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Implementation of Capacitor Charging Factor Method in Solar Panel Simulator Design

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ABSTRACT

This study aims to implement the capacitor charging factor method in the design of solar test simulator for solar panels. This method aims to improve the accuracy of current and voltage measurements during the charging process of capacitors connected to solar cells. The test was carried out using three capacitors of different capacities, namely 470uF, 3300uF, and 4700uF, to analyze the characteristics of the charge curve and its impact on system performance.

The results show that the 3300uF capacitor provides optimal performance with a charging time of approximately 1223 milliseconds, close to the simulation results using the Psim software. The 470uF capacitors, while fast in charging, do not provide sufficiently detailed data, while the 4700uF capacitors display more detailed readings but suffer significant voltage drops. This study emphasizes the importance of selecting the right capacitor in the solar panel test series and recommends the development of more sensitive current sensors to improve measurement accuracy. This finding can be a reference in designing a more effective and efficient solar test simulator system in testing the performance of solar panels.

Keywords: capacitor charging, solar test simulator, solar panel, current measurement, voltage.

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1. INTRODUCTION

The increasingly real global energy crisis due to the depletion of fossil energy reserves and the increasing need for energy encourages scientists and researchers to find alternative energy sources that are environmentally friendly. One renewable energy source that has great potential is solar energy. The sun produces a very large and unlimited amount of energy, so its utilization through solar panel technology is an attractive option in overcoming energy problems in the future.

Solar panel technology (*solar cell*) is a device that converts sunlight energy into electrical energy through photovoltaic effects. However, until now, one of the biggest challenges in the utilization of solar panels is the low efficiency of the energy conversion produced. This condition is further exacerbated in areas with minimal sunlight, where the intensity of light received by solar panels is much lower, thus having a direct effect on the electrical power produced. This is a serious problem, especially in an effort to increase the contribution of renewable energy in various regions with suboptimal levels of solar lighting.

One of the solutions that continues to be researched to overcome this efficiency problem is to use a reflector system that can reflect sunlight back to the surface of solar panels and apply the capacitor charging factor method to store and stabilize the energy obtained. Reflectors serve to increase the amount of light that hits the surface of the panels, while capacitors can help reduce energy loss and improve the stability of electrical power output.

This study aims to design and implement the capacitor charging factor method on the Solar Test Simulator, which will be used as a tool to simulate varying solar lighting conditions. With this simulator, it is hoped that more accurate data can be obtained regarding the effectiveness of the use of reflectors and capacitor charging methods in improving the efficiency of solar panels, especially in areas with minimal sunlight.

The results of this research are expected to be a reference in the further development of more efficient solar panel technology, so that it can be optimally utilized as a renewable energy solution, especially in areas with low sunlight intensity.

2. LETERATURE REVIEW

To find out the characteristics of solar cells, it is necessary to analyze the parameters listed on the module's datasheet. However, the real condition in producing output power does not necessarily achieve maximum results as stated in the datasheet. One important tool for understanding solar cell performance is the I-V characteristic curve, which provides comprehensive information about the output parameters of the solar cell. The I-V characteristic curve explains that when the current and voltage are at the maximum power point (MPP), then the solar cell will produce the maximum output power. However, this output power is greatly influenced by environmental conditions, especially temperature and radiation levels. These two parameters play an important role in influencing the performance and efficiency of solar cells.

A. Characteristics of Solar Cells

Solar Cell Performance Model

Solar cells are devices that convert light into electrical energy. Solar cells are also called *hotovoltaic cells*, *photovoltaic* (light-electric) means Solar cells rely on *photovoltaic* effects to absorb solar energy and cause current to flow between two oppositely charged layers.

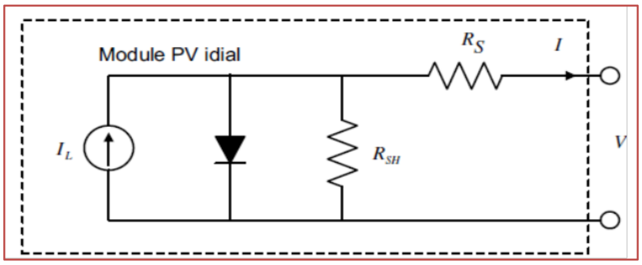


Figure 1. Solar cell equation series

The mathematical equation from the above series can be written as follows: [10]

$$I = I_L - I_o\left[exp.\left(\frac{(V+IR_S)}{nKT/q}\right) - 1\right] - \frac{(V+IR_S)}{R_{SH}} \quad (1)$$

Where:

Io = reverse *saturation*
current (Ampere) *n* = diode
ideal factor *q* = electron
charge factor (1.602·10-19 C)
k = Boltzman constant
(1.3806.10-23 J.K-1)
T = solar cell temperature (^{oK})

B. Environmental Factors Towards Solar Cell Output

Temperature

Temperature also affects cell performance and photovoltaic efficiency, If the solar cell is in cold conditions it will generate more power. In general, when irradiation 2 0 on the cell is 1 kW/m The cell temperature is approximately 30 C higher than the ambient air. The characteristics of temperature changes in solar cells are shown in the figure below:

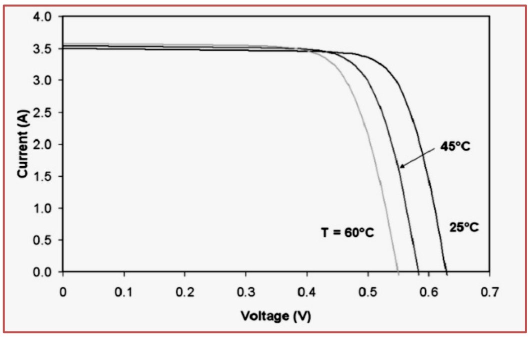


Figure 2. The surface temperature characteristics of solar cells are different.

Light Intensity

The state of influence on the amount of sunlight energy obtained by solar cells (photovoltaic) decreases or the intensity of the light weakens, the voltage and electric current produced will also decrease. The voltage drop is relatively smaller than the current drop. The figure below shows the current and voltage changes of the solar cell (photovoltaic) based on the intensity of the sunlight obtained changing its value.

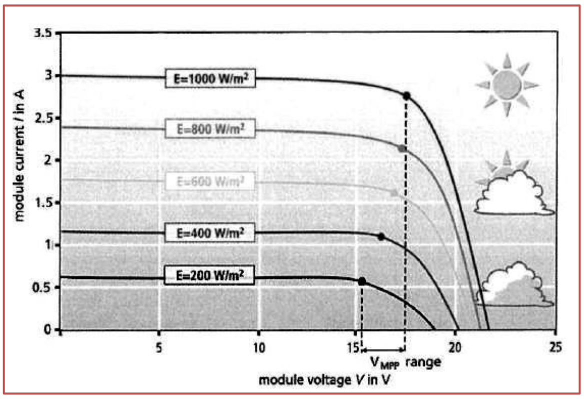


Figure 3. I-V Curve Relative to Irradiance and Temperature

Capacitive Load

In a direct current circuit, the presence of a capacitor for a long time can usually be considered a broken wire (open circuit). The process occurs after the charging of the capacitor occurs. It can be explained in the figure that at the beginning, the capacitor has not been charged so it can be considered a closed circuit (connected wire) without a capacitor as follows.

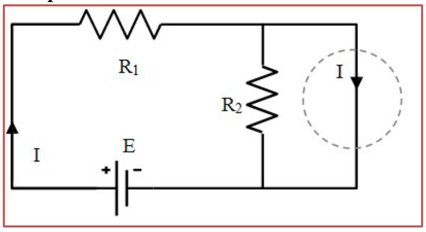


Figure 4. Overcurrent through capacitors

$$E - IR1 = 0 \quad (8)$$

But after a long time and the capacitor has been charged, the capacitor becomes polarized in the opposite direction of the battery and against the current. So the capacitor can be considered as an open wire as below, and the current I prefers to pass through R2 rather than through the capacitor.

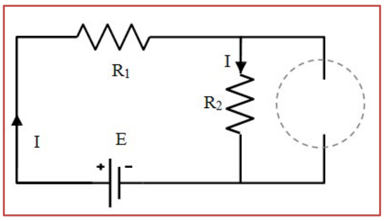


Figure 5. open wire capacitor

C. Control System
Hardware Equipment (Arduino Mega)

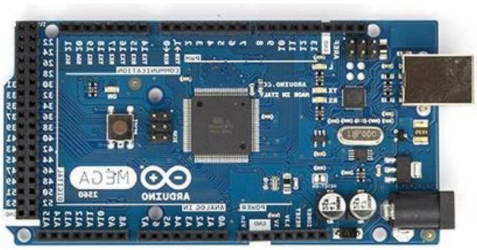


Figure 6. Arduino Mega 2560 Module

The Arduino Mega 2560 is an Atmega 2560-based microcontroller board that has various features according to the specifications listed in the datasheet. The board is equipped with 54 digital input or output pins, of which 15 can be used as PWM (*Pulse Width Modulation*) outputs. In addition, there are 16 analog inputs, 4 UARTs (Universal Asynchronous Receiver/Transmitter), 16 MHz crystal oscillators, USB connections, power jacks, ICSP (In-Circuit Serial Programming) headers, and reset buttons.

3. RESEARCH METHOD

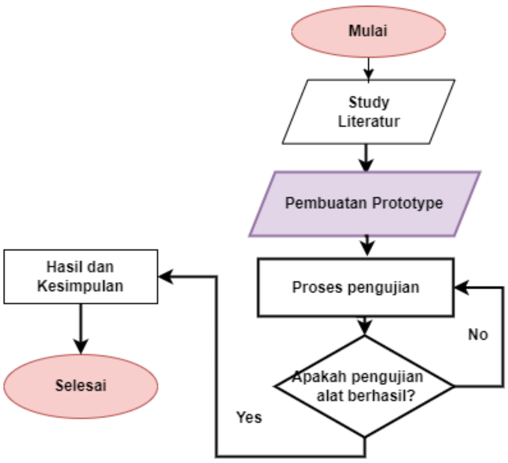


Figure 7. Flowchart

Here is a description of the flowchart:

1) Start: The starting point of the process.
2) Literature Studies: Conduct research and review relevant literature to understand the theoretical background or gather information.
3) Prototyping: Designing and developing prototypes based on literature studies and problems at hand.

4) Process: Testing or analyzing a prototype through experiments or practical applications.
5) Does Tool Testing Work?: Decision points:
6) If "Yes", proceed to Results and Conclusions.
7) If "No", go back to "Prototyping" to improve the design or approach.
8) Results and Conclusions: Based on successful testing, analyze the data and summarize the results.
9) Done: The process ends here.

This flow shows the process of developing and testing the tool, starting from research to final conclusion.

4. Results And Discussion

A. Network Simulation

Solar cell testing is carried out by applying a short circuit to the circuit. Based on the characteristics of the current-voltage curve (I-V) of a solar cell system, when a short circuit occurs, the voltage is at zero, while when an open circuit occurs, the voltage is at the maximum position. The design of the components in this system was initially simulated using Psim software to obtain the desired results and visualize the shape of the characteristic curve according to the solar cell circuit used. The simulation of the series can be seen in the following figure.

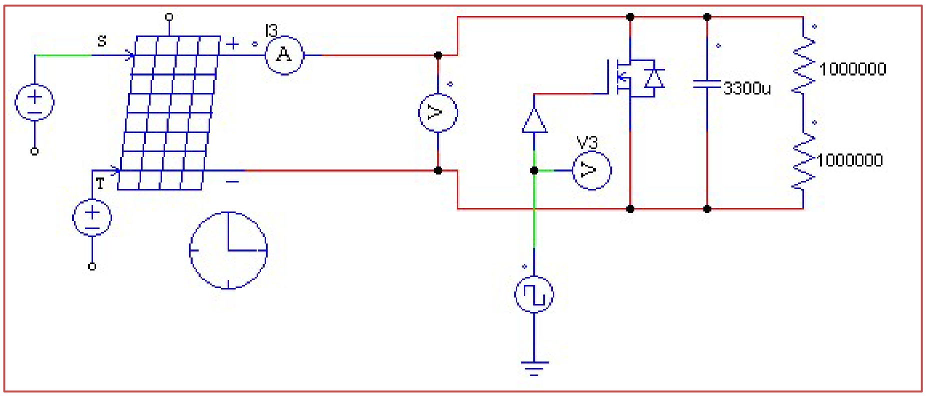


Figure 8. Prototype Design IV Tracer and Sensor Components

In the network simulation, the test is carried out based on the specifications of solar cells designed using short circuit circuits and capacitive loads. The solar cells used have a voltage specification of 5 Vdc and a current of 189 mA. Given the relatively small specifications of solar cells, detailed readings of the characteristics of solar cells need to be carried out to obtain accurate results.

The capacitive load selection aims to obtain the characteristics of the curve with voltage variations that depend on the properties of the capacitor charging factor. In this series, the capacitive load is paired in parallel with an R load of 2 MΩ. A large resistance value is chosen to achieve the open circuit voltage when the capacitor is fully charged. In addition, MOSFETs are used in circuits to vary voltages, so that they can change the conditions from an open circuit to a short circuit. This non-linear load principle results in a curve shape that shows the characteristics of capacitive loads in real time. Capacitors with large values were chosen to extend the charge time, allowing for better visualization of voltage variations against changes in conditions in the solar cell.

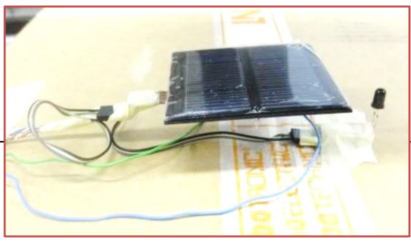


Figure 9. Light Sensor Position

The performance of the circuit using MOSFETs aims to obtain voltage variations in solar panels, based on the charging process on the capacitors. When the switch is connected, the solar cell is in a short circuit condition, and the capacitor releases its charge, so the capacitor charge becomes empty. When the switch is removed, the solar cells begin to charge the capacitor to the full, at which point the circuit is considered to be in an open circuit condition. The installation of large resistors in a circuit is intended so that, when the capacitors are full, the circuit is considered open circuit. The simulation results show the current, voltage, and I-V characteristics that illustrate the relationship between current and voltage, as can be seen in the following figure:

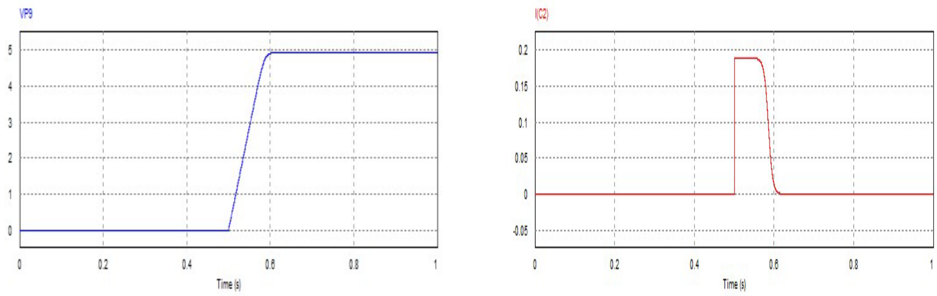


Figure 10. a. Capacitor Curve B. Capacitor Current Curve

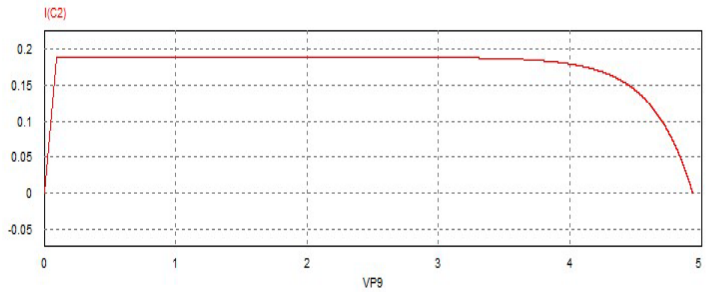


Figure 11. Current yield curve on capacitors

From the results of simulation and testing of the IV tracer series using capacitors with varying capacities, there are several important points that can be analyzed based on the data obtained:

1. Effect of Capacitors on Voltage Variation: Capacitors mounted in series with solar cells serve as energy-storing loads. When the capacitor is charged, the voltage at the capacitor terminals will increase until it reaches the maximum value of the solar cell voltage. Since the capacitor and solar cell are in a series configuration, the current flowing through the capacitor is the same as the current generated by the solar cell. This can be seen from the characteristics of the current and voltage curves that show the change from zero to reaching the maximum voltage, according to the charging capacity of the capacitor.
2. Capacitor Capacity Selection: The selection of capacitors with different capacities (240uF, 3300uF, and 4700uF) aims to study the effect of capacity on charging time and circuit behavior. Capacitors with larger capacities take longer to fully charge, as larger capacities can store more charges. For example, a 3300uF capacitor takes about 1223 milliseconds to reach the maximum

voltage, which results in close to simulations performed on the PSIM software. This shows that the capacity affects the charging rate as well as the voltage achieved in a given time.

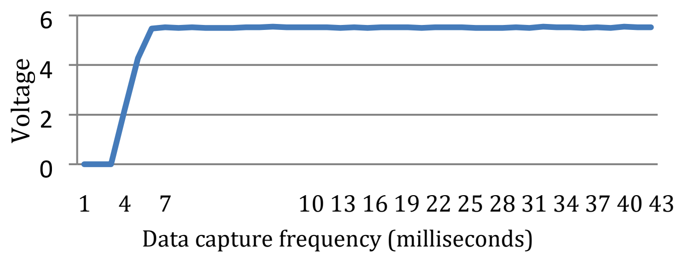
3. Effect of Capacitor on Charge Time and Open Circuit Conditions: When the capacitor is fully charged, there is no more current flowing in the circuit, and this is referred to as the open circuit condition. A larger capacity leads to a longer charging time, while a smaller capacity allows the capacitor to reach the maximum voltage faster. At a capacity of 3300uF, the charging time is ideal enough to get accurate data without charging times that are too long or too fast.
4. Use of ATmega 328 Microcontroller and Sensor Reading: The use of ATmega 328 microcontroller attached to the Arduino board helps in monitoring voltage and current changes in real-time. These microcontrollers do a good job of recording data related to voltage variations in capacitors during charging and discharging. The temperature reading of solar cells through temperature sensors also provides a more complete picture of the influence of environmental temperature on the performance of solar cells. Temperature can affect the efficiency of solar cells, so it is important to monitor temperature changes during experiments.
5. Correlation of Simulation and Experimental Results: The test results using a capacitor with a capacity of 3300uF show a voltage curve that is close to the simulation results from the Psim software. This shows that simulations can provide a fairly accurate picture of the behavior of the circuit before physical testing is carried out. However, there are small differences that may be caused by environmental factors such as lighting intensity and temperature variations, which are difficult to reproduce precisely in simulations.

Overall, the experimental results show that the capacitor with a capacity of 3300uF provides the most optimal results in creating voltage variations in solar cells in a fairly fast time and close to the simulation results. The right selection of capacitors is important in the application of the IV tracer test circuit to obtain the expected voltage and current characteristics.

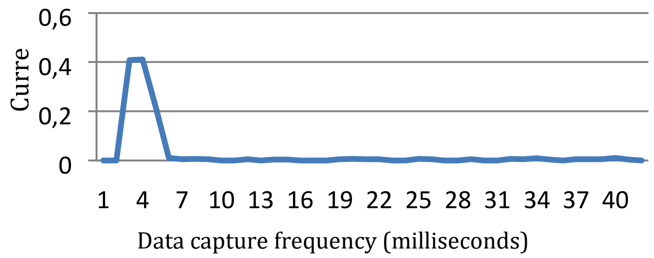
Table 1. 450uF Capacitor measurement results

450uF Capacitor Temperature=39/ lux=3586

Chart shape Solar cell voltage



Shape of the current graph on the capacitor



Current and voltage chart shape

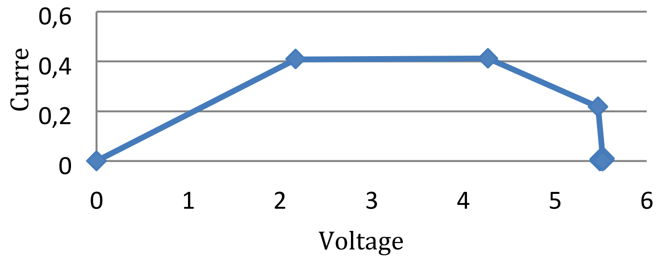
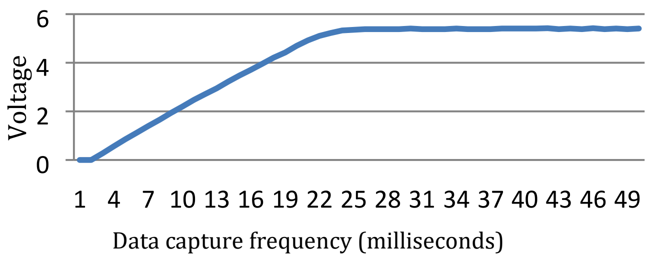


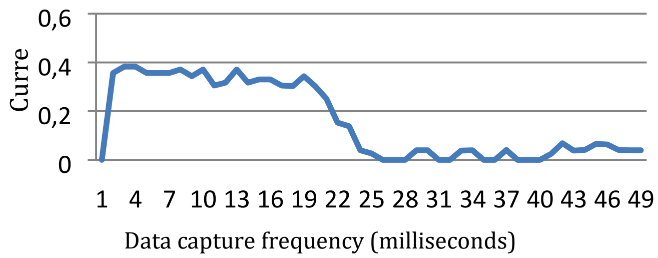
Table 2. Picture of the measurement result of the 3300uF Capacitor

3300uF Capacitor Temperature = 36 / lux=2789

Chart shape Solar cell voltage



Shape of the current graph on the capacitor



Current and voltage chart shape

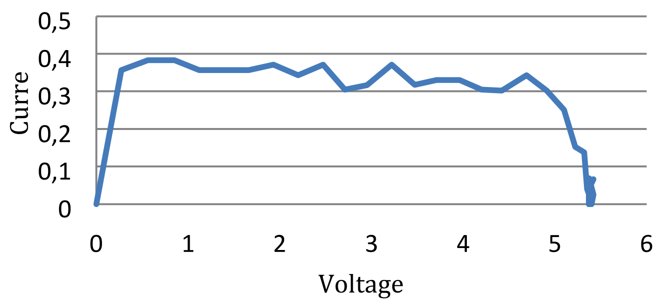
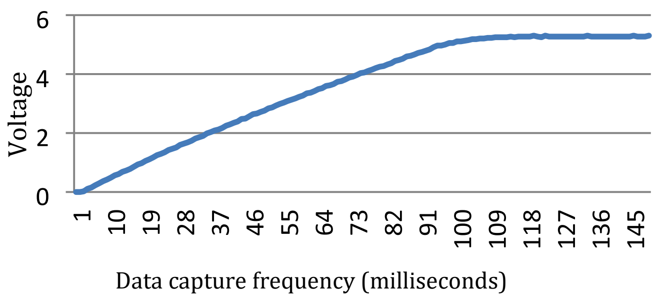


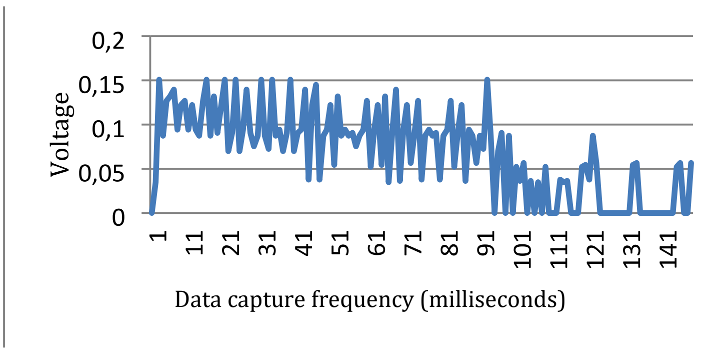
Table 3. Drawing of the measurement results of the 4700uF Capacitor

Capacitor 4700uF Temperature =34/ lux=2634

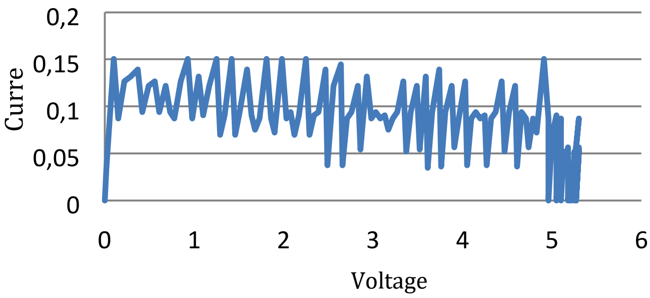
Chart shape Solar cell voltage



Shape of the current graph on the capacitor



Current and voltage chart shape



From the results of testing the IV tracer series using capacitors with different capacities, several important things can be analyzed and concluded regarding the influence of capacity on the characteristics of the voltage curve, current, and charging time. This discussion will describe the results of the use of 470uF, 3300uF, and 4700uF capacitors based on the experimental data obtained.

1. Use of 3300uF Capacitors: The use of capacitors with a capacity of 3300uF shows that the test results have curve characteristics that are close to those of simulations performed using Psim software. The capacitor has a moderate charging time of 1223 milliseconds, which gives a clear picture of the charging factor in the capacitor charging process. This shows that the 3300uF capacitor can capture voltage and current variations well, without charging times too fast or slowly, making it suitable for application in IV tracer circuits that require measurement accuracy.
2. Analysis of Current Reads on Capacitors: In experiments, current readings on capacitors were problematic, mainly because very small currents were not read by the current sensor used. However, the calculation of the current in the capacitor is still carried out based on the

measured voltage, so that the charge factor can be determined in more detail. The results of this calculation help to understand the rate of charge of the capacitor during the experiment, even if the current reading is not optimal. A more sensitive current sensor design may be necessary to obtain more accurate readings at very small currents.

3. Use of 470uF Capacitors: 470uF capacitors exhibit very fast charging characteristics, i.e. approximately 1048 milliseconds. Due to the smaller capacity, the charge on these capacitors occurs more quickly, resulting in shorter voltage and current curves. This signifies that small capacitors such as the 470uF are not ideal for applications that require more detailed voltage and current variations, as the fast charging process does not allow enough time to record significant changes. Therefore, these small capacitors are suitable for experiments that require fast charging, but are less ideal if more detailed data is desired.
4. Use of 4700uF Capacitors: In contrast, the use of capacitors with larger capacities, such as 4700uF, shows more detailed results, especially when it comes to charge charges. The required charging time is about 3873 milliseconds, which is much longer compared to the 3300uF and 470uF capacitors. This slower charging provides an opportunity for the sensor to record more detailed data, including voltage changes during the charging process. However, the curve shape generated by the 4700uF capacitor tends to be less favorable due to voltage drops and fluctuations during charging. This may be due to the size of the capacitor being too large in relation to the parameters of the solar cell used, so that the solar cell undergoes a momentary voltage drop.
5. Solar Cell Voltage Drop on Large Capacitors: In large capacitors, such as 4700uF, there is a significant drop in solar cell voltage at the beginning of charging. This decline is likely due to the inability of solar cells to directly charge large capacitors quickly, mainly due to the relatively small parameters of the solar cells compared to the capacitors used. Large capacitors require a greater current to fully charge for a longer period of time, which causes the voltage of the solar cells to drop temporarily before the capacitor is fully charged.
6. Regarding the Suitable Capacitors: Based on the results of this experiment, the 3300uF capacitors show the most ideal results in terms of the balance between the charging time and the measurement details. These capacitors provide a more stable filling curve and are closer to the simulation results, without charging times that are too long or too fast. Meanwhile, 470uF capacitors have charging times that are too fast to get detailed data, and 4700uF capacitors produce charging that takes too long in the presence of unwanted voltage drops.

Overall, capacitors with more moderate capacity, such as 3300uF, are the optimal choice for use in IV tracer circuits that require stable and accurate voltage and current readings. Capacitors with smaller or larger capacities may still be usable, but with certain limitations as per the testing requirements.

CONCLUSION

The test results show that the selection of the right capacitor greatly affects the accuracy and effectiveness of the measurement. The 3300uF capacitor proved to be the optimal choice because it provided a balance between fill time and measurement detail, resulting in a characteristic curve that was close to the simulation results. In contrast, the 470uF capacitor shows fast charging but is less informative for in-depth analysis, while the 4700uF capacitor produces detailed data but with a significant voltage drop.

Thus, this study emphasizes the importance of selecting suitable capacitors in the solar panel test circuit, as well as the need to develop more sensitive sensors to improve the accuracy of current measurements. These findings can be the basis for designing a more effective solar test simulator system.

REFERENCES

Rusdi, M., Rahmawaty, R., Pulungan, M. A., Azis, A., Irawan, S., & Othman, Z. (2024). Analysis of Temperature Variation to Light Variation in Solar Test Simulator Design Using Peltier. Journal of Materials Engineering, Manufacturing and Energy, 7(1).

Devita, R., & Iriani, J. (2021). Design and build solar panel I–V tracers using the capacitor charging factor method. Telecommunication Network Engineering Technology, 1(2), 107-120.

Dwidayanti, R. (2017). Optimization of battery charging on solar panels using maximum power point tracking (MPPT).
Huda, A., & Siraju, W. (2021). Maximum Simulation Design of Power Point Tracking P&O Method on Solar Panels in Azzahra Hydroponic Juata Tarakan. Elektrika Borneo, 7(1), 5-10.
Rakhmawati, R., Sutedjo, S., Oktaviani, F. N., Irianto, I., Yanaratri, D. S., & ADILA, A. F. (2023). Estimation of State of Charge in Lead Acid Batteries using Elman Recurrent Neural Network. ELKOMIKA: Journal of Electrical Energy Engineering, Telecommunication Engineering, & Electronics Engineering, 11(4), 864.
Suriadi, S., Fajri, I. N., Munadi, R., & Gapy, M. (2019). Power Oscillation Reduction in Solar Panel MPPT Using the PNO and Fuzzy Combination Method. Journal of Electrical Engineering, 15(2).
Prasojo, A. (2023). Design of Power Supply for Electrostatic Precipitator with Solar Cell on Fish Smoking Chimney (Doctoral dissertation, SULTAN AGUNG ISLAMIC UNIVERSITY).
Assegaf, A., Aming, D., & Alvianto, F. (2021). Design of maximum power point tracking with incremental conductance algorithm for PLTS 100 Wp. JITEL (Scientific Journal of Telecommunications, Electronics, and Electricity), 1(1), 1-8.