UNDERGRADUATE THESIS

ASSESMENT OF HYBRID POWERPLANT IN MATENGGENG DAM

EVELY TIRZA
NPM : 6102001086

ADVISOR 1: Ir. Doddi Yudianto, Ph.D.

ADVISOR 2: Okky Ahmad Purwana, Ph.D.

PARAHYANGAN CATHOLIC UNIVERSITY
FACULTY OF ENGINEERING
DEPARTEMENT OF CIVIL ENGINEERING
BACHELOR PROGRAM
(Accredited by SK LAM Teknik No.0216/SK/LAM Teknik/AS/VIII/2023)
BANDUNG
JULY 2024

UNDERGRADUATE THESIS

ASSESMENT OF HYBRID POWERPLANT IN MATENGGENG DAM

EVELY TIRZA
NPM : 6102001086

ADVISOR 1: Ir. Doddi Yudianto, Ph.D.

ADVISOR 2: Okky Ahmad Purwana, Ph.D.

PARAHYANGAN CATHOLIC UNIVERSITY
FACULTY OF ENGINEERING
DEPARTEMENT OF CIVIL ENGINEERING
BACHELOR PROGRAM

(Accredited by SK LAM Teknik No.0216/SK/LAM Teknik/AS/VIII/2023)
BANDUNG
JULY 2024

UNDERGRADUATE THESIS

ASSESMENT OF HYBRID POWERPLANT IN MATENGGENG DAM

EVELY TIRZA
NPM : 6102001086

BANDUNG, 19 JULY 2024

ADVISOR 1:	ADVISOR 2:
Ir. Doddi Yudianto, Ph.D.	Okky Ahmad Purwana, Ph.D.

PARAHYANGAN CATHOLIC UNIVERSITY
FACULTY OF ENGINEERING
DEPARTEMENT OF CIVIL ENGINEERING
BACHELOR PROGRAM

(Accredited by SK LAM Teknik No.0216/SK/LAM Teknik/AS/VIII/2023)

BANDUNG
JULY 2024

UNDERGRADUATE THESIS

ASSESMENT OF HYBRID POWERPLANT IN MATENGGENG DAM

EVELY TIRZA
NPM : 6102001086

ADVISOR 1 :	**Ir. Doddi Yudianto, Ph.D.**	22/07/2024
ADVISOR 2 :	**Okky Ahmad Purwana, Ph.D.**	23/07/2024
EXAMINER 1:	**Ir. Dr. Steven Reinaldo Rusli**	24/07/2024
EXAMINER 2:	**Ir. Stephen Sanjaya, S.T., M.Sc.**	24/07/2024

PARAHYANGAN CATHOLIC UNIVERSITY
FACULTY OF ENGINEERING
DEPARTEMENT OF CIVIL ENGINEERING
BACHELOR PROGRAM

(Accredited by SK LAM Teknik No.0216/SK/LAM Teknik/AS/VIII/2023)
BANDUNG
JULY 2024

LEMBAR PERNYATAAN

Saya yang bertanda tangan di bawah ini,

Nama	: Evely Tirza
Tempat, tanggal lahir	: Jakarta, 25 April 2002
NPM	: 6102001086
Judul skripsi	:**ASSESMENT OF HYBRID POWERPLANT IN MATENGGENG DAM**

Dengan ini Saya menyatakan bahwa karya tulis ini adalah benar hasil karya tulis saya sendiri dan bebas plagiat. Adapun kutipan yang tertuang sebagian atau seluruh bagian pada karya tulis ini yang merupakan karya orang lain (buku, makalah, karya tulis, materi perkuliahan, internet, dan sumber lain) telah selayaknya saya kutip, sadur, atau tafsir dan dengan jelas telah melampirkan sumbernya. Bahwa tindakan melanggar hak cipta dan yang disebut plagiat merupakan pelanggaran akademik yang sanksinya dapat berupa peniadaan pengakuan atas karya ilmiah ini dan kehilangan hak kesarjanaan.

Demikian pernyataan ini saya buat dengan penuh kesadaran dan tanpa paksaan dari pihak manapun.

(Kutipan pasal 25 ayat 2 UU no. 20 tahun 2003)

Bandung, 19 Juli 2024

METERAI ELEKTRONIK 10000

Evely Tirza

PENILAIAN SISTEM HIBRIDISASI PEMBANGKIT TENAGA LISTRIK DI BENDUNGAN MATENGGENG

EVELY TIRZA
NPM : 6102001086

Pembimbing-1: Ir. Doddi Yudianto, Ph.D.

Pembimbing-2: Okky Ahmad Purwana, Ph.D.

UNIVERSITAS KATOLIK PARAHYANGAN
FAKULTAS TEKNIK
PROGRAM STUDI SARJANA TEKNIK SIPIL
(Terakreditasi Berdasarkan SK LAM Teknik No.0216/SK/LAM Teknik/AS/VIII/2023)
BANDUNG
JULI 2024

ABSTRAK

Produksi listrik Indonesia masih bergantung oleh sumber daya tidak terbarui, dipimpin oleh uap di 48% dan gas di 28%. Indonesia harus mulai mengubah sumber energinya karena sumber daya tidak terbarui seiring berjalannya waktu dapat merusak lingkungan. Salah satu, sumber daya terbarui yang melimpah di Indonesia adalah tenaga air yang cukup besar, namun produksi listrik oleh air ini sangat bergantung dengan ketersediaan air yang terpengaruhi oleh musim. Bendungan Matenggeng di rencanakan memiliki Pembangkit Listrik Tenaga Air (PLTA) yang memiliki kapasitas 19 m^3/s. Dengan analisis pola operasi waduk Matenggeng dapat menghasilkan listrik berkapasitas sebesar 11,74 MWac (33 GWh/tahun) yang terjadi pada elevasi normal ±194 m. Kemudian, ketika musim kemarau melanda produksi nya menurun menjadi 5,74 MWac (19 GWh/tahun) yang terjadi pada elevasi terendah bendungan ±148m. Hal ini mengindikasikan bahwa daya berkurang sebesar 6 MWac (14 GWh/tahun). Selain itu, sumber daya terbarui oleh tenaga surya, juga memiliki potensi yang besar di Indonesia didukung oleh letak Indonesia yang berada di garis khatulistiwa dan memiliki iklim tropis, yang mengartikan bahwa Indonesia akan ada di bawah sinar matahari sepanjang tahun. Maka dalam studi ini dilakukan, upaya mengoptimasi penurunan produksi listrik yang ada di Matenggeng dengan adanya Hibridisasi PLTA dengan Pembangkit Tenaga Listrik Surya (PLTS) terapung. Dari hasil analisis, luasan PLTS terapung yang diperlukan adalah 236 x 291 m dengan 132 tambatan dan 44 angkur blok di setiap sisi pulau PLTS tersebut. PLTS telah berhasil menghasilkan energi listrik sebanyak 14 GWh setiap tahunnya, di mana penghasilannya stabil tiap bulan sebanyak 1.200 MWh per bulannya. Pada studi sebelumnya telah dilakukan optimasi dengan limpasan air yang ada, limpasan ini di tampung ke dalam pipa yang memiliki kapasitas yang sama dengan PLTA. Sistem ini menghasilkan listrik sebanyak 78 GWh pertahun-nya. Efektivitas sistem ini jauh lebih besar ±30% daripada PLTS terapung. Dapat dinyatakan bahwa system hibridisasi ini kurang efektif yang di akibatkan oleh kecilnya energi listrik yang dihasilkan oleh PLTS oleh karena kurangnya lahan yang tersedia saat elevasi air rendah.

Kata Kunci: Bendungan Matenggeng, Hibridisasi Pembangkit Tenaga Listrik, Pembangkit Listrik Tenaga Air (PLTA), Pembangkit Listrik Tenaga Surya (PLTS) terapung, Sumer daya terbarui

ASSESMENT OF HYBRID POWERPLANT IN MATENGGENG DAM

EVELY TIRZA
NPM : 6102001086

ADVISOR 1: Ir. Doddi Yudianto, Ph.D.

ADVISOR 2: Okky Ahmad Purwana, Ph.D.

PARAHYANGAN CATHOLIC UNIVERSITY
FACULTY OF ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING
BACHELOR PROGRAM
(Accreditated by SK LAM Teknik No.0216/SK/LAM Teknik/AS/VIII/2023)
BANDUNG
JULY 2024

ABSTRACT

Indonesia's electricity production is dominated by non-renewable resources, with coal at 48% and gas at 28%. Indonesia should start changing its energy sources as non-renewable resources over time can damage the environment. One of the abundant renewable resources in Indonesia is hydropower, but the production of electricity by water is highly dependent on the availability of water, which is affected by seasonal variability. Matenggeng Dam is planned to have a Hydroelectric Power Plant (PLTA), which has a discharge capacity of 19 m^3/s. By analyzing the operation pattern of the Matenggeng reservoir, it can produce power of about 11.74 MWac (33 GWh/year), which occurs at the normal elevation of ±194 m. Then, when the dry season hits, its power production decreases to 5.74 MWac (19 GWh/year), which occurs at the lowest elevation of the dam, 148 m. This indicates that the power is decreased by 6 MWac (14 GWh/year). Furthermore, solar renewable resources also have great potential in Indonesia, supported by Indonesia's location on the equator and tropical climate, which means that Indonesia will be in the sun all year round. So, in this study, an attempt was made to optimize the decrease in existing electricity production in Matenggeng by hybridization of hydropower with floating solar power plants (PLTS). According to the analysis, the area of the floating solar power plant required is 236x291 m with 132 moorings and 44 anchor blocks on each side of the solar power plant island. Furthermore, the solar power plant has successfully produced 14 GWh of energy annually, where the monthly generation is stable at 1,200 MWh per month. In previous studies, optimization has been carried out with existing spilled water, which is tapped into a pipe that has the same capacity as the hydropower plant. This system produces 78 GWh of electricity per year. The effectiveness of this system is much greater by at least 30% than floating solar power plants. This hybridization system is less effective due to the small amount of electrical energy generated by the solar power plant, which is due to the lack of available land at the lowest water elevation.

Keywords: Floating Solar Panels, Hybrid Powerplant, Hydropower, Matenggeng Dam, Renewable Energy Resources.

PREFACE

The accomplishment of this undergraduate thesis is achieved with the help of many parties. First of all, gratitude is mentioned to Jesus Christ for the guide to make an opportunity to have a topic of novelty, which is a Hybrid Powerplant of Hydropower and Floating Solar Panels. This thesis is written due to the requirements of graduating as a Civil Engineering Major, Engineering faculty of Catholic Parahyangan University.

During the process, the writer gets numerous help, such as advice, criticism, suggestions, and even encouragement from some people. By this, the writer wants to give thanks especially for:

1. Doddi Yudianto, Ph. D., was the main advisor of the thesis, who provided time, energy, advice, and decision-making. The writer really appreciates how fast and caring Sir Doddi is even though he was very busy. Also, the way he makes a target to have a process every week really helps make the process more durable than ever. (For those who want to take the thesis in TSDA, I really recommend him.)
2. Okky Purwana, Ph.D, as the second advisor of this thesis and the topic giver. The writer really appreciates him for teaching such expensive knowledge of FPV. Also, the way he targets and teaches specific parts a bit by week really helps the process be easier and more durable than ever.
3. Willy, S.T., M.T. and Theo Senjaya, S.T., M.Eng., as the data provider for Matenggeng Dam. Numerous guidance, criticism, and advice has been given to the writer by these two people. Several discussions was done during the process, including a guide of where the writer should start and the stupid questions that the writer gives. Gratitude for both of them that bare from the writer annoying approach.
4. Finna Fitriana, S.T., M.S. and Calvin Wimordi, S.T., M.Eng. For helping the writer with difficulty technical problems in data collecting or graphic making or drafting. Also, solely for Finna Fitriana, S.T. for proof reading the first draft of the thesis.
5. Dr. Steven Reinaldo Rusli and Albert Wicaksono, Ph.D. For giving numerous criticism and advice for the base of the thesis. The writer really appreciates personal discussion about the thesis.

6. Stephen Sanjaya, S.T., M.Sc. and Obaja Triputera Wijaya, Ph.D. For proofreading the first draft of the thesis and giving several pieces of advice and criticism on them.
7. Bambang Adi Riyanto, M.Eng. For teaching the basic theory of hydrology and hydraulics over the years the writer is in the university. This gives the writer several piece of knowledge for the thesis.
8. My family, Hadi W. as Father and Djie Lian Ing as Mother. For the writer's financial support from stress buying even stress eating. Also, the motivation to finish the thesis.
9. Jovan F.C. and Candice (the writer's cat) are the place of numerous times of stress ranting, silliness bombs from the writer, and sources of motivation. Both of them make the process feel super durable. Also, Jovan helps the writing process, even though he always makes the writer feel very left out because of how fast he is at writing.
10. Raihan A., for proofreading the overall draft and giving me a lot of guidance and suggestions for better writing.
11. Yudha Primus K., Moh. Demirel P., Moh. Raul Z., and Imam A.F. As fellows with the same advisor, they encourage the writer every week so that the writer is mentally prepared to face Sir Doddi.
12. Fara Nadia A.P, Diva K.C, Laurentius R.J, Tasya W., Danur R.P, Moh. Fadilah H. and Metta Lim. As for the fellow from the TSDA thesis, it gives the encouragement and motivation to do the work. Even though Metta Lim had already passed last semester.
13. Anastasia E.H, Timothy T., Jovian J., Laras A.M., Michael S.S., Ingrid G., and Thedrick L. As the friends that gives several motivations to the writer because of fear of being left out. Also, companies the writer during the process.
14. Mila K.V., Leonardy C., Andres S.W., Jocelyn I., Kirana M., Kelvin H., Alditio M., Mr Alman, and Ms. Sarah from the lab. For helping and giving numerous moral supports from different kinds of sources.

With full modesty, the author realizes that in writing this thesis, there are still shortcomings, so the author is very grateful if there are suggestions and criticisms submitted so that this thesis can be better.

Bandung, 1 July 2024

Evely Tirza
6102001086

TABLE OF CONTENTS

ANNOTATION

A	: The area of single solar panel (m^2)
A	: Area affected by the wind (m^2)
A	: Contact Area of the Anchor (m^2)
A'	: Required contact area of the anchor (m^2)
AC	: Alternating Current
β	: Bottom Slope
C_a	: Wind load coefficient
C_d	: Drag coefficient
C_d	: Discharge Coefficient
C_s	: Shielding coefficient
DC	: Direct Current
D_f	: Anchor embedment (m)
E	: Environmental factor
ECRD	: Earth Core Rockfill Dam
E_r	: Vertical distribution coefficient
η	: Dimensionless efficiency of the turbine
$F_{current}$	: Current Load (N)
FPV	: Floating Photovoltaic
F_{waves}	: Wave Load (N)
F_{wind}	: Wind Load (N)
g	: Gravity acceleration (m/s^2)
G	: Submerged weight of the designed anchor (kN)
γ	: Anchor submerged unit weight (kN/m^3)
GHI	: Global Horizontal Irradiation
GW	: Gigawatt
GWh	: Gigawatt-hour
H	: Height (m)
H	: Anchor Horizontal Load (kN)
h	: Height of the Anchor (m)
h'	: Required height of the anchor (m)

H_e : Head effective (m)

HEC-HMS : Hydrology Engineering Center-Hydrology Modeling System

HHMT : Hujan Harian Maksimum Tahunan

H_s : Wave height (m)

HWL : Highest Water Level

I_w : Usage coefficient

JIS : Japanese Building Code

L : Projected length of the island base on the azimuth (m)

LWL : Lowest Water Level

L_α : Projected length of the island base on the azimuth (m)

L_β : Projected width of the island base on the azimuth (m)

MWac : Megawatt-alternating current, capacity of generated power in the form of alternating current.

MWh : Megawatt-hour, generated energy that can be fed to electricity grid.

MWp : Megawatt-peak, peak capacity of electrical parts in the form of direct current.

N : Number of panels

P : Power (watt)

Φ : Friction Angle

PLTA : Pembangkit Listrik Tenaga Air

PLTS : Pembangkit Listrik Tenaga Surya

PMF : Probable Maximum Flood

PMP : Probable Maximum Precipitation

PV : Photovoltaic

Q : Flow rate (m^3/s)

q_p : Wind pressure (N/m^2)

ρ : Density of water (kg/m^2)

SCS : Soil Conservation Service

Sf_a : Safety Factor of Axial Load

Sf_l : Safety Factor of Lateral Load

SI	: Storage Indication
Su	: Shear Strength (kPa)
Ø	: Angle of the mooring lines
θ	: Angle
t_m	: Thickness of the module (m)
TWh	: Terrawatt-hours
U	: Wind base speed (m/s)
u_*	: Friction velocity (m/s)
V	: Current speed (m/s^2)
V	: Anchor Vertical Load (kN)
V_0	: Base wind speed (m/s)
W_f	: Wind load acting on the solar panels (N)

TABLE OF FIGURES

TABLE OF TABLES

Chapter 1
INTRODUCTION

1.1 Study Background

In early 2022, Indonesia predominantly generated its electricity from non-renewable energy, especially coal, by 48%, followed by gas by 28%, as seen in Figure 1.1. This non-renewable energy leaves emissions that can harm the environment and induce climate change (Foster and Elzinga, 2015). On the other hand, renewable energy resources do not leave emissions behind, which is called green energy (Just Energy, 2021). Furthermore, the increasing demand for green electricity in Indonesia is driven by the rise of electric vehicles and growing environmental concerns (IEA, 2022). The country has been working to increase its renewable energy production, with a target of 23% of its energy mix coming from renewable energy by 2025 and 31% by 2050 (Ardiansyah, 2022). Due to searching for renewable energy, sources such as geothermal, hydroelectric, solar, and wind power have been gaining traction and attention in Indonesia's energy landscape.

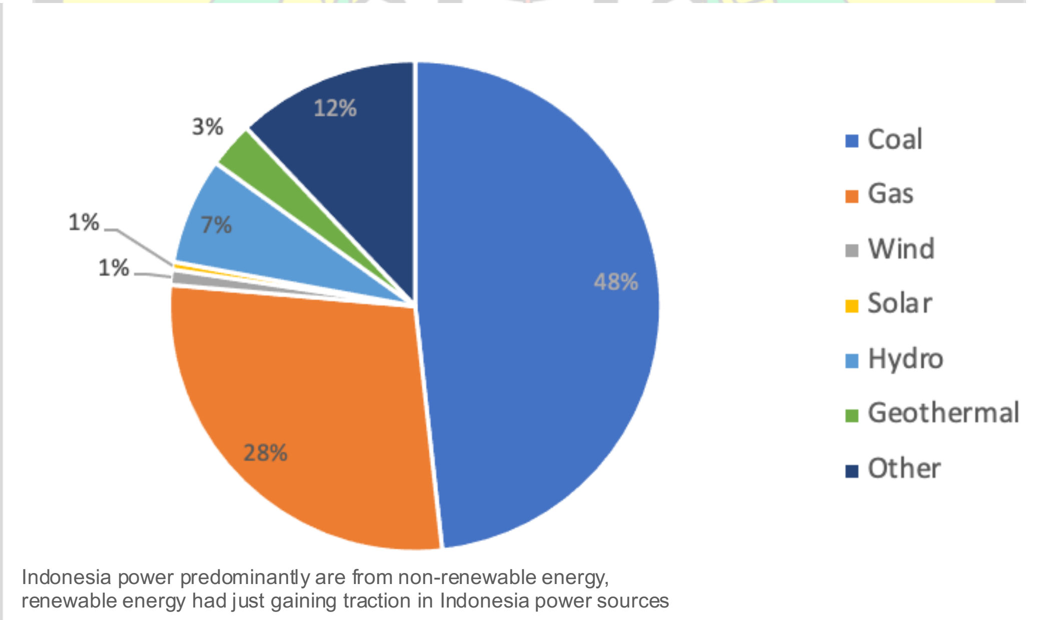

Figure 1.1 Installed Power Capacity in Indonesia 2021 (Indonesia Power Market Report and Long-Term Outlook, 2022).

Hydropower is a renewable source of energy that is generated by harnessing the power of moving water. It is a simple process of taking advantage of falling water (Egré, D., and Milewski, J. C., 2002). Indonesia has significant potential to expand its hydropower energy production with over 800 rivers that can be harnessed; Indonesia has the potential to generate 75 gigawatts (GW) of electricity. Despite the vast potential, Indonesia's hydropower production is currently underutilized. The country is currently only utilizing around 7% of its energy mix from hydropower, which is less than its potential (Ardiansyah, 2022). Also, global generation from hydropower fell 3.5% in 2021 to around 4,218 terawatt-hours (TWh). This is caused by climate-induced changes in operating conditions (Gibb et al., 2022).

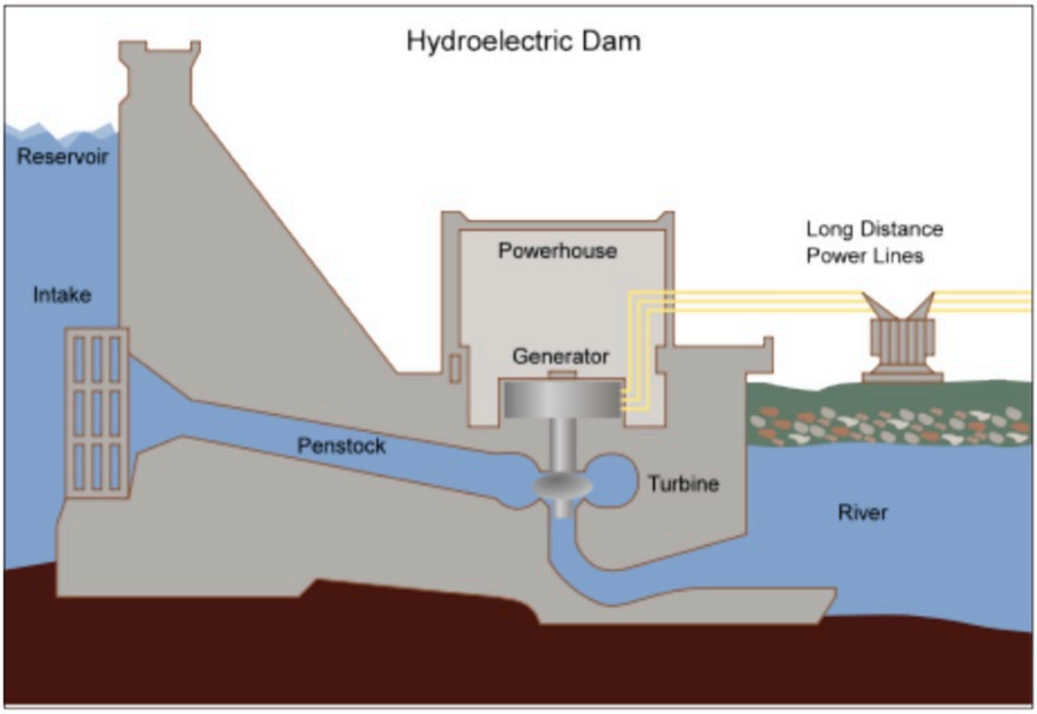

Figure 1.2 Cross-section of a conventional hydroelectric dam (Tennessee Valley Authority, 2000).

Hydropower energy production is affected by significant seasonal variations that can be pronounced in the river basins, resulting in higher hydropower generation during the wet/summer season while lower generation during the dry/winter season (Singh et al., 2022). This is due to the availability of water resources, which can be affected by precipitation patterns and runoff (Li et al, 2020). Furthermore, climate change causing more extreme weather events, namely droughts, making the flexibility of hydropower in managing seasonal variability becomes increasingly important (Laurita, 2023).

Aside from being a hydroelectric power plant, reservoirs can also be utilized for storing drinking water, managing floods, and providing irrigation. The reservoir inundation areas can also be utilized to enhance the reservoir's value, making it multifunctional. These inundation areas can be used for tourism, water sports, and aquaculture. In 2020, the reservoir inundation areas can be used for floating photovoltaic (PV) (PLTS), with a regulation allowing only 5% of the reservoir inundation area to be used at normal conditions (PUPR, 2020). Owing to the newly installed floating PV in Cirata Dam, the regulations have changed, allowing up to 20% utilization of the reservoir inundation areas (PUPR, 2023).

A hybrid powerplant combining floating PV and hydropower plants could be considered. It can be one of the most effective innovations for floating PV to compensate for the electricity production in that area. This option is best conceived as a way to maximize the utility of existing hydropower stations rather than as a way to justify the building of new dams (Gadzanku et al, 2022). Where rainfall patterns are highly seasonal, as in monsoon areas, there is an additional advantage of complementarity over the year: More solar power is generated during the dry season, where water levels and hydropower output are low. The reverse is true for the rainy season. These systems make the Floating PV and Hydropower plants work optimally. Where water resources and solar energy can compensate for each other (World Bank Group et al, 2019).

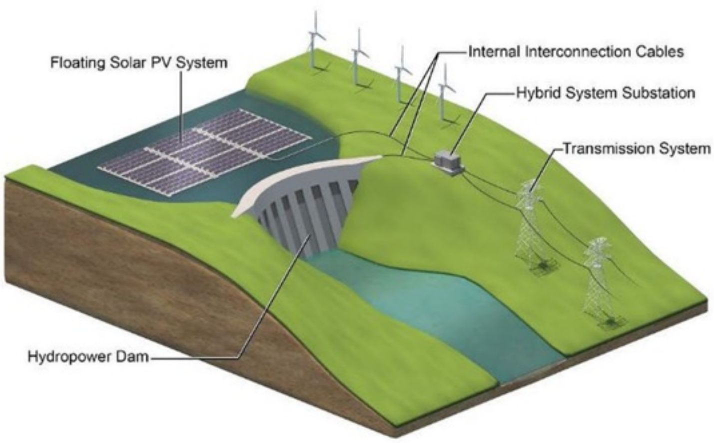

Figure 1.3 Hybrid operation of hydropower and floating PV (PV Magazine, 2022).

In this thesis, the chosen dam is Matenggeng Dam, located in Cilacap, Central Java, Indonesia. Matenggeng Dam is currently in its planning phase and is planned to have a hydropower plant. Matenggeng also had great potential in PV generation; if we put 1 Megawatt-peak (MWp) panels on Matenggeng, there is a potential to make 1 Gigawatt-hour (GWh) of electricity per year (Global Solar Atlas, n.d). This makes Matenggeng Dam a potential site for implementing a hybridization system between the hydropower plant and floating PV.

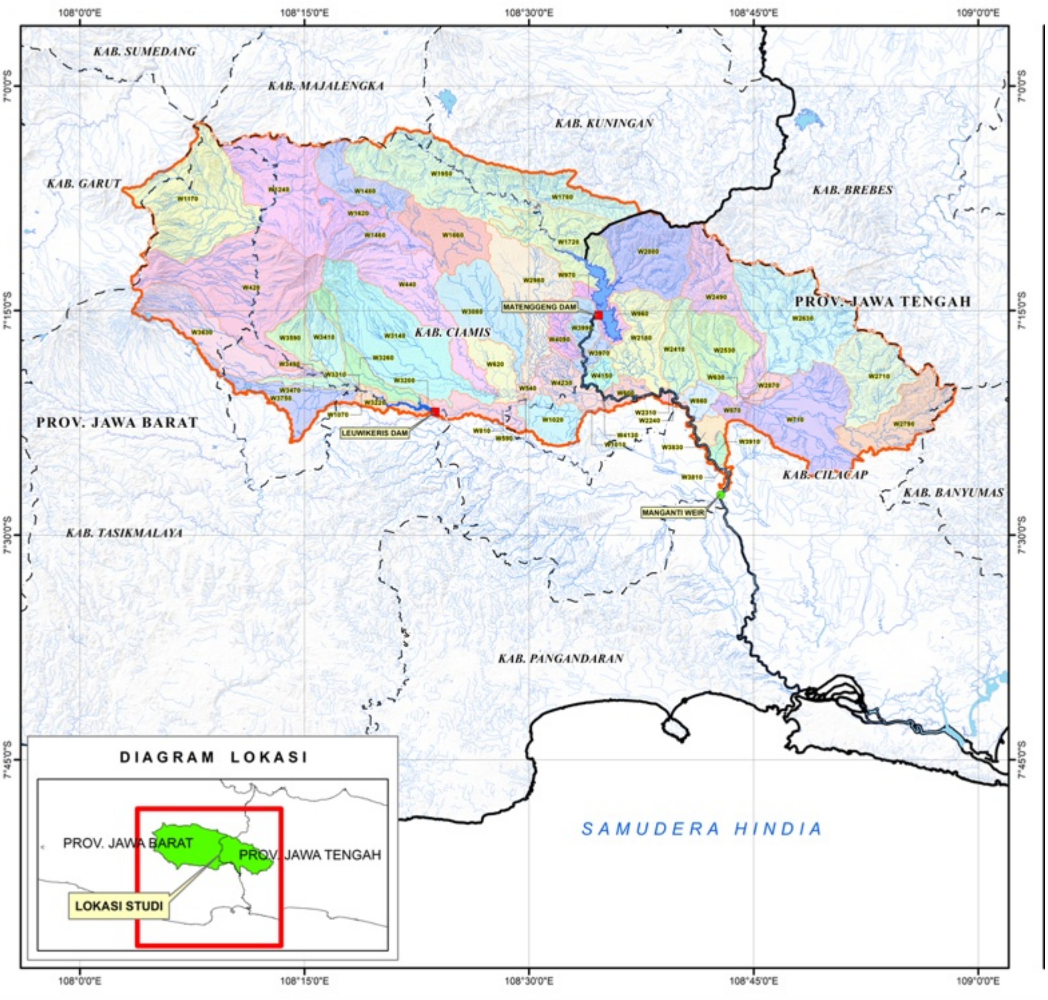

Figure 1.4 Location of Matenggeng Dam (PT. Intimulya, 2023)

Implementing floating PV might be a good opportunity for Indonesia because the country has been depending on non-renewable energy resources. These types of energy resources leave emissions behind that can harm the environment and might cause climate change, where hydropower energy yield is affected. Also, the idea of a hybrid power plant combining floating PV and hydropower is a rarely discussed and new topic where a hybrid power plant is employed to ensure a sustainable and uninterrupted supply of electricity.

1.2 Study Objective

The study's purpose is to assess the system's effectiveness of a hybrid power plant, where a floating PV power plant augments the hydroelectric capacity of the Matengeng Dam. The study will consider site conditions and the characteristics of the hydro dam.

1.3 Scope of Study

The scope of study of this study is as follows:

1. Analyzing the reservoir operation patterns used in Matenggeng, including the inflow and outflow of the reservoir, is provided. This determines water availability for the hydroelectric power plant (PLTA) intended for this project's projected capacity. Additionally, water level fluctuation is ascertainable to determine the datum and required length of the mooring.
2. Determine solar power production from monthly irradiation data provided by Solcast. This can also be used to predict the required area of solar panels (PLTS). The solar panels are intended to compensate for hydropower plant electricity losses. Thus, the area of solar panels depends on the projected capacity needed.
3. Determining the location of solar panels by reservoir inundation area data and topography without considering the sedimentation and flow circulation of the dam.
4. Analyze the energy production of a hybrid power plant operated with solar panels and hydropower, then compare the effectiveness of the system with the optimization system used in the previous study.

1.4 Research Methodology

The research methodology used in this study is a literature review to determine the main issue and scope of the study. Furthermore, data collection is needed to begin the analysis of the project, such as dam operation pattern analysis, mapping, loadings, and anchoring and mooring. Lastly, there would be a conclusion to the study. The plot of this study is shown in Figure 1.5.

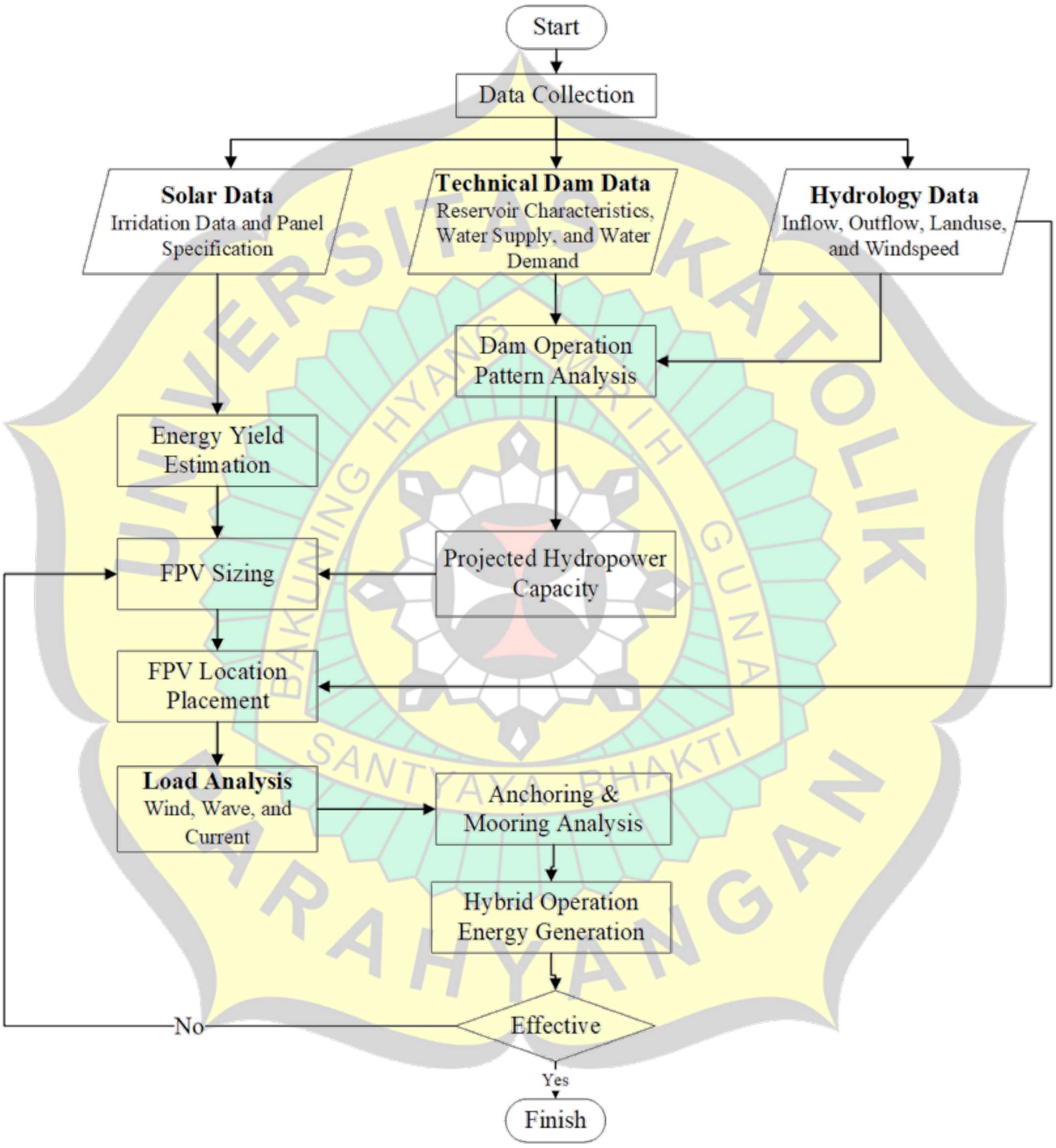

Figure 1.5 Flow diagram of the study

1.5 Reporting Systematics

This thesis will include:

Chapter 1 Introduction

This chapter includes background, the main issue, study objectives, scope of study, research methodology, and writing systematics

Chapter 2 Literature Study

This chapter includes the main idea of dam operation pattern analysis, floating PV mechanism, and electricity yield for hydropower and solar PV.

Chapter 3 Study Area and Data Availability

This chapter explains the area of Matenggeng Dam and provides the data that are needed for the analysis

Chapter 4 Analysis and Result

This chapter shows the analysis process and the result of the analysis

Chapter 5 Conclusion

This chapter provides the conclusion of the study and gives an explanation of the result of the analysis.