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IMPLEMENTATION OF MICROHYDRO POWER PLANTS IN REMOTE AND UNDEVELOPED AREAS

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Abstract

Electric energy is a vital element for the Indonesian community. However, in frontier, underdeveloped, and remote areas, access to electricity is uneven. An appropriate solution is necessary to overcome these supply limitations. This research aims to construct a microhydro power plant utilizing existing river flows. The research employed descriptive analysis with a qualitative approach, while the equipment's performance analysis used the fuzzy time series method. Findings indicate that microhydro technology can generate up to 40 kW using four generators, relying on a minimum river flow rate of 60 litres per second. This system can meet the needs of 72 households with a lifespan of up to 15 years. The core concept was to use river flow to drive turbines, generating electrical power. Consequently, the government can minimize electricity development costs from major urban centres. Ultimately, microhydro power generation technology serves as a solution for frontier, remote, and underdeveloped areas, providing access to electricity and illumination, and supporting the community's living requirements.

Keywords: Electric energy, Fuzzy time series, Microhydro power plant.

1. Introduction

Electric energy is one of the fundamental elements required by the Indonesian community. As a country, Indonesia possesses significant energy potential due to its abundant natural resources, such as oil, coal, and natural gas [1, 2]. However, in frontier, underdeveloped, and remote areas, access to electricity is not uniformly distributed. Therefore, an appropriate solution is needed to overcome the limitations in supplying electricity to these regions. Mountains and numerous rivers characterize Indonesia's topography. Exploiting these conditions, Indonesia has abundant potential for renewable energy sources. One of the renewable energy sources that can be maximally developed is Microhydro Power Plants (MHPP) [3]. Microhydro Power Plants are a concept of power generation utilizing water energy on a small scale [4]. Approximately 10.68% of electricity in Indonesia is generated through hydropower systems [5, 6]. This energy is produced from falling water, such as in steep mountain rivers, generating electrical power ranging from 5 kW to 10 kW [7]. Through this concept, the generated energy is modified to be utilizable by the community [8]. This underscores the potential of Microhydro Power Plants as a sustainable and community-oriented solution, particularly in Indonesia's frontier, remote, and underdeveloped areas.

The previous research on Microhydro Power Plants (MHPP) emphasizes the importance of generating renewable energy for rural development worldwide. The focus lies on introducing efficient software developed for analysing the feasibility studies of MHPP. The effectiveness of this software is validated through specific applications in Cameroon, Bakassa, and Kemken, comparing it with traditional methods. The results indicate that the new software, considering local advantages and constraints, is more effective for MHPP feasibility studies than conventional methods [9]. This saves time, alleviates tedious calculations, and facilitates timely decision-making, crucial for preventing project delays due to a lack of local expertise and skills. Another related study focuses on validating fundamental physics models against the nonlinear behavior of MHPP [10]. The real-time application of the MHPP model shows a strong correlation with experimental data. Simulation results and practical tests reveal the limitations of simple linear PI controllers with fixed parameters for effectively regulating the frequency of MHPP under varying loads. Therefore, this paper proposes an ELC control strategy with self-tuning fuzzy PI controllers for frequency regulation. Simulation results confirm the feasibility of the proposed controller, and practical tests on the MHPP prototype validate its effectiveness in enhancing dynamic performance despite the system's complexity and nonlinearity. Compared to some previous studies, the distinction in this research is its focus on developing microhydro power generation in the 3T areas (Frontier, Underdeveloped, and Remote) by utilizing existing river flows.

Applying the microhydro power concept can benefit communities in Frontier, Underdeveloped, and Remote (3T) areas, enabling them to access electricity, a vital necessity in daily life [11]. Therefore, this research aims to construct a microhydro power plant that utilizes existing river flows.

2.Method

The following steps were undertaken in this research: Data collection for equipment requirements and resource data division into primary and secondary data. Primary data measured the water flow precisely to obtain accurate information on the amount of water passing through the river for the Microhydro Power Plant (MHPP). Secondary data were utilized to calculate the river flow that could be harnessed and its effectiveness in power generation equipment [12]. Subsequently, quantitative approaches were applied to calculate the electricity consumption produced by the turbine. Lifespan calculations, maintenance costs, and the affordability of electricity usage can be performed using the fuzzy time series method to predict the equipment's longevity and the efficiency level of the created tool [13]. The collected and analysed data determine the optimal efficiency level for the Microhydro Power Plant (MHPP) [14, 15]. This is applied to frontier, underdeveloped, and remote areas to optimize costs and resources used in the tool's design.

2.1. Research location

The research was conducted in 3T areas with rivers exhibiting both swift and slow/minimal flow. The study considered the river cycles and assessed whether they maintain a consistent flow throughout the year or experience fluctuations in specific months.

2.2. Research data

The research data comprises river flow discharge, population count, river cross-sectional area at the MHPP construction location, river flow maps, and other supporting components.

2.3. Fuzzy time series

Fuzzy time series was employed to determine predictive outcomes of MHPP usage using previously occurred time series data to forecast one upcoming period. It was used to predict the lifespan and effectiveness of MHPP usage over one year.

In general, a fuzzy set can be interpreted as a boundary of numbers with vague limitations. If U is a universal set, then its membership function is:

$$A_i = \mu_{A_i}(u_i)|\, u_i + \cdots + \mu_{A_p}\left(u_p\right)|u_p \tag{1}$$

where $\mu_{A_i}(u_i)$ represent membership degree of u_i ke A_i and $\mu_A(u_i) \in [0,1]$ and $1 \leq i \leq p$.

Figure 1 shows the steps for using MHPP with the fuzzy time series method. From the flowchart in Fig. 1, the following are the forecasting formulas for the steps in the time series data.

- Find the value U based on Min and Max:

$$U = [d_{min}\, , d_{max}] \tag{2}$$

- Determine range numbers of interval:

$$R = [d_{max}\, , d_{min}] \tag{3}$$

- Determine numbers of intervals based on Sturge equation:

$$K = 1 + 3{,}22 \times \log n \tag{4}$$

- Specifies the width of the interval:

$$I = \frac{range\ R}{K} \tag{5}$$

- Find the mid value:

$$mi = \frac{Upper\ limmit + Lowe\ limmit}{2} \tag{6}$$

- Defining fuzzy sets A_i and performing fuzzification. Suppose A1, A2, A3 are fuzzy sets with linguistic values; they can be defined as follows:

$$A_1 = \{u_1, |1\} + \{u_2, |0.5\} + \{u_3, |0\} + .. + \{u_n, |0\}$$
$$A_2 = \{u_1, |0.5\} + \{u_2, |0.1\} + \{u_3, |0.5\} + .. + \{u_n, |0\}$$
$$\vdots$$
$$A_n = \{u_1, |0\} + \{u_2, |0\} + \{u_3, |0\} + .. + \{u_n, |0\} \tag{7}$$

- Determining defuzzification. The standardized weight matrix (w*) is multiplied by (mi) to generate the forecast value. From the fuzzy time series calculation, Eq. (6) can be used.

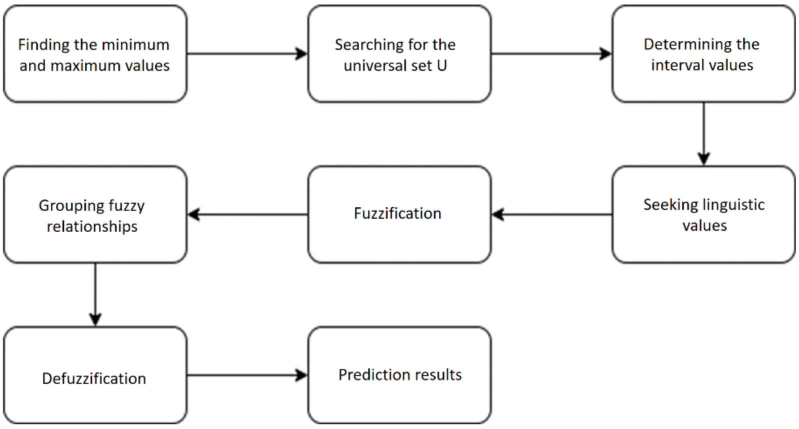

Fig. 1. Fuzzy time series steps.

3. Results and Discussion

The value of U using the available data predicts the efficiency level during a full year of usage. This calculation used a generator with an assumed electricity price of 1459/kWh for a generator producing power ranging from 5-10 kW. Table 1 shows data on the electricity usage cost from National Electricity Power Grid (PLN) for 18 households.

Using the National Electricity Power Grid (PLN), each household pays around 4,822,055 annually. However, employing Microhydro Power Plants (MHPP) can save electricity expenses because MHPP only requires maintenance, and the generator's lifespan can last up to 15 years.

The construction of an MHPP entails a relatively substantial cost, approximately 15 million per 1000 watts, or 1 kW. For example, building a 10 kW generator would cost around 150 million to 200 million for a single MHPP construction. This estimate assumes the use of 20 units of 12V, 100Ah batteries. Table 2 provides data on the durability of generator usage and MHPP construction, assuming six years, along with battery endurance.

Table 1. Electricity usage data cost PLN.

Month	Numbers of kW	Electricity cost PLN (IDR)	Number of consumers
1	7	7.409.500,00	18 Houses
2	6	6.351.000,00	18 Houses
3	5	5.292.500,00	18 Houses
4	8	8.468.000,00	18 Houses
5	9	9.526.500,00	18 Houses
6	6	6.351.000,00	18 Houses
7	7	7.409.500,00	18 Houses
8	7	7.409.500,00	18 Houses
9	7	7.409.500,00	18 Houses
10	9	9.526.500,00	18 Houses
11	5	5.292.500,00	18 Houses
12	6	6.351.000,00	18 Houses
Total	82	79.700.000,00	18 Houses

Table 2. Battery durability data.

Year	Generated Electricity	Battery Life
1	10000	100%
2	99000	97%
3	9800	93%
4	9500	89%
5	8900	83%
6	8700	80%

3.1. Predicting data process according to generated electricity

3.1.1. Finding the universe of discourse (set U)

The universe of discourse, U, was obtained by first finding the minimum and maximum values in the data. From the data obtained, the maximum value was 100, and the minimum values were 80. The value 0 was assigned to D1, and the value 1 was assigned to D2.

$D_1 = 0$
$D_2 = 1$
$U = [\min - D_1, \max + D_2]$
$U = [80 – 0, 100+1]$
$U = [80, 101]$

3.1.2. Interval

The interval was obtained when the range and numbers of the class were already found.

Range = Max – Min =100-80 =20
Numbers of Class = 1+3.3(log(N)) = 1+3.3(log (6)) = 3.5
Interval length = range/numbers of class = 20/3.5 = 5.7

3.1.3. Linguistic value

Linguistic values were derived from the number of intervals from minimum to maximum. The linguistic values are shown in Table 3.

Table 3. Linguistic.

Linguistic Value	Class
8700 - 9071.4	U1
9071.4 - 9442.8	U2
9442.8 - 9814.2	U3
9814.2 - 10185.6	U4

3.1.4. Fuzzification

Fuzzification was derived from linguistic values. For example, in the first column of Table 4, A4 was obtained due to the 100% battery lifespan value contained in the linguistic value. The fuzzification values are shown in Table 4.

Table 4. Fuzification.

Year	Generated Electricity	Linguistic
1	10000	A4
2	99000	A4
3	9800	A3
4	9500	A3
5	8900	A1
6	8700	A1

3.1.5. Grouping FLR into FLRG

After obtaining the fuzzy data, this fuzzy data was associated with fuzzy logic relationships. The range data is presented in Table 5, and the FLRG is shown in Table 6.

Table 5. FLR

Data	FLR
10000	A4-> A4
99000	A4->A3
9800	A3->A3
9500	A3->A1
8900	A1->A1

Table 6. FLRG

Group	FLRG
1	A1->A1
2	A3->A1, a3
3	A4->A3, A4

3.1.6. Defuzzification

The defuzzification process was the final step, presenting the forecasted data. Table 7 shows the estimated data for the electricity generated by the Microhydro Power Plant tool.

Table 7. Defuzzification.

Year	Generated Electricity	Linguistic	Midpoint	Forecast
1	10000	A4->A3, A4	9628.5, 9999.9	-
2	99000	A4->A3, A4	9628.5, 9999.9	9814.2
3	9800	A3->A1, a3	8885.7, 9628.5	9814.2
4	9500	A3->A1, a3	8885.7, 9628.5	9257.1
5	8900	A1->A1	8885.7	9257.1
6	8700	A1->A1	8885.7	8885.7
7	-	-	-	8885.7

3.2. Prediction battery based on usage of battery

3.2.1. Finding the universe of discourse (set U)

The universe of discourse, U, was obtained by first finding the minimum and maximum values in the data. From the data obtained, the maximum value was 100, and the minimum values were 80. The value 0 was assigned to D1, and the value 1 was assigned to D2.

$D_1 = 0$
$D_2 = 1$
$U = [\min - D_1, \max + D_2]$
$U = [80 - 0, 100+1]$
$U = [80, 101]$

3.2.2. Interval

The interval was obtained when the range and numbers of the class were already found.

Range = Max – Min =100-80 =20
Numbers of Class = 1+3.3(log(N)) = 1+3.3(log (6)) = 3.5
Interval length = range/numbers of class = 20/3.5 = 5.7

3.2.3. Linguistic value

Linguistic values were derived from the number of intervals from minimum to maximum. The linguistic values are shown in Table 8.

Table. 8 Linguistic value.

Linguistic Value	Class
80-85.7	U1
85.7-91.4	U2
91.4-97.1	U3
97.1-102.8	U4

3.2.4. Fuzzification

Fuzzification was derived from linguistic values. For example, in the first column of Table 9, A4 was obtained due to the 100% battery lifespan value contained in the linguistic value.

Table 9. Fuzzification.

Year	Battery life	Linguistic
1	100%	A4
2	97%	A4
3	93%	A3
4	89%	A2
5	83%	A1
6	80%	A1

3.2.5. Grouping FLR into FLRG

After obtaining the fuzzy data, this fuzzy data was associated with fuzzy logic relationships. The range data is presented in Table 10, and the FLRG is shown in Table 11.

Table 10. FLR.

Data	FLR
100%	A4-> A4
97%	A4->A3
93%	A3->A2
89%	A2->A1
83%	A1->A1

Table 11. FLRG.

Group	FLRG
1	A1->A1
2	A2->A1
3	A3->A2
4	A4->A3, A4

3.2.6. Defuzzification

The defuzzification process is the final step, and this process presents forecasted data. Table 12 shows the estimated battery lifespan data for the Microhydro Power Plant tool.

Table 12. Defuzzification.

Year	Battery Life	Linguistic	Midpoint	Prediction
1	100%	A4->A3, A4	94.25, 99.95	-
2	97%	A4->A3, A4	94.25, 99.95	97.1
3	93%	A3->A2	88.55	97.1
4	89%	A2->A1	82.85	88.55
5	83%	A1->A1	82.85	82.85
6	80%	A1->A1	82.85	82.85
7	-	-	-	82.85

3.3. Comparison with current studies

This study can be used for further development. This study gave new information in the current literature [16-22].

4. Conclusion

In conclusion, microhydro power generation technology can be established as a solution for frontier, remote, and underdeveloped areas, providing access to electricity and illumination and supporting the living needs of the population. The performance analysis of the equipment, conducted using the fuzzy time series method, indicates that by harnessing microhydro technology, electric power up to 40 kW can be generated using four generators. With a minimum river flow rate of 60 litres per second, the microhydro system can fulfil the needs of 72 households with a lifespan of up to 15 years.

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