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by Akun Cek

Designing a Flexible Charging System Prototype for Electric Car Sunroofs Using 100wp Solar Panels Based on IoT

Abstract – *Limited access to charging infrastructure can create serious limitations for electric vehicle users, especially in situations where public charging stations are not available. To address this issue, this study proposes a flexible solar-based backup charging system integrated on the sunroof of an electric vehicle. Flexible solar panels were selected because their lightweight and adaptable structure allows installation on curved and limited surfaces such as vehicle sunroofs without major structural modification, enabling practical on-vehicle energy generation. The proposed system uses a 100 Wp monocrystalline flexible solar panel, an MPPT charge controller, a 48 V 15 Ah $LiFePO_4$ battery, protection circuits, and an ESP8266-based IoT monitoring module connected to the Telegram platform for real-time monitoring. Experimental testing was conducted under direct outdoor sunlight conditions to evaluate solar panel performance, MPPT efficiency, battery charging characteristics, protection functionality, and monitoring accuracy. The results show that the solar panel produced a maximum output power of 96 W under peak sunlight conditions, while the MPPT operated with an efficiency ranging from 88% to 94%. During the three-day test period, the battery State of Charge (SoC) increased gradually from its initial level of 0% to 60%, indicating stable and controlled charging performance. The IoT monitoring system was able to transmit voltage, current, power, and SoC data in real time with update intervals of approximately 5–10 seconds. Comparison with a calibrated digital multimeter showed measurement differences of less than ±2%, confirming the accuracy of the monitoring system. These results indicate that the proposed system can serve as a practical and reliable emergency backup charging solution for electric vehicles, while allowing users to monitor charging conditions remotely.*

***Keywords**: solar panel, electric car sunroof, IoT, flexible charging*

I. Introduction

The trend of electric vehicles (EVs) has been on the rise in Indonesia and around the world in recent years. As part of the Indonesian government's efforts to reduce carbon emissions and decrease its dependence on fossil fuels, it has established a strategy to accelerate the adoption of electric vehicles [1]. However, the lack of charging infrastructure is a major obstacle to the implementation of EVs, especially in areas that do not yet have a network of Public Electric Vehicle Charging Stations (SPKLU) [2]. This situation causes range anxiety, which is the concern of users about running out of battery power in locations with insufficient charging facilities.

To overcome this limitation, a number of studies have begun to look at renewable energy —specifically solar panels installed on vehicles —as an alternative. In the literature, this concept is called Vehicle-Integrated Photovoltaics (VIPV). VIPV offers a portable, environmentally friendly, and off-grid charging solution that can serve as an emergency power source in situations where access to SPKLU is not available [3], [4].

In emergency situations, users need to know the available battery capacity and charging status in order to make immediate decisions, such as whether the vehicle can continue operating or needs to stop for energy conservation. Therefore, real-time monitoring through IoT platforms becomes essential, as it allows users to remotely monitor voltage, current, power, and battery condition instantly without needing direct physical access to the system. This capability is particularly important when the vehicle is located far from charging infrastructure, as it provides timely information that helps users manage limited energy resources more effectively [5]. ~~This real-time accessibility becomes especially valuable when the vehicle is far from charging infrastructure, helping users manage limited energy more confidently and effectively.~~

Compared to grid-based charging, the energy

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produced by solar panels installed on vehicles is relatively limited. In addition, many previous studies have evaluated solar panel performance under static laboratory conditions using conventional rigid panels [6]. These panels are generally heavier, thicker, and require flat installation surfaces, making them less suitable for integration into vehicle structures. In contrast, flexible solar panels offer advantages in terms of lighter weight and the ability to follow curved surfaces, such as vehicle roofs or sunroofs. Furthermore, when installed on actual vehicles, solar panels are exposed to real operating conditions, including continuous sun exposure, temperature variations, and vibrations during vehicle movement [7]. These factors can influence system performance but are not fully represented in static testing environments.

Therefore, evaluating the system under conditions closer to real applications becomes important to obtain more realistic performance resultsCompared to charging sources from the electrical grid, the amount of energy generated by solar panels installed on vehicles is relatively small. In addition, many previous studies have evaluated solar panels under static conditions using conventional rigid panels, which are generally thicker, heavier, and require larger installation areas. These characteristics make them less practical for mobile applications because they cannot be easily integrated into vehicle structures or transported flexibly. In contrast, flexible solar panels can be installed directly on curved vehicle roofs, such as sunroofs, following the contour of the surface. Furthermore, in real vehicle applications, the panels are also exposed to vibrations during travel and higher operating temperatures due to continuous sun exposure. These mechanical and thermal factors can affect the energy output and system efficiency, but cannot be fully represented through static testing.

Therefore, performance evaluation under real operating conditions becomes important to obtain more accurate and applicable results. However, energy from solar panels can help electric vehicles last longer in emergency charging situations [8]. A 100 Wp solar panel in Indonesia is estimated to be able to generate 400–800 Wh of energy per day under ideal conditions, with an average solar radiation potential of around 4–7 effective hours per day. Taking into account losses due to panel efficiency, temperature, system efficiency, and Maximum Power Point Tracking (MPPT) control, the clean energy available each day ranges from 300 to 600 Wh [9], [10].

This energy is equivalent to an additional range of approximately 2–8 km/day when converted to electric vehicle energy consumption of 150 Wh/km. Although its contribution to increasing daily mileage is not significant, this additional power is quite significant as a backup solution when SPKLU is not available within a close radius [11].

Advances in flexible solar panel technology now allow panels to be installed on limited or curved surfaces, such as sunroofs or vehicle roofs. Flexible solar panels have several advantages over conventional solar panels, including lighter weight, designs that can be adapted to the contours of vehicle surfaces, and easier installation [12]. Therefore, adaptable solar panels are the right choice for designing backup charging systems for portable and adaptable electric vehicles [13].

However, addressing range anxiety requires not only an alternative energy source but also an accessible monitoring system. Based on this need, this study proposes and demonstrates a flexible solar panel-based emergency charging system integrated on a vehicle roof and supported by an IoT-based real-time monitoring system using the Telegram platform [14]. The flexible solar panel enables direct integration with curved vehicle surfaces, while the Telegram-based monitoring system allows users to easily access charging information using commonly available smartphones without requiring specialized applications[15]. This combination provides both a practical emergency energy solution and accessible information, which together help improve user confidence and support better decision-making during emergency conditions [16].

Previous research has largely focused on analyzing the performance of static solar panels or studying the optimization of solar panel systems that are not directly integrated into electric vehicles as emergency charging solutions [11]. In addition, previous research has not typically tested the system directly on prototypes or in the context of application in electric vehicles. Unlike previous studies, this research concentrates on creating a prototype of a flexible 100 Wp solar panel-based charging system that is symbolically installed on a replacement roof structure for electric cars. Using ESP8266, which is connected to the Telegram messaging service, this system is designed to allow users to view system parameters such as voltage, current, power, and battery capacity in real time [12]. This system is intended to provide an emergency backup charging solution for electric vehicles in areas with low SPKLU levels [13].

LiFePO₄ batteries were used as the energy storage component in this study, and IMEI Team Umsida

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Formatted: Indent: Hanging: 0.01 ch, Left -0.01 ch, First line: -0.01 ch electric vehicle batteries were used as the prototype test object [[illegible]]. This battery was selected because it is the same type of battery used in the IMEI Team electric vehicle, allowing the proposed charging system to be directly tested on an actual electric vehicle energy storage system before future implementation on a real vehicle roof. This approach enables realistic prototype validation and ensures that the developed system is relevant to real-world electric vehicle applications. In addition, $LiFePO_4$ batteries offer good thermal stability and safety characteristics, which are important for solar-based charging systems operating under outdoor environmental conditions [18].

The 100 Wp flexible solar panel was selected primarily due to budget limitations, while still offering a lightweight structure, sufficient efficiency, and practical feasibility for prototype development. Its lighter weight makes it suitable for installation on vehicle roofs without adding significant mechanical load, while its power capacity remains adequate for emergency charging purposes [19]. Therefore, the 100 Wp panel represents a practical and efficient solution that balances cost, performance, and ease of integration in vehicle-based applications.

Furthermore, the ESP8266 microcontroller was used for the IoT monitoring system because it provides integrated WiFi capability, low cost, and sufficient performance for real-time data transmission, making it appropriate for prototype-scale implementation. To ensure measurement reliability, the voltage and current data obtained from the monitoring system were validated using an external digital multimeter as a reference instrument during testing [20]. This approach allows the study to contribute to the development of technology that supports the use of electric vehicles in Indonesia. In addition, the study offers practical solutions for implementing simple VIPVs on a real vehicle scale scale.

LiFePO4 batteries were used as backup batteries with specific capacities and voltages as prototype test objects in this study. IMEI Team car batteries were used as a representation of real and applicable energy sources in this study [16]. This method allows the study to contribute to the development of technology that supports the use of electric vehicles in Indonesia. In addition, the study offers practical solutions for implementing simple VIPVs on a real vehicle scale [20] .

II. Method

This research was conducted using a quantitative experimental Research and Development (R&D) approach, beginning with the identification of the problem of limited SPKLU infrastructure for electric vehicles, which drives the need for an emergency charging system. Next, a literature review was conducted to examine electric vehicle technology, solar panel characteristics, MPPT working principles, battery management, and IoT integration as the basis for system design [21].

II.1. *Tool Performance System Diagram*

The limited infrastructure of public charging stations for electric vehicles has driven the need for emergency charging systems. A literature review was then conducted to examine electric vehicle technology, solar panel characteristics, MPPT working principles, battery management, and IoT integration as the basis for system design [21]. Based on this review, a prototype was designed that included the selection and integration of key components such as a 100 Wp solar panel, MPPT charge controller, DC-to-DC boost converter, $LiFePO_4$ battery, protection system, and ESP8266-based IoT unit for real-time monitoring of voltage, current, power, and battery capacity data [22][23].

Electrical parameter measurements were performed using an INA219 sensor module to measure charging current and system voltage, combined with a 0–25 V voltage sensor module based on a voltage divider circuit to monitor higher voltage levels that exceed the direct input range of the microcontroller. The next stage is the assembly and implementation of the prototype according to the specified circuit diagram, followed by experimental testing to obtain system performance data, including energy charging efficiency, MPPT characteristics, and IoT monitoring performance[24]. The INA219 sensor was selected due to its high measurement accuracy, digital I2C communication capability, and suitability for real-time power monitoring applications. Meanwhile, the voltage divider-based sensor allows safe voltage scaling so that higher battery voltages can be measured reliably by the ESP8266 analog input [23].

To ensure measurement validity, the voltage and current readings obtained from the INA219 and voltage sensor module were calibrated and compared with an external digital multimeter used as a measuring instrument. This validation process was conducted under various charging conditions to confirm that the measurement error remained within an acceptable range for prototype-scale energy monitoring applications.

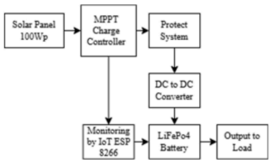

Fig. 1. Block Diagram

The 100 Wp solar panel-based flexible charging system generates solar energy and stores it for use when needed. The MPPT charge controller regulates the solar panel's energy to maintain its maximum power point regardless of light conditions. In addition, protected systems, such as fuses and other components, are protected from excessive current or damage [24]. Then, the safe energy is sent through a DC-to-DC converter to sensor meet the voltage requirements of the LiFePO4 backup battery. The battery management system (BMS) does this to protect the battery from overcharging, ~~overdischarging~~over discharging, and overheating [25]. When electric vehicles are in areas with minimal SPKLU, this backup energy can be used as an additional power source. This system is also equipped with an ESP8266 module for real-time monitoring, which sends voltage, current, power, and battery capacity data via Telegram~~telegr~~ notifications ~~[25],~~ [26].

The block diagram of the proposed system is shown in Fig. 1.

II.2 Solar Panel Charging Mechanism

The process from start to finish of a 100 Wp solar panel-based flexible charging system is illustrated in this flowchart. The flow begins when the solar panel captures solar energy and generates DC electricity [27]~~[26]~~. To ensure that the current and voltage generated are safe and do not damage system components, this current is then checked through protection components such as fuses and diodes .

After the initial check, the battery management system (BMS) checks the condition of the battery. The BMS checks whether the battery is properly connected and in a safe condition to receive a charge. If everything is safe, the energy is sent to the MPPT Solar Charge Controller, which serves to optimize the working point of the solar panel ~~-~~ [28]~~[24]~~. This allows the energy generated to charge the battery.

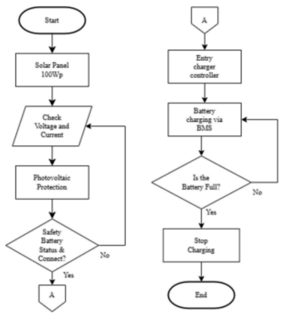

Fig. 2. Flowchart System

II.2 Circuit Design Schematic

The design process serves to regulate and operate the backup charging system in solar panel-based electric vehicles. The design of this device uses several components, which are described as follows: The circuit in the figure consists of a monocrystalline solar panel as a source of DC electrical energy, an MCB as a current and short circuit protector, a solar charge controller (SCC) to regulate and protect the battery charging process, a DC to DC boost converter that functions to increase the voltage to suit the battery requirements, a 48 V $LiFePO_4$ battery as an energy storage medium, a current sensor INA219 and DC voltage sensor to monitor the system's electrical parameters, and an ESP8266 as a data processing center and transmission of IoT-based monitoring information to user devices ~~[27],~~ [29]~~, [29]~~. The schematic diagram of the complete system is presented in Fig 3.

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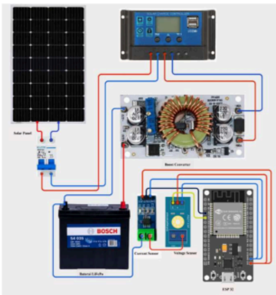

Fig. 3. Hardware Design Schematic

Fig. 4. 3D Prototype Design

Fig. 5. Scheme for implementing PV on electric car sunroofs

III. Result and Discussion

The result of the design and implementation of a flexible solar panel-based charging system designed to support the energy needs of electric vehicles. The system development process began with the design of a flexible and portable mechanical structure, the selection of 100 Wp monocrystalline solar panels, and the integration of supporting components such as MPPT charge controllers, energy storage batteries, and monitoring modules. The frame design was created so that the solar panels could be positioned optimally towards the direction of sunlight and easily moved according to usage needs in the field.

Fig. 6. Prototype

The final prototype of the flexible solar panel system is shown in Figure 6, which shows the physical configuration of the solar panels, support frame, control unit, and battery in a compact and portable system. This prototype serves as the basis for testing the performance of the solar panels, MPPT efficiency, and the system's ability to charge batteries gradually. The prototype visualization shows that the system is well integrated and ready for further testing to evaluate the performance and reliability of the solar-based charging system.

III.1. Testing and Data Collection Procedures

The system was tested in stages to evaluate the performance and reliability of a 100 Wp solar panel-based flexible charging system integrated with a LiFePO4 battery and an IoT-based monitoring system. Testing began with testing the solar panel features, MPPT performance, battery charging process, protection system, and real-time data monitoring using ESP8266.

At the Electrical Engineering Laboratory Muhammadiyah University Sidoarjo, located at Jl. Raya Gelam No.250, Pagerwaja, Gelam, Candi District, Sidoarjo RegencyKec. Candi, Kabupaten

Sidoarjo, data was collected in the yard for three days with direct sunlight exposure from 09.00 to 14.00 WIB. This time was chosen because it represents the longest period of sunlight intensity in a day. To allow each component to be analyzed separately or in an integrated manner, the testing was conducted in stages.

The output power of the solar panel was calculated by multiplying the measured voltage and current. Due to the absence of a solar irradiance sensor, irradiance values were estimated based on the ratio between measured panel power and the rated panel capacity. The MPPT efficiency was calculated as the ratio of MPPT output power to panel power. A DC–DC boost converter (10–50 V) was used to match the charging voltage with the 48 V $LiFePO_4$ battery. Battery charging current and energy were calculated based on output power and charging duration, while the State of Charge (SoC) was limited to 60% to ensure battery safety.

III.2. Solar Panel Characteristic Test

Solar panel characteristics were tested to determine the performance of a 100 Wp monocrystalline solar panel against variations in radiation intensity (irradiance). The output voltage (V), output current (I), output power (Ppv), and efficiency (η) of the panel were observed. The optimum operating voltage (Vmp) of the solar panel is 18 V, the optimum operating current (Imp) is 5.55 A, and the open circuit voltage (OCV) is 21.67 V. Thus, in field conditions, the voltage value is between 18 and 20 V, and the actual power is lower than the nominal power due to the influence of temperature and light angle.

Solar panel output power equation:

$$P_{pv} = v_{Pv} \times I_{Pv} \quad (1)$$

Solar Panel Efficiency:

$$\eta_{Panel} = \frac{P_{pv}}{G \times A} \times 100\% \quad (2)$$

Equation for calculating irradiance:

$$G_{rad} = \frac{P_{measured}}{P_{rated}} x1000 \quad (3)$$

Information :

G_{rad} = Estimated irradiance (W/m²)
$P_{measured}$ = Measured panel power (W)
P_{rated} = Nominal panel power (100 W)

Ppv = Solar Panel Power (W)
Vpv = Panel Voltage (V)
Ipv = Panel Current (A)

TABLE 1
SOLAR PANEL CHARACTERISTICS TEST RESULTS

Time	Irradiance (W/m²)	Voltage (V)	Current (A)	Power Panel (W)
Day 1				
09.00	476	22.0	2.16	47.6
10.00	636	22.4	2.84	63.6
11.00	787	22.8	3.45	78.7
12.00	882	23.0	3.83	88.2
13.00	760	22.6	3.36	76.0
14.00	574	22.2	2.59	57.4
Day 2				
Time	Irradiance (W/m²)	Voltage (V)	Current (A)	Power Panel (W)
09.00	453	21.9	2.07	45.3
10.00	614	22.3	2.75	61.4
11.00	811	22.9	3.54	81.1
12.00	931	23.2	4.01	93.1
13.00	774	22.7	3.41	77.4
14.00	595	22.3	2.67	59.5
Day 3				
Time	Irradiance (W/m²)	Voltage (V)	Current (A)	Power Panel (W)
09.00	464	22.0	2.11	46.4
10.00	658	22.5	2.92	65.8
11.00	825	23.0	3.59	82.5
12.00	960	23.4	4.10	96.0
13.00	787	22.8	3.45	78.7
14.00	617	22.4	2.75	61.7

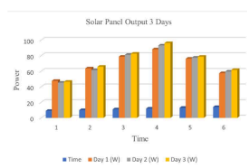

Fig. 7 panel characteristics graph

The test results show that the increase in irradiance is directly proportional to the increase in panel output power. The maximum power was

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reached at 12:00 p.m. at 9685 W, close to the panel's nominal value of 100 Wp.

III.3. MPPT Efficiency Testing

MPPT charge controller efficiency testing was conducted to determine the ability of the MPPT charge controller to extract maximum power from the solar panel and distribute it to the system. The testing process was carried out for three consecutive days, with data collection every hour from 09:00 to 14:00 WIB. The parameters observed included the MPPT solar panel input power (Ppv) and MPPT output power (Pout) using the following equation :

$$\eta MPPT = \frac{P_{out}}{P_{pv}} x100\% \qquad (4)$$

The parameters in the MPPT efficiency calculation consist of Pout as the output power of the MPPT charge controller (W) and Ppv as the input power from the solar panel (W). The ratio of these two parameters is used to determine the efficiency of the MPPT in supplying power to the charging system.

TABLE 2
MPPT EFFICIENCY TEST RESULTS

Time	Power Panel (W)	Output Power MPPT (W)	Efficiency (%)
Day 1			
09.00	47.6	41.9	88.0
10.00	63.6	58.0	91.2
11.00	78.7	73.2	93.0
12.00	88.2	81.1	91.9
13.00	76.0	70.7	93.0
14.00	57.4	52.2	91.0
Day 2			
Time	Power Panel (W)	Output Power MPPT (W)	Efficiency (%)
09.00	45.3	40.2	88.7
10.00	61.4	56.5	92.0
11.00	81.1	76.1	93.8
12.00	93.1	87.1	93.6
13.00	77.4	72.4	93.5
14.00	59.5	54.6	91.8
Time	Power Panel (W)	Output Power MPPT (W)	Efficiency (%)
09.00	46.4	41.4	89.2
10.00	65.8	60.8	92.4
11.00	82.5	77.6	94.1
12.00	96.0	90.1	93.9
13.00	78.7	73.8	93.8
14.00	61.7	56.5	91.6

The MPPT efficiency value is in the range of 88–943%, indicating that the MPPT algorithm works optimally in tracking the maximum power point even when there are dynamic changes in light intensity.

III.4. Battery Charging Testing

Battery charging tests were conducted to determine the ability of the MPPT-based solar panel system to gradually charge a 15 Ah (48 V) $LiFePO_4$ battery from a low State of Charge (SoC) to near full capacity. The test was conducted for 3 consecutive days with an effective charging duration of approximately 5 hours per day. The charging energy was calculated cumulatively to see the total energy contribution to the battery.
Battery energy:

$$E_{bat} = v_{bat} \times Ah \qquad (5)$$

$$E_{bat} = 48 \times 15 = 720\, Wh$$

State of Charge (SoC) Percentage :

$$SoC\,(\%) = \frac{E_{input}}{E_{bat}} \times 100\% \qquad (6)$$

$$E_{max} = 0{,}6 \times 720 = 432\, Wh$$

Total Energy Input :

$$E_{total} = \sum E_{input} \qquad (7)$$

Battery charging calculation parameters include a nominal battery voltage of 48 V and a battery capacity of 15 Ah, which are used to determine battery energy (Ebat), input energy, total charging energy, and State of Charge (SoC) percentage.

TABLE 3
BATTERY CHARGING TEST RESULTS

Day	Charging Time (Hour)	Daily Energy Intake (Wh)	Cumulative Energy Input (Wh)	SoC (%)
1	5	182	182	25.3
2	5	165	347	48.2
3	5	85	432	60.0

The results indicate that the 100 Wp solar panel system equipped with an MPPT controller is capable of charging a 48 V 15 Ah $LiFePO_4$ battery up to 60% State of Charge within three days of testing. The charging energy decreases on the third day due to SoC limitation imposed by the battery management system, indicating safe and controlled charging behavior.

III.5. Protection And Security Testing

Protection testing is conducted to ensure that the system is safe against abnormal conditions such as overcurrent, overvoltage, and overheating. The entire protection system works well and is capable of protecting key components from potential damage.

TABLE 4
PROTECTION TEST RESULTS

Protection Type	Test Condition	Threshold	Result
Overcurrent Protection	Load exceeds nominal current	I load > I max	Functioning
Overvoltage Protection	Input voltage exceeds allowable limit	V in > V max	Functioning
Reverse Polarity	Input polarity reversed	Negative voltage detected	Functioning
Thermal Protection	Device temperature increases	T operation > T max	Functioning
System Isolation	Leakage current simulation	No significant leakage current	Safe

III.6. Iot Control Testing (Esp 8266)

An Internet of Things (IoT)-based monitoring system is used to monitor the performance of the charging system in real time. The parameters monitored include battery voltage, charging current, system power, and WiFi connection status. Data is obtained from voltage and current sensors connected to a microcontroller, then automatically sent to users via the Telegram application in the form of periodic notifications. The monitoring system allows users to directly monitor battery charging conditions without having to be at the system location.

Based on the results of testing and monitoring during the battery charging process, the battery voltage was in the range of 48-50 V, indicating that the $LiFePO_4$ battery was within normal operating limits during charging. The charging current was monitored to be stable in the range of 2.5–4.0 A, in line with the MPPT and battery charging test results, which showed that the charging process took place without excessive current surges. The monitored system power was in the range of 40–80 W, in accordance with the solar panel and MPPT output power obtained in previous tests. In addition, The IoT monitoring system successfully transmitted data with update intervals of approximately 5–10 seconds. Comparison with a calibrated digital multimeter showed measurement differences of less than ±2%, confirming the accuracy and reliability of the monitoring systemthe WiFi connection was monitored to be stable so that the transmission of monitoring data to Telegram could take place in real time and continuously..

TABLE 5
IOT DATA MONITORING

Parameter	Average Value	Status
Battery Voltage	48 – 50 V	Normal
Charging Current	1.2 – 4.0 A	Stable
System Power	40 – 80 W	Normal
WiFi Connection	Stable	Active
SoC Battery	20-60%	Normal

IV. Conclusion

The experimental results confirm that the proposed 100 Wp flexible solar panel charging system is capable of delivering a maximum output power of 96 W under peak outdoor sunlight conditions, which corresponds to approximately 96% of its rated capacity. The MPPT charge controller operated with an efficiency ranging from 88% to 94%, demonstrating its ability to effectively extract and regulate solar power under varying irradiance conditions. During the three-day outdoor testing period, the $LiFePO_4$ battery showed a consistent increase in State of Charge (SoC), reaching 25.3% on the first day, 48.2% on the second day, and 60% on the third day. This gradual increase confirms that the system was able to provide stable and continuous charging performance under real environmental conditions. These results indicate consistent daily charging capability rather than a single full charging cycle.

All protection features, including overcurrent, overvoltage, reverse polarity, and thermal protection, operated as designed and ensured safe system operation throughout the testing process. The IoT monitoring system was able to transmit voltage, current, power, and SoC data to the Telegram platform in real time, with update intervals of approximately 5–10 seconds. Validation against a calibrated digital multimeter showed measurement differences of less than ±2%, confirming the reliability of the monitoring system.

Overall, the results demonstrate that the proposed system is technically feasible as an emergency backup charging solution for electric vehicles. Future work may include the integration of irradiance sensors for more accurate environmental measurements, longer-term testing under different

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weather conditions, and the implementation of cloud-based data storage for extended monitoring and analysis.

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Feedback dari Reviewer A:

1. Hubungan antara "terbatasnya akses charging" dengan solusi spesifik "panel surya fleksibel di sunroof" belum begitu terhubung. Mengapa harus fleksibel? Mengapa di sunroof?
2. Hasil daya maksimum (96 W dari 100 Wp) terlihat efisiensi konversi sistem sangat baik, namun penulis tidak menyebutkan kondisi lingkungan saat pengujian. Apakah ini di bawah simulator surya (STC) atau di bawah sinar matahari langsung?
3. Kalimat "increase in State of Charge (SoC) of up to ±92% during three days" bersifat ambigu. Apakah baterai terisi dari 0% ke 92%? Atau terjadi penambahan akumulatif total 92% selama 3 hari (yang bisa saja siklus charge-discharge)?
4. Pernyataan "IoT monitoring system was able to reliably display..." bersifat kualitatif, lebih baik jika ditambahkan metrik kuantitatif untuk memperkuat aspek teknis IoT nya

Mengapa monitoring real-time itu penting untuk situasi darurat? Perjelas hubungan antara "emergency" dan "monitoring (IoT)".
Mungkin bisa ditambahkan 1-2 kalimat penghubung (bridging) kemudian bisa diberikan penjelasan misal ketika situasi darurat maka user dapat langsung memantau secara real-time melalui telegram.

Gap sudah terlihat namun belum tertulis secara baik. Author baru menuliskan bahwa penelitian yang lain dilakukan secara statis. Untuk memperkuat gap sebaiknya berikan penjelasan mengapa statis itu kurang optimal/akurat. Kondisi nyata (suhu atap mobil, lengkungan panel fleksibel, getaran) dapat mempengaruhi efisiensi yang tidak bisa ditangkap ketika pengujian statis.

1. Author membuat alat, namun belum menegaskan bahwa kombinasi antara panel fleksibel (mekanik) dan notifikasi instan (IoT/Software) adalah solusi holistik untuk masalah range anxiety.
2. Kata "concentrates on creating" (berkonsentrasi pada pembuatan) terdengar seperti tujuan tugas akhir. Jurnal mencari kata yang lebih kuat seperti "proposes" (mengusulkan), "demonstrates" (mendemonstrasikan), atau "validates" (memvalidasi).
3. Poin poin novelty yang bisa digabungkan menjadi satu paragraf yang kuat:
   a. Fleksibilitas fisik - integrasi pada atap lengkung (bukan panel datar biasa).
   b. Aksesibilitas data- menggunakan platform umum (Telegram) sehingga tidak butuh aplikasi berat/mahal (cocok untuk negara berkembang/HP spesifikasi rendah).
   c. Konteks darurat - fokus pada backup power, bukan pengisi daya utama.

1. Author belum menjelaskan Selection Criteria. Mengapa memilih panel 100 Wp? Apakah karena ukuran atap mobil terbatas? Mengapa LiFePO4, bukan Li-Ion biasa (apakah karena faktor keamanan suhu)? Mengapa ESP8266 (apakah karena biaya atau cukup untuk data kecil)?
2. Berikan detail experimental setup. Misalnya alat ukur apa yang digunakan untuk memvalidasi sensor

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ESP8266? (Apakah ada multimeter eksternal sebagai pembanding?)
3. Periksa kembali redudansi pada setiap paragraf, gabungkan menjadi suatu paragraf yang mengalir sehingga tidak mengulang-ulang

1. Instrumen pengukuran tidak spesifik, ESP8266 adalah mikrokontroler, bukan sensor. Sensor apa yang dipakai? Apakah INA219? ACS712? Atau pembagi tegangan (voltage divider)? sebutkan sensor yang digunakan dan validitasnya
2. Author menuliskan "testing to obtain... IoT monitoring performance", kata "Performance" itu abstrak. Apa indikatornya? apakah latency? ketepatan data dibandingkan dengan multimeter standar? untuk memperjelas kata tersebut dapat definisikan secara opersional.

Author mengandalkan ESP8266 dan sensor (yang belum disebutkan namanya) untuk mengambil data tegangan/arus. Bagaimana author tahu angka 12.5 Volt di Telegram itu benar? apakah sudah dikalibrasi sebelumnya dengan alat ukur pembanding, misalnya dengan multimeter?
Secara umum saat ini naskah baru menceritakan "apa yang dibuat" (desain), tetapi belum menceritakan "bagaimana cara memastikan datanya benar" (validasi).

Sudah memadai dan terstruktur dengan baik, sehingga memudahkan pembaca untuk memahami tren kinerja prototipe yang diuji.

Author cukup baik dalam mengaitkan hasil eksperimen yang diperoleh dengan studi-studi sebelumnya.

Sebaiknya kesimpulan ini dipertajam dengan mengganti frasa kualitatif yang subjektif seperti "operates well" dan "close to nominal value" dengan data kuantitatif spesifik. Selain itu, narasi mengenai pengujian baterai selama tiga hari perlu diperjelas susunan kalimatnya agar pembaca langsung memahami bahwa capaian SoC 88-94% adalah bukti konsistensi performa harian dalam berbagai kondisi cuaca, bukan durasi waktu yang dibutuhkan untuk satu kali pengisian penuh.

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