Comparison of Two Simple Power Plant Design at Different Height and Water Discharge

Tri Ariani[1] , Ovilia Putri Utami Gumay [2]
[1,2]Physic Education Program, STKIP PGRI Lubuklinggau, Lubuklinggau, Sumatera Selatan, Indonesia

Coressponding Author. E-mail:
[1] triariani.ta@gmail.com
[2] zhoulia@gmail.com

Received: December 18th, 2020 *Accepted:* January 26th, 2021 *Online Published:* January 30th, 2021

Abstract

This study aims to determine the comparison of two electrical energy produced by the Minihidro Power (PLTMH) at different heights and water discharge. After all the systems that support the construction of the mini-hydro have been designed and connected to each other to form the expected mini-hydro system, the next step is the mini-hydro work testing phase. As for the implementation using the experimental method by operating a mini-hydropower plant with variations in changing the height and water discharge. This research was conducted to determine the current and voltage produced by observing the current and input voltage and current and output voltage of the inverter circuit. The test is carried out using ammeters and voltmeters, then the measurement results are entered in a table. This study obtained data V and me to calculate the electric power generated (P). The analysis was done descriptively by comparing the data obtained to observe the effect of water height (h) and water discharge (Q) on electric power (P). From the experimental results, the greater the price of h and Q, the greater the P produced. So from this experiment, we can be implemented in a PLTMH builder by knowing the maximum water level and discharge from a water source. From the results of these experiments it can be said the higher the water to the generator, the greater the electrical energy produced. This is in accordance with the potential energy it has. The greater the potential energy of an object means the greater the electrical energy. From the comparative data of Experiments 1 and 2, it is obtained that the amount of water debit greatly influences the amount of energy/electricity generated. This is due to the large mass of water that will hit the turbine so the generator turns faster, resulting in large mechanical energy. So to build a PLTMH, water flow and altitude must be considered..

***Keywords**: Minihidro; Electricity; Voltage; Current; Discharge.*

How to cite this article :

Ariani, T. & Gumay, O. P. U.(2021). Comparison of Two Simple Power Plant Design at Different Height and Water Discharge. *IJIS Edu : Indonesian Journal of Integrated Science Education, 3*(1), 78-85. doi:http://dx.doi.org/10.29300/ijisedu.v3i1.4183

INTRODUCTION

Energy has an important role in global and socio-economic development. Today, the need for energy has increased because of the growing amount of energy used in industry, housing and agricultural activities. Energy demand is often met by conventional methods based on fossil fuels. The reduction and harmful effects on the environment of fossil fuel resources have led to sustainable and environmentally friendly energy sources (Celikdemir, S., Yildirim, B., & Ozdemir, M. T, 2017). Energy is a supporting element which is very important for the overall development of a nation. efficient use will be a powerful tool to stimulate the country's economic growth. for this reason, it is understandable that in recent times the demand for power generation has increased in countries around the world. Broadly speaking, it can be said that, in terms of energy needs, it is almost certain that all countries in the world are really experiencing an "energy crisis" and various activities are being carried out to explore the use of various alternative energy generation to meet the increasing needs (Warsito, s ., Syakur, a., & Nugroho, A. A., 2005).

Energy is an important aspect of life as a whole. The energy source that is currently widely used in Indonesia comes from coal, which is known to be limited in number. So that we need another source that is renewable and can always be used as a source of sustainable energy. Energy sources that can be utilized are wind energy, water, sunlight and geothermal energy. According to the 2005-2025 National Energy Management Blueprint data issued by the Ministry of Energy and Mineral Resources (DESDM) in 2005, petroleum reserves in Indonesia in 2004 are estimated to be exhausted within 18 years with the reserve / production ratio for that year. Meanwhile, gas is estimated to run out within 61 years and coal 147 years (Sulistiyono et al. 2013).

Different to fossil fuel, which is evidently producing greenhouse gas emission, the environmental impact associated with mini hydropower plants has not been thoroughly explored. Flury and Frischknecht (2012) conducted life cycle inventories of hydroelectric power generation in Europe. Their report showed that marine ecotoxicity, human toxicity and global warming were the highest impact related to the operation of hydropower plants. However, they omitted the infrastructure of the hydropower plant from their study (Hanafi, J., & Riman, A. ,2015).

The existence of water resources is currently not fully utilized. The amount of water in West Java reaches 4.3 billion m^3 / year, but only 28% is used (Bappenas, 2011). One of the potential uses of water resources is as a power plant. One of the renewable energy sources and has great natural resource potential in Indonesia that has not been utilized as a primary energy source for electricity generation purposes is Hydro energy. The potential of hydro energy possessed by Indonesia is very large, while its use as primary energy for generating purposes is only about 6% of the existing potential (Taofeq, t., Anggoro, b., & Arfianto, t., 2013). Micro Hydro Power Plant (PLTM) is not a new thing, the idea of using water energy has been around since 1970. However, its use in Indonesia is not too much. Overall, the use of renewable energy power plants in 2012 was still low, reaching 11.31% of the total energy produced (Kementrian ESDM 2013).

Electric power is one of the supporting elements which is very important for the overall development of a nation. Proper utilization uses a powerful tool to stimulate the country's economic growth. Recently the demand for electricity generation is increasing in countries around the world. In terms of general electricity needs, it can be said that the State of Indonesia is inadequate for even distribution of energy sources, especially in rural areas, especially now that all community activities use electricity as a source of energy. Electricity is a vital need of society that cannot be separated from everyday life. Starting from the simplest function, namely lighting to other functions as a means of obtaining entertainment and information such as (television, radio, cell phone charger, and others). In this modern era, electricity is also used to replace fuel oil or gas used for cooking through the use of electric cooking utensils, such as rice cookers and electric water cookers. Likewise with cell phones, in the era of information and openness, nowadays cell phones have penetrated into villages (Setiawan Wie, D., 2017).

The condition of a water source that can be used as a power-producing resource is that it has a certain flow capacity and height from the installation. The greater the flow capacity and height of the installation, the greater the energy that can be used to generate electricity (Kadir

2010). Technically, micro hydro has three main components, namely water as an energy source, turbines and generators. Flowing water with a capacity is channeled from a certain height through a rapid pipe to the powerhouse (Sukamta and Kusmantoro 2013).

Utilization of water energy is a very good step to improve the function of this energy which has been used only as daily necessities and as irrigation in the agricultural sector but can also be used or utilized as a power plant for remote or rural areas. still not reached by State Electricity Enterprise. Current research and technology development by utilizing hydropower as a mini-hydro power plant is a very appropriate step to meet the electricity needs of people living in remote areas or in rural areas. Making mini hydro turbines is very commercial and is very widespread on a large scale, so that affordable mini hydro turbines are also needed (Kosjoko, 2015).

Nowadays electricity needs are the main needs for the community. In order to support human activities, electricity should be felt by all people. However, until now electricity has not been felt by all people because of the inadequate use of resources and energy that have the potential to generate electricity. Meanwhile, the government's ability, in this case State Electricity Enterprise, to meet electricity needs is very limited. Therefore, the government strongly encourages the private sector / community to take part in alternative energy procurement efforts, one of which is the Mini Hydro Power Plant (PLTM). Mini Hydro Power Plant (PLTM) is an alternative source of electrical energy for the community. PLTM provides many benefits, especially for rural communities throughout Indonesia. At a time when other energy sources are running low and have a negative impact, water is a very important source of energy because it can be used as a cheap and non-polluting source of energy for electricity generation.

Minihydro or what is meant by Mini Hydro Power Plant (PLTM) is a small-scale power plant that uses hydropower as its driving force such as irrigation channels, rivers or natural waterfalls by utilizing the waterfall height (head) and the amount of water discharge. Microhydro is a term consisting of micro which means small and hydro which means water. Technically, it has three main components, namely water (as an energy source) and generator. Microhydro gets energy from water flows that have a certain height difference. Mini-Hydro power generation could be planned on small-scale on existing small rivers, canals etc. as it could be beneficial in utilization of all existing water reservoirs and streams so as to generate hydro power which is renewable in nature (Adhau, S. P., Moharil, R. M., & Adhau, P. G, 2012).

Minihydro utilizes the potential energy of falling water (head). The higher the water drop, the greater the potential energy of water which can be converted into electrical energy. The relatively small amount of energy produced by micro-hydro compared to large-scale hydropower plants has implications for the relative simplicity of equipment and the small area required for micro hydro installation and operation. Thus, the micro hydro generating system is suitable for reaching the availability of electrical energy networks in remote and rural areas.

In this research, a mini-hydro electric power prototype with a capacity of 5-10 watts was designed to turn on the LED lamp. The minihydro being developed is a simulation of a mini hydro power plant. The working principle of this mini hydro power plant, or mostly known as PLTM, is a form of changing hydropower with a certain height and discharge into electricity using a water turbine and generator.

In general, PLTMH in principle takes advantage of the difference in height and the amount of water discharge per second that is in the flow of irrigation channels, rivers or waterfalls. This water flow will rotate the turbine shaft to produce mechanical energy. This energy then drives generators and generators to produce electricity. A micro-hydro scheme requires two things, namely, water discharge and head height to generate usable power. This is an energy conversion system from the form of height and flow (potential energy) into the form of mechanical energy and electrical energy (Syarif, A., 2019). In this research, 2 mini hydro prototypes will be made. What distinguishes these two prototypes is the cross-sectional area of the wheel used. By distinguishing the size of this cross-sectional area, it is hoped that the researchers will know the stresses produced by the minihydro are the greatest in which cross-sectional area. The difference between the research conducted by the researchers from previous studies is the development of mini hydro power plants with a capacity of 5-10 watts which are used as simulations of large-scale micro hydro power plants

METHOD

The research design used in this study is research and development. Called research-based development. According to Sugiyono (2013), the development research method is a method research used to produce certain products, and assessing the effectiveness of the product. The product developed in this study is a simple power plant.

Overall, the research begins with the measurement of the cross-sectional area of the waterwheel to distinguish the two minihydro to be made, the measurement of the cross-sectional area of the hose used to determine the difference in water discharge produced by the water velocity, the rotational speed of the wheel made, and the stress. The method of direct observation in the field through measurements begins with measuring the perpendicular cross-sectional area of the water flow to get the flow of water flowing as initial data in the analysis of the ability of the minihydro power, then to analyze electrical energy, the initial data is taken from the measurement of the height of the water fall including the measurement of the distance from the water dam into the falling water.

To determine the potential as a micro-hydro power plant, the following data are required:

a. Calculation of the resulting voltage using voltmeter
b. Electrical power

$$P = 9.8 \; x \; Q \; x \; Hn \; x \; h \qquad (1)$$

Where :
P = power (Kw)
Q = Discharge (m3 / s)
Hn = Head Net (m)
H = overall efficiency

c. Water flow rate

$$V = \frac{P}{t_{rata-rata}} \qquad (2)$$

Where:
V = velocity (m / s)
P = channel length (m)
$T_{Average}$ = average time (seconds)

d. Water discharge

Flow discharge is the volume of water flowing in a certain unit of time. Water discharge is the height of river water as measured by a water level measuring instrument. In the SI system of units, the amount of discharge is expressed in units of cubic meters per second (m3 / s). The principle of implementing discharge measurement is measuring the wet cross-sectional area, flow velocity and water level. The discharge can be calculated by the equation:

$$Q = A.V \qquad (3)$$

Where :
Q = Discharge (m^3/s)
A = Channel Section Area (m^2)
V = Speed of water flow (m/s)

RESULTS AND DISCUSSION

Data from micro hydro experiment 1

a. Water flow rate

Dik. P = 200 cm
$t_{rata-rata}$= 35 sekon
Dit. V.....?
Answer : $V = \frac{P}{t_{rata-rata}}$

$$V = \frac{200}{35} = 5.714 \text{ m/s}$$

a. Water discharge

Dik. A = 0,7 cm
V = 5,714 m/s
Dit. Q.....?
Answer : $Q = A.V$
Q = 0.7 x 5,714
Q = 3.9998 m^3/s

Table 1. Data from microhydro measurement results 1

h (cm)	V (mvolt)	I (mAmpere)	P(mwatt)	P (watt)
30	41.35	13	537.5500	0.5376
	40.95	12.98	531.5310	0.5315
	40.89	12.87	526.2543	0.5263
	41.24	12.65	521.6860	0.5217
	41.26	12.65	521.9390	0.5219
40	43.77	13.98	611.9046	0.6119
	44.5	13.78	613.2100	0.6132
	44.57	13.98	623.0886	0.6231
	44.65	13.85	618.4025	0.6184
	43.78	13.98	612.0444	0.6120
50	47.87	15.05	720.4435	0.7204
	47.93	15.89	761.6077	0.7616
	47.98	16.01	768.1598	0.7682
	47.75	16	764.0000	0.7640
	47.98	15.87	761.4426	0.7614
60	50.11	16.54	828.8194	0.8288
	51.03	16.89	861.8967	0.8619

	51.22	16.89	865.1058	0.8651
	50.74	16.75	849.8950	0.8499
	50.89	16.78	853.9342	0.8539
70	55.67	18.89	1051.6063	1.0516
	56.01	19.23	1077.0723	1.0771
	55.85	18.87	1053.8895	1.0539
	56	18.5	1036.0000	1.0360
	55.98	18.45	1032.8310	1.0328

Data from micro hydro experiment 2

a. Water flow rate

Dik. P = 200 cm

$t_{rata\text{-}rata}$= 18 sekon

Dit. V.....?

Jawab :

$$V = \frac{P}{t_{rata-rata}}$$

$$V = \frac{200}{18} = 11.111 \text{ m/s}$$

b. Water discharge

Dik. A = 1.8 cm

V = 11.111 m/s

Dit. Q.....?

Jawab: $Q = A.V$

Q = 1.8 x 11.111

Q = 19.99 m^3/s

Table 2. Data from microhydro measurement results 2

h (cm)	V (mvolt)	I (mAmpere)	P(mwatt)	P (watt)
30	85.31	20.35	1736.06	1.73606
	83.29	22.43	1868.19	1.86819
	84.87	21.09	1789.91	1.78991
	85	22.17	1884.45	1.88445
	84.91	23.43	1989.44	1.98944
40	98.56	28.96	2854.3	2.8543
	98.75	28.36	2800.55	2.80055
	98.75	28.45	2809.44	2.80944
	97.89	28.01	2741.9	2.7419
	99.13	29.05	2879.73	2.87973
50	100.05	30.98	3099.55	3.09955
	100.01	30.87	3087.31	3.08731
	101.01	30.45	3075.75	3.07575
	101.11	30.67	3101.04	3.10104
	101.15	30.58	3093.17	3.09317
60	102.45	32.21	3299.91	3.29991
	102.45	32.89	3369.58	3.36958
	102.9	32.67	3361.74	3.36174
	102.98	32.99	3397.31	3.39731
	105.11	32.32	3397.16	3.39716
70	110.85	34.67	3843.17	3.84317
	110	35.09	3859.9	3.8599
	110.65	35.54	3932.5	3.9325
	110.78	34.87	3862.9	3.8629
	110.98	34.68	3848.79	3.84879

Water is a renewable energy source and is a technology that has long been known to prove reliable. Water is a source of energy that is cheap and relatively easy to obtain, because the potential energy is stored in water (in falling water) and kinetic energy (in flowing water). Hydropower is energy obtained from flowing water. The energy possessed by water can be utilized and used in the form of mechanical energy and electrical energy. Utilization of water energy is mostly carried out by using waterwheels or water turbines that take advantage of a waterfall or water flow in a river. Minihidro Power Plant (PLTM) is a power plant that utilizes mechanical energy from water to be converted into electrical energy using all water turbines installed on an electric generator. river. Water flowing through the intake and forwarded by the carrier channel to the penstock, will rotate the turbine shaft to produce mechanical energy (Prasetyo, T. E., & Pane, Z, 2013).

Micro hydro is a Renewable and eco friendly energy source. It is perhaps oldest technique that harness energy from water. Since our environment suffers from greenhouse gas emission and carbon die-oxide,the use of renewable energy is the best solution to refrain from global warming effect. Though Bangladesh has potentiality of hydro electric power, feasibility and implementation of this kind of power are still legging behind. The main reasons behind this are; firstly, the potential sites are located in hilly and remote areas. Secondly, some of them are not commercially viable. The last and most importantly, there is very little policy attention (Al Mamun, K. A., Yusuf, M. S., Alam, M. A., Ahmed, S., & Nath, A, 2018).

This study aims to determine the comparison of the two electrical energies produced by the Minihydro Power Plant (PLTMH) at different heights and water flows. Minihydro is a term used for medium-scale power plant installations that use water energy. Water conditions that can be used as a power source of electricity have an effective discharge capacity and height. The greater the discharge and the height of the dropping point, the greater the electrical energy that can be generated. The larger the scale of the water discharge that rotates the turbine, the greater the electrical energy that will be generated (Sipayung, H. P, 2019). After all the systems that support the development of this minihydro have been designed and connected to each other so that the expected mini-hydro system is formed, then the next step is the mini-hydro testing phase, where the mini-hydro testing aims to: To find out whether the mini-hydro that was built can work as expected , To determine the performance capability of the designed turbine, to find out how much electrical energy the PLTMH system produces, to find out any errors that occur, with the hope that it can be repaired immediately. As for its implementation, it uses an experimental method by operating a mini-hydro power generator with variations in changing the height and water discharge. This research was conducted to determine the current and voltage generated by observing the input current and voltage and the current and output voltage of the inverter circuit. The test is carried out using an ammeter and voltmeter, then the measurement results are entered into the table. A mini-hydro power plant converts hydropower into electricity, at first the potential for hydropower is converted into mechanical power in a water turbine, which then turns the water turbine into a generator so that it can produce electric power (Jamali, F, 2014).

The mini-hydro testing process is simple, namely by placing, mini-hydro and flowing the water in the pipe to the minihydro propeller, so that the potential power of the flow can rotate the turbine. With the turning of the turbine, the process of generating electrical energy in the generator begins so that it can be seen the amount of energy produced from the generation process. If there is an error in the performance of the minihidro, corrective action is taken immediately for the part of the system that is experiencing work errors. Meanwhile, if there is no apparent error from the minihidro system, the minihidro is considered to have been completed.

Figure 1. Operation of PLTMH prototype

The method that is often used in measurement is to use a current meter, because of several advantages of this tool. First, it is easy to use, then the observation error factor is small, and by using a current measuring instrument, the correction factor is neglected (Jamali, F, 2014). The calculation of the potential amount of electric power that can be generated by the PLTM development plan is influenced by two main parameters, namely the amount of water discharge availability and head. This study obtained data V and I to calculate the electric power generated (P). The analysis was carried out descriptively by comparing the data obtained to observe the effect of water level (h) and water discharge (Q) on electric power (P). Discharge is an important parameter in MHP planning. The size of the water discharge will determine the amount of energy that can be produced. The discharge will also determine the size and type of turbine to be used (Candra Mayana, H, 2013). From the experimental results, it is found that the greater the h and Q prices, the greater the P produced. So that from this experiment we can be implemented in the PLTMH builder by knowing the height and maximum water discharge from the water source. From the results of these experiments it can be said that the higher the water to the generator, the greater the electrical energy produced. This is in accordance with the potential energy it has. The greater the potential energy of the object, the greater the electrical energy, With the increasing number of generator water discharge, the electric energy produced will be even greater. This is in accordance with the potential energy it has. The greater the potential energy of the object means the greater the electrical energy (Rizki, AA, & Alfi, I, 2019).) From the comparison of experimental data 1 and 2, it is obtained that the amount of water discharge greatly affects the amount of energy. the electric power generated. This is due to the large mass of water that will hit the turbine so that the generator rotates faster, resulting in large mechanical energy. So that to build a PLTMH, the water discharge and the height must be considered.

The mini-hydro power plant is a power plant that generates electrical energy using water energy as a source of producing electrical energy. PLTM is an environmentally friendly generator because it uses renewable energy, namely water as the main medium. PLTM requires good water flow and water level (head) to produce mechanical power to rotate the turbine to produce electrical energy. The PLTM is expected to be able to guarantee a reliable, sustainable supply in the supply of electrical energy.

CONCLUSION

Based on research can conclude: a) In this research, a mini-hydro electric power prototype with a capacity of 5-10 watts was designed to turn on the LED lamp. The mini-hydro that was developed is a simulation of a mini-hydro power plant which later can be used as a practicum tool for students. The research produced 2 mini hydro prototypes. What distinguishes these two prototypes is the cross-sectional area of the wheel used. By distinguishing the size of this cross-sectional area, it is hoped that the researchers will know which stress is generated by the minihydro in which cross-sectional area, b) The resulting voltage and current varies, the greater the height of the pipe the greater the resulting voltage and current, c) The amount of electric power depends on the voltage and current generated, the greater the voltage and current generated, the greater the power and d) The amount of water discharge produced is influenced by the large cross-sectional area and the volume of water produced every second.

REFERENCES

Adhau, S. P., Moharil, R. M., & Adhau, P. G. (2012). Mini-hydro power generation on existing irrigation projects: Case study of Indian sites. *Renewable and Sustainable Energy Reviews*, *16*(7), 4785-4795. https://doi.org/10.1016/j.rser.2012.03.066

Al Mamun, K. A., Yusuf, M. S., Alam, M. A., Ahmed, S., & Nath, A. (2018). Design And Implementation Of A Micro Hydro Module For Small Falling Water Source. In *2018 International Conference on Computer, Communication, Chemical, Material and Electronic Engineering (IC4ME2)* (pp. 1-4). IEEE.

Candra Mayana, H. Study Potensi Pembangkit Listrik Tenaga Mikro Hidro Di Nagari Sibarambang Kecamatan X Koto Di Atas Kabupaten Solok Sumatera Barat. In *Seminar Nasional Teknik Elektro (SNTE)* (pp. 1-10). Politeknik Negeri Padang.

Celikdemir, S., Yildirim, B., & Ozdemir, M. T,. (2017). Cost Analysis of Mini Hydro Power Plant Using Bacterial Swarm Optimization. *International Journal of Energy and Smart Grid*, *2*(2), 64-81. doi: 10.23884/IJESG.2017.2.2.05

Flury, K., & Frischknecht, R. (2012). Life cycle inventories of hydroelectric power generation. *ESU-Services, Fair Consulting in Sustainability, commissioned by Oko-Institute eV*, 1-51.

Hanafi, J., & Riman, A. (2015). Life cycle assessment of a mini hydro power plant in Indonesia: a case study in Karai river. *Procedia Cirp*, *29*, 444-449. doi: 10.1016/j.procir.2015.02.160

Jamali, F. (2014). Studi Perencanaan Pembangkit Listrik Tenaga Minihidro Berbantuan Program Turbnpro di Desa Sinar Pekayau Kecamatan Sepauk Kabupaten Sintang. *Jurnal Teknik Elektro Universitas Tanjungpura*, *1*(1).

Kadir R. 2010. Perancangan pembangkit listrik tenaga mikro hidro (PLTM) disungai marimpa kecamatan pinembani. [Tesis publis]. Palu (ID): Universitas Tadulako.

Kosjoko, Kosjoko. "Cros Flow as Turbine Power Plant Minihidro (Pltm) Village to Self Energy" *Infoteknik*, vol. 16, no. 2, 2015, pp. 159-170. DOI: http://dx.doi.org/10.20527/infotek.v16i2.200

Kurniawan A, Gunawan AI, Maryono A, Ikhsan A, Susandi A, Sudaryanto A, Adriawan C, Boediyono C, Mamesah C, Kusdiana D *et al.*. 2009. *Pedoman Studi Kelayakan Sipil, Buku 2B*. Jakarta (ID) : Direktorat Jenderal Listrik dan Pemanfaatan Energi, Departemen ESDM.

Prasetyo, T. E., & Pane, Z. (2013). Studi Proteksi Pada Pembangkit Listrik Tenaga Minihidro (PLTM) Silau 2 Tonduhan Kabupaten Simalungun. *Singuda ENSIKOM*, *2*(3), 113-118.

Rizki, A. A., & Alfi, I. (2019). *Rancang Bangun Mini Mikro Hidro Sebagai Pembangkit Sederhana Dengan Pemanfaatan Arus Air Kran wudu Otomatis Menggunakan Metode Turbin Air Vertical* (Doctoral dissertation, University of Technology Yogyakarta).

Setiawan Wie, D. (2017). Perencanaan Dan Implementasi Prototipe Pembangkit Listrik Tenaga Mikro Hidro (PLTMH). *Jurnal Teknik Elektro*, *7*(01).

Sinaga, B.J. (2009). Perancangan turbin air untuk sistem pembangkit listrik tenaga mikro hidro (Studi kasus Desa Way Gison Kecamatan Sekincau Kabupaten Lampung Barat). *Jurnal Sains dan Inovasi.* 5(1) : 64-75.

Sipayung, H. P. (2019). Studi Kelayakan Pembangkit Listrik Tenaga Minihidro (OLTM) di Sungai Berkail Kecamatan Bahorok Kabupaten Langkat.

Sugiyono. 2013. Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif, dan R&D. Bandung: Alfabeta.

Sulistiyono, Sugiri A, Eka Y. 2013. Studi potensi pembangkit listrik tenaga mikrohidro (PLTM) di Sungai Cikawat Desa Talang Mulia Kecamatan Padang Cermin Kabupaten Pesawaran Propinsi Lampung. *Jurnal FEMA*. 1(1): 48-54

Sukamta S, Kusmantoro A. 2013. Perencanaan pembangkit listrik tenaga mikrohidro (PLTM) Jantur Tabalas Kalimantan Timur. *Jurnal Teknik Elektro*. 2(5): 58-63

Syarif, A. (2019). Rancang bangun prototipe pembangkit listrik tenaga mikro hidro (pltmh) turbin pelton. *Kinetika*, *8*(2), 1-6.

TAOFEQ, T., ANGGORO, B., & ARFIANTO, T. (2013). Perancangan Sistem Kelistrikan Pada Pusat Listrik Tenaga Minihidro Lapai 2x2000 kW di Sulawesi Tenggara. *REKA ELKOMIKA*, *1*(2)

Warsito, S., Syakur, A., & Nugroho, A. A. (2005). Studi Awal Perencanaan sistem Mekanikal dan Kelistrikan Pembangkit Listrik Tenaga Mini-Hidro. In *Seminar Teknik Ketenagalistrikan, Teknik Elektro Fakultas Teknik Universitas Diponegoro, Semarang.*