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Analysis of Solar Test Simulator Design Using Snubber Circuit Damping System

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Abstract— The technology of solar panel testing equipment is carried out through equipment simulation called a solar test simulator. Settings are made on this tool through variations in light and temperature so as to be able to provide detailed information about the optimal performance of solar panels. The performance of solar panels is shown through a monitor display that is placed on the design which will contain information about the solar panel as a whole. Measurements are made by varying the light and temperature and then short circuiting the output of the solar panel. The snubber circuit method as a damper for the switching process of the IRF540 mosfet according to the capacity of the 20 WP solar panel tested so that the capacity value of the capacitor is 47 uF and the resistor is 4.7 Ω with than capacitor 3300uF load from solar panel.

Keywords: Solar Panel, Circuit Snubber, Mosfet, Solar Test Simulator, Fill Factor.

I. INTRODUCTION

The reputation of optimizing the potential of solar energy is growing today. Solar energy potential is greatly affected by climate change. To determine the properties of solar modules must be tested. Parameters that can affect the performance of solar panels are light intensity, solar panel temperature, angle of incidence and solar radiation [1,4]. In accordance with the parameters that affect the weather factor, optimizing the performance of solar panels to produce energy has a big impact. Testing of solar panels under various conditions in certain environments is carried out to determine the properties of solar panels in producing electrical energy. The power generated by solar modules has properties that are described as current and voltage characteristics (IU) [4,9]. The curve contains information about the important parameters of the solar module. contains parameters contained in current and voltage characteristics (IU); maximum power (Pmax), maximum voltage (Vmax), maximum current (Imax), no-load voltage (Voc), short circuit current (Isc) and charging factor (FF)[1].

The parameters contained in the solar module are determined by testing the solar module charging circuit. The charging circuit in previous studies used two (2) MOSFETs to produce the shape of the current and voltage characteristic curve (IV) of the solar module [4,5]. The research being carried out is to simplify the circuit using MOSFETs as a switching system when the voltage varies.

The series obtained from previous research is simplified and then simulated in PSIM software to show the results that will occur in the circuit. The simulation was carried out with the aim of obtaining conditions according to the standard test (STC), namely irradiance of 1000 W/m^2 and temperature of 25 ^{0}C [1,6,8]. The simulation performed shows the conditions that occur in the circuit when the current and voltage characteristics (IV) are formed. The circuit simulation was carried out with low power solar panels and does not contain exhaustive information.

Thus, it is hoped that the data obtained through the simulation will show the evolution of ideal current and voltage (IV) characteristics according to the data sheet included in the module with important parameters depending on the conditions of the solar module.

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II. LITERATURE REVIEW

Solar Module Characteristics

The Equivalent Model of a Solar Module The operation of the solar module itself is actually identical to that of a semiconductor diode [1,2]. The form of the solar cell circuit equation, where current (I) and voltage (V), solar modulus (IL/current photo cell), then series resistance (Rs) and shunt resistance (Rsh) can be seen in the following figure:

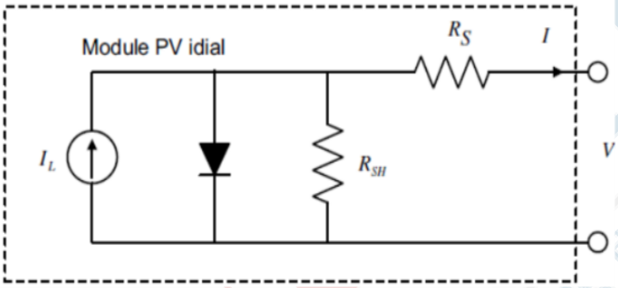

Figure 1. Solar module equivalent circuit [1]

The mathematical equation of the circuit above can be written as follows: [1,2]

I=I_L-I_o[exp.(((V+IR_S))/(nKT/q))-1]-((V+IR_S))/R_SH (1)

Where :
I =solar cell equivalent circuit current (Ampere)
io =reverse saturation current (Amperes)
n= diode ideal factor
q =factorelectron charging (1.602 10-19 C)
k =Boltzman constant (1.3806.10-23 JK-1)
T =solar cell temperature (oK)

Solar Module Characteristic Curve

The electrical properties of solar panels in generating electricity can be observed from the electrical properties of these cells based on the current and voltage under different conditions of light intensity and temperature [11,13]. This characteristic is usually described by a current and voltage curve (IV curve) as shown in the figure below.

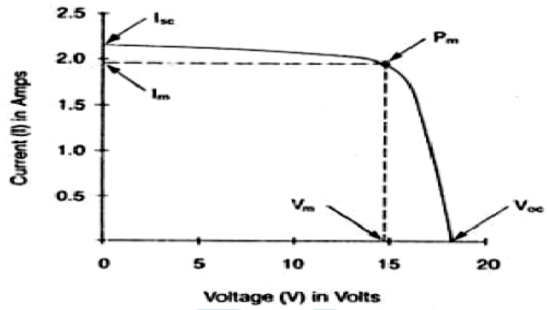

Figure 2. Characteristic curve I – V on solar modules [12]

Characteristic curve parameters IV can be classified among others [9, 13]:

Maximum power point value (MPP)
Short circuit current (Isc)
Open circuit voltage (Voc)

Fill Factor (FF) is defined as the ratio of maximum photovoltaic power to product Voc and Isc. The fill factor is also a measure of the deviation of the IV characteristic from the ideal diode characteristic.

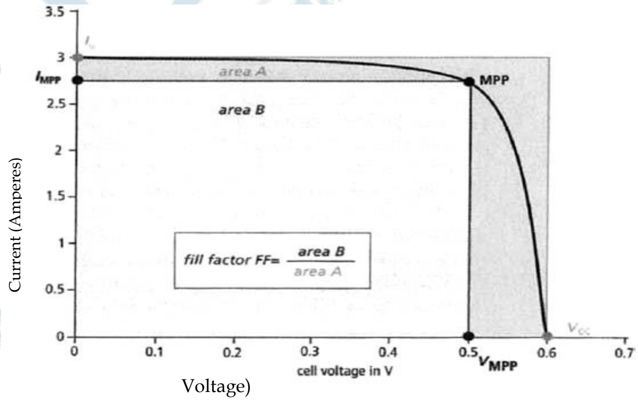

Figure 3. The fill factor of the Solar Module [10]

Influence of Environmental Factors temperature

The characteristic shape of the temperature change in solar cells is shown in the figure below [1]. :

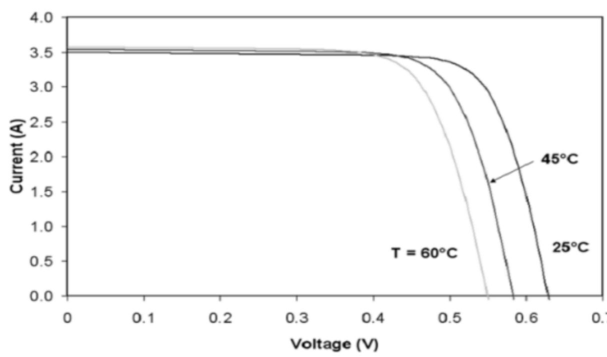

Figure 4. Characteristics of IV at different surface temperatures of solar modules [11,14]

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Light intensity

The image below shows the variation of the current and voltage of the solar module (photovoltaic) based on the intensity of sunlight obtained, varying the value [12]

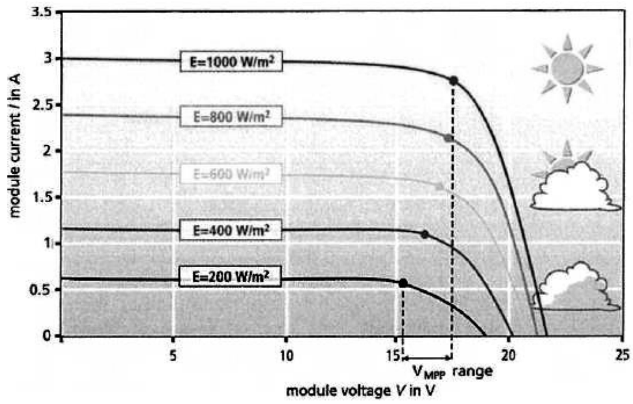

Figure 5. IV Curve Against Fixed Irradiance and Temperature [12]

Switching System

The design in this study uses a switching converter intended to condition an open circuit to be short circuited. The components used are N-type MOSFETs with IRF540N type. The switching converter shows the function of the transistor as an electronic switch that can be opened (OFF) and closed (ON) [3].

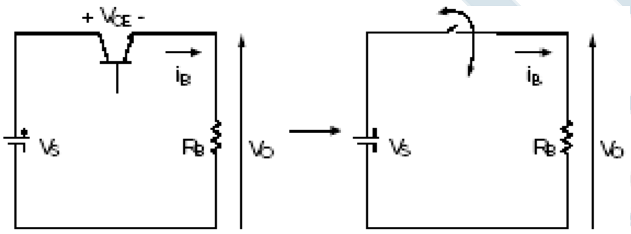

Figure 6. Basic switching converter circuit [3.15]

MOSFET As Switching

Uses The Metal Oxide Semiconductor FET (MOSFET) is widely used in digital circuits where the device has a switch characteristic. [3].

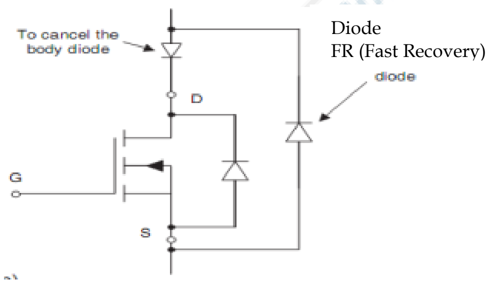

Figure 7. MOSFET as Switch [3]

In a MOSFET, the change in gate voltage (Vgs) is adjusted to affect the line and source resistances. The characteristics of an open switch are that the voltage that passes through the switch is quite large while the current is zero and vice versa. The output voltage setting graph of the MOSFET characteristics (switching characteristics) can be explained in the figure below.

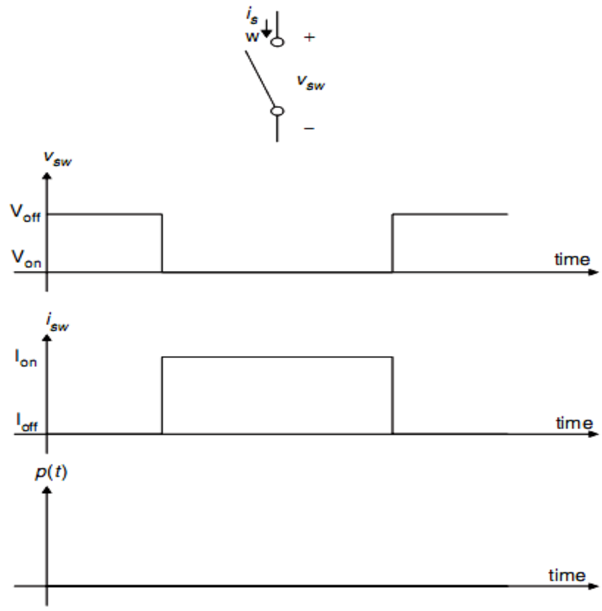

Figure 8. Input and output voltage waves on the MOSFET [3]

PWM (Pulse Width Modulation)

PWM is a technique for generating an output signal whose period repeats between high and low, where we can set the duration of the high and low signal as desired.

The duty cycle is a conditional parameter of the high signal period and the low signal period [15]. The duty cycle condition is directly proportional to the average generated voltage, e.g. high conditions 5 V and low conditions 0 V. Pulse Width Modulation (PWM) tuning is a technique used in power control systems. The PWM formation process consists of a triangular wave, a reference voltage and a comparator [26,28]. A comparator is a device for comparing two input signals. The two input signals being compared are triangular waves with a DC reference voltage.

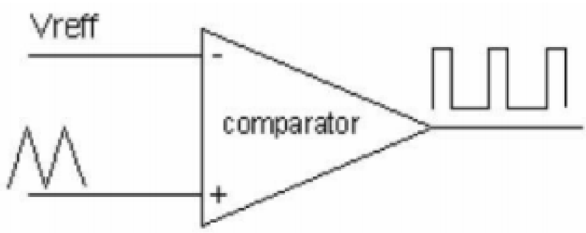

Figure 9. PWM circuit [15]

The results of the comparison of a triangular wave with a DC voltage produce a square wave with adjustable pulse width. The pulse width setting is done by varying the DC reference voltage value [3].

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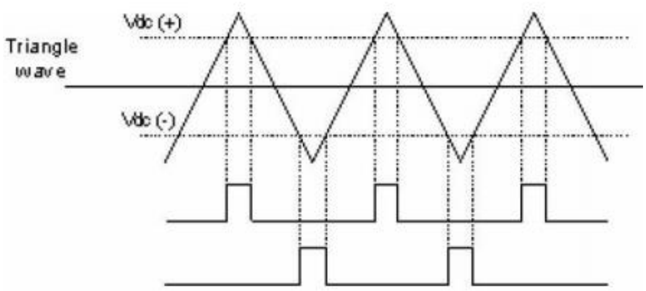

Figure 10. PWM output pulse wave [3]

If you want a square wave with ON and OFF timing as an inverter, a negative DC reference voltage is required. To get a negative DC voltage, a positive DC voltage must be fed into the inverter circuit.

Snubbers Network

In the DC-DC converter circuit, a snubber circuit is needed to interrupt the Vds voltage which has a high voltage ripple (peak) on the MOSFET [3,18,19]. Once the converter circuit is supplied with voltage on the input side, the peak voltage caused by the leakage inductance is high enough that a damper circuit is required to operate to reduce the peak voltage. In the snubber circuit, the higher the value of the capacitor used, the higher the voltage drop [3.19]. However, the value of the capacitor used must match the resistance that is connected in series with the parallelized capacitor and fast diode.

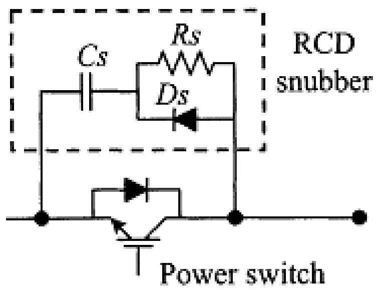

Figure 11. The snubber circuit [3.18]

Rs value and Cs value can be calculated by the following equation [3].

$$R_S=t_{on}/5C \quad (2)$$
$$Cs=(I_L t_f)/(2V_f) \quad (3)$$

Note:
Rs = snubber resistance (Ω) Cs = snubber capacitor (F)
Vf = MOSFET Voltage(V) IL = MOSFET Load Current (A)
tons = MOSFET life time (S) tf = MOSFET Fall Time (S)

III. RESEARCH METHODOLOGY

In this research, circuit simulation was carried out using Power Simulation (PSIM) software. PSIM is software that is used to determine the conditions in the circuit in detail with adjustable parameters. The resulting current and voltage (IV) characteristic curves are expected to show the characteristic parameter values of the solar module according to the datasheet.

The solar module used is a polycrystalline type solar module with a power of 20. MeanwhileThe prototype of the solar module being tested can be listed in the specificationsas follows [20].

Type	:SLP020-12U
Maximum voltage	:17.2V
Maximum current	:1.31 A
Maximum output	:20W
Dimensions	:576mm x 357mm x 30mm.
Number of cells	: 36 (2x18)

Figure 12. Solar modules being tested

Modules like the above have parameters based on input conditioning in the PSIM simulation software. The next design is by simplifying using MOSFETs and snubber circuits. The schematic image of the IV Tracer solar module with a short circuit circuit with a 3300uF load capacitor attenuation system is shown in the following figure;

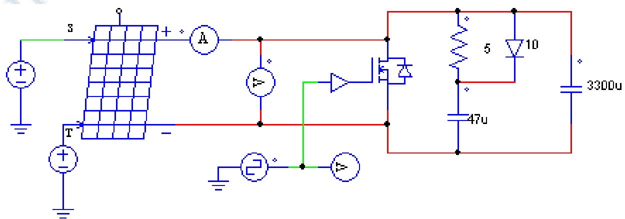

Figure 13. Loading series of IV Tracer solar modules

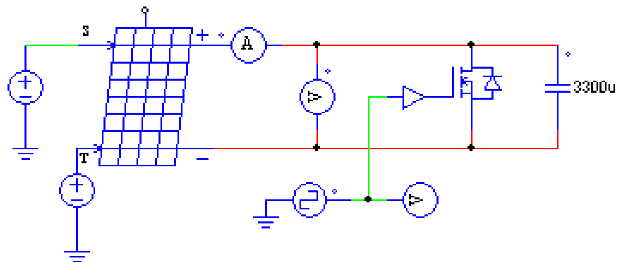

Figure 14. Loading series of IV Tracer solar modules

The design of a solar module circuit using the n-type MOSFET IRF540N has a parameter on resistance of 22mΩ, a diode threshold voltage of 4V with a snubber circuit. The

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circuit that is applied is a solar module short circuit system. The switching process causes voltage spikes so that the snubber is designed to minimize the interference that occurs with the combination of high-frequency diodes of the FR-207 type. The snubber circuit is designed based on the value of the IRF540 MOSFET component datasheet, namely IL = 16A tons = 11 ms, tf = 35 ms Vf = 6V so that it can be determined as calculated as follows;[3]

$$C=\frac{I_L t_f}{2V_f}=\frac{16\times35\times10^{-6}}{2\times6}=46{,}66\ uF \qquad (4)$$

$$R_S=\frac{Dt\times T}{5\times C_S}=\frac{11\times10^{-6}}{5\times46{,}66\times10^{-9}}=4{,}7\Omega \qquad (5)$$

Based on the calculation above, the component values are chosen that are close to these results with a capacitor value of 47uF and a resistor of 5Ω.

Changes in environmental conditions that affect will be tested with the parameters of changes in light intensity and temperature. Parameter testing will be carried out with three changes in conditions, both light intensity and temperature. Changes in duty cycle with PWM settings affect the voltage at the MOSFET gate so that switching occurs until a value is obtained based on the voltage variation setting in the circuit.

IV. RESULTS AND DISCUSSION

The design analysis was carried out by comparing the series of solar panel characteristic curves using and without the snubber circuit. determining the value of the capacitor used is 3300uF according to the test in previous research. Application of the snubber design with a solar panel capacity of 20 WP with parameters adjusted to the IRF540 switching mosfet system design datasheet. The simulation was carried out within 1 second with the characteristics adjusted for the mofset and solar panels used with a nominal light conditioning of 1000 Wm2 and a temperature of 33oC. The results of the analysis are presented in the following explanation

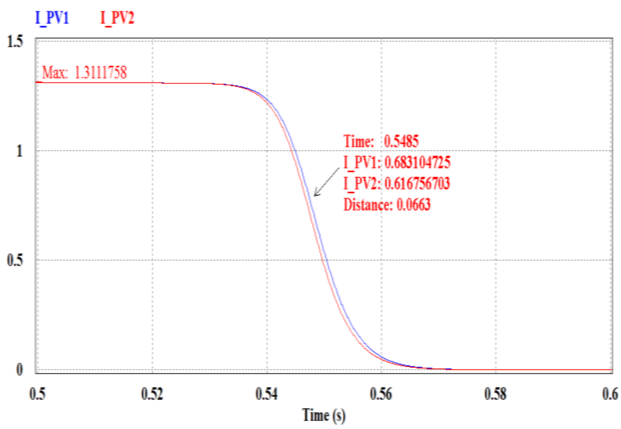

Figure 15. Image comparison current on solar panels

The current comparison difference of 0.0663A provides information on the differences caused by the use of a snubber circuit. The shape of the current curve between the two types of circuits is the same as the aris on solar panel 2 which has decreased first due to not applying a snubber circuit damper. The maximum current corresponds to the characteristics of a 20 WP solar panel. The biggest difference occurs at 0.5485 seconds with the current value in each panel totaling 0.683 A for PV1 and 0.616 A for PV2.

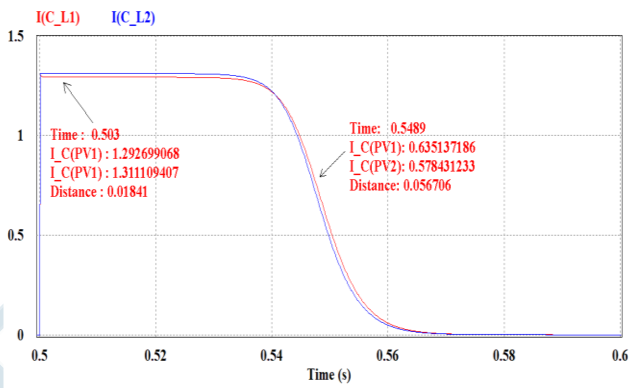

Figure 16. Image comparison of the current on the capacitor load

The condition for capacitive loads occurs in conditions where the initial condition of the capacitor at PV1 has decreased in value by a distance of 0.01841 A at 0.503 seconds. The second condition is that there is a delay in the decrease in current in PV1 with the current in PV2 preceding it, which is due to the absence of damping and the application of capacitor characteristics. This second condition has a maximum of 0.0567 A at 0.5489 seconds. Furthermore, it can be observed that the same conditions for the Mosfet current occurred in the time range of 0.5 to 0.6 seconds. At the MOSFET there is no difference in performance, but at the beginning of the circuit there is a difference in the starting current caused by different values of the capacitors in the circuit.

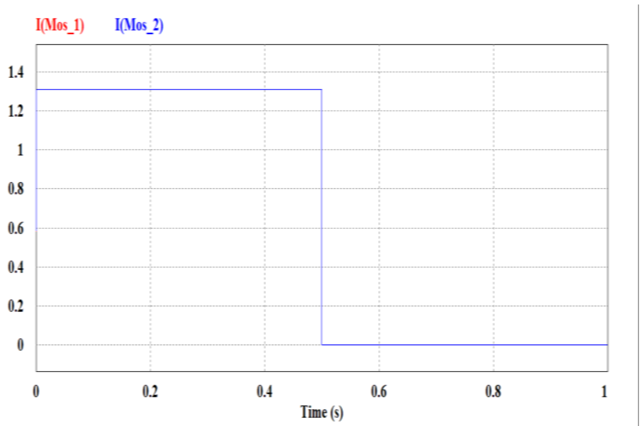

Figure 17. Picture of the current condition of the mosfet component used, namely irf540

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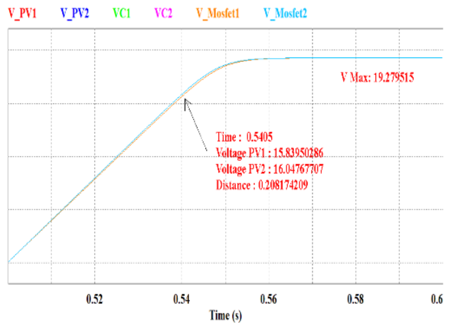


Figure 18. Picture of the voltage conditions in the PV1 and PV2 circuits

The voltages in the PV1 and PV2 circuits show the same value in the overall PV1 voltage circuit that exists in the snubber system, mosfet and lapacitive loads in the circuit. There is a difference in the voltage value when the switching process occurs, namely at the time of 0.5405 which obtains a difference of 0.208174209 V. The simulated solar panel performance value obtains a value of 19.2795 V. The voltage value is based on unit parameters obtained from the solar panel datasheet used.

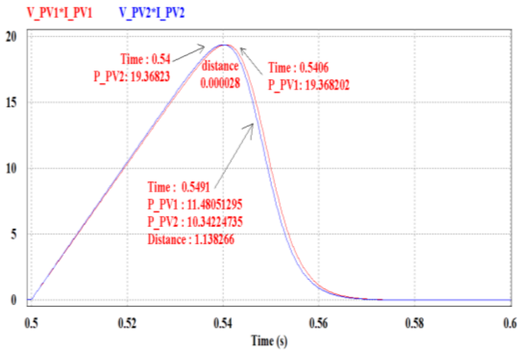
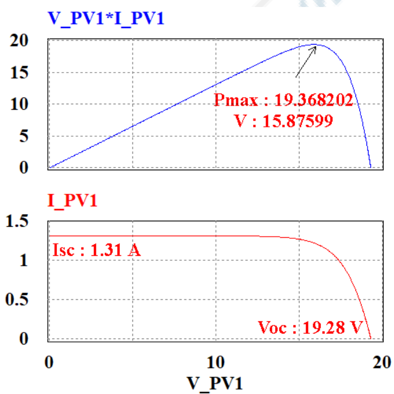
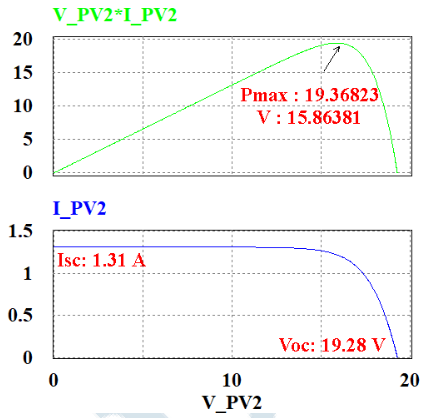


Figure 19. Image comparison of PV1 and PV2 power values

There is a difference of 0.000028W between the two panels. Peak power was first obtained by PV2 at 0.54 seconds with me at 19.36823W while PV1 followed at 0.5406 seconds with a power of 19.368202. This power difference will certainly affect the power utilization and performance factors of solar panels.



a)



b)

Figure 20. Figure the characteristic curve of a solar panel a) a solar panel using a snubber circuit, a) a solar panel without using a snubber circuit

In detail, the image does not show a significant difference due to the small size of the solar panel in testing with large data samples. The shape of the characteristic curve is in accordance with the datasheet but the difference is in Pmax PV1 19.368202W and PV2 of 19.26823W.

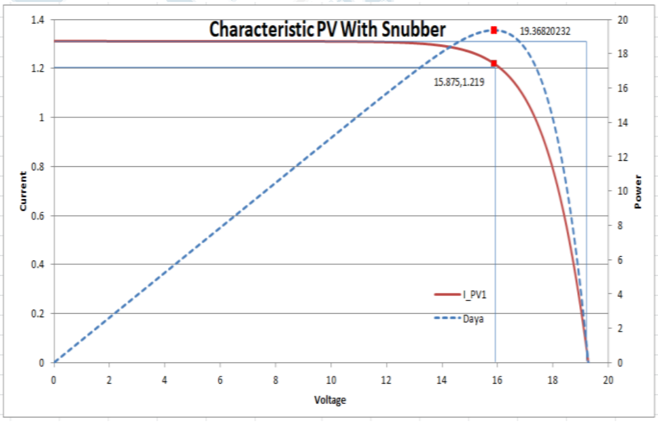


Figure 21. Draw the shape of the solar panel characteristic curve by applying the snubber circuit

The shape of the characteristic curve of the solar panel using a snubber circuit is more conditioned by the function of the snubber circuit as a damper. The deepening of the snubber circuit provides a delay to the power value so that it can be controlled according to the expected characteristic shape of the solar panel

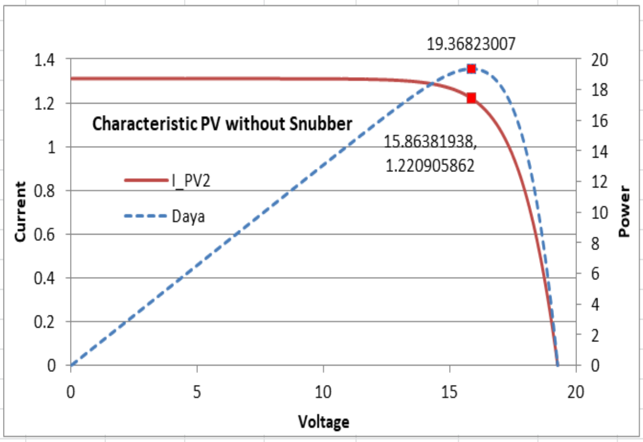


Figure 22. Draw the shape of the solar panel characteristic curve without applying the snubber circuit

The solar panel characteristic curve parameters are shown in the following table with the resulting values based on the circuit parameters used, namely the 20 WP solar panel and the irf 540 switching mosfet. The parameters obtained show the difference in values contained in the planned circuit. The results of the tests carried out will provide alternative circuits with the characteristics that exist in each circuit and the utilization of solar panels will be able to utilize energy optimally. The results of the paral=meter are in the following table.

Table 1. Table of the results of testing the parameters of the solar panel characteristic curve

	PV 1	PV2	difference
Pmax(W)	19.3682023	19.3682301	2.78X10-5
Voc(V)	19.2795161	19.2795161	4.01X10-13
Isc (A)	1.3111776	1.3111776	1.55X10-9
Vmax (V)	15.8759915	15.8638194	1.22X10-2
Imax (A)	1.2199680	1.2209059	9.38X10-4
Fill Factor	0.7661815	0.7661826	1.10X10-6

The table shows a comparison of the parameters that are very influential on this snubber system circuit at maximum voltage$1.22X10^{-2}$ is inversely proportional to the open circuit voltage (Voc), which is $4.01X10^{-13}$ which has very little effect. The maximum voltage is influenced by the calculation results of the power with the current which affects the energy utilization capacity. The utilization factor is quite influential with an average difference of $2.19x10^{-03}$ based on the overall value of the test parameters

V. CONCLUSION

The application of the snubber circuit as a parameter recording system for solar panel characteristics is quite good with a fill factor of 0.766 with the difference between the two systems giving a difference of 1.10X10-6. The application of a 3300uF capacitor is in accordance with the design of a solar panel characteristic curve recording system combined with a snubber circuit. And Suggestion for next research is recommended for further research that the circuit be applied to a solar test simulator by applying various conditions of the solar panels, both the type and the conditioning carried out in the environment.

VI. ACKNOWLEDGMENTS

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