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Solar-Based Smartphone Charging Stations with Voltage, Current, and Power Monitoring

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ABSTRACT

Renewable energy sources continue to be developed as alternative energy sources to reduce the use of fossil energy sources. One of them is a solar power plant that uses a light source from sunlight. For the public, electrical energy is useful to support work and communication activities such as using smartphones, but not many chargers are found in public places to charge smartphone batteries. It has designed and implemented a smartphone charging station to charge smartphone batteries using solar power. The smartphone battery charging on this smartphone charging station can display voltage, current, and power when charging the battery; this tool is equipped with an INA219 sensor, ATmega328 microcontroller, and solar power to make this tool look smart. The purpose of making this tool is to find out the working principle, voltage, current, and power and compare the charging time of the smartphone battery between the smartphone charging station and the manufacturer's charger. The working principle is that when this tool charges the smartphone battery, the INA219 sensor receives output value data in the form of current and voltage. Furthermore, the sensor sends a signal to the ATmega328 to be converted and displayed as data on the LCD so that users can see the output value. The test results of the tool, when charging a smartphone battery using Micro USB, showed the average values of voltage, current, and power, respectively, of 11.7 volts, 0.48 amperes, and 5.98 watts. USB Type C shows the average voltage, current, and power values of 11.33 volts, 0.71 amperes, and 8.37 watts, respectively. The comparison of the duration of battery charging time on the manufacturer's Micro USB with the smartphone charging station has a difference of 27 minutes; the comparison of the duration of the smartphone battery charging time using the manufacturer's USB Type C with the smartphone charging station has a difference of 22 minutes.

Keywords: Battery, Smartphone, Smartphone Charging Station, INA219 Sensor, Solar Power

ABSTRAK

Sumber energi terbarukan terus dikembangkan sebagai sumber energi alternatif untuk mengurangi penggunaan sumber energi fosil. Salah satunya adalah pembangkit listrik dengan tenaga surya yang menggunakan sumber cahaya dari sinar matahari. Bagi masyarakat, energi listrik berguna untuk menunjang aktifitas pekerjaan dan komunikasi seperti menggunakan smartphone, namun tidak banyak ditemukan charger di tempat umum untuk mengisi daya baterai smartphone. Telah dirancang dan diimplementasikan sebuah alat smartphone charging station yang mampu mengisi baterai smartphone dengan menggunakan tenaga surya. Pengisian daya baterai smartphone pada smartphone charging station ini mampu menampilkan tegangan, arus, dan daya saat pengisian baterai berlangsung, alat ini dilengkapi dengan sensor INA219, mikrokontroler ATmega328, dan tenaga surya sehingga menjadikan alat ini terlihat pintar. Tujuan dari pembuatan alat ini untuk mengetahui prinsip kerja, tegangan, arus, dan daya serta membandingkan waktu pengisian baterai smartphone antara smartphone charging station dengan charger pabrikan. Prinsip kerjanya, ketika alat ini melakukan pengisian baterai smartphone maka sensor INA219 menerima data nilai keluaran berupa arus dan tegangan. Selanjutnya sensor mengirim sinyal ke ATmega328 untuk dikonversi dan ditampilkan dalam bentuk data pada LCD agar pengguna dapat melihat berapa nilai keluarannya. Hasil pengujian alat saat pengisian baterai smartphone menggunakan Micro USB, menunjukkan nilai rata-rata tegangan, arus, dan daya secara berturut-turut sebesar 11,7 volt, 0,48 ampere, dan 5,98 watt. Pada USB Type C, menunjukkan nilai rata-rata tegangan, arus, dan daya secara berturut-turut sebesar 11,33 volt, 0,71 ampere, dan 8,37 watt. Perbandingan durasi waktu pengisian daya baterai pada Micro USB pabrikan dengan smartphone charging station memiliki selisih 27 menit, perbandingan durasi waktu pengisian daya baterai smartphone menggunakan USB Type C pabrikan dengan smartphone charging station memiliki selisih selama 22 menit.

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Keywords: Baterai, Smartphone, Smartphone Charging Station, Sensor INA219, Energi Matahari

1. Introduction

The energy problems that plague the world have implications for savings in all fields. Renewable energy sources continue to be developed as alternative energy sources to reduce the use of fossil energy sources [1-3]. One of them is a solar power plant that uses a heat source from sunlight. One of the uses of solar power is as a source of electricity in public open spaces, such as campuses requiring electrical energy. So far, the use of solar energy has only focused on street lighting, with systems that have not been integrated into regulating electrical energy sources automatically [4,5].

Energy poverty is when individuals or households spend more than 10% of their income on energy costs, including electricity, heating, and cooling. Solving problems in energy poverty has been widely discussed in energy-related research [6]. Over the past few decades, the energy burden for low-income households has increased due to fluctuations in the prices of fossil fuels, household appliances, and homes that do not use energy efficiently compared to middle-income households. Energy supplies for low-income households must be reliable, affordable, and accessible. Energy poverty issues should be addressed systematically and comprehensively, with policies shifting from simple fuel supplies to affordable low-carbon energy supplies [7]. Solar energy technology, which was first applied in space, can now be used anywhere it is needed. Solar energy production is one of the most promising and mature technologies for renewable energy production. The technology is environmentally friendly and has become a popular power generation tool. Solar power technology is currently one of the renewable energy sources that occupy the third most used position in the world after hydropower and wind, ranked first and second, respectively [8]. In addition, solar energy sources can produce electricity with low carbon emissions that cause global warming. The electricity comes from fossil fuels, while CO_2 emissions from silicon-based solar panels can be eliminated. Solar power is safe, efficient, non-polluting, and reliable. Therefore, solar power technology has very attractive prospects as one way to meet the world's energy needs in the future [9].

The high use of a lot of hardware and software has increased the energy demand significantly. Lithium-ion batteries are the most commercialized in several energy storage devices because of their energy density, long life cycle, safety, less pollution, and cost-effectiveness [10–12]. A smartphone receives energy from the battery needed to run its system. The rechargeable battery used is packaged by implanted inside the device or can be removed. Charging a smartphone battery is essential when using various applications for a certain time. Due to this continuous wear, proving that smartphone batteries are limited in capacity, they need to be recharged periodically or sequentially (perhaps several times a day, depending on how long they are used). The energy capacity of a battery is determined and limited by its chemical properties. However, researchers have not been able to move forward in increasing the capacity of smartphone batteries. Research on batteries has been done for a long time. As a result, battery capability (especially in capacity) is much lower than other mobile device components [13].

In research related to charging stations on smartphones conducted by [14], sunlight is one of the necessary factors in the placement of solar panels; if the solar panels are placed in a place that is blocked by sunlight, then solar panels will not get good light intense and do not produce maximum power; placement of solar panels in locations that have good sunlight intensity will make solar panels produce power well and maximally.

A study researching charging stations stated that the use of battery batteries is very influential because when the weather is cloudy, the battery can still charge smartphones because of the electrical energy produced by solar panels [15]. Based on the description above, the author made the study on the utilization of smartphone charging stations based on microcontroller ATmega328 using solar power; it is hoped that this research can affect the optimal use of solar power and contribute to efforts in energy problems.

2. Method

This study needs several tools and materials: a solder, smartphone, hair dryer, computer, cutting pliers, knife, screwdriver, electric drill, and multimeter. In addition to the tool, the tool consists of ATmega328 Microcontroller material, LCD 16 x 2 Characters, Solar Panel, Battery, USB Type C Cable, Cable MicroUSB, Wireless Charging Cable, INA219 Sensor and Solar Charge controller, PCB, Transistor, Capacitor, Resistor, Diode, USB Port, 7805 Regulator IC, Lm2596 IC and 12C LCD Module. The working principle of this research begins when solar panels absorb sunlight, and there is a movement between positive and negative electrons, which creates an electric current. Electric current flows to the solar charge controller to be stabilized, as well as limiting the number and rate of charging Solar Panel Sensor INA219 ATmega328 LCD 16x2 Wireless charging Solar charge controller USB Port Battery Regulator 18 to the battery. After the current enters the battery, the current will be stored then flowed to the INA219 regulator and sensor. At the regulator, the current is stabilized and goes into the ATmega328. The current passing through the INA219 sensor is measured when USB and wireless charging ports are used. When the outgoing current goes to the USB port and wireless charging to the user's smartphone, the outgoing or used current will be read and measured output by the INA219 sensor. The measured current is then sent to ATmega328, then converted into digital form. At the end, the outgoing current is displayed on the 16x2 LCD.

3. Results and Discussion

3.1. Solar Panel and Power Supply Circuit Testing

Tests are carried out to determine how much current and voltage solar panels and batteries are at the charging time; observations are carried out every 1 hour starting from 08.00-18.00 WIB. Solar panel voltage testing is carried out by directly testing the negative and positive probes of solar panels in an open circuit (V_{oc}), while current testing is carried out by testing the current of solar panels directly without load or short circuit current (I_{sc}). Solar panels use monocrystal type.

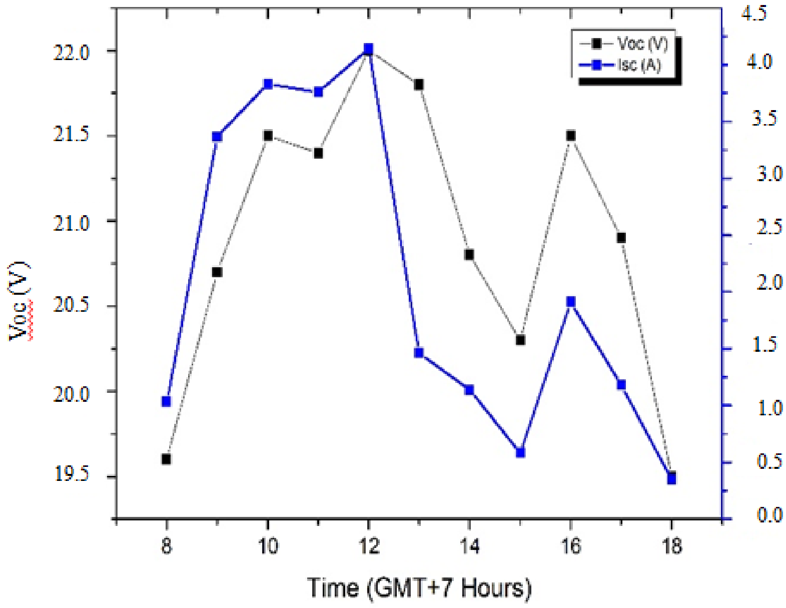


Figure 1. Voltage and current curves from solar panel.

3.2. Testing Using Micro USB

Figure 2 is a graph of charging using a smartphone charging that has a battery with a capacity of 4320 mAH and uses a Micro USB cable.

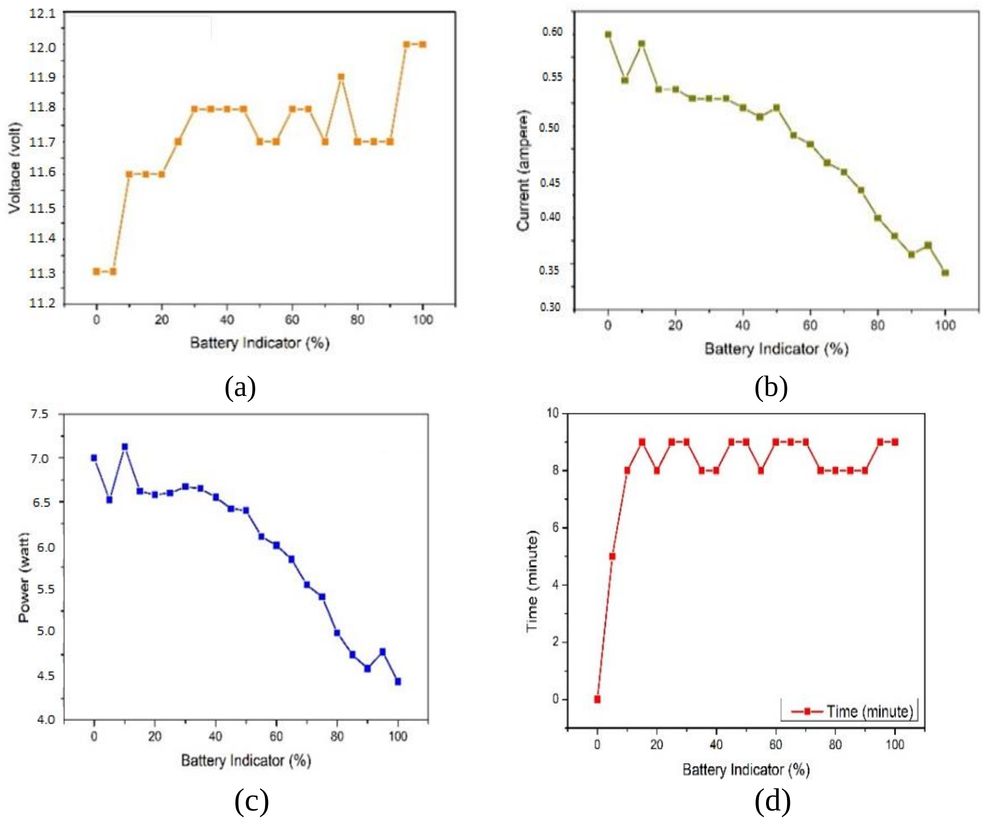


Figure 2. Charging graph using micro USB: (a) voltage; (b) current; (c) power; and (d) time.

Charging the battery on the manufacturer's micro USB cable starts from 0% to 100% takes 140 minutes or about 2 hours 20 minutes, while the time spent on charging the battery from 0% to 100% on the micro USB smartphone charging station is 167 minutes or about 2 hours 47 minutes. There is a difference in the battery charging time of 27 minutes.

Figure 3 compares the two types of smartphone battery charging using the manufacturer's micro USB cable with the micro USB smartphone charging station cable.

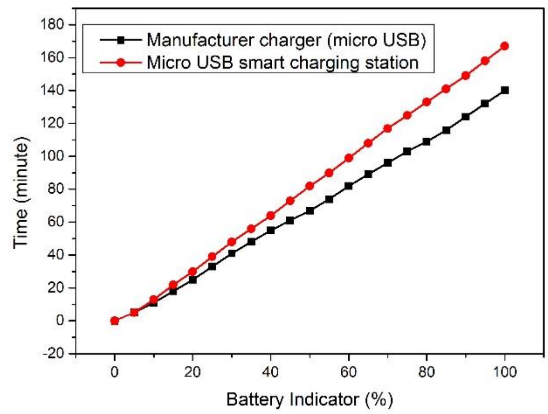
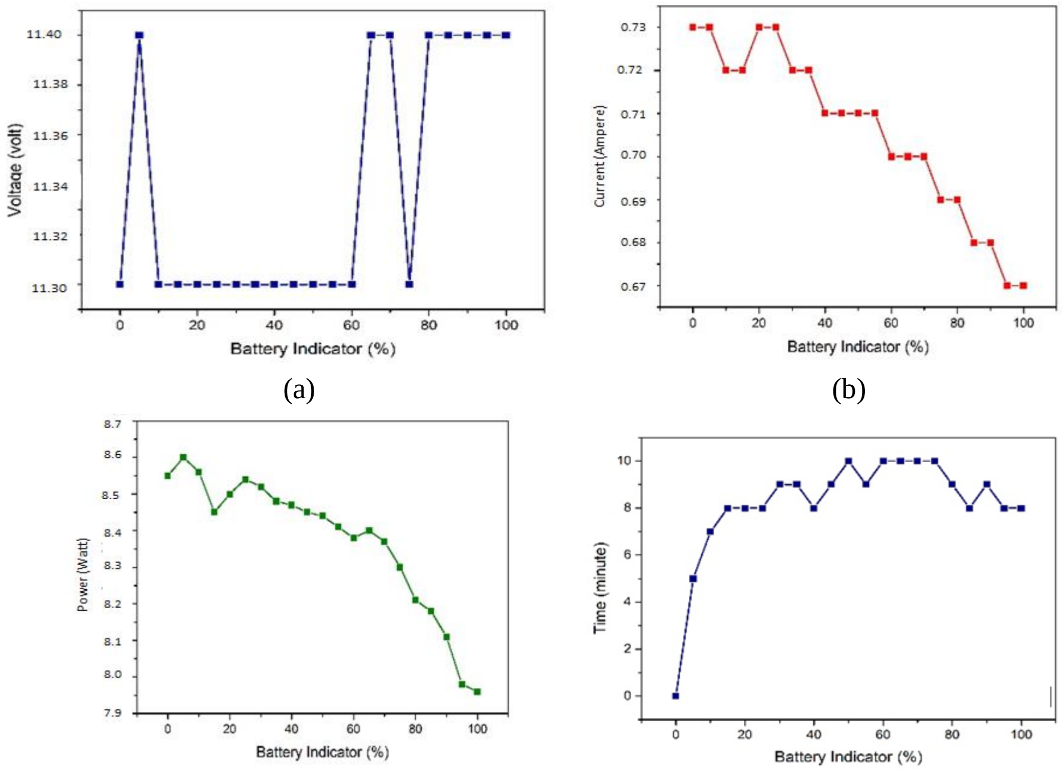


Figure 3. Micro USB smartphone battery charging comparison chart.

Figure 3 is a comparison chart of smartphone battery charging using a Micro USB smartphone charging station and a Micro USB manufacturer. It can be seen that the increase in smartphone batteries when charging 0-15% is very fast because the condition of the battery is in a discharged state, so the smartphone battery quickly absorbs incoming current and voltage. At charging, 20-90% of the charging time depends on the activity of the smartphone. If the smartphone is often turned on, charging runs long, and vice versa. Charging at 95-100% often increases or runs for a long time due to a little current to keep the smartphone temperature normal or not overheating.

3.3. Testing Using USB Type C

Figure 4 is a smartphone charging with a battery with a capacity of 4230 mAh and uses a USB Type C cable. Data retrieval is carried out at intervals of 5% when charging the battery, starting from the battery indicator 0 - 100%.



(a) (b) (c) (d)

Figure 4. Charging graph using USB Type C: (a) voltage; (b) current; (c) power; (d) time.

From the test results above, it is known that the overall data on USB Type C usage was obtained; the average voltage produced was 11.34 volts, the average current was 0.71 amperes, and the average power was 8.37 watts. Likewise, with the increase in the percentage of smartphone batteries by 5%, which is 8.1 minutes, a graph is formed according to Figure 4, which shows a graph of testing smartphone charging stations using USB Type C cables.

Testing is also carried out by charging the smartphone battery using the manufacturer's charger, the smartphone is connected to PLN's electric current so that a comparison of time spent in charging the smartphone battery can be seen.

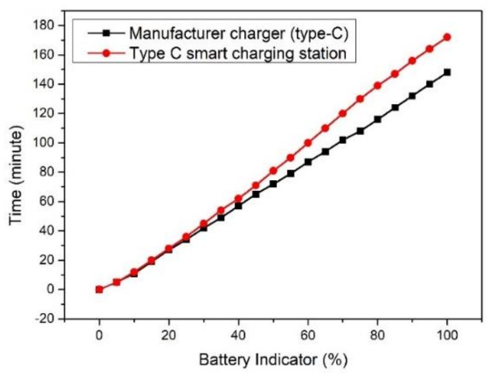


Figure 5. Comparison chart of charging time using USB Type C.

Figure 5 is a comparison graph of smartphone battery charging using a USB Type C Smartphone charging station and a USB Type C manufacturer. It can be seen that the increase in smartphone batteries when charging 0-20% is very fast because the condition of the battery is in a depleted state, so the smartphone battery quickly absorbs the incoming current and voltage. USB Type C is very stable at 25-90% charging time.

The battery used with a capacity of 5000 mAh is the cause of one factor affecting the length of charging time. However, in this charging, the adapter on the USB Type C cable is the cause of the longer charging time on the USB Type C Smartphone charging station. The USB port as an adapter used in the Smartphone charging station can only provide an output of 5V, 2.1A, with a power of 10.2 watts. While on USB Type C, the adapter manufacturer can provide an output of up to 15 watts. Charging at 95-100% often increases or runs for a long time due to a little current to keep the smartphone temperature normal or not overheating.

From the test results using the three types of battery charging, several factors that affect the smartphone charging process are battery capacity used, USB port as the current output on smartphones, and temperature on smartphones.

4. Conclusion

The research shows that the smartphone charging station's working principle is that the solar panel's electric current flows to the solar charge control and the battery. After that, the current flows into the battery and is stored, then flows to the regulator and the INA219 sensor. The current is stabilized at the regulator and enters the ATmega328; the voltage, current, and power passing through the INA219 sensor are measured when the smartphone charging station is used. Furthermore, the output data is sent to ATmega328 and converted into digital form. Finally, the current and voltage will be displayed on the 16x2 LCD. The current and voltage used in smartphone charging stations are divided into three types of battery charging. At Micro USB, the average voltage produced is 11.7 volts, the average current used is 0.48 amperes, and the average power is 5.98 watts. In USB Type C, the average voltage produced is 11.33 volts, the average current used is 0.71 amperes, and the average power is 8.37 watts. The comparison of time spent on charging the smartphone battery on the smartphone charging station with the manufacturer's charger on the manufacturer's micro USB cable starts from 0% to 100% spent for 140 minutes or about 2 hours 20 minutes, while the time spent on the micro USB smartphone charging station is 167 minutes or about 2 hours 47 minutes. There is a difference in the length of battery charging time, for 27 minutes. The comparison of time spent charging the smartphone battery on the smartphone charging station with the manufacturer's charger on the manufacturer's USB Type C cable starts from 0% to 100% spent for 148 minutes or about 2 hours 28 minutes, while the time spent on the USB Type C smartphone charging station is 172 minutes or about 2 hours 52 minutes. There is a difference in the length of battery charging time for 22 minutes.

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