Coin-Operated Public Electric Vehicle Charging Station with Solar Panels as the Energy Source

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Abstract *– Electric transport is becoming increasingly popular as another option to use environmentally friendly energy in the form of transport. To support the development of electric transport, efficient and accessible charging infrastructure is required. Public Electric Vehicle Charging Stations (SPKLU) have become a major part of supporting long-distance travel and reducing the impact of greenhouse gas emissions on the environment. To increase the availability of SPKLUs and expand accessibility for electric vehicle users, this research aims to design an innovative coin-based SPKLU system that also utilizes solar energy through solar panels. The station can have a smaller environmental effect and lower operating costs by employing solar energy as its primary source. The examination included a review of the economy as well. As a result, those in charge, business owners, and communities who want to promote the usage of electric vehicles find it to be a desirable alternative. As a result of this research, it was found that a full charge of a 20Ah battery only requires a coin of Rp 7000.*

Keywords*: solar panel, charging stations, SPKLU, electric vehicle*

I. Introduction

In the past few years, there has been a notable increase in public attention towards sustainable transportation, driven by a heightened environmental consciousness regarding the detrimental impacts of greenhouse gas emissions and reliance on fossil fuels[1]. To mitigate pollution and decrease dependence on traditional fuels, electric vehicles have gained prominence as a viable alternative[2]. A suitable infrastructure for charging, however, is one of the obstacles associated with the advancement of electric car technology[3].

Public Electric Vehicle Charging Stations (SPKLU) are key in driving the adoption of electric vehicles by providing easy and convenient access to battery charging[4][5]. The Indonesian government's support for electric cars is stated in Presidential Regulation No. 55/2019 on the Acceleration of Battery-Based Programmes for Road Transportation[6]. It also discusses the incentives that will be provided to encourage the acceleration of the conversion of electric-based vehicles[7].
However, the limited availability of SPKLU and dependence on conventional energy resources have become obstacles in the development of electric vehicle charging infrastructure[8]. In this context, this research aims to design and develop an innovative concept for SPKLU that addresses some of these challenges[9]. This approach will integrate coin-based charging and the utilization of solar panels as an alternative energy source[10]. The use of coin acceptors as payment receivers provides flexibility to electric vehicle users to pay only according to their needs, while solar panels help reduce dependence on conventional energy sources[11]. In terms of planning, the system has a simple workflow. When the solar power plant absorbs light, the electricity generated will be stored in the battery of the SPKLU prototype. And when the coin acceptor receives the coin. The part will be read

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and calibrated, then the amount of energy obtained from the coin. The coin data will be sent and processed by the Wemos D1 mini, then the coin value will be read by the LCD screen. The PZEM 004 sensor acts as a measure of the energy used, which is then displayed on the blynk application.

I.1 SPKLU

A Public Electric Vehicle Charging Station (SPKLU) is an infrastructure used for charging electric vehicles such as electric cars, hybrid cars, and other electric vehicles[12]As the name implies, SPKLU is a place where electric vehicles recharge their battery power on their electric vehicles[13]. The existence of charger stations needs to be increased to support the growing number of electric vehicles in Indonesia. SPKLU in Indonesia was built by PLN and also by other parties. SPKLU built by other parties is referred to as SPKLU non-PLN. Based on an online survey, the following are the locations of non-PLN SPKLUs that have been built in 2021 and 2021.

TABLE 1. LOCATION AND NUMBER OF NON-PLN SPKLU

No	Location	Owner	Total
1	Jakarta, BPPT Thamrin	BPPT	1
2	Banten, B2TKE - BPPT Serpong	BPPT	2
3	Sumba, BPPT	BPPT	1
4	Bandung, BPPT-LEN	BPPT - LEN	1
5	Jakarta,Kuningan Gas Station	Pertamina	4
6	Jakarta, Pertamina Centre	Pertamina	1
7	Jakarta, Plaza Indonesia	Mercedez beruz	1
8	Jakarta, Pacific Place	Tesla	2
9	Jakarta, Mampang Blue Bird	Blue Bird	12
10	PLTA Cirata	PJB	2
11	Banten, Bandung Soekarno Hatta	API	2
12	Jakarta	Transjakarta	1
13	Jakarta	Mitsubishi	15
14	Banten, Pool grab BSD	Grab	20
	Total		65

1.1. Solar Panels

Fig 1. Solar Panels

Solar panels are electronic devices designed to capture solar energy and convert it into electrical power[14]. Embracing solar panels offers significant advantages such as mitigating greenhouse gas emissions, lessening dependence on fossil fuels, and yielding long-term cost savings on electricity[15]. While the initial investment for the installation and purchase of solar panels may be relatively high, ongoing technological advancements are expected to drive down costs, leading to enduring economic and environmental benefits[16]. In the realm of small-scale solar power systems, typical configurations involve solar modules with peak power ranging from 50 to 100 Wp, generating approximately 150 to 300 Wh of electricity per day[17]. In this study, solar panels with a size of 100 Wp will be used. And a 12Ah battery with an initial current of 3.6A. So can be calculated to fully charged solar panel battery can be calculated by the formula[18]

$$Times = \frac{battery\ capacity}{Current}$$

$$Times = \frac{12}{3{,}6}$$

$$= 3{,}3\ hours$$

From the calculations obtained to fully charge the battery in SPKLU is 3.3 hours but the heat factor and weather intensity are also quite influential on how quickly the battery can be fully charged.

I.2 Coin Acceptor Multi

A coin acceptor is an electronic device designed to accept and identify physical coins inserted into it[19]. This coin acceptor functions as a sensor to detect whether the coins inserted by consumers into the

SPKLU are coins as specified in the design[20]. Coin Acceptors can read coins by distinguishing their diameter but can now distinguish coins by measuring frequency, resonation, and metal detector[21].

To determine the shape and number of coins to be used, it is necessary to calibrate the coin acceptor[22]. Calibration is done by entering coins with the same value 20 times with different coins so that the reading accuracy becomes accurate[23]. After calibration, it can be checked that the unregistered coin will come back out and not be accepted by the coin acceptor[24]. In this study, researchers used a reference coin of Rp 500 yellow, Rp 500 white, and Rp 1000. The following is the coin-checking table of the reference coin.

Fig 2. Coin Acceptor Multi

Reference coin Rp 500 yellow

TABLE 2. REFERENCE COIN 500 YELLOW

No	Rp 500 (K)	Rp 500 (P)	Rp 1.000
1	√	×	×
2	√	×	×
3	√	×	×
4	√	×	×
5	√	×	×

Reference coin Rp 500 White

TABLE 3. REFERENCE COIN RP500 WHITE

No	Rp 500 (K)	Rp 500 (P)	Rp 1.000
1	×	√	×
2	×	√	×
3	×	×	×
4	×	√	×
5	×	√	×

Reference coin Rp 1000

TABLE 4. REFERENCE COIN RP1000

No	Rp 500 (K)	Rp 500 (P)	Rp 1.000
1	×	×	√
2	×	×	√
3	×	×	√
4	×	×	√
5	×	×	√

The table 4 is a coin check after calibration, the √ sign means the coin is read according to the reference, while the × sign means the coin is not read. When checking the 500 white reference some coins are not read. This is because the coin that was inserted was damaged. Therefore, the coin is not read.

II. Research Method

The research method applied is a case study, where we selected one location to build a prototype coin-based Public Electric Vehicle Charging Station (SPKLU) with solar panels. The research methodology includes financial analysis and energy performance monitoring over a certain period. Financial data involves operational costs, revenue from coin usage, and total power obtained in each coin. Meanwhile, energy performance monitoring involves measuring energy production from solar panels and energy usage by charged vehicles. The following is a flowchart of the coin-based SPKLU design method with solar panels as the energy source.

Program Flowchart

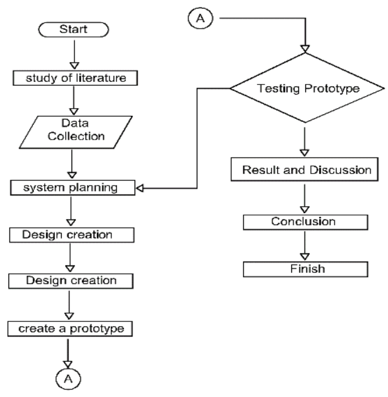


Fig 3. Design system flow diagram

The program will run when the coin acceptor is connected to the solar panel, and the LCD can be lit up. The initial display of the LCD will show the name of the PKM Group. Then the display "Welcome

Insert coin" will appear. When the coin acceptor inserts a coin. The sensor on the coin acceptor will read it which will then be forwarded to Wemos. Wemos will act as a controller that calculates and determines how much energy can be generated from the inserted coin. This data will be forwarded to the Pzem sensor which can finally be read by Blynk. The LCD will show the number of coins and the coin's energy output after it has been counted. Then, after plugging the electric car into an accessible outlet, the starter button is pressed to begin the charging procedure. The LCD will show how much energy is used up while the device is charging. When finished, the LCD will display “Finish”.

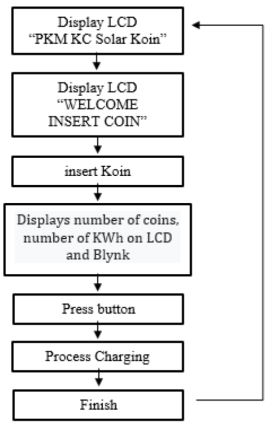


Fig 4. Prototype performance flow diagram

2.2 Design Stage

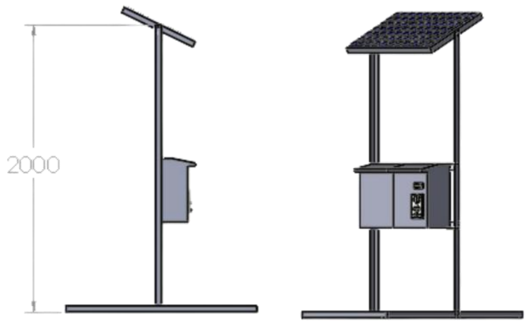


Fig 5. SPKLU 3D Design

The design stage of the coin-based SPKLU Prototype with solar panels as an energy source is intended to provide an overview of the physical form and system to be run. The 3D design shown is the result of design from Solidworks 2019 software.

The design is made in such a way by considering various things so that the absorption of solar energy can be done optimally. The frame design is made using strong angle iron so that it can support the panel box, battery, solar panel, and other components placed in the panel box. The design is made with the appropriate size so that it can be used and accessed easily by consumers.

Fig 6. The SPKLU design is coin-operated

Electrical Design

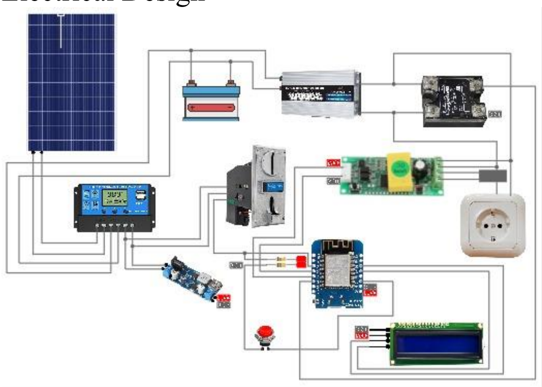
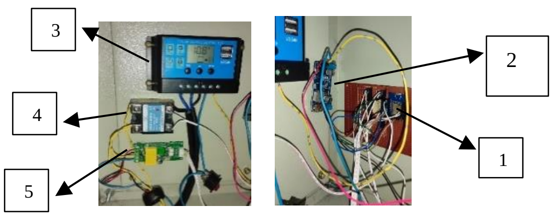


Fig 7. Electrical design

III. Results and Discussion

This chapter will explain the results of the prototype design that we made. The results obtained will be used as a basis for conclusions and evaluation for future development. The following is a snapshot of the component placement of the prototype we made. The placement of these components is done according to design and takes into account ease of access and material efficiency. The placement of components is coated with an insulator behind it so that it is safe and there is no short circuit. The following is the assembly placement of the coin-based SPKLU with solar panels as an energy source.



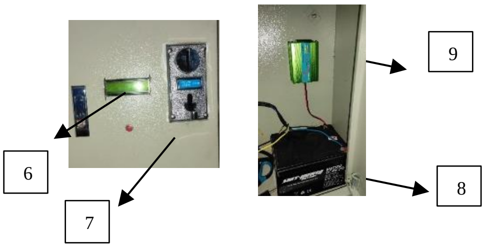


Fig 8. Assembling SPKLU

1 - WEMOS D1 mini
2 - Step down 12-5V
3 - Solar Charger controller
4 - Solid state relay
5 - PZEM-004 T
6 - LCD I2C
7 - Coin Acceptor
8 - Battery
9 - Inverter 220

Here is the initial display of the LCD when it is switched on.

Fig 9. SPKLU initial display

In addition, the LCD also displays how to use this SPKLU Prototype. Such as commands to enter coins, the number of coins converted, and notification when charging is complete.

Fig 10. CD Display

In addition to the LCD found on the SPKLU. We also utilize Blynk from Wemos to monitor the amount of energy that has been used in the SPKLU. This monitoring will later be used to determine operational and maintenance costs as well as evaluate the effectiveness and feasibility of coin-based electric vehicle charging stations with solar panels as an energy source. The following is a BLYNK view of a coin-based SPKLU with solar panels as an energy source.
as an energy source.

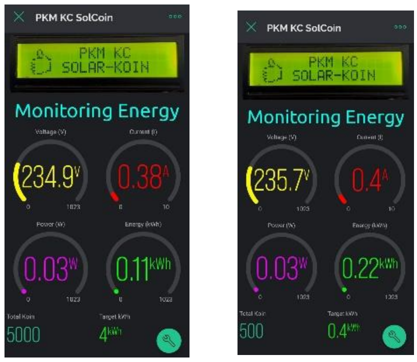


Fig 11. Blynk View

To get the efficiency of this SPKLU design, the first thing to do is to calculate the conversion of coins to kWh. In the calculation, the results are obtained as shown in the table 5.

TABLE 5. CONVERTS A TOTAL OF COINS TO KWH

No	Coin		Total
1	Rp	1.000	0.8
2	Rp	2.000	1.6
3	Rp	3.000	2.4
4	Rp	4.000	3.2
5	Rp	5.000	4.0

The above results are the result of calculations and price references set by PLN, which is for 1 Kwh valued at around Rp. 1,300. therefore for a coin of Rp. 1000 the result is around 0.8 Kwh.
In addition, in the charging experiment, we tried using several coins and produced the time until the end of charging as follows.

TABLE 6. TIMES CHARGING

No	Total coin		Times Charging
1	Rp	1000	56 Minutes
2	Rp	2000	2 hrs 5 mins
3	Rp	5000	4 hrs 45 mins

In addition to the table 6 data, we also calculate how much power is needed to fully charge 1 electric

bicycle. using an electric bicycle with a 48V/20Ah battery capacity with a charger power of about 144 watts. Then it can be calculated
48 × 20 = 960 wh

$$Times = \frac{960}{144} = 6{,}6$$

$$Total\ Kwh = \frac{960 \times 6}{1000} = 5{,}7Kwh$$

$$lots\ of\ Coin = \frac{5{,}7}{0{,}8} = 7$$

So for the battery charger to be fully charged takes about 6 hours. And requires about 5.7 kWh of power. Therefore, for 1-time charger, it is estimated that it requires 7 coins of Rp 1000 to be fully charged. This is considered quite economical than conventional vehicles need quite a lot of money to fill the tank of an electric vehicle.
The operation of the coin-based SPKLU with solar panels itself can be considered quite economical. Apart from being seen from the payment side. The installation cost is quite simple because it can be installed on the roof of the SPKLU. The energy generated from this solar panel is very high. From the monitoring results of the prototype made, the following data were obtained:

TABLE 7. SOLAR PANEL ABSORPTION VOLTAGE

Times	Voltage Battery
09.00	12.45
10.00	13.22
11.00	14.40
12.00	14.40
13.00	14.40
14.00	14.40
15.00	13.75
16.00	13.45
17.00	13.00

From the table 7 taken from the Solar Charger Controller monitoring, it can be seen that starting at 11.00 the voltage generated from the solar charger reaches the maximum limit that has been set on the installed solar charger controller. This means that the battery gets a high energy supply from the absorbed light intensity. The maximum absorption time continues until 14.00. This means that the area used for laying coin-based SPKLU with solar panels as an energy source has great potential for further development.

The figure 12 is a graph of the energy absorption voltage monitoring.

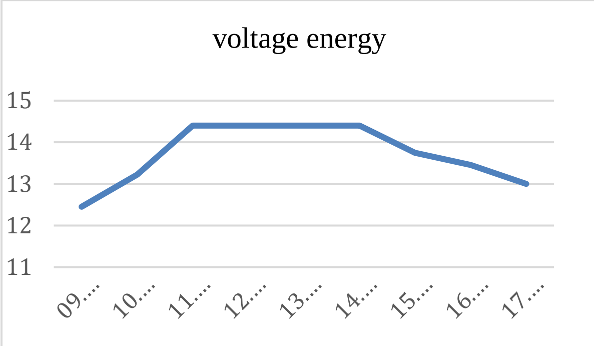


Fig 12. Energy absorption voltage monitoring

However, from the data that has been displayed above, this research also has some limitations. Further development is needed regarding the reliability and security of coin-based payment systems. In addition, economic and regulatory aspects related to the operationalization of coin-based electric vehicle charging stations need to be considered in depth.

IV. Conclusion

The study's finding is that this coin-based charger station can get beyond the drawbacks of the existing electric vehicle charging infrastructure. This may promote greater usage of electric vehicles and lessen reliance on fossil fuels, potentially lowering greenhouse gas emissions and hurting the environment. The conversion results obtained are 1 Rp 1000 coin can produce 0.8 Kwh. To do a full charger for a 48/20 Ah battery size requires a coin of Rp 7000. Seeing the energy absorption from the solar panel itself is quite good, making this coin-based SPKLU with solar panels as an energy source can be an attractive and sustainable investment in supporting the energy transition and the development of electric vehicles in Indonesia.
Overall, this study offers a solid groundwork for designing and putting into operation coin-operated electric vehicle charging stations that use solar energy. It is intended that this research can act as a springboard for more work on fixing the problems with electric vehicle charging infrastructure and promoting the broad use of electric vehicles to achieve sustainable transportation.

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