

## PANEL INSTALLATION WORK

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### Abstract

Energy is the ability to do work. Energy is power that can be used to carry out various activity processes including mechanical energy, heat, etc. Therefore, almost all disputes in this world stem from the struggle for energy sources. This research also aims to explain the utilization of solar energy as an alternative source of electricity through the photovoltaic process, as well as identify the effectiveness of electrical energy storage in batteries controlled by regulators and power conversion from DC to AC through inverters. The findings indicate that precise planning, skilled labor, and compliance with safety regulations are essential for successful panel installation. Common challenges identified include improper load calculations, inadequate circuit protection, and wiring faults, which can lead to inefficiencies and system failures. Recommendations for enhancing installation practices include the adoption of smart panels, automated monitoring systems, and rigorous safety training for electricians. In conclusion, efficient panel installation requires a combination of technical expertise, regulatory adherence, and modern technology integration. By implementing best practices, panel installations can be optimized for safety, efficiency, and long-term reliability, contributing to a more stable and sustainable electrical infrastructure.

**Keywords:** solar cell; design analysis; photovoltaic system; electric power

### Introduction

Energy is the ability to do work. Energy is power that can be used to carry out various activity processes including mechanical energy, heat, etc. Therefore, almost all disputes in this world stem from the struggle for energy sources. There are several natural energies as alternative energy that are clean, non-polluting, safe and have unlimited supply, known as renewable energy (Al-Nini et al., 2023). New and renewable energy sources in the future will increasingly have a very important role in meeting energy needs (Salvarli & Salvarli, 2020). This is because the use of fossil fuels for conventional power plants over a long period of time will deplete sources of oil, gas and coal whose reserves are increasingly depleting. In Indonesia, which is located in a tropical area, it actually has quite a big advantage, namely that it receives continuous sunlight throughout the year. Unfortunately, this energy seems to be wasted for natural purposes only (Hasan, 2012). Apart from that, solar energy can be utilized with the help of other equipment, namely by changing solar radiation into other forms (Myers, 2017). There are two ways to convert solar radiation into other energy, namely through solar cells and collectors (Kasaeian et al., 2018).

There is no doubt that solar energy is an environmentally friendly energy

source and is very promising in the future, because no pollution is produced during the energy conversion process, and the energy source is widely available in nature.

Therefore, the application of Solar Power Plant (PLTS) technology to utilize the potential of solar energy available in these locations is the right solution (Al Garni & Awasthi, 2018).

PLTS or better known as solar cells (Photovoltaic cells) will be more in demand because they can be used for various relevant purposes and in various places such as offices, factories, housing and others. So this is deemed necessary to be studied further, in order to obtain a technically comprehensive study.

In this research, we will analyze the design results of a 50 WP capacity solar power generation system on a laboratory scale (Patel & Beik, 2021). With the research aim of calculating the characteristics of a solar power plant using a 50 WP Solar Cell and calculating the maximum power produced by the resulting solar power plant. So that the performance of the solar power generation system design for a capacity of 50 WP can be analyzed (Guo & Kors Jr, 2021). The basic principle of making solar cells is to utilize the photovoltaic effect, which is an effect that can convert sunlight directly into electrical energy. If a metal is exposed to light in the form of photons with a certain frequency, then the kinetic energy of the photons will shoot into the metal atoms, then the irradiated metal atoms will release their electrons. These free electrons are what flow a certain amount of current. Conventional solar cells work using the p-n junction principle, namely the junction between p-type and n-type semiconductors. N-type semiconductors have excess electrons (negative charge) while p-type semiconductors have excess holes (positive charge) in their atomic structure. The working principle of solar cells is to utilize the photovoltaic effect (PV, photo = light and voltaic = electricity) in the form of solar cells or solar cells made from single crystal silicon. Sunlight which carries energy will be received by cells and absorbed into the semi-conductor, thereby affecting the electrons in it.

The solar energy absorbed by the earth is 120,000 TeraWatt. In principle, solar power can be used to generate electricity in two ways:

1. Production of steam with a mirror field used to drive a turbine. (Large-scale solar power plant)
2. Convert sunlight into electrical energy using photovoltaics. (Small-scale solar power plants).

Panel installation is a fundamental process in electrical system design and implementation, ensuring the safe and efficient distribution of electricity in residential, commercial, and industrial environments. An electrical panel serves as the central hub for controlling and distributing power to various circuits, making proper installation crucial for system reliability, energy efficiency, and user safety. Improper installation can lead to electrical hazards, such as short circuits, overloads, and fire risks, highlighting the need for strict adherence to electrical standards and safety regulations.

With the increasing demand for modern electrical systems, panel installation has evolved to incorporate advanced technologies, including smart panels, automated monitoring, and energy-efficient components. These innovations enhance power management by providing real-time data, fault detection, and remote control capabilities. However, despite these advancements, challenges remain in ensuring proper wiring, load balancing, and compliance with regulatory guidelines.

The novelty of this research lies in several innovative approaches to optimizing solar power generation systems. First, this study introduces an optimal placement strategy for solar panels, ensuring they are positioned to maximize sunlight absorption while considering environmental factors such as shading from trees or buildings. Unlike previous

studies that often installed solar panels statically, this research emphasizes the importance of panel orientation and tilt adjustments to enhance energy capture efficiency.

Furthermore, several recent studies support the significance of this research. El-Shahat et al. (2019) designed a solar power system for simple households but did not focus on panel placement optimization. Yilmaz dan Dincer (2017) analyzed the impact of inverters on solar power systems but did not explore energy storage efficiency. Raza (2023) compared the performance of mono-silicon and poly-silicon solar panels but overlooked environmental factors affecting sunlight absorption. Yilmaz & Dincer (2017) studied the optimization of panel tilt angles, which is considered in this research as a key factor for efficiency. Siudek et al. (2020) conducted an economic analysis of solar panel installations but did not examine energy storage and distribution efficiency.

The effectiveness of panel installation depends on several key factors, including accurate load calculations, circuit protection mechanisms, grounding techniques, and skilled workmanship (Joffe & Lock, 2011). In many cases, errors in installation—such as improper wire connections, lack of surge protection, or incorrect circuit breaker sizing—can result in system inefficiencies, equipment damage, and safety risks. Therefore, a structured and standardized approach to panel installation planning, execution, and maintenance is essential to guarantee long-term performance and safety (Kumar et al., 2013).

This study aims to explore the best practices, common challenges, and emerging trends in panel installation work. By analyzing technical requirements, safety protocols, and modern innovations, the research seeks to provide practical insights for electricians, engineers, and facility managers. The findings will contribute to a better understanding of how to optimize panel installations for enhanced safety, efficiency, and sustainability in electrical distribution systems.

**Research Methodology**

Installation of solar panels begins with providing components, tools and materials that have been determined according to the components that will be used with the solar panels (Noviandi 2019). The components used or loads used are as shown in table 1 below. Table 1. RGI electricity usage load No (Joffe & Lock, 2011). Power Load (Watts) Pcs Number of Power (Watts) 1 Pos LED lights 10 3 30 2 Warehouse LED lights 5 7 35 The above load usage is rounded up to 400 Watts and daily usage is 12 hours. So to find the calculation for solar panels and batteries, the load must be used in units of Watt Hours (Wh), ie

**Table 1 Electricity usage expenses**

No	Burden	(Watt) Pcs	amount watt
1	Light LED Pos	10 3	30
2	Light LED warehouse	5 7	35

12 hours \* 400 W = 4800Wh (1) For Solar Panel calculations, Sinar The sun is effective for 1 day in Indonesia is 5 hours. Solar Panels required is, 4800Wh / 5h = 960Wp (2) Can use 2 pcs 510Wp Solar Panels which will be connected in series (24V System).

For Battery Calculation,

$4800\text{Wh} / 12\text{Vdc} = 400\text{Ah}$  (3) then add +20% battery tolerance, then uses 4 pcs 120Ah 12V batteries connected in Series - Parallel, becomes 240Ah 24V.

This study adopts a qualitative and quantitative research approach to evaluate the effectiveness, challenges, and best practices in panel installation work. The methodology includes research design, data collection methods, data analysis techniques, and ethical considerations, ensuring a comprehensive assessment of installation procedures, safety standards, and technological advancements in electrical panel systems.

### 1. Research Design

This study employs a descriptive and analytical research design to investigate the technical and safety aspects of panel installation work. It focuses on identifying key factors influencing installation quality and performance, assessing compliance with safety and regulatory standards, and analyzing challenges while proposing best practices for improved efficiency. Through a combination of field observations and technical evaluations, the research examines real-world panel installations to evaluate their adherence to industry standards and ensure optimal safety, reliability, and performance.

### 2. Data Collection Methods

#### a. Primary Data Collection

Primary data is collected through site observations, expert interviews, and surveys with professionals involved in panel installation, including electrical engineers and technicians responsible for installation and maintenance, safety inspectors and regulatory officials ensuring compliance with electrical codes, and industry professionals working with modern panel technologies. Site observations are conducted at various panel installation sites to evaluate wiring techniques, circuit configurations, panel safety measures such as grounding and circuit protection, as well as common installation errors and their impact on system performance. In-depth expert interviews help identify best practices in panel installation and safety protocols, challenges faced in residential, commercial, and industrial installations, and technological advancements that improve installation efficiency. Additionally, structured surveys are distributed to electricians and engineers to assess their experiences and insights regarding installation challenges and solutions, knowledge of regulatory requirements and compliance levels, and the adoption of modern technologies, such as smart panels and automated systems.

#### b. Secondary Data Collection

Secondary data is obtained from industry reports, regulatory guidelines, academic studies, and manufacturer manuals related to panel installation techniques, safety standards, and emerging trends. Key sources include the National Electrical Code (NEC) and local electrical regulations, technical manuals on panel wiring and circuit protection, and previous studies on energy-efficient electrical installations. This data provides valuable insights into best practices, compliance requirements, and advancements in panel installation technology, ensuring a comprehensive analysis of industry standards and innovations.

### 3. *Data Analysis Techniques*

A combination of quantitative and qualitative methods is used to analyze the collected data. Descriptive statistics are applied to survey responses using statistical tools to measure common challenges, compliance levels, and industry trends. Comparative analysis is conducted to evaluate the efficiency, safety, and effectiveness of different installation methods across various settings. Additionally, thematic analysis is employed to code expert interviews and site observations into key themes, helping to identify best practices in panel installation, safety concerns, and areas for improvement.

### 4. *Ethical Considerations*

To ensure ethical integrity, this research follows strict guidelines. Informed consent is obtained from all participants, including engineers and technicians, after they are informed about the purpose of the study. Confidentiality is maintained by ensuring that personal and company data collected from panel installation sites remain secure and are used strictly for research purposes. Additionally, objectivity and accuracy are prioritized throughout data collection and analysis, preventing bias and ensuring valid and reliable findings.

### Conclusion of Methodology

By combining field observations, expert interviews, technical surveys, and industry literature, this research provides a comprehensive evaluation of panel installation work. The methodology ensures a detailed assessment of installation quality, regulatory compliance, and technological advancements, offering practical recommendations for improving safety, efficiency, and sustainability in electrical panel installations.

### **Results and Discussion**

PLC Omron CPM2A-20 CDR is a basic industrial automation practicum tool designed with a mobile concept, which is easy to carry so that users do not experience difficulties if they want to hold a simulation in front of the class or in other places. A complete description of the construction design of the training module can be seen in. The framework of this training module has a length of 1300 mm, a width of 500 mm and a height of 1200 mm. The development of a lift trainer kit with voice control based on PLC Omron CP1E in the subject of electric motor installation adapts the ADDIE (Analyze, Design, Development, Implementation, Evaluation) development research model according to Lee and Owens with several adjustments. After the creation of media, handbooks and job sheets is completed, the next step is testing and performance by media experts, material experts and students.

## 1. Results of the Study

The findings of this study provide insights into the practices, challenges, and technological advancements associated with panel installation work. Data collected from field observations, expert interviews, and surveys highlight the importance of proper wiring techniques, circuit protection, grounding, and compliance with safety regulations.

### a. Effectiveness of Panel Installation Practices

The study reveals that proper panel installation plays a crucial role in improving electrical safety, system efficiency, and maintenance ease. Proper grounding and circuit protection help reduce the risk of electrical fires and equipment damage, ensuring a safer electrical system. Well-structured panel installations optimize electricity distribution, minimizing energy losses and enhancing overall system performance. Additionally, organized panel layouts with clearly labeled circuits facilitate easier troubleshooting and system upgrades, improving long-term maintenance efficiency.

### b. Common Challenges in Panel Installation

Despite the benefits of proper panel installation, several challenges were identified during the research:

<b>Challenge</b>	<b>Description</b>	<b>Impact</b>
<b>Improper Load Calculation</b>	Inaccurate estimation of electrical demand	Leads to overloading and frequent circuit breaker trips
<b>Faulty Wiring Connections</b>	Poorly connected or loose wires	Causes short circuits and potential fire hazards
<b>Inadequate Grounding</b>	Insufficient or missing grounding in panel installations	Increases the risk of electrical shocks and system failures
<b>Lack of Compliance with Standards</b>	Failure to follow national electrical codes	Results in safety violations and potential legal issues
<b>Insufficient Training for Technicians</b>	Lack of awareness and technical knowledge	Leads to errors in installation and maintenance

### c. Technological Advancements in Panel Installation

The study highlights the role of modern technology in enhancing the efficiency and safety of panel installations. Key advancements include smart panels, which integrate digital monitoring systems for real-time data tracking and remote access, allowing for better system management. Automated circuit breakers improve safety by detecting overloads and automatically disconnecting to prevent electrical hazards. Additionally, wireless monitoring systems utilizing IoT-based technology enable remote monitoring and fault detection, ensuring proactive maintenance and minimizing downtime. These innovations contribute to a more reliable, efficient, and secure electrical infrastructure.

## 2. Discussion on the Findings

### a. The Importance of Proper Load Calculation

One of the most critical factors in panel installation is accurate load calculation. Incorrect load distribution often leads to overloading, frequent tripping, and reduced panel lifespan. To address this, electricians should use advanced load calculation tools and adhere to industry standards when designing panel systems.

### b. Enhancing Wiring and Grounding Techniques

The study confirms that faulty wiring and poor grounding are major causes of electrical failures. Proper techniques, such as using high-quality cables, securing wire connections, and implementing effective grounding systems, can significantly reduce electrical risks and enhance panel longevity.

### c. Compliance with Electrical Safety Standards

Adherence to national and international electrical regulations is crucial to ensuring safe panel installations. The study suggests that increased training programs, certification requirements, and regular inspections can help improve compliance rates among electrical professionals.

### d. The Role of Smart Technologies in Panel Installations

The integration of smart panels and IoT-based monitoring systems has emerged as a key trend in panel installation. These technologies allow for real-time monitoring, predictive maintenance, and remote troubleshooting, ultimately improving system reliability and reducing downtime.

### e. Recommendations for Improving Panel Installation Efficiency

Based on the findings, the study recommends several best practices to enhance the efficiency and safety of panel installation work. Utilizing advanced load calculators ensures proper distribution of electrical loads, preventing overloading and system failures. Adopting high-quality wiring materials helps reduce the risk of short circuits and connection failures, improving system reliability. Proper grounding techniques should be implemented to minimize electrical hazards and enhance overall safety. Compliance with national electrical codes and regulations is essential to maintain industry standards and ensure safe installations. Integrating smart panel technologies allows for automated monitoring, real-time data tracking, and improved system efficiency. Additionally, providing continuous training programs for electricians and panel installation technicians ensures they stay updated with the latest industry advancements and safety protocols, leading to higher-quality installations and reduced risks.

## Conclusion of Results and Discussion

The results confirm that panel installation plays a crucial role in electrical system efficiency and safety. However, challenges such as improper wiring, overloading, and lack of compliance must be addressed through technological advancements, improved training, and strict adherence to safety standards. By implementing modern solutions, panel installations can be optimized for long-term performance, reliability, and sustainability in various electrical applications.

## Installation Scheme

All components required on PLTS installation is composed of 3 systems sorted. starting with the input system is the parent component for absorbing sunlight energy namely solar panels. On In this activity we use solar panels 420 wp powered to be

distributed to the system operation. The operating system contains a control system in the form of an SCC component to regulate and monitor the incoming and outgoing power energy and power energy storage systems viz battery. The battery stores the power it has distributed by the input system in the form of voltage and direct current (DC) and there are systems conversion to change voltage and current

### Solar Characteristics

The characteristics of solar can be obtained based on three parameters, namely open circuit voltage ( $V_{oc}$ ), short circuit current ( $I_{sc}$ ) and fill factor ( $F_f$ ). The amount of the fill factor can be known from the equation.

$F_f$  = Fill factor

$I_{mp}$  = Maximum current (Ampere)  $V_{mp}$  = Maximum voltage (Volts)

$I_{sc}$  = Short circuit current (Ampere)  $V_{oc}$  = Open circuit voltage (Volts)

Radiation parameters and the influence of ambient temperature, maximum power output (PMPP), voltage ( $V_{MP}$ ) when PMPP and current ( $I_{MP}$ ) when PMPP is reached from the solar panel. Likewise, in unloaded solar panels, a short circuit current ( $I_{sc}$ ) can be found from a characteristic point of the solar cell. If a large load is applied, no current will pass through, this condition is the same as breaking the link on the ammeter and the result of the voltmeter reading is the no-load voltage ( $V_{oc}$ ). Conversion efficiency is the comparison between the power that can be obtained by a solar cell and the power received from the sun. The energy density of solar light that reaches the outside of the earth's atmosphere is around  $136 \text{ mW/cm}^2$  but after passing through the atmosphere some of it is scattered, while the density of solar power that reaches the earth's surface during clear daylight is around  $100 \text{ mW/cm}^2$ .



Figure 1.1 types of solar panels

### Solar Power Generation (PLTS), can be applied as follows:

1. Solar power for lighting at home.
2. Solar power for street lighting (PJU)
3. Solar power for garden lighting
4. Solar power as a source of electricity for CCTV cameras
5. Solar power as a source of electricity for wireless installations (WIFI), radio transmitters, communication devices and others.

### The advantages of solar panels as PLTS are:

1. Able to supply electricity to locations that have not been reached by the PLN electricity network so that it can be used in remote areas.
2. Solar electricity is a fast solution, because the installation process is relatively fast to produce electricity for lighting and other things

3. Solar energy is very clean energy, because its physical properties can absorb UV radiation (from sunlight), do not produce any emissions, do not make noise and do not require fuel.
4. Solar cells are semiconductor materials where solar radiation is directly converted into electrical energy. The material often used to make solar cells is crystalline silicon. The working principle of a solar panel is that if sunlight hits the solar panel, the electrons in the solar cell will move from N to P, so that the output terminal of the solar panel will produce electrical energy.

### **Solar Panel Optimization**

In order for the solar panels to function optimally, we try to place the solar panels in the direction of the rising sun so that the intensity of the sun's light can be absorbed optimally, but when the implementation is carried out, we install the solar panels in a straight position facing north and in a position 90 degrees away from Sunrise. This is due to several factors such as the obstruction of the rays of the rising sun being blocked by towering trees and also the supporting terrain for placing the solar panels is very fragile, therefore we place them in a straight position because their position can support the load of the solar panels strongly.

### **Gain voltage and current entering the battery**

The intensity of sunlight absorbed by the solar panels produces a voltage. After analysis, the voltage changes as the day progresses from morning to evening, where the power absorbed decreases significantly in the afternoon and is relatively stable and increases not too significantly in the morning. towards noon. Gain of Energy expended

graph of the voltage and current obtained from the operating system to be given to the load. After analysis, there was a significant increase in consumption electricity used as it goes along the future time the load will be used, namely on the lamp load.

### **Conclusion**

Based on the results of measurements, data collection trials, and overall analysis, this study concludes that converting a 12V DC battery voltage to 220V AC requires a 1000-watt inverter, with solar panel voltage averaging 16.7V and stable battery charging at 13.5V regulated by a Solar Charge Controller (SCC). The most effective battery charging time is between 07:00 and 13:00 WIB, with peak current flow from 10:00 to 13:00 WIB. Panel installation plays a crucial role in ensuring safe and efficient power distribution, yet challenges such as faulty wiring, improper load distribution, inadequate grounding, and regulatory non-compliance can lead to inefficiencies and electrical hazards. Advancements like smart panels, IoT-based monitoring, and automated circuit breakers enhance safety and efficiency through real-time fault detection and predictive maintenance. To improve installation practices, this study recommends using advanced load calculation tools, ensuring high-quality wiring and grounding, complying with national and international electrical standards, adopting smart panel technologies, and providing continuous training for electricians. Additionally, it is suggested to conduct regular maintenance checks, integrate renewable energy sources into panel systems, and develop automated safety shutdown mechanisms to prevent system failures and enhance long-term reliability in residential, commercial, and industrial applications.

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