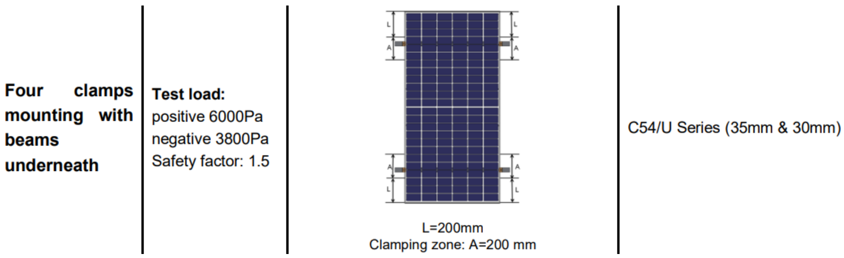

Fig. 3. 23 Structure Guideline Installation

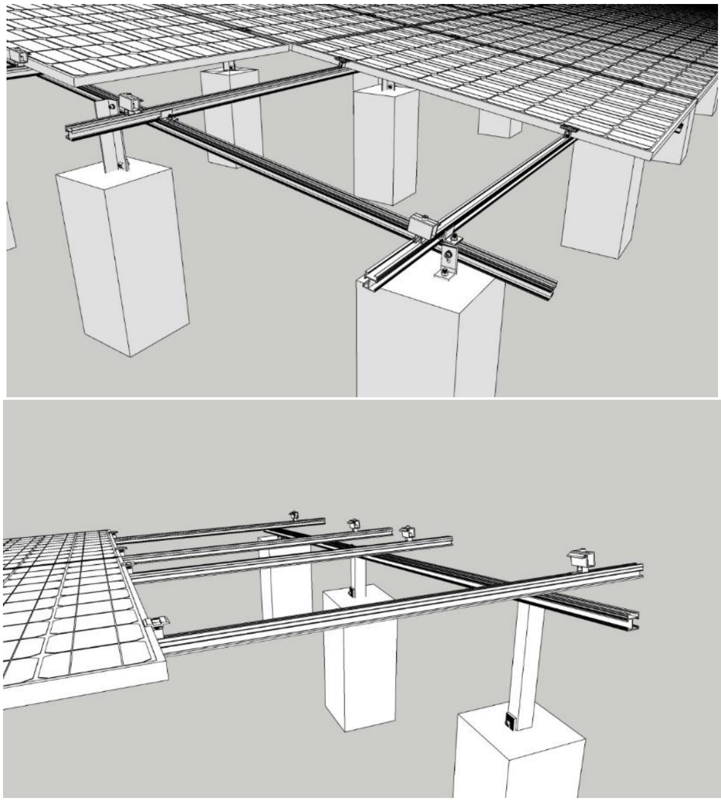

Fig. 3. 24 3d Structure Installation Proposed

Solar panel manufacturers establish several guidelines for construction near the sea to ensure the equipment issued by the manufacturer lasts. Suntech developed several installation guidelines for solar panels near beaches. Several procedures are provided, including the following: Avoid damaging the corrosion-resistant coating on the modules and mounting systems during installation. Connect/tighten modules and mounting systems using corrosion-resistant components (nut, bolt, gasket, etc.). Insulate the joint installation points, where the mounting and grounding hardware is attached to the frame, with gaskets. We recommend mica lamination or silicone or fluoride-based insulating materials for insulation gaskets. The installation of the gasket is depicted in Figure 3.25.

Additionally, the manufacturer provides guidelines for grounding wire installation in solar panel installations near the sea. The general rule is to use a fluorocarbon varnish on the grounded part. Coat the grounding block with fluorocarbon varnish to create an anti-corrosion coating. This coating shall completely cover the module frame or mounting system's grounding block and junction area. Manufacturing asserts that an installation system like this one will be able to meet the IEC61701 salt mist corrosion test for photovoltaic modules IEC and 61730-2 2004 photovoltaic module safety qualification-part 2 test requirements with this installation system.

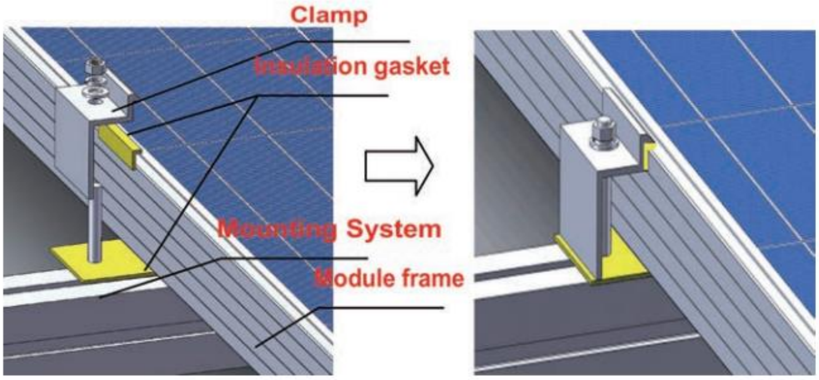

Fig. 3. 25 Anti Corrosion Gasket Instalation

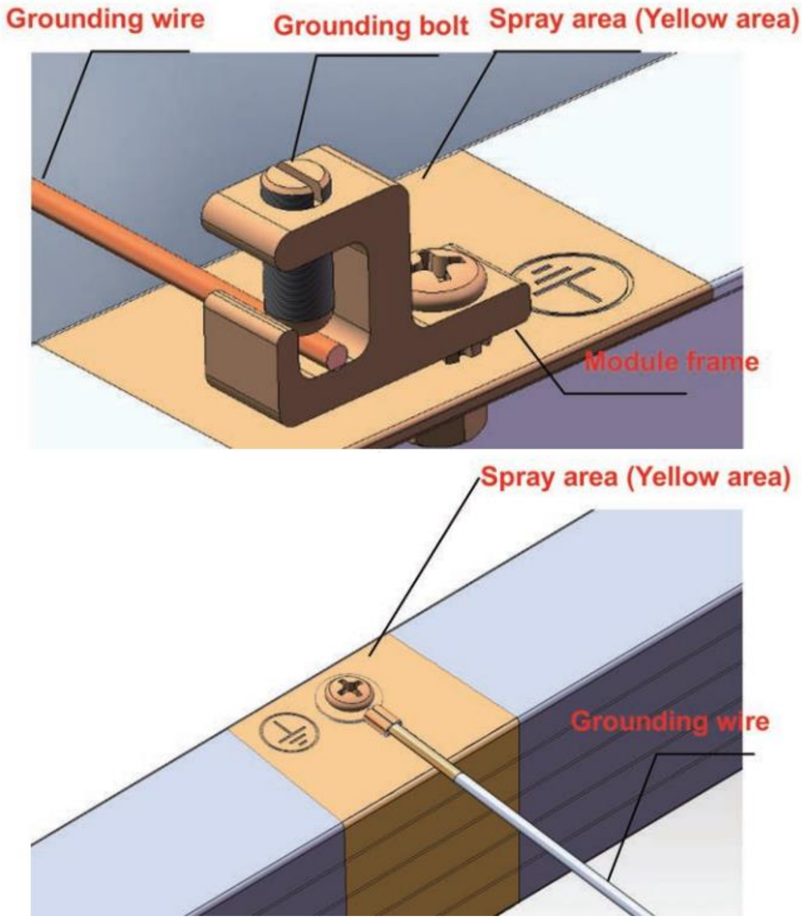

Fig. 3. 26 Anti Corrosion Grounding Instalation

4.5.7 Solar Energy Output Projected

Table 2. 11 Hourly Profile irradiance in Semarang city

Hour	lux	W/m2
7 - 8	5946	49.55
8 - 9	8050	67.0833333
9 - 10	10396	86.6333333
10 - 11	11168	93.0666667
11 - 12	26716	222.633333
12 - 13	54578	454.816667
13 - 14	56455	470.458333
14 - 15	54877	457.308333
15 - 16	18770	156.416667
16 - 17	7450	62.0833333

Source: Analisis Potensi Energi Sinar Matahari Dan Energi Angin di Pusat Kota Semarang

According to data from the journal Analysis of the Energy Potential of Solar and Wind Energy in Semarang City Center, the city of Semarang receives the highest solar irradiation of 470W/m2 between 12 and 13 AM. This figure inputs a 2MW solar panel design into an electrical simulation application. After input, it is determined that with a 470W/m2 irradiation capacity, it can generate only 954 kW of power. This power is close to the specifications for shore connections capable of supplying 1MW of power.

Solar panels can only supply electrical power to vessels from 9 AM to 3 PM for supply to vessels, which on average require less than 200kW of power. The Julianto and Ibrahim Zahier vessels can be powered entirely by solar energy beginning at 8 AM. At 1 PM, the solar panels produced nearly five times the amount required. Excess production will be sold to PLN. The sale of power to PLN is quantified using a Net Meter tool that determines the amount of energy transmitted from the solar energy power plant to the PLN grid. The proceeds from the sale of power are expected to reduce the company's monthly payments to PLN. Pelindo is hoped to benefit from this payment discount and operate a shore connection using environmentally friendly energy for approximately 6 hours per day.

Solar energy's capacity to electricity vessels ranges between 37% and 40%, depending on the vessel's specifications. This is illustrated in the following table 2.12. Solar energy contributes the most to the Soemantri Brojonegoro vessel's load, which is 40%. The vessel consumes less energy than other vessels, such as the Pusri Indonesia 1. Since Pusri Indonesia 1 requires the most electrical power than other vessels, solar panel power can only supply 37% of the vessel's power needs.

Table 2. 12 Percentage solar power participation

Vessel Name	Average Load kW	Energy Consumption in a day kWh	Average energy supplied by PV in a day kWh	Solar energy sends to vessel kWh	Percentage vessel energy consumption supplied by PV
IBRAHIM ZAHIER	156.89	3765.44	4202.42	1424.88	38%
PUSRI INDONESIA 1	173.94	4174.47		1534.95	37%
SOEMANTRI BROJONEGORO	121.28	2910.64		1175.57	40%
ABUSAMAH	147.30	3535.13		1357.71	38%
JULIANTO MD	135.51	3252.16		1275.18	39%

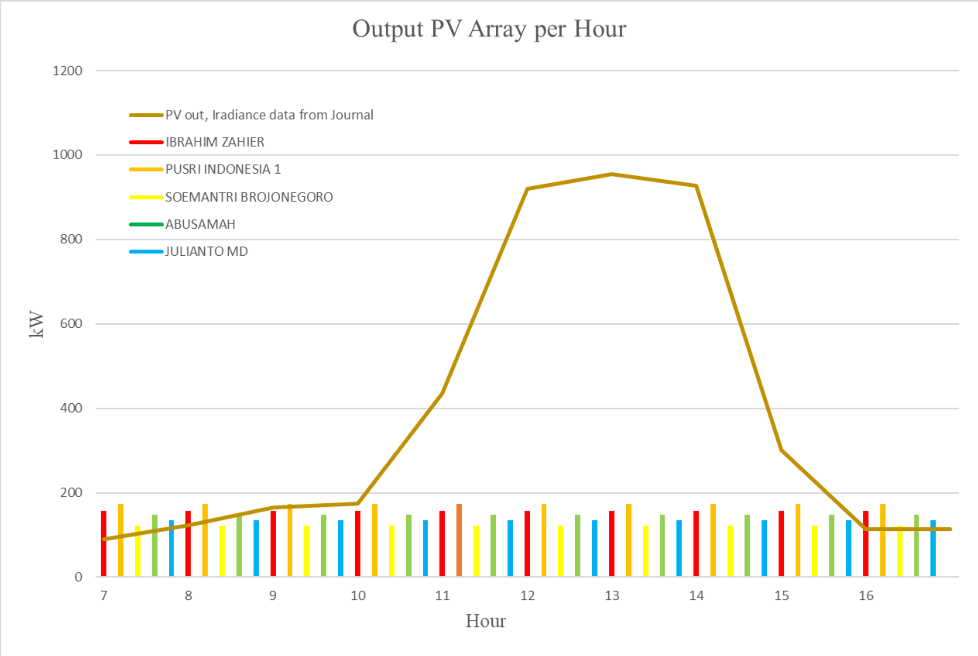

Fig. 3. 27 Graphic of PV Output/Hour & Average vessel load

According to the calculations, the energy requirements of vessels aware of the Dwimatama pier range between 3200 and nearly 4200 kWh per day. Meanwhile, the solar power plant generates approximately 4200 kWh of energy per day. However, because the system is designed as an on-grid system, solar energy contributes between 25% and 29%

of the vessel's energy needs in a single day. This 25% participation was achieved when supplying the Pusri Indonesia 1 vessel, as the Pusri Indonesia 1 vessel consumes the most power, nearly 200kW. However, the additional electrical energy generated by the solar panels will be sent to the PLN grid, resulting in a monthly fee reduction that Pelindo pays to PLN.

Table 2. 13 Tabel of comparison Pelindo Income/day

Income									
Vessel Name	Energy vessel need (kW)	Energy sends to vessel (kWh)	Energy handle by PV (kWh)	Energy send to Grid (kWh)	Bill if 100% Using energy grid (Rp)	Income from selling to vessel (Rp)	Income selling to PLN (Rp)	Total Income per vessel/day using Solar Power (Rp)	Income if using PLN (Rp)
IBRAHIM ZAHIER	3765.44	1424.9	38%	2777.54	3,900,165	7,741,739	2,876,918	6,718,492	3,844,511
PUSRI INDONESIA 1	4174.47	1534.9	37%	2667.47	4,323,829	8,582,703	2,762,916	7,021,790	4,262,130
SOEMANTRI BROJONEGORO	2910.64	1175.6	40%	3026.85	3,014,781	5,984,273	3,135,155	6,104,646	2,971,762
ABUSAMAH	3535.13	1357.7	38%	2844.71	3,661,618	7,268,230	2,946,494	6,553,105	3,609,369
JULIANTO MD	3252.16	1275.2	39%	2927.24	3,368,526	6,686,449	3,031,979	6,349,901	3,320,459
							Average Income per day	6,549,587	3,601,646

According to the projections in Table 2.13, Pelindo initially paid electricity bills if using electricity 100% from PLN ranging from Rp3,014,781.00 for the vessel with less power requirement, the Soemantri Brojonegoro vessel, to Rp4,323,829.00 for Pusri Indonesia's one vessel, the vessel with the largest power requirement that rests on the Dwimatama pier. After supplying energy from the solar power plant, it was discovered that Pelindo could not anymore pay for electricity daily; instead, PLN purchased electricity from Pelindo. The payments from PLN ranged from Rp2,762,916.00 to Rp3,135,155.00 per day, and Pelindo could receive payments ranging from Rp5,984,273.00 Rp4,323,829.00 per day. Because there has been an oversupply of electrical power from the solar power plant to the load at some point, the excess energy is sold to PLN to ensure that expectations of only reducing payments result in PLN paying for the electricity supplied to the grid. The total average income per day if using solar power plant + PLN to provide shore connection is Rp5,549,547.00. This income is almost double from the average now day income which is Rp3,601,646.00.

4.5.8 Break-Even Point

To determine BEP, we must first determine Capital and Operational Expenditures. As a result, the authors develop a budget for the project's financing. The total capital expenditure is 11.8 billion rupiahs; this money was issued for the first time during the construction of this project to serve as initial capital. Additionally, maintenance is required to ensure that solar energy plant planning operates effectively and correctly. The author assumes 260 million rupiahs in annual maintenance costs. This money will be distributed yearly to cover maintenance expenses. Table 2.14 summarizes these costs.

Table 2. 14 Cost Table

Capex	Total Price
Office n security	Rp 150,000,000
Planning Area	Rp 920,000,000
Price Solar Array Support Structure	Rp 2,629,032,000
Price Solar Panel	Rp 6,661,200,000
Price Inverter	Rp 1,000,000,000
Price Panel	Rp 500,000,000
Total Capex	Rp 11,860,232,000
Maintenance	Rp 261,000,000

Along with CAPEX and OPEX, annual revenue is required. The selling price of electricity determines this revenue to vessels and the PLN. The authors add the two types of sales to determine the company's total daily revenue. It is known that the company earned Rp. 2,390,599,249.76 in the first year from the sale of electricity to PLN and vessels. The table below calculates the company's daily revenue in the first year; the author distinguishes revenue from year to year by considering the annual degradation factor on solar panels.

Table 2. 15 Income in First Year

Income First Year					
Vessel Name	Energy send to vessel	Energy send to Grid	Income from selling to vessel	Income selling to PLN	Total Income
IBRAHIM ZAHIER	1424.9	2777.54	Rp 7,741,739	Rp 2,876,918	Rp 6,718,492
PUSRI INDONESIA 1	1534.9	2667.47	Rp 8,582,703	Rp 2,762,916	Rp 7,021,790
SOEMANTRI BROJONEGORO	1175.6	3026.85	Rp 5,984,273	Rp 3,135,155	Rp 6,104,646
ABUSAMAH	1357.7	2844.71	Rp 7,268,230	Rp 2,946,494	Rp 6,553,105
JULIANTO MD	1275.2	2927.24	Rp 6,686,449	Rp 3,031,979	Rp 6,349,901
Average income per day					Rp 6,549,587
Income in first year				Rp 2,390,599,249	

The Break Event Point is the point at which profit equals cost. In this case, the sale of solar energy via an on-grid system to vessels anchored at the Dwimatama pier and to PLN is in its seventh year of BEP. This is evident by the 2% decline in solar panel production in the second year and the 0.55 percent decline in the following year. This decrease in production results from the panel's performance degrading, which is well documented based on the manufacturer's claims. Considering all of these factors, beginning production in 2021 will result in BEP in 2027.

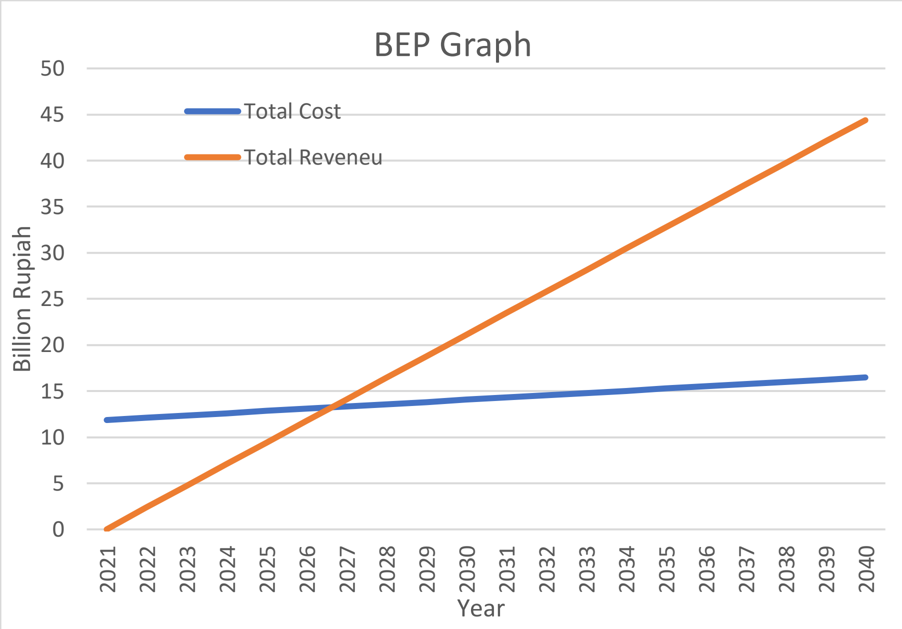

Fig. 3. 28 BEP Graph

4.5.9 Load Flow

Based on the results of load flow simulation using application modeling. The data is obtained in the table below. *The following data are AC power distribution data. This simulation was carried out under several conditions. The simulation conditions here follow the supplied load, such as vessels with different power requirements. The data taken is data from each bus that has been modeled in the application.

Table 4.11 Value of Grid’s Load Flow

Table Value of Grid’s Load Flow						
Vessel	From	To	P (kW)	Q (kVAr)	S (kVa)	I (A)
Ibrahim Zahier	Grid	Bus 1	156.5	1.17	156.5	4.5
	Bus 1	Bus 2	156.5	1.17	156.5	4.5
	Bus 2	Bus 3	156.4	0.225	156.4	226
	Bus 3	Bus Load	156.2	0.084	156.2	226
Pusri Ind	Grid	Bus 1	173.4	1.44	173.4	5

	Bus 1	Bus 2	173.4	1.43	173.4	5
	Bus 2	Bus 3	173.2	0.276	173.2	250.3
	Bus 3	Bus Load	173	0.103	173	250.3
Sumantri B	Grid	Bus 1	120.7	0.696	120.7	3.5
	Bus 1	Bus 2	120.7	0.695	120.7	3.5
	Bus 2	Bus 3	120.6	0.134	120.6	174.3
	Bus 3	Bus Load	120.5	0.05	120.5	174.3
Abusamah	Grid	Bus 1	146.6	1.03	146.6	4.2
	Bus 1	Bus 2	146.6	1.03	146.4	4.2
	Bus 2	Bus 3	146.5	0.197	146.5	211.6
	Bus 3	Bus Load	146.3	0.074	146.3	211.6
Julianto MD	Grid	Bus 1	134.7	0.866	134.7	3.9
	Bus 1	Bus 2	134.7	0.865	134.7	3.9
	Bus 2	Bus 3	134.5	0.166	134.5	194.4
	Bus 3	Bus Load	134.4	0.062	134.4	194.4

Following the simulation using the application, I summarized the power flow results based on electricity supply from the grid in this table. Bus 2 to Bus 3 and Bus 3 to Bus Load were found to have the average apparent and actual power loss. A transformer is involved in the transfer of power from bus two to bus three. The transvormator equipment is expected to suffer due to the decrease in power on bus 2 and bus 3. In addition, losses in the cable are expected to cause a reduction in power on bus 3 to bus load.

Table 4.12 Value of Grid's + PV's Load Flow

Table Value of Grid's + PV's Load Flow						
Vessel	From	To	P (Kw)	Q (kVAr)	S (kVa)	I (A)
Ibrahim Zahier	Grid	Bus 1	74.3	-0.435	74.3	2.1
	Bus 1	Bus 2	74.3	-0.436	74.3	2.1
	Bus 2	Bus 3	74.3	-0.649	74.3	107.3
	Bus 3	Bus Load	156.6	0.084	156.6	226.2
	Inverter	Bus AC PV1	82.4	-29	87.4	2.5
	Bus AC PV1	BUS AC PV 2	82.4	1.03	82.4	2.4
	BUS AC PV2	Bus Load	82.3	0.76	82.3	189.9
Pusri Indoneisa 1	Grid	Bus 1	82.3	-0.407	82.3	2.4
	Bus 1	Bus 2	82.3	-0.407	82.3	2.4
	Bus 2	Bus 3	82.2	-0.668	82.2	118.8
	Bus 3	Bus Load	173.5	0.104	173.5	250.7
	Inverter	Bus AC PV1	91.4	-28.9	95.9	2.8
	Bus AC PV1	BUS AC PV 2	91.3	1.13	91.4	2.6
	BUS AC PV2	Bus Load	91.3	0.81	91.3	131.9
Sumantri B	Grid	Bus 1	57.5	-0.474	57.5	1.7
	Bus 1	Bus 2	57.5	-0.474	57.5	1.7
	Bus 2	Bus 3	57.5	-0.602	57.5	83
	Bus 3	Bus Load	120.7	0.05	120.7	174.4
	Inverter	Bus AC PV1	63.3	-29.2	69.8	2
	Bus AC PV1	BUS AC PV 2	63.3	0.825	63.3	1.8

	BUS AC PV2	Bus Load	63.3	0.671	63.3	91.4
Abusamah	Grid	Bus 1	69.7	-0.449	69.7	2
	Bus 1	Bus 2	69.7	-0.449	69.7	2
	Bus 2	Bus 3	69.6	-0.636	69.6	100.6
	Bus 3	Bus Load	146.6	0.074	146.6	211.8
	Inverter	Bus AC PV1	77.1	-29.1	82.4	2.4
	Bus AC PV1	BUS AC PV 2	77.1	0.967	77.1	2.2
	BUS AC PV2	Bus Load	77	0.738	77	111.3
Julianto MD	Grid	Bus 1	64.1	-0.463	64.1	1.8
	Bus 1	Bus 2	64.1	-0.463	64.1	1.8
	Bus 2	Bus 3	64	-0.621	64	92.5
	Bus 3	Bus Load	134.7	0.062	134.7	194.6
	Inverter	Bus AC PV1	70.7	-29.2	76.5	2.2
	Bus AC PV1	BUS AC PV 2	70.7	-29.2	76.5	2.2
	BUS AC PV2	Bus Load	70.7	0.9	70.7	2

After simulating the software, the writer compiled the following table of power flow data based on grid + PV supply. In the transmission from the ac pv1 bus to the ac pv2 bus, and finally the ac pv2 ac bus to the load bus, the average apparent and real power decreased. Losses in the cable are to suspect for the power drop in the ac pv1 to ac pv2 bus transmission. According to the distance from the solar panels to the jetty, the cable used is 1.6 kilometers long. In addition, losses in the transformer are to suspect for the decrease in power between the ac pv 2 bus and the bus load. The transformer is located between the AC PV 2 bus transmission system and the load bus.

Table 4.13 Value of PV's Load Flow

Table Value of PV's Load Flow						
Vessel	From	To	P (Kw)	Q (kVAr)	S (kVa)	I (A)
Ibrahim Zahier	Inverter	Bus AC PV1	156.6	-29	159.3	4.6
	Bus AC PV1	BUS AC PV 2	156.5	1.03	156.5	4.5
	BUS AC PV2	Bus Load	156.3	0.084	156.3	226
Pusri Ind	Inverter	Bus AC PV1	173.5	-28.8	175.9	5.1
	Bus AC PV1	BUS AC PV 2	173.3	1.26	173.3	5
	BUS AC PV2	Bus Load	173.1	0.104	173.1	250.4
Sumantri B	Inverter	Bus AC PV1	120.8	-29.4	124.3	3.6
	Bus AC PV1	BUS AC PV 2	120.7	0.612	120.7	3.5
	BUS AC PV2	Bus Load	120.6	0.05	120.6	174.3
Abusamah	Inverter	Bus AC PV1	146.4	-29.1	149.5	4.3
	Bus AC PV1	BUS AC PV 2	146.5	0.903	146.5	4.2
	BUS AC PV2	Bus Load	146.4	0.074	146.4	211.7
Julianto MD	Inverter	Bus AC PV1	134.7	-29.3	137.8	4
	Bus AC PV1	BUS AC PV 2	134.6	0.762	134.6	3.9
	BUS AC PV2	Bus Load	134.5	0.064	134.5	194.4

Following the simulation with the application, I summarized the data obtained from the power flow based on the electricity supplied by the PV in this table. The average apparent and actual power losses were determined to occur during the transmission from bus ac pv1 to bus ac pv 2, and from bus ac pv2 to bus load. The decrease in power transmitted from the ac pv1 bus to the ac pv2 bus is caused by cable losses. Given the distance between the solar panels and the jetty, it is known that the cable used is 1.6 kilometers long. Additionally, the power loss between the ac pv 2 bus and the bus load occurs due to transformer losses. The transformer is located between the transmission system of the AC PV 2 bus and the load bus.

4.5.10 Voltage Drop

Voltage drop studies are carried out in conjunction with power flow studies. Based on the simulation results, the authors make a data recap about the voltage drop on each bus. This analysis is carried out for AC power flow. This simulation is also carried out with various schemes according to the load supplied, considering that the Dwimatama pier is a TUKS port so that the vessels that are lean on can be determined to be fixed.

Table 4.14 Value of Grid's Voltage Drop

Table Value of Grid's Voltage Drop					
Vessel	Bus	kV	Vd	kV final	% V final
Ibrahim Zahier	BUS 1 PLN	20	0	20	100.00%
	BUS 2 PLN	20.0	0	20	100.00%
	BUS 3 PLN	0.4	0.8	0.3992	99.80%
	BUS Load	0.4	0.88	0.3991	99.78%
Pusri Ind	BUS 1 PLN	20.0	0	20	100.00%
	BUS 2 PLN	20.0	0	20	100.00%
	BUS 3 PLN	0.4	0.48	0.3995	99.88%
	BUS Load	0.4	1	0.3990	99.75%
Sumantri B	BUS 1 PLN	20.0	0	20	100%
	BUS 2 PLN	20.0	0	20	100%

	BUS 3 PLN	0.4	0.32	0.3997	99.92%
	BUS Load	0.4	0.68	0.3993	99.83%
Abusamah	BUS 1 PLN	20.0	0	20	100%
	BUS 2 PLN	20.0	0	20	100%
	BUS 3 PLN	0.4	0.4	0.3996	99.90%
	BUS Load	0.4	0.84	0.3992	99.79%
Julianto MD	BUS 1 PLN	20.0	0	20	100%
	BUS 2 PLN	20.0	0	20	100%
	BUS 3 PLN	0.4	0.36	0.3996	99.91%
	BUS Load	0.4	0.76	0.3992	99.81%

The voltage data on each bus is obtained after simulating the power flow with a grid power source using the application. I summarized it to create this table. The table shows that the average voltage drop occurs in a 400-volt low-voltage distribution system. The voltage drop of 0.02 to 0.25 percent

Table 4.15 Value of Grid's + PV's Voltage Drop

Table Value of Grid's + PV's Voltage Drop					
Vessel	Bus	kV	Vd	kV final	% V final
Ibrahim Zahier	BUS 1 PLN	20	0	20	100%
	BUS 2 PLN	20	0	20	100%
	BUS 3 PLN	0.4	0.2	0.3998	99.95%
	BUS Load	0.4	0.4	0.3996	99.90%
	BUS AC PV 1	20	0	20	100%
	BUS AC PV 2	20	8	19.992	99.96%
Pusri Ind	BUS 1 PLN	20	0	20	100%
	BUS 2 PLN	20	0	20	100%

	BUS 3 PLN	0.4	0.2	0.3998	99.95%
	BUS Load	0.4	0.44	0.39956	99.89%
	BUS AC PV 1	20	0	20	100%
	BUS AC PV 2	20	10	19.99	99.95%
Sumantri B	BUS 1 PLN	20	0	20	100%
	BUS 2 PLN	2	1800	0.2	10%
	BUS 3 PLN	0.4	0.16	0.39984	99.96%
	BUS Load	0.4	0.32	0.39968	99.92%
	BUS AC PV 1	20	0	20	100%
	BUS AC PV 2	20	6	19.994	99.97%
Abusamah	BUS 1 PLN	20	0	20	100%
	BUS 2 PLN	20	0	20	100%
	BUS 3 PLN	0.4	0.16	0.39984	99.96%
	BUS Load	0.4	0.36	0.39964	99.91%
	BUS AC PV 1	20	0	20	100%
	BUS AC PV 2	20	8	19.992	99.96%
Julianto MD	BUS 1 PLN	20	0	20	100%
	BUS 2 PLN	20	0	20	100%
	BUS 3 PLN	0.4	0.16	0.39984	99.96%
	BUS Load	0.4	0.36	0.39964	99.91%
	BUS AC PV 1	20	0	20	100%
	BUS AC PV 2	20	8	19.992	100%

After simulating the power flow with a grid + PV power source using the application, the voltage data on each bus is obtained. I summarize it to make a table like this. From the table, it is more or less the same as before, and it can be seen that the average voltage drop occurs in a low voltage distribution system of 400 volts. Power drop in the range of

0.03% to 0.11%. In addition, a decrease in voltage also occurs in the medium voltage bus, namely the ac pv 2 bus. This decrease in voltage on the medium voltage bus occurs because of losses in the cable where the simulated cable has a length of 1.6 km.

Table 4.16 Value of PV's Voltage Drop

Table Value of PV's Voltage Drop					
Vessel	Bus	kV	Vd	V final	% V final
Ibrahim Zahier	BUS AC PV 1	20	0	20	100%
	BUS AC PV 2	0.4	0.36	0.39964	99.91%
	BUS Load	0.4	0.76	0.39924	99.81%
Pusri Ind	BUS AC PV 1	20	0	20	100%
	BUS AC PV 2	0.4	0.4	0.3996	99.9%
	BUS Load	0.4	0.84	0.39916	99.79%
Sumantri B	BUS AC PV 1	20	0	20	100%
	BUS AC PV 2	0.4	0.28	0.39972	99.93%
	BUS Load	0.4	0.6	0.3994	99.85%
Abusamah	BUS AC PV 1	20	0	20	100%
	BUS AC PV 2	0.4	0.32	0.39968	99.92%
	BUS Load	0.4	0.72	0.39928	99.82%
Julianto MD	BUS AC PV 1	20	0	20	100%
	BUS AC PV 2	0.4	0.28	0.39972	99.93%
	BUS Load	0.4	0.64	0.39936	99.84%

The voltage data on each bus is obtained after simulating power flow with a photovoltaic power source using the application. I summarized it to create this table. The voltage drop occurs on the ac pv 2 bus and bus load, as indicated by this table. The decrease from 0.07 to 0.1 percent on the ac pv 2 bus is due to cable losses, as the cable used is 1.6 kilometers long. Additionally, the voltage drop on the bus load is between 0.15 and 0.21 percent. This decrease occurs due to transformer losses, resulting in a voltage drop.

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CHAPTER 5

CONCLUSION

5.1 Conclusion

1. According to this research, Cipta Beach's area is very likely to be used for a solar power plant that will supply electricity to Semarang's Dwimatama Pier. According to the calculation results, the area required to generate nearly 1000kwp with a panel specification of 410Wp is almost 4 hectares. The 4 hectares area for 1000kwp with a distance between the arrays of 5m. For the Semarang area, the panel's maximum output time is approximately 12 to 13 AM. Solar panels can fully power the vessel from 9 AM to 4 PM. With this configuration, the solar panels can produce 4202.42 kWh per day with 954.25 kWp. Solar energy provides between 37% and 40% of the vessel's power requirements.
2. The most significant power loss, according to analysis, occurs between 0.3 and 0.5 kW. All of this happens on the bus output transformer. The transformer's bus outputs are Bus 3 PLN and Bus Load. This demonstrates that these losses occur in the transformer, resulting in a relatively significant power reduction compared to others.
   The most significant voltage drop occurs in a 400V low voltage distribution system. As can be seen from this voltage, the voltage drop ranges between 0.02 and 0.25 percent for a pure PLN distribution system and between 0.11 and 0.3 percent for a PLN + PV system. And an entire solar panel system results in a decrease in medium and low voltage; this decrease is caused by the nearly 2-kilometer length of the pull cable. There is a 0.15 percent to 0.21 percent reduction in low voltage. Additionally, 0.07 percent to 0.1 percent for high voltage

5.2 Suggestion

1. To obtain an accurate hourly average power output profile, it is recommended to measure the irradiation level over a while directly.
2. To ensure that the final data is valid, it is preferable to have complete product data and then enter data into the application.
3. Excess electricity production at a particular time can be stored to meet power requirements when solar panels cannot produce enough energy; this could be a new point of discussion.

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REFERENCES

Arifin, Z., Tamamy, A. J., & Amalia, A. (2019). Analisis Potensi Energi Sinar Matahari Dan Energi Angin di Pusat Kota Semarang. *Setrum: Sistem Kendali-Tenaga-elektronika-telekomunikasi-komputer*, *7*(2), 296-304.

Borkowski, T., & Tarnapowicz, D. (2012). „Shore to vessel" system-an alternative electric power supply in port. Journal of KONES, 19, 49-58.

Ericsson, P., & Fazlagic, I. (2008). Shore-side power supply. Master of Science Thesis–Chalmers University of technology–Goteborg Sweden.

Harahap, P. (2020). Pengaruh Temperatur Permukaan Panel Surya Terhadap Daya Yang Dihasilkan Dari Berbagai Jenis Sel Surya. RELE (Rekayasa Elektrikal dan Energi): Jurnal Teknik Elektro, 2(2), 73-80.

IEC 60364-5-52 Low-voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – Wiring systems

IEEE Std 141-1993 Recommended Practice for Electric Power Distribution for Industrial Plants

Pangestuningtyas, D. L., Hermawan, H., & Karnoto, K. (2014). Analisis pengaruh sudut kemiringan panel surya terhadap radiasi matahari yang diterima oleh panel surya tipe larik tetap. *Transient: Jurnal Ilmiah Teknik Elektro*, *2*(4), 930-937.

Paul, D., & Haddian, V. (2009, October). Shore-to-vessel power supply system for a cruise vessel. In 2009 IEEE Industry Applications Society Annual Meeting (pp. 1-7). IEEE.

Radwan, M. E., Chen, J., Wan, Z., Zheng, T., Hua, C., & Huang, X. (2019). Critical barriers to the introduction of shore power supply for green port development: case of Djibouti container terminals. Clean Technologies and Environmental Policy, 21(6), 1293-1306.

Setyono, J. S., Mardiansjah, F. H., & Astuti, M. F. K. (2019). Potensi Pengembangan Energi Baru dan Energi Terbarukan di Kota Semarang. *Jurnal Riptek*, *13*(2), 177-186.

Silaksanti, D., & Sudarmo, S. T. (2020). COST AND ENVIRONMENTAL BENEFIT IN THE USE OF SHORE CONNECTION IN BJTI PORT. Advances in Transportation and Logistics Research, 3, 38-45.

Widodo, D. A., & Andrasto, T. (2010). Pemberdayaan Energi Matahari Sebagai Energi Listrik Lampu Pengatur Lalu Lintas. *Jurnal Teknik Elektro*, *2*(2), 6.