The FA-ANFIS Hybrid Method is used for LFC Optimization in Micro Hydro Power Generation

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***Abstract* — Micro hydro power plants have the advantage of being environmentally friendly, economical and easily made. In areas that are difficult and far out of reach of electricity, Micro hydro is perfect for use. Distribution instability due to load changes results in frequency fluctuations in the system. So it can cause electrical appliances to be damaged. Therefore, in this study how to optimize the frequency controller with the arrangement of Proportional Integral Derivative (PID) controller to set Load Frequency Control (LFC). To get the optimal parameter of PID controller, in this research used the combination method (Hybrid) that is Firefly Algorithm and Adaptive Neuro Fuzzy Inference System (FA-ANFIS). This study compares several control methods such as PID with conventional methods, PID Auto Tuning Matlab, with PID-tuned FA and FA-ANFIS. In the Micro hydro power generation system in this study using an induction generator, the servo is operated as a governor, and several components. This plant is modeled in simulation using Matlab-Simulink program. The simulation results show that the FLC controlled FA-ANFIS has the fastest response time and smallest overshoot. This research will be developed with other artificial intelligence methods.**

***Keywords* — ANFIS, FA, LFC, Micro hydro , PID**

I. INTRODUCTION

Basically, Micro hydro utilizes the potential energy of water fall. Water flows through a quick pipe to a generator house commonly built along the river bed to drive a Micro hydro turbine or water mill. Technically, Micro hydro has three main components: water, turbine and generator. The Micro hydro gets energy from the flow of water that has a certain height difference.

The frequency and voltage generated by the Micro hydro generator is strongly influenced by the rotation speed generator. While the rotation speed of the generator is influenced by the load. At night, many consumers turn off the lights, then the burden of micro hydro becomes down. This will cause the wheel to spin faster. As a result, the frequency of electricity will increase and if too high will damage the electronic devices used at home [1].

In order for the performance of Micro hydro generator unit more optimal, it is necessary to control Load Frequency Control (LFC). To get the most optimal PID controller parameters, Hybrid is the FA-ANFIS (Firefly Algorithm - Neuro Fuzzy Inference System). This study compares several control methods such as PID with conventional methods, PID Auto Tuning Matlab, with PID-tuned FA and FA-ANFIS.

II. LITERATUR REVIEW

The energy used for power plants today, mostly comes from fossil energy. In addition to the relatively expensive price, fossil energy is also limited to its supply and cause damage to the environment. Some alternative sources of energy include wind, solar, and water. Indonesia is a tropical country with abundant natural resources. In addition, Indonesia is also an archipelagic country that has many highlands that flow river or waterfall.

2.1. Micro hydro Generator

The mechanical energy derived from the rotation of the turbine shaft is converted to electrical energy by a generator. Micro hydro can take advantage of water levels that are not too large, for example with a water level of 2.5 meters can produce 400 watts. This is one of the benefits of Micro hydro, which does not cause environmental damage. Micro hydro power systems are suitable for reaching the availability of electrical energy networks in remote and rural areas.

The Micro hydro power generation system in this study uses an induction generator, a servo motor operated as a governor, and several components modeled on the simulation using the Matlab-Simulink program [3].

2.2. PID Controller

PID (Proportional Integral Derivative) Controller is a controller to determine the precision of an instrumentation system with the characteristics of feedback on the system. PID component consists of 3 types, namely Proportional, Integrative, and Derivative. The three can be used simultaneously or individually, depending on the response we want to a plant. [3,4] As shown in the figure 1:

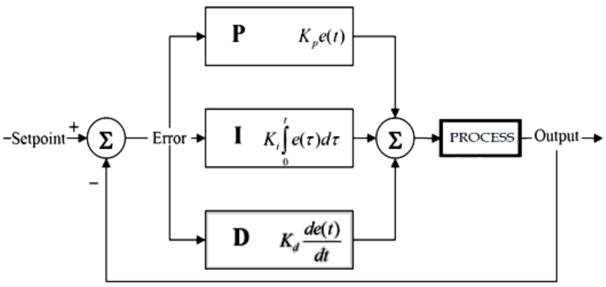

Fig 1. Range of PID Control

2.3. Ziegler Nichls

The basic method of tuning Ziegler-Nichols can be divided into 2, which are:

A. 1st Method of Ziegler-Nichols

The 1st method is based on the response of the plant to the open ladder input. The non-integrator plant produces a response curve to the ladder input such as the S curve in Figure 2. The plant response curve is used to find the time delay L and the time constant T.

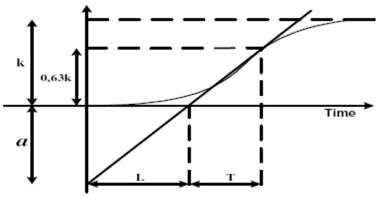

Fig 2. The response curve in the form of S

The parameters obtained from the reaction curve are used to determine the PID control parameters based on the empirical moisture of Zielger-Nichols. The formulas for the control parameters using the curve reaction method are labeled in Table 1.

TABLE I
TUNING THE 1ST METHOD ZIEGLER-NICHOLS

Controler	Kp	Ti	Td
P	1/a	-	-
PI	0.9/a	3L	-
PID	1.2/a	2L	L/2

B. 2nd method Ziegler-Nichols

In the second method, the tuning is done in closed-loop where the reference input used is the step function. The controller of this method is only the proportional controller. Kp, is increased from 0 to the critical value Kp, so that the obtained output continuously oscillates with The same amplitude. This critical value of Kp is called an ultimate gain.

In the end of period, Tu, is obtained after the system output reaches a continuous, oscillating condition. The base period, Tu, and base strength values, Ku, are used to determine the control constants in accordance with the empirical Ziegler-Nichols in Table 2.

TABLE II
TUNING ZIEGLER-NICHOLS 2ND METHOD

Controller	Kp	Ti	Td
P	Ku/2	-	-
PI	2Ku/5	4Tu/5	-
PID	3Ku/5	Tu/2	3Tu/25

2.4. Firefly Algorithm(FA)

Firefly Algorithm is one of algorithms in the Artificial intelligence field. There are two matters and very important in the Firefly Algorithm, that is light intensity and attractive function.

1. *Attractive firefly*

The level of the Light intensity on the firefly (x) can be seen as :

$$I\,(x) = f\,(x) \qquad (1)$$

I value is the level of light intensity on the firefly (x) which is comparable to the solution of the function of problem will be searched *f(x).*

$$\beta(r) = \beta_0 * e(\gamma r^m). \qquad (m \geq 1) \qquad (2)$$

Attractiveβ has the relative value, because light intensity have to be seen and assessed by other fireflies. So, the results of assessment will different depend on distance between a firefly and other firefly r ij. Besides, light intensity will go down, because it is absorbed by media, for example air γ.

2. *Distance between firefly*

Distance between firefly i and j in the location x, xi and xj can be determined when doing the laying down of point where this firefly is spread randomly in diagram Cartesians with formula :

$$r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i + y_j)} \qquad (3)$$

3. *The movement of firefly*

The movement of the firefly (i) moves to the best light intensity level. It can be seen the following equation:

$$x_i = x_i + \beta_0 * exp\left(-\gamma r_{ij}^2\right) * \left(x_j - x_i\right) + \alpha * \left(rand - \tfrac{1}{2}\right) \quad (4)$$

Where the first variable (xi) shows the first position of firefly in the location (x), then the second equation which is consist of variableβ_0 = 1.0 This variable is the value of the first attractive firefly, variable (exp) exponential numeral, variable γ = 1.0 is value of the rate of absorption in the firefly around area is air and the last (r ij) is separation variable in the first distance between firefly i and j.[5,6,7,8]

2.5. Adaptive Neuro Fuzzy Inference System (ANFIS).

Adaptive Neuro-Fuzzy Inference System (ANFIS) is the incorporation of fuzzy inference system mechanism described in the neural network architecture. The fuzzy inference system used is the first-order fuzzy model of Tagaki-Sugeno-Kang (TSK) model with consideration of simplicity and ease of computing [3,4].
The first order fuzzy inference TSK mechanism with two x and y inputs (Fig 4). The rule base with two fuzzy if-then rules, like below:
Rule 1 : if x is A1 and y is B1 then f1 = p1x + q1y + r1
Rule 2 : if x is A2 and y is B2 then f2 = p2x + q2y + r2
Input: x and y. Consequent is f.

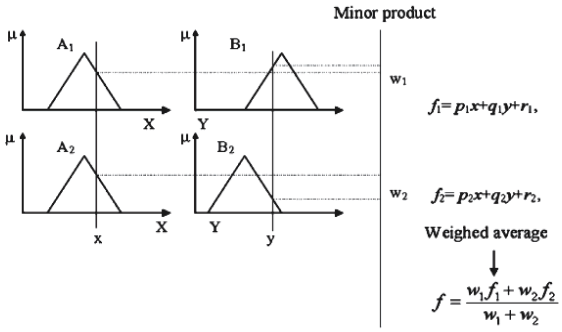

Fig 4. Fuzzy inference system

As for ANFIS Structure can be seen in (Figure 5)

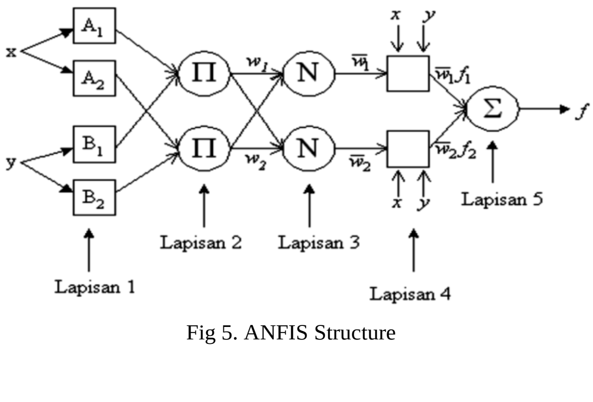

Fig 5. ANFIS Structure

III. MICRO HYDRO AND CONTROL MODEL

3.1. Micro hydro Model

Micro hydro system diagram can be seen in figure 6

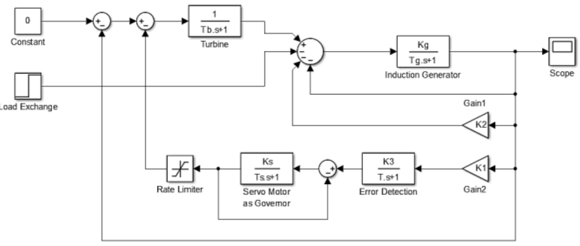

Fig 6. Micro hydro system block diagram

From the error detection block, the signal Δω will be forwarded to the servomotor block used as the governor. These parameters have Ks and Ts parameters. As for signal output governor give input to generator. Also on the output of this governor is passed to a rate limiter which serves to limit the signal at the highest and lowest saturation value that has been determined. From the output of this limiter rate, it is forwarded as input on the water turbine block.

3.2.*Parameters Micro hydro*

In the block diagram above there are parameters showing each part of the Micro hydro power plant. Starting from the input system whose value is obtained from the amount of water discharge to rotate the water turbine. Furthermore, entering on Water Turbine block which has parameter Tw on turbine, turbine water energy is converted into mechanical power which becomes one of input value for generator. From the error detection block, the signal will be forwarded to the servo motor block used as the governor. In this block there are parameters Ks and Ts. As for the output side of the governor there is a signal that is fed back to the input value of the governor. Also the output from the governor is passed to the rate limiter which serves to limit the signal at the highest and lowest saturation value which has been determined. From this output of rate limiter, it is continued as input on the turbine block.

In addition to predefined parameters, there are also input values on generators coming from Load Exchange or load frequency changes. The input signal due to the load change is a very decisive part of how the frequency setting system is running. The value of this signal may vary in value, depending on the amount or the amount of power load used by the customer

TABLE III
MICRO HYDRO POWER PLANT PARAMETERS

	Value	Information
Tb	1	Water turbine time response (s)
Kg	1	Reinforcement of generator induction regulator (s)
Tg	13.333	Response time induction generator (s)
K1	5	Error Detection confirmation constant
K2	8.52	Frequency deviation constant
K3	0.004	Strengthening Error Detection
T	0.02	Time response Error Detection
Ts	0.1	The governor's time constant (s)
KS	2.5	Strengthening governor governor
Sg	40	Micro hydro power generator rating (kVA)
pf	0,8	Power factor
Vg	400/231	Nominal voltage generator (V)
ω	1500	Nominal rotational speed (rpm)
fg	50	Frequency nominal micro hydro (Hz)

3.3. *Control Model*

PID Controller at micro hydro system diagram can be seen in figure 7

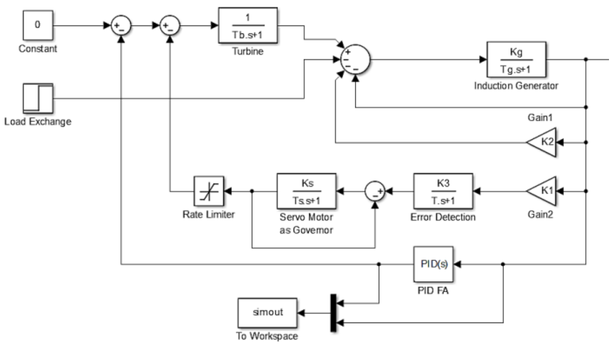

Fig. 7. PID Controller at micro hydro

ANFIS Controller at micro hydro system diagram can be seen in figure 8

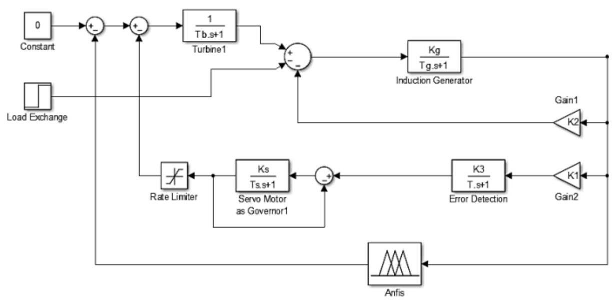

Fig. 8. ANFIS at micro hydro

The constants of Kp, Ki and Kd in PID can be seen in the table below:

TABLE IV
THE CONSTANTS OF Kp, Ki AND Kd

	PID	PID-Auto	PID-ZN	PID-FA	PID-FA-ANFIS
Kp	1	15,664	10	43,453 2	-
Ki	1	21,619	1,21	1,0021	-
Kd	0	-2,711	0	0,01	-

Forms of simulation model can be seen in figure 8:

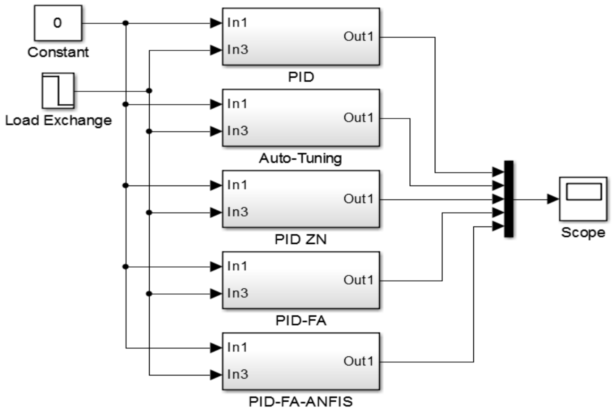

Fig 9. Simulation model of some controls

IV. RESULT AND DISCUSSION

The results can be illustrated in Figure 9:

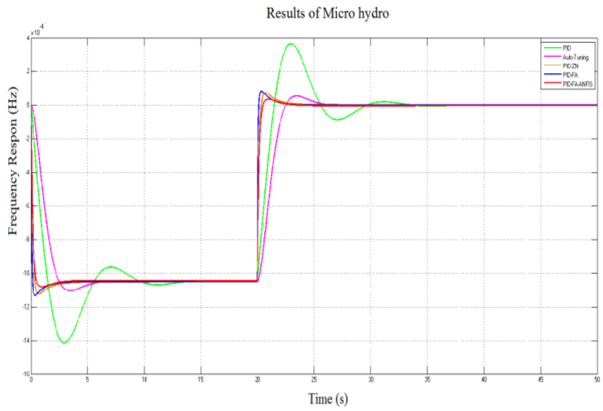

Fig 10. ResultsofMicrohydro responses

The above graph results can be interpreted that; Standard PIDcontroller obtained overshoots = 3,6507x10^{-4}, settling time 28.76s. PID-Auto Tuning Matlab obtained overshoots = 6.4566x10^{-5}, settling time 25.37s. PID Ziegler Nichols controller obtained overshoots = 7.4619x10^{-5}, settling time 16.74s. PID-FA controller obtained overshoots = 8.1417x10^{-5} settling time 9.22s. PID-FA-ANFIS controller obtained oershoots = 3.5764x10^{-5} settling time 3.61s.

V. CONCLUSION

From the comparison of the results of several PID control models it is compacted that the smallest overshoot ($3.5764x10^{-5}$) in the PID-FA-ANFIS setting model and fastest settling time (3.61 seconds). This shows that with the PID-FA-ANFIS control model the system will respond faster and improve the frequency to remain constant.

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