Modeling and Simulation of Hydro Power Plant by Using MATLAB

Harish D Mude [1], Manjusha D Hedau[2], Akash A Gophane [3],

[1] *Assistant Professor at Department of Electrical Engineering Jawaharlal Darda Institute of Engineering and Technology, Yavatmal,Maharastra India*
[2]*Assistant Professor at Department of Electrical Engineering*
Jagadambha College of Engineering and Technology Yavatmal,Maharastra India
[3]*Assistant Professor at Department of Electrical Engineering Jawaharlal Darda Institute of Engineering and Technology, Yavatmal,Maharastra India*

Abstract :-*The demand of electricity increases day by day. The hydropower plant becomes the best source of electricity on the earth. It is produced due to the energy provided by moving or falling water. The cost of electricity remains constant over the year. Because water is a natural source of energy present on the earth. About 71% area of earth is surrounded by the water. So producing electricity with water is the best way to keep environment – ecofriendly. The hydropower plant model was developed using MATLAB/Simulink software.*

The plant consist of hydro turbine connected to synchronous generator, which is connected to public grid. The dynamic response of the system to the disturbances on the system network was studied. A three phase to ground fault was introduced in the model at 0.2 sec and cleared at 0.4 sec. The simulated result shows that the generated voltage quickly regained its stability on the removal of fault the stator current went into transient after the fault was cleared and become stable at 0.6 sec. The excitation voltage also regain its stability but it was slower and the speed of the rotor was out of stable after the occurrence of the disturbance on the system. The result shows that perfect generation of energy to resist the fault.

Key Words —Hydraulic Turbine, Penstock, Governor, Synchronous Generator, System Simulation

1.INTRODUCTION

Energy is one of the most fundamental elements of our universe. It is inevitability for survival and indispensable for development activities to promote education, health, transportation and infrastructure for attaining a reasonable standard of living and is also a critical factor for economic development and employment. In the last decade, problems related to energy crisis such as oil crisis, climatic change, electrical demand and restrictions of whole sale markets have a risen world-wide. These difficulties are continuously increasing, which suggest the need of technological alternatives to assure their solution.

One of these technological alternatives is generating electricity as near as possible of the consumption site, using the renewable energy sources that do not cause environmental pollutions such as wind, solar, tidal and hydro-electric power plants. Hydro-electric power is a form of renewable energy resource, which comes from the flowing water. To generate electricity, water must be in motion. When the water is falling by the force of gravity, its potential energy converts into kinetic energy. This kinetic energy of the flowing water turns blades or vanes in a hydraulic turbines, the form of energy is changed to mechanical energy. The turbine turns the generator rotor which then converts this mechanical energy into electrical energy. The power generated from falling water has been harnessed in various applications such as milling grains, sawing wood and pumping water for irrigation. The slow-moving water wheels were used to harness the mechanical power from flowing water. The design and efficiency improvements made to these early water wheels led to the rise of the hydro-electric turbines. The first hydro-electric power systems were developed in the 1880's. According to the international energy agency (IEA), large-scale hydroelectric plants currently supply 16% of the world's electricity. However, such kind of projects requires tremendous amounts of land impoundment, dams and flood control, and often they produce environmental impacts.

The water at head have potential energy when it flows through the penstock it has high speed and this fast flowing water. When arrives at turbine, it rotates and produce kinetic energy. This kinetic energy then supply to the generator which is connected to the turbine by the shaft. The generator converts the kinetic energy into the mechanical energy.

2.HYDRO TURBINE GOVERNOR

Hydro power plant is the conventional source of energy. It has basically its two main sections, firstly the mechanical part of the plant which includes hydraulic turbine, penstock, controller, hydraulic servo motor, control valve etc. Second part of the plant is electrical section which mainly consists of generator and load.
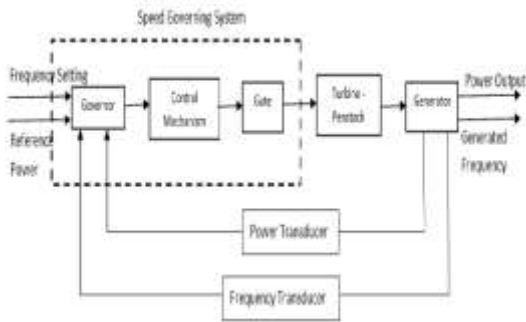
Fig 1 Functional Block Diagram of a Hydraulic Power Plant

The combined form of hydraulic turbine, controller and hydro-electric servo system is known hydro turbine governor. In order to explain the mathematical modelling of hydro turbine governor, this chapter is introduced.

Figure 1 shows a complete block diagram of hydro power plant. The stored water at certain head contains potential energy. This energy is converted to kinetic energy. When it is allowed to pass through the penstock, this kinetic energy is converted to mechanical energy (rotational energy) which allows water to fall on the runner blades of the turbine. As the shaft of the generator is coupled to the turbine, the generator produces electrical energy by converting the mechanical energy into electrical energy. The speed governing system of turbine adjusts the generator speed based on the feedback signals of the deviations of both system frequency and power with respect to their reference settings. This ensures power generation at synchronous frequency.

3. MODEL OF HYDROPOWER PLANT

An extensive review of the modeling of hydropower plant is handled at this level with the help of a model of hydraulic turbine designed by IEEE working group (1992), [21] under Matlab simulation software and available on the Mathworks website, [18]. The model is first described and further modified and simulated. The Hydraulic Turbine and Governor block implements a nonlinear hydraulic turbine model, a PID governor system, and a servomotor as described in figure 2.
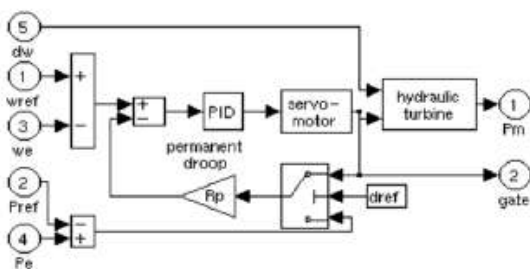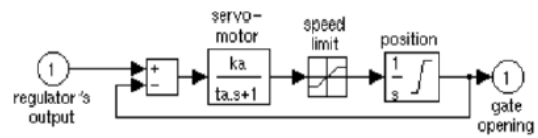

Fig 2: Typical model of hydropower plant

The hydraulic turbine is modeled by the nonlinear system illustrated in figure 3
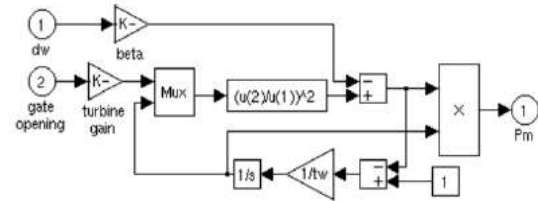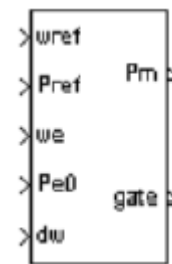

Fig 3: Nonlinear model of hydraulic turbine

The gate servomotor is modeled by a second-order system shown in figure 4.

Fig 4: Model of Gate Servomotor

Fig 5: Summarized model of hydraulic turbine under Matlab/Simulink

Pref: Reference mechanical power in pu.

- **ωe**: Current Speed of Machine in pu.

- **Pe0**: Electrical power of the machine in pu. This input can be left unconnected if the gate position is used as input to the feedback loop instead of the power deviation.

- **dw**: Speed deviation, in pu

- **Pm**: Mechanical power Pm for the Synchronous Machine block, in pu.

- **Gate**: Gate opening, in pu.

With consideration to all the components described previously in figures 2, 3 and 4, the final model of figure 5 is built and simulated under Matlab/Simulink. The model consists of a synchronous machine associated with the Hydraulic Turbine and Governor (HTG) and Excitation System blocks. This model is extracted from Matlab 2012 examples, [22] and modified to serve as an extensive review on the hydropower plant. The model is made of a 250 MVA, 14 kV three-phase generator with a nominal speed of 112.5 rpm that is connected to a 161 kV network through a Delta-Y transformer rated 300 MVA.

4.GENERAL REPRESENTATION OF SUB-MODEL

In general, linear models are used for small signal performance of turbine whereas non-linear models are more appropriate for large domain signal-time simulations.

On the other hand several models were not made analytical but consisted of simulated systems under various software
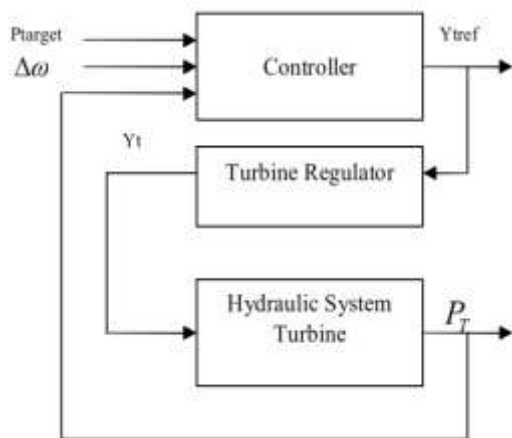

Fig 6: general representation of sub-models

Where

- Ptarget: Power set-point

- ΔW: Deviation of Energy

- Ytref: Set-point position governor guide vane

- Yt: Position governor guide vane

- PT: Power of the turbine

For instance, the model presented by Nassar (2009), [16] was built in Simulink and consisted of the following dynamic sub-models: controller, hydraulic and mechanical system, turbine regulator. Figure 6 presents the block system of the entire model with its sub-systems.

The type of turbine is Francis with a rated power of 300 (MW), a rated flow of 218.5m3/s and a rated head of 151.2m. Power generation and speed control model have been further modeled analytically and simulated. Such system is more adapted to increasing power generation than the analytical model because it is built on feedback that are solution to high level differential equations that best describe the dynamic nature of the flowing water. The controller includes artificial intelligence such as PID control.

5.WORKING MODEL

In this simulation we use feedback close system at the synchronous generator. When the input supplies to the generator the error can be remove by using close loop feedback system by PID controller. In this model a bus bar is

present. At that the stator voltage of quadrature axis, the stator voltage of direct axis, rotor speed deviation and output active power are present. The excitation voltage is used to supply the power to the synchronous generator. There are three scope are present which represents three characteristic such as speed, output voltage and excitation voltage with respect to time.

Here a transformer is used to step up the voltage at transmission line. So that we can achieve the increased load demand and then the supply is given to the public grid. One conversion is use to converts volt to pu value. At steady state condition the system works properly. But to check the response at faulty condition we introduced a three phase to ground fault into the system at t=0.2 sec and fault clear at t=0.4 sec. when fault occur the output voltage changes from 1 pu amplitude to 0.4 pu and speed changes from 1 pu to 1.01 pu and excitation voltage increase highly from 1.5 pu to 11.5 pu which causes positive response to the system.

Because excitation voltage produces the flux which induced the E.M.F into the system which help us to return back the output voltage into its original position. The speed is controlled by the governor system. Automatically the excitation voltage drops and continues with oscillation in order to main the output voltage can start after the fault was removed at t=0.4 sec the system quickly regain stability with an output voltage 1 pu which is equivalent to the previous steady state value. Automatically the excitation voltage drop and continue with oscillation in order to maintain the voltage constant. It can be realised that the speed also oscillate around and average value of 1 pu. The oscillation of the speed took longer time to stabilize as compare to the voltage and this may be due to the rate of value opening/ closing the governor system.
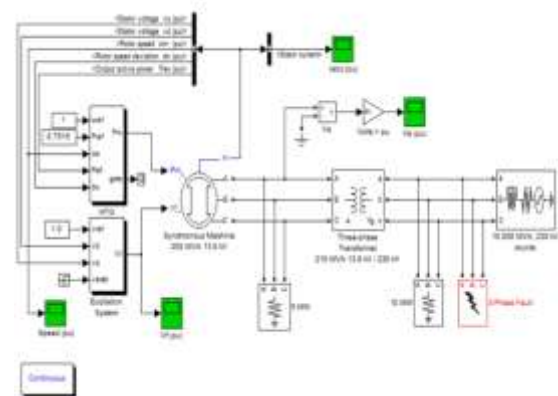

Fig 7 :Modeling And Simulation Of Hydropower Plant By Using Matlab

6.RESULT

To analyse the simulation results, three graphs have been plotted. The firstone is speed characteristics second is output

characteristics and third one is the excitation voltage with respect to time. The reliability of the hydropower plant can be tested if the fault occur in the system then the plant should be overcome that fault quickly and effectively. For this, we introduced a short circuit fault into the system in order to analyse its response. A three phase to ground fault is introduced in the system at t=0.2 sec in steady state condition with nominal speed of 1 pu, an output voltage of amplitude 1 puand an excitation voltage is about 1.5 pu.

When a three phase to ground fault is introduced in the system at t=0.2 sec a significant drop in the output voltage which becomes 0.4 pu in amplitude. The excitation voltage increased highly to an average of 11.5 pu and the speed also increased slightly to 1.01 pu. The increase in the excitation voltage is a very positive response of the system. Because it lead to an increase in the flux value which further relates to the induced voltage by the famous equation

$$E = K\emptyset\ N$$

Where,

K = constant related to the machine.

$\emptyset$ = The flux per pole.

N = the speed.

The above equation shows that the induced voltage is proportional to the flux and therefore, an increase in the flux will have effect of bringing the voltage back to its previous value as it has highly reduced by the fault.

When induced voltage is increases the speed can also be increase and this is controlled by the governor from the opening and closing of wicket gates. However increased in speed did not yield a big change as it can be observed that the increase in the speed was only about 0.01 pu due to the fact that it is dependent on the availability of the flowing water.
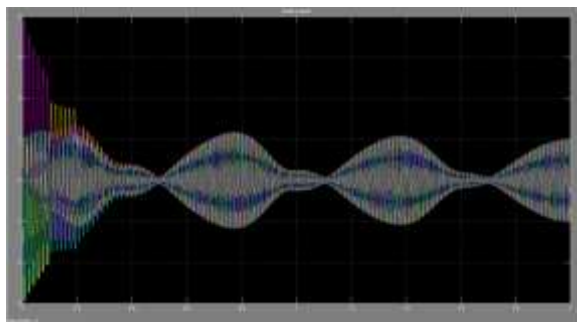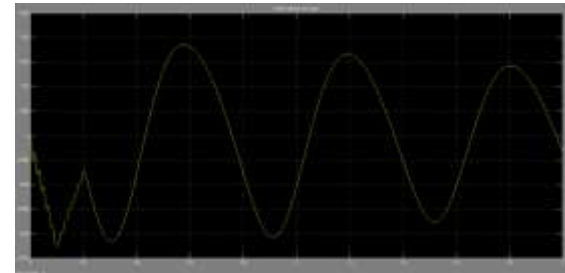

Fig 8 : output of model (Iabc) (pu)
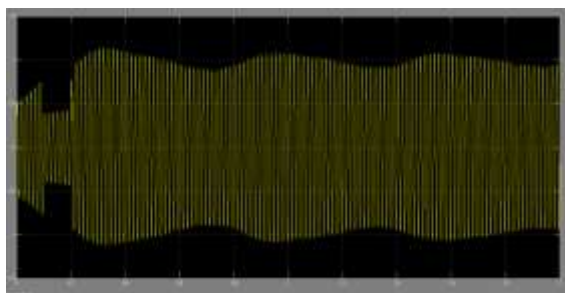
Fig 9 :output of model (va) (pu)
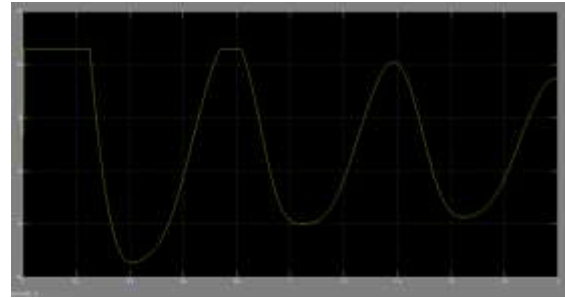
Fig 10: output of model (vf) (pu)

Fig 11: output of model (Speed) (pu)

7. LITERATURE REVIEW

- Li et al. [8] developed a model of the hydraulic turbine and governor to represent the generation of hydropower. Real – time simulation were carried out on single machine infinite bus to validate the nodal performance moreover, the proper transfer of MAT/SIMULINK model of real- time simulation environment was also performed.
- siJahnviTiwari , Ashish Kumar Singh, Ashish Yadav and Rakesh Kumar introduced the hydroelectric power plant using MATLAB model for chemical control.
- Moosasattoof describe the dynamic model of the two main components of hydro power plant, the synchronous generator and the hydro-turbine governor. Detailed mathematical representation of the hydro-turbine penstock also present in this paper. This paper discuss the use of SIMULINK software of MATLAB in the dynamic modelling of hydropower plant component.
- Dr. D. Vimalakeerthy, humaid Abdullah Fadhi, Al-Hinai introduce an improvement design of micro electric hydropower plant. in this paper an attempt has mode to develop.

8. CONCLUSION

SIMULINK is a powerful software package for the study of dynamic and non linear system. This model were revealed inadequate for the proper modelling of the dynamic aspect of flowing water, gate controlling and others. The common objective of this modelling was changes in speed variation, the generated power and its stability and dependency on input

parameter such as opening and closing of gate (which is related to the speed and amount of water flowing to the turbine), penstock, turbine and generator modelling. The review show that modern system adopt software simulation approach among with MATLAB / SIMULINK software.

The result is obtained in terms of the stability of speed and output voltage by overcoming the fault. A three phase to ground fault was introduced at 0.2 sec, the system output voltage quickly becomes stable after the removal of the fault at t = 0.4 sec showing to the excitation voltage that was maintained high because of the PID control system. However, in reality, the rise in excitation voltage is also limited to the capacity of the existing source of supply, in case of this simulation, the rise in excitation is about 10 pu which is actually very difficult to attain in real conditions. An additional rise in speed can help to improve upon the problem but the control system established in the simulation show that the rise in speed were negligible, it is hence for the recommended that the governor control system should be improved upon with modern control techniques such as fuzzy logic and this should be embedded in in nature models of hydropower plants.

References:

[1] Karady, G. G and Holbert .K>E 2013, electric generating station. In Electric energy conversion and transport, an interactive computer based approach, second edition, john Wiley &sons

[2] Snaghizadeh, R.A, Jazebi.s and Vahidi, B. 2012 Modelling Hydropower plants and turning hydro governance as an educational guideline International Review on modelling and simulations (I.R.E.M.O.S) Vol.5, N,4

[3] IEEE Working group. 1992. Hydraulic turbine and control models for system dynamic studies. IEEE Trans on power system, 92:1904-15

[4] Singh, M and Chandra, A. 2010. Modelling and control of isolated micro hydropower plant with battery storage system National Power Electronic Conference, Roorkee, India.

[5] Ramey, D. G. and Skooglund, J. W. 1970. Detailed hydro governor representation for system stability studies. IEEE Trans on Power Apparatus and Systems, 89:106–12.

[6] Bhaskar, M. A. 2010. Non Linear Control of STATCOM. IEEE Internaltional Conference on Recent Trends in Information Telecommunication and Computing, pp. 190-195.

[7] Luqing, Y. E., Shouping, W. E. I., Malik, O. P. and Hope, G. S. 1989. Variable and time varying parameter control for hydroelectric generating unit. IEEE Trans Energy Conv, 4:293–9, Wozniak.

[8] Nassar, I. A., Weber, H. 2009. Dynamic Model of Unit 1 of Ataturk Hydro Power Plant in Turkey. 13th Middle East Power Systems Conference, MEPCON' Assiut University, Egypt

[9] D. E. Hesmondhalgh and E. R. Laithwaite, Method of analysing the properties of 2-phase servo-motors and AC tachometers, Volume 70, 1987-1993.

[10] P. Drtinaand and M. Sallaberger, Hydraulic turbines—basic principles and state-of-the art computational fluid dynamics applications, *ProcInstnMechEngrs*, Volume 213 (C), 1999.

[11] G. Singh and D. S. Chauhan et al., Simulation and modeling of hydro power plant to study time response during different gate states, *International Journal of Advanced EngineeringSciences and Technologies*, Volume 10 (1), 042 – 047 (2011).

[12] A. Kaabeche, M. Belhamel and R. Ibtiouen, Optimal sizing method for stand-alone hybrid PV/wind power generation system, *Revue des Energies Renouvelables SMEE'10 BouIsmail Tipaza*, 205 – 213 (2010).

[13] L. N. Hannett, B. Fardanesh, Field tests to validate hydro turbine-governor model structure and parameters, *IEEE Transactions on Power System*, Volume 9(4) (1994).

[14] X. Zhang, M. Zhang, An adaptive fuzzy PID control of hydro-turbine governor, *International Conference on Publication Year: 2008*, 4139 – 4143(2002).

[15] Singh, G., and Chauhan, D. S. 2011. Simulation and Modeling of Hydro Power Plant to Study Time Response during Different Gate States. (IJAEST) INTERNATIONAL JOURNAL OF ADVANCED ENGINEERING SCIENCES AND TECHNOLOGIES Vol. No. 10, Issue No. 1, 042 - 047

[16] Prillwitz, F., Al-Ali, S. E., Haase, T., Weber, H. and Saqe, L. 2007. Simulation Model of the Hydropower plant Shkopeti. 6th EUROSIM Congress on Modelling and Simulation, Ljubljana, Slovenia

[17] . IEEE Working Group on Prime Mover and Energy Supply Models for System Dynamic Performance Studies. 1992. Hydraulic Turbine and Turbine Control Models for Dynamic Studies. Transactions on Power Systems, Vol.7, No.1, pp. 167-179.