

PHOTOVOLTAIC CHARGING CONTROLLER USING MAXIMUM POWER POINT TRACKING WITH INCREMENTAL CONDUCTANCE METHOD

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Abstract

Photovoltaic functions to convert solar energy into electrical energy. The use of photovoltaic requires a charging controller to improve the performance of PV to be more optimal. The parts of the charging controller consist of a DC-DC converter and maximum power point tracking (MPPT). DC DC converter is used to change the value of the output voltage of the photovoltaic to reach the peak power of the photovoltaic. To determine the peak power value of photovoltaic, MPPT is needed with incremental conductance algorithm. The DC-DC converter uses a buck converter type with a switching frequency of 150kHz and an inductor of 35μH. The incremental conductance algorithm embedded in the microcontroller works by comparing changes in current and voltage to get the peak power value. The result of this microcontroller is a pulse wave whose duty cycle varies based on the results of the algorithm. This pulse wave will control the buck converter. From the results of this study the charging controller is able to work by changing the value of the duty cycle according to the PV conditions when absorbing power.

Keywords: *Photovoltaic, Buck Converter, Incremental Conductance Algorithm*

1. INTRODUCTION

Photovoltaic(PV) is a device capable of converting solar energy into electrical energy. PV was invented by Becquerel in 1839 but was not developed as a power source until 1954 by Chapin, Fuller and Pearson using the silicon semiconductor. The use of installed PV grew from 200 MW in 1990 to over 80,000 MW (80 GW) in 2012, with the same growth rate is expected to continue[1][2]

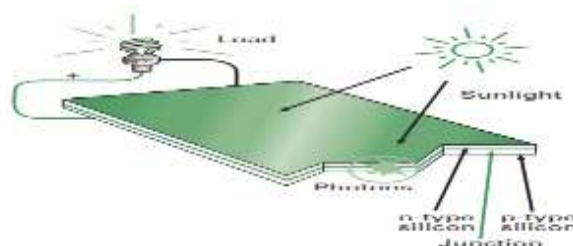
The PV system consists of a battery for storage, a charging controller, an inverter and a monitoring system. The charging controller has an important role in managing the output of the PV. The charging controller has a function by adjusting the PV performance so that it is always optimal and protects. Its charge control function protects the battery by turning off the charging current when it is fully charged and by disconnecting the battery from a DC load when sensing low voltage conditions[2]. Buck converter is a DC DC converter that is able to lower the voltage. According to Marian K. Kazimierczuk, the highest efficiency of the buck converter is around 93%. This efficiency depends on the value of the load resistance with the value of the duty cycle[3].

To maintain the optimal PV value, the maximum power point tracking (MPPT) method is used to achieve peak power from the PV output. MPPT consists of various methods, one of which is the incremental conductance method. Fiko Senrianokxi has conducted research and proved that the incremental conductance algorithm has higher efficiency than petrub and observe[4][5].

Based on this, the author made the title "Design of Photovoltaic Charging Controller Using Maximum Power Point Tracking (MPPT) With Incremental Conductance Algorithm".

2. THEORETICAL BASE

Photovoltaic (PV)

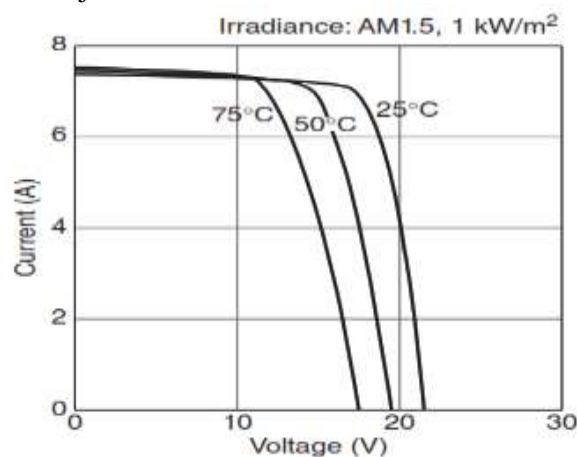


Picture 1. How PV works

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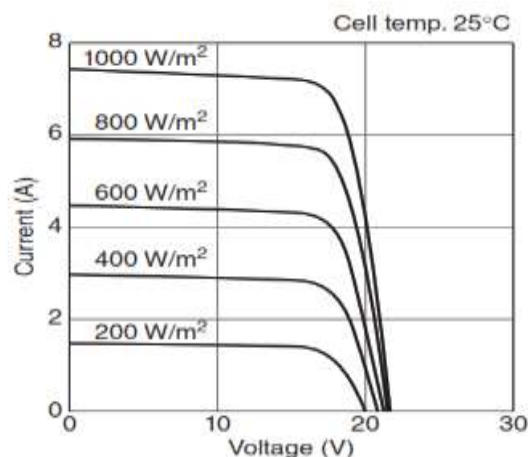
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PV generally consists of two p-type and n-type semiconductor materials which, when exposed to solar radiation, will flow electrons. This flow of electrons is known as the flow of electric current in the form of DC. The semiconductor material used by solar cells is made of silicon. In silicon there are at least two layers, namely a positively charged layer and a negatively charged layer, which are separated by a junction between the two layers. The junction formed between the n-type silicon and the p-type surface layer produces an electric field that causes the diode characteristics as well as the PV effect. The PV effect is the release of photon energy when exposed to sunlight on metal objects.



Picture 2. Effect of parallel-connected modules on current

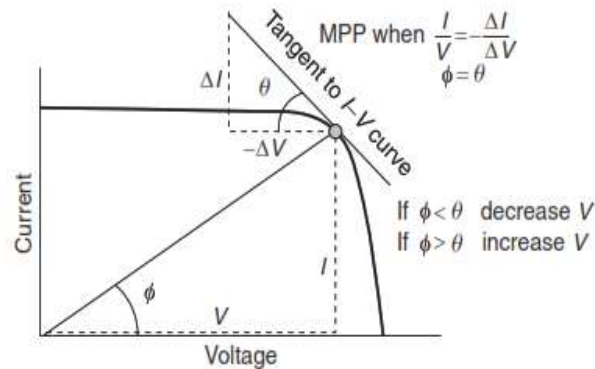
Temperature is very influential on the performance of PV where the temperature will affect the value of the voltage. Figure 2 explains that with different temperatures with constant radiation there is a change in voltage. The higher the temperature around the PV, the lower the voltage.



Picture 3. Effect of photovoltaic on radiation

Solar radiation is an unlimited source of energy in PV itself, radiation plays a big role. It can be seen from Figure 3 that the current will increase if the radiation increases with a constant temperature.

Incremental Conductance Algorithm

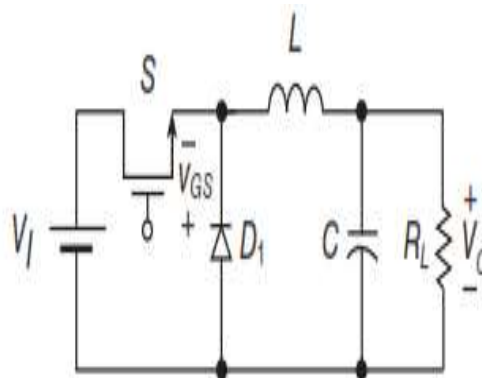


Picture 4. MPP curve interpretation with incremental conductance method

The I/V ratio, called instantaneous conductance, is based on measurements of PV current and voltage taken in fixed increments of time. The ratio $I/\Delta V$, called the incremental conductance, indicates the possible change in I and V during one of these time steps. Figure 5 shows one interpretation of this conductance on the PV I – V curve. Instantaneous conductance is the slope of the line drawn from the origin to the operating point. Incremental conductance is the negative slope of the I – V curve at the same operating point. From the figure, it can be seen that the MPP angle formed by the two slopes is the same. The MPP can be found by increasing the buck converter of the converter until the incremental ratio changes V and I equals I/V i.e. until the angles and are equal.

Buck Converter

In an MPPT there is a main circuit that functions to support MPPT performance. The circuit is a circuit that serves to convert the voltage value. DC DC converter is a circuit capable of changing the value of the voltage. Buck converter is a circuit used to lower the visible DC voltage[5]. Figure 2.12 which is a circuit of a buck converter.



Picture 5. Buck converter circuit

In designing a buck converter, the minimum and maximum output power values of the converter must be considered.

$$\begin{aligned} P_{\text{max}} &= & 1 \\ V_O \cdot I_{\text{omax}} & \dots\dots\dots \\ P_{\text{min}} &= & 2 \\ V_O \cdot I_{\text{omin}} & \dots\dots\dots \\ & \dots\dots\dots \end{aligned}$$

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Every electronic circuit has a resistance value as well as a buck converter circuit. To calculate the resistance value as follows:

$$R_{L_{max}} = \frac{V_o}{I_{omin}} \dots\dots\dots 3$$

$$R_{L_{min}} = \frac{V_o}{I_{omax}} \dots\dots\dots 4$$

By comparing the value of the output and input voltages, the value of the DC voltage transfer will be obtained.

$$M_{VDCmin} = \frac{V_o}{V_{Imax}} \dots\dots\dots 5$$

$$M_{VDCnom} = \frac{V_o}{V_{Inom}} \dots\dots\dots 6$$

$$M_{VDCmax} = \frac{V_o}{V_{Imin}} \dots\dots\dots 7$$

...

By determining the frequency value, the minimum and used inductor and capacitor values will be obtained.

$$L_{min} = \frac{R_{L_{max}}(1-D_{min})^2}{2f_s} \dots\dots\dots 8$$

$$C_{min} = \frac{D_{max}V_o}{2f_sR_{Lmin}V_{Cpp}} \dots\dots\dots 9$$

Arduino

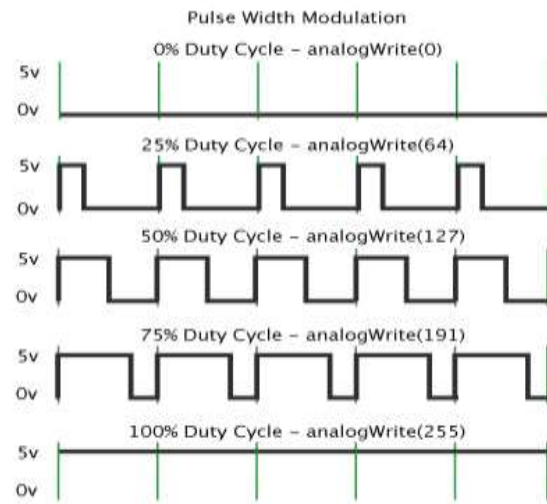
Arduino uno is a microcontroller that uses the Atmega328 microprocessor. Arduino uno works on a voltage of 5V for system operation and an input voltage of 7V to 12V with a CPU speed of 16 MHz. Table 2.1 specifications of the Arduino Uno. Arduino uno has 14 digital input and output pins, of which there are 6 PWM output pins. In Figure 6 you can see the Arduino Uno pins.



Picture 6. Arduino Pin

Arduino provides 8bit Pulse Width Modulation (PWM) output on pins 3, 5, 6, 9, 10 and 11. Figure 7 shows the duty cycle settings on the Arduino. Because Arduino provides 8 bits of PWM output which means it has a variation value of $2^8 = 256$ with a conversion value of 0-255. So for

the value of duty cycle 0% using a value of 0, the value of duty cycle 50% using a value of 127 and for a value of 100% using a value of 255.



Picture 7. Arduino PWM

3. IMPLEMENTATION METHOD

In this stage the author makes a research flow chart made to make it easier to analyze and implement a system.

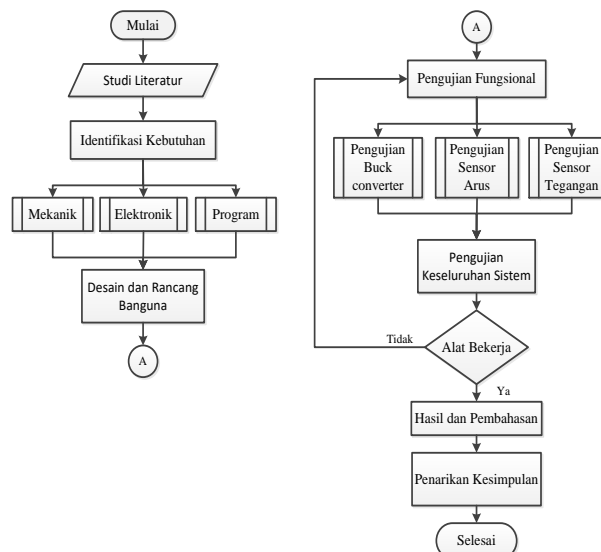


Figure 8. Research methodology flowchart

The description of the flow chart above includes literature study, design stage, development stage, testing, data collection, analysis, and drawing conclusions from the research results.

Block diagram

In the system model, the author makes a block diagram of the tool to be designed. This block diagram is made to simplify the process of making the tool you want to build and to know the working system of the tool. The components contained in the block diagram include a pH sensor, ultrasonic sensor HC-SR04, relay module, Arduino Uno, LCD, buzzer and 12 volt DC water pump.

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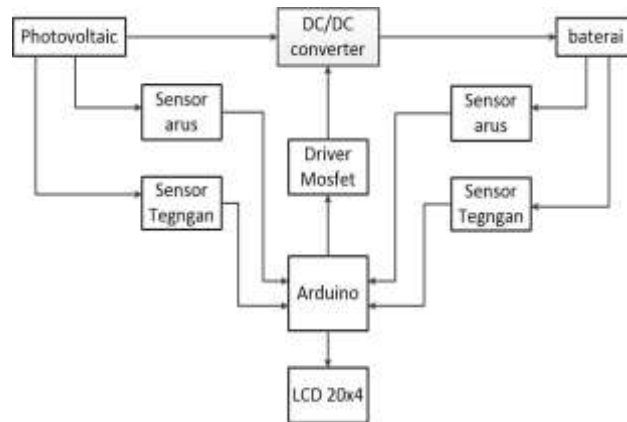


Figure 9. Block diagram tools

1. PV is an energy source which can convert solar energy into electrical energy. In this study, PV will be used as a source where the output will be adjusted to reach the MPP . point
2. Buck converter is a device used to lower the voltage. The use of the buck converter is to adjust the PV output to reach the MPP point and match the battery charging voltage.
3. Arduino uno as the center for controlling the tool where arduino uno adjusts the buck converter with PWM to be able to reach the MPP value. Arduino is also used to read the results of the current sensor and voltage sensor.
4. Current sensor as a tool used to measure the current value where the output is connected to Arduino. The use of the current sensor is also aimed at the incremental conductance algorithm where the output current value of the PV is required for the algorithm.
5. The voltage sensor is used to measure the voltage value with the output connected to the Arduino. Voltage sensors also have other uses as well as current sensors.
6. The mosfet driver is used to increase the amplitude of the Arduino output in the form of a pulse wave so that it can activate the MOSFET in the buck converter circuit.
7. The 20x4 LCD is used for monitoring the results of the current sensor and voltage sensor measurements.
8. The motor is used as a load.

Buck converter design

The design of the buck converter uses a PV input with a power value of 100 WP, a maximum voltage of 5V, an open circuit voltage of 6V and a maximum current of 20A. While the output of the buck converter uses a battery with a battery capacity specification of 80Ah with a charging voltage of 4V and a discharging voltage of 3.6V. From the PV and battery specifications it is obtained and $V_f = 4V - 6V$, $V_o = 4V$, $I_o = 1 - 20A$

$$P_{omax} = 3,6 \times 20 = 72watt$$

$$P_{omin} = 3,6 \times 1 = 3,6watt$$

Maximum and minimum load values based on the formulas 2.14 and 2.15

$$RL_{max} = \frac{3,6V}{1A} = 3,6\Omega$$

$$RL_{min} = \frac{3,6}{20} = 0,18\Omega$$

The minimum, nominal, and maximum values of the DC voltage transfer function are:

$$M_{VDCmin} = \frac{3,6}{6} = 0.6$$

$$M_{VDCnom} = \frac{3,6}{5} = 0,72$$

$$M_{VDCmax} = \frac{3,6}{4} = 0,9$$

Assume the buck converter has an efficiency of =90%. The nominal minimum and maximum duty cycle values are as follows

$$D_{min} = \frac{0,6}{0,6 + 0,7} = 0,46$$

$$D_{nom} = \frac{0,72}{0,72 + 0,7} = 0,5$$

$$D_{max} = \frac{0,9}{0,9 + 0,7} = 0,56$$

The selection of the switching frequency is 150kHz so that it can reduce the value of the inductor used. Determine the minimum value of the inductor value based on the 9 . formula

$$L_{min} = \frac{3,6(1 - 0,46)^2}{2 \times 150 \times 10^3} = 35\mu H$$

The choice of capacitor affects the voltage ripple. The smaller the ripple, the better the resulting voltage. For this reason, we assume that the value of a small voltage ripple is 0.01. In accordance with the formula 10 then to calculate the value of the capacitor is as follows

$$C_{min} = \frac{0,56 \times 4}{3 \times 10^4 \times 0.18 \times 0,01} = 415\mu F$$

For that choose a capacitor with a value of 470 F which is easy to obtain.

4. RESULTS AND DISCUSSION

Buck converter test

The buck converter test is carried out to measure the value of the change in voltage at the output of the buck converter. Power supply is used as input with a load resistor of 1Ω. Arduino is used to issue a pulse wave which then increases the amplitude with the mosfet driver.

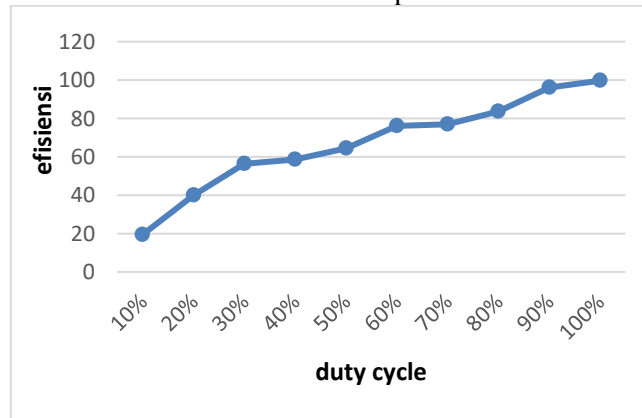


Figure 10. Buck converter efficiency graph

Figure 10 is a graph of the efficiency of the buck converter. From the graph, it can be seen that the higher the duty cycle value, the higher the efficiency value of the buck converter. The lowest efficiency value is around 19% when the duty cycle is set at 10% and the efficiency reaches 90% when the duty cycle is 100%.

Current sensor testing

Sensor testing is done by using a power supply and a load in the form of a 1Ω resistor. This test is carried out to obtain the error value between the ampere meter and the current sensor. Figure 11 is a graph of the ACS712 current sensor test. The error value is getting lower when the current measured is higher. However, the value increased at 4.99 A measurement.

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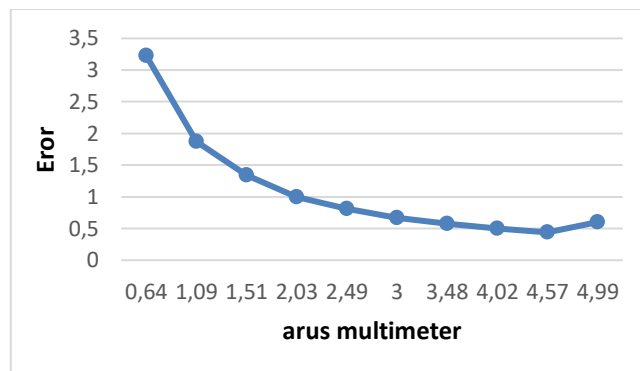


Figure 11. Current sensor test graph

Voltage Sensor Test

Testing the voltage sensor is done by connecting the power supply to the voltage sensor. By changing the value of the power supply voltage and comparing the value displayed on the 20X4 LCD with a volt meter. The test circuit can be seen in Figure 12 the voltage sensor test circuit.

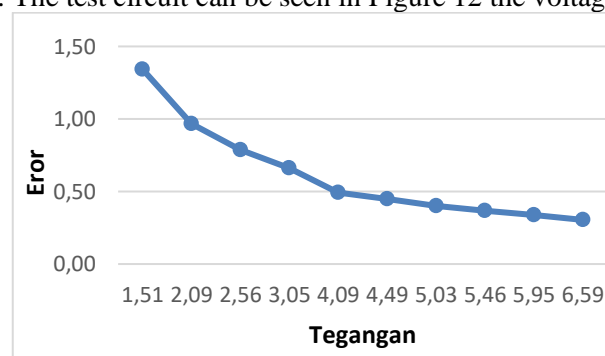


Figure 12. Voltage sensor test graph

Overall testing

Table 1. Voltage And Current Table

O'clock	light (klux)	Temperature (oC)	Vin (V)	Vout (V)	Iin (A)	Iout (A)	Pin (W)	Pout (W)	D
08:00	14.7	33	3.84	2.86	3.25	3.95	0.74	12.48	11.30
08:30	16.7	34	3.93	3.04	3.43	4.05	0.77	13.48	12.31
09:00	30.6	32	4.03	3.03	3.51	4.25	0.75	14.15	12.88
09:30	45.7	32	4.15	3.15	3.64	4.37	0.76	15,11	13.77
10:00	44.8	31	4.08	3.08	3.39	4.1	0.75	13.83	12.63
10:30	57.6	39.4	4.25	3.35	3.45	4.03	0.79	14.66	13.50
11:00	69.8	43.2	4.42	3.52	3.45	4.05	0.80	15.25	14.26
11:30	72.3	44.2	4.61	3.67	3.63	4.25	0.80	16.73	15.60
12:00	77.3	46.7	4.52	3.52	3.64	4.39	0.78	16.45	15.45
12:30	78.4	45, 9	4.69	3.79	3.78	4.28	0.81	17.73	16.22
13:00	65.4	46.1	4.32	3.33	3.51	4.27	0.77	15,16	14.22
13:30	76.1	43.8	4.49	3.47	3.53	4.27	0.77	15.85	14.82
14:00	71.4	36	4.68	3.71	3.62	4.29	0.79	16.94	15.92
14:30	68.3	37	4.53	3.61	3.71	4.35	0.80	16.82	15,70
15:00	60.4	38	4.43	3.43	3.4	3.93	0.77	15.06	13.48
15:30	45.6	40.3	4.41	3.42	3.61	4.25	0.78	15.92	14.54

16:00	40.3	36	4.38	3.34	3.56	4.23	0.76	15.59	14.13
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The output voltage on the PV will increase if the light intensity value increases as well. This is because if the value of light intensity increases, it will cause the value of solar radiation to increase as well. Meanwhile, the PV output voltage drops by a slight difference which indicates the buck converter is working well during the overall test.

The change in duty cycle indicates that the incremental conduction algorithm is working well. For example, testing on December 21, the duty cycle at peak power at 12:30 reached a value of 0.81 or 81%. This is because the change in maximum power increases causing the microcontroller to increase the duty cycle value in order to maximize the power absorbed by the PV.

5. CONCLUSION

The conclusions that can be drawn from the discussion of the discussion of the tools made are as follows:

1. The incremental conductance algorithm works by comparing changes in current and voltage at the PV output. To find out changes in current and voltage, current and voltage sensors are needed. The voltage sensor used has an error of 0.61% and the current sensor used has an error of 0.88%. The current and voltage values are processed in the microcontroller to determine the duty cycle output used.
2. Buck converter is built using mosfet, diode, inductor and capacitor. The mosfet used is of the IRF3205 type which has the ability to flow 80A of current and the diode used is MUR 1650 type. The buck converter that is built can reduce the voltage with the highest efficiency of 99.65% by testing using a 1Ω load.
3. The performance of the charging controller using MPPT with the incremental conductance method is able to work by changing the duty cycle value. The duty cycle will be higher if the power absorbed by PV increases.

REFERENCES

- Bustani, B., Khaddafi, M., & Nur Ilham, R. (2022). Regional Financial Management System of Regency/City Regional Original Income in Aceh Province Period Year 2016-2020. *International Journal of Educational Review, Law and Social Sciences (IJERLAS)*, 2(3), 459–468. <https://doi.org/10.54443/ijerlas.v2i3.277>.
- Falahuddin, F., Fuadi, F., Munandar, M., Juanda, R., & Nur Ilham, R... (2022). Increasing Business Supporting Capacity In Msmes Business Group Tempe Bungong Nanggroe Kerupuk In Syamtalira Aron District, Utara Aceh Regency. *Irpitage Journal*, 2(2), 65–68. <https://doi.org/10.54443/irpitage.v2i2.313>.
- F. Senrianokxi, “Rancang Bangun Modul Converter DC-DC Menggunakan Mikrokontroler Arduino Berbasis IoT Untuk Penelitian MPPT (Maximum Power Point Tracking) Pada Panel Surya,” *Semin. Has. Elektro S1 ITN Malang*, 2020.
- G. M. Masters, *RENEWABLE AND EFFICIENT ELECTRIC POWER SYSTEMS*, Second edi. New Jersey: John Wiley & Sons, 2013.
- Geovani, I., Nurkhotijah, S., Kurniawan, H., Milanie, F., & Nur Ilham, R... (2021). Juridical Analysis of Victims of The Economic Exploitation of Children Under the Age to Realize Legal Protection from Human Rights Aspects: Research Study at The Office of Social and Community Empowerment In Batam City. *International Journal of Educational Review, Law and Social Sciences (IJERLAS)*, 1(1), 45–52. <https://doi.org/10.54443/ijerlas.v1i1.10>.
- Ilham, Rico Nur. *et all* (2019). Comparative of the Supply Chain and Block Chains to Increase the Country Revenues via Virtual Tax Transactions and Replacing Future of Money. *International Journal of Suplly Management*. Volume 8 No.5 August 2019.
- Ilham, Rico Nur. *et all* (2019). Investigation of the Bitcoin Effects on the Country Revenues via Virtual Tax Transactions for Purchasing Management. *International Journal of Suplly Management*. Volume 8 No.6 December 2019.

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- Lasta Irawan, A. ., Briggs, D. ., Muhammad Azami, T. ., & Nurfaliza, N. (2021). The Effect of Position Promotion on Employee Satisfaction With Compensation As Intervening Variables: (Case Study on Harvesting Employees of PT. Karya Hevea Indonesia). *International Journal of Social Science, Educational, Economics, Agriculture Research, and Technology (IJSET)*, 1(1), 11–20. <https://doi.org/10.54443/ijset.v1i1.2>
- Likdanawati, likdanawati, Yanita, Y., Hamdiah, H., Nur Ilham, R., & Sinta, I. (2022). Effect of Organizational Commitment, Work Motivation And Leadership Style on Employee Performance of Pt. Aceh Distribus Indo Raya. *International Journal of Social Science, Educational, Economics, Agriculture Research, and Technology (IJSET)*, 1(8), 377–382. <https://doi.org/10.54443/ijset.v1i8.41>.
- M. H. Rashid, *Power electronics: devices, circuits and applications*, Fourth Edi. Pearson Education, 2014.
- M. K. Kazimierczuk, *Pulse-Width Modulated DC–DC Power Converters*, Second Edi. Ohio: John Wiley & Sons, 2016.
- Majied Sumatrani Saragih, M., Hikmah Saragih, U., & Nur Ilham, R... (2021). Relationship Between Motivation and Extrinsic Motivation to Increasing Entrepreneurship Implementation from Spp Al-Falah Group at Blok 10 Village Dolok Masihul. *Morfai Journal*, 1(1), 1–12. <https://doi.org/10.54443/morfai.v1i1.11>
- Nur Ilham, R., Arliansyah, A., Juanda, R., Multazam, M., & Saifanur, A. (2021). Relathionsip Between Money Velocity and Inflation to Increasing Stock Investment Return: Effective Strategic by Jakarta Automated Trading System Next Generation (Jats-Ng) Platform. *International Journal of Economic, Business, Accounting, Agriculture Management and Sharia Administration (IJEBA)*, 1(1), 87–92. <https://doi.org/10.54443/ijeabas.v1i1.27>
- Nur Ilham, R., Heikal, M., Khaddafi, M., F, F., Ichsan, I., F, F., Abbas, D., Fauzul Hakim Hasibuan, A., Munandar, M., & Chalirafi, C. (2021). Survey of Leading Commodities of Aceh Province As Academic Effort to Join and Build The Country. *Irpitage Journal*, 1(1), 13–18. <https://doi.org/10.54443/irpitage.v1i1.19>
- Nur ilham, R., Likdanawati, L., Hamdiah, H., Adnan, A., & Sinta, I... (2022). Community Service Activities “Socialization Avoid Study Investment” to The Student Bond of Serdang Bedagai. *Irpitage Journal*, 2(2), 61–64. <https://doi.org/10.54443/irpitage.v2i2.312>
- Rahmaniar, R., Subhan, S., Saharuddin, S., Nur Ilham, R. ., & Anwar, K. . (2022). The Influence of Entrepreneurship Aspects on The Success of The Chips Industry In Matang Glumpang Dua and Panton Labu. *International Journal of Social Science, Educational, Economics, Agriculture Research, and Technology (IJSET)*, 1(7), 337–348. <https://doi.org/10.54443/ijset.v1i7.36>
- Sandi, H. ., Afni Yunita, N. ., Heikal, M. ., Nur Ilham, R. ., & Sinta, I. . (2021). Relationship Between Budget Participation, Job Characteristics, Emotional Intelligence and Work Motivation As Mediator Variables to Strengthening User Power Performance: An Emperical Evidence From Indonesia Government. *Morfai Journal*, 1(1), 36–48. <https://doi.org/10.54443/morfai.v1i1.14>.
- Selamat, M, Saifuddin. M.J, Wahyu F, Asran. Application of Off-Grid Solar Panels System for Household Electricity Consumptions in Facing Electric Energy Crisis, *IJESTY*, Vol 2, No 1, 2022.
- Sinta, I., Nur Ilham, R., Kumala Sari, D., M, M., Khaidir, K., & Ekamaida, E. (2021). Training The Processing of Tomato Sauce For A Home-Based Business The Scale of SMES. *Irpitage Journal*, 1(1), 26–28. <https://doi.org/10.54443/irpitage.v1i1.24>
- Sinurat, M., Heikal, M., Simanjuntak, A., Siahaan, R., & Nur Ilham, R... (2021). Product Quality on Consumer Purchase Interest with Customer Satisfaction as A Variable Intervening In Black Online Store High Click Market: Case Study on Customers of the Tebing Tinggi

- Black Market Online Store. *Morfai Journal*, 1(1), 13–21.
<https://doi.org/10.54443/morfai.v1i1.12>.
- T. W. Twidell, John, *Renewable Energy Resources*, Third edit. New York: Routledge, 2015.
- Yusuf Iis, E., Wahyuddin, W., Thoyib, A., Nur Ilham, R., & Sinta, I. (2022). The Effect of Career Development and Work Environment on Employee Performance With Work Motivation As Intervening Variable At The Office Of Agriculture And Livestock In Aceh. *International Journal of Economic, Business, Accounting, Agriculture Management and Sharia Administration (IJEBAS)*, 2(2), 227–236.
<https://doi.org/10.54443/ijevas.v2i2.191>.

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