International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 11 ǁ November 2013 ǁ PP.11-18

Hydro Hybrid Power Plant and Control System Feedback (Using regenerative principle)

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ABSTRACT**:** *This paper briefly explains about mini hydropower plant featuring prime components namely turbine, alternator and distribution system, with regenerative (feedback mechanism) using suction technique and control system.*

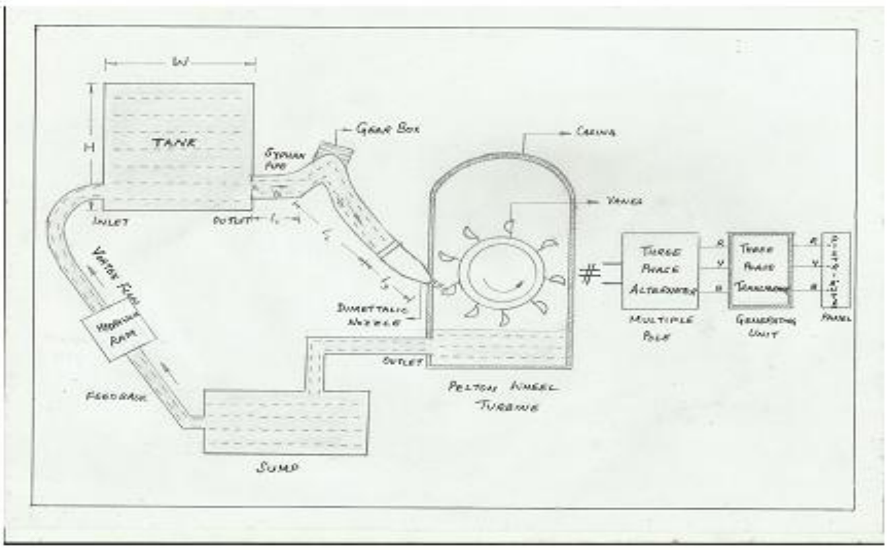
KEYWORDS: *syphan pipe; regenerative mechanism; control system; suction technique; distribution and feeder panel.*

I. INTRODUCTION

This paper elucidates the use of a miniature hydropower plant (using regenerative principle) so as to generate and distribute the electricity produced to a colony or a society of families. The setup constitutes: tank, turbine, alternator and distribution and feeder panel as primary parts and syphon pipe, nozzle and gear box as secondary parts. The tank is elevated to a height of 35-50 meters. The outlet of the tank is connected to 'Syphon pipe' with gear box assembly. The gushing water from the pipe moves the vanes of the 'Pelton wheel' turbine, causing the turbine to rotate. This mechanical output is coupled and fed as the input to the alternator with an objective to generate electricity and then to 'Shell type' transformer, successively. The transformer output is fed to distribution and feeder through control system mechanism. The water used in the turbine action is guided by pipes and stored in a sump, and thereby suction and regenerative mechanisms are used to feed back the water to the tank. The process turns out to be cyclic in nature, making it feasible, efficient and more importantly eco-friendly.

II. THEORY

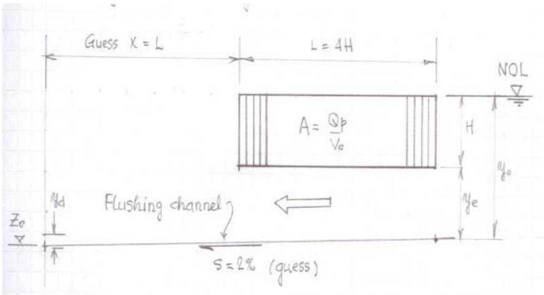
According to sources, rural areas require power of approximately (15-20) KW/day. Also when we consider urban areas, a 2 BHK flat system needs (0.75-1) KW/day approx. So let us consider a society having 20 such flats having a power requirement of 20KW/day with losses to be 25KW/day (maximum).Thus our motto is to generate 50KW/day (minimum).



III. COMPONENTS

1. Tank

The Tank is a permanent storage structure, situated at a height of (35-40) meters. The tank is cylindrical in structure and is made up of reinforced concrete and cement with a capacity of 500 gallons.



The approx. dimensions of tank will be 15ft*8ft*15ft. The tank will be filled with underground water, rain water from harvesting sump and the left over water from turbine by using regenerative and controlled mechanism. The Gross Head (H) is the maximum available vertical fall in the water, from the upstream level to the downstream level.

2. Syphon Pipe (Outlet)

This is the medium of sending water from tank to turbine. We will use a special high pressure pipe known as syphon pipe. The pipe has a curvilinear structure and bears very high pressure.The use of gear box is to reduce the damage of pipe due to high pressure. The summit point at the crest of the pipe is the point of maximum water pressure. As soon as the Valve at the inlet of turbine is opened, the water flows to the turbine. Flow Rate of water (**Q)**, and Head (**H)** play a vital role in syphon action.[2]

The syphon barrel dimensions are normally determined witht he provision that the Froude Number $\mathbf{N_{s=V/(gh)}^{1/2}}$ which should not exceed 0.8,where Ns=Froude Number, V=Velocity of flow(m/s), h=head(m)

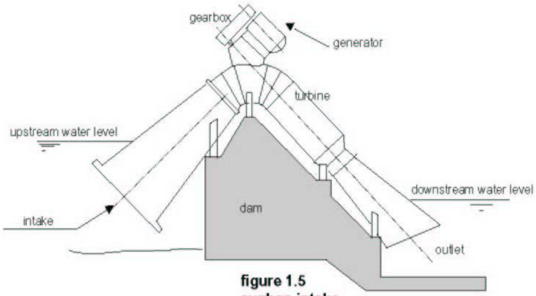
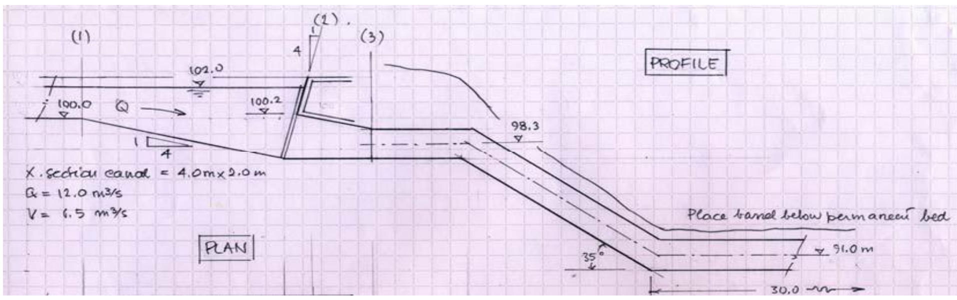
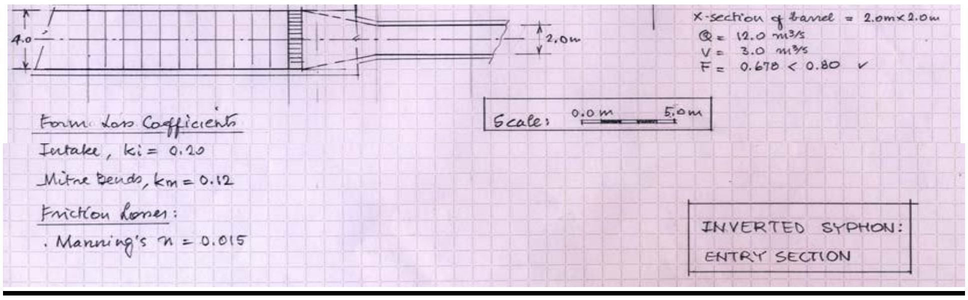


figure 1.5
syphon intake

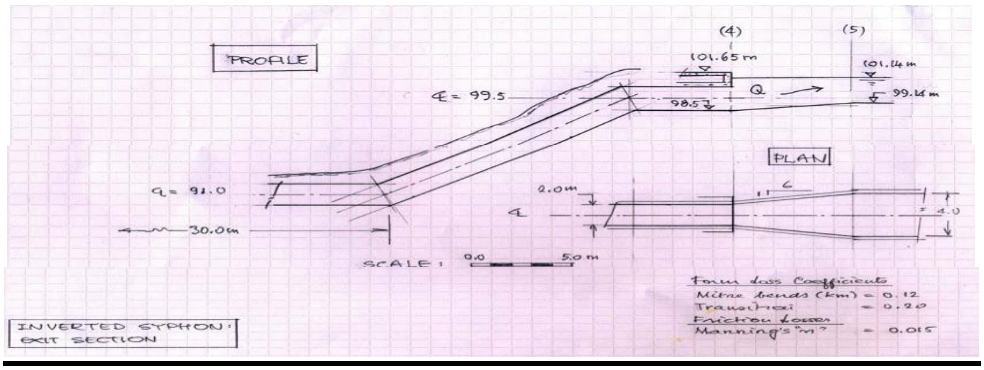
Layout of a typical inverted syphon

ENTRY SECTION





EXIT SECTION



3. Penstock

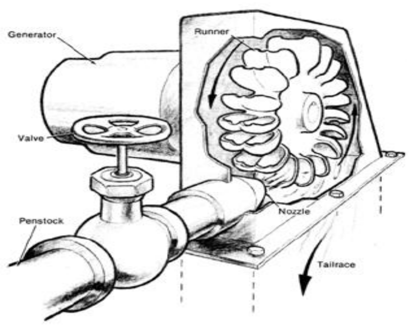
The main objectives of good design of Penstock are:

• To prevent entry of floating debris.
• To avoid formation of air entraining vortices.
• To minimize hydraulic losses

4. Turbine

Turbine Type	Head Classification		
	High (>50m)	*Medium (10-50m)*	*Low (<10m)*
Impulse	Pelton Turgo Multi-jet Pelton	Crossflow Turgo Multi-jet Pelton	Crossflow
Reaction		Francis (spiral case)	Francis (open-flume) Propeller Kaplan

Here we are using Pelton wheel Turbine.



Calculation of mechanical output power

The two vital factors to consider are the **flow** and the **head** of the water. The **flow** is the volume of water which can be captured and re-directed to turn the **turbine**, and the **head** is the distance covered by the water on its way to the generator.The quantity of water and distance covered by the water course depend upon the flow and head, respectively. Larger the value of head and flow, more is the energy available for conversion into electricity. These quantities affect the magnitude of electrical power produced.
In this research, we consider a **Head** of **30 metres,** a **high head** site.
Power = Head x Flow x Gravity

where power is measured in Watts, head in metres, flow in litres per second, and acceleration due to gravity in metres per second per second.

The acceleration due to gravity is approximately 9.81 metres per second per second - i.e. each second an object falls, its speed increases by 9.81 metres per second (until it reaches its terminal velocity).
Flow Rate (Q) is the volume of water flowing per second, measured in m^3/sec.
For small schemes, the flow rate may also be expressed in litres/second or 1 m^3/sec.

Equation for Average Flow Velocity
Pipe design is usually based on Manning's equation, which gives the average velocity of liquid flow in the pipe as follows:

$$\mathbf{V= (R_H^{2/3} * i^{1/2)} /n}$$

Where
V = average flow velocity (m/s)
R_H = hydraulic radius (m)
i = pipe slope (dimensionless)
n = Manning's roughness coefficient ($sm^{-1/3}$)

Average flow velocity indicates the fact that the velocity of liquid in the pipe is not uniform at various points in the cross section of the flow.
The roughness coefficient (**n**) is assumed to be independent of the level of liquid in the pipe and depends only on the roughness of the pipe and the nature of the liquid.

Table: Examples of values of the roughness coefficient used in Manning's equation when the liquid is water or an aqueous solution with the same viscosity as water.

Type of pipe	Manning's coefficient, *n* (s m-1/3)
Smooth plastic pipe	0.008 to 0.011
Vitrified clay pipe	0.011 to 0.017
Concrete pipe	0.012 to 0.016
Uncoated iron pipe	0.012 to 0.015
Corrugated pipe	0.020 to 0.030

Here,we use syphon pipe which is made up of uncoated iron whose Manning's coefficient, **n=0.012**

The **hydraulic radius,** R_H , is defined as

$$\mathbf{R_{H=} A_w/P_w}$$

where Aw= cross-sectional area of the flow;
Pw = wetted perimeter

$P_{w=}$ **(θ*d)/2** and $A_{w=(} d^2$ **(θ-sin θ))/8**
where θ = angle (in radians) and d = inside pipe diameter
Now
$R_{H=}$ d(**θ-sin θ)/4** and $\mathbf{V=[d^{2/3} (1\text{-}\sin\theta/ \theta)^{2/3} *i^{1/2}] /4^{2/3}*n}$

Substituting values of d, θ**,** i and n
We get V=76.3m/s

Equation for Flow Rate
The equation for flow rate is derived as follows from the above equation for average flow velocity. The flow rate is defined by:

$Q= V A_w$

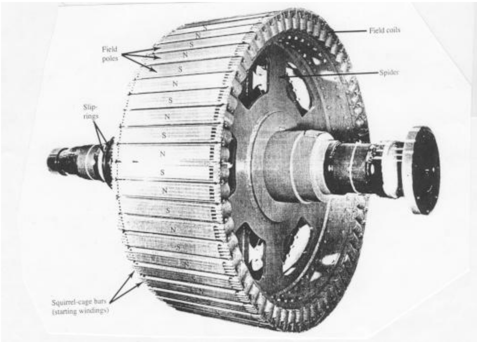
$Q=7.63*0.19=1.4497\ m^3/s$

$P=30*14.497*9.8=426.2118\ Kw$

This is the output power of Pelton Wheel Turbine.

5. Alternator

The mechanical output of the turbine is coupled with a 3-phase multiple pole alternator, thus converting mechanical domain to electrical domain.



'Capacity factor' is a ratio summarizing how hard a turbine is working, expressed as follows:
Capacity factor (%) =Energy generated per year (kWh/year) / (Installed capacity (kW) x 8760 hours/year)
The annual energy output is estimated using the Capacity Factor (CF) as follows[4]:
Energy (kWh/day) = P (in KW) *CF *24
Output Power by Alternator = (412.02*0.045*24) KW
=226.067 KW (approx.)
Efficiency (η) = (Output Power/Input Power) *100
= (226.067/426.2118)*100 = **53.05%** (approx.)

6. Transformer And Distribution Panel:

Transformer plays an important role to transfer electrical energy from generating station to the consuming center. In Indian transmission system we generally have 11KV Distribution Voltage which is then fed to the bus bar. Here we will use 3-phase Shell Type Transformer[4].
Output equation of three phase transformer

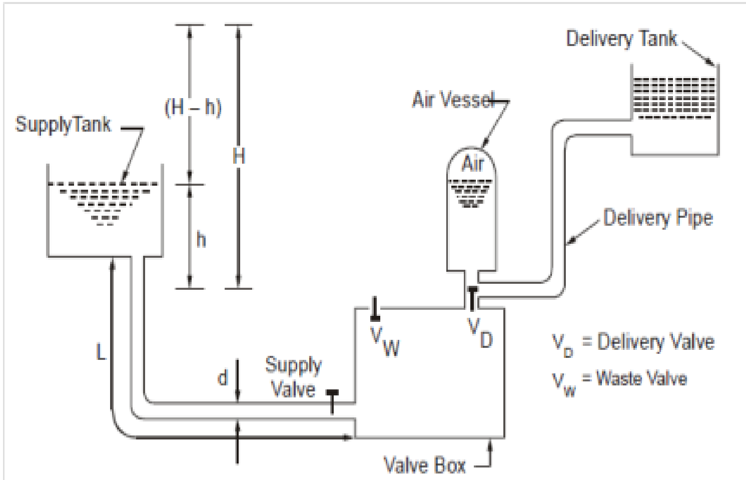
$$\mathbf{E=3.33fb_m}\delta A_w K_w A_i*10^{-3}(KVA)$$

This voltage is fed to primary distribution center by stepping it down to (11/33) KV. Electric power transmission is the bulk transfer of electrical energy: a process in the delivery of electricity to consumers. For this type of hydro power scheme, we select overhead transmission for its cost effectiveness.

Feeder is used at primary and secondary distribution end .By using a step down transformer at the distribution end, we will obtain 415V for 3 phase and 230V for 1phase consumers, respectively.

7. Feedback Mechanism By Using Hydraulic Ram

Water flows down the drive pipe from the source and escapes out through the impulse valve. When the flow of water past the impulse valve is fast enough, this flow and the upward force on the valve causes the valve to shut suddenly, halting the column of water in the drive pipe[1]. The momentum of the stopped column of water produces a sudden pressure rise in the ram, which will, if it is large enough, overcome the pressure in the air chamber on the delivery valve, allowing water to flow into the air chamber and then up to the header tank. The pressure surge or hammer in the ram is partly reduced by the escape of water into the air chamber, and the pressure pulse 'rebounds' back up the drive pipe producing a slight suction in the ram body. This causes the delivery valve to close, preventing the pumped water from flowing back into the ram. The impulse valve drops down, water begins to flow out again, and the cycle is repeated. . The air chamber is necessary to even out the drastic Pressure changes in the ram, allowing a more steady flow of water to the header tank. The air in the chamber is always compressed, end needs to be constantly replaced as it becomes mixed with the water and lost to the header tank. The ram is tuned to pump the greatest amount of water possible.

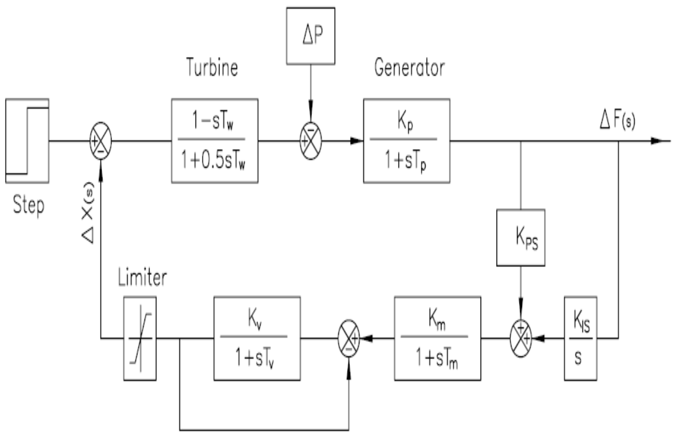


Flow Rate = 1440*(Efficiency. source flow rate)/ (lift by fall ratio)
=1440 *(0.6*S) / (L/F) gallons
=1440{(0.6) (1.8)}/(35/15)
= 444.97 gallons per day

8. Use Of Control System And Feedback Mechanism

Small hydro schemes are normally unattended and operated through an automatic control system. Because not all power plants are alike, it is almost impossible to determine the extent of automation that should be included in a given system[2].

A flow control approach for the speed control of hydro turbines. Power can be controlled by controlling the rotary motion of the spear valve. A servomotor is used to control the flow of water by controlling the rotational motion of the spear valve. . The suitability of servomotors for the control of small hydro power[2] A DC servomotor is an example of a type zero servo mechanism. We have considered the use of a DC servo motor for our model. Servo motors are suited for the control of small hydro power systems as they have a simple design, require less maintenance and are less expensive than conventional governors. PI controllers are used to further enhance their governing capability.



K_p-power system gain constant (Hz/s)
T_w - nominal starting time of water in penstock (s).
K_{is}- integral gain constant for servo system.
K_{ps}-proportional gain controller constant for servo motor

PID controllers are commonly used to regulate the time- domain behavior of many different types of dynamic plants. These controllers are extremely popular because they can usually provide good closed-loop response characteristics, can be tuned using relatively simple design rules, and are easy to construct using either analog or digital components[2].

A PID controller treats the error in three different ways: proportional, integral and derivative.
The approximate transfer function for the servo motor based governor is considered for the analysis and is given by

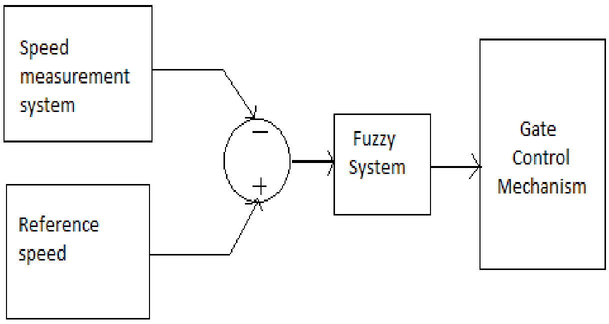
G(s) = (1/ (1+ sT1)) *(1/(1+sT2))

Where,
T_1 = mechanical time constant
T_2 = electrical time constant
In addition, unity gain is applied feedback.
A PI controller with following transfer function is super-imposed on servo motor based governor.

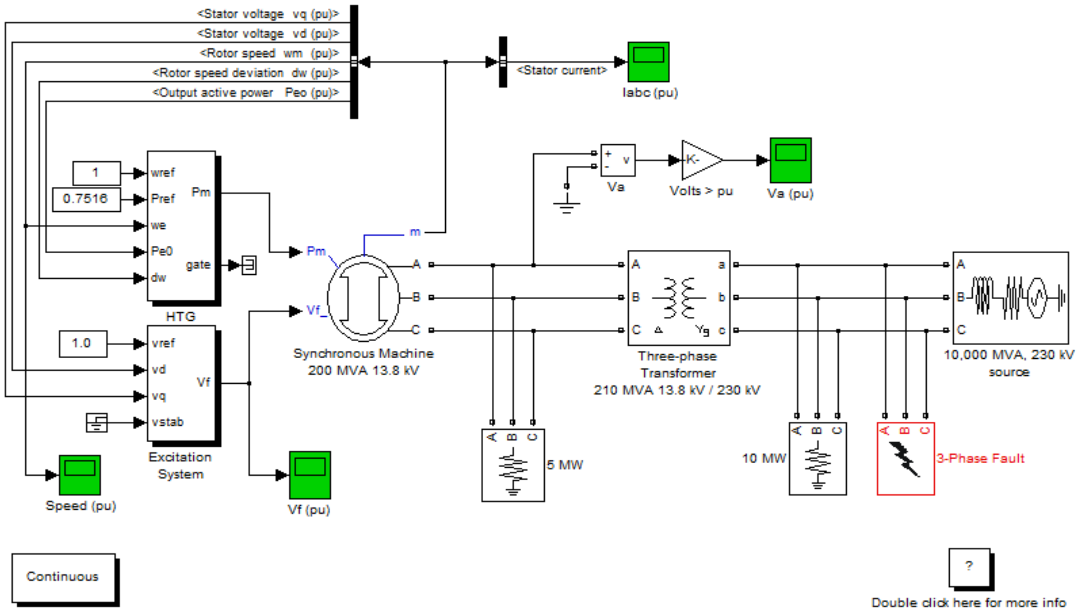
$G(S) = K_{pl} + K_i/S$

Where,
K_{pl} = Proportional constant,
K_i = Integral constant

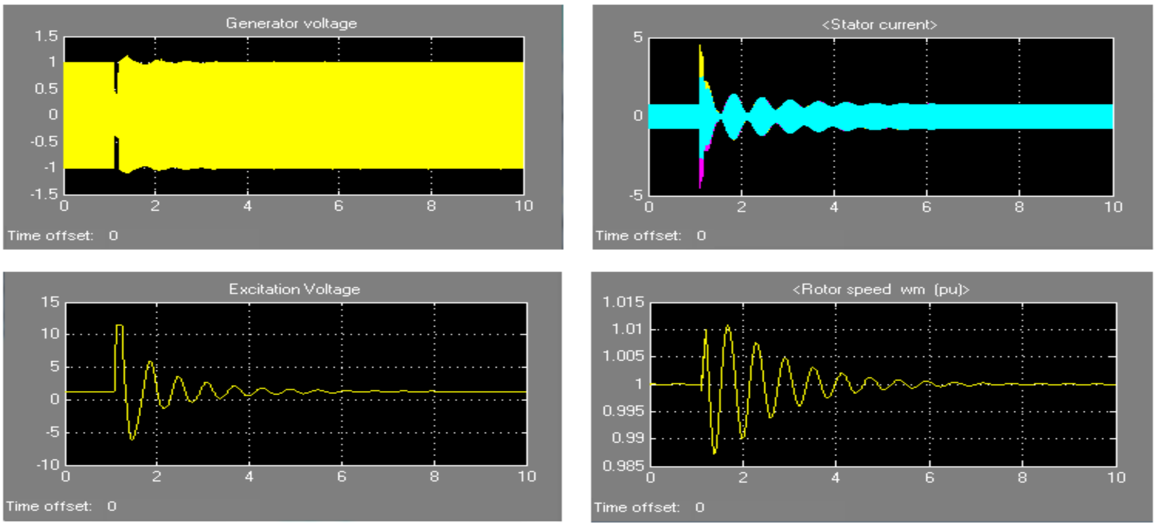
Fuzzy Based Turbine Governor for Hydro Power Plant
Fuzzy Control System
The design of the fuzzy controller depends on experience of a human expert. Present paper describes Fuzzy control system for small HPP are to establish turbine governor.Fuzzy control provides a formal methodology for representing, manipulating, and implementing a human's heuristic knowledge about how to control a system. The fuzzy controller is an artificial decision maker that operates in a closed-loop system in real time. It gathers plant output data, compares it to the reference input, and then decides what the plant input should be to ensure that the performance objectives will be met. We take the speed difference from the measuring system as an input for FIS.Rotor speed is compared with referenced speed to find speed deviation. This speed difference is input for FIS. The output control signal of FIS is control signal for valve opening mechanism. The gate opening mechanism consists of servomotor. This
control signal drives the servomotor which intern controls the gate opening. Fuzzy control system for defining the control signal of turbine gate opening mechanism is mentioned in present paper. Fuzzy Based System Suggested is shown in fig



Simulation Model of Power Plant



Simulation Result Of Short Circuit



IV. CONCLUSION

This work has proposed a novel technique of power generation using flow control. By constructing a prototype of hydro hybrid power plant using control system mechanism, we can serve effectively to rural as well as urban areas and can bring revolution in the current trend of generating electricity. Towards the development of this technique, the suitability of servo motor as a governor for small hydro power plants was established. These simulations have demonstrated the suitability of the proposed model for the control of small hydro power plants.

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