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Effect of Guide Blade Opening on Cavitation Level at the Inlet Side of the Vertical Francis Turbine Suction Pipe Unit 4 Stairway Hydroelectric Power Plant at PT Inalum Power Plant

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ABSTRACT

PLTA Tangga P.T. Inalum Power Plant is one of company that has thelargest power plant in Indonesia. Type of turbine which is used by that company is Vertical Francis Turbine which has problems in operation. One of kind problems is cavitation. Cavitation is the process of forming water bubbles on turbine because of water pressure on turbine drop becomes vapor pressure, that effects vibrations,erosion, and efficiency drop. Cavitation phenomenon can be predicted and be avoided by calculating the cavitation level of turbine, is a comparison of actual Thoma number and critical Thoma number. Cavitation level that is observed is in Entrance of Vertical Francis Turbine Draft Tube Unit 4 PLTA Tangga P.T. Inalum Power Plant. Cavitation level as the dependent variable that is searched for the influence to Guide Vane Opening (GVO) as the independent variable in this experiment. The total of GVO that is used in this experiment is nine variation, there are 102 mm; 132 mm; 161 mm; 168 mm; 176 mm; 183 mm; 186 mm; 191 mm; and 195 mm. Based on this experiment, we can know the cavitation level on every GVO. The highest cavitation level in this experiment is 0.96867 on GVO 195 mm, meanwhile the lowest cavitation is 0,81005 on GVO 102 mm. The entrance of the draft tube can happen the cavitation if the cavitation level is more than 1 or actual Thoma number is more than critical Thoma number. Cavitation can not happen on it if the cavitation level is less than 1 or actual Thoma number is less than critical Thoma number. So the best GVO for avoiding cavitation in the Entrance of Vertical Francis Turbine Draft Tube Unit 4 PLTA Tangga P.T. Inalum Power Plant is 102 mm because it has the lowest cavitation level, meanwhile the GVO that is avoided and the most vulnerable cavitation is 195 mm because it has the highest cavitation level.

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1. INTRODUCTION

Energy is a vital thing needed by the whole world to carry out various work processes or activities (Baharun, 2018). Energy has many forms, namely heat energy, wind energy, water energy, fossil energy, and so on (Widayana, 2012). The energy comes from nature which can be used as an energy source either directly or indirectly (Azhar & Satriawan, 2018). Energy sources are generally divided into two, namely renewable and non-renewable energy sources (Maulina et al., 2020). Non-renewable energy sources such as oil, natural gas, coal, etc., if exploited continuously, one day they will run out (Cipta, n.d.). In addition, the negative impact on the environment is also an important consideration and reason for switching to renewable energy sources (Syafa'i, 2021). Based on the Presidential Regulation of the Republic of Indonesia Number 5 of 2006, renewable energy is an energy source that is produced from natural energy resources (Kholiq, 2015)will not run out and can be sustainable if managed properly, including: geothermal, biofuel, river water flow, solar heat, wind, biomass, biogas, ocean waves, and sea depth temperature (Butar-Butar et al., 2013). Indonesia as a country consisting of many freshwater rivers and lakes has great potential in utilizing renewable energy sources, especially water energy (Lubis, 2007). Water energy is energy obtained from flowing water. Hydroelectric power (PLTA) is one of the proven technologies, does not damage the environment, supports energy diversification by utilizing water energy and supports the program to reduce the use of fuel (Lukas et al., 2017). The potential for water energy in Indonesia is 74,976 MW, as many as 70,776 MW are outside Java, which has been utilized is 3,105.76 MW, most of which are located on the island of Java. By seeing the great potential of water energy in Indonesia, the author is interested in raising the fluid engine course at the Department of Mechanical Engineering (Gunawan et al., 2020).

North Sumatra University as a reference course in this final project (Setiawan & Lubis, 2017). The water energy can be utilized optimally by using a water turbine engine. A water turbine is a prime mover that converts the potential and kinetic energy from the flow of water into mechanical energy that drives a generator to produce electricity. The first hydropower plant was developed in America in 1882 and has grown very rapidly to date (Hadimi et al., 2006). The turbines are divided into two based on the action of water on the turbine blades, namely impulse turbines and reaction turbines (Larasakti et al., 2012). Impulse turbines are examples of Pelton turbines and Cross Flow turbines while reaction turbines are for example Francis turbines, Kaplan turbines and propellers (Putra & Prasetyo, 2019). In this final project, we will discuss about the Francis turbine, especially regarding cavitation problems that often occur during operation (Gurning et al., 2017). Cavitation is in the form of water bubbles that cause erosion, sound, and vibration in turbine components which reduce turbine efficiency (Sitompul & Ibrahim, 2021). The cavitation phenomenon can be predicted by calculating the Thoma number (σ) so as not to pass the critical number that has been determined according to the turbine specifications (Rakhasiwi, 2020). The author hopes that this final project is useful for all readers and professionals, especially those engaged in engineering, so that they can utilize water energy as efficiently as possible by paying attention to the work of components on the turbine so that problems in operation can be avoided (Purba et al., 2020).

The objectives of this study are as follows: (a) To obtain the largest and smallest cavitation levels in the Guide Vane Opening (GVO) at the Inlet Side of the Suction Pipe (Draft Tube) Vertical Francis Turbine Unit 4 PLTA Stairway PT Inalum Power Plant . (b) To predict whether cavitation occurs at the intake side of the turbine suction pipe by calculating the aqueous and critical Thoma numbers. (c) To find the best GVO size used to avoid cavitation and avoid cavitation to avoid cavitation at the intake side of the turbine suction pipe. The benefits of this research are as follows: (a) For PT Inalum Power Plant (PT IPP) it can be considered to avoid cavitation at the inlet side of the vertical Francis turbine suction pipe at the Tangga PLTA. (b) For PT Inalum Power Plant (PT IPP) it can be an advantage in terms of maintaining turbine efficiency, extending turbine life, and reducing maintenance costs if cavitation can be avoided. (c) For researchers, it can be used as a means to apply theoretical knowledge from college to problems in the work environment directly. (d) For academics, it can be used as additional knowledge, especially on the effect of Guide Vane Opening (GVO) on the cavitation level at the intake side of the Francis turbine suction pipe.

2. RESEARCH METHOD

2.1 Data Processing Method

The data processing method used in this study is divided into two, namely: (a) Calculation Analysis Method(Pasaribu, 2021). This calculation analysis method uses formulas sourced from the library

(Muchson & MM, 2017). The formulas used are: the Hazen-Williams equation, the formula for minor head losses, the continuity equation, and the Thoma number (Mustafidah, 2019). Calculations using these formulas are carried out in Microsoft Office Excel 2007 software so that the calculated data can be displayed in tables and graphs (Hadi, 2008). (b) Simulation Method. The simulation method is carried out as a comparison with the results of the calculation analysis method so that the error value is obtained. The simulation method in this study uses two software, namely Pipe Flow Expert V 6.39 Software (simulation of head losses) (Aldini, 2018).

2.2 Research Procedure Data

The research procedure in this thesis is divided into two flow charts (Flow Chart), which are as follows: (a) Research flow chart (Calculation Analysis Method), (b) Research flow chart (Simulation Method with Pipe Flow Expert Software V 6.39)

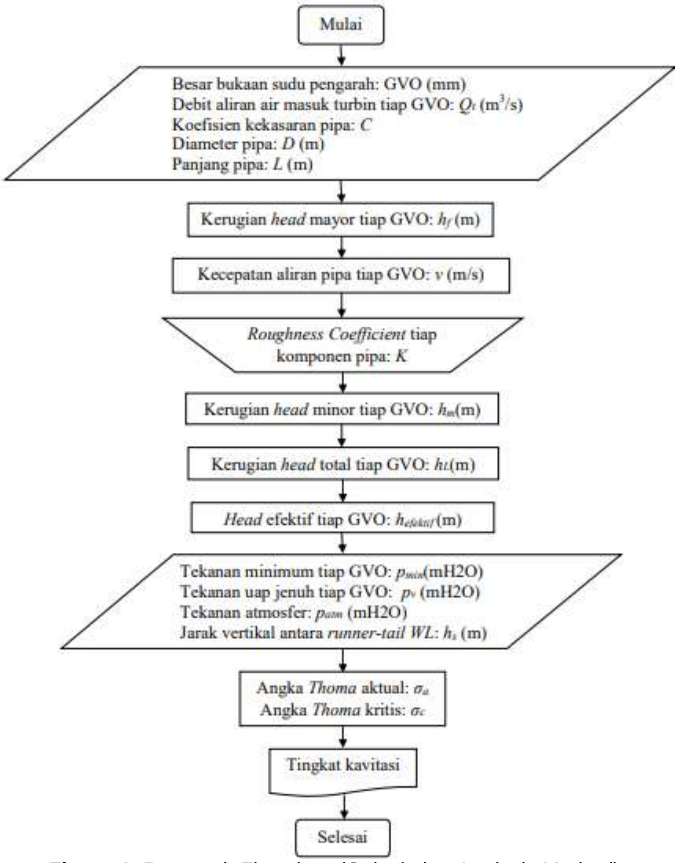

Figure 1. Research Flowchart (Calculation Analysis Method)

3. RESULTS AND DISCUSSIONS

3.1. Rice Bran Biodiesel Relationship Between Steering Blade Aperture (GVO) and Water Discharge

The guide vane opening (GVO) data on the turbine inlet water flow (QT) below is the result of the Vertical Francis Turbine Unit-4 PLTA Tangga test conducted by PT Inalum Power Plant (PT IPP) on August 13, 2012 (appendix 2). There are nine variations of the guide vane aperture (GVO) used, namely 102 mm; 132mm; 161 mm; 168 mm; 176 mm; 183 mm; 186 mm; 191 mm; and 195 mm. The relationship between the guide vane opening (GVO) and the turbine inlet water discharge (QT) is shown in table 4.1 below.

Table 1. Relationship of guide vane opening (GVO) and turbine inlet water discharge (QT)

GVO (mm)	*Q_T (m^3/s)*
102	16,136
132	23,136
161	30,11
168	31,933
176	33,746
183	35,58
186	36,53
191	37,385
195	38,22

The following is a graph of the relationship between the guide vane opening (GVO) and the turbine inlet water flow (QT) which is shown in Figure 4.1.

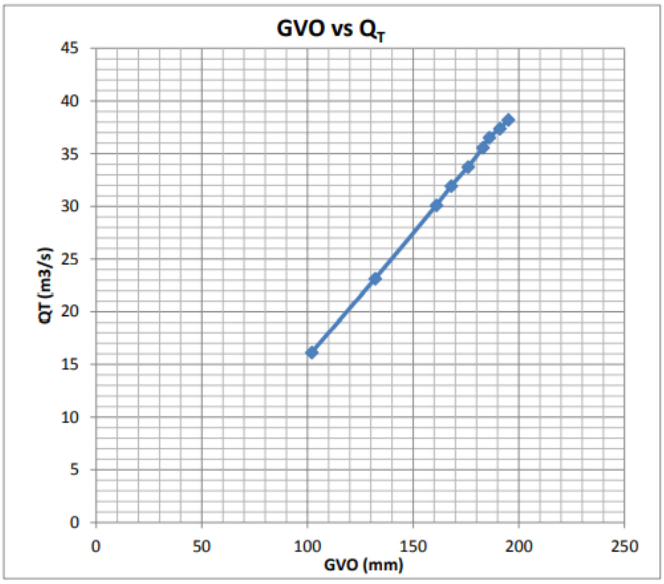

Figure 2. Graph of Relationship Between Steering Blade Aperture (GVO) and Turbine Inlet Water Discharge (QT)

The graph in Figure 4.1 shows that the larger the guide vane opening (GVO), the higher the turbine inlet water discharge (QT). This is because the larger the GVO aka guide vane, which closes the incoming water before entering the turbine, the more open it is. The bigger the opening, the more water enters (intake water discharge/QT).

3.2. Effective Head Calculation on Each GVO

The effective head calculated in this study is the maximum head on the Francis Vertical Turbine Unit-4 PLTA Tangga PT IPP which is reduced by the total head loss from the gate valve to the inlet valve. The total head loss used in calculating the effective head comes from calculations using the calculation and simulation analysis method (Software Pipe).
Flow Expert V 6.39).

3.3. Relationship between GVO and Pressure at the Suction Pipe Inlet

The guide vane opening data (Guide Vane Opening/GVO) to the minimum pressure (pmin) and saturated vapor pressure (pvapor/pv) below are the results of the Vertical Francis Turbine Unit-4 Stairway Hydroelectric Test conducted by PT Inalum Power Plant (PT IPP)) on August 13, 2012 (attachment 2). The minimum pressure measured is at the inlet side of the draft tube because this is the part where cavitation occurs the most. Table 4.36 below shows the minimum pressure and saturated vapor pressure for each GVO on the side
enter the suction pipe.

Table 2. Minimum Pressure and Saturated Vapor Pressure Each GVO (Test)

GVO (mm)	p_{min} (mH_2O)	p_v (mH_2O)
102	3	**0,367**
132	1,8	**0,367**
161	1	**0,367**
168	1	**0,367**
176	1	**0,367**
183	0,9	**0,367**
186	0,9	**0,367**
191	0,9	**0,367**
195	0,8	**0,367**

The minimum pressure value above is obtained from the reading of the pressure transducer gauge on the turbine panel. The minimum pressure above is the pressure value obtained after testing 3 times and the smallest pressure value is taken. The value of the saturated vapor pressure at each GVO is 3.598 kPa. This value is obtained from the interpolation of the Physical Properties of Water table attached in appendix 5. The vapor pressure is located at a temperature of 27oC (water temperature measured at PT IPP on August 13, 2012/appendix 2). The value of the saturated vapor pressure in kPa units is converted to mH2O units so that it has the same units as the

minimum pressure at the intake pipe where 1 kPa is equal to 0.101972 mH2O. So the saturated vapor pressure at the intake pipe is 0.367 mH2O. The unit of mH2O is the same as the unit of length in meters (m) in general. H2O indicates the type of fluid that is under pressure. Figure 4.8 the following is a graph that shows showing
the minimum pressure and the saturated vapor pressure at each GVO at the intake pipe.

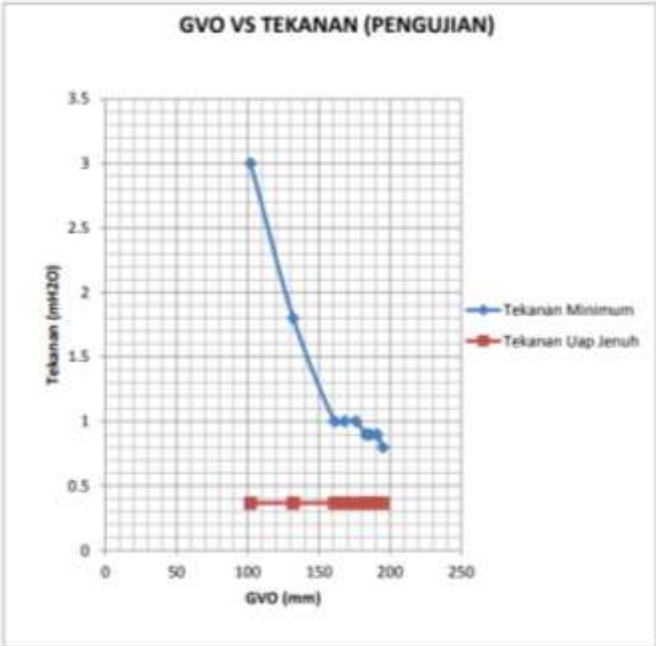

Figure 3. Graph of Minimum Pressure and Saturated Vapor Pressure Each GVO

Based on the graph in Figure 4.8 above, it shows that at the beginning the GVO experienced an increase in pressure and in the middle and at the end the GVO experienced a decrease in pressure. The highest minimum pressure is 3 mH2O at 102 mm GVO, while the lowest minimum pressure is 0.8 mH2O at 195 mm GVO. Saturated vapor pressure has a fixed value because this value will be used as a component of the calculation of the critical Thoma number whose value is also constant.

3.4. Relationship between GVO and Thoma Number at the Inlet Side of the Inlet

The Thoma number calculated in this study is the actual Thoma number and the critical Thoma number. The actual Thoma number (σa) is calculated based on equation 2.22 and the critical Thoma number (σc) is calculated based on equation 2.24. Table 4.37 below shows the relationship between GVO and the calculated actual and critical Thoma numbers at the intake side of the suction pipe.

Table 3. Actual and Critical Thoma Numbers on Each GVO

GVO (mm)	p_{atm} (mH_2O)	p_{inlet} (mH_2O)	p_v (mH_2O)	h_s (m)	h_{ef} (m)	σ_a	σ_c
102	10.332	3	0.367	-3.90	239.4289	0.04691	0.05791
132	10.332	1.8	0.367	-4.00	237.4628	0.05277	0.05881
161	10.332	1	0.367	-4.00	234.867	0.05676	0.05946
168	10.332	1	0.367	-4.00	234.0853	0.05695	0.05966
176	10.332	1	0.367	-4.00	233.2653	0.05715	0.05987
183	10.332	0.9	0.367	-4.00	232.394	0.05780	0.06009
186	10.332	0.9	0.367	-4.10	231.9252	0.05835	0.06064
191	10.332	0.9	0.367	-4.10	231.4937	0.05846	0.06076
195	10.332	0.8	0.367	-3.90	231.0638	0.05813	0.06001

The value of atmospheric pressure (patm) above is the value of the pressure in the outside air, which is 1 atm. This value is converted to 10.332 mH2O. The value of Hs (vertical distance between runner position and tail race water level) above is negative because the turbine runner is located below the water level at the tail race water level (reference point). Based on table 4.37 above, the largest actual Thoma number value is 0.05846 at 191 mm GVO; while the smallest actual Thoma number is 0.04691 at 102 mm GVO. In addition, the largest critical Thoma number is 0.06076 at 191 mm GVO; while the smallest critical Thoma number is 0.05791 at 102 mm GVO. Figure 4.9 below is a graph showing the relationship between GVO and the actual and critical Thoma numbers at the intake side of the suction pipe.

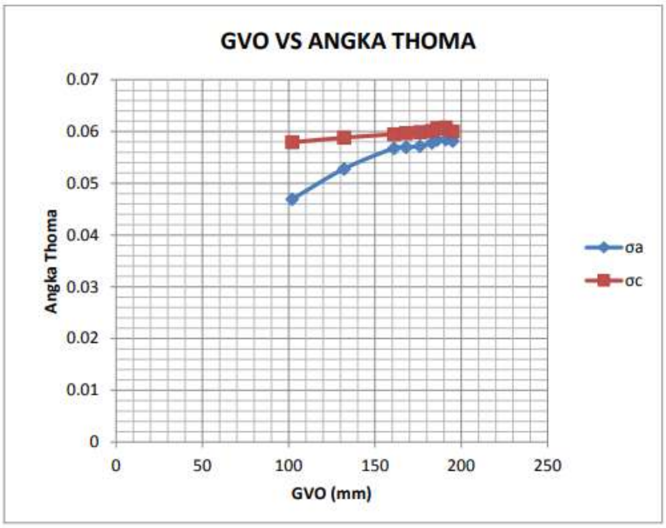

Figure 4. Graph of Relationship Between GVO and Actual and Critical Thoma Numbers at Intake Pipe

Based on the picture above, it is shown that the greater the GVO, the greater the actual Thoma number and the critical Thoma number at the intake side of the suction pipe.

3.5. Balige Relationship between GVO and Cavitation Level at the Inlet of the Suction Pipe

The cavitation rate is calculated based on equation 2.25. The cavitation level below will show the amount of cavitation shown in the non-united values at the cavitation level. This is because the cavitation rate is a comparison between the actual Thoma number value and the Critical Thoma number value. If the value of the Cavitation Level obtained is more than a value of 1, it can be predicted that the intake side of the suction pipe that has a Cavitation Level value of more than 1 will experience cavitation and vice versa. The cavitation
can be avoided by looking at the GVO experiencing a cavitation level of more than 1 so that the turbine can be adjusted by the Governor so as not to open the GVO experiencing cavitation. Table 4.38 below shows the relationship between GVO and the calculation results of the cavitation level at the intake side of the suction pipe.

Table 4. Relationship of GVO and Cavitation Level at the Inlet Side of the Suction Pipe

GVO (mm)	σ_a	σ_c	σ_a/σ_c
102	**0.04691**	**0.05791**	**0.81005**
132	0.05277	0.05881	0.89730
161	0.05676	0.05946	0.95459
168	0.05695	0.05966	0.95458
176	0.05715	0.05987	0.95457
183	0.0578	0.06009	0.96189
186	0.05835	0.06064	0.96224
191	0.05846	0.06076	0.96215
195	**0.05813**	**0.06001**	**0.96867**

Figure 4.10 below is a graph showing the relationship between GVO and Cavitation Level at the intake side of the suction pipe.

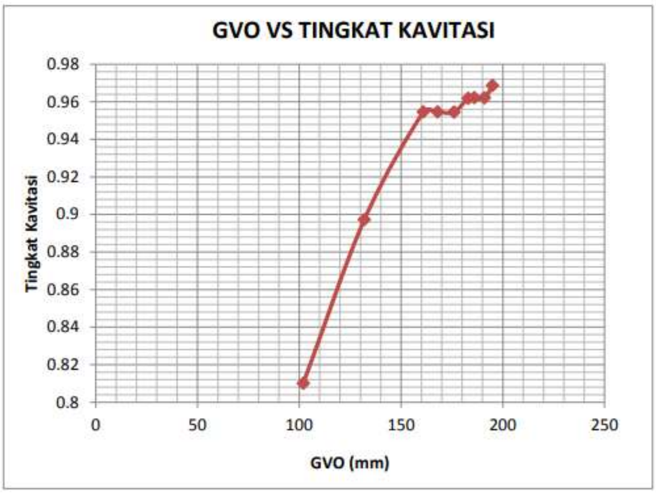

Figure 5. Graph of Relationship between GVO and Cavitation Level at the Inlet of the Suction Pipe

Based on the graph in Figure 4.10 above, it is shown that at the beginning to the middle of the GVO, the cavitation level experienced a not very significant decrease; whereas in the middle and end of GVO, the cavitation rate increased significantly. The largest cavitation rate is 0.96867 at 195 mm GVO; while the smallest cavitation level is 0.81005 at 102 mm GVO. Based on the value of the cavitation level above for each GVO, it is known that at the intake side of the suction pipe there is no cavitation, but a value close to 1 is experienced at the largest cavitation level, namely at GVO 195 mm. It is recommended that the turbine guide blade opening (GVO) be at 102 mm to avoid cavitation because it has the lowest cavitation rate.

4. CONCLUSION

The conclusions obtained after analyzing the calculations in the calculation results in this study are as follows: (a) The largest cavitation level is at the Inlet Side of the Suction Pipe (Draft Tube) Vertical Francis Turbine Unit 4 PLTA Ladder PT. Inalum Power Plant is 0.96867 at Guide Vane Opening (GVO) of 195 mm, while the smallest cavitation level is 0.81005 at GVO of 102 mm. (b) Cavitation does not occur at the Inlet Side of the Vertical Francis Turbine (Draft Tube) Unit 4 HEPP Stairs PT. Inalum Power Plant at GVO 102 mm because the cavitation level is below the value 1 where the actual Thoma number is 0.04691 which is smaller than the critical Thoma number, which is 0.05791; whereas at 195 mm GVO cavitation did not occur either, but vulnerable to it because the cavitation level is close to 1 where the actual Thoma number is 0.05813 and the critical Thoma number is 0.06001. (c) The best guide vane opening (GVO) is used to avoid cavitation at the inlet side of the turbine suction pipe, which is at 102 mm because it has the smallest cavitation level, while GVO is avoided because it is most susceptible to cavitation, namely the GVO of 195 mm because it has greatest cavitation rate.

The suggestions that the author gives after analyzing the calculations in the results of the calculations in this study are as follows: (a) The author suggests that readers who want to do further research on cavitation in turbines should also research runners, guide vanes, stay vanes, or spirals. case so that it can be seen that the turbine component has the highest cavitation level at the same guide blade opening. (b) When processing data using pipe flow, pay attention to fitting and bending components so that data errors do not occur that cause data errors.

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REFERENCES

Aldini, S. S. S. (2018). *Perancangan Aplikasi Komputer Berbasis Web Untuk Manajemen Sumber Daya Manusia Berbasis Kinerja Dan Kompetensi Pada Industri Reparasi Kapal*. Institut Teknologi Sepuluh Nopember.

Azhar, M., & Satriawan, D. A. (2018). Implementasi kebijakan energi baru dan energi terbarukan dalam rangka ketahanan energi nasional. *Administrative Law and Governance Journal*, *1*(4), 398–412.

Baharun, H. (2018). Peningkatan kompetensi guru melalui sistem kepemimpinan kepala madrasah. *At-Tajdid: Jurnal Ilmu Tarbiyah*, *6*(1), 1–26.

Butar-Butar, D. P., Amin, M. N., & Kasim, S. T. (2013). Analisis Biaya Produksi Listrik Per-Kwh Menggunakan Bahan Bakar Biogas Limbah Cair Kelapa Sawit (Aplikasi Pada PLTBGS PKS Tandun). *Singuda Ensikom*, *3*(1), 17–22.

CIPTA, P. K. M. K. (n.d.). *PROPOSAL PROGRAM KREATIVITAS MAHASISWA JUDUL PROGRAM" SI-PAPA GAYA"(RANCANG BANGUN "MESIN PARUT KELAPA*.

Gunawan, R., Junaidi, J., & Kurniawan, F. (2020). OPTIMASI KINERJA TURBIN PELTON RESPON KEMIRINGAN BUCKET DENGAN DIAMETER NOSEL MENGGUNAKAN SOFTWARE STATISTIKA. *Jurnal Simetri Rekayasa*, *2*(1), 76–81.

Gurning, F. P., Nasution, A. H., Gultom, S., Zulkifli, A., & Ariani, F. (2017). PENGARUH BUKAAN SUDU PENGARAH TERHADAP TINGKAT KAVITASI DI SISI MASUK PIPA ISAP TURBIN FRANCIS VERTIKAL. *DINAMIS*, *5*(3), 13.

Hadi, S. (2008). *Mengenal Microsoft Excel Untuk Pemula*. Tiara Aksa.

Hadimi, H., Supandi, S., & Rohermanto, A. (2006). Rancang bangun model turbin Pelton mini sebagai media simulasi/praktikum mata kuliah konversi energi dan mekanika fluida. *Semesta Teknika*, *9*(1), 16–24.
Kholiq, I. (2015). Analisis Pemanfaatan Sumber Daya Energi Alternatif Sebagai Energi Terbarukan untuk Mendukung Subtitusi BBM. *Jurnal Iptek*, *19*(2), 75–91.
Larasakti, A. A., Himran, S., & Arifin, A. S. (2012). Pembuatan dan Pengujian Pembangkit Listrik Tenaga Mikrohidro Turbin Banki Daya 200 Watt. *Jurnal Mekanikal*, *3*(1).
Lubis, A. (2007). Energi terbarukan dalam pembangunan berkelanjutan. *Jurnal Teknologi Lingkungan*, *8*(2).
Lukas, L., Rohi, D., & Tumbelaka, H. H. (2017). Studi kinerja pembangkit listrik tenaga air (plta) di daerah aliran sungai (das) brantas. *Jurnal Teknik Elektro*, *10*(1), 17–23.
Maulina, W., Sulistiyo, Y. A., & Purwandari, E. (2020). Biobriket Arang Sekam Padi sebagai Sumber Energi Terbarukan untuk Aplikasi Pandai Besi. *Warta Pengabdian*, *14*(4), 222–230.
Muchson, M., & MM, S. E. (2017). *Metode riset akuntansi*. Spasi Media.
Mustafidah, H. (2019). *Optimalisasi Tingkat Kehilangan Air PDAM Kota Mojokerto Dengan Penerapan Sistem Distric Meter Area (DMA) Ditinjau Dari Aspek Teknis, Kelembagaan Dan Finansial*. Institut Teknologi Sepuluh Nopember.
Pasaribu, A. F. O. (2021). Analisis Pola Menggunakan Metode C4. 5 Untuk Peminatan Jurusan Siswa Berdasarkan Kurikulum (Studi Kasus: Sman 1 Natar). *Jurnal Teknologi Dan Sistem Informasi*, *2*(1), 80–85.
Purba, B., Nainggolan, L. E., Siregar, R. T., Chaerul, M., Simarmata, M. M. T., Bachtiar, E., Rahmadana, M. F., Marzuki, I., & Meganingratna, A. (2020). *Ekonomi Sumber Daya Alam: Sebuah Konsep, Fakta dan Gagasan*. Yayasan Kita Menulis.
Putra, T. D., & Prasetyo, A. (2019). Pengaruh Sudu Hydrofoil Naca 9407 Terhadap Efisiensi Turbin Aliran Silang (Cross-Flow) Pembangkit Listrik Tenaga Mikrohidro (PLTMH). *Proton*, *10*(2), 12–19.
Rakhasiwi, W. G. (2020). *ANALISIS PENGARUH BEBAN OPERASI TERHADAP TINGKAT KAVITASI TURBIN FRANCIS VERTIKAL DI PT PLN (PERSERO) UNIT PENGENDALIAN PEMBANGKITAN BENGKULU, UNIT III PLTA MUSI*. 021008 Universitas Tridinanti.
Setiawan, H., & Lubis, Z. (2017). Peningkatan Motivasi Dan Hasil Belajar Mahasiswa Pada Mata Kuliah Bahasa Arab Materi Hiwar Dengan Menggunakan Metode Role Play Pada Program Studi Pendidikan Agama Islam Semester Ii Universitas Muhammadiyah Sumatera Utara. *Intiqad: Jurnal Agama Dan Pendidikan Islam*, *8*(2), 47–51.
Sitompul, Y. S., & Ibrahim, H. (2021). ANALISIS PENGARUH BUKAAN SUDU TERHADAP TINGKAT KAVITASI DI SISI MASUK SUCTION PIPE TURBIN FRANCIS HORIZONTAL UNIT 3 DI PLTA PAKKAT PT ENERGY SAKTI SENTOSA. *Prosiding Konferensi Nasional Social & Engineering Polmed (KONSEP)*, *2*(1), 216–221.
Syafa'i, I. (2021). *Analisis Kebijakan Pemerintah Kabupaten Kotabaru Terhadap Kewajiban Korporasi Perkebunan Dalam Pengolahan Limbah Kelapa Sawit*. Universitas Islam Kalimantan MAB.
Widayana, G. (2012). Pemanfaatan energi surya. *Jurnal Pendidikan Teknologi Dan Kejuruan*, *9*(1).