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SEPIC Coupled Inductor Using Incremental Conductance Algorithm as Maximum Power Point Tracking for Solar Panel Applications

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Abstract:
This paper presents the design and experimental evaluation of a photovoltaic (PV) maximum power point tracking (MPPT) system using a Single-Ended Primary-Inductor Converter (SEPIC) with a coupled inductor and the Incremental Conductance (INC) algorithm. The SEPIC converter was first tested using a DC power supply to assess its voltage-conversion characteristics, and was subsequently connected to a 50 Wp PV module and a 14.2 Ω resistive load. The converter was operated at a switching frequency of 31.4 kHz. Under a 22.5 V input, the measured output voltage was 2.2 V at a 10% duty cycle, 21.54 V at 50%, and 26 V at 55%, demonstrating step-down and step-up operation. During PV characterization, the maximum measured output power was 43.39 W at an irradiance of 983.11 W/m^2. The average SEPIC conversion efficiency is 89,2%. Comparative tests indicate that INC-based MPPT adapts the converter duty cycle to changing PV conditions and produces higher output power than fixed-duty-cycle operation. The efficiency improvements were 7.06% and 5.41% for unused and used MPPT in the 35% and 60% of duty cycle. These results demonstrate the potential of the coupled-inductor SEPIC converter with INC control for PV power extraction.

Keywords:
SEPIC Converter, Coupled Inductor, Incremental Conductance Algorithm, Maximum Power Point Tracking, Solar Panels.

1. Introduction

Energy is an important factor in social and economic development in a country which is accompanied by increasing demand driven by technological advances [1]. One of the resources that can drive technological progress is electrical energy resources. Developing countries like Indonesia have many renewable energy sources. Indonesia has abundant renewable energy resources with a potential of more than 400,000 MW, of which around 50% or 200,000 MW comes from solar power. However, the utilization of solar power currently only reaches around 150 MW, which is equivalent to 0.08% of its total potential. The Director General of New, Renewable Energy, and Energy Conservation of the Ministry of Energy and Mineral Resources, Dadan Kusdiana, revealed that demand for sustainable products from the green industry sector continues to increase. He also added that funding for fossil fuel-based industries is increasingly difficult to obtain, while the renewable energy sector, especially solar power plants, is growing rapidly with costs decreasing over time [2].

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Renewable energy resources such as wind, solar and water energy can be used as reliable, environmentally friendly and sustainable energy [1]. The continuous use of conventional energy sources will cause an energy crisis and increased pollution, so that the need for clean energy is increasing. The development of reliable technology to utilize existing energy sources is the basis for the transition to alternative energy from fuels derived from conventional energy. In this context, Photovoltaic (PV) is used because of its ability to convert one of the renewable energy sources (Solar Energy) into Electrical energy [3][4].

The conversion of solar energy into electricity through photovoltaic (PV) technology is growing rapidly because it has various advantages, such as being environmentally friendly, quiet, and requiring minimal maintenance, but PV systems also have two major drawbacks, namely low power conversion efficiency and non-linear output power characteristics [5]. The output power generated by PV changes continuously if there is a change in the environment, thus the load characteristics need to be adjusted to track the maximum power point on the IV and PV curves [6]. The power generated depends on weather factors, such as ambient temperature and sunlight intensity [5]. To ensure maximum PV power conversion, PV panels need to be operated at the highest power point using MPPT Technique [4]. The MPPT method has been developed for PV systems with the aim of finding the optimal working point so that the product of voltage and current reaches the highest value, which in theory occurs when the output impedance of the PV cell is balanced with the load impedance, so that MPPT is carried out by adjusting the PV output impedance to match the load impedance gradually, and because environmental factors affect the impedance, MPPT adjustment is carried out by aligning the load impedance in real-time to improve the efficiency of energy conversion from the PV array to the electrical system [5].

The use of MPPT techniques to maximize the peak power produced by PV to the electrical system generally utilizes a switching device. The main function of the switching device is to regulate the PV output voltage so that it can supply maximum energy to the load [5]. In this study using the DC-DC Buck Boost Converter type SEPIC (Single Ended Primary Inductor Converter) or topology that can increase or decrease the input voltage. SEPIC is one type of Buck Boost converter that has the same voltage polarity as the input polarity (Non-Inverting). The SEPIC type converter by utilizing two inductors wound in one iron core or called coupled inductance can reduce the inductance value and reduce the inductor current ripple [7]. MPPT techniques generally work using a control method or algorithm. In this case, from various MPPT techniques, the incremental conductance (INC) method can be effective in tracking MPP under dynamic conditions such as in PV [4]. In this peak power tracking, the MPP point can be obtained by comparing the incremental conductance ($\Delta I/\Delta V$) with the instantaneous conductance I/V of the PV generated. When the condition is at the MPP point, then the magnitude of the instantaneous conductance and the incremental conductance are zero. If the system is on the right side of the MPP, then the sum of the conductance is negative, while when the condition is on the left side of the MPP then the sum of the conductance is positive PV [4]. To overcome the shortcomings of the power transformation generated by PV to the load, this article presents the design of Maximum Power Point Tracking (MPPT) based on SEPIC Coupled Inductor using the Incremental Conductance Algorithm to overcome the shortcomings of PV. The Incremental Conductance algorithm has better performance compared to the PO algorithm. The Incremental Conductance algorithm for tracking MPP can find the maximum power point more accurately with a faster response [8].

2. Materials and Methods

2.1. Sepic Converter

SEPIC (Single Ended Primary Inductor Converter) is a type of DC/DC converter that can function as an output voltage booster or reducer, similar to a buck-boost converter. The output voltage of the SEPIC can be controlled through the switching process on the MOSFET according to the desired duty cycle

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value. If the duty cycle is below 50%, this converter operates as a voltage reducer, while if the duty cycle exceeds 50%, this converter acts as a voltage booster. This converter has a non-inverting output, where the polarity of the input voltage is the same as the polarity of the output voltage, and uses a coupling capacitor to reduce ripple current, so that it can avoid overheating of components when working under heavy conditions. When the switch is disabled, this converter is able to follow a large transient dump, so that the voltage can drop to 0V [9]. The following is a series of Sepic Converters.

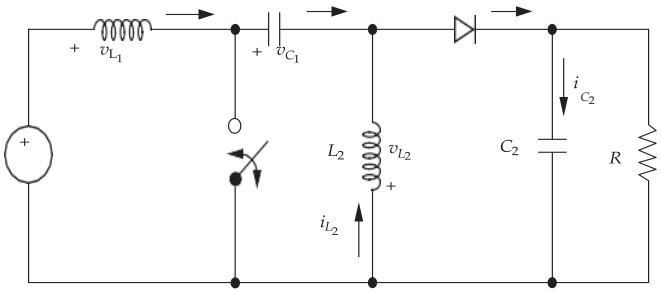


Figure 1: Sepic Converter Circuit

The inductor current and capacitor voltage limitations will be removed later to investigate the current and voltage fluctuations. The inductor current is assumed to be continuous in this analysis. Another observation is that the average inductor voltage is zero and the average capacitor current is zero for steady state operation [10]. Kirchhoff's voltage law around the path containing Vs, L1, C1, and L2, so that the following equation is obtained:

$$-Vs + Vc1 + Vl1 - Vl2 = 0 \quad (1)$$

The average voltage obtained is,

$$-Vs + 0 + VC1 - 0 = 0 \quad (2)$$

So from the equation above it shows that the voltage flowing on VC1 is the same as the input voltage.

$$VC1 = Vs \quad (3)$$

When the switch is closed, the diode is off, with the Inductor voltage VL1 at the DT interval (ON Cycle Time) being the same as the source voltage (Vs).

$$VL1 = Vs \quad (4)$$

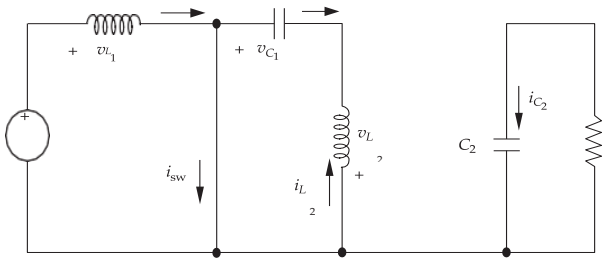


Figure 2: Sepic Converter Circuit when Switch ON

When the MOSFET Switch is off, the Diode is Forward biased by flowing power to the load. The Khircoff Law that occurs when the MOSFET or Switch is OFF is as follows.

$$-Vs1 + VL1 + VC1 + Vo = 0 \quad (5)$$

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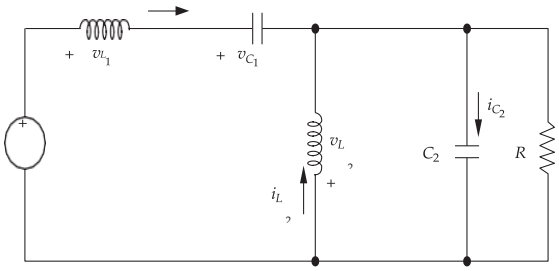


Figure 3: Sepic Converter Circuit when Switch OFF

Assuming the voltage at VC1 is constant or the same as the source voltage Vs in equation 3, then the equation when Switch OFF (1-D)T is:

$$-Vs + VL1 + Vs + Vo = 0 \quad (6)$$

$$VL1 = -Vo \quad (7)$$

Since the average voltage across the inductor is zero for periodic operation, Eq. 4 and Eq. 6 are combined to obtain,

$$(VL1, sw\ closed)(DT) + (VL1, sw\ open)(1 - D)Y = 0 \quad (8)$$

$$Vs(DT) - Vo(1 - D)T = 0 \quad (9)$$

Where D is the duty ratio of the MOSFET switching. From the equation above, the following formula is produced,

$$Vo = Vs\left(\frac{D}{1 - D}\right) \quad (10)$$

Sepic converters with coupled inductors are implemented using two inductors wound on the same magnetic core. The use of coupled inductors is more common because it produces more synchronous performance, better integration, and reduces the inductance value compared to using two separate inductors. Inductors L1 and L2 do not have to be wound together on one magnetic core, but there are advantages if both are on one inductor core. If L1 and L2 are tightly coupled, the ripple current will be divided between them, so the required inductance value can be reduced by half[11]. The inductance value of an inductor can be determined using the following equation:

$$L1 = L2 = 0{,}5\ \frac{Vs\ x\ Dmax}{\Delta IL\ x\ fs} \quad (11)$$

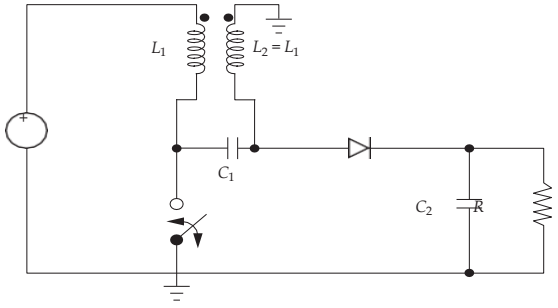


Figure 4: Sepic Converter Coupled Inductor Circuit

In designing the Sepic Converter Coupled Inductor specifications, of course, we must pay attention to the use of component values according to needs. The use of the required component values will later affect the performance of the Sepic Converter in the efficiency of electrical power conversion. The following are the component values designed in this study.

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Table 1: Spesifikasi SEPIC Coupled Inductor

Data	Specifications
Frecuency Switching	31,4 kHz
Inductor L1 L2	46 uH
Capacitor Coupling	220 uF 100 V
Capacitor Input	100 uF 100V
Capacitor Output	220 uF 100V
Duty Cycle Min	0,557
Duty Cycle Max	0,718

2.2. PV Characteristics

The working principle of photovoltaic cells is to generate electrical energy when light photons transfer energy to negatively charged electrons in semiconductor materials, where negative charges are attracted to one side of the surface and positive charges to the other side, so that both charges are collected by the front and rear conductive surfaces of the solar cell, while the characteristics of the I-V curve on solar cells include several main parameters, such as short circuit current (Isc), open circuit voltage (Voc), and maximum power point (Vmp, Imp) which affect performance, where during operation, power becomes a measurable parameter obtained by multiplying the current and output voltage on the I-V curve to determine the output power[12]. The PV current and voltage characteristic curves can be seen in the figure below.

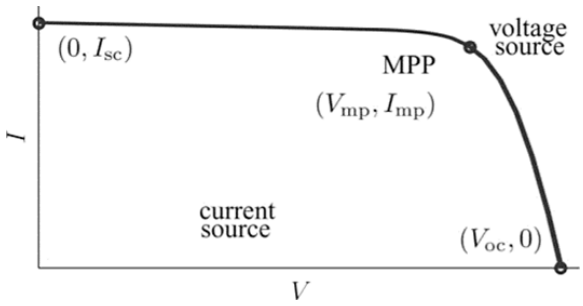


Figure 5: PV Current and Voltage Characteristic Curves

Solar panels consist of solar cells that effectively absorb solar energy. When exposed to sunlight, the temperature of the solar cells increases, which can reduce the panel's output power. In addition, wind speed also affects the performance of the panel, because wind can help cool its surface and increase the efficiency of the system[13]. The equations used in this study are as follows.

- **PV input power formula:** The input power of a solar panel is the electrical power generated by the intensity of solar radiation hitting the solar panel surface. The input power of a solar panel can be found using the following equation.

  $$Pin = J\ x\ A \quad (12)$$

  Where:

  Pin : Input Power (W)
  J : Solar Irradiation Intensity (W/m2)
  A : Solar Module Area (m2)

- **Fill Factor PV:** Fill factor is one of the parameters used to determine solar cell performance. It is a dimensionless quantity that expresses the ratio of the maximum power produced by a solar cell to the product of Voc and Isc. Fill Factor PV can be found using the following equation.

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$$FF = \frac{Vmp\ x\ Imp}{Voc\ x\ Isc} \quad (13)$$

Where:
FF : Fill Factor
Vmp : voltage at maximum working point (V)
Imp : current at maximum working point (A)
Voc : open circuit voltage (V)
Isc : short circuit current(A)

- **Output Power PV:** The output power of a solar panel is the amount of electricity produced by multiplying the maximum current (Imp) by the maximum voltage (Vmp). The output power of a solar panel can also be found by multiplying the short circuit current (Isc), open circuit voltage (Voc), and the PV fill factor used. The PV output power can be calculated using the following equation.

$$Pout = Voc\ x\ Isc\ x\ FF \quad (14)$$

Where:
Pout : Output Power (W)

- **PV Efficiency:** Solar panel efficiency is the ability to convert input power to the PV to produce electrical power. The efficiency of a solar panel can be calculated using the following equation:

$$Efficiency\ (\%) = \frac{Pout}{Pin} x100 \quad (15)$$

The solar panel characteristic tests were conducted at the Power Conversion Laboratory 1 Electrical Department, Engineering Faculty, University of Jember, on January 11, 2025. Each measurement was repeated three (3) times at every time interval to ensure measurement reliability and to obtain an average value that minimizes random error. The environmental conditions during testing, including ambient temperature and wind speed, were recorded and kept as consistent as possible across all repetitions to avoid external influences on the panel's output performance.

2.3. Incremental Conductance Algorithm

The Incremental Conductance method adjusts the terminal voltage of the PV array to match the voltage at the maximum power point (MPP). This principle is based on the analysis of the incremental conductance and instantaneous conductance of the PV module. The criteria for the Incremental Conductance method in PV are that the slope of the power curve against the PV array voltage is zero MPP, positive to the left of MPP, and negative to the right of MPP[4].

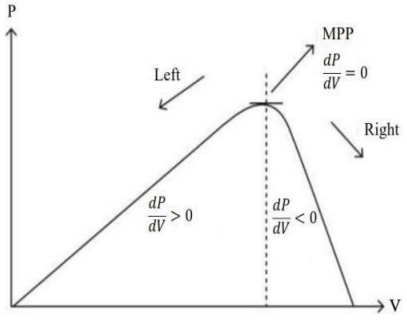


Figure 6: MPP Characteristic Curve

$$\frac{dP}{dV} = \frac{d(VxI)}{dV} = I\ \frac{dV}{dV} + V\ \frac{dI}{dV} = I + V\ \frac{dI}{dV} \quad (16)$$

MPP on solar panels can be achieved when,

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$$\frac{dP}{dV} = 0 \; or \; \frac{dI}{dV} = -\frac{I}{V} \tag{17}$$

MPPT is a method based on control techniques that allow solar panels or PV to produce maximum electrical power. The MPPT method is used to find the global maximum power point (GMPP), which is then implemented in the DC-DC converter. In the DC-DC converter, this method will determine the duty cycle value used as a switching signal in the converter[12].

If the MPP is on the right side, then the value of dI/dV < -I/V, so the PV voltage needs to be reduced to achieve the MPP. This method is effective in increasing the efficiency of the PV system, while reducing power losses and system costs[14].

Fig. 7 show the algorithm of the INC. This INC uses the measured PV voltage and current to determine whether the PV operating point is at, to the left of, or to the right of the maximum power point (MPP). At sampling instant k, the controller records $V_{PV}(k)$ and $I_{PV}(k)$, then calculates as $DV(k)= V_{PV}(k) - V_{PV}(k-1)$, $DI(k)= I_{PV}(k) - I_{PV}(k-1)$ and $DP(k)= V_{PV}(k).I_{PV}(k)$. The controller applies the following decision criteria:

- If Delta I/Delta V = -I/V, the operating point is at the MPP, and the duty cycle is retained.
- If Delta I/Delta V > -I/V, the operating point is to the left of the MPP, so the PV operating voltage must be moved upward.
- If Delta I/Delta V < -I/V, the operating point is to the right of the MPP, so the PV operating voltage must be moved downward.

The controller updates the duty cycle by a fixed step, Delta D, according to the required direction of change in PV voltage. The duty cycle is limited to the range Dmin < Dmax. The direction of the duty-cycle adjustment depends on the converter's response and the firmware sign convention; the actual rule used in the implemented controller is stated below and must be verified against the Arduino code and experimental operation.

When Delta V is sufficiently close to zero, the controller avoids calculating Delta I/Delta V. It instead evaluates the current change using the implementation's selected tolerance 0. This prevents division by zero and reduces unnecessary duty-cycle changes due to measurement noise. After updating or retaining the duty cycle, the controller outputs the corresponding PWM signal to the MOSFET driver. The resulting PV measurements are used in the next control iteration.

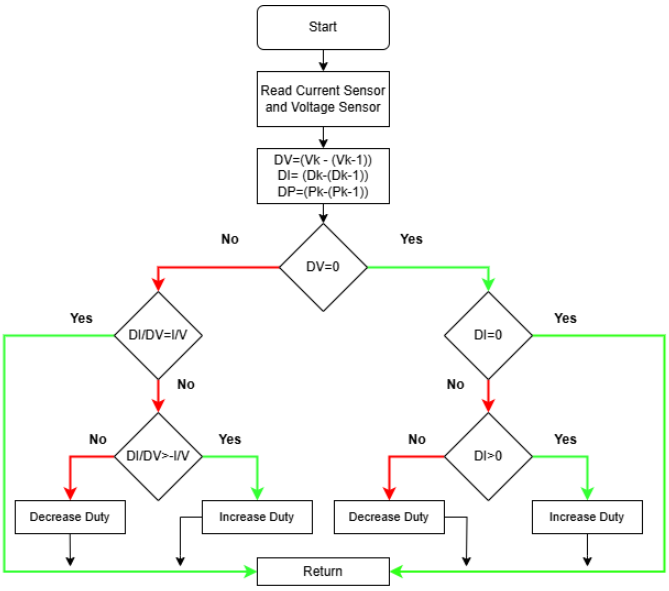


Figure 7: Incremental Conductance Algorithm Flowchart

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2.4. Block diagram of MPPT System

MPPT functions to regulate the panel output voltage to supply maximum energy to the load and usually involves three main components, namely a switch mode DC/DC converter, a control system, and tracking components[5]. The large switch time setting on the Converter using MPPT Technique, requires PV Output Current and PV Output Voltage as a reference in its control.

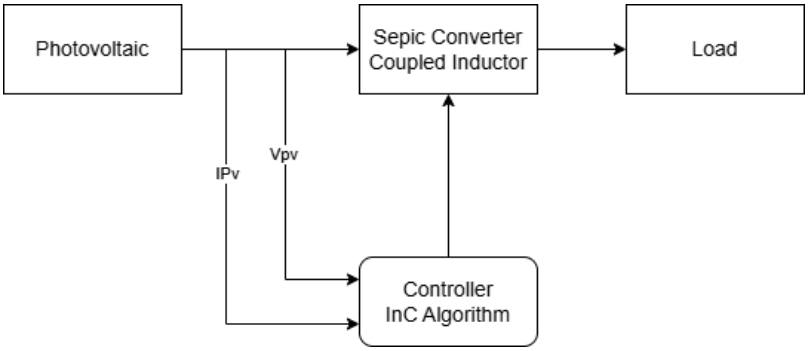


Figure 8: Block Diagram of the MPPT System

2.5 Comparison of PV Output Power and Efficiency: MPPT vs. Non-MPPT Testing Procedure

The comparison tests between the MPPT technique and the non-MPPT (fixed duty cycle) technique were conducted under the following standardized conditions to ensure a fair and reproducible comparison:

- Same Solar Panel: A 50 WP solar panel (SP-50-M36) was used as the input source for both MPPT and non-MPPT tests.
- Same Load: A 14.2 Ω resistive load (chalk resistor) was connected to the SEPIC converter output for both test conditions.
- Same Irradiance Conditions: All tests were conducted during the same daylight period (08:30–15:00 WIB) on the same day, so that the solar irradiance profile was identical for both MPPT and non-MPPT comparisons.
- Same Initial Voltage/Operating Point: The converter was started from the same initial DC bus voltage before entering the MPPT tracking phase or maintaining a fixed duty cycle.
- Measurement Instruments: The same current and voltage sensors were used for both tests, with measurement uncertainties of ±5% for voltage and ±5% for current, as specified by the instrument datasheets.
- Data Sampling: Output voltage, current, and power were logged at 1-second intervals using a data acquisition system connected to the Arduino microcontroller.
- Number of Repetitions: Each MPPT and non-MPPT test condition was repeated three (3) times, and the average values are reported in the results.

By maintaining these identical conditions, any differences in output power or efficiency between the MPPT and non-MPPT results can be attributed solely to the presence or absence of the maximum power point tracking algorithm, rather than to variations in environmental or experimental conditions.

3. Result and Discussion

3.1. PWM (Pulse Width Modulation) Pulse Testing

Switching on the Sepic Converter is done with MOSFET controlled from the Arduino Uno Microcontroller using PWM waves. To drive a high powered MOSFET, a driver is needed to amplify the

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PWM wave from the Microcontroller. In this article, a Mosftet amplifier driver is designed using the TLP250 Optocoupler.

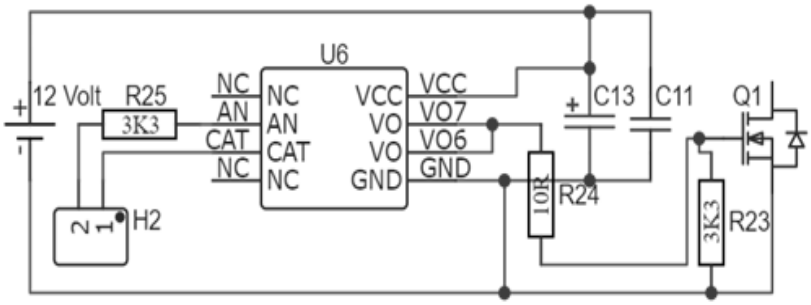


Figure 9: MOSFET Driver Circuit

The TLP 250 Mosfet Driver is used to drive the MOSFET switching on the Sepic Converter circuit with the left side of the IC being the control pin connected to the Microcontroller and the right side being the output with a strong signal to the MOSFET gate pin. The following are the results of PWM testing with Duty Cycle variations at a frequency of 31.4 kHz. The results of the MOSFET Gate Driver test are presented in Figure 9.

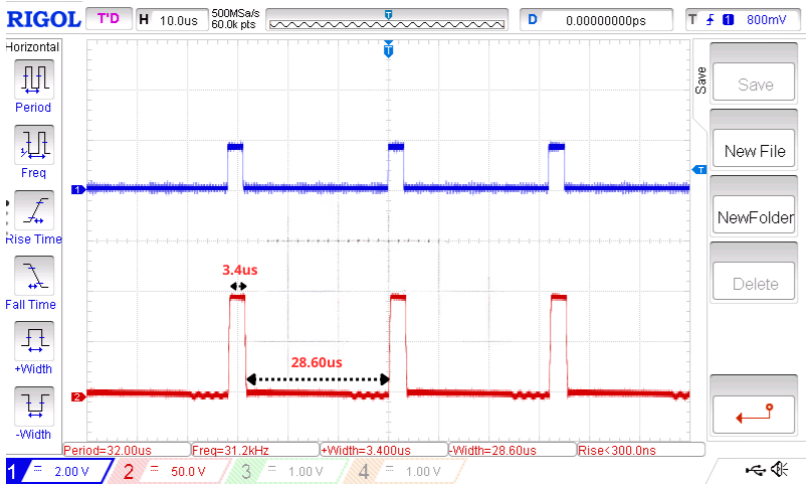


Figure 10: Duty Cycle 10%

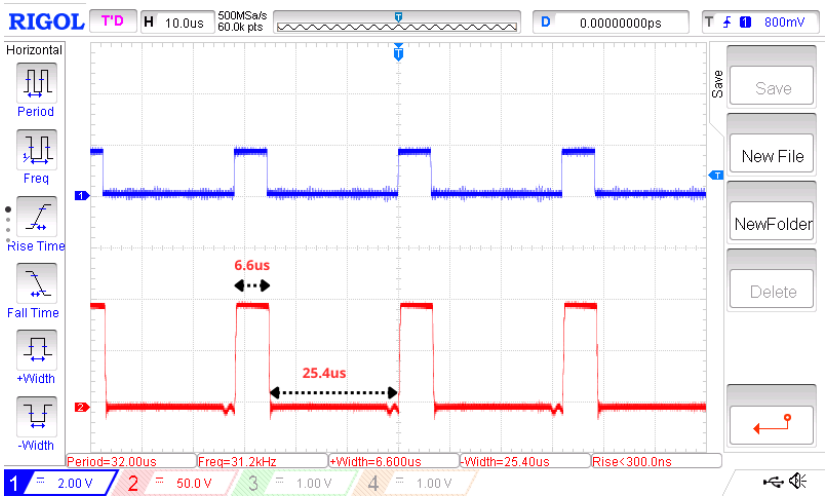


Figure 11: Duty Cycle 20%

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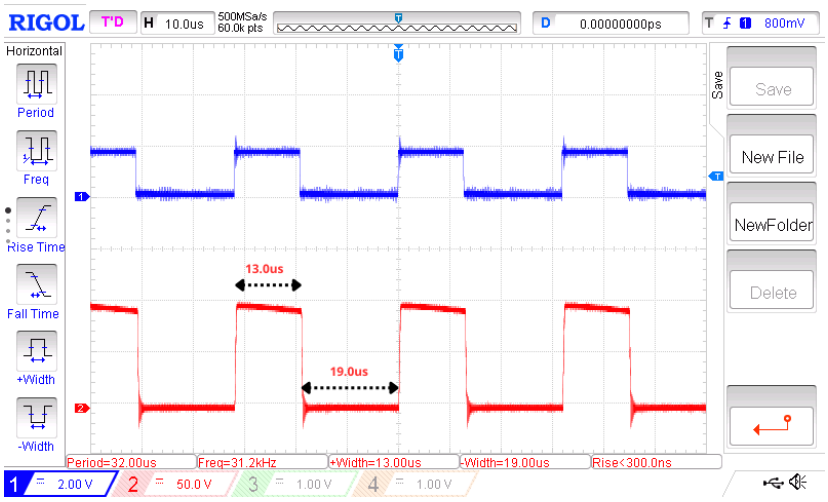


Figure 12: Duty Cycle 40%

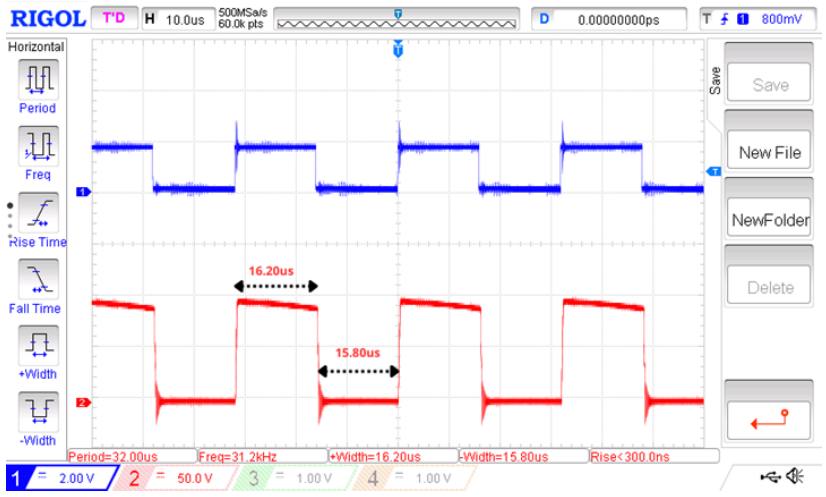


Figure 13: Duty Cycle 50%

From figure 10 until figure 13. is the result of testing the TLP250 MOSFET Switching Driver. Testing is done at Duty Cycle 10%, 20%, 40% and 50%. On the oscilloscope display the test shows the PWM wave in blue is the PWM wave from the Arduino Microcontroller and the red wave is the PWM wave output from the TLP250 MOSFET Driver. From the test results the average rise time switching is very fast at 300ns, the difference in width High and Low PWM waves at Duty Cycle 50 percent there is a slight difference. At Width High (+) has a time of 16.20 us and at width Low (-) has a period of 15.80 us.

3.2. Accuracy testing of Sepic Converter Coupled Inductor

In this test, the design results of the Sepic converter were tested using a 22.5 Volt Power Supply with a coupled load of 14.2 Ω. The test was carried out using a variation of the duty cycle. The test requires a 2-channel oscilloscope to see the work of the PWM and two digital multimeters to see the success of the SEPIC Coupled Inductor power conversion.

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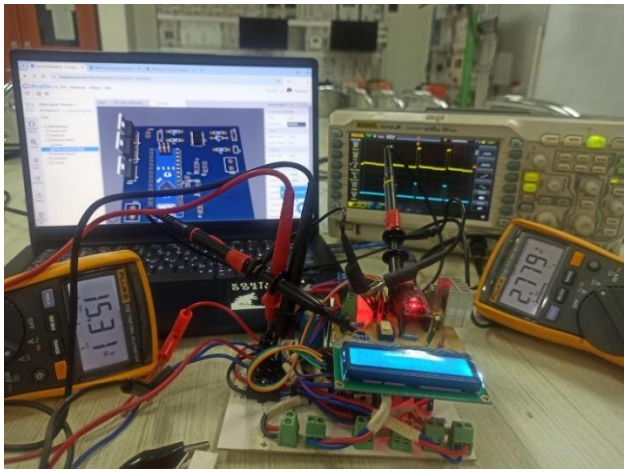


Figure 14: Experiment set up

Figure 14 shows the experimental set up of the SEPIC Coupled Inductor. The test was conducted to see the results of the conversion of electrical power from input power to output power using a digital multimeter. The experimental results shown in Table 2. The results of the SEPIC Coupled Inductor tool seen from the varying voltage along with the changes in the working Duty Cycle. The following are the results of the voltage accuracy test of the SEPIC Coupled Inductor.

Table 2: Sepic Converter accuracy testing

Vin (V)	Duty Cycle (%)	Variable Value		Error (%)
		Multimeter	Theory	
22,5	10	2.2	2.5	12.00
	20	5.3	5.62	5.69
	30	9.4	9.6	2.08
	40	14.6	15	2.67
	50	21.54	22.5	4.27
	55	26	27.45	5.28

From Table 2 shows that the output voltage of the sepic converter can operate according to Theory. At 50% Duty Cycle, the Input Voltage is the same as the Output voltage and when the Duty Cycle is below 50%, the output voltage is smaller than the input voltage and when the Duty Cycle is above 50%, the output voltage is greater than the input voltage.

The difference between the theoretical and measured output voltages in Table 2 may be attributed to component losses and non-ideal characteristics, such as inductor winding resistance, diode forward-voltage drop, MOSFET on-state resistance, and capacitor equivalent series resistance (ESR). Actual component values and inductance may also differ from their nominal values. In addition, measurement-instrument tolerances, variations in duty cycle and switching frequency, and test conditions may affect the results.

The largest error, 12% at a 10% duty cycle, occurs at a low output voltage, where a small absolute difference can result in a comparatively large percentage error. At the other test points, the reported errors range from 2.08% to 5.69%. Since this study does not specify a formal acceptance criterion, these values should be reported as measurement errors rather than as evidence that the results meet a particular tolerance. Future work should establish an acceptance limit based on the design specifications or a relevant standard, and report measurement uncertainty and repeated-test results to support the evaluation.

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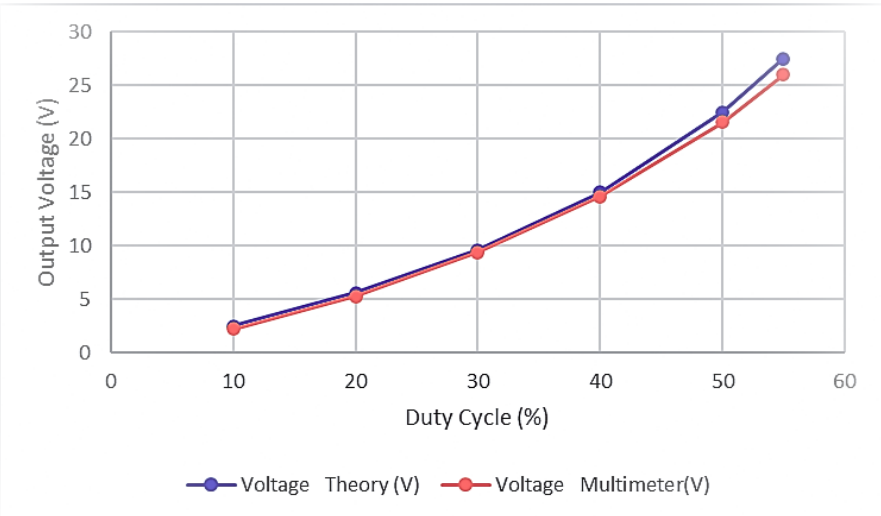


Figure 15: Sepic Converter Accuracy Testing Graph

From figure 15 it shows that the output voltage value of the sepic converter is linear with the size of the duty cycle. From the figure it can be seen that the larger the Duty Cycle, the larger the Output Voltage.

3.3. Sepic Converter Efficiency Testing

This test is conducted to determine the Electrical Power Conversion Efficiency of the designed Coupled Inductor sepic converter. The test is conducted using a 14.2Ω resistive load with Duty Cycle variations.

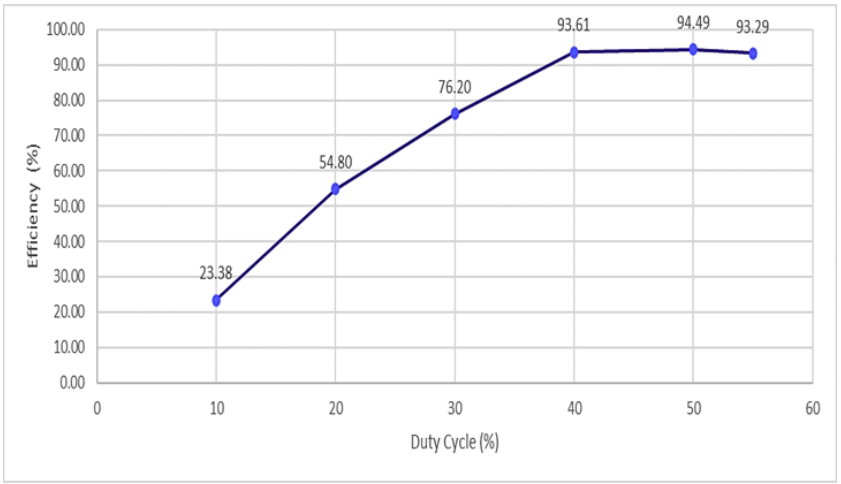


Figure 16: Sepic Converter Efficiency Test Graph

From the results of Figure 16, it shows that the efficiency that works on the Sepic converter depends on the Duty Cycle that works. When the Duty Cycle work above 25%, the average efficiency is 89,2%. The duty cycle take above of 25%, because the range operation is above 25%.

3.4 Testing Sepic Conveter Coupled Inductor with varying loads.

In this test, it is done by giving a load in the form of varying resistive on the Sepic Converter. The resistors used in this test are 14.2 ohms and 5.7 ohms. In this test, a power supply with a constant voltage value is used.

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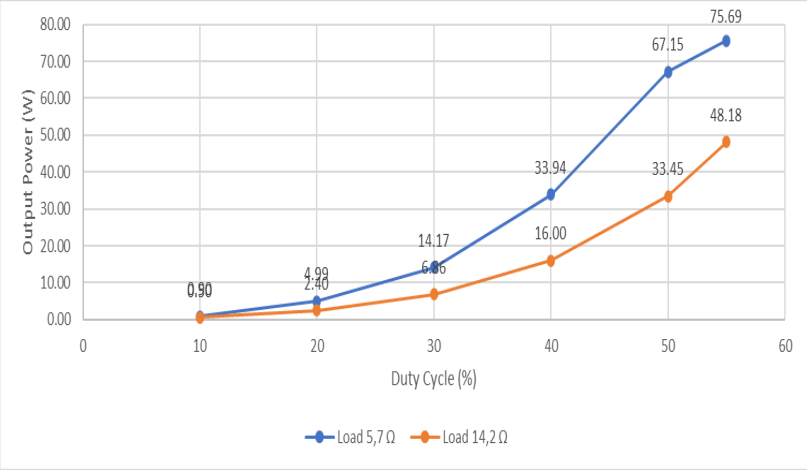


Figure 17: Comparison graph of output power of varying loads

From Figure 17 shows that the variation of the load coupled with the sepic converter can produce different Converter characteristics. With the same Duty Cycle of 50%, the output power generated using a load of 5.7 Ω gets an output power of 67.15 W and at a load of 14.2 Ω gets an output power of 33.45 W.

3.5 PV Characteristics Analysis

The test of solar panel characteristics using 50 WP was carried out at the Power Conversion Laboratory 1 on January 11, 2025. The following are the specifications of the solar panels tested.

Table 3: Solar Panel Specifications

Data	Specifications
Modul Type	SP-50-M36
Pmax	50 W
Current(Imp)	2.85 A
Voltage(Vmp)	17.6
Current(Isc)	3.04 A
Voltage(Voc)	22.5 V

In this test, it is done to determine the characteristics of Irradiation, current, Voltage and power of solar panels by utilizing measurements of open circuit Voltage (Voc) short circuit current (Isc) on solar panels to be able to determine the maximum PV power. Table 4 presents the test results based on calculations in Eq. 12 until Eq. 1.

Table 4: PV Characteristics Testing

Time	Irradiance (W/m2)	Voc (V)	Isc (A)	Incident solar power (W)	Pout (W)	Efficiency (%)
08.30	364.06	19.6	1.16	129.97	16.60	12.77
09.00	402.8	19.9	1.19	143.80	17.34	12.06
09.30	450.5	20.1	1.25	160.83	18.41	11.45
10.00	480.8	20.1	1.37	171.65	20.11	11.72
10.30	495.68	20.1	1.38	176.96	20.21	11.42
11.00	760.05	20.2	1.43	271.34	21.05	7.76
11.30	820.87	20.9	1.54	293.05	23.55	8.04
12.00	842.6	21.1	1.87	300.81	28.74	9.55

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12.30	852.08	21	2.21	304.19	33.93	11.15
13.00	983.11	20.5	2.90	350.97	43.39	12.36
13.30	689.56	20.4	1.99	246.17	29.57	12.01
14.00	503.88	20	1.38	179.89	20.21	11.24
14.30	385.26	20.1	1.10	137.54	16.13	11.73
15.00	364.06	19.9	1.14	129.97	16.60	12.77
Average	599,67	20,28	1,57	214,08	23,27	11,11

Based on the results of the test of the characteristics of the solar panel, it can be seen that by using PV 50 WP, the Irradiation value affects the Voltage and Current produced by the solar panel. In the test carried out, the maximum peak power value of the PV was at 13:00 WIB when the Irradiation was 983.11 W / m2 with a power of 43.39 W and the smallest peak power was obtained at 08:30 WIB when the Irradiation was 365.06 W / m2 with a power of 16.60 W.

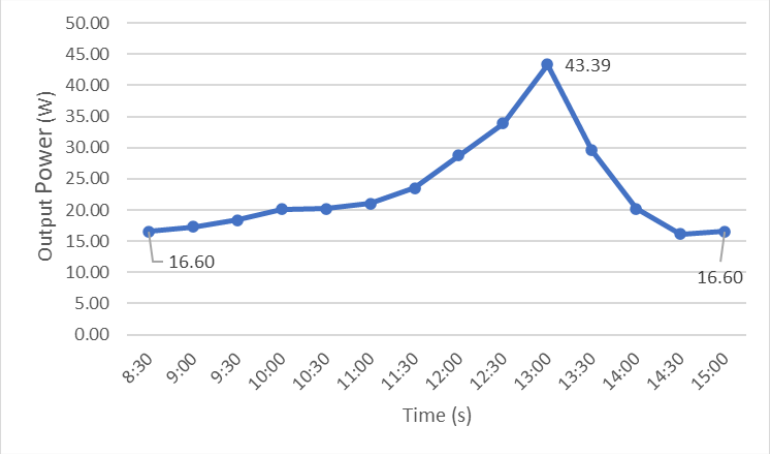
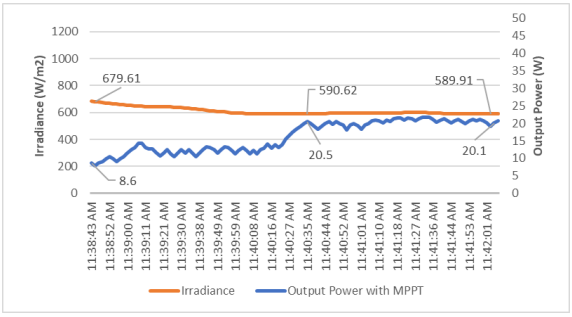


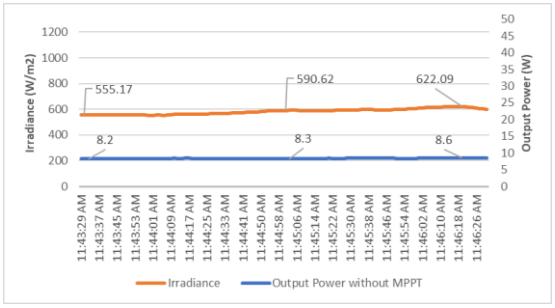
Figure 18: PV Characteristic Testing Graph

3.6 Comparison of PV output power using MPPT technique and without MPPT technique

This test uses a 50 WP solar panel as the input of the Sepic Converter Coupled Inductor with a 14.2 Ω chalk resistor as the load connected to the converter. The DC-DC converter is equipped with current and voltage sensors to measure input power, output, and power transformation efficiency from the solar panel to the load. In the MPPT Technique Test, the duty cycle value will change in finding the best power point and without the MPPT Technique will use a constant Duty Cycle.

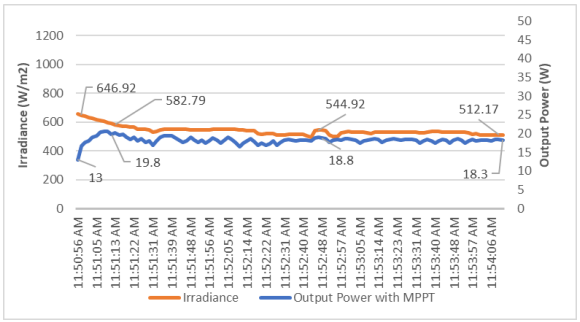


(a)

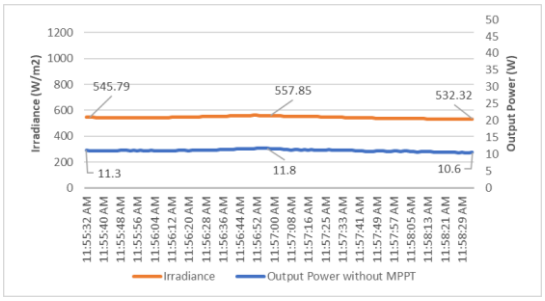


(b)

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(c)



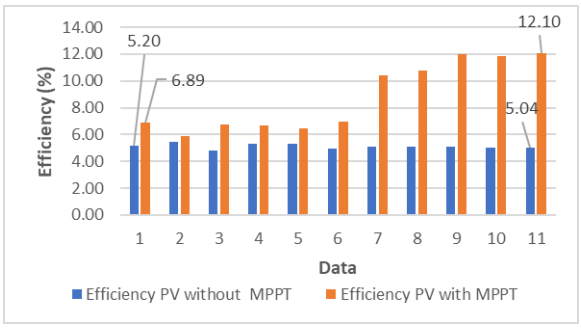
(d)

Figure 19: Comparasion Testing; (a) MPPT testing Duty 35%, (b) Testing without MPPT Technique Duty 35%, (c) MPPT Testing Duty 60%, (d) Testing without MPPT Technique Duty 60%

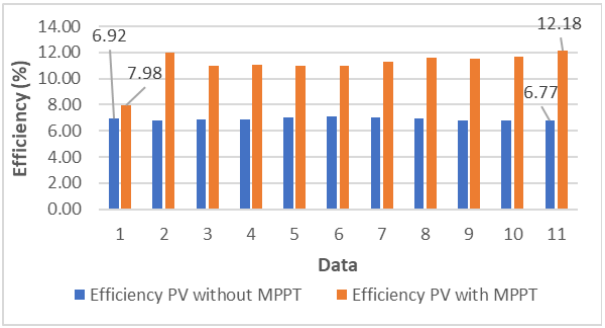
From the results of both figures 19a and 19c, it shows that when the converter uses the MPPT technique, it will be more adaptive to produce the highest output power with changes in solar irradiation, marked by an increase in MPPT output power caused by dynamic MOSFET switching. Figures 19b and 19d show that the output power is constant and small due to the absence of a tracking process to obtain the highest PV output power point.

3.7 Comparison of PV Efficiency using MPPT Technique and without MPPT Technique

This test uses a 50 WP solar panel as the input of the Sepic Converter Coupled Inductor with a 14.2 Ω chalk resistor as the load connected to the converter. The DC-DC converter is equipped with current and voltage sensors to measure input power, output, and power transformation efficiency from the solar panel to the load. In the MPPT Technique Test, the duty cycle value will change in finding the best power point and without the MPPT Technique will use a constant Duty Cycle.



(a)



(b)

Figure 20: Comparasion Testing; (a) Duty Cycle 35%, (b) Duty Cycle 60%

Using the Incremental Conductance MPPT algorithm improved the system's reported efficiency compared with operation without MPPT. For an initial duty cycle of 35%, the efficiency improvement was 7.06%. When the initial duty cycle was 60%, the reported improvement was 6.25%. These results indicate that the MPPT controller can adjust the converter's duty cycle in response to changes in the PV operating conditions, helping the system track the maximum power point more effectively than a fixed-duty-cycle approach. In addition, the SEPIC coupled-inductor converter achieved a reported power-conversion efficiency of 89,2%. when transferring power from the PV output to the load. This converter-efficiency figure describes the proportion of electrical power delivered to the load relative to the power supplied to the converter; it is distinct from the efficiency-improvement percentages reported for the MPPT comparisons.

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3.8 Power Conversion Efficiency of Sepic Converter Coupled Inductor

In Figure 16, it can be seen that the efficiency of the Sepic Converter is quite good, around 89,2% at average duty cycle above 25%. This test was carried out using the MPPT Technique Incremental Conductance Algorithm with a coupled load on the Converter of 14.2 Ω.

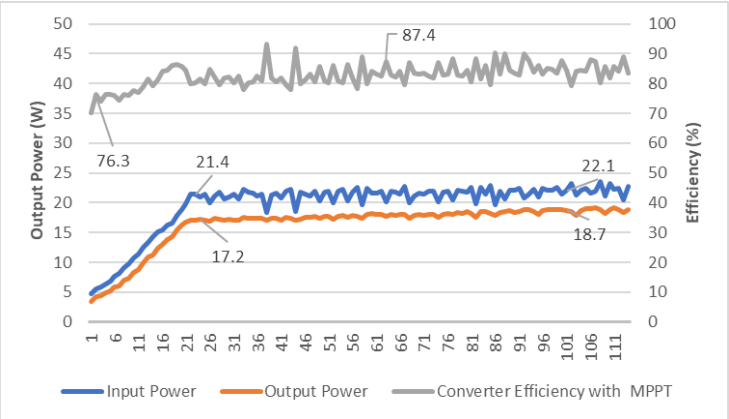


Figure 21: Sepic Converter Power Efficiency

4. Conclusions

This paper presents the design and testing results of SEPIC Coupled Inductor using MPPT Algorithm Incremental Conductance Technique. To optimize the maximum power conversion results produced by PV requires a switching tool. The tool used in this study is the DC-DC SEPIC Converter which has been integrated with MPPT Control Algorithm Incremental Conductance. This algorithm works using changes in current and voltage generated from the PV output when coupled to the load. The algorithm will continue to oscillate continuously to get the best current and voltage so that the power at the PV output can be converted maximally to the load. The test results show that the use of MPPT control will have a more adaptive ability in converting power to the load than without MPPT control. This is because the use of MPPT control has the ability to Track peak power from the control algorithm used. The research results are as follows:

The design and testing of Sepic Converter Coupled Inductor shows good performance, where at duty cycle below 50%, the converter functions as a voltage reducer (buck), at duty cycle 50% the input voltage is the same as the output voltage, and at duty cycle above 50%, the converter functions as a voltage increaser (boost). Testing with an input voltage of 22.5 V produces an output voltage of 2.2 V at a duty cycle of 10%, 21.54 V at a duty cycle of 50%, also 26 V (experiment) and 27.45 V (theory) at a duty cycle of 55%.

The efficiency value using MPPT technique on solar panel power conversion has greater results. At the initial duty cycle of 35 percent has 7.06% better efficiency and the initial duty cycle of 60% has 6.25% better efficiency, and from the electrical power conversion Sepic converter has average 89,2% in converting PV output power to the load.

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