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Control and Monitoring of Hydro Power Plants: A Review

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ABSTRACT
In hydro power plants there is a main interest for the implementation of digital systems for control and monitoring replacing the conventional control systems for power, speed and voltage. As a result it is indispensable to build up mathematical models accomplished to accurately describe both dynamic and stationary behavior of the hydro plants, in order to be able to execute digital control algorithms. A significant development in stability of the system has been observed. This paper presents the comparison of simulation and modeling of the hydro power plants and performs of different control structures and algorithms.

KEYWORDS: *Hydro power plant, Control System, Digital Control Algorithms*

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1. INTRODUCTION

Hydropower golden age was in the first half of the 20th century before oil control of the force of the dominant in the provision of energy [1]. Several growth republics gradually began to get rid of traditional energy originals that built on oil, coal and the usual gas, owing to oil price increment, fossil fuel cost, thermal pollution and crisis of worldwide energy and renewable hydro plant facilitates over conventional [2]. Hydro power is now a fundamental energy resource for the fulfillment of power requisite for the growth and development of the country. It a pollution free, renewable and environmental friendly source of energy.[3] Hydropower represents use of water resources towards inflation free energy due to absence of fuel cost with mature technology characterized by highest prime moving efficiency and spectacular operational flexibility. Hydro electricity plays an important role in the safe, steady, and efficient operation of the electric power system. Nowadays, the size of hydro power plants and the structure complexity of the hydraulic-mechanical-electrical system have been increasing. The proportion of electricity generated by intermittent renewable energy sources have also been growing. Therefore, the research on control strategy and transient process of hydro power plants is of great importance [4].

2. Servomotor as a Governor

Servo motor is basically based on the servo mechanism, and is an automatic device which works on the negative feedback to correct the performance of a system. The servo term is applies only to those system where the feedback or error correction signal help in controlling the mechanical position, speed or other parameters. The structure of the servomotor actually consists of four things: a normal D.C motor, a gear reduction unit, a position sensing device (usually a potentiometer) and a control circuit. The main function of the servo is to receive a control signal that represent a desired output position of the servo shaft, and apply its power to its DC motor until its shaft turn to that position. It generally uses the position sensing device to determine the rotational position of the servo shaft so it knows which way the motor must turn to move the shaft to the commanded position. The shaft typically does *not* rotate freely round and round like a DC motor, but rather can only turn 200 degrees or so back and forth [5]. In our scheme we have proposed the use of a servomotor as a governor. A servo motor may be thought of as a precision electric motor whose function is to cause motion in the form of rotation or linear motion in proportion to a supplied electrical command signal. We have used Type Zero servomechanism for our proposed system. A feedback control system of Type Zero is generally referred to as a regulator system. Such systems are designed primarily to maintain the controlled variable constant at a certain desired value despite disturbance. 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 [6] maintenance and are less expensive than conventional governors.

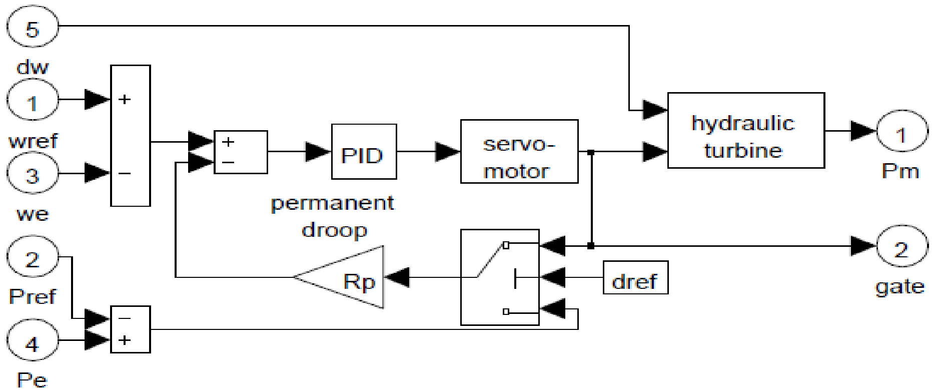

FIG.1 showing model of speed governor system [3]

A. **Servo-motor**: The gain Ka and time constant Ta, in seconds (s), of the first-order system representing the servomotor.
B. **Gate opening limits**: The limits gmin and gmax (pu) imposed on the gate opening, and vgmin and vgmax (pu/s) imposed on gate speed.
C. **Permanent droop and regulator**: The static gain of the governor is equal to the inverse of the permanent droop Rp in the feedback loop. The high-frequency gain of the PID is limited by a first-order low-pass filter with time constant Td (s).
D. **Hydraulic turbine**: Speed deviation damping coefficient β and water starting time Tw (s).
E. **Droop reference**: Specifies the input of the feedback loop: gate position (set to 1) or electrical power deviation (set to 0).
F. **Initial mechanical power**: The initial mechanical power Pm0 (pu) at the machine's shaft. This value is automatically updated by the load flow utility of the Powergui block. [6]

3. PID Controller:

A proportional–integral–derivative controller (PID controller or three-term controller) is a control loop mechanism employing feedback that is widely used in industrial control systems and a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an error value as the difference between a desired set point (SP) and a measured process variable (PV) and applies a correction based on proportional, integral, and derivative terms (denoted P, I, and D respectively), hence the name. Heuristically, these values can be interpreted in terms of time: P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, or the power supplied to a heating element. In the absence of knowledge of the underlying process, a PID controller has historically been considered to be the best controller. By tuning the three parameters in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set point and the degree of system oscillation. [5]

This block shows a PID controller, which continuously calculates an error value e= (t) as the difference between a desired set point SP= r(t) and a measured process variable PV=y(t), and applies a correction based on proportional, integral, and derivative terms. The controller attempts to minimize the error over time by adjustment of a control variable, such as the opening of a control valve u= (t), to a new value determined by a weighted sum of the control terms.

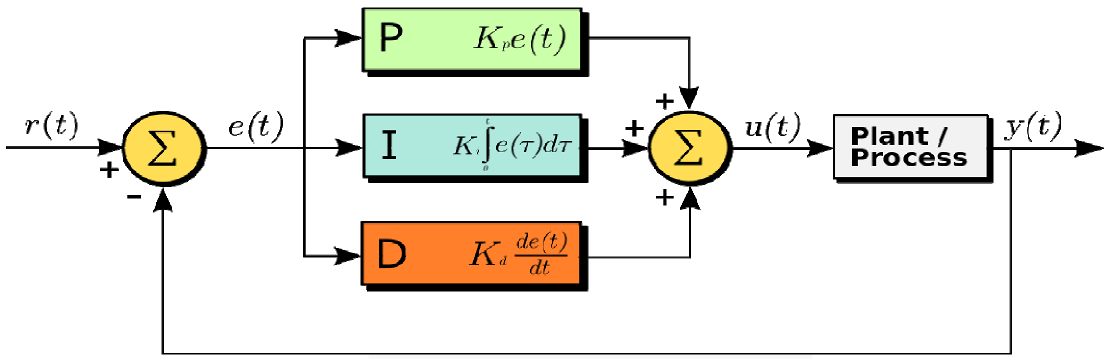

Fig. 2 PID controller in a feedback loop [5]

- Term P is proportional to the current value of the SP − PV error e(t). For example, if the error is large and positive, the control output will be proportionately large and positive, taking into account the gain factor "K". Using proportional control alone will result in an error between the set point and the actual process value, because it requires an error to generate the proportional response. If there is no error, there is no corrective response.
- Term I accounts for past values of the SP − PV error and integrates them over time to produce the I term. For example, if there is a residual SP − PV error after the application of proportional control, the integral term seeks to eliminate the residual error by adding a control effect due to the historic cumulative value of the error. When the error is eliminated, the integral term will cease to grow. This will result in the proportional effect diminishing as the error decreases, but this is compensated for by the growing integral effect.

- Term D is a best estimate of the future trend of the SP – PV error, based on its current rate of change. It is sometimes called "anticipatory control", as it is effectively seeking to reduce the effect of the SP – PV error by exerting a control influence generated by the rate of error change. The more rapid the change, the greater the controlling or dampening effect [7].

4. Excitation system:

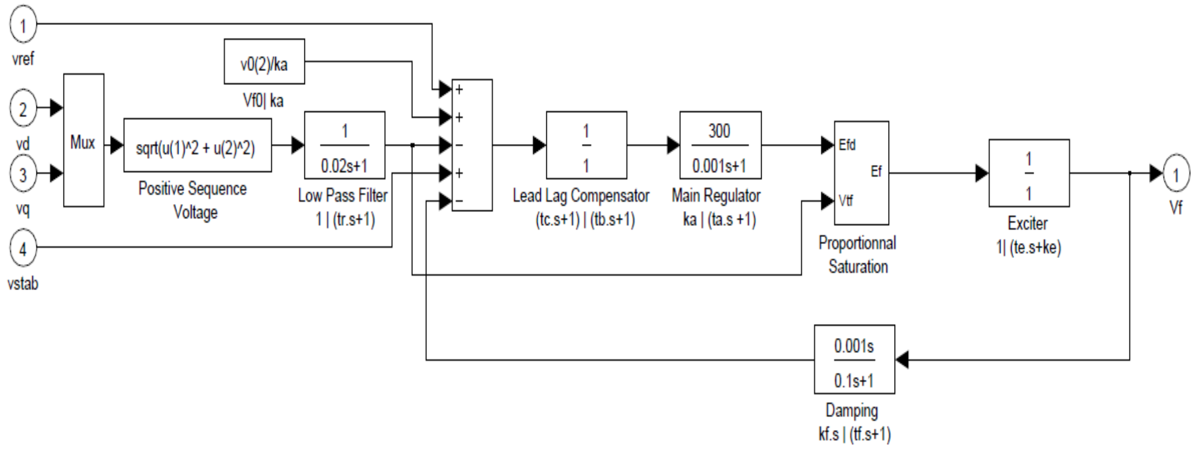

FIG.3 Showing the model of the excitation system

The Excitation System block is a Simulink system implementing a DC exciter described in [6], without the exciter's saturation function. The basic elements that form the Excitation System block are the voltage regulator and the exciter. The exciter is represented by the following transfer function between the exciter voltage Vfd and the regulator's output ef:

Vfd/ef = 1/Ke+sTe

A. **Low-pass filter time constant**: The time constant Tr, in seconds (s), of the first-order system that represents the stator terminal voltage transducer.
B. **Regulator gain and time constant**: The gain Ka and time constant Ta, in seconds (s), of the first-order system representing the main regulator.
C. **Exciter**: The gain Ke and time constant Te, in seconds (s), of the first-order system representing the exciter.
D. **Transient gain reduction**: The time constants Tb, in seconds (s), and Tc, in seconds (s), of the first-order system representing a lead-lag compensator.
E. **Damping filter gain and time constant**: The gain Kf and time constant Tf, in seconds (s), of the first-order system representing a derivative feedback.
F. **Regulator output limits and gain**: Limits Efmin and Efmax are imposed on the output of the voltage regulator. The upper limit can be constant and equal to Efmax, or variable and equal to the rectified stator terminal voltage Vtf times a proportional gain Kp. If Kp is set to 0, the former applies. If Kp is set to a positive value, the latter applies.
G. **Initial values of terminal voltage and field voltage**: The initial values of terminal voltage Vt0 (pu) and field voltage Vf0 (pu). When set correctly, they allow you to start the simulation in steady state. Initial terminal voltage should normally be set to 1 pu. Both Vt0 and Vf0 values are automatically updated by the load flow utility of the Powergui block.

5. Related Work

K. Anil Naik et al [8] presented a PID governor controller with Internal Model Control (IMC) tuning method for the hydro electric power plant including water hammer effect is presented. The IMC has a single tuning parameter to adjust the performance and robustness of the controller. The proposed tuning method is very efficient in controlling the overshoot, stability and the dynamics of the speed-governing system of the hydro electric power plant supplying an isolated/grid connected load. The results of the proposed IMC tuning method have been compared in the midst of controller with singular frequency (SF) based tuning and Ziegler-Nichols (Z-N) closed loop tuning. A remarkable improvement in stability of the system has been observed with IMC tuning justifying its applicability. Simulated results given in the paper show the feasibility and versatility of the IMC tuning technique in hydro power plant in the presence of water hammer effect.

WIDODO P. M. et al [9] presented that the speed control problem was solved by applying the Electrically Balanced Load method, the dynamic model problem was solved by the data-driven estimation method, and the cross-coupling effect problem was overcome by adding decoupling blocks to the input of the plant model. All three solutions are implemented in a compact frequency voltage control design that uses dual PID controllers, as well as additional double decoupling blocks. By choosing the right values of *Kp*, *Ti*, and *Td*, the output voltage and output frequency can be produced which meet the permitted standard. It can be concluded that a small single-phase electric water pump used in this study can be used as a turbine generator for standalone pico hydroelectric power generation.

J. Fraile-Ardanuy et al [10] presented a speed control of run-of-river adjustable speed hydro plant. The advantages of adjustable speed hydroelectric generation have been highlighted by several authors. The optimum speed for actual working conditions must be continuously implemented by means of an appropriate control system. This process gives rise to dynamic changes in operation variables.

Lie Jasa et al [11] presented that the micro-hydro power plants are power plants with small capacity, which is built in specific locations. The main problem of micro-hydro is the voltage generated is not stable at 220 VA and frequency of 50 Hz. A microhydro that was constructed in Gambuk village at Pupuan sub-district, abanan district of Bali province, Indonesia in 2010 is still an open loop system in which spin turbine is stable when it is set from the high water level in reservoirs. This will be problematic when the generator loads changes. This study will overcome the problem by proposing to build a closed loop system from the change in output frequency for the control circuit. The control circuit is a circuit constructed neural network based PID control by using the Brandt-Lin algorithm to control the governor. The governor function is to regulate the amount volume of water running into turbine. By applying Matlab simulation, the result shows that the best output is obtained when the change in frequency will stabilize at about 40 seconds and using the value of Kp =0.0637533, Ki=0.00021801 and Kd=0.00301846.

W. Ali et al [12] represented the research work that made an effort to analyze the behavior of the PID vs PI (Proportional-Integral) controllers; for speed governor operation of grid connected MHPP, deploying synchronous generator, under the influence of a electrical disturbance; to identify more suitable controller from the regulation point of view. The dynamic performance of the proposed controllers for speed governor function is fully validated through digital simulations carried out using MATLAB/Simulink software package. The most of the micro hydro power plants operating in isolated mode are based upon induction generator technology.

Ali Thaeer Hammid et al [13] represented a self-tuning control of hydropower system that suggested and confirmed under Automatic Generation Control (AGC) in power scheme. The suggested power system involves one single area. The suggested self-tuning control system is employed in performing the automatic generation control for load frequency control request and compared it with conventional control structure. The power system dynamic modeling has regularly built in several essential parameters which have a significant influence According to frequency limitation. The main problem with all controllers is an exaggerated reaction to minor errors, producing the system to oscillate. The output response results for hydropower system obviously proved the benefit of using maximum load demand by tuning PID controller. Whereas, tuning PID controller has got properly more rapid output response and minimal overshoot.

Maria Regina Gomes Zoby et al [14] that this work was to study the primary control system of a hydropower plant in isolated mode. The power plant was modeled by differential equations and results are compared to field data from an actual hydropower plant, presenting deviations lower than 1.0%. The study of primary control system is conducted in order to define useful sets of parameters for controllers. Four controllers are studied: traditional, PI, PID and PI-PD. The performances are evaluated by stability criteria and a performance index. For the hydropower plant studied, the PI controller has the best performance.

Matei Vinatoru et al [15] presented the possibilities of modeling and simulation of the hydro power plants and perform an analysis of different control structures and algorithms. In hydro power plants from Romania, there is a major interest for the implementation of digital systems for monitoring and control replacing the conventional control systems for power, frequency and voltage. Therefore is necessary to develop mathematical models capable to accurately describe both dynamic and stationary behavior of the hydro units, in order to be able to implement digital control algorithms. Moreover, it is necessary to implement systems for monitoring and control of hydro power plants in a cascade system along a river, in order to optimize the use of the river resources.

Conclusion

The possibility of accomplishment of digital systems for monitor and controlling for speed and voltage in the cascade hydro power plant was discussed. The simplify mathematical models capable to precisely illustrate dynamic and stationary behavior of the hydro units were developed and simulated and these results were compared with the experimental results. The tuning PID controller has properly got well output system response.

References

[1] Mishra, M. K., N. Khare, and A. B. Agrawal, Small hydro power in India: Current status and future perspectives. Renewable and Sustainable Energy Reviews, 2015. 51: p. 101-115.

[2] Duque, E. A., J. D. González, and J. C. Restrepo, Developing Sustainable Infrastructure for Small Hydro Power Plants through Clean Development Mechanisms in Colombia. Procedia Engineering, 2016. 145: p. 224-233.

[3] Roshni Bhoi, Dr. S. M. Ali "Simulation for Speed Control of the Small Hydro Power Plant Using PID Controllers" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 3, Issue 4, April 2014

[4] Weijia Yang , Jiandong Yang, Wencheng Guo, Wei Zeng " A Mathematical Model and Its Application for Hydro Power Units under Different Operating Conditions" Energies 2015, 8, 10260-10275; doi:10.3390/en80910260

[5] http://en.wikipedia.org/wiki/PID_controller.

[6] M Hanmandlu, Himani Goyal & D P Kothari (2007) An Al based Governing Technique for Automatic Control of Small Hydro Power Plants, IETE Journal of Research, 53:2, 119-126, DOI: 10.1080/03772063.2007.10876128

[7] Araki, M. "PID Control" (PDF)

[8] K. Anil Naik, P. Srikanth, and Pankaj Negi "IMC Tuned PID Governor Controller for Hydro Power Plant with Water Hammer Effect" Procedia Technology 4 (2012) 845 – 853

[9] WIDODO P. M., RINALDY D. " PERFORMANCE EVALUATION OF SINGLE PHASE ELECTRIC WATER PUMP OPERATED AS TURBINE-GENERATOR SET" Journal of Engineering Science and Technology Vol. 14, No. 2 (2019) 1055 – 1070

[10] J. Fraile-Ardanuy, J. R. Wilhelmi, J. Fraile-Mora, J. I. Pérez and I. Sarasúa " Speed control of run-of-river variable speed hydro plants" RE&PQJ, Vol. 1, No.4, April 2006

[11] Lie Jasa , Ardyono Priyadi , Mauridhi Hery Purnomo "PID CONTROL FOR MICRO-HYDRO POWER PLANTS BASED ON NEURAL NETWORK" Proceedings of the I ASTED Asian Conference, Modelling, Identification, and Control (AsiaMIC 2012) April 2 - 4, 2012 Phuket, Thailand

[12] W. Ali, H. Farooq, W. Abbas, M. Usama, A. Bashir "PID VS PI CONTROL OF SPEED GOVERNOR FOR SYNCHRONOUS GENERATOR BASED GRID CONNECTED MICRO HYDRO POWER PLANT" JFET 24(1) (2017) 53-62

[13] Ali Thaeer Hammid, Mojgan Hojabri, Mohd Herwan Bin Sulaiman "Load Frequency Control for Hydropower Plants using PID Controller" Journal of Telecommunication, Electronic and Computer Engineering, ISSN: 2180-1843 e-ISSN: 2289-8131 Vol. 8 No. 10

[14] Maria Regina Gomes Zoby, Jurandir Itizo Yanagihara "Analysis of the Primary Control System of a Hydropower Plant in Isolated Model" J. of the Braz. Soc. of Mech. Sci. & Eng. , January-March 2009, Vol. XXXI, No. 1 / 11

[15] Matei Vinatoru "MONITORING AND CONTROL OF HYDRO POWER PLANT" IFAC Workshop ICPS'07 2007, July 09-11 Cluj-Napoca, Romania