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Improved of Frequency Stability Response using the High Speed Valve Control (HSVC) of the Micro Hydro Power Plant

[1]Syarifuddin Nojeng, [1]Sugianto, [2]R.A. Reny Murniati and [3]Shiddiq Yunus
[1]Department of Electrical Engineering, Universitas Muslim Indonesia, Makassar, Indonesia
[2]Department of Electrical Engineering, Universitas Sawerigading, Makassar, Indonesia
[3]Department of Electrical Engineering, Politeknik Negeri Ujung Pandang, Makassar, Indonesia

Abstract: Micro-Hydro Power Plant (MHPP) is one of popular renewable based power plants that appropriate to be installed in developing countries such as Indonesia due to its stability, efficient operation and economic point of view. Frequency stability of power plant systems refers to the ability of generator to maintain the steady frequency during and post faults and rapid dynamic load. In order to keep the stability of power system frequency from fluctuations, generating units change their power output automatically according to the change of the system frequency or load through balancing of the active power with the loads. To keep the stability frequency on MHPP, active power fast control is employed in this study and all the system of MHPP and the frequency control are carried out and simulated extensively using MATLAB/Simulink. With the active power control through fast valving mechanism using HSVC method, duration of stability frequency response is faster compared to the system without fast control.

Key words: Frequency stability response, HSVC method, hydro power plant, renewable energy, frequency, appropriate

INTRODUCTION

Now a days, world is facing the act of detrimental effects of conventional based power plants on environment. Therefore, many countries all around the world are intensively develop the technology for renewable based power plants such solar cell, wind, biomass, etc. For example, the significant installation of wind (Yunus *et al*., 2012, 2011a-c; Khamaira *et al*., 2013) hydropower (Firman *et al*., 2017) and solar cell (Yunus and Saini, 2016). In Indonesia, Micro Hydropower Plants (MHPPs) become popular renewable based power plants due to its economic point of view. A MHPP is not only suitable based on the economic reason but also its location that normally close to the remote communities. Moreover with its simple and mature technology a MHPP could provide a stable and efficient power to the remote community. However, it is important to employ a proper technique to maintain the frequency stability during and post faults as well as load instability. Frequency stability of power plant systems refers to the ability of generator to maintain steady frequency during or post faults or in condition of rapid change in the dynamic load. In order to keep the power system frequency from fluctuations, generating units change their power output automatically according to the change of system frequency or load through balancing of the active power with load. This technical strategy can be achieved using active power control of MHPP. Normally an MHPP has capacity <100 kW and commonly located in remote areas and connected to non-grid communities. A MHPP system, generally, consists of a synchronous generator, excitation system and turbine system with their control. As water debit usually large whereas the loads sometimes fluctuate which in turns will affect the frequency response, the fast active power control approach is suitable to be applied in MHPP. Therefore, the performance of MHPPs in terms of frequency control is very important. The research on active power control method and dynamic processes of SHPPs is of great importance. The frequency stability of MHPP is a critical factor of power system stability including the power quality for costumer. The active power response time is applied to evaluate the frequency stability and response characteristic which are two key indicators for generator performance.

Stability improvement: The synchronous stability of the synchronous generator is strongly influenced by the parameters of the synchronous machine (Chen *et al*., 2014). The machines parameters such as frequency, voltage and power angle will experience swing in the event of interference (Saarinen, 2014). To maintain the stability of the generator, interference must be restored before the power angle exceeds the critical severance angle (Wang *et al*., 1993; Park, 1973). Some of methods

Corresponding Author: Syarifuddin Nojeng, Department of Electrical Engineering, Universitas Muslim Indonesia, Makassar, Indonesia

that can be done to improve the transition stability of the generator which are minimizing the effect of faults by minimizing the duration of interference including improve the stored synchronization mode (Demello *et al*., 1992). To reduce acceleration torque, an active power control can be applied for turbine by setting the mechanical power using an artificial load. Some papers proposed the hydraulic system modeling method and further investigation of the interactions between power system oscillation and the dynamic characteristics of the hydraulic mechanical system (De Jaeger *et al*., 1994), (Machowski *et al*., 1999). A study conducted in Demello *et al*. (1992) proposed a scheme for improving transitional stability of the system by using a method of coordination between fast valving and generator excitation setting (Matsuzawa *et al*., 1995). Research in proposed a fast valving method by using a parallel valve system to improve system stability. A braking resistor as part of the reduction of torque acceleration through artificial loads is proposed where this method could reduce the area of acceleration when using a breaking resistor of 0.125 pu (Tamersi *et al*., 2011) introduced a design of system called the Micro Grid Voltage Stabilizer (MGVS) (Fang *et al*., 2008; Souza *et al*., 1999; Munoz-Hernandez and Jones, 2012). Have constructed nonlinear models for the transient characteristic of the hydro power plant with a focus on the influence of the surge tank. An integrated system analysis model with respect to the rotational speed and active power control during hydropower plant operation is proposed in (Strah *et al*., 2005). A high-order model of Hydropower Plants (HPPs) with islanded power networks operation to determine unstable operation of hydroelectric systems is proposed in (Nicolet *et al*., 2007). In, an approach is established to refine model for pumped storage of power plant. The study also studied the nonlinear characteristic and intensively explored the active power oscillation issue based on a pumped storage power plant. While, an operating model for grid-connected pumped storage power plants is proposed in (Perez-Diaz *et al*., 2014), to study the hydraulic short circuit characteristics (Kishor *et al*., 2007). Conducts review to several research results about modeling, control strategies, etc., as well as regulation and operation performance for HPPs. In general, the equation which states the balance of active power on the generator is expressed as follows:

$$J\omega_m \frac{\partial^2 \delta_m}{\delta t^2} = P_a = P_m - P_e$$

Where:

- J : Momen Inertia
- ω_m : Angle of mechanical
- δ_m : Angle of angular
- P_m : Mechanical Power
- P_e : Electrical Power
- P_a : Acceleration Power

MATERIALS AND METHODS

Method of controlling the mechanical power of a turbine is rapidly used to improve the stability of the generator switch. The principle work of the system is to reduce the mechanical power of the turbine with the closure of the valve (valve) quickly. The High Speed Valve Control (HSVC) mechanism uses double nozzle system with variable speed motor drive. The ability of the water valve to close and open quickly will be depended on the type of governor system used. The type of electro-hydraulic turbine governor that equipped with an electronic state drive system and a high pressure hydraulic drive is capable for fast valve control. The HSVC method can also be used in mechanical hydraulic governor turbines but it less flexible and more difficult to implement on the system Fig. 1.

RESULTS AND DISCUSSION

Data and parameters of the system under study can be seen in Table 1 time of valve mechanism (assumption):

- t = 0.5 sec (With-out HSVC)
- t = 0.25 sec (HSVC)

Acceleration of active power setting through valve closure and valve opening at synchronous mechanical power input of synchronous generator can improve the stability of synchronous generator.

In Fig. 2, it is shown that when the power plant loses the load suddenly of 0.2 pu, the synchronous generator will be swing for 8 sec to return stable if without using fast valving. Meanwhile, by using fast valve acceleration, the generator will achieve stability for 4.5 sec. While, the amplitude of the rotor frequency changes reach of 0.0145 pu without fast valving. However, if using fast valving it is only change about 0.0125 pu. Figure 3 shows that when the power plant loses the load suddenly by 0.8 pu. The synchronous generator will be swing for 8 sec until it

Table 1: Data and parameters of the system

Parameters		Value (pu)
Sinkron reaktance	X_d	0.6
	X_q	0.4
Transient reaktance	X'_d	0.15
	X'_q	0.3
Sub transient reactance	X''_{do}	0.1
	X''_{qo}	0.25
Time constant of transient	T'_d	3.0
	T'_q	0.1
Time constant of sub transient	T''_{do}	0.01
	X''_{qo}	0.03
Leakage inductance	X_l	0.15
Resistance of stator	R_a	0.005
Constant of inertia	H	n/a
Constant of damp	D	n/a

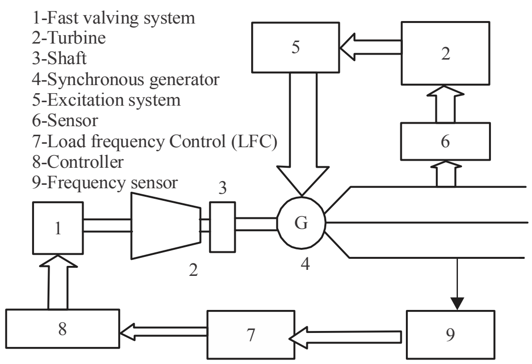

Fig. 1: Micro hydro power plant systems

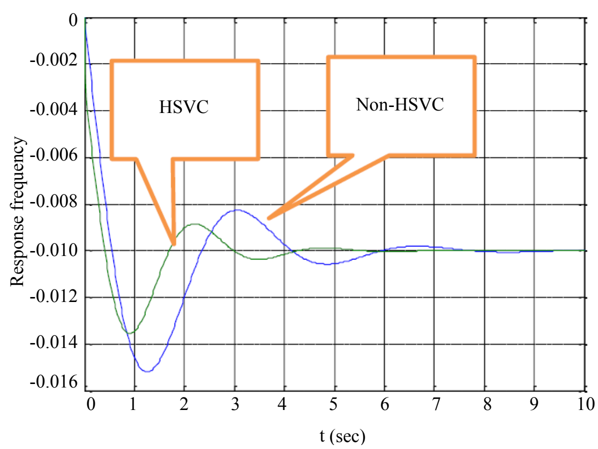

Fig. 2: Frequency response with the generator loses the load suddenly of 0.2 pu

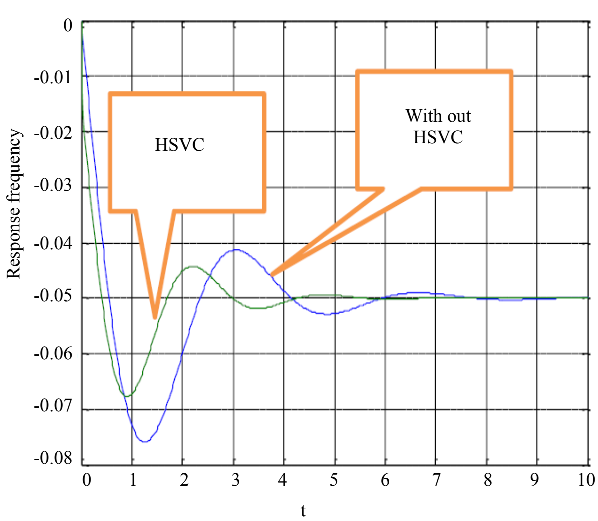

Fig. 3: Frequency response with the generator loses the load suddenly of 1.0 pu (all loads)

returns stable if without using HSVC. By using fast valve acceleration, however, the generator will achieve stable faster in 6 sec. While, the amplitude of the rotor frequency changes reached 0.06 pu without fast valving by HSVC method. In contrast, it is only reach 0.055 pu when using fast HSVC.

CONCLUSION

Based on the simulation using MATLAB/Simulink program, it can be concluded that: by using fast control for valve mechanism (HSVC), the mechanical power swing duration of generator will be smaller than without fast control of active power. However, a sudden power change will result a greater transient time on the generator. The mechanical power transient of turbine has smaller duration time when using fast control with fast valving than without fast control of active power

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