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Hydro Power Station Load Frequency Control Using Fuzzy Logic Controller

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Abstract—*The generation of electricity is more significant because of expanding need for energy. To fulfil the need, limited scope hydropower plants are built notwithstanding enormous scope hydropower plants so small-scale hydropower plants are constructed in addition to large-scale hydropower plants. Hydropower plants have a predominant role in the generation of electrical energy. Smaller hydropower plants are acquiring fascination because of the cost-effective source for rural electrification in developing countries attributable to their environmental-friendly operation. Most of the Micro Hydro Power Plants are isolated from the national electrical grid network, which requires a good control system to keep the Micro Hydro Power Plant frequency and voltage outputs constant despite changing user loads. The proposed work aims to manage the complete operation of the generating unit by using the fuzzy controller. The proposed fuzzy controller regulates the frequency output of the despite changing the consumers loads and it also limits the waste of water.*

Keywords— *Hydro Power Plant, Fuzzy logic controller, load frequency control, coupled generator.*

I. INTRODUCTION

Climate change, global warming, population growth and the continuing demand for energy and electricity have made renewable energy the most appropriate and suitable to respond to all changes in our environment. Electricity generation is more important due to its rising demand and increased environmental awareness such as reducing polluting emissions. Electricity generation depends on user's consumption and their need. Power supply systems are progressively developing in terms of size and complexity. The dynamic behavior of the systems depends on disturbances and changes in the point of work.

It consists of many generating units, loads and their total power control and demand vary continuously throughout the day. Due to the change in consumer demands or some other troubleshooting problems in generating units or grids, the frequency system may have some fluctuations or corruption. But the change in frequency should be limited. Otherwise, due to these excessive swings, the loads could be pulled out of the network and thus the producers would suffer the damage. Currently, people are trying to prefer cheap, clean, and renewable energy due to increased global warming.

Hydroelectric resources are available more all over the world. The Asian continent still has a large untapped potential for hydroelectric resources. The hydroelectric power plant can save the environment by reducing respectively 950, 12 and 5 tons of Carbon Dioxide & Sulphur oxides and nitrogen oxides compared to the coal-fired power plant. Load frequency control (LFC) is the primary way for providing reliable and quality operation. Therefore, the design of load frequency controllers has received great attention from researchers and many control frequency control methods have been developed. The voltage is usually controlled by varying the excitation voltage while the frequency is controlled using the regulator.

The basic function of the regulator is to control the speed of the generator to keep the system's frequency constant. Some standard methods such as mechanical hydraulic controller, electro-hydraulic PI controller and PID controller are used to control the load frequency of the mini-hydropower plant. The mechanical hydraulic regulator has a slow response so it will not be reliable for today's complex power system in demand on sharing distributed generation. The PID-based regulator also encountered the problem of adjusting the parameters. Incorrect adjustment in PID-based regulators can cause failure in frequency control during transient conditions. The PID controller is also not suitable for complex and non-linear systems because it has serious integrator winding problems [20]. To overcome this problem, several techniques for PID optimization have been proposed. However, setting up PID controllers is not a simple problem especially when the systems to be controlled are non-linear and unstable.

As an alternative to conventional control methods, fuzzy logic was first presented in 1965 it had been studied for modelling complex systems over the past few decades. Fuzzy logic controllers have been widely used for nonlinear, complex, and uncertain systems. The fuzzy logic controller is one of the most reliable controllers for these systems. The fuzzy logic controller is based on fuzzy set theory and is

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represented with the experience and knowledge of a human system operator. The fuzzy logic controller does not require any mathematical knowledge of a system.

Many researchers have used a conventional controller and an optimal PID controller to control the frequency deviation and power of the Tie-Line. In this document, an LFC is designed for frequency and power deviation control. The proposed Fuzzy logic provides the best results compared to the conventional controllers like PID controller; the results of the intelligent controller are compared to the classic controller using MATLAB software. The power deviation and frequency response obtained by the fuzzy logic controller in LFC are compared to the LFC with PID controller in terms of settling time, rise time and peak passes. Fuzzy has been found to perform better than conventional controllers.

II. Hydropower Plant

Hydropower generation is an enduring technology, which converts mechanical energy of water into electrical energy to obtain electricity. The major components of hydroelectric power plant are hydraulic turbine, an electric generator and includes a dam or reservoir or wall. The dam or reservoir is made along with the width of the river so that the water level can increase to other side of the retaining wall. On the other side installed with water turbines. The mechanical energy of the water is used to run the turbines, then the turbines run the generators to produce electricity.

The water stored in the tanks offers flexibility to solicit electricity on demand and reduces the dependence on the variability of the inflow. Very large tanks can store the inflow for months or perhaps years but are usually designed for seasonal storage, to provide water during dry seasons. Hydropower storage facilities are more flexible than RoR (Run-of-the-River) facilities and should be used to provide base load energy, but as a peak load due to its ability to be packed and restarted at short notice, eagerly awaiting demand within the installation [19]. Given their ability to manage water flows, storage tanks are often built as multipurpose systems, providing additional benefits such as control, structure, irrigation, navigation, and recreation. The main advantage of hydroelectric plants with storage is their ability to store large volumes of energy and to respond to variable load needs, from short-term variability (daily peak) to weekly and seasonal variability. Such reservoirs are becoming increasingly important and valuable also for storing energy from other renewable sources.

III. Problem Statement

The rated frequency of operation within the Indian grid is 50.0 Hz and the allowable wave range specified by the Indian Electricity Grid Code (IEGC) is also between 49.5 Hz and 50.2 Hz. Since May 3, 2010. Few countries have used 60.0 Hz. Among the various components in a hydroelectric power plant, the turbine plays a significant role in achieving efficiency while maintaining its operating conditions. Uncontrolled frequency leads to decreased performance and efficiency of a hydroelectric power plant. To achieve higher performance and targeted output efficiency, it is necessary to manage the frequency 50Hz in India.

IV. Existing Problem

So far, the frequency is controlled by using conventional controllers such as PI, PD and PID in hydroelectric power plants. The PID controller is a tool used in controlling industrial applications to manage the temperature, flow, pressure, speed, and other process variables. PID (Proportional Integral Derivative) controllers use a bearing ring feedback mechanism to regulate process variables and are the most accurate and stable controllers.

In most of the existing works the controllers were designed with non-linear systems but not designed for the hydroelectric power plant. As we know that conventional PID controllers show poor performance in controlling the integrated process and not suitable for complex, nonlinear, uncertain, high-order and oversized time delay process [8]. Those controllers cannot include ramp type set point change or slow noise.

V. Proposed System

The hydroelectric power plant shows that the measured synchronous speed is returned to compare it with the reference speed signal. The speed deviation produced by the comparison of the reference speed and the synchronous generator is used as the input for the controller-based speed regulator. The regulator produces the command signal, causing a variation in the opening of the gate. The turbine then produces the torque, activating the synchronous machine that generates the electrical power as output. The speed controller continuously monitors the speed deviation to intervene. The water is drawn from the river by diverting it through an outlet in a small weir. The weir is an artificial barrier across the river that maintains a continuous flow through the inlet. Before descending to the turbine, the water passes through a settling tank or "bow bay" where the water is slowed down sufficiently for the suspended particles to settle. The water is carried to the bow bay by a small channel or "leat". A pressure pipe, known as a penstock, conveys the water from the bow compartment to the turbine. All installations need a valve or gate, so the kinetic energy of the water due to the high pressure is converted into electricity with the help of a turbine.

VI. Proposed Block Diagram

In Fig.1 [19] the block diagram of hydroelectric power plant shows that the measured synchronous speed is retransmitted to match the reference speed signal. The speed deviation produced by comparing the reference speed and the synchronous generator is used as input for the controller-based speed regulator. The regulator produces the control signal, causing the change within the gate opening. The turbine then produces the torque, driving the synchronous machine that generates the power.

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The speed controller continuously monitors the speed deviation to require action. The water is drawn from the river by diverting it through the outlet in a small weir. A pressurized pipe, called a gate, conveys the water from the bow to the turbine. The system has equipped with a valve or gate, so the mechanical energy of the water tanks to the heavy pressure is converted into voltage with the help of a turbine.

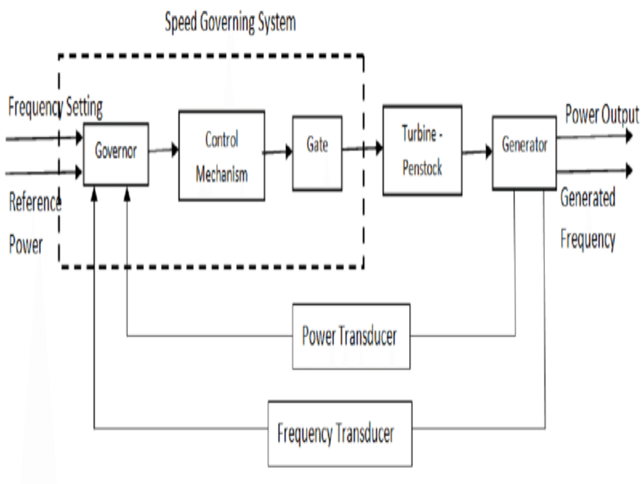

Fig. 1. Block diagram of hydro power plant

6.1 Governor

The steering system or governor is the main controller of the hydraulic turbine. The regulator was varying the flow of water through the turbine to manage its speed or power. Governor can also adjust the speed of the generating units and the frequency of the system. Voltage is produced by the generator driven by a primary engine, which is typically a turbine or internal combustion engine. The turbine is equipped with a regulator, which controls the speed of the generation unit in accordance with the predefined grid frequency characteristics.

6.2 Gate Valve

In hydropower system gates are adjustable and pivot around the periphery of the turbine in terms of regulating the level of the water flow to the turbine. Ports are regulated by the servo actuators which, controlled by the controller.

6.3 Turbine

Turbine is a rotary machine that converts mechanical energy and potential energy of water into mechanical work. In 19th century Water turbines has developed and they were widely used in industrial energy before power grids. But now highly used in power generation.

6.4 Kaplan Turbine

The variable changing in geometry of the gate and turbine blades it allows efficient operation in changing flow conditions. The efficiency of the Kaplan turbine which is typically greater than 90% but possibly lower at very low head applications.

6.5 Penstock

Gate valves are the conduit constructed of steel or concrete. The penstock connects the bow or the surge tank to the scroll casing turbine. Their main function is to retain water from the dam to the turbine. The suction pipe increases the operating head on the turbine

6.6 Generator

Generators, it supports the connection between magnetism, motion and electricity. Generators typically uses electromagnet; it is made up of electricity and a rapidly rotating turbine to deliver a huge amount of current. The quality generator contains a bunch of cylinder-shaped insulated wire spools.

6.7 Power Transducer

A power watt transducer which is used to measure the actual power delivered to load and it converts that measurement into a DC voltage or current signal where it is proportional to the measured structure. The often the angle by which the present carries or delays tension. Its measurement is more important for accurately determining true power.

6.8 Frequency Transducer

The work of the frequency transducer is to measure the frequency supply over a specified frequency range, and it is converted to an industry standard signal that is directly proportional to the measured input. These transducers provide an output independent of the load and isolated from the input. For analysing and controlling the output will be connected to controllers, data loggers, PLCs, analogy / digital indicators, and recorders.

VII. Fuzzy Controller

Non-linear fuzzy system can be a system that supports fuzzy logic, it is an mathematical system which is used to analyse analog input values in terms of logic variables that deal with continuous values between 0 and 1, as opposed to classical or digital logic, which operates at discrete values of either 1 or 0 (termed as true or false, respectively). Symbolic logic is employed to formulate a system model by aggregating a collection of linearized local subsystems that roughly identify the pattern, and a fuzzy feedback controller is intended using conventional linear feedback theory and fuzzy reasoning. Mathematical logic could be a logic or a system with n-valued logic system that uses the "degrees of truth" status degrees of the inputs and it produces outputs that are based on the states of input and the rate of change of those states (rather "true or false" (1 or 0), low or high Boolean (binary) on which the trending computer is based). It provides the basis for rough reasoning using imprecise decisions and allows us to use linguistic variables. A symbolic logical statistic is often 0, 1, or between these numbers, which is 0.17 or 0.54. A formal logic system is more flexible and allows for modification within the rules. From the study, the fuzzy logic improves the system performance effectively. Also, the stability of the

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system was thus maintained effectively by the proposed controller [20]. Inaccurate, distorted and error input information is also accepted by the system. Systems were easily built. Fuzzy Logic controller is very effective to suppress the frequency oscillations caused by load disturbances [20]. Fuzzy provides desirable performance against sudden load change in the system [11].

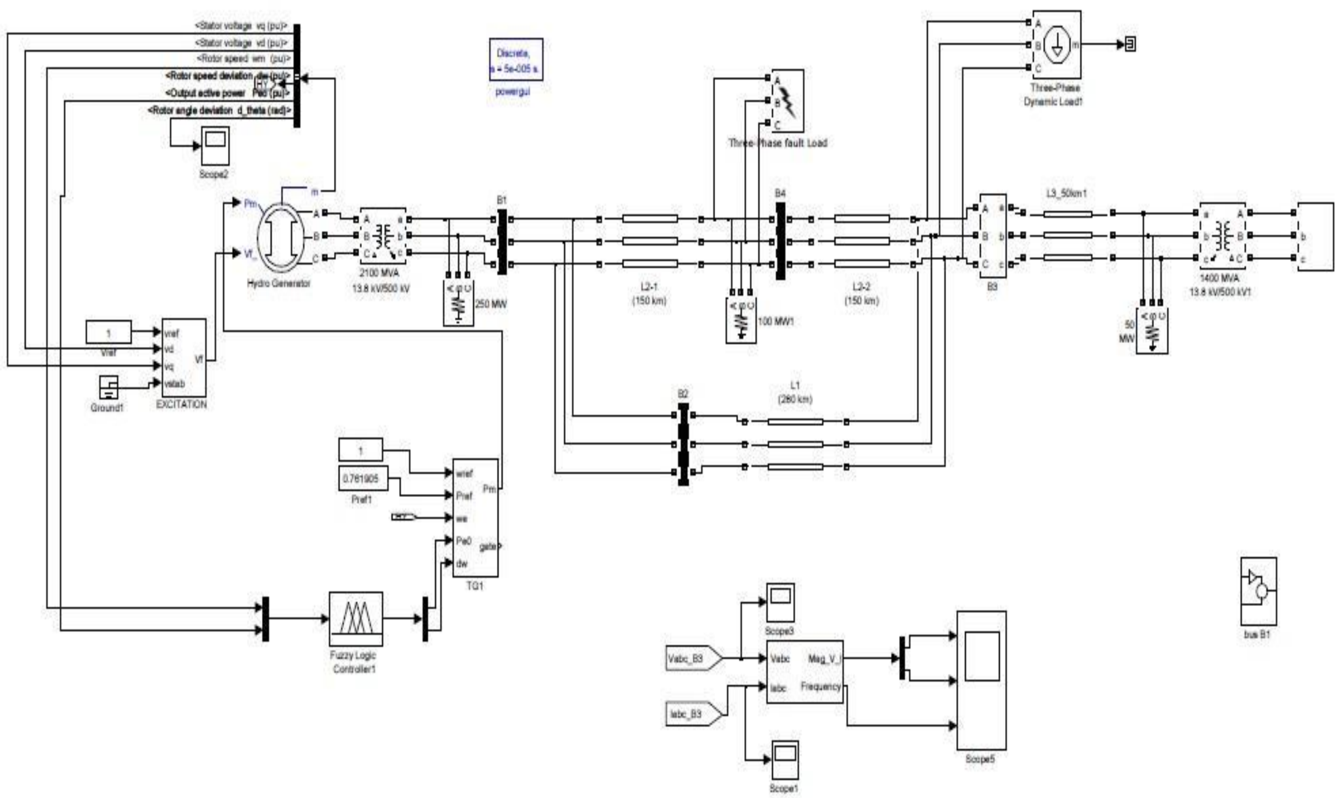


Fig. 2. Simulation Model

VIII. Simulation

The simulation model of the hydroelectric power plant was developed using the blocks available in the Matlab simpower tool. The hydroelectric power plant model is composed with the following components. The MATLAB simulation model is illustrated in below Figure 2 and the following main parameters of the proposed system [21]:

Excitation system link: Implements type 1 synchronous machine voltage regulator combined with an exciter. The output of the field voltage id blocks vfd in pu, to be applied to the Vf Simulink input to the synchronous machine block.

Three phase loads: Two loads are connected to the output of the synchronous machine Load 1 and load 2 implement the RLC series load.

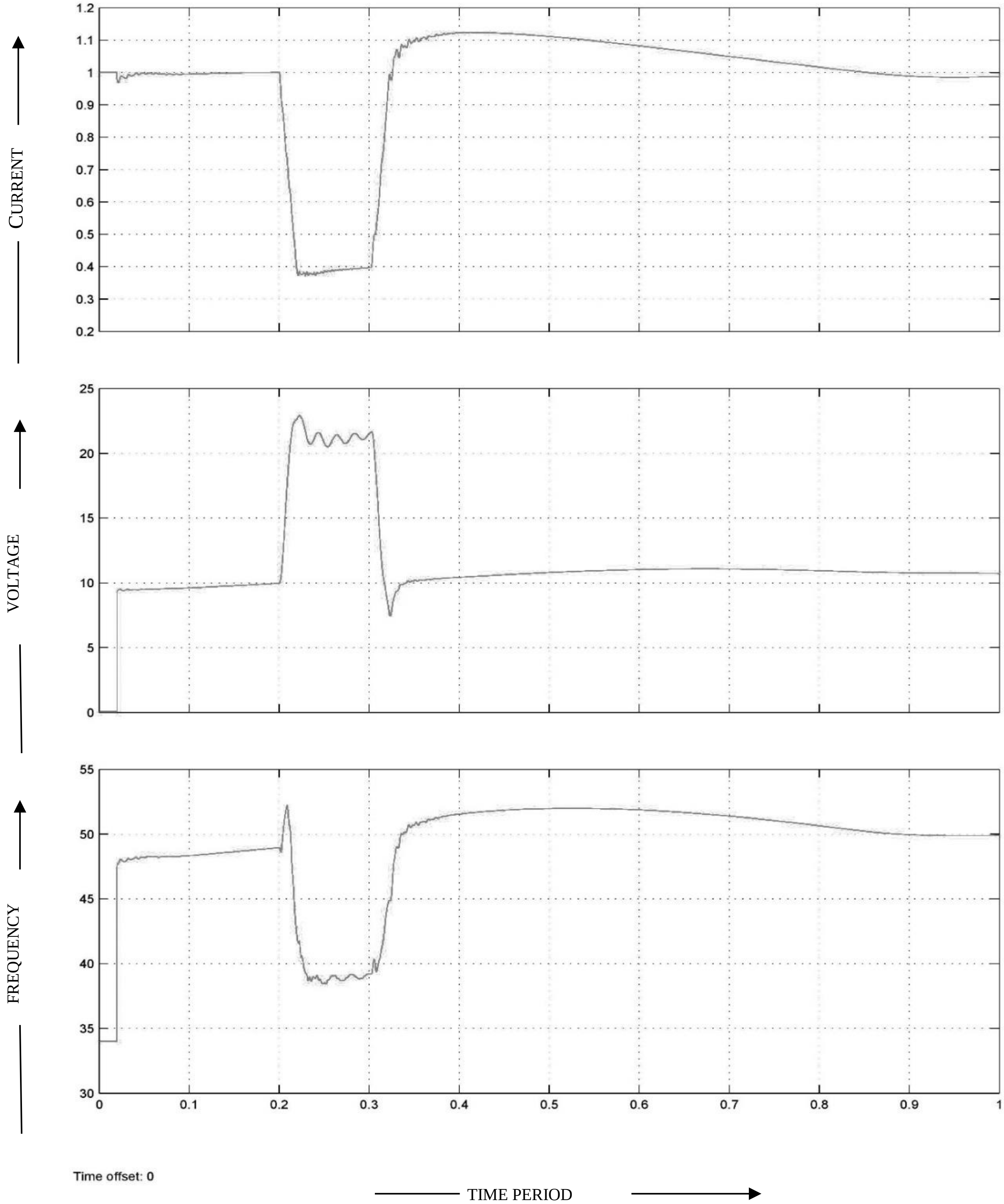
Turbine: The block represents turbine transfer function block having [-4 1] as numerator coefficient and [2,1] as denominator coefficient.

Fuzzy controller: This block represents the connection of the fuzzy controller that implements the fuzzy inference system preloaded in the workspace.

S and H block: This block S and H hold the signal. If the latch (buffer) input is selected, this block produces the value from the input at the previous time step.

IX. Simulation Working:

When a fault occurs in a line or network or when a dynamic load is placed, a command will be sent through the feedback loop to the fuzzy controller. Fuzzy in turn through excitation controls the hydro-generator to reduce the voltage drop and increase the current generation to stabilize the frequency. In



this way, the simulated model works to control the frequency variations during the variations.

Fig. 3. Simulink Output for Hydro Power Plant

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X. SIMULATION RESULT

To demonstrate the effectiveness of the fuzzy strategy, the simulation was performed. The performance of the closed loop system using a fuzzy logic controller is tested. The frequency deviations of areas 1, 2 and 3 for the three-area LFC system considering the communication delays are shown in Figure 3.

XI. HARDWARE PROTOTYPE

Since it is not possible to design a model to control load frequency, but it can be controlled with a prototype which controls the variations in load frequency. So, here we made a prototype working with generator coupled to control the load frequency variations as shown below in Fig. 4. A Step-down transformer is used to change the voltage from 230V AC to 12V AC. the voltage is supplied to the power board where the AC power is converted to pure DC power and the diode is also used in a board to indicate the power. For controlling the variation which happens in the range of the frequency a Fuzzy Logic controller is inserted with 12V DC power supply to atmega 8 microcontroller. To reverse the DC to AC, supply the output from the controller is reversed to an inverter. In the developed prototype we used a Step-down transformer to lower the voltage from 12V AC to 5V AC which provide input power to the load through the current transformer. An LCD is used to display the frequency range and the current is pushed according to the load.

When a frequency changes due to the voltage drop caused by extra is added, their variation is analyzed through the feedback loop. Then Fuzzy in turn through excitation controls the hydro-generator to reduce the voltage drop and by increasing the current generation to stabilize the frequency. Meanwhile we used an opto coupler to isolate electrical equipment to avoid harmful conditions. By this, the simulated model works to control the variations in frequency during the variations.

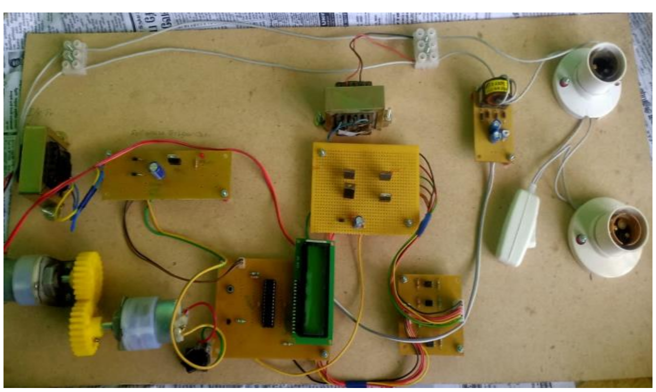

Fig. 4. Hardware Prototype

XII. RESULT

To demonstrate the effectiveness of the fuzzy strategy, the simulation has been carried out. The performance of the closed-loop system using fuzzy logic controller is tested and received the outcome as shown in Fig.5. Proposed system is also tested in varying frequency with single and multi-load.

The frequency of the plant is tested periodically during the generation of energy and the frequency is controlled using the fuzzy logic controller through feedback loop instantly. It has also been tested with varying position of the gate to maximize the water flow rate to satisfy the required load request as well as keep the frequency at the value nominal. The frequency variation is stabilized after the gate opening action performed by the fuzzy controller on the input side and the frequency has been stabilized by performing the corrective action in the proposed controller, and now the plant is able to satisfy the higher demand load, which is accurately shown in current and voltage waveforms and the correct frequency of the installation after adding the controller.

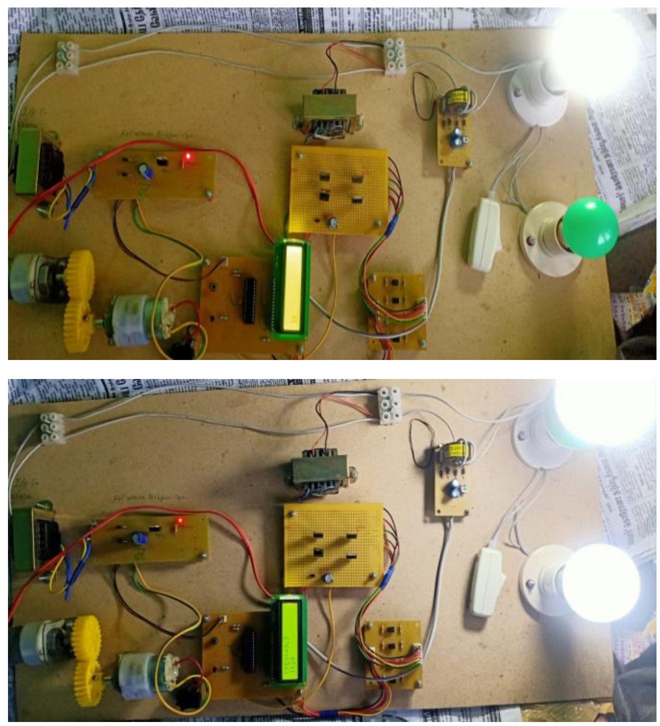

Fig. 5. Hardware Result

XIII. CONCLUSION

The new technique proposed for regulating the load frequency of the hydroelectric power plant guarantees a reliable efficiency. It is proposed in capable of keeping the frequency constant despite changing the user loads at any point of operation. The response of the fuzzy-based regulator is compared to the conventional PID-based regulator showed that the fuzzy regulator offered robust control [20], along

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with better response in system frequency control than the PID-based regulator.

On addition to that it reduces the waste of water by limiting the power on the load and it manages the available water in terms of consumer demand. At random and large load variations, the proposed control system maintains efficient dynamics as expected. The simulation results describes the feasibility and reliability of the proposed fuzzy control system, so far this work provides an important contribution in terms of controlling the hydroelectric power plants and provides guidelines for the choice of new controlling schemes for systems improvement.

XIV. Future Scope

For in future consideration, the fuzzy-based governor will be designed and developed to control the load frequency of Nerinjipettai barrage using simulation. We aimed to simulate a Simulink model with real-time values for the Nerinjipettai barrage.

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