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# Utilizing the HSVC of the micro hydro power plant to improve frequency stability response

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ABSTRACT

One of the popular renewable-based power plants that are appropriate to be installed in developing countries such as Indonesia due to its stability, efficient operation, and economic point of view is Micro-Hydro Power Plant (MHPP). Frequency stability of power plant systems refers to the ability of the generator to maintain a steady frequency during and post faults and rapid dynamic load. 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 by balancing 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 systems of MHPP and the frequency control are carried out and simulated extensively using MATLAB/Simulink. With the active power control through a fast valving mechanism using the HSVC method, the duration of stability frequency response is faster compared to the system without fast control.



## 1. Introduction

The world is facing the act of detrimental effects of conventional-based power plants on the environment. Therefore, many countries all around the world are intensively developing the technology for renewable-based power plants such as solar cells, wind, biomass, etc. For example, the significant installation of wind (Yunus et al., 2012a; 2012b; 2012c; 2012d; Khamaira et al., 2013) hydropower (Firman et al., 2017), and solar cells (Yunus and Saini, 2016). In Indonesia, Micro Hydropower Plants (MHPPs) become popular renewable-based power plants due to their economic point of view. An MHPP is not only suitable based on economic reasons but also its location is normally close to the remote communities. Moreover, with its simple and mature technology, an MHPP could provide 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 the generator to maintain steady frequency during or post faults or in the condition of rapid change in the dynamic load. To keep the power system frequency from fluctuations, generating units change their power output automatically according to the change of system frequency or load by balancing the active power with load. This technical strategy can be achieved using the active power control of MHPP. Normally an MHPP has a capacity of <100 kW and is commonly located in remote areas and connected to non-grid communities. An MHPP system, generally, consists of a synchronous generator, excitation system, and turbine system with their control. As water debit is usually large whereas the loads sometimes fluctuate which in turn 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 the active power control method and dynamic processes of SHPPs is of great importance. The frequency stability of MHPP is a critical factor in power system stability including the power quality for a costumer. The active power response time is applied to evaluate the frequency stability and response characteristic which are two key indicators for generator performance.

### 1.1. 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

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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 that can be done to improve the transition stability of the generator which is minimizing the effect of faults by minimizing the duration of interference including improving the stored synchronization mode (Demello et al., 1992). To reduce acceleration torque, active power control can be applied to the 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 by Demello et al. (1992) proposed a scheme for improving the transitional stability of the system by using a method of coordination between fast valving and generator excitation settings (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 braking 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), and Munoz-Hernandez and Jones (2012) Have constructed nonlinear models for the transient characteristic of the hydropower plant with a focus on the influence of the surge tank. An integrated system analysis model concerning the rotational speed and active power control during hydropower plant operation is proposed (Strah et al., 2005). A high-order model of Hydropower Plants (HPPs) with islanded power networks operation to determine the unstable operation of hydroelectric systems is proposed (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.

## 2. Materials and methods

The 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 a 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 is equipped with an electronic state drive system and a high-pressure hydraulic drive is capable of fast valve control. The HSVC method can also be used in mechanical hydraulic governor turbines but it is less flexible and more difficult to implement in the system Fig. 1.

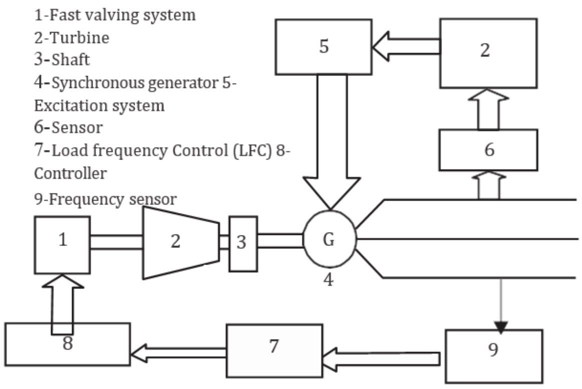


**Fig. 1:** Micro hydropower plant systems

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

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

where $J$: Momen Inertia; $\omega_m$: Angle of mechanical; $\delta_m$: Angle of angular; $P_m$: Mechanical Power; $P_e$: Electrical Power; and $P_a$: Acceleration Power.

**Table 1:** Data and parameters of the system

| Parameters | | Value (pu) |
|---|---|---|
| Sinkron reaktance | Xd | 0.6 |
| | Xq | 0.4 |
| Transient | X'd | 0.15 |
| reaktance | X'q | 0.3 |
| Sub transient | X"do | 0.1 |
| reactance | X"qo | 0.25 |
| Time constant of | | 3.0 |
| transient | T'q | 0.1 |
| Time constant of | T"do | 0.01 |
| sub transient | X"qo | 0.03 |
| Leakage inductance | X1 | 0.15 |
| Resistance of stator | X1 | 0.005 |
| Constant of inertia | H | n/a |
| Constant of damp | D | n/a |

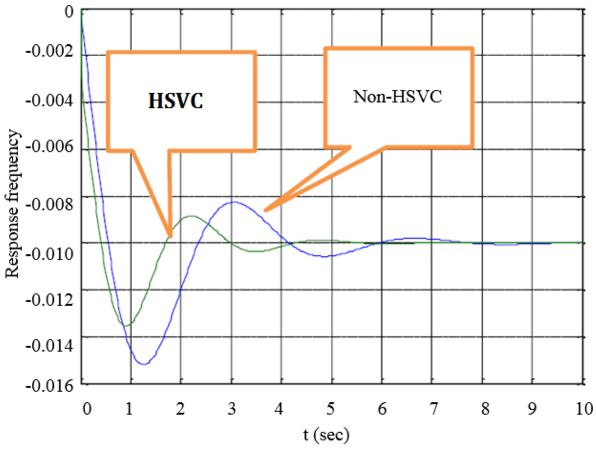


**Fig. 2:** Frequency response with the generator loses the load suddenly of 0.2 pu

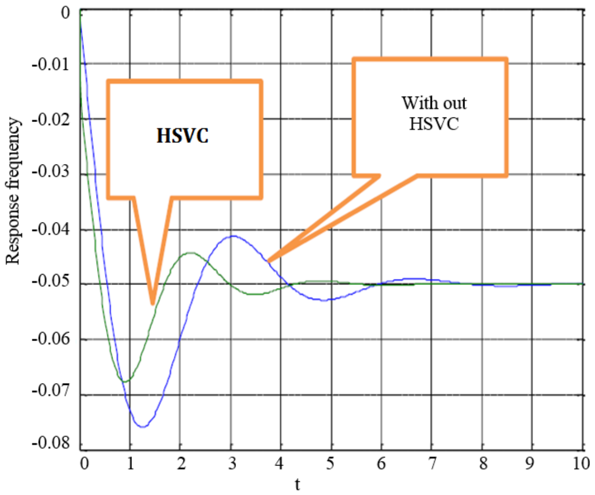


**Fig. 3:** Frequency response with the generator loses the load suddenly of 1.0 pu (all loads)

## 4. 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 the generator will be smaller than without fast control of active power. However, a sudden power change will result from a greater transient time on the generator. The mechanical power transient of turbine has a smaller duration time when using fast control with fast valving than without fast control of active power

## Compliance with ethical standards

## Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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