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OPTIMIZATION OF HYDROPOWER PLANT PERFORMANCE USING FUZZY BASED RULE.

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Keyword:
Optimization, hydropowe, fuzzy-based rule

ABSTRACT: *The inconsistence in power supply from hydropower has arisen as a result of decrease in output power. It can be surmounted by Optimization of hydropower plant performance using fuzzy based rule. This can be done by determining the amount of output power that flow in hydropower through optimization, designing a fuzzy rule that increases the output power and designing a Simulink model for optimization of hydropower plant performance using fuzzy rule. The result obtained is 67.83% increase in output power using fuzzy rule and 32.16% output power increase without using fuzzy.*

1.0 INTRODUCTION.

Hydroelectric power is electrically generated energy using natural forces such as gravity of flowing water. Usually, it is produced from dams which can store and direct large volumes of water. Dams can generate electricity because they contain special mechanisms designed to take the energy in flowing water and convert it into electrical power.

Lots of water is stored in the reservoir behind the dam. Near the crest of the dam is the water intake to which the penstock is connected. The position of the penstock connection enables the force of gravity inside the dam to cause water flow through the penstock to the turbine connected to the generator assembly. As the water through the penstock falls on the turbine propeller, the turbine begins to spin.

The spinning turbine propeller in turn causes a metal shaft of the generator to which it is also connected to spin producing electricity. Thus, in the case of hydropower, the power source is water itself, stored in the turbine. In this research, the components of a prototype hydropower system and generation procedure will be analyzed. This will be carried out through a mathematical modeling with the view to optimizing the overall stability of hydropower generator using appropriate control tools.

In reality the efficient performance of hydro turbine, which is the major component that turns the generator in order to generate electricity is mainly determined by parameters of the water being supplied to it through"Optimization" that comes from the same root as "optimal", which means *best*. When optimizing the hydropower, it

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is being made best. But "best" can vary. If the flow in hydropower, is maximizedand the cost of maintaining the hydropower is minimized the output becomes increased generated power. Both maximizing and minimizing are types of optimization problems.

Basically, optimization problem consists of the objective function, f(x), which is the output value required to be maximize or minimize, while some problems have constraints and some do not and there can be one variable or many. Variables can be discrete (for example, only have integer values) or continuous. Some problems are static (i.e. do not change over time) while some are dynamic (continual adjustments must be made as changes occur).

2.0 Methodology

To determine the amount of output power that flow in hydropower system under study through optimization The amount of output power that flow in hydropower through optimization has three variables namely; 87.14m, 90.85m,92.73m corresponding to Water heads of 1.1m, 1.2m and 1.25m flow rates of 1.31605, 1.3720 and 1.4004 and velocities of 4.654m/s, 4.85m/s and 4.952m/s were used to form optimization equations in x1, x2, and x3 respectively as shown below.

Max

$Z = 86.97x_1 + 90.85X_2 + 92.730X_3$

Where : X_1 = penstock diameter

X_2 = Actual water head

X_3 = flow rate

Z = output power

Subject to

$0.06X_1 + 1.1X_2 + 1.3135X_3 \leq 4.645$

$0.06X_1 + 1.2X_2 + 1.3720X_3 \leq 4.852$

$0.06X_1 + 1.25X_2 + 1.3994X_3 \leq 4.949$

Recall that the reason for optimization as mentioned is to achieve an optimal and exact stability point in hydropower system design. The result obtained is shown in fig 1.

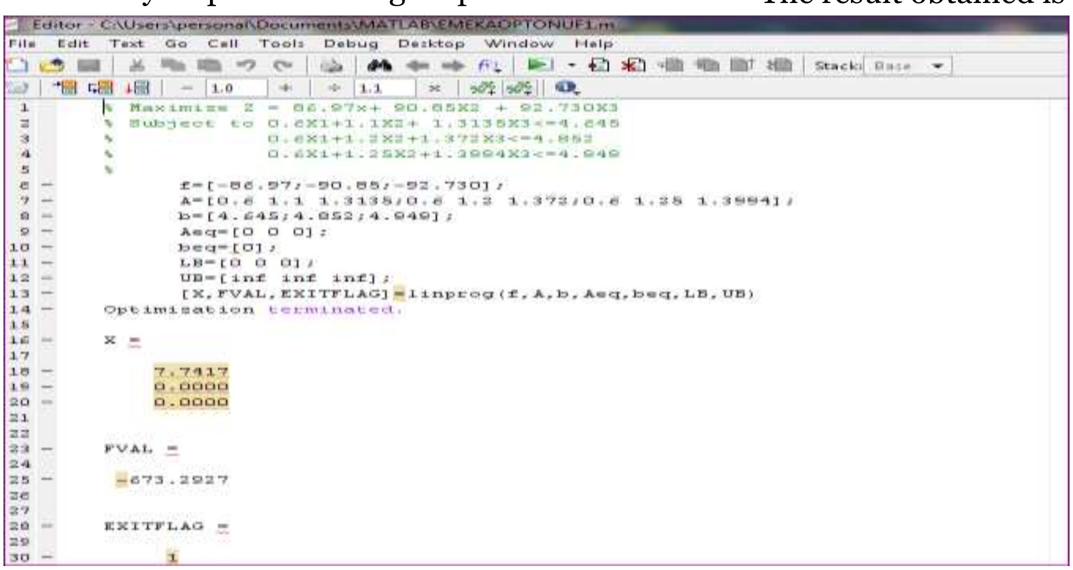

Figure 1: Showing the MATLAB/Simulink Optimization codes and result.

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From the values obtained after the optimization process the MATLAB/Simulink code of figure 1 from which the graph in figure 1 was generated. This graph shows the output power values before and after optimization with values of 90.85kw and 673.2927kw respectively.

To design a fuzzy rule that increases the output power

This was carried out to transform a numerical variable to a linguistic variable that is, real number to fuzzy number, and there after develop a guide to enhance stability of the turbine of hydropower system. After the necessary analysis needed to generate the membership functions, twenty five fuzzy–based rules were created to achieve system stability, based on parametric values earlier calculated which were fed into the FIS as inputs.

MATLAB Software tool was used to achieve this. The output and rules were designed intuitively, using the Fuzzy-guided genetic algorithm (FGA).

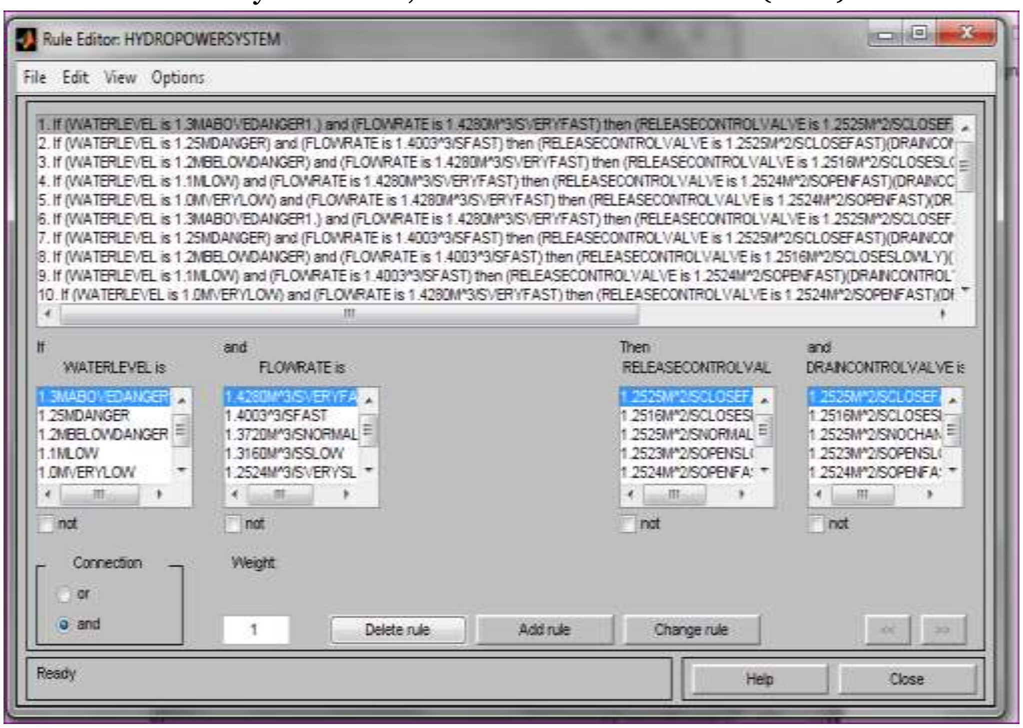

Figure 2: the first 10 of the 25 Fuzzy–based rules for the optimized hydropower plant

The researcher hereby presents a clearer interpretation of these rules which are referred to as IF…….THEN rules. These rules are a combination of different levels in parameter of Flow rate, Water level, Release control valve and Drain valve in their optimized form.

It should be noted that these rules are deemed sufficiently adequate for the stability of the designed hydropower system. The rules are five in number formulated as follows:

1st Rule; IF Water level is 1.3m (Above Danger) and Flow rate is 1.4280m3/s (Very Fast) @ a

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velocity of 5.050m/s, THEN Release control valve is 1.25252 m^2/s (Closed Fast) and Drain valve is 1.25252m^2/s (Closed Fast).

2nd Rule; IF Water level is 1.3 (Above Danger) and Flow rate is 1.4003 m^3/s (Fast) @ a velocity of 4.952 m/s, THEN Release control valve is 1.25252 m^2/s (Closed Fast) and Drain valve is 1.25252 m^2/s (Closed Fast).

3rd Rule; IF Water level is 1.3 (Above Danger) and Flow rate is 1.2525 m^3/s (Normal flow)@ a velocity of 4.852m/s, THEN Release control valve is 1.2516 m^2/s (Closed slowly) and Drain valve is 1.2516 m^2/s (Closed slowly).

4th Rule; IF Water level is 1.3 (Above Danger) and Flow rate is 1.3160 m^3/s (Slow)@ a velocity of 4.645m/s, THEN Release control valve is 1.25238 m^2/s (Open slowly) and Drain valve is 1.25238 m^2/s (Open slowly).

5th Rule; IF Water level is 1.3 (Above Danger) and Flow rate is 1.252 m^3/s (Very slow)@ a velocity of 4.429m/s, THEN Release control valve is 1.2524 m^2/s (Open fast) and Drain valve is 1.2524 m^2/s (Open fast).

6th Rule; IF Water level is 1.25 (Danger) and Flow rate is 1.4280 m^3/s (Very fast) @ a velocity of 5.050m/s, THEN Release control valve is 1.2525 m^2/s (Closed fast) and Drain valve is 1.2525 m^2/s (Closed fast).

7th Rule; IF Water level is 1.25 (Danger) and Flow rate is 1.4003 m^3/s (Fast) @ a velocity of 4.952m/s, THEN Release control valve is 1. m^2/s (Closed fast) and Drain valve is 1.2525 m^2/s (Closed fast).

8th Rule; IF Water level is 1.25 (Danger) and Flow rate is 1.3720 m^3/s (Normal flow) @ a velocity of 4.852m/s, THEN Release control valve is 1.2516 m^2/s (Closed slowly) and Drain valve is 1.2516 m^2/s (Closed slowly).

9th Rule; IF Water level is 1.25 (Danger) and Flow rate is 1.3160 m^3/s (Slow) @ a velocity of 4.645m/s,, THEN Release control valve is 1.2524 m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

10th Rule; IF Water level is 1.25 (Danger) and Flow rate is 1.2524 m^3/s (Very slow) @ a velocity of 4.429m/s, THEN Release control valve is 1.2524 m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

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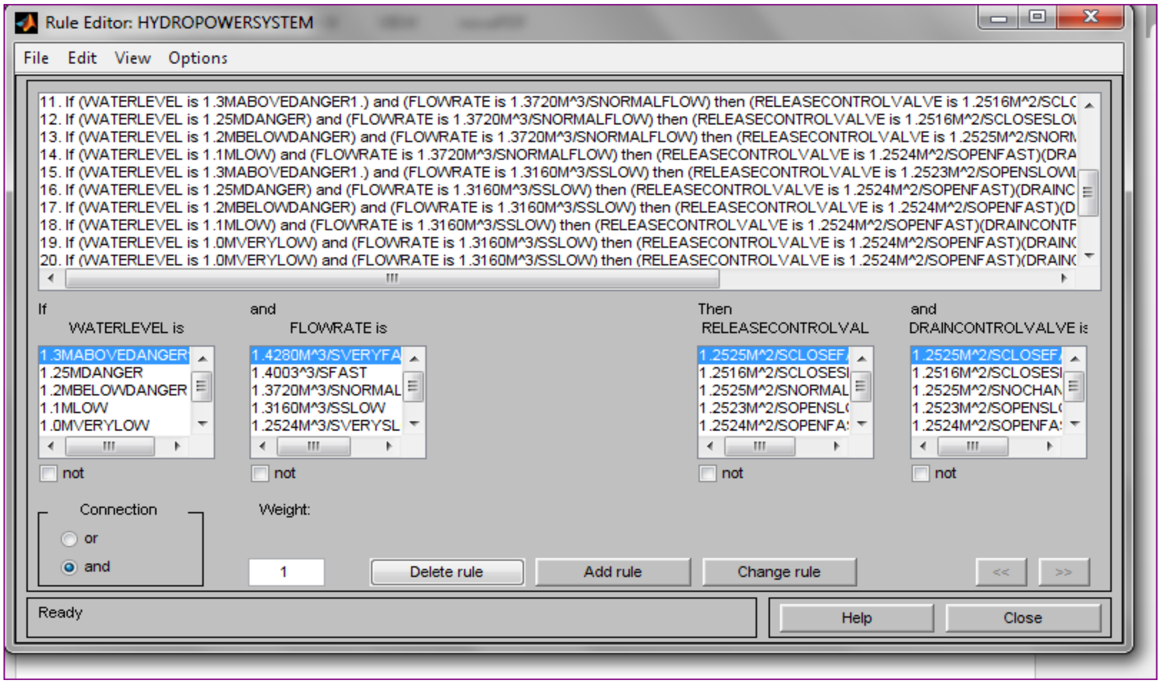

Figure 3: the next 11 to rules of the 25 Fuzzy–based rules for the optimized hydropowerplant.

11th Rule; IF Water level is 1.2 (Below danger) and Flow rate is 1.4280 m3/s (Very fast) @ a velocity of 5.050m/s, THEN Release control valve is 1.2516 m²/s (Closes slowly) and Drain valve is 1.2516 m²/s (Closes slowly).

12th Rule; IF Water level is 1.2 (Below danger) and Flow rate is 1.4003 m3/s (Fast) @ a velocity of 4.952m/s, THEN Release control valve is 1.2516 m²/s (Closes slowly) and Drain valve is 1.2516 m²/s (Closes slowly).

13th Rule; IF Water level is 1.2 (Below danger) and Flow rate is 1.3720 m3/s (Normal flow) @ a velocity of 4.852m/s, THEN Release control valve is 1.2525 m²/s (Normal) and Drain valve is 1.2525 m²/s (Normal).

14th Rule; IF Water level is 1.2 (Below danger) and Flow rate is 1.3160 m3/s (Slow) @ a velocity of 4.645m/s, THEN Release control valve is 1.2524 m²/s (Open fast) and Drain valve is 1.2524 m²/s (Open fast).

15th Rule; IF Water level is 1.2 (Below danger) and Flow rate is 1.2524 m3/s (Very slow) @ a velocity of 4.429m/s, THEN Release control valve is 1.2524 m²/s (Open fast) and Drain valve is 1.2524 m²/s (Open fast).

16th Rule; IF Water level is 1.1m (Low) and Flow rate is 1.4280 m3/s (Very fast) @ a velocity of 5.050m/s, THEN Release control valve is 1.2524 m²/s (Opens fast) and Drain valve is 1.2524 m²/s (Opens fast).

17th Rule; IF Water level is 1.1m (Low) and Flow rate is 1.4003 m3/s (Fast) @ a velocity of 4.952m/s, THEN Release control valve is 1.2524

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m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

18th Rule; IF Water level is 1.1m (Low) and Flow rate is 1.3720 m^3/s (Normal flow) @ a velocity of 4.852m/s, THEN Release control valve is 1.2524 m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

19th Rule; IF Water level is 1.1m (Low) and Flow rate is 1.3160 m^3/s (Slow) @ a velocity of 4.645m/s, THEN Release control valve is 1.2524 m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

20th Rule; IF Water level is 1.1m (Low) and Flow rate is 1.2524 m^3/s (Very slow) @ a velocity of 4.429m/s, THEN Release control valve is 1.2524 m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

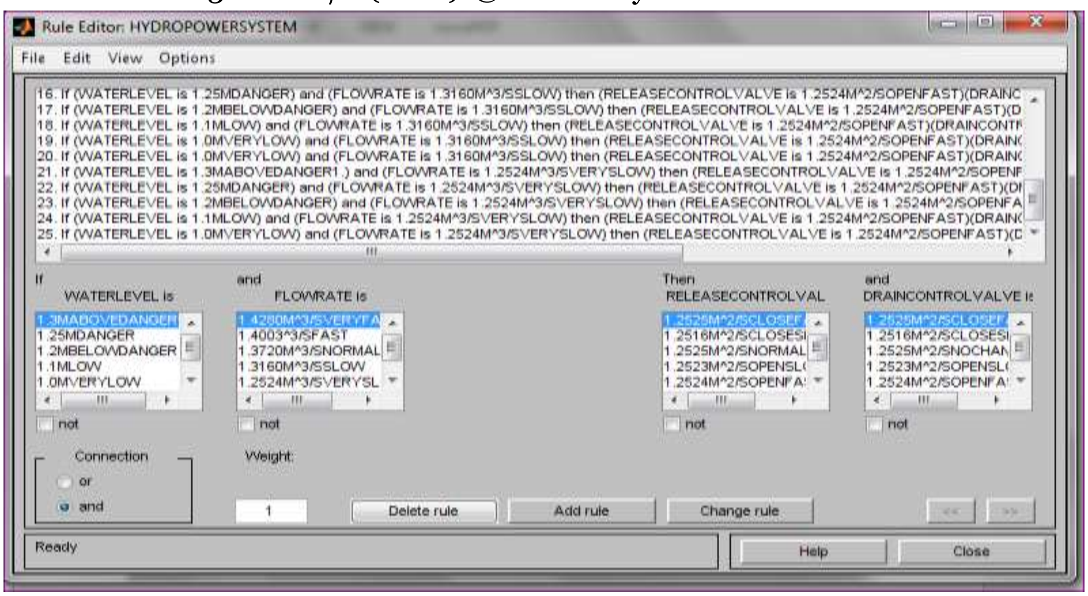

Figure 4: the last 21 to 25 of the 25 Fuzzy–based rules of optimized hydropower plant

The results of implementation of **objective 3**. This result shows the conditions or rules to achieve system stability for the designed hydropower plant model. MATLAB software tool was used to actualize this and Fuzzy Guided Genetic algorithm (FGA) was used to design these rules.

21st Rule; IF Water level is 1m (Very low) and Flow rate is 1.4280 m^3/s (Very fast) @ a velocity of 5.050m/s, THEN Release control valve is 1.2524 m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

22nd Rule; IF Water level is 1m (Very low) and Flow rate is 1.4003 m^3/s (Fast@ a velocity of 4.952m/s,) THEN Release control valve is 1.2524 m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

23rd Rule; IF Water level is 1m (Very low) and Flow rate is 1.3720 m^3/s (Normal flow) @ a velocity of 4.852m/s, THEN Release control

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valve is 1.2524 m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

24th Rule; IF Water level is 1m (Very low) and Flow rate is 1.3160 m^3/s (Slow) @ a velocity of 4.645m/s, THEN Release control valve is 1.2524 m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

25th Rule; IF Water level is 1m (Very low) and Flow rate is 1.4280 m^3/s (Very slow) @ a velocity of 4.429m/s, THEN Release control valve is 1.2524 m^2/s (Opens fast) and Drain valve is 1.2524 m^2/s (Opens fast).

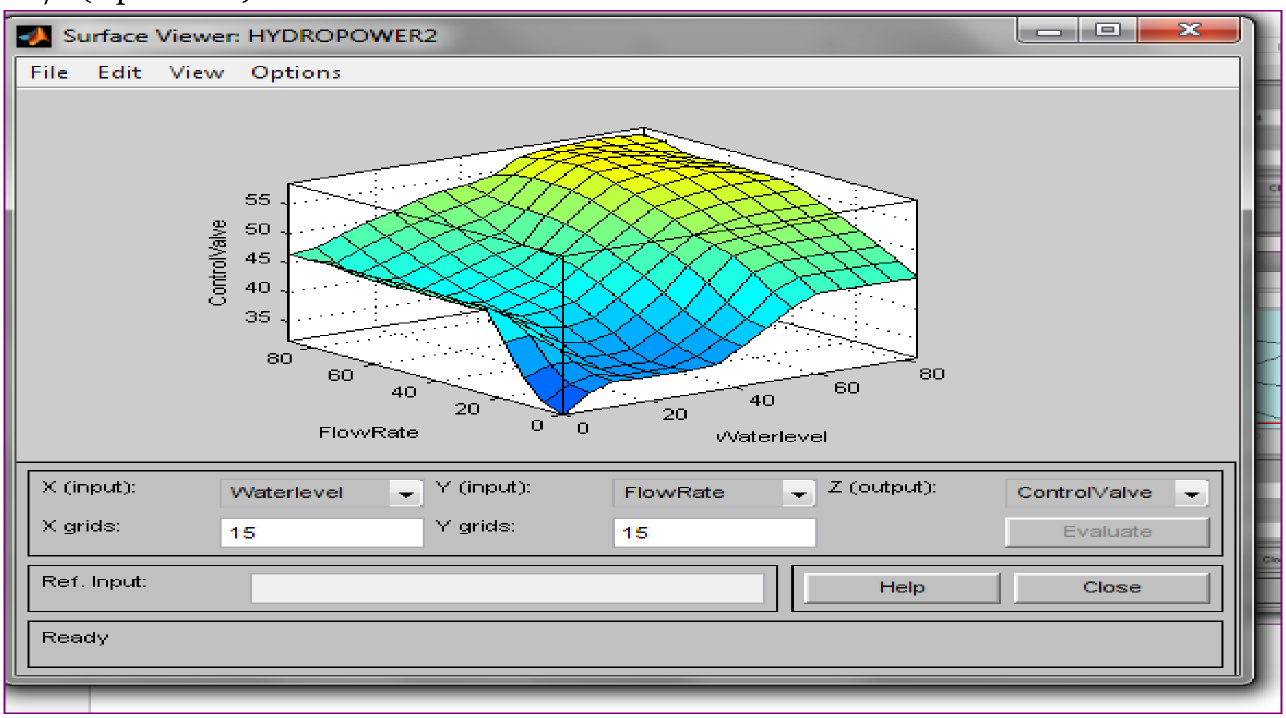

Figure 5: the surface view of the 5 fuzzy–based rules of the optimized hydropower plantmodel.

To design a Simulink model for optimization of hydropower plant performance without using fuzzy rule

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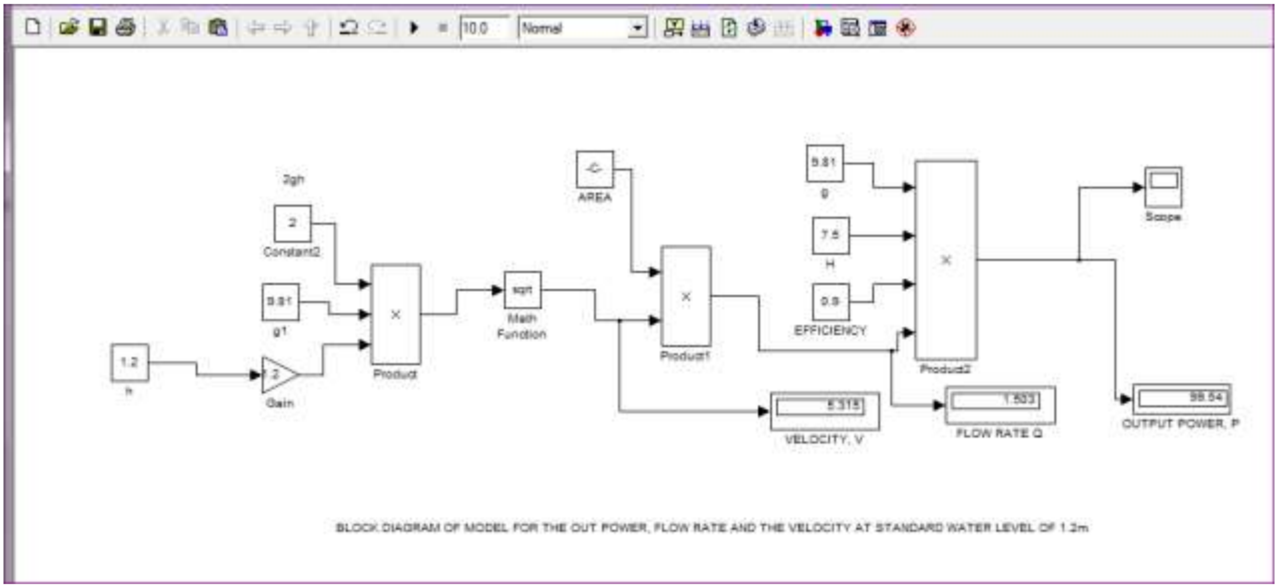

Fig 6 designed Simulink model for optimization of hydropower plant performance without using fuzzy rule

Fig 6 shows designed Simulink model for optimization of hydropower plant performance without using fuzzy rule. The result obtained is 99.54KW power output after simulation.

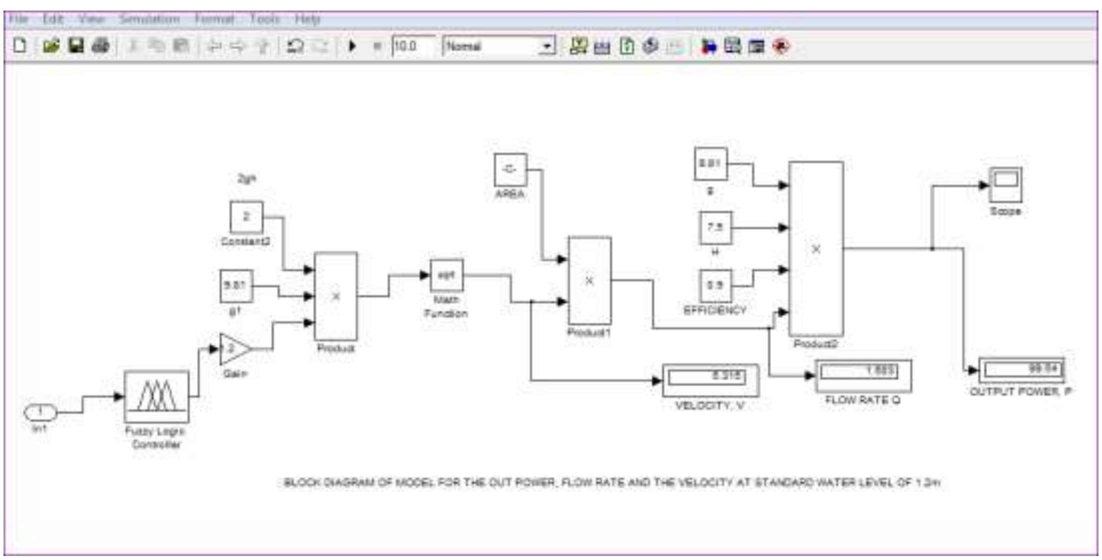

Fig 7: designed Simulink model for optimization of hydropower plant performance using fuzzy rule

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Figure 7 shows designed Simulink model for optimization of hydropower plant performance using fuzzy rule. The obtained result is 209.9KW which is 67.83% when compared to without fuzzy.

3.0 Result Analysis

Table1 comparing the output power in optimization of hydropower plant performance without and with fuzzy

OUTPUT POWER WHEN FUZZY IS NOT USED	OUTPUT POWER WHEN FUZZY IS USED	TIME(S)
99.54	209.9	1
99.54	209.9	2
99.54	209.9	3
99.54	209.9	4
99.54	209.9	5
99.54	209.9	6
99.54	209.9	7
99.54	209.9	8
99.54	209.9	9
99.54	209.9	10

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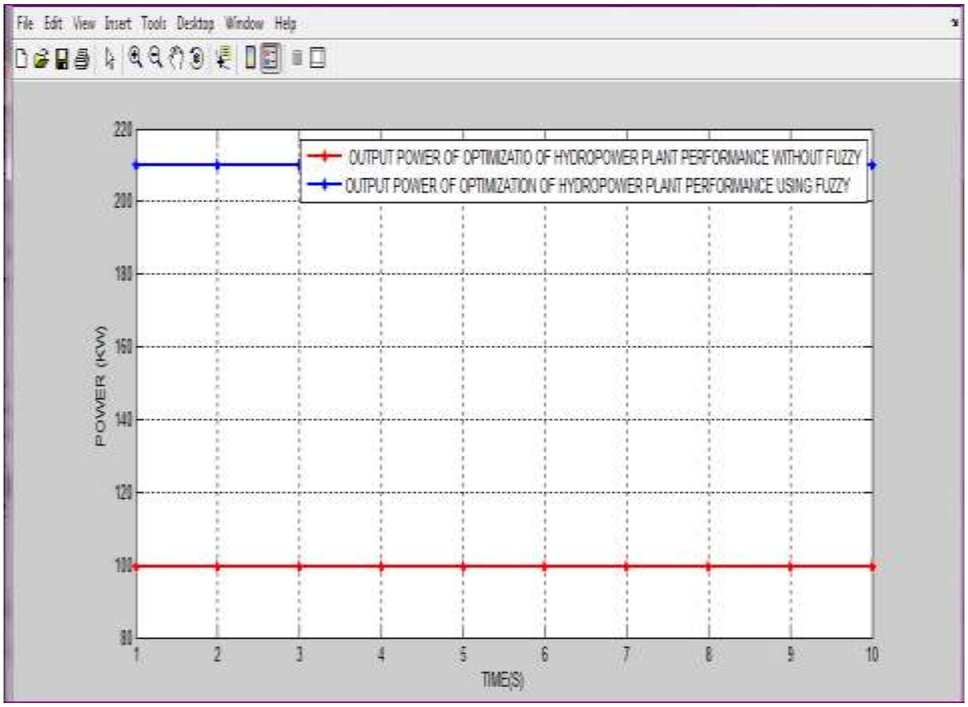

Fig 10 comparing the output power in optimization of hydropower plant performance without and with fuzzy

Figure 10, Shows the comparison of the output power in optimization of hydropower plant performance without and with fuzzy. The results obtained are 99.54KW output power without fuzzy and 209.9KW output power when fuzzy is incorporated in the designed model.

4.0 Conclusion

Irregular power supply in our society and the country at large has rendered many homes financially incapacitated because their source of income solely depends on power. This has arisen as a result of insufficient output power that would meet to the demand. This can be overcome by.optimization of hydropower plant performance using fuzzy based rule. It is achieved bydetermining the amount of output power that flow in hydropower through optimization, designing a fuzzy rule that increases the output power and designing a Simulink model for optimization of hydropower plant performance using fuzzy rule. The result obtained is an increase power output when fuzzy is incorporated in the model which is better than the result obtained when fuzzy is not imbibed.

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