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Study of Efficiency of Harumandala Micro Hidro Power Plant (Pltmh) At Pangandaran, West Java

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ABSTRACT: *This paper is facus on micro hydro power plant operasion investigation at Harumandala village, Pangandaran West Java. The power plant have 27 kW capacity with 16,5 meter head and 250 l/sec flow rate. The paper is design to determine or analyse the best power plant efficiency which is utilise cross flow turbine, 3 phasa sinkron generator, speed 1500 (rpm) and power factor 0,8. The Analyse cover load, turbin and generator efficiency.*

KEYWORD: *MHP, efficiency, installed capacity*

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I. INTRODUCTION

Harumandala MHP is in Harumandala Village, Cigugur District, Pangandaran, West Java. Started construction in 2011 with funds from the Regional budget (APBD) of West Java province through the West Java Provincial Energy and Mineral Resources (ESDM) Agency. The MHPP utilize Ciharuman River stream that flows throughout the year stably. Installed capacity 27 kW.

Fig.1 Map of Harumdala MHP

The MHPP (PLTMH) system is basically the same as the Hydro Power Plant in general. However, the difference is the size of the power system. MHPP utilizes a water source that is not too large.

MHP is one of the renewable and alternative energy because it has several advantages compared to other power plants, especially fossil power plant, among others, is the driving force of hydropower available in nature, operating cost and maintenance are cheaper, and operation can be stopped every time without going through complicated procedures. The MHP System is very simple and good toughness. Because MHP is renewable energy project, it can be categorized as a sustainable development project that reduces carbon emisions, including social economic development.

In simple terms, the electricity generation process from MHPP is to direct the flow of river water into the carrier channel and then flow through the rapid pipeline to the turbine to rotate the turbine blades coupled with the generator so that it will rotate and drive the generator togenerate electricity again into the original flow, so it doesn't affect the surrounding ecology much.

The advantages of MHPP development for rural communities, disadvantaged villages, remote villages, border villages are:

1. Reducing dependence on the use of fossil fuels;

2. Encouraging rural economic activities and increasing the intelligence of rural residents, which in turn will improve the welfare of the population, and
3. Awareness of the importance of protecting the environment, especially water.

MHPP component consist of Civil component, namely: weir, intake, settling basin, waterway or headrace, forebay, penstock, tail race and power house. The mechanical component consist of: turbines and mechanical transmissions, while the Electrical components consist of: generator. Control panel, protection system, power cable, distribution or transmission channel.

Mainstay Debit

Mainstay debit is a debit that is still possible for the operational security of a water building, in this case MHP. Examples of reliable debit recapitulation are presented in the following tables and graphs:

Table 1 Sorted of Debit

No.	Probability (%)	Debit of river (M^3/sec)
1	10	4,20
2	20	3,15
3	30	2,75
4	40	2,35
5	50	2,05
6	60	1,55
7	70	1,45
8	80	1,02
9	90	0,60
10	95	0,38

And we can show flow duration curve (FDC) below

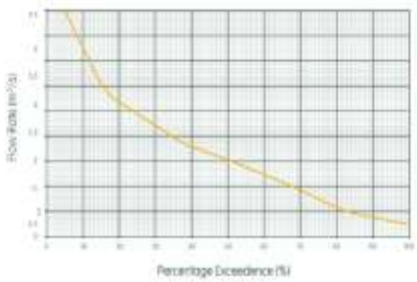

Fig.2. Flow Duration Curve(FDC)

Estimated discharge and probability are depicted in a flow duration curve that describes the probablity or percentage of water availibility on the ordinate axis anda the main discharge rate on an axis axis. To find out the amount of flow duration cuve (FDC) is made by sorting the average daily discharge data form the larges to the smallest anda each debit data is given a probability calculated using the Weibul equation. (Guideline for Hidrological FS Study).

$$\overline{Q_{10\ harian}} = \frac{Q_1 + Q_2 + ... + Q_n}{n}$$

$$P_w = \frac{m}{n+1} x\ 100\% \qquad .... (1)$$

$\overline{Q_{10\ harian}}$ = average debit in period (m^3/sec)

P_w = probability value

M = data to

N = amount of data

Effective fall Height /Head effective

Effective fall height is the difference between the pool water level (forebay) and the tail water level (TWL) reduced by total compressive height loss.

Heff = EFB – TWL – hl ………………….. (2)

Where:

Heff = effective fall height (m)
EFB = forebay water level (m)
TWL = tail water level (m)
hl = total high – pressure loss

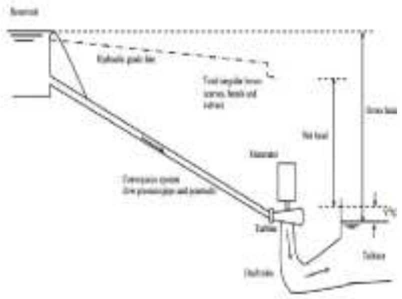

Fig. 3. Skecth of High Effective Fall

Selection of Turbines

Water turbine are turbines with water as working fluids. Water flowing from a higher place to a lower place, this has potential energy. In the process of flowing in the pipe, the potential energy gradually changes to mechanical energy, where water rortates the turbin wheel. The turbine wheel is connected to a generator that converts mechanical energy (motion) to electrical energy.

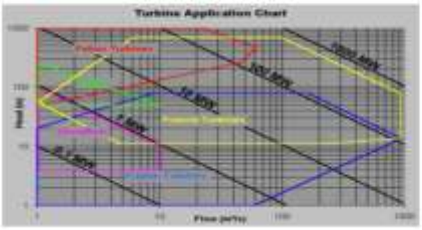

Fig.4. Head and flow relationship graph

Water turbines paly role in converting water energy (potential energy, pressure, and kinetic energy) into mechanical energy in the form of shaft rotation. In this study the determination of the type of turbine is based on design discharge and fall height. Determination of turbine type based on falling height can be seen in the following table:

Table 2. High Fall Classifiaction

Turbine type	Net head
Kaplan and Propeller	$2<H_n<40$
Francis	$25<H_n<350$
Pelton	$50<H_n<1300$
Banki	$5<H_n<200$
Turgo	$50<H_n<250$

Turbine type	Head range (meter)
Kaplan and propeller	$2<H_n<40$
Francis	$10<H_n<350$
Pelton	$50<H_n<1300$
Cross-flow (Banki-Michell)	$3<H_n<200$

Crossflow turbine also named Banki. The specific speed of eaech turbine has arange, including the following:

Table 3. Spesific speed range

Turbine type	Specific speed range (meter)
Pelton one nozzle	$5\leq N_s\leq 25$
Pelton two nozzles	$7\leq N_s\leq 35$
Pelton four nozzles	$10\leq N_s\leq 50$
Cross-flow (Banki-michell)	$20\leq N_s\leq 200$
Francis	$50\leq N_s\leq 350$
Kaplan and propeller	$200\leq N_s\leq 1550$

By nowing Spesisifc speed (Ns) turbine, planning and selecting the type of turbine will be easier. For estimation calculations can be done using the following formula:

$$N = \frac{Ns \times H^{5/4}}{P^{1/2}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:
N = speed of turbine (rpm)
Ns = specific speed (rpm)
h = high effective fall (m)
P = power output (kW)

Fig5. Turbine Nameplate

Classification of Electric Machines

In general, electric machines can be divides into two parts, namely static electricity machines and dynamic electric machines.

A static electricity machine is a transformer, a device for transferring electrical energy form the primary to the secondary with a chance in voltage at the same frequency.

Dynamic electric machines consist of electric motor and generators. An electric motor is a device for converting electrical energy into rotational mechanical energy. A generator is a tool for converting mechanical energy into electrical energy.

Table 3. Generator Efficiency

Rated Power (kW)	Best Efficiency
10	0,910
50	0,940
100	0,950
250	0,955
500	0,960
1000	0,970

Fig.6. Generator Nameplate

Load factor

Load factor is a comparison between the magnitude of the average load for a certain time interval of the highest peak load in the same time interval (for example, one day or one month). While the average load for a certain time interval is the amount of kWh production in that time interval divide by the number of hours from that time interval. From the description above obtained:

Load Factor; For electricity providers, the system load factor is desirable as high as possible because the higher the load factor means the system loads is more flat, so the level of utilization of the tools in the system can be tried as high as possible.

load factor = average load / peak load

In practice, the annual system load factor ranges from 60% - 80%.

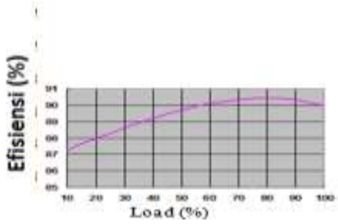

Fig.7. Efficiency vs Loading

Calculation of Power and Energy

The Capacity of MHP is determined by the amount of power and the amount of energy generated per year, which can be calculated by equations:

Teorytical Power = 9.8 x Q H eff ………………… (4)

Turbines power = 9.81 x ηt x Q x Heff ………………… (5)

Generator Power = 9.81 x ηg x ηt x Q x Heff ………………… (6)

Where:

P = power output (kW)

ηt = turbines efficiency

ηg = generator efficiency

ρ = density of water

Q = debit (m3/dt)

Heff = high effective fall (m)

Annual energy Production

That is the amount of energy produces in one year.

E = P x 24 x n ………………. (7)

where:

E = Energy produced (kWH)

P = power output / produced (kW)

n = number of days

II. MATERIAL AND METHOD

The result was conducted at Harumandala MHPP, located in Pangandaran West Java Province, Indonesia. The method used in this research is descriptive qualitative method, that is to analyze the Study of efficiency of Harumandala Micro Hydro Power Plant (MHPP), Pangandaran, West Java. Researches got the data by name plate of turbines and generator, calculations of the load, efficiency of the power plant.

III. RESULT AND DISCUSSION

3.1. Research result

From the theoretical basis above and by using field survey data collection can be discussed and the following result: 1) turbine efficiency; The operation of the Harumandala MHP aims to meet the electricity needs of the villagers of Desa Harumandala, Pangandaran, West Java, totaling 114 families. With a falling height of an average of 16.5 m and a discharge of 0.250 m^3/sec., from fig. 15. The crossflow/ Banki Turbine is selected (installed)

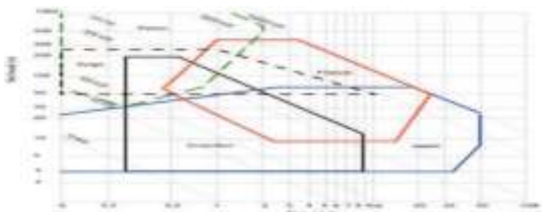

Fig. 8. Ranges of specific turbine types application

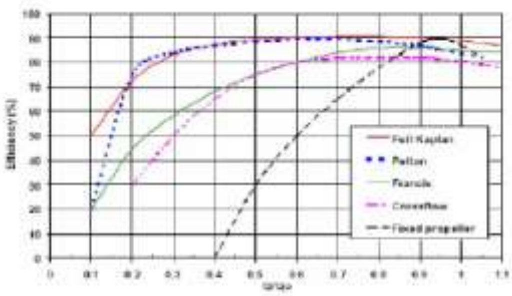

Fig.9. efficiency of small hydropower plant turbine types

Table 4. Harumandala MHP Turbine Spesification

Type	Crossflow
Head	16,5 m
Mainstay Debit	0,250 m3/sec
Power	25,1 kW 27 kW
Efficiency	62 % at 25,1 kW 67% at 27 kW

By using the above formula, the MHP Harumandala Turbines Efficiency is:
ηt = P / (9.81xQxHeff), with: P = actual / generated power (kW) 25.1 kW (25,100 Watts), then;
ηt = 25.1 / (9.81 x 0.250 x 16.5) = 0.62 (62%)
If using Power rated at 27 kW, then:
ηt = 27/ (9.81 x 0,250 x 16.5) = 0,667 (67%)
at the same discharge and related power, turbine efficiency increases by **ηt = (67- 62)/67 = 7,5 %.** At load lower than rated power, the efficiency will be lower.Turbine efficiency is influenced by water discharge and turbine rotation while turbine rotation is strongly influenced by load variation (loading).When the load increases, the rotation of the turbine-generator will be reduced so that efforts are needed to restore the rotation by increasing the flow of water entering the turbine.

Generator

Rated data generator Harumandala MHPPis 30,7 kW, then from Table 3. obtained generator efficiency between **91-94 %.**Load Factor:From the generator name plate it is known that the generator works at a power factor 0.8 and with 30.7 kW, the apparent power can be calculated:
Load Factor = kW/kVAorFake Power (kVA) = 30.7/0,8= 38,4 kVA

3.2. Discussion

Harumandala MHPP operates from 17.00 to 07.00 or an average of 14 hours a day continuously with the highest load of 25.1 kW and the load is 27 kW. Assuming there is no interference with the generator, the Energy Production per month for a year is calculated using the formula E = P x t x n, which can be seen in Table 5.

Table 5 Power and Energy (Load 25.1 kW)

Month	Number of day	Operating hours*)	Number of day x operating hours	Max load (kW)	Energy (kWh)
Jan	31	14	434	25.1	10.893.40
Feb	28	14	392	25.1	9.893.20
Marc	31	14	434	25.1	10.893.40
April	30	14	420	25.1	10.542.00
May	31	14	434	25.1	10.893.40
June	30	14	420	25.1	10.542.00
July	31	14	434	25.1	10.893.40
Aug	31	14	434	25.1	10.893.40
Sept	30	14	420	25.1	10.542.00
Oct	31	14	434	25.1	10.893.40
Nov	30	14	420	25.1	10.542.00
Dec	31	14	434	25.1	10.893.40
	365	168	5110	Total	128.261.0

Table 6 Power and Energy (Load 27 kW)

Month	Number of day	Operating hours*)	Number of day x operating hours	Max load (kW)	Energy (kWh)
Jan	31	14	434	27	11.718.00
Feb	28	14	382	27	10.584.00
Marc	31	14	434	27	11.718.00
April	30	14	420	27	11.340.00
May	31	14	434	27	11.718.00
June	30	14	420	27	11.340.00
July	31	14	434	27	11.718.00
Aug	31	14	434	27	11.718.00
Sept	30	14	420	27	11.340.00
Oct	31	14	434	27	11.718.00
Nov	30	14	420	27	11.340.00
Dec	31	14	434	27	11.718.00
	365	168	5110	Total	137.970.0

Calculation of Capacity factors as follows:
Load 25.1 kW:
Capacity Factors = Production kWh a year /Install capacity kW x 8760 hours)= 128.261/ (30.7 x 5110) = 0.817or **81.7%.**
Load 27 kW:
Capacity Factors = Production kWh a year /Install capacity kW x 8760 hours)= 137.970/(30.7 x 5110) = 0.879 or 87.9%.

IV. CONCLUSION

With a Head 16,5 m and mainstay discharge of 0.250 m^3/sec. according to the chart of the Ranges of specific Turbine types application, Cross flow Turbines are used;
For hydropower /MHP, the annual capacity factors ranges from 80 – 90%, this is related to water availability. The greater the annual electricity production, the greater the annual capacity factor;
With the availability of sufficient water discharge and assuming no damage to the plant installation, the Harumandala MHP can supply energy throughout the year;
By using the reference graph.1 of Efficiency vs. Loading as a reference, the generator efficiency of around 91 – 94% is at a load of around 80-90% (25.1 kW of 30.7 kW around 81.7%, 27 kW of 30.7 kW around 87.9%) as in the calculation of the capacity factor;
The calculation of Turbine efficiency is 62% at load 25.1 kWand67% at load 27 kW with a discharge of 0.250 m^3/sec. in practice, the annual system load factor ranges from 60% - 80%;
Increased generator efficiency can be done by setting the laod.

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