

Fast charging station based on hybrid solar panels and Grid

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ABSTRACT

The growing number of electric vehicles (EVs) has increased the demand for fast and sustainable charging infrastructure. Currently, most charging stations in Indonesia rely heavily on electricity from the national grid (PLN), resulting in high operational costs, especially during peak hours. On the other hand, the potential of renewable energy sources, such as solar power, has not been optimally utilized. This final project aims to design and develop a hybrid fast-charging station prototype that combines power sources from PLN (60%) and solar panels (40%). The system is designed to support the charging needs of electric motorcycles produced by PT Len Industri (Persero), using fast-charging technology that is efficient and environmentally friendly. Testing is conducted to ensure the system provides a fast, stable charging solution while reducing dependence on the conventional power grid. The results of this project are expected to contribute to the development of a more sustainable national electric vehicle infrastructure.

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1. INTRODUCTION

The increasing number of Electric Vehicles (EVs) worldwide is one of the strategic steps in reducing carbon emissions and dependence on fossil fuels. However, accelerating the adoption of electric vehicles requires adequate supporting infrastructure, especially in terms of charging stations. Fast charging stations are a major need, given the much shorter charging time compared to the usual charging method, where fast charging is able to charge an electric vehicle battery up to 80% in about 30-45 minutes, while the usual charging method (slow charging) can take 6-8 hours for a full charge, IEA [1]. On the other hand, energy sustainability issues encourage the utilization of renewable energy sources, such as solar panels, as a solution to reduce dependence on conventional power grids. The integration of solar panels on charging stations can reduce the load on the PLN power grid by up to 30%, while reducing carbon emissions generated by the fossil fuel-based electricity production process [2].

Solar power and batteries can be an innovative and sustainable solution. The utilization of solar power is expected to reduce dependence on conventional power grids and also provide a more environmentally friendly alternative. By utilizing solar panels, this charging station can provide sufficient energy for charging electric vehicles in a sustainable manner. Because full dependence on PLN's electrical energy for charging stations can increase the burden on the electricity network, especially during peak load times which in Indonesia generally occur between 17:00 and 22:00 WIB. This is in accordance with the PLN report which states that the peak load in 2024 reached 61,287.80 MW, an increase of 5.15% compared to the previous year [3]. The successful utilization of PLN and PLTS electricity resources optimally, reducing dependence on fossil resources and increasing the use of renewable energy has discussed in [4]. However, the research is only in a panel box that cannot be moved and is not yet based on fast charging and is only limited to electric vehicles with a maximum voltage limit of only 36 V. In an effort to overcome this problem, the development of hybrid-based electric vehicle charging stations by combining two energy sources between

PLN electricity and solar power. Charger station, or Electric Vehicle Charging Station (EVCS), is an infrastructure designed to provide electrical energy to electric vehicles (EVs). Charger stations play an important role in supporting the transition from fossil fuel vehicles to electric vehicles. This infrastructure enables efficient charging, both in public and private locations [5].

2. METHOD

Hybrid charger stations combine various energy sources, such as energy from the electricity grid (PLN) and renewable energy (solar panels, wind, or storage batteries). The use of solar panels on charging stations can reduce electricity consumption by up to 40% during the day, especially in regions with high sun exposure. Hybrid systems also offer power backup when the PLN network is disrupted [6]. A motor charger is a device used to charge the battery of a two-wheeled electric vehicle, such as an electric motor, by converting electrical energy from a power source (such as the PLN power grid or solar panels) into energy that can be stored in the battery. The motor charger is designed to ensure efficient, safe charging, and in accordance with battery specifications [7].

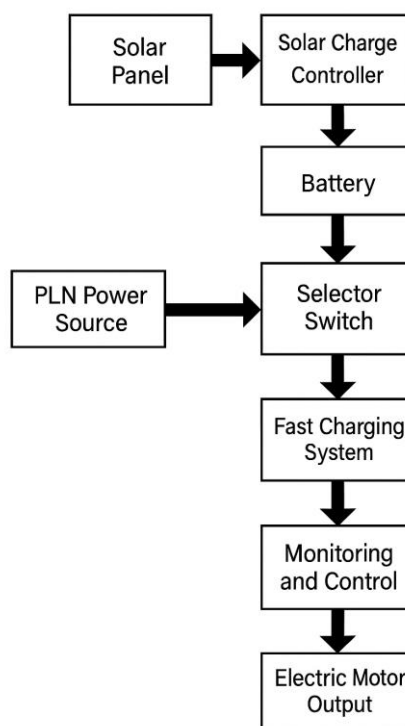


Figure 1. Block Diagram

The performance of solar panels is affected by sunlight intensity, ambient temperature, and photovoltaic cell module efficiency [8]. SCC or Solar Charge Controller is a device that regulates the flow of power from the solar panel to the battery to prevent overcharging and ensure optimal charging. SCC plays an important role in increasing the efficiency and lifespan of batteries in photovoltaic systems [9]. The function of this SCC is to regulate the amount of current and voltage from the solar panel to match the battery specifications, prevent the battery from overcharging which can damage the battery, prevent the backflow of electricity from the battery to the solar panel at night or when the panel does not produce electricity and disconnect the load from the battery when the battery voltage drops below a certain threshold [10]. The battery serves as an energy storage component in a solar panel system to provide electricity when solar energy sources are not available (e.g., at night) [11]. Selector switches help ensure that the system runs according to user needs and available resource conditions [12].

A flowchart or also referred to as a flow chart is a diagram that shows what steps must be taken to execute a process in a program. Diagrams connected through lines or arrows indicate each step. Flowcharts are very important when choosing steps or features to create programs that involve many people simultaneously. In addition, the diagram will make the flow of the program clearer and more concise. Figure 2 shows a flowchart.

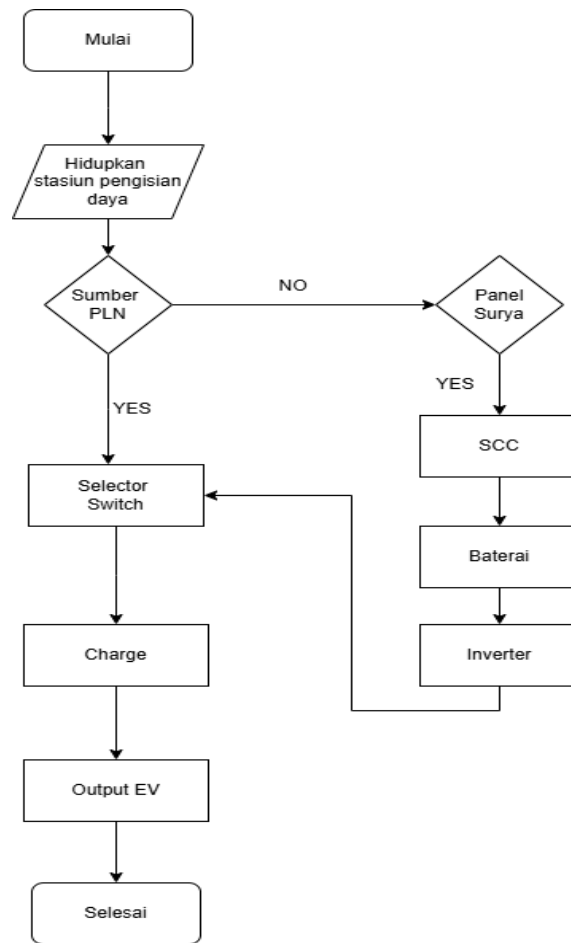


Figure 2. Flowchart

Hardware design consists of mechanical design and electrical circuit design. The design for mechanics is to make a mechanical design form of the tool system and electrical design, namely making electrical circuits that will be used in the tool.

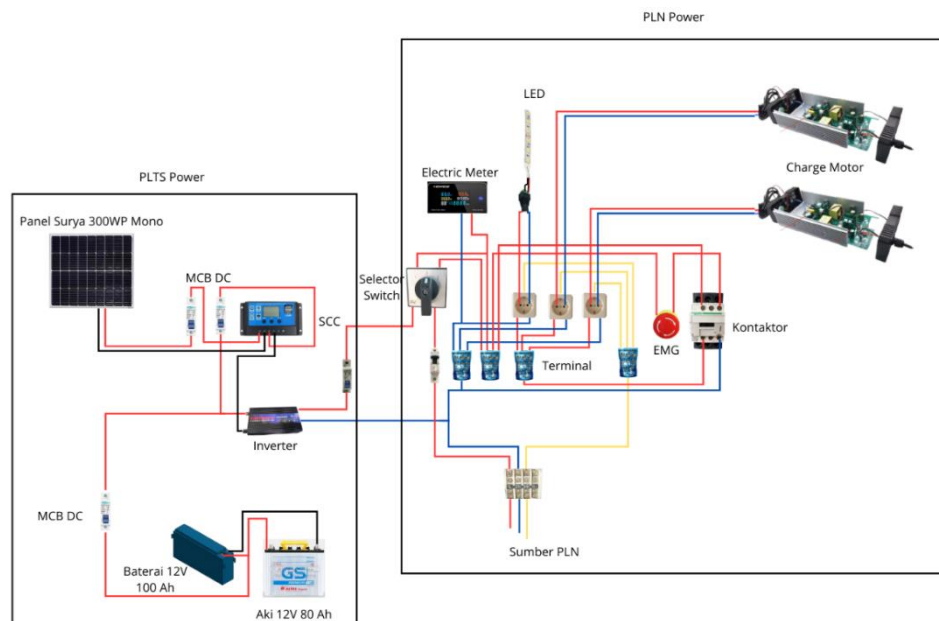


Figure 3. Schematic circuit

In this circuit has constituent components, for a circuit that will use solar panels starting from 300 WP mono solar panels then heading to the SCC then the battery will store energy from solar panels which will be channeled to the inverter to be converted into AC voltage then will go to the selector switch for later activated if it is using a source from solar panels. While the source from PLN itself goes directly to the selector switch to be activated later if it is using a source from PLN. Inverters are electronic devices that function to convert direct electric current (DC) into alternating electric current (AC) at a certain frequency and voltage, inverters are used in renewable energy systems such as solar panels to convert the power generated by solar modules (DC) into AC power that can be used by household appliances or integrated into the power grid [13].

Mechanical design aims to provide an overview of the physical form of a series of mechanical devices that are useful for knowing the placement of the position of components or parts so that they can function as desired when the program is run. This mechanical design is made in 3D using solidwork software and this can also help facilitate the assembly process.

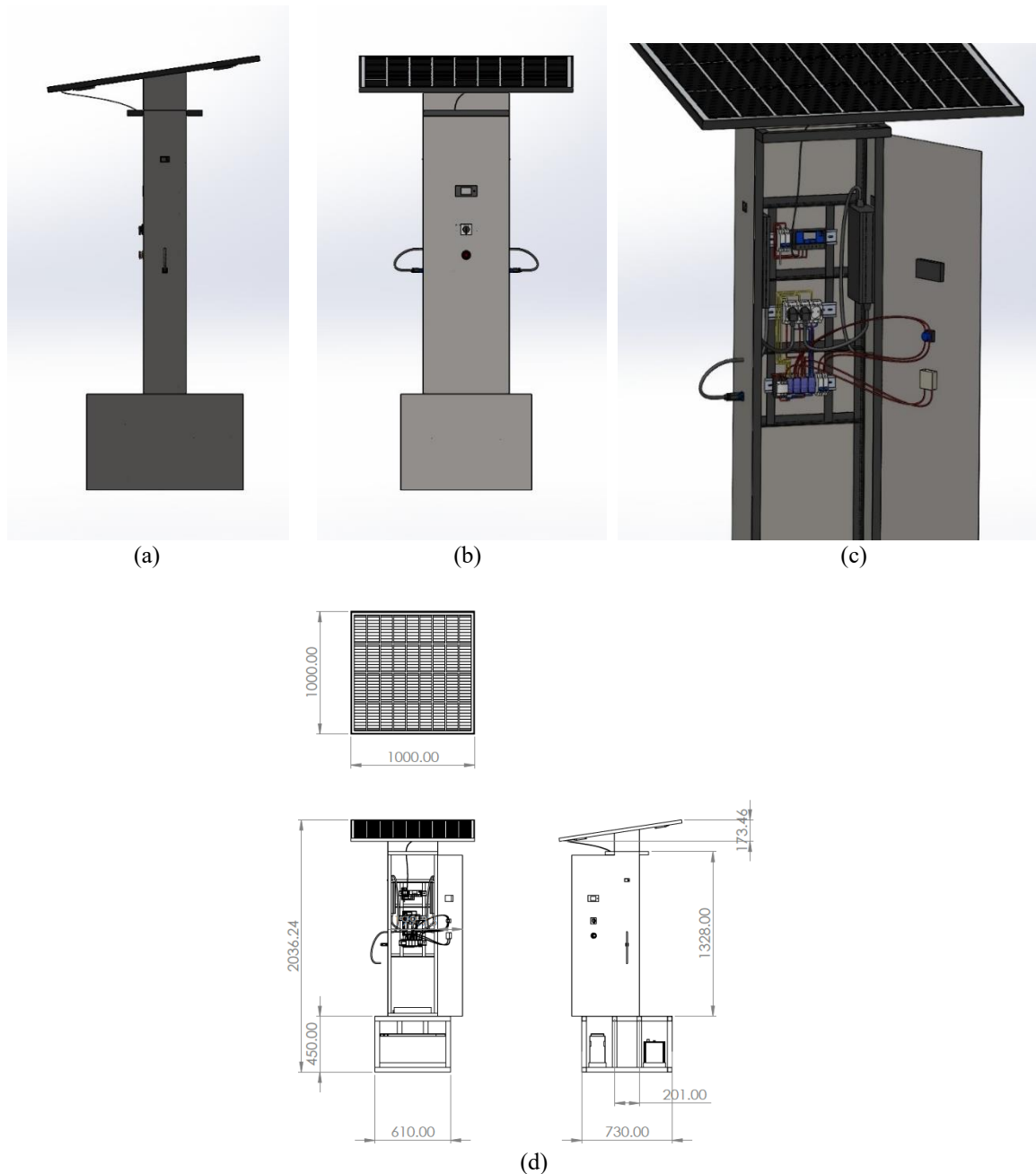


Figure 4. Hardware design (a) Side part, (b) Front part, (c) Inside part, (d) Design dimension

This hybrid-based fast charging system is designed to charge electric vehicles (EVs) using two energy sources, namely solar energy sources (solar panels) and energy sources from PLN. The SCC controller and Inverter regulate the current and voltage from the solar panel to be efficient, as well as perform DC to AC conversion. Solar charge controller is an important component in a solar power generation system, functioning to regulate the voltage and electric current entering from solar panels to the battery or load system so that overcharging or overdischarging does not occur [14]. The switching selector switch system manages manual switching between the use of solar panels and PLN based on energy availability. The fast charging unit (EV Charger) is able to provide high power to accelerate the charging process of electric vehicle batteries. The purpose of this system is to optimize the use of renewable energy and reduce the burden of electricity usage from PLN, as well as provide fast charging for electric vehicles

3. RESULTS AND DISCUSSION

The purpose of the test is to determine whether the system is able to charge the electric vehicle battery in a shorter time than conventional charging and ensure that the charging voltage and current are in a safe and stable range, testing the integration and switching between energy sources from the PLN power grid and solar panels, this test aims to ensure that both sources can function alternately or simultaneously according to system conditions and power requirements. To determine the efficiency of power conversion from each energy source to the load (charger) and how much power loss occurs during the charging process, observing the stability of the system in maintaining the output voltage and current during the charging process, especially when there are fluctuations in the load or changes in the power source, ensuring that protection systems such as overvoltage, overcurrent, and source protection can function properly in abnormal or overload conditions, so that the system remains safe [15]. To evaluate the performance of the system under various operational conditions, such as during sunny, cloudy, nighttime, or when the load changes. This is important to see the extent to which the system can work optimally in the field. The following is a table for charging times.

Table 1. Charging time

No	Energy source	Output voltage (V)	Output current (A)	Battery capacity (Ah)	Estimated charging time	Description
1	PLN (Direct to Charger Fast Charging)	220 V AC (input) → 72 V DC (output)	20 A (maximum)	40 Ah	±1 hour 30 minutes	Stable, fast time, high efficiency
2	Solar Panel via 12V Inverter → Charger	67-72 V (fluctuating)	±14-18 A (average 15 A)	40 Ah	±3 hours 45 minutes - 4 hours	Depending on weather and inverter system efficiency

For 72 V 40 Ah motorcycle battery, test started from ±20% capacity (≈32Ah to charge). The theoretical time can be found using the formula:

$$\text{Time} = \frac{\text{Energi yang diperlukan (Ah)}}{\text{Arus output (A)}}$$

The PLN source shows more stable performance and faster time. Solar panels experience fluctuations depending on solar intensity and inverter efficiency (usually only 80-90%). This hybrid system uses 300 WP monocrystalline solar panels which are fed through a PWM solar charge controller (SCC) to two paralleled 12V batteries (100Ah + 84Ah), then converted by a 12VDC-220VAC inverter before entering the fast charging charger. The charger output voltage from the solar source tends to drop as the load increases. The output current is still able to approach the target (up to ~19 A), but it is not ideal for constant fast charging. A drop in inverter voltage indicates the inverter is working close to its limits, indicating insufficient power from the battery for continuous heavy loads. Weather and light intensity greatly affect the output performance of the solar system. The PLN source is directly connected to the charger input (220V AC), then produces 72V DC at the output with a maximum current of 20A. Furthermore, the energy conversion efficiency used in this charging station is to calculate the ratio between the incoming power from the energy source (PLN or solar panel) and the power received by the battery.

$$\text{Efficiency} = (\text{Output Power} / \text{Input Power}) \times 100\%$$

Table 2. Energy conversion efficiency with solar panels

No	Time	Input Power from Panel (W)	Output Power to Load (W)	Efficiency (%)	Description
1	10:00 AM	200	140	70%	Sunny weather, optimal conversion
2	11:00 AM	220	150	68%	Inverter is slightly hot
3	12:00 AM	250	165	66%	Efficiency decreased due to inverter load
4	13:00 PM	180	115	63.9%	The weather is getting cloudy
5	14:00 PM	150	90	60%	Low efficiency due to solar intensity

Table 3. Energy conversion efficiency with grid

No	Charging Condition	Input Power from PLN (W)	Output Power to Motor Battery (W)	Efficiency (%)	Description
1	Start of charging	1550	1400	90.3%	High efficiency
2	Full fast charging	1600	1440	90.0%	Stable voltage and current
3	Battery 80%	1200	1080	90.0%	Charger start taper
4	Charging end (cutoff)	600	500	83.3%	Power decreases, efficiency drops

The difference in energy conversion efficiency in this hybrid-based fast charging system is clearly visible between PLN and solar panel electricity sources. Charging using PLN electricity shows a higher conversion efficiency, reaching more than 85%, because energy from the grid is directly used by the charger without going through additional storage or conversion processes. In contrast, in the solar panel route, the conversion efficiency is relatively lower, ranging from 65% to 75%, due to several stages of energy conversion, namely from the solar panel to the battery through the solar charge controller, then from the battery to the inverter, and finally to the fast charging charger. This shows that although solar panels are more environmentally friendly, in terms of energy conversion efficiency, the PLN line is still superior under current system conditions.

4. CONCLUSION

The hybrid fast charging system was successfully designed and realized by utilizing two energy sources, namely PLN electricity and 300 Wp solar panels combined with 12 V 100 Ah and 84 Ah batteries in parallel. The use of a PWM type solar charge controller (SCC) allows charging the battery from the solar panel efficiently with stable voltage and current control. The energy stored in the battery is then converted using a 12 VDC to 220 VAC inverter to be used as an alternative source to the fast charging charger. The fast charging charger used has an output of 72 V with a maximum current of 20 A, so as to speed up the charging process of electric vehicle batteries compared to conventional methods. The test results show that the efficiency of energy conversion from solar panels to loads through batteries and inverters ranges from 65% to 75%, depending on the intensity of sunlight, battery conditions, and loads. Meanwhile, the charging efficiency directly from PLN to the charger shows an efficiency above 85%. With this hybrid system, users can reduce dependence on conventional power sources, as well as provide a more environmentally friendly and energy-efficient charging solution, especially in areas with high sunlight intensity. The system also provides flexibility and sustainability, as it can continue to operate even if one of the energy sources (PLN or solar) is not available.

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