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Research paper

PID Control of Hydraulic Turbine with Excitation and Synchronization Systems

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Abstract

Hydroelectric energy is a major source of renewable electricity in the world. The industry is continuously searching for ways to improve the efficiency and reliability with which it produces energy. Here suggested a PID approach to turbine governor by utilizing human experience. The simulation model of Hydro Power Plant was constructed based on mathematical equations that summarize the behavior of the power plant. The simulation model of power plant is useful in stability studies. Simulation models are suitable for use in large scale system stability studies. The PID controller is designed and tested for three phases to ground fault by simulations which are reported in this paper. Results obtained by simulation show the rapidity and robustness of the PID controller. This controller is able to maintain the generated electrical power characteristics in spite of the changing user load.

The invention and design of stabilized system means the ability of the system working with different load and fault. Controlling voltage system represent control an active power in electrical power grid by increasing and decreasing the generator voltage. In this paper completed models test that stability and flexibility of the Synchronized generator with over exciter, and under exciter by Governor and Excitation systems.

Keywords: *distributed generation, synchronous generator, active power, voltage regulator, speed regulator.*

1. Introduction

Hydro-electric energy is the most important renewable energy in the world [1]. It provides energy to various loads. User load requires a uniform and uninterrupted supply of input energy. The load demand varies continuously. It affects the terminal voltage and frequency. The objective of the control strategy is to generate and deliver power in an interconnected system as economically and reliably as possible while maintaining the voltage and frequency within permissible limits. Hydro-electric power station is equipped with hydraulic turbine governor and excitation control. Hydraulic turbine governor controls the frequency intern speed of the turbine according to load variation. Reactive power requirement is controlled by Excitation system [2]. The control of Active and Reactive power keeps the system in the steady state [3]. Several controllers such as PID controller, intelligent controller, Adaptive controller have been applied for the turbine governor of hydroelectric power plant [6- 11]. However conventional PID controllers are not suitable for such complex high order time delay, nonlinear system process. The fuzzy logic was an important technology and a successful branch of automation and control theory, which provides good results in control of power system. The fuzzy logic is first presented by Zadeh in 1965. It is widely used for nonlinear, complex, renewable energy, modeling and power electronics [12, 13].

"Hydro Power Plant" simulation model of hydropower plant was developed by utilizing the blocks available in MatLab simpower tool. The hydropower plant model is made up of following components [2], [4-5]

1. Excitation control
2. Three phase Transformer
3. Three phase Loads
4. Three phase Short Fault
5. Three phase source
6. Synchronous Generator
7. Hydraulic Turbine Governor [5]

Electric power systems can be defined as the systems which can deliver energy in real-time. It means the ability to generate, transport and supply power at the term you push button to turn the light on. The systems of electric power are not storage arrangement system, like gas and water systems. Instead, generators supply energy according to the need of request. The process of generation means producing electrical energy in the power plant then convert it into the power high or low voltage depend on sending or receiving case.

The power plants produce energy as Hydraulic, chemical, solar, wind, geothermal, nuclear, heat, mechanical, and other.

The Transmission lines transport electrical energy over long distances to the distribution places with high voltage power.

In the last, substations convert this high voltage electrical power into lower voltage power by using stepdown transformer. The transmission lines are more convenient for the delivery of electrical power energy to its terminus, where it is once more altered for residential, commercial, and industrial consumption.

2. Main body

To obtain a stable operation with alternating current AC power system, the voltage, and frequency must be approximately with constant values or varying with a partial and under control mode according to oscillating of active or reactive loads. Active power flowing depends on the energy coming to prime mover, and speed of the synchronous generator (SG). In contrast, control reactive power is linked to the voltage at the terminal. Excessively electric active power load would cause speed breakdown, despite the fact that more reactive power load would effect voltage failure. To remain constant with load generator the frequency may be controlled by its speed, if actions remain signal on the load terminal, or definitely are the over strong in definite area of a power system, this may be called isochronous control. On the contrary, when the SG is portion of a big system of power, and electric generation is collective by two or more SGs, frequency, and speed. The speed could not be controlled to stay constant because it would prevent generation division among several SGs, by control with speed sag may solve this problem in order to allow reasonable generation of distribution. Automatic generation control (AGC) deal out the generation duty among SGs, according to that, the speed control system of each SG controls its speed or frequency with sufficient speed sag so that preferred generation allocation is achieved. In the figure (1) all the following apparatuses can be distinguished:

1. Speed governor and the excitation system.
2. Prime mover/turbine and SG.
3. Voltage, current, and speed sensors.
4. Added PSS to the voltage controller input.
5. Power system electromagnetic field (emf), Es, transmission line (XT), step-up transformer.

Excitation system consists of equipment used to provide DC field power for a synchronous machine, by including all control and protective functions to the specific field [1]. We define the portion of this system to provide power to main field as the "exciter" Figure (2). This is the sours of the main field voltage, Efd and current, Ifd. The exciter may be a rotating power amplifier like an AC or DC generator. If the exciter is an AC type, then the output must be rectified to DC. Either stationary or rotating rectifiers accomplish the conversion from AC to DC.
The exciter also may be a static device with some form of solid – state converter/controller. The amount of power required to provide the magnetic field to the generator to operate. The verity of magnetic field different from machine to machine. A very rough rule of thumb is that it takes typically 1% of the machine's output power to excite it at rated power and rated power factor.

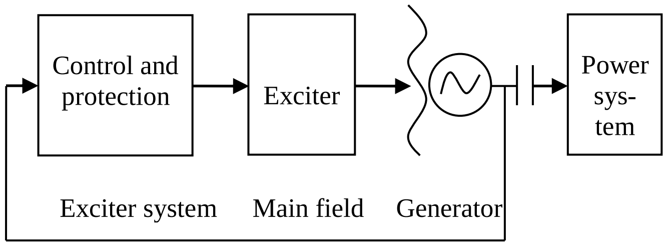

Fig. 2: Power system /Generator / Excitation System

The percent of machine output required to excite the field tends to be lower for high-speed machines driven by gas or steam turbines and higher for low-speed machines, such as those driven by hydraulic turbines. The Automatic Voltage Regulator is responsible for controlling and regulating the output of the synchronous machine. The AVR works through the exciter. In some cases, the

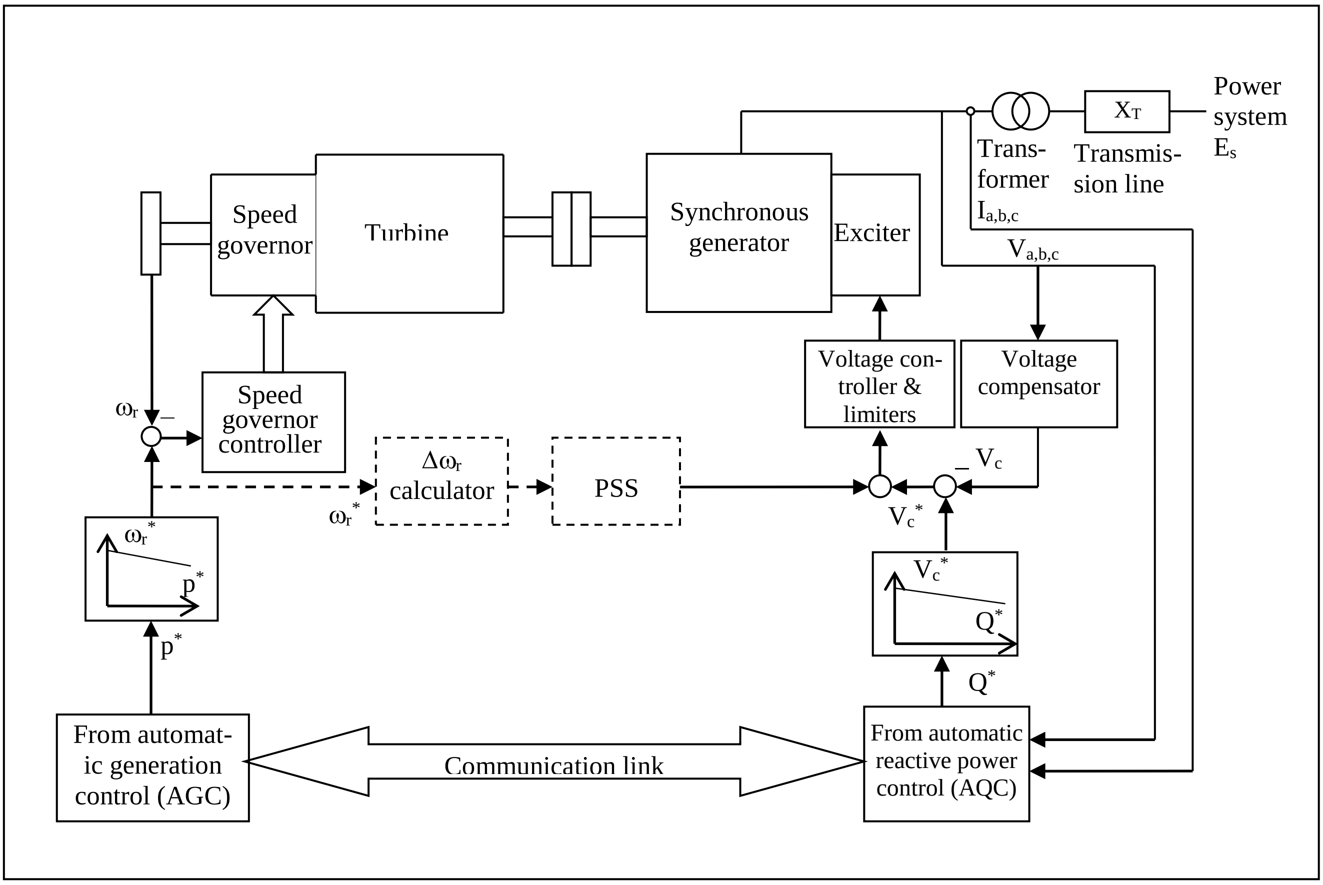

Fig. 1: General synchronous generator control system

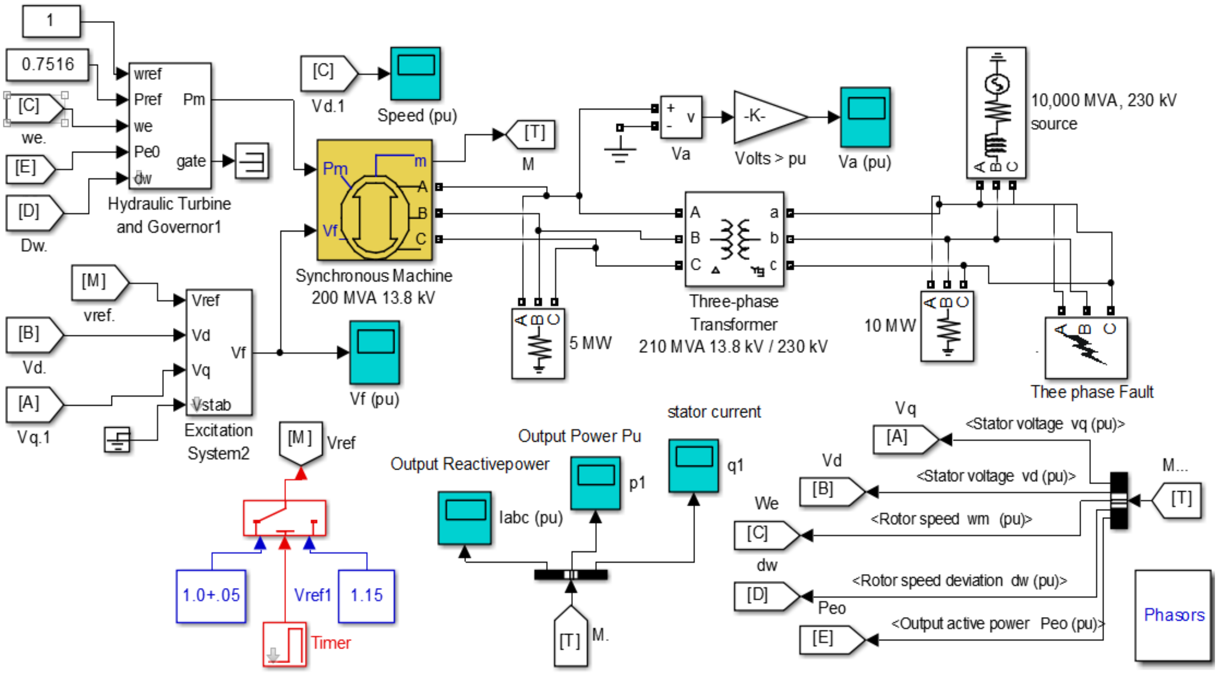

Fig. 3: Hydraulic turbine with Syn. generator

AVR is a part of the exciter; in other cases, it is a separate device. The pilot exciter is the device that supplies power to the AVR.

Model of synchronous generator is connected to hydroelectric turbine (Fig. 3). This model represented by a three phase generator has rated apparent power is 200 MVA, with 13.8 kV voltage and 112.5 rpm speed. Generator is connected at time t=0.1 s, to the three-phases transformer (210MVA, 13.8 kV/230 kV), whose terminals are connected in delta. Three-phases ground fault take place on the 230 kV buss, the fault is clarified at time t=0.2s. During this sample, this system could be initialized in order to start in steady state with the generator supplying 200 MW of active power and observe the dynamic response of the machine and of its voltage and speed regulators. The design of the PID controller depends on the experience of a human expert. Present paper describes PID control system for small hydroelectric power station are to establish turbine governor. 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. [14] We take the speed difference from the measuring system as an input for Rotor speed is compared with referenced speed to find speed deviation. This speed difference is input for The output control signal is control signal for Gate opening mechanism. The gate opening mechanism consists of servomotor. This control signal drives the servomotor which intern controls the gate opening. PID system for defining the control signal of turbine gate opening mechanism is mentioned in present paper.

The model is considering regulator servomotor, turbine and generator. The servomotor is used as governor and it is regulated depending on the signal coming from PID controller. The model was designed using Matlab-Simulink. After the controller based hydraulic controller was designed, the simulation results were obtained for three phases to ground fault. Results are observed on four scopes which show such parameters as generator terminal voltage, excitation voltage, stator current, rotors speed.

In order to test the control system in response of the generator voltage and stability the generator model run up to 20 s and 12.1 s times been upgraded alternator voltage by 0.05 pu for a period of 0.2 s.

The Fig. 4 show generator voltage has stabilized after 2 s of running system.

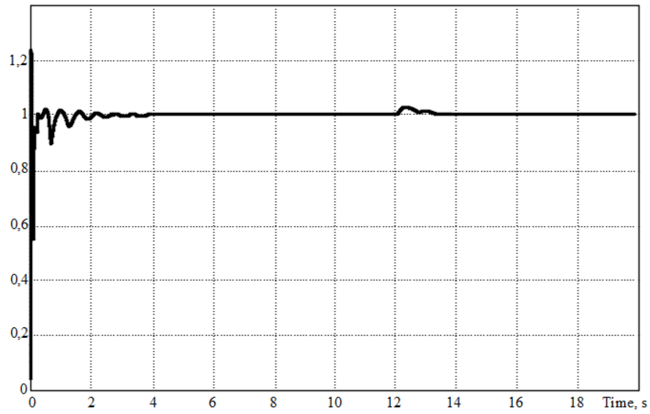

Fig. 4: Generator voltage (pu) with Time (s)

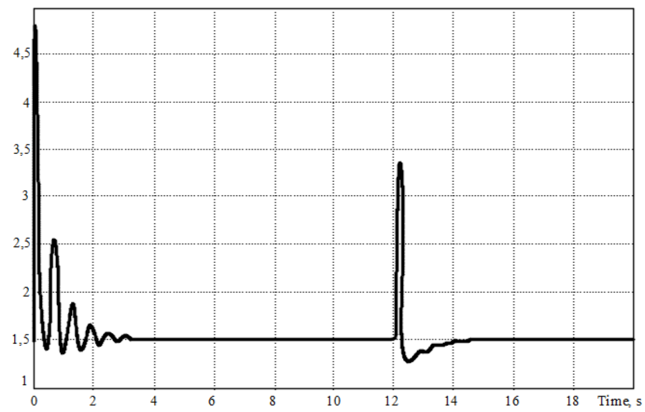

Fig. 5: Value of the control signal voltage Gen

Outgoing control of PID type voltage AVR where increased signal controlled by 1.7 pu at the starting generater as in Figure (5).

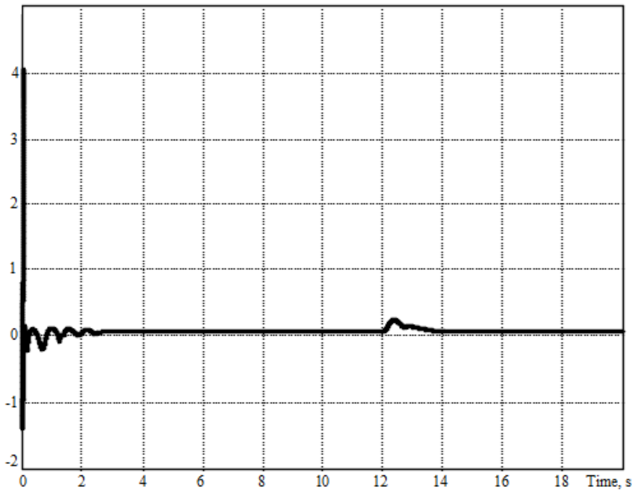

Fig. 6: Reactive power (pu) with Time (s)

Figure (6) represents output power in pu. In time 12.1s the signal has small peck for 0.02s.

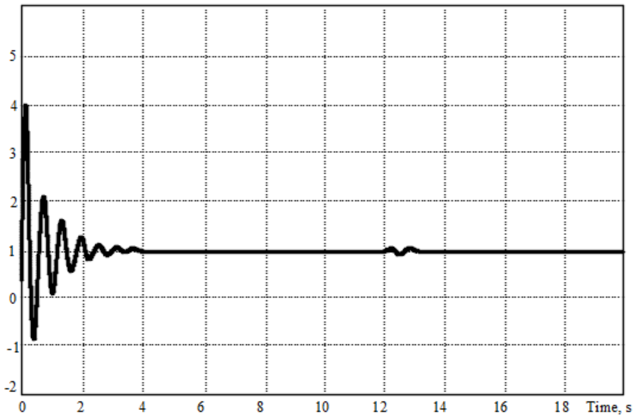

Fig. 7: Active power (pu) with Time (s)

Figure (7) shows a slight swing of active power at 2s going to stabile. After 12.1 the system becomes unstable for 0.2s

Over Exciter. The purpose of this test is to study generator behaviour of incitement and the responsiveness of system control.

Model has time with 20s at 12.1s the system will become over exciter because the voltage excitation changes to 0.15 pu.

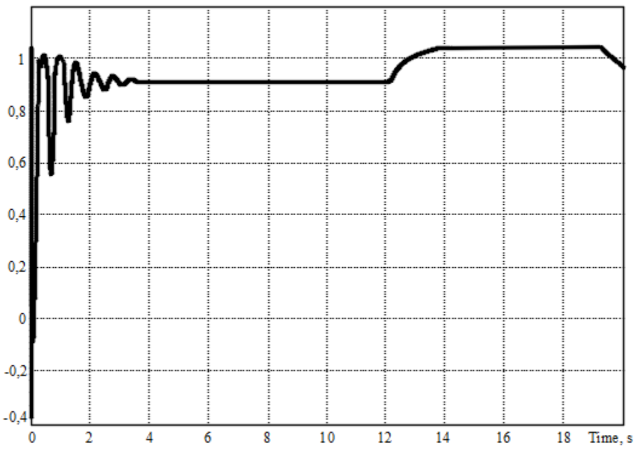

Fig. 8: Generator voltage (pu) with Time (s)

Figure (8) represents the value of the generator voltage when the generator is increased voltage by 0.15 pu, as shown in figure. The control system in response voltage AVR.

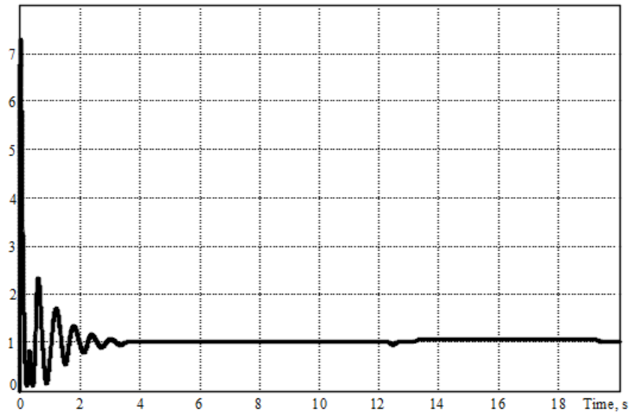

Fig. 9: Generator current (pu) with Time (s)

Figure (9) shows the value of the generator behaviour by increasing the voltage will increase power for up to 1.1 pu due to rising reactive power Q.

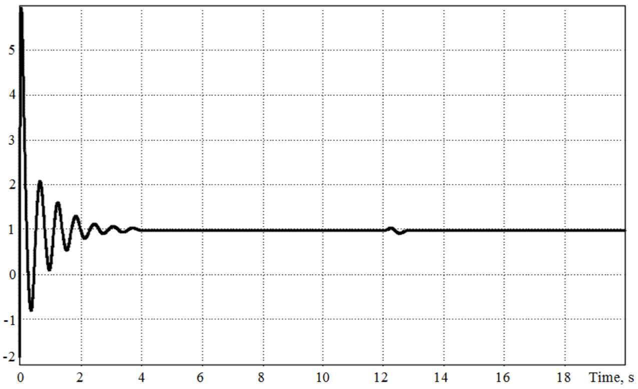

Fig. 10: Active power (pu) with Time (s)

Fig. 10 shows the value of effective active power at time 2s when the system going to stable.

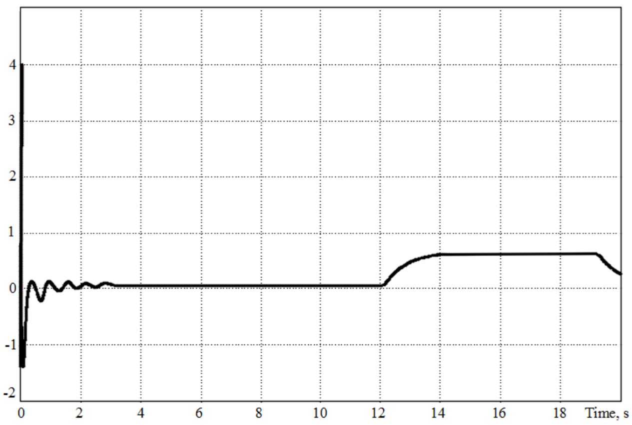

Fig. 11: Reactive power (pu) with Time (s)

The power will increase to 0.6 pu at time from 12.1s to 19s (Fig. 11). At this time the system has stable condition.

Under Exciter. The purpose of this test is to study behavior generator under excitation the incitement and the control system in response to the voltage of the generator and the stability system.

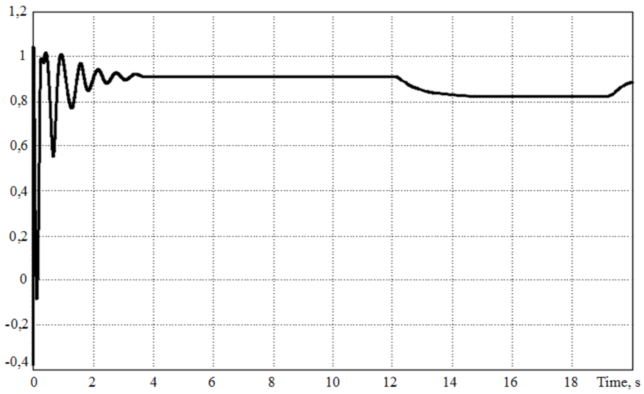

Fig. 12: generator voltage (pu) with Time (s)

Figure (12) shows the values of the generator voltage where at 12.1s the generator voltage decreases to 0.1 pu and voltage reaches 0.95 as shown that system response control voltage.

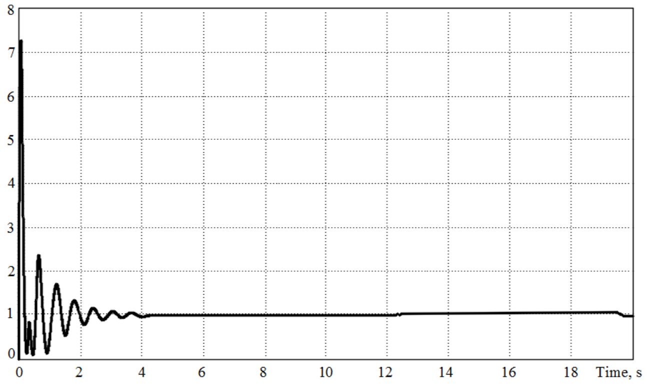

Fig. 13: Generator current (pu) with Time (s)

Figure (13) shows the value of the generator where the voltage drop at the increased power up to 1.1 due to the consumption of reactive power.

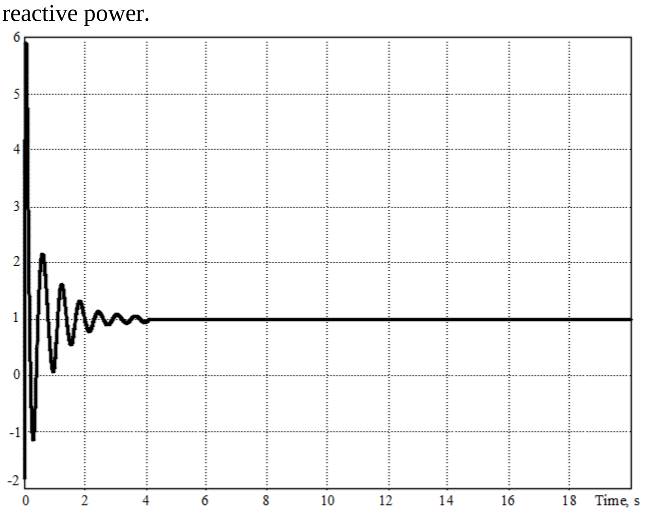

Fig. 14: Active power (pu) with Time (s)

Figure (14) shows the value of the active power pu where a slight swing can be recognized.

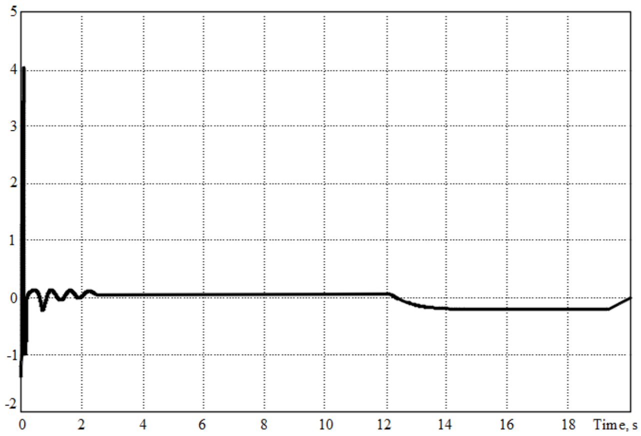

Fig. 15: Reactive power (pu) with Time (s)

Figure (15) shows the value of reactive power Q at the low voltage up to Q = -0.2ll.

With over exciter the active power will get a small swing for 1 sec to get stability since increasing the value of generator current will cause increase of the reactive power as in previous picture shown with power factor reach up to 0.89.

With under exciter we notified that the value of generator current would become lower than normal value because of absorbing the reactive power with small swing of active power of generator with power factor reach to 0.98.

AVR is power control to protect network from raising and lowering the generator voltage, since the stability of power will have bad influence on generator system. So the engineers try to limit the high and low excitation current under exciter or over exciter by pushing the voltage return back to the system.

Finally, the generator is protected from the high voltage fall in the range of 65-70% of the voltage drop. The methods developed will determine the limits of the values that govern the system.

3. Conclusion

The simulation results prove that PID based turbine governor has good performances. Moreover, good transient and steady state responses for different operating points of the processes can be achieved. Synchronous generators being nonlinear will be suitable for it.

Finally, in this paper we test the stability and flexibility of the synchronized generator with over exciter and under exciter by governor and excitation systems.

References

[1] Recommended Practice for Excitation System Models for Power System Stability Studies, IEEE® Standard 421.5- 1992, August, 1992. DOI: 10.1109/IEEESTD.2016.7553421.

[2] Spreng S, Weber H, Hladky M, "Investigation of the Dynamic Behaviour of Hydropower Plants For Restoration scenarios", *14th PSCC*, Sevilla, 24-28 June 2002, session 06, paper 5, Page 1.

[3] Goyal H, Hanmandlu M, Kothari DP, *An Artificial Intelligence based Approach for Control of Small Hydro Power Plants*, Centre for Energy Studies, Indian Institute of Technology, New Delhi-110016 (India).

[4] *Hydroelectricity 2005*, World Encyclopedia 2005, Oxford University Press.

[5] http://www.mathworks.com/help/toolbox/physmod/powersys/ref/hydraulicturbineandgovernor.html

[6] Chang J, Xiao Z, Qingwnag S, "Neural network predict control for the hydro turbine generator set", *The second international conference on machine learning and cybernetics*, 2003, pp:2-5.

[7] Mohamed HA, "Wavelet neural network load frequency controller", *Energy conversion and management* Vol.46, (2005), pp:1613-1630.

[8] Kishor SP, Singh AS, Sharma PR, "Fuzzy Models for the study of Hydro Power Plant Dynamics", *international symposium on Evolv-*

ing fuzzy Systems, September 2006. DOI: 10.1109/ISEFS.2006.251131.

[9] Shu-qing W, Su-yi L, Zi-peng Z, "Research on the Improved Learning Algorithm of FNNC for the Control of Hydraulic Turbine Generating units", *Proceedings of the Sixth International conference on machine Learning and cybernetics*, Hong Kong, 19-22 August 2007, pp:617-622.

DOI: 10.1109/ICMLC.2007.4370219.

[10] Khodabakhshian A, Edrisi M, "A New robust PID load frequency controller", *Control Engineering Practice*, Vol.16, (2008), pp:1069-1080.

DOI: 10.9790/1676-10525868. Djukanovic M, Novicevic M, Dobrijevic Dj, Babic B, Sobajic J, Yoh-Han P, "Neural Net Based Coordinated Stabilizing Control for the Exiciter and governor loops of low head hydropower plants", *IEEE Transaction on energy Conservation*, Vol.10, No.4, December 1995, p.392. Salhil L, Doubabi S, "Fuzzy controller for frequency regulation and water energy save on microhydroelectrical power plants", *International Renewable Energy Congress*, Sousse Tunisia, November 2009.

[11] Hassan LH, Mohamed HAF, Moghavvemi V, Yang SS, "Automatic Generation control of Power System with fuzzy Gain Scheduling Integral and derivative Controller", *International Journal of Power, Energy and Artificial Intelligence*, Vol.1, No.1, (ISSN: 1985-6431), August 2008, pp:29-33.

[12] Passino KM, Yurkovich S, *Fuzzy Control*, Department of Electrical Engineering, The Ohio State University.