Automatic Gate System Based on Water Flow Within the Intake of a Micro-Hydro Power Plant

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Abstract. The micro-hydro power plant is an alternative to provide electricity especially in regions that are far from the PLN network. The micro-hydro power plant uses water flow to generate electricity. The micro-hydro power plant uses a gate that is utilised to distribute water to the turbine. However, the watergate is commonly controlled manually which results in drawbacks such as unfavourable stabilization and the need for direct monitoring that requires lots of constant expense as well as labour. The objective of this research is to make equipment that can work automatically in substituting a labourer’s role in opening and closing the watergate according to the required water flow. A water flow sensor is used to measure the water flow, the result of the sensor reading is carried on to microcontroller (set up as Fuzzy Logic Control) and Controller sends the control signal to the actuator (DC motor). The Fuzzy Logic method as the watergate controller is used as the research’s prototype system. Based on the data acquired by the research that has been done, the system is oscillated towards the change of the water flow. However, it’s capable to approach the set value point. It can be seen from the water flow trial with a set point of 3 L/min the steady-state response of system undergoes at range of 2.92 L/min–2.95 L/min and with a set point of 3.5 L/min, the steady-state response of system undergoes at range of 3.44 L/min - 3.47 L/min.

1. Introduction

Indonesia has many potentials for water that are not utilized optimally, with around 75,000 MW and only 10.1% or as small as 7,572 MW being used. In 2014, the potential for mini/micro-hydro is as big as 1.2 GW for 240 micro-hydro power plant units with each generating 5 MW [1]. Micro-hydro is known as white resources because the installation of the power plant yields the resources given by nature and is environmentally friendly. The term micro-hydro is not standardized yet, but it is certain that micro-hydro power plant uses water as its main source of energy [2, 3]. The micro-hydro power plant is an electric generator system that can change water potential with a certain altitude and water flow to become electricity with the use of turbines and generators [4, 5].

Alternative energy can be divided into two types namely renewable and non-renewable energy. Micro-hydro is one of the renewable energy sources and an increasingly developed energy [6, 7]. For the use of an induction generator, there is the effect of the capacitor on the generator output voltage under load connected conditions. The greater the value of the load connected to the induction generator results in a large voltage shrinkage as well. Poor voltage regulation is one of the disadvantages of induction generators [8-10].

The micro-hydro power plant has a water gate in the inlet that is used to flow the water to the turbine. Watergates used commonly at the current moment are controlled manually and have some weaknesses namely unfavourable stabilization and the need for direct monitoring that requires lots of constant expense as well as labour [11].
The automatic device of a control system functions to minimize human error, while water is the most needed resources in daily life [12]. Almost all aspects of human have experienced rapid development [13]. This development is supported by advances in electronics and information technology. The use of tools that work manually has now been replaced with many automated systems and has been helping people do things.

The research is done to help solve the problem in the automatization of renewable energy in the form of micro-hydro power plant. Automatic controlling in the research is done to control the opening/closing of the watergate according to the established schedule using the Fuzzy Logic Controller.

2. System Design

Figure 1 explains the overall system design. The water flow sensor results will be processed by Arduino Uno and will then be using the fuzzy logic method. The value from the fuzzy logic method determines the elevation for the opening and closing of the watergate using a DC motor, as well as a velocity optocoupler sensor and a rotary decoder disc which controls the elevation position of the watergate whether it is according or not. The velocity optocoupler sensor outcome will be feedbacks, so Arduino Uno can control the direction of the DC motor, which rotates clockwise as well as counterclockwise (gate opening or closing).

2.1. Software Design

The overall system flow diagram begins when turning on the Arduino Uno then initialisation of the pin and used variables, after that the water flow reading process using a water flow sensor. The results after reading the water flow sensor will be an input to the fuzzy logic control process which only process if the time is delayed > fuzzy interval. Delay time is a difference of the starting time of activating the Arduino Uno and the last time of doing the calculation for fuzzy, whereas the fuzzy interval is the time determined by the fuzzy to start the calculation. The outcome from the fuzzy logic is delta h that will be accumulated by h (the width of the door gap for now), therefore earning a new h value, the new h value is then used to determine the motor position so it can move according to the expected way. The diagram flow can be seen in Figure 2.
2.2. Fuzzy Logic Method

The main method used in this system is the fuzzy logic method. There are two input from the water flow data in this system called the error value and the delta error. The output from the fuzzy logic method is in the form of elevation of the watergate. A system using the fuzzy logic method for its main method could have several procedures that are linked.

Figure 3 shows the flow diagram on the fuzzy logic which starts with the input error value and delta error from the water flow sensor reading. The input value consists of the crisp input therefore the error value and delta error need to be changed into fuzzy value, after that the crisp value will be changed into fuzzy input value. Thereafter, the fuzzy input value will be converted into a fuzzy inference system process using the rules of “if-then” to a fuzzy output. Due to needing crisp value so it can be processed by the microprocessor so then the fuzzy output value is converted to a crisp output with the defuzzification so the crisp output becomes delta $h$. 

![Diagram of fuzzy logic method](image-url)
3. Results and Discussion
This subheading will discuss the testing and analysing of the device realisation. The testing is divided into 2 steps. The first step is to test the accuracy of the subsystem which are the sensor system and the actuator system on the plant. The second step is to test the integrated overall system. The testing is done to learn the reliability of the system that is made.

3.1. Water flow sensor calibration
The testing is done to learn about the accuracy of the water flow sensor. By comparing the water flow output manually and using the water flow sensor, these testing procedures are used for each measurement methods:

- Manual measurement by transferring the water in the plant within 10 seconds and collecting the water that passed the plant onto the measuring vial.
- Using water flow sensor by turning the Arduino Uno on and transferring the water in the plant so the propeller on the water flow sensor rotates. The output from the rotating propeller is converted into the velocity of the water flow.

Figure 4 shows the statistic descriptive analysis in the form of boxplot from the water flow measurement using a water flow sensor and the manual method. In general, the length in between different parts of the boxplot shows the spread and slope in the data and showing an outlier. Moreover, from bottom to top, each line represents the minimum value, lower quartile, upper quartile, median, and maximum value.
Figure 4. Water Flow Sensor Calibration

Figure 4 shows the output from the water flow measurement using the water flow sensor 30 times in 10 seconds. The average water flow acquired is 4.6316 litres/minute. Whereas manually for 30 times in 10 seconds using a stopwatch to fill up a measuring cup acquired a water flow of 4.7417 litres/minute. The long side from Figure 4 the water flow value measurement with the sensor is lower than water flow value from the manual measurements which means that the standard deviation of the water flow value sensor is lower than the manual measurement. The small value of the water flow sensor standard deviation shows the sensor’s accuracy that is higher than the manual method.

3.2. Testing of watergate actuators

The testing purpose is to learn if the motor functions well in moving the watergate.

Figure 5. Opening the watergate actuators test.
Figure 6. Closing watergate actuators test.

Figure 5 and 6 consecutively show the output of the watergate elevation testing manually using a calliper and automatically using the Arduino. By giving commands to the motor to move according to the elevation intended the testing is done, then the output of the elevation by the Arduino is compared to the watergate elevation by the calliper. The algorithm used in the actuator system calculation is stated below:

\[
\text{watergate height output} = FK \times P
\]  

Whereas:

\(FK\) = Correction factor (335°/mm)  
\(P\) = Watergate height orders

The correction factor is obtained by trial and error of the DC motor movements and the width of the watergate opening gap, therefore obtaining a certain degree value, below are the values acquired from the trial and error experimental results:

\[FK = \frac{D}{L} = \frac{19190°}{54 \text{ mm}} = 355°/\text{mm}\]  

Whereas:

\(D\) = Degree value acquired from the gate movement results (19190°)  
\(L\) = the width of the watergate gap after the DC motor moves (54 mm)

Figure 5 and 6 shows the test output from the calibrated actuator system, acquiring an average value from the percent error of 1.32% with the biggest error value of 0.089. The percent error value is obtained from (Error Value/measurement device) *100%. Therefore, it can be concluded as the accuracy value is 98.67% (100 – percent error average).

3.3. Testing of the overall of control system

Testing with the fuzzy logic method is done by determining the water elevation according to the desired setpoint, then the motor moves to open or close according to the already made fuzzy logic system output. The testing is done with 2 set points which are 3 litres/minute and 3.5 litres/minute.

3.3.1. First Testing at Setpoint 3.5 liter/minute
Based on Figure 7, it can be seen that the characteristic of this system undergoes oscillation, this happens because of the changing water flow output. With those changes, the maximum overshoot can be seen happening in the second minute with 20.28%. On the second minute, the water flow achieved 4.15 L/min and starts to be in a steady-state after 26 minutes with a ranging water flow of 3.44 L/min – 3.47 L/min when the response comes in ±2% from the steady-state condition. The maximum percent overshoot value is acquired from the equation below:

\[
\text{Maximum percent overshoot} = \frac{C(p) - C(\sim)}{C(\sim)} \times 100\% 
\]

Whereas:

- \(C_p\) = The highest water flow value
- \(C\sim\) = The water flow value in its steady-state

### 3.3.2. Second Testing at Setpoint 3 liter/minute

Figure 7. Water flow rate at setpoint 3.5 litres/minute.

Figure 8. Water flow rate at setpoint 3 litres/minute.
Figure 8 shows that in minute-2 the maximum percent overshoot of 25.76% happening when the water flow becomes 3.71 l/m then the system experience steady state after 26 minutes with a range of flow water of 2.92 l/m – 2.95 l/m when the responding system came in ±2% in its steady-state condition.

4. Conclusion
The application of the fuzzy logic in the system is done fairly well, this can be seen in the output of the flow water testing on 3.5 L/min and 3 L/min set points with a maximum percent overshoot not more than 25.76% and the respond system is able to approach the set points when in steady-state with flow water range of 3.44 L/min – 3.47 L/min on the testing of 3.5 L/min and flow water range of 2.92 L/min – 2.95 L/min on the testing of 3L/min when the respond system come in at ±2% from the steady-state condition.

References

[1] Kumara, N.S., Telah terhadap program percepatan pembangunan listrik melalui pembangunan PLTU Batubara 10.000 MW. Majalah Ilmiah Teknologi Elektro, 2009. 8(1).
[2] Fraenkel, P., et al., Micro-hydro Power, in Micro-hydro Power: A guide for development workers. 1991, Practical Action Publishing. p. 1-127.
[3] Monition, L., M. Le Nir, and J. Roux, Micro hydro-electric power stations. 1984.
[4] Smith, N., Motors as generators for micro-hydro power. 1994: Intermediate Technology Publications London.
[5] Arismunandar, A. and S. Kuwahara, Buku pegangan teknik tenaga listrik. 1974: Association for International Technical Promotion.
[6] Akella, A., R. Saini, and M.P. Sharma, Social, economical and environmental impacts of renewable energy systems. Renewable Energy, 2009. 34(2): p. 390-396.
[7] Hafez, O. and K. Bhattacharya, Optimal planning and design of a renewable energy based supply system for microgrids. Renewable Energy, 2012. 45: p. 7-15.
[8] Bhadouria, P. and M. Ilyas, Voltage and Frequency Control of Asynchronous Generator for an Isolated Wind Energy Conversion System.
[9] Tischer, C.B., et al., Proportional-resonant control applied on voltage regulation of standalone SEIG for micro-hydro power generation. IET Renewable Power Generation, 2017. 11(5): p. 593-602.
[10] Scherer, L.G., R.V. Tambara, and R.F. de Camargo, Voltage and frequency regulation of standalone self-excited induction generator for micro-hydro power generation using discrete-time adaptive control. IET Renewable Power Generation, 2016. 10(4): p. 531-540.
[11] Firmansyah, E. and M. Isnaeni, Pengendalian Beban Generator Secara Otomatis Dengan Algoritma Pid Pada Pltnh Berbasis Arduino Uno. 2012. Jurnal Teknologi.
[12] Jeranyama, P., Irrigation water management. Cranberry 2009 chart book, management guide for Massachusetts, 2009: p. 53-54.
[13] Pramudita, D. and A. Ulinuha, Prototype Sistem Buka Tutup Pintu Air Otomatis pada Persawahan Berbasis Arduino Uno. 2017, Universitas Muhammadiyah Surakarta.