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Development of Floating and Utilization of Flood Early Warning Equipment in Bening Widas Dam, Madiun, East Java

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Abstract

The search for alternative energy is increasing along with the increasing global demand for electricity. Utilization of dams as an alternative energy source using a Floating Solar Power Plant (FSPP) by utilizing the pool area of the dam. FSPP is a flagship program, the electricity price is quite good, licensing is simpler, does not require land acquisition, and can be developed with a large enough capacity. This research utilizes the open space of the Bening Widas Dam, Madiun, Indonesia to be developed as a floating solar power plant. The research method uses quantitative analysis of secondary data to calculate rainfall intensity, planned flood discharge and FSPP design on the surface of the water and the Global Solar Atlas application to calculate the duration of sunlight around the dam. The results showed that the area puddle in Dam Clear Widas 570 ha, with a maximum utilization of 5% which is 285,000 m^2. The maximum capacity of FSPP that can be produced is around 29.63. With an area of 1 hectare, the resulting generating capacity is 1.04 MWp. The value of Global Horizon Irradiation (GHI) around the Bening Widas Dam is 1,962.3 Kwh/m ^{2}. The role of the Bening Widas Dam as a flood controller can be maximized by placing FEDS, a flood early detection tool equipped with sensors for rainfall, temperature, humidity and water level.

Keywords: Early detection of floods, FSPP, GHI, Dam

Introduction

The increasing demand for electricity globally has led to an increase in the search for alternative energy with solar photovoltaic as one of the most feasible. Research on the potential development of floating solar power plants (FSPP) by utilizing dams has been carried out in Brazil [1] . Indonesia, which is located in the tropics, has the advantage of high and constant sunlight in almost all seasons, thus making Indonesia a country that has the potential to develop solar power plants. The development of floating solar power plants (FSPP) by utilizing reservoirs or dams has been widely carried out in Indonesia. One of the dams that has the potential for FSPP development is the Bening Widas Dam in Madiun Regency and currently used for tourism and as flood control.

Damayanti, et.al (2021) researched the utilization of ex-mining pits as dams and developing a floating solar power plant (FSPP) [2] . Zareef, et. al (2021) stated that without sustainable management many dams or dams lose their effective life due to sedimentation which causes a decrease in water quality and its ability to supply energy. The use of floating solar power plants is the right solution to overcome these problems [3]. Siciliano, et.al (2018) suggests that energy infrastructure as a technical social system requires an energy equity approach to capture the environmental sphere in energy production and consumption [4] .

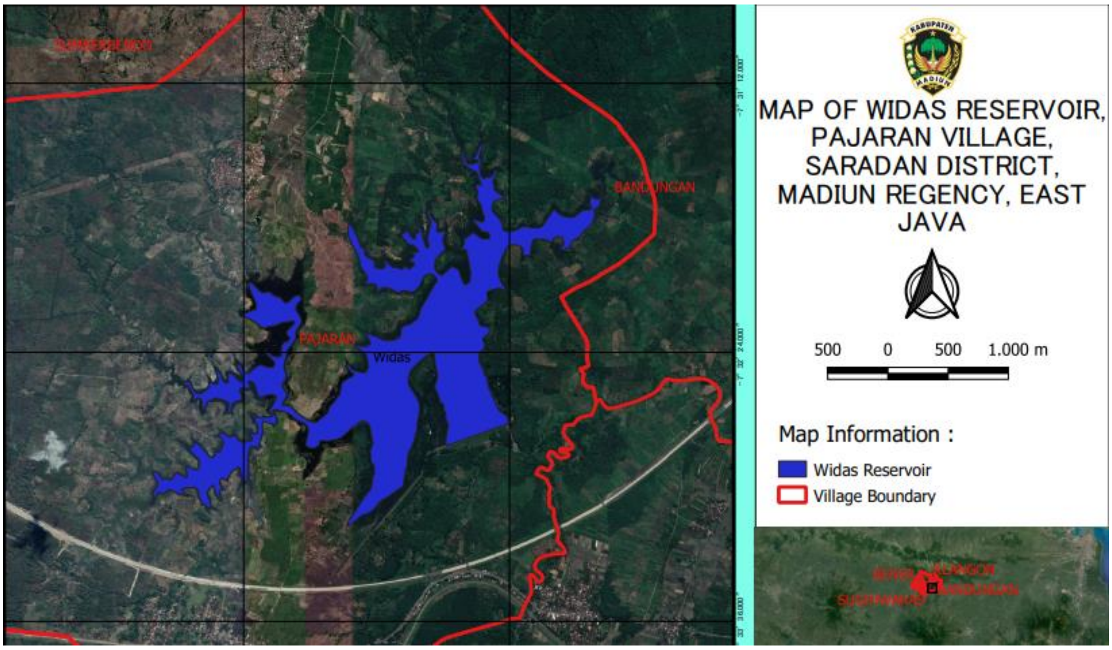

Fig 1: *Area of Bening Widas Dam, East Java, Indonesia.*

Materials and Methods

This study uses the calculation of the planned flood discharge in the area around the Bening Widas Dam (Fig.1). The data collected is rainfall, water level, dam volume data, dam technical data, and others derived from internet searches. This research is included in the type of experimental research, namely research conducted in a laboratory by developing a prototype FEDS (Floods Early Detection System) tool. This tool aims to detect and provide an early alarm regarding flood disasters, especially in low-lying cities such as Jakarta. This research was planned with the aim of calculating the potential for electric power generated by solar panels through FSPP in the Bening Widas Dam, as well as for early flood detection with the help of the FEDS (Floods Early Detection System) tool which is a development tool from the FEWS model.

Rain intensity is the height of rainfall in a certain period expressed in mm/hour. To determine the amount of rain intensity, the Mononobe formula [5] is used :

$$\mathbf{I} = \frac{\mathbf{R_{24}}}{\mathbf{24}} \left(\frac{\mathbf{24}}{\mathbf{t}}\right)^{\mathbf{2/3}} \quad (1)$$

Where
I = Rain intensity (mm/hour)
t = Rain duration (hour)
R_{24} = Rainfall intensity (mm/hour)
For the calculation of hourly rainfall using the formula

$$R_t = (t \times R_t) - ((t-1)(R_t - 1)) \quad (2)$$

Where:
Rt = Percentage of rain intensity
t = time to start raining
Meanwhile, to get the hourly rainfall intensity using the formula:

$$I = \text{Ratio} \times C \times ({}^{R_{24}}/_{100})(3)$$

Where:
I = hourly rainfall intensity
R_{24} = Effective rainfall in 1 day

The next equation used is the rational debit method. The rational method is used for urban areas with a DPS area of less than 200 acres or ±81 ha [6] with the equation :

$$Q = 0{,}278CIA(4)$$

where:
C = Run-off coefficient (from table or by formula)
I = Maximum intensity during concentration time (mm/hour)
A = area of flow (km^2)
Q = maximum discharge (m^3/second)

Madiun Regency, East Java has a fairly stable heat potential as indicated by the largest heat potential in September and the lowest heat potential in February (https://madiunkab.bps.go.id/, 2021).

Results

The intensity of rainfall is an important indicator to calculate the amount of flood discharge in the future. The amount of water discharge in the Bening Widas Dam needs attention because it is closely related to the potential for flooding in the downstream area and also as an indicator to maintain the area of inundation used as a floating FSPP area.

Table 1. *Rainfall Intensity Mononabe Method*

No	Hour	Ratio	Hourly Rain (mm/day)					
			2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
1	1.00	55.03	37.18	38.99	40.09	41.41	42.34	43.23
2	2.00	14.3	9.66	10.13	10.42	10.76	11.00	11.23
3	3.00	10.03	6.78	7.11	7.31	7.55	7.72	7.88
4	4.00	7.99	5.40	5.66	5.82	6.01	6.15	6.28
5	5.00	6.75	4.56	4.78	4.92	5.08	5.19	5.30
6	6.00	5.9	3.99	4.18	4.30	4.44	4.54	4.64
Daily Rain Probability			160.20	167.99	172.74	178.41	182.41	186.27
Flow Coefficient			0.422	0.422	0.422	0.422	0.422	0.422
Effective Rain (mm/day)			67.57	70.85	72.86	75.25	76.93	78.56

Based on the calculation of the rainfall intensity in Table 1, the next step is to calculate the flood discharge in the Bening Widas Dam for the same period. The calculation of the planned flood discharge is intended to help dam managers maximize the performance of the Bening Widas Dam, which functions as a flood controller.

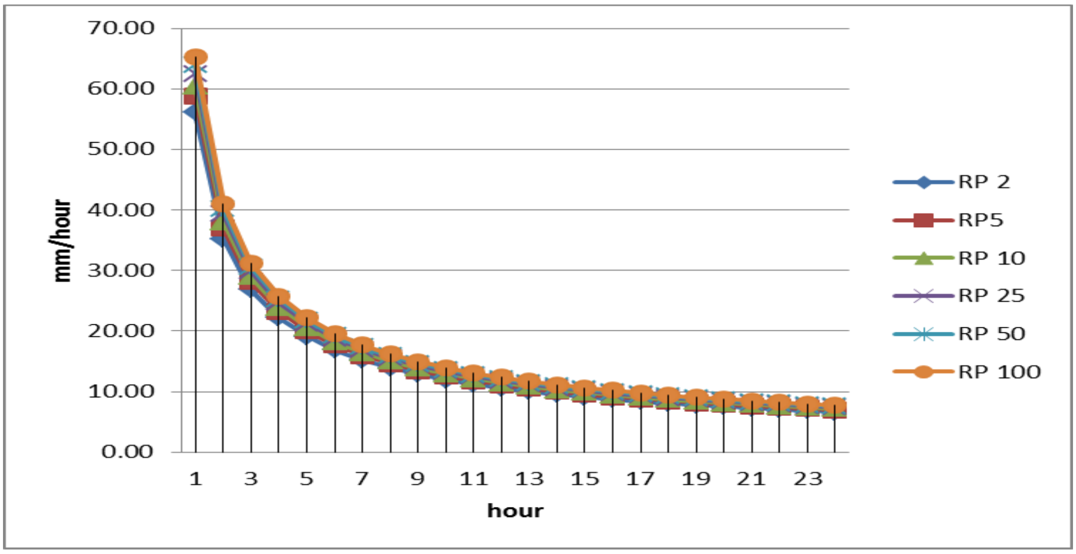

Fig. 2 *IDF Curves*

Fig. 2 shows an overview of the design flood discharge using return periods of 2, 5, 10, 25, 50 and 100 years using the IDF method. The reference data used in calculating rain intensity is based on rainfall in the Madiun Regency area for the last 8 years (2011-2018). This rainfall can affect the discharge of the Bening Widas Dam which also functions as a flood controller. Increasing the intensity of rainfall will affect the high water discharge in the dam.

The development of a floating solar power plant in the Bening Widas Dam is very possible because it is located in an area that gets sunlight evenly throughout the year. The floating PV mini-grid in the Bening Widas Dam is designed by placing the PV module above the pool area of the dam. The design form of the floating solar power plant developed at the Bening Widas Dam can be seen in Fig. 3. It can be seen that the PV module is placed on top of the pontoon and places anchors at the bottom of the dam to hold the floating PV in place at the specified location.

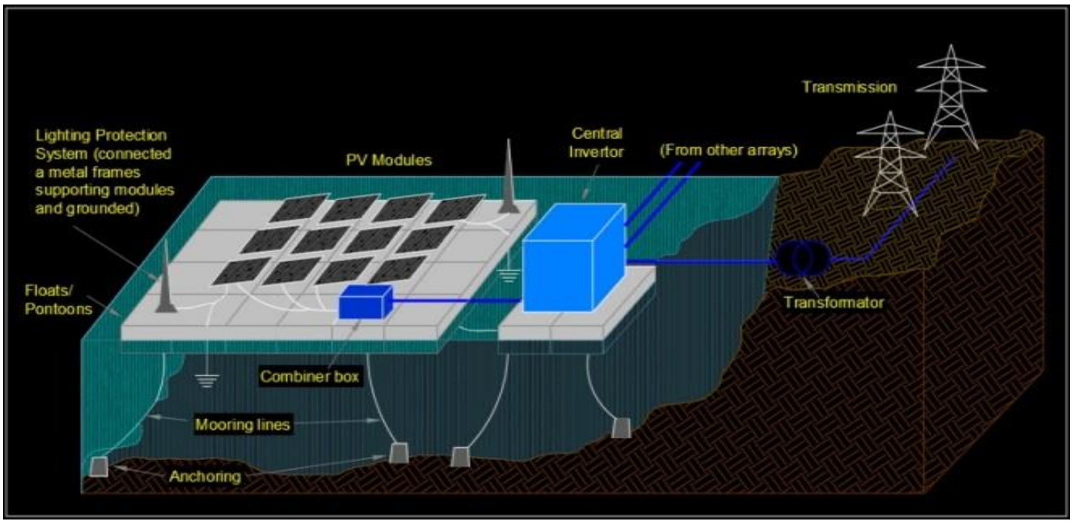

Fig. 3 *Design of Floating Solar Cell*

The sunlight in the Bening Widas Dam is quite large, this is indicated by the average length of irradiation for 6.6 hours. The lowest irradiation time was 4.21 hours while the highest irradiation was 8.61 hours. August and September are the months with the highest direct irradiation of the year (Fig. 4). Throughout the year the Bening Widas Dam area has a large direct normal irradiation, especially from June to October, which means that the heat potential in the area is quite large

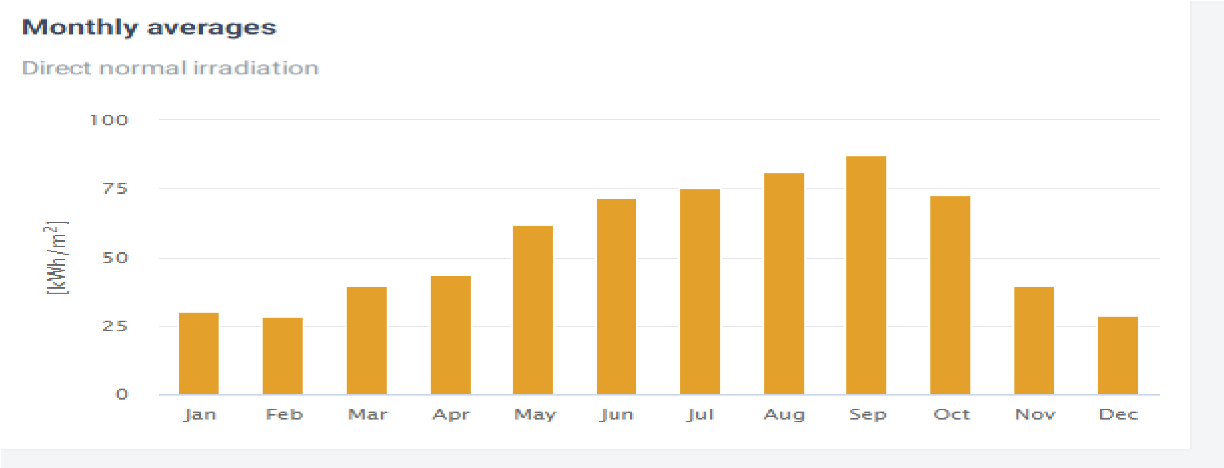

Fig. 4 *Direct Normal Irradiation*

The value of Global Horizon Irradiation (GHI) is the total number of shortwave terrestrial radiation received horizontally to the ground surface. The GHI value around the Bening Widas Dam is 1,963.3 kwh/$m^{2.}$ [7]. Another analysis shows that the highest thermal temperature and total photo voltaic power output (Kwh) in Madiun Regency is from June to October throughout the year, namely at a value of 4,006 kWh to 4,766 kWh throughout the year (Fig. 5).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6	4	1	2	2	2			0	7	17	23	10
6 - 7	74	63	73	85	88	71	65	82	127	150	138	103
7 - 8	202	193	224	247	250	242	241	266	317	329	295	236
8 - 9	334	336	382	406	406	396	406	439	484	485	433	364
9 - 10	430	444	496	517	510	502	522	561	603	585	525	457
10 - 11	484	517	562	581	568	567	586	630	665	626	560	500
11 - 12	495	524	570	587	571	576	591	638	668	605	538	490
12 - 13	455	492	512	537	529	536	554	601	617	561	480	425
13 - 14	383	426	431	439	447	463	480	524	530	477	391	352
14 - 15	267	289	301	312	330	356	371	412	404	336	254	234
15 - 16	150	160	164	174	193	217	241	266	247	186	126	121
16 - 17	65	69	71	65	68	78	98	110	93	65	47	52
17 - 18	15	17	7	4	2	2	4	6	4	3	3	5
18 - 19												
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	3,359	3,531	3,794	3,956	3,962	4,006	4,157	4,535	4,766	4,425	3,811	3,350

Fig 5 *Average Profile and Total Power Out*

Based on the Regulation of the Minister of Public Works and Housing of the Republic of Indonesia No. 6 of 2020 concerning amendments to the Regulation of the Minister of Public Works and Public Housing, Indonesia, No. 27/PRT/M/2015 concerning dams, it is stated that the inundation area of the dam that can be used for floating solar power plants is a maximum of 5% (five percent) of the surface area of the dam at normal water level [8] . The surface area of the dam inundation is 570 ha or 5,700,000 m^2 , the size of the dam surface area that can be used to install solar panels is 5% X 5,700,000 m^2 = 285,000 m^2 .

The capacity of the solar panels that are planned to be used in the Bening Widas Dam is 250 Wp with the following specifications: Maximum power (Pmax) 250 Wp, Voltage at pmax (Vmp) 30.6 V, Maximum voltage at STC is 26 V, Current at pmax (Imp) is 8.5 A and Short circuit current (Isc) is 9.18 A

The maximum total solar panels that can be built are as follows:
Total area = total solar panels X dimension of solar panels
285,000 = Total solar panels X 1.636 X 0.992
Total Solar Panels = 175,610 units

With the maximum total solar module units that can be built on the permitted land, the solar module capacity is as follows:

Number of solar panels = 175,610 units, and capacity = 250 watts. PV capacity = 175,610 x 250 watts = 43,902,565 Wp

The level of ambient temperature will affect the performance of the solar panel. Ideally, solar panels will work at a maximum temperature of 25°C. If the temperature increases, the efficiency of solar panel performance will also decrease. The temperature in the territory of Indonesia itself ranges from 25-35°C, and solar panels can experience a degradation of production efficiency by up to 10%. Then the maximum capacity of FSPP is as follows:

PV capacity = 43,902,565 Wp X 90 %
PV capacity = 39,512,309 Wp

By considering network losses or system losses as a whole which reaches 25% [9] , the maximum capacity of FSPP that can be generated is as follows:

Solar power plant capacity = 39,512,250 x 75% = 29.634.187.50
Solar power plant capacity = 29.63 MWp

With the above calculation, it can be seen that with an allowable inundation area of 28.5 hectares, the resulting generating capacity is:

29.63 MWp / 28.50 ha = 1.04 MWp / ha

With the results of the above calculations, with an area of 1 hectare, the resulting generating capacity is 1,040 MWp.

Research by Kim, et.al (2016) shows the use of floating solar power plants as an alternative energy that is currently in demand in Korea. During the period 2009 to 2014, Korea has built 13 floating FSPP units to meet the energy needs of its citizens [10]. Bening Widas Dam is not only used as a place for recreation and a Floating Solar Power Plant, but also has another function, namely as flood control. The function of dams as flood control can be utilized optimally when interested parties obtain accurate information in a short time. The placement of the Flood Early Detection System (FEDS) tool can help provide the information needed [15]. This tool can use an existing solar power supply, can detect water level, rainfall, humidity and ambient air temperature, using the IoT-based Blynk application, ultrasonic sensor, ESP 8266 module, and Arduino Nano [11].

The flood detection tool that will be developed in the Bening Widas Dam has several sensors which are expected to provide the information needed in connection with early flood detection. The sensors used include rainfall sensors, water level sensors and water discharge sensors (Fig. 6).

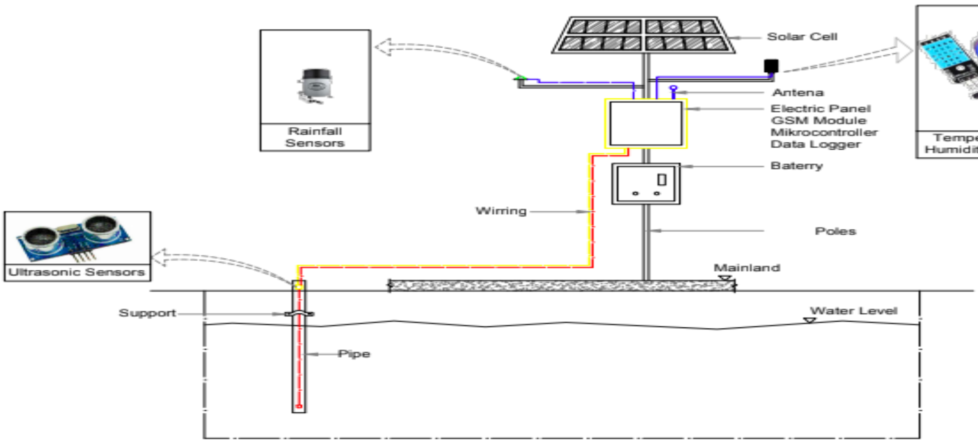

Fig. 6 *Sensor Used on FEDS*

Basheer, et.al (2017) in their research showed that based on the slope side sensitivity analysis, it did not affect the peak discharge time and had a small effect on the peak outflow value. While the time required to reach the limit is very sensitive to both peak discharge and peak discharge time. Warlina and Guinensa (2018) used slope, geological structure, rainfall, soil type, land use and distance to rivers to measure flood vulnerability in Pangkal Pinang City, Bangka Belitung, Indonesia. The results of this study can be used as a flood disaster mitigation plan by considering the behavior of the community and the urban drainage system [12]. An integrated flood early detection system utilizes communities in flood-affected areas. Making manuals for communities based on flood early detection can help communities deliver flood early warnings in real time so as to reduce the negative impact of floods [13].

The flood early detection system was not only developed to overcome the impact of repeated floods, but was also used to provide real time information on flash flood events, especially in areas prone to landslides [14]. The placement of flood detection equipment around the Bening Widas Dam and the rivers that serve as water runoff routes for the Bening Widas Dam is expected to provide information about the possibility of flooding, so as to reduce the impact that may occur. The following is the design of a flood early detection system (FEDS) that can provide the information needed as a flood detection tool. The government has carried out a plan to develop a dam as a floating solar power plant (FSPP) through a Government Regulation that regulates the use of dams or dams. Utilization of dams as floating solar power plants (FSPP) is only 5% of the dam inundation area, because dams have many functions. Another function of the dam is as a flood controller where rainfall and dam water discharge become one of the instruments for early flood detection. The FEDS tool will be placed at the sluice gate to monitor the amount of rainfall, water discharge and water level.

Conclusion

The total area of the dam is 8960 ha with a puddle surface area of 570 ha. The permit inundation area for the development of floating solar power plants is 5%, so the allowable area is 285,000 m^2 . with the permitted area for the development of floating solar panels is 5%, the maximum total solar panel units that can be installed is 175,610 units. The maximum total solar module units that can be built on the permitted land, then the solar module capacity is 43,902,500 Wp. The temperature in Indonesia itself ranges from 25-35°C, so that solar panels can experience a production efficiency degradation of up to 10%, so the maximum capacity of FSPP is as follows 39,512,250. By considering network losses or system losses as a whole, which reaches 25%, the maximum capacity of FSPP that can be produced is around 29.63 MWp. With an area of 1 hectare, the resulting generating capacity is 1.04 MWp. The FEDS device can be placed on the edge of the dam to monitor the amount of rainfall, temperature, humidity and dam water level

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