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Study of Floating Photovoltaics in Dam as a Renewable Energy Using IoT Application

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ABSTRACT

Saguling Reservoir is a reservoir located in West Bandung Regency, West Java Province at an altitude of 643 m above sea level. The pool area of this reservoir is around 5,606 ha with an initial storage volume of 875 million m3 of water. Several studies have been carried out regarding the plan to build Floating Photovoltaics (FPV) power plant on this reservoir. However, the results of this research are still felt to be less practical because they still use manual tools and use old technology. Therefore, it is very important to be able to develop a floating PV cell that is reliable, environmentally friendly, affordable and IoT-based, by paying attention to existing regulations. The aim of this research is to create a FPV cell design and analyze the potential for new renewable energy produced from IoT-based PV cell, useful for the development of environmentally friendly AC electrical energy. The method used is the quantitative analysis design, using IoT Blynk application. The floating solar power plant design is carried out at the reservoir location, taking into account rainfall, temperature, humidity, and solar energy potential from time to time in 1 full year. Data processing is carried out by means of quantitative analysis. For a 1 ha area, FPV have potential development results of 1.04 MWp. The PV cell capacity obtained from the development of the FPV design in the Saguling Reservoir is 1,165.82 MWp
Keywords: Floating Photovoltaics, IoT, Dam, Energy

ABSTRAK

Waduk Saguling merupakan waduk yang terletak di Kabupaten Bandung Barat, Provinsi Jawa Barat pada ketinggian 643 m di atas permukaan laut. Luas genangan waduk ini sekitar 5.606 ha dengan volume tampungan awal air sebesar 875 juta m3. Beberapa kajian telah dilakukan terkait rencana pembangunan pembangkit listrik Floating Photovoltaics (FPV) di waduk ini. Namun hasil penelitian tersebut masih dirasa kurang praktis karena masih menggunakan alat manual dan menggunakan teknologi lama. Oleh karena itu, sangat penting untuk dapat mengembangkan sel PV terapung yang andal, ramah lingkungan, terjangkau, dan berbasis IoT, dengan memperhatikan regulasi yang ada. Tujuan dari penelitian ini adalah untuk membuat desain sel FPV dan menganalisis potensi energi baru terbarukan yang dihasilkan dari sel PV berbasis IoT, berguna untuk pengembangan energi listrik AC yang ramah lingkungan. Metode yang digunakan adalah desain analisis kuantitatif, dengan menggunakan aplikasi IoT Blynk. Perancangan PLTS terapung ini dilakukan di lokasi waduk dengan mempertimbangkan curah hujan, suhu, kelembaban, dan potensi energi matahari dari waktu ke waktu dalam 1 tahun penuh. Pengolahan data dilakukan dengan cara analisis kuantitatif. Untuk lahan seluas 1 ha, FPV mempunyai potensi hasil pengembangan sebesar 1,04 MWp. Kapasitas sel PV yang diperoleh dari pengembangan desain FPV di Waduk Saguling adalah 1.165,82 MWp.
Kata Kunci: Fotovoltaik Terapung, IoT, Dam, Energi

1. INTRODUCTION

Saguling Reservoir is a reservoir located in West Bandung Regency, West Java Province at an altitude of 643 m above sea level. This reservoir is one of three reservoirs that dam the flow of the Citarum River, which is the largest river in West Java. The other two reservoirs are Jatiluhur Reservoir and Cirata Reservoir. The pool area of this reservoir is around 5,606 hectares with an initial storage volume of 875 million m^3 of water. Several studies have been carried out regarding the plan to build a floating solar power plant on this reservoir. However, the results of this research are still felt to be less practical because it still uses manual tools, while the second research still uses the GPRS cellular network, using old technology. Hence, there's a significant importance in creating a Floating Photovoltaic (FPV) system that is dependable, eco-friendly, cost-effective, and integrated with Internet of Things (IoT) technology.

In line with the government's program to develop new renewable energy, the waters of the Saguling Dam have great potential to become a Solar Power Plant or photovoltaics on the surface of the river. The benefits are that the location has a flat area, without the need to own land, an affordable construction system and materials that are easily found on the market. Dam utilization regulations can reach 20% or more of the normal water surface area. This provision has been regulated in Public Works and Housing Ministerial Indonesia Decree No. 7 of 2023 concerning the Second Amendment to Public Works and Housing Ministerial Regulation Indonesia, No. 27/PRT/M/2015 concerning Dams. In this case, the use of FPV must pay attention to the panel area because it can affect dam safety, reservoir function, social, economic & cultural conditions, and the destructive power of water.

Some of the problems that must be addressed are those related to the dam utilization area, the climate of the dam area, bathymetry, the cultural situation of the population, and renewable energy engineering calculations, as well as FPV design. The aim of this research is to analyze the potential for IoT-based FPV renewable energy in the Saguling Reservoir.

Bening/Widas Reservoir, Madiun, East Java was researched by Permana as a FPV location. The results of this research indicate that the allowable inundation area in the dam. This around 944,893 m^2 and FPV , which can develope around two tens module with a design area of FPV 1 of around 8000 m^2. Energy produced by 20 modules FPV within two mercy month around 19,668.52 MWh (Permana et al., 2019). Utilization of water energy can also be done by utilizing sea water channels at the outlet plant of the Gas and Steam Power Plant located in Cilegon, Banten. Designing a Pico hydro hydropower prototype by analyzing several numbers of Pico hydro turbine propeller blades. The analysis results show that the highest mass flow rate, circumferential speed and rotational speed are found on blade 6. Pico hydro produces green energy, which can replace some of the fossil energy energy requirements (Biantoro et al., 2021).

To measure the potential for FPV above the surface of the reservoir, It's essential to compute the flood discharge within the region. The projected flood discharge represents the highest potential volume of flooding that could happen within an area, considering a specific probability of occurrence. Determining the flood discharge aids in designing drainage network systems for planning purposes or for the early detection of potential flood disasters, calculated based on rainfall water discharge (Risnawati, 2013). Rain intensity refers to the measurement of rainfall height during collection (Loebis, 1992). In this study, the Mononobe method is employed, and the corresponding formula, known as the Mononobe formula, is utilized in the equation (Safitri et al., 2020). Two methodologies, namely the Gumbel distribution approach and the log Pearson type III distribution approach, were employed to assess the frequency distribution of rainfall data. Several stages of the planned flood discharge analysis are rain validity test, distribution distribution, and Kolmogorov Smirnov suitability test.

Rainfall that occurs in the dam area needs to be taken into account to calculate the occurrence of flooding in areas downstream from the dam. The use of the internet of things to anticipate flooding in downstream areas is applied to the Ciliwung river by calculating water discharge and taking into account the amount of rainfall that occurs in the upstream area of the river (Biantoro, Wahyudi, Niam, et al., 2022).

Previous studies on floating photovoltaic (FPV) systems in the reservoir have been limited by outdated technology and manual tools. This research aims to address these limitations by developing an IoT-based FPV system that is reliable, eco-friendly, and cost-effective. The study aligns with government initiatives to expand renewable energy sources, utilizing the extensive water surface of the reservoir without requiring additional land. The specific research objectives are to design an FPV system, assess its energy production potential, and evaluate the environmental benefits and challenges associated with its implementation.

Several studies have explored the potential of FPV systems, but gaps remain in integrating modern IoT technology to enhance efficiency and monitoring capabilities. This research builds on previous work by incorporating IoT applications such as the Blynk app, which provides real-time data on reservoir conditions, including water levels, rainfall, temperature, and humidity. By organizing the literature review into thematic sections, it becomes clear that this study uniquely contributes to the field by combining advanced technology with renewable energy solutions, addressing both the technical and environmental aspects of FPV implementation.

Kim *et al* (2016) study demonstrates the current demand in Korea for floating solar power plants as an alternative energy source. From 2009 to 2014, Korea constructed 13 FPV units to fulfill the energy requirements of its population (Kim et al., 2016). The development of FPV plants is also being studied in the Palembang area, South Sumatra. The results indicate that FPV has the potential to be developed in the Palembang region, South Sumatra, because it has several reservoirs or dams that can be used as locations for FPV (Junianto et al., 2020). The specific aim of this research is to design FPV and make an analysis of the energy potential produced from the FPV based on IoT, useful for the development of new and renewable, environmentally friendly electrical energy.

2. METHODOLOGY

This research method uses design analysis and quantitative methods regarding the energy potential of FPV in Indonesia, especially in the Saguling Reservoir. Next, FPV plant design is carried out at the reservoir location, taking into account rainfall, temperature, humidity, wind speed and solar energy potential from time to time in 1 full year. Data processing is carried out by means of quantitative analysis. Data processing is very necessary in the scientific method, because in its implementation the data is processed and can have useful meaning for descriptive analysis and concluding research results (Rinaldi & Mulyono, 2021).

The methodology involves a detailed design analysis and quantitative assessment of the FPV system in the Saguling Reservoir. The IoT technology employed includes various sensors to monitor environmental parameters and optimize energy production. Specific sensors used are ultrasonic sensors for water level measurement, rainfall sensors, and temperature and humidity sensors. Data collected from these sensors are processed using the Blynk application, providing real-time insights and facilitating efficient management of the FPV system. This comprehensive approach addresses potential biases by cross-verifying data and incorporating multiple data points to ensure accuracy.

Return period rain is used to ensure rain intensity (Permana et al., 2019). In this research, return period rainfall is calculated using the Pearson Log III method and the Gumbell method. The results of these two procedures selected the highest return period rainfall value. The concentration time represents the duration needed for rainwater, from its farthest point, to stream towards the outlet or control point. This is calculated using the formula (Permana et al., 2019):

$$Tc = \frac{0.606\,(L)^{0.467}}{S^{0.234}} \quad (1)$$

Tc = concentration time (hours)
L = length of water channel (km)
S = average slope (m)

Rain intensity refers to the measurement of rainfall height during collection (Loebis, 1992). In this study, the Mononobe method is employed, and the corresponding formula, known as the Mononobe formula, is utilized in the equation :

$$It = \frac{R_{24}}{Tc}\left(\frac{Tc}{t}\right)^{2/3} \quad (2)$$

Information :
It: Rainfall intensity at hour t (mm/hour);

planning rainfall height 24 hour condition (mm);

Tc: concentration time (hours);

t: 1st hour to 1st hour tc

The standard representation of flood discharge is commonly expressed as follows (Kodoatie, 2013):

Q = CIA (3)

Where:

Q: peak discharge (m^3/sec),

C: runoff coefficient,

I: rainfall intensity with duration equivalent to flood concentration time (mm/hour),

A: watershed area (km^2)

For convenience in unit determination:

Qp = 0.278 CIA (4)

Where:

Qp: peak discharge (m^3 /sec),

C: runoff coefficient,

I: rainfall intensity for the duration matching the flood concentration time (mm/hour),

A: watershed area (km^2)

Ray cells sun or cell sun is tool which can convert energy Sun into electrical energy with the principle of the photovoltaic effect. Solar cells are composed of several layers of semiconductors with different charges. Surface layer minus charge while the layer both are positively charged. The most commonly used semiconductor material for solar cells is silicon (Roza et al., 2019). In its application, the electrical energy produced from one solar cell module is still quite small, so in its use several modules are combined using a series or parallel connection which is called an *array*. This *array* form is applied for solar power plants (FPV).

Power is a number energy required per unit time. Each solar panel can emit a number certain energy at a time maximum lighting sun. The amount of power generated in accordance with of the products used. Power generated by 1 solar panel at maximum lighting sun around 250 Wp. The amount of electrical power produced by the generator here it is which will be later offered to PLN. And can used For supplying the country's electricity needs. The amount of energy produced depends on the solar radiation in the area. The formula used to calculate energy is as follows:

$$E = P \times \text{solar radiation} \quad (5)$$

Where :

E : FPV electrical energy (kWh); P: AC power (kWp);

Solar radiation: constant (kWh/kWp).

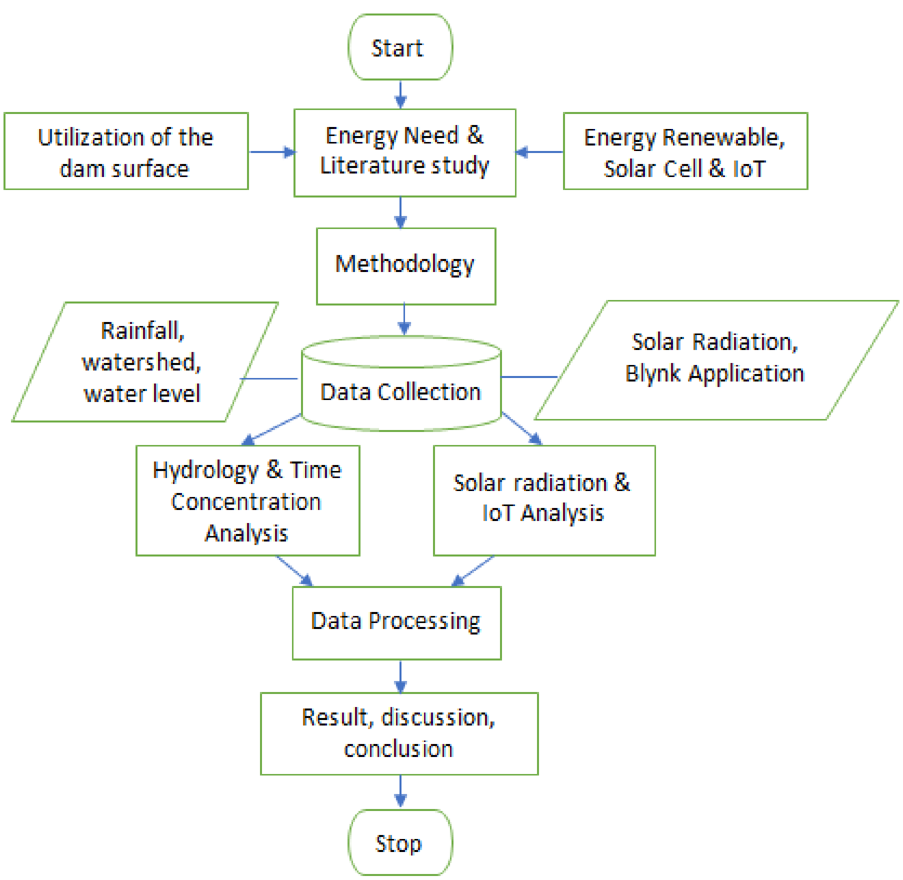


Figure 1. *System Flow Diagram*

3. RESULT AND DISCUSSIONS

3.1. Results

Reservoir Saguling is located in the area West Bandung Regency is one of them three dammed reservoir the flow of the Citarum River which is river largest in West Java. Wide puddle reservoir Saguling around 5,606 hectares with storage volume beginning amounting to 875 million m^3 of water. Reservoir Saguling own function main as generator electricity through a 700 MW hydroelectric power plant that can awaken electricity as much as 2,156 GWh per year. Reservoir construction Saguling help extend age service reservoir Jatiluhur, as well help control frequent flooding occurred in the area Karawang, Purwakarta and Bekasi.

Rainfall that falls in the Saguling reservoir area affects the volume of water in the reservoir and influences the water discharge in the reservoir. The Saguling Reservoir area has an average annual rainfall of 2,000 mm to 3,000 mm. By utilizing rainfall data that occurs in the area around the reservoir over a period of 15 years (2008 – 2022), it is possible to predict the intensity of rainfall and the planned flood discharge that will occur in the Saguling Reservoir.

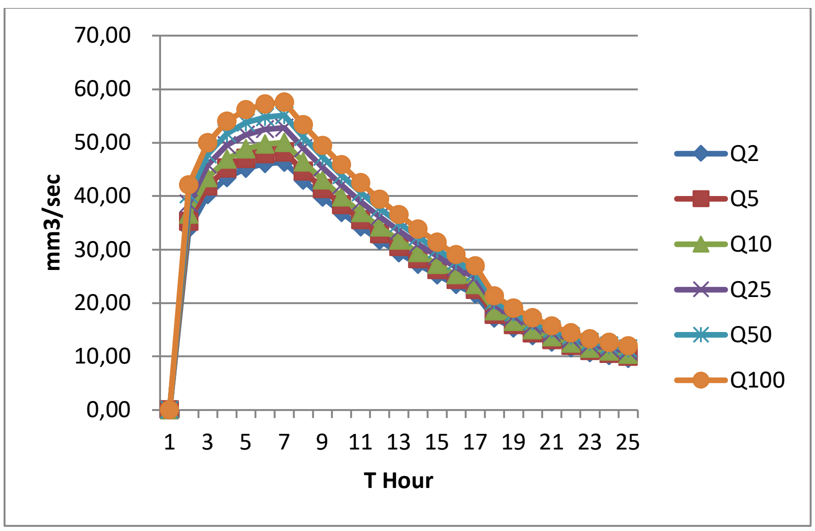


Figure 2. IDF Curve Nakayasu Method

The IDF curve image (Figure 2) shows the prediction of the intensity of rain that occurs during a 24 hours period in the Saguling Reservoir area for a return period of 2 to 100 years using Nakayasu Method. The intensity of rainfall in the area around the reservoir influences the volume of water stored in the reservoir and influences the amount of water flowing along the reservoir channel.

Table 1. Flood Discharge Plan Using 2022 Data

Return Period	Coefficient	Weight C	I (mm/hour)	A (Km^2)	Q (mm^3/sec)
2	0.278	0.050	7.100	56.06	5.53
5			7.389	56.06	5.76
10			7.668	56.06	5.98
25			8.090	56.06	6.30
50			8.443	56.06	6.58
100			8.822	56.06	6.87

The estimated scale of the intended flood discharge offers insight into the potential for water overflow in the Saguling reservoir area in the event of heavy rainfall (Table 1). This information can help management to warn people living in waterways so they can prepare themselves if a possible flood occurs. Rainfall intensity and water discharge are taken into consideration when planning the construction of FPV plants, because they will affect the installation of solar panels which are used as a tool to harvest sunlight.

There is enough heat potency on reservoir Saguling, Bandung District this can see from big the Global Horizon Irradiation (GHI) value reaches 1,799 KWh/m^2 per year, Direct Normal Irradiation (DNI) 1,184.2 KWh/m^2 and the annual average is 1,190.9 KWh/m^2 per year (Figure 3). Average value of Direct Normal Irradiation for every the month show that PV is the highest happened on the moon August.

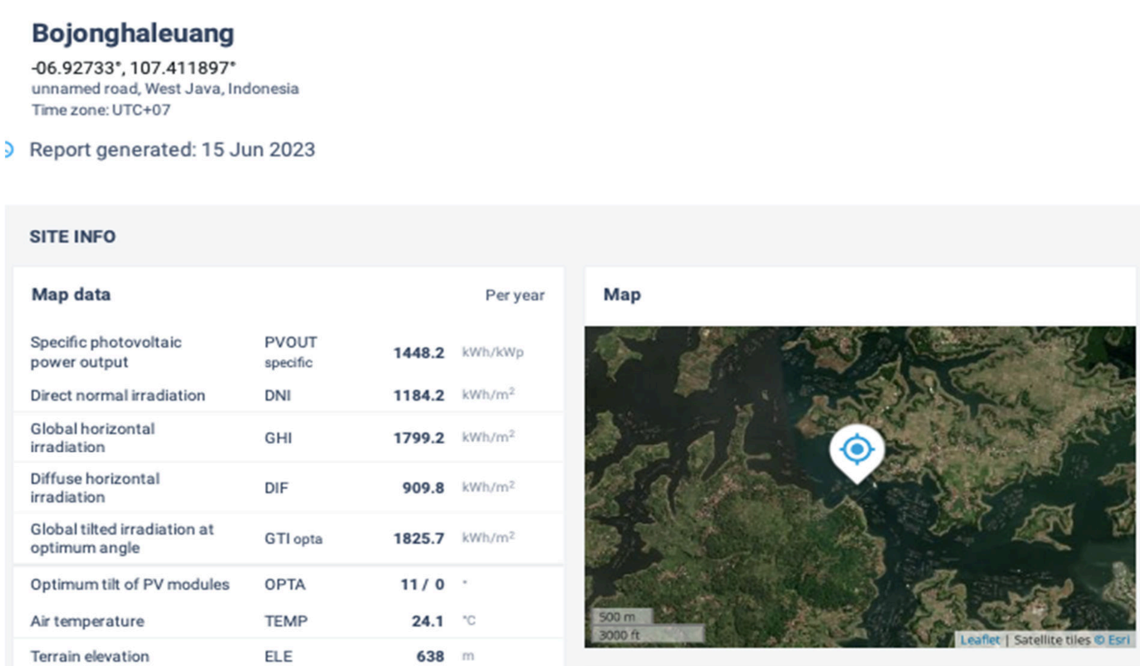
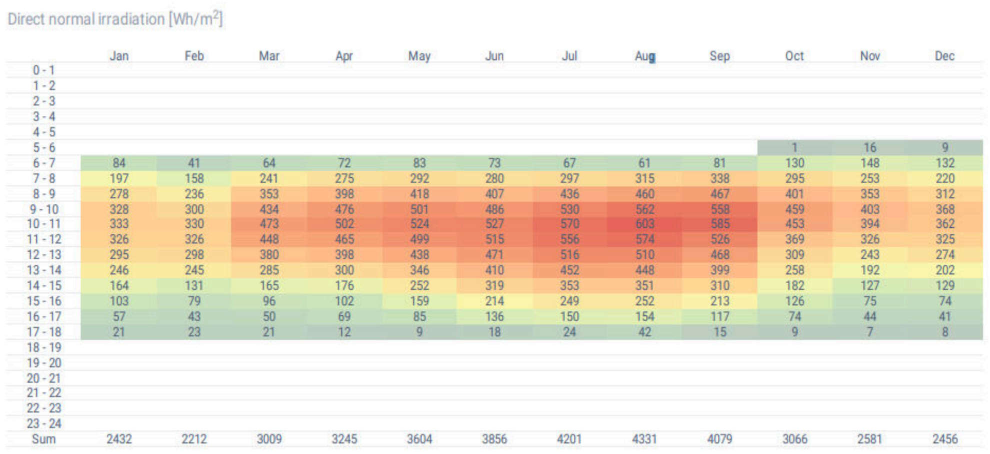


Figure 3. Map data Global Horizon Irradiation (GHI) and Direct Normal Irradiation (DNI) Value.

Analysis others who can obtained via the global solar atlas website is the highest total photo voltaic power output (KWh) in the region West Bandung Regency, precisely in the region Reservoir Saguling there is on month June until with September with the amount of PV output is between 3,856 KWh to with 4,331 KWh.


Direct normal irradiation [Wh/m2]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6										1	16	9
6 - 7	84	41	64	72	83	73	67	61	81	130	148	132
7 - 8	197	158	241	275	292	280	297	315	338	295	253	220
8 - 9	278	236	353	398	418	407	436	460	467	401	353	312
9 - 10	328	300	434	476	501	486	530	562	558	459	403	368
10 - 11	333	330	473	502	524	527	570	603	585	453	394	362
11 - 12	326	326	448	465	499	515	556	574	526	369	326	325
12 - 13	295	298	380	398	438	471	516	510	468	309	243	274
13 - 14	246	245	285	300	346	410	452	448	399	258	192	202
14 - 15	164	131	165	176	252	319	353	351	310	182	127	129
15 - 16	103	79	96	102	159	214	249	252	213	126	75	74
16 - 17	57	43	50	69	85	136	150	154	117	74	44	41
17 - 18	21	23	21	12	9	18	24	42	15	9	7	8
18 - 19												
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	2432	2212	3009	3245	3604	3856	4201	4331	4079	3066	2581	2456

Figure 4. Total Power Out Reservoir Saguling

The regulation for FPV utilization is 20% or more of the normal water surface area. This regulation has been regulated in the Minister of Public Works and Public Housing Regulation No. 7 of 2023 concerning the Second Amendment to the Regulation of the Minister of Public Works and Public Housing No. 27/PRT/M/2015 concerning Dams. The use of FPV must pay attention to the panel area because it can affect dam safety, reservoir function, social, economic and cultural conditions, and the destructive power of water. Previous regulations stated that the maximum area of a reservoir pool that could be used as a FPV was a maximum of 5%.

Figure 5. Saguling Dam in Bandung District, West Java.
Source : https://jabar.inews.id/berita

Reservoir Saguling have wide puddle reservoir reaching 5,606 hectares or amounting to 56,060,000 m^2. Based on regulation minister of Ministry of Public Works and Housing Indonesia, then big wide puddle reservoir that can utilized For solar panel installation is 20%. The planned solar panel capacity aims to achieve 250 watts peak (Wp) and is described by the subsequent details: It includes a Maximum power (Pmax) of 250 Wp, with a maximum Voltage at Pmax (Vmp) of 30.6 volts, along with a Current at Pmax (Imp) of 8.5 amperes, short circuit current (Isc): 9.18 amperes, wide PV cell ((m^2) = $1.636 x 0.992$, degradation on solar panel efficiency : 10%, and system losess:

Table 2. Total PV Comparison based on Regulation Minister Work General And Republic of Indonesia Public Housing

Maximum Use	5%	20%	Unit
Reservoir Inundation Area	56,060,000	56,060,000	m^2
Maximum Utilization	2,803,000	11,212,000	m^2
Maximum solar panel (PV Cell)	1,727,142	6,908,569	Pieces
Solar modules that can be obtain	431,785,580.49	1,727,142,321.95	Wp
PV Capacity with 10% degradation	388,607,022	1,554,428,090	Wp
System Loss Maximum	25%	25%	
Maximum Production	291,455,267	1,165,821,067	Wp
PV Capacity	291.46	1,165.82	MWp
PV Capacity / ha	1.04	1.04	MWp/ha

Based on Table 2, the area that can be used as a PV solar cell location for the maximum 5% regulation is 2,803,000 m^2, whereas based on the maximum 20% regulation the pool area that can be used is 11,212,000 m^2. The wider pool that can be used is expected to increase the electricity production produced.

Based on Table 2, the number of PV solar cells that can be accommodated by a pool area with a maximum of 20% is 6,908,569. With the number of PV solar cells that can be used, it is hoped that they can absorb more sunlight and produce a larger electricity supply. By increasing the maximum limit for using the reservoir pool area, the amount of electricity production for each hectare of land will be greater. At a maximum limit of 20%, the amount of electricity produced reaches 1.04 MWp.

The development of IoT-based FPV plants can provide information about reservoir water levels, rainfall, temperature and humidity as well as the magnitude of water flows. Utilizing ultrasonic sensors to measure reservoir water levels can help determine whether the reservoir is experiencing drought or has a normal discharge level. Rainfall sensors help provide information about the amount of rainfall that occurs in the reservoir area, so that it can monitor whether the rain collected by the reservoir is still within normal limits or can cause flooding.

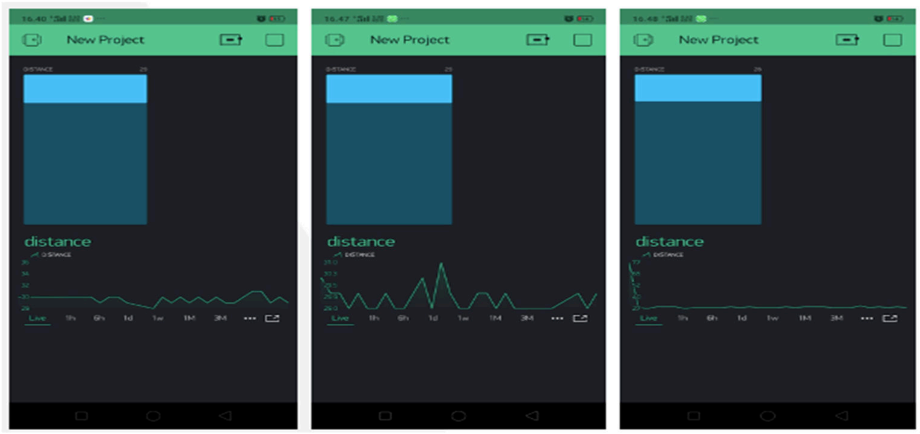


Figure 6. Display of water level in the Blynk application on a smartphone

Ultrasonic sensor test results can be obtained using a smartphone that has the blynk application installed. Blynk is an application that functions as a translator of data sent by sensors on a cellphone so that it can be understood (Figure 6). Utilizing IoT, parties in charge of the dam can keep track of the high water level in the reservoir that serves as the site of the FPV plant. This technology is able to deliver information on flood danger prediction in downstream river sites by utilizing the IoT-based Blynk application. (Biantoro, Wahyudi, & Niam, 2022). The tool system utilizes the Blynk application and sensors, with measurement error values for the water level sensor of 3.0%, rainfall sensor of 2.6%, temperature sensor of 4% and humidity sensor of 3.0%. Electrical power is energy efficient because it uses solar cells (PV), with a capacity of 20 Wp 10 A, with backup energy storage in the form of a 3.5 Ah, 12 V battery. Residents or community leaders residing in areas downstream of the river can utilize this instrument by strategically situating it both upstream and downstream. This placement allows for prompt, accurate, and real-time communication of early flood information.

3.2. Discussion

Development of FPV plants based IoT Not yet Once done , generally study about development of floating solar power plants focus more on the number of solar panels that can be installed And wide required area for build a FPV plant that. Study about utilization reservoir as alternative location FPV construction has been lots done.

Reservoir pools can be utilized for FPV plants by dam owners and managers whose dams have obtained a dam operation permit by the Minister of Public Works and Public Housing and a recommendation from the Dam Safety Commission (Rinaldi & Mulyono, 2021).

Analysis use study documents, regulations related And discussion technical with para party manager dam. Results study literature showing that development puddle reservoir For generator electricity power FPV can give optimal impact for utilization reservoirs, both single purpose and multipurpose, in Indonesia (Rinaldi & Mulyono, 2021).

Power plant construction FPV electricity, need studies environment and technical special For evaluate appropriateness FPV project like topography and bathymetry. Analysis regarding FPV related with topography, composition soil, bathymetry, water depth, variations Water Level and speed wind on site around reservoir.

After assembled with PV panels, floating platform withdrawn to specified location. Platforms then moored For still on position still For avoid hit edge while follow variation water height. Design system retainer usually consists from : Stem spreader aluminum installed on lifebuoy for possible connection rope mooring to island And spread burden through two ear connection buoy. Cable For connect stem spreader to anchor, sized in accordance variation water height. Chain at the end cable For adapt long . Anchor For tether island at the bottom or on the edge For withhold burden wind And For reduce movement island on the surface of the water. Chain For connect every component : anchor and cable, cable and chain, chain and stem spreader.

The implementation of the Cirata FPV has proven highly efficient in its development phase. Initiated in 2020, the construction of the Cirata FPV's first phase concluded by the end of 2021, achieving a 50-megawatt (MW) milestone, while the subsequent phases are scheduled to continue through 2022. Floating PV also has the potential to become a government priority as an effort to accelerate the energy mix target of 23% in 2025 (Hidayat, Ramdani, et al., 2022). The plan to develop FPV plants in several reservoirs is very useful for knowing which areas have the potential for heat and produce better energy.

FPV designs can follow needs or adapt to locations that have the potential to develop FPV plant which consists of a barge with a catamaran hull as a floating medium for solar panels and inverters so that later one FPV can meet the electricity needs of several sub-districts even though they are on different islands (Hidayat, Ramdani, et al., 2022). Numerical simulations were carried out to understand the toughest conditions that FPV will experience, especially in extreme conditions and strong winds. The outcomes from the simulation indicate the specific inundated zone that possesses the least flow velocity and sediment concentration suitable for locating FPV installations. Through the analysis, it was determined that approximately 242.93 hectares, accounting for roughly 4.1% of the entire inundation area of the Cirata Reservoir, meet these criteria. This area is an inundation area with a minimum water flow velocity, namely < 5 cm/s, and a floating sediment concentration < 10 gr/m^3. This value can be used as an initial assessment in making recommendations for placing FPV panels in the Cirata Reservoir area (El Islamy & Aryawan, 2018).

Based on data analysis and results mapping found in the area Java west that is There are 7 reservoirs located in the area Bogor Regency, Regency Cianjur, Regency Purwakarta, Regency Cimahi, Regency Majalengka, Regency Sumedang, Regency Bandung West, Regency Brass. With thereby digitalization This can become reference for government For optimizing potential for FPV plants in West (Diniardi et al., 2022).

Figure 6 shows the results of testing the ultrasonic sensor used to measure the water level in the reservoir pool. Placing PV solar cells on the surface of the reservoir has quite a high level of difficulty, because the PV solar cells will float above the water surface, so it is necessary to measure the water level so that it can be minimized if the water level exceeds the limit because it will affect the length of the anchor rope attached to it on FPV.

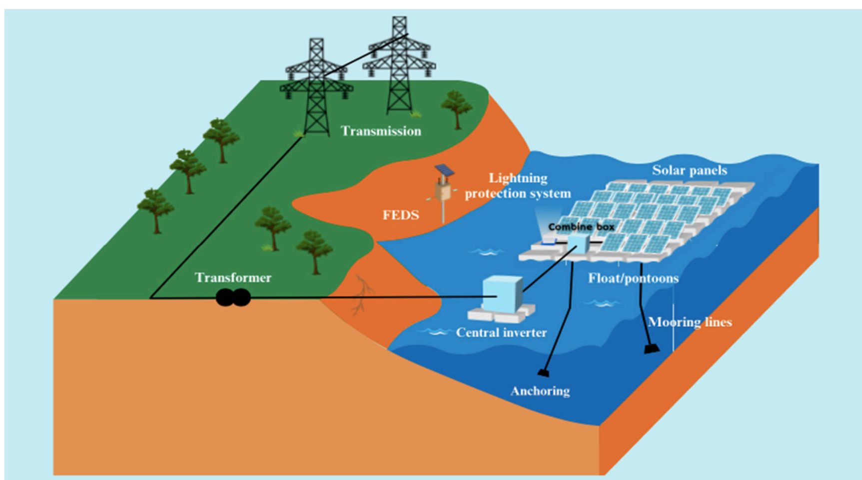


Figure 7. FPV on existing Hydro reservoirs

Rainfall sensors help provide information about the amount of rainfall that occurs in the reservoir area, so that it can monitor whether the rain collected by the reservoir is still within normal limits or can cause flooding. The FEDS (Flood Early Detection System) tool which utilizes the Blynk Internet of Things (IoT) application, can be used and placed on the edge of the dam, intended for managers to monitor weather changes around floating PV panels, for example changes in water level, rainfall, temperature. and humidity so that you can anticipate undesirable things (Figure 7) (Biantoro, Wahyudi, & Niam, 2022). The use of IoT helps reservoir managers obtain data in real time, so they can continuously monitor the condition of the FPV and take anticipatory action according to the needs at that location.

The research on real-time monitoring systems of solar panel performance based on the internet of things has been successfully carried out. Monitoring consists of solar panels' voltage, current, power, and temperature through the Blynk application. The testing was conducted by comparing the measuring instrument and blynk applications. As per the assessments conducted, the voltage testing exhibited an error percentage of 0.59%, while current testing showed a mere 0.0001% error. Additionally, power testing resulted in a 1.03% error, and temperature testing yielded a 2.09% error. This study indicates that a robust internet connection will markedly influence the device's efficacy in real-time monitoring of solar panel performance using the Internet of Things (IoT) (Inayah et al., 2022).

Selecting rainfall data that is close to the research location is very effective for predicting the amount of rainfall in the future and can be used as a benchmark for statistical calculations. Apart from rainfall data, historical data regarding water discharge is also important for consideration and data validation. These two data are very important in influencing river water levels (Hidayat, Basysyar, et al., 2022). River water can also be used as a new renewable energy alternative. The reliable discharge analysis calculation uses NRECA with a 60% probability equivalent to 5.8 m^3/s. The value served as an input for discharge design, aiding in the calculation of the potential yearly energy output. The power plant's capacity was computed based on three key assumptions: a net height of 159 meters, a generator efficiency of 0.95, and a turbine efficiency of 0.85. These factors were instrumental in determining the energy generation capability for a span of one year (Sebayang et al., 2018).

The solar panels used in floating solar panels on the regulating pound are 20,441 Polycristaline solar panels, 300 Wp power type Blue Sun Solar Energi BSM270-300P-60 (300W), the power generated is 6,123,300 Wp (6,123.3 kWp) or 6, 12 MWp. The batteries in PLTS consist of 275 series and 3.5 parallel and the total battery required is 1,100 JYC Batteries, OPzV3000 type batteries, and 9 inverters of the ABB brand PVI 500 TL CN with a power of 560 kW and a voltage of 360 V. The potential obtained from the PLTS planning in Regulating Pound for North Renun Hydroelectric Power Plant using Helioscope software simulation is 489,659 kWh/month (Muchtar et al., 2023). This solar power is capable of powering a 120 W aerator for 12 hours during the day and a 100 W aerator for 8 hours at night. In battery discharge conditions, the average panel output voltage is 12.89 V and the average current is 6.2 A and in battery charging conditions, the average panel output voltage is 12.39 V and the average current is 6.6 A. The highest system efficiency in battery discharge conditions is 99%. This is because in the afternoon the solar radiation is low so that the current generated by the solar panel is low and gets supply from the battery (Herlambang et al., 2023).

One of the problems is most of Indonesian people have not understood yet the differences and benefits between solar power plant and PLN electrical energy. Therefore, there must be an educational activity to explain the advantages and disadvantages between solar power plant and PLN electrical energy. It includes technical factors and economic factors. Technical factors mean system of PLTS, generated current (Ampere), generated voltage (Volt), and generated power (kWh) / Watt peak (WP). Whereas, economic factors conceive investment cost, and money saving (Nurjaman & Purnama, 2022). The designed Floating PV need an initial investment cost of IDR 13,551,481,157, with the result of economic analysis, obtained value of each parameter including the NPV value is IDR 7,470,053,884, BCR is 2.66, and PP is less than 25 years (Laksana et al., 2023). The study findings indicate that advancing Photovoltaic Solar Power in Sibolga is highly beneficial, considering the city's substantial monthly sunlight radiation averaging 150.00 kWh/m2. Additionally, several key government agencies require consistent electricity supply. Therefore, it's strategically important to focus Photovoltaic Solar Power development in North Sibolga district and Sibolga City (Siregar et al., 2022).

The discussion elaborates on the practical and policy implications of the findings. The integration of IoT technology in FPV systems offers significant benefits for energy production and environmental sustainability. The research suggests that policymakers should consider supporting the development of IoT-based FPV systems as part of broader renewable energy strategies. Additionally, the broader applicability of these findings to other reservoirs and regions underscores the potential for widespread adoption of FPV technology. The discussion also addresses the limitations of the study and proposes areas for future research, such as exploring additional IoT applications and conducting long-term performance assessments.

4. CONCLUCION

Floating PV uses solar energy, a renewable energy source with minimal impact on the environment. With the use of reservoirs and FPV technology, we can produce environmentally friendly electricity without releasing greenhouse gases into the atmosphere and reduce our dependence on fossil fuels. Land Use By adding solar panels to the reservoir, limited land use may be made more effective. For FPV installation, the existing water surface area can be utilized without requiring additional land. For an area of 1 ha, FPV has a potential development output of 1.04 MWp. The development of the floating PLTS design in the Saguling Reservoir resulted in a PLTS capacity of 1,165.82 MWp. The development of floating PV in reservoirs helps diversify energy sources. By harnessing solar energy and water together, we can reduce dependence on a single energy source and increase sustainability. By utilizing electrical power sources that exist in nature, FPV in reservoirs can produce clean and renewable energy, reduce greenhouse gas emissions, and support energy sustainability. The development of an IoT-based FPV generator using the Blynk application can provide information regarding reservoir water levels, rainfall, temperature and humidity as well as the amount of water flow. Utilizing ultrasonic sensors to measure reservoir water levels can help determine whether the reservoir is experiencing a drought or has a normal discharge level. Rainfall sensors help provide information about the amount of rainfall that occurs in the reservoir area, so that it can monitor whether the rainwater collected in the reservoir is still within normal limits or can cause flooding.

In conclusion, the development of an IoT-based FPV system in the Saguling Reservoir demonstrates significant potential for enhancing renewable energy production and environmental monitoring. The study highlights the importance of integrating modern technology with sustainable energy solutions, providing practical recommendations for future research and policy development. By utilizing the extensive water surface area of reservoirs, FPV systems can contribute to energy sustainability, reduce greenhouse gas emissions, and support the transition to renewable energy sources. The findings of this research underscore the value of IoT technology in optimizing FPV systems and ensuring their efficient and effective implementation.

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