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Impact of micro hydro power plants on transient stability for the micro grid 20 kV system

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ABSTRACT

Transient stability analysis is conducted to determine the ability of the electric power system in maintaining the operating stability after a major disturbance. The disturbance can be trigger an impact on the stability of the rotor angle, voltage, and system frequency which can cause loss of synchronization. In this paper, the impact of the interconnection of the Tombolo-Pao mini hydro power plant (MHPP) on the stability of the system was analyzed by several scenarios to determine the behavior of system parameters in a 20 kV system interconnection network. This research is an implementation of regulatory provisions relating to the study of the connection to the PLN distribution network through by regulator. Based on the result of simulation study, transient stability of generators at Tombolo-Pao power plant about 0.1 second, will not occur with network configuration according to modeling activation of anti-islanding protection of Tombolo Pao Power Plant which is set by 2 second. The simulation results show that the location of the disturbance in the electric power system has been influenced by the behavior of the power plant (synchronous generator) which can lead to the instability of the micro-hydro connected to the micro-grid system 20 kV.

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1. INTRODUCTION

Transient stability analysis is carried out to determine the ability of the electric power system to maintain operating stability after a major disturbance. The disturbance can have an impact on the stability of the rotor angle, voltage, and system frequency which can cause loss of synchronization. The stability condition is the validity of the conditions for connecting the generator to PLN's distribution network, which is the Regulation of the Minister of Energy and Mineral Resources NO. 12/ESDM/2014 concerning purchase of electricity energy from hydropower plants to the State of Electricity Company (PT. PLN) and provisions of the board of directors of PT. PLN through the Regulation No.0357.K /DIR/2014, concerning guidelines for connecting renewable energy power plants to distribution systems PLN [1]. It is a challenge for electricity providers to always provide a reliable and sustainable electricity supply by building renewable plants that can improve the appearance of the system [2]. Transient stability analysis is carried out to determine the ability of the electrical power system to maintain the initial stability of operation after a major disturbance that can have an impact on the stability of the rotor angle, voltage, and the system frequency which can cause the loss of synchronization, and in the worst conditions, it can cause the black-out system. The stability problems

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arising in micro-grid are very similar to those arising in large-sized power systems: transient stability, voltage stability, and small-signal stability. The micro-grid is represented as the combination of several distributed energy sources and the load on a small network system. With the limited power of distributed generators having a small-scale generator capacity in a micro-grid system, the effect is more reactive than the large generators. Therefore, it is more important to know the dynamic behavior of synchronous machines or time-domain stability in power systems provides information about rotor angular stability and synchronization capability after major and minor disturbances, such as bus voltage drops or load changes [3]. An analysis of the voltage stability in the power system can be obtained by comparing the respective bus pre-fault voltages with the existing voltage calculated or observed after the fault is cleared [4]. In this paper, the main focus is the transient stability of the micro-grid, which is defined as the operating conditions in power systems. This paper is divided into five sections: introduction, literature review, problem statement, case study and result, and conclusion.

2. LITERATURE STUDY

The unbalance between load and generation in the power system will make the voltage and frequency system instability. Generally, on power system interconnection, there are two conditions of system stability: dynamic and transient stability. Dynamic stability is how the system looks when there is a dynamic change in the load. Meanwhile, transient stability in the system refers to the ability of a system to recover voltage and frequency by anticipating sudden load losses [5]. In case of sudden power failure, it needs to be maintained, so that the transient stability of the power system can reach an operating condition that can become a new equilibrium state or a stable state after the disturbance has disappeared [6]. Through the power flow analysis, it will provide information about the balance point of the power system used to determine the transfer capacity limit before the major disturbance occurs. The transient stability analysis with a simulation time domain is also required to observe transient system response during major disturbances [7]. When other major disturbances, such as a network line break where the plant is not connected to the power system grid, the short recovery time through the rapid protection system can improve system reliability and safety [8]. The ability of the system to maintain dynamic and transient stability is strongly influenced by several factors, especially those related to the transient parameters of the synchronous generator [9]-[11], in addition, the constant parameter of the control system device on the turbine. With regard to system stability, the impact on the micro-grid is not different from the stability of a large power system such as transient stability, voltage stability, and small frequency stability [12]. However, the limitation of small-scale generators (MHPP) with micro-grid systems, the response is more reactive than the large generators. The response to the disturbances in the micro-grid system can lead to transient instability, requiring a rapid disconnection of healthy parts. If the disturbance is allowed, the entire micro-grid system can experience voltage and frequency collapse [13]. In order to prevent the stress collapse of the micro-grid due to the overall disruption of the tissue, a technique for isolating the micro-grid is required which is called the islanding technique [14]-[16]. In general, transient stability studies and analysis are carried out to review the ability of the electric power system to maintain initial stability of operation after a major disturbance has an impact on the stability of the rotor angle, voltage, and system frequency which can cause out of step or out of sync, and in the worst conditions, it can cause black-out system [16], [17].

In a grid or transmission system, the thing that needs to be considered from the results of the transient stability analysis is the critical disconnection time (critical clearing time), which is the critical time limit before an out of step or out of sync is expected that circuit breaker (CB) will open the channel during disturbances. In addition, the transient stability study in the case of connecting renewable energy power plants to the PLN 20 kV distribution system is also to see whether it will have an impact on the formation of an islanding operation or an isolated system so that the renewable energy power plant only supplies local loads, and is not connected to the PLN system [1]. This is because the renewable energy power plant connected to the 20 kV system has a small role in destabilizing the grid system which is assumed to be a swing or slack or infinite bus whose capacity is very large and strong [17]. In a grid or transmission system, the thing that needs to be considered from the results of the transient stability analysis is the critical disconnection time (critical clearing time), which is the critical time limit before an out of step or out of sync is expected that circuit breaker (CB) will open the channel during disturbances. In addition, the transient stability study in the case of connecting renewable energy power plants to the PLN 20 kV distribution system is also to see whether it will have an impact on the formation of an islanding operation or an isolated system so that the renewable energy power plant only supplies local loads and is not connected to the PLN system [1]. This is because the renewable energy power plant connected to the 20 kV system has a small role in destabilizing the grid system which is assumed to be a swing or slack or infinite bus whose capacity is very large and strong [17]. In a grid or transmission system, the thing that needs to be considered from the results

of the transient stability analysis is the critical disconnection time (critical clearing time), which is the critical time limit before circuit breaker (CB) will open the line during disturbances. In addition, the transient stability study in the case of connecting renewable energy power plants to the PLN distribution system 20 kV is also to see whether it will have an impact on the formation of an islanding operation or an isolated system so that the renewable energy power plant only supplies local loads and is not connected to the PLN system [1]. This is because the renewable energy power plant connected to the 20 kV system has a small role in destabilizing the grid system which is assumed to be a swing or slack or infinite bus whose capacity is very large and strong [17]. Some papers have been explored a new distributed secondary control scheme of distributed generators in islanded micro-grids [18]-[20]. While, time frequency regulation scheme strategy based active power control is presented in [21], [22], which can also to control of frequency system according to the reference value [23], [24]. Then, in [25], presented a transient current based micro-grid connected power system protection algorithm in micro-grid connected power systems for the fault location detection using wavelet method.

3. PROPOSE METHOD

Regulation of the Minister of Energy and Mineral Resources NO. 12/ESDM/2014 concerning purchase of electricity energy from hydropower plants to the PT. PLN (State of Electricity Company) and provisions of the Board of Directors of PT. PLN through the Regulation No.0357.K /DIR/2014, established a guideline for connecting renewable energy power plants to distribution systems PLN. The regulator (PLN) request purchase of electricity energy from hydropower plants to the PT PLN, should be an interconnection study before system will be operate. Therefore, with multiple generators that are in a balanced state, the following equation will apply,

$$J_i \frac{d^2 \theta_{m-i}}{dt^2} = T_{m-i} - T_{e-i} \quad (1)$$

where,

J = Momen Inertia

θ_{mi} = rotor angle of generator -i

T_{m-i} = Mechanical Torque of generator -i

T_{e-i} = Electric Torque of generator -i

The (2) [1] can be expressed as (2),

$$J\omega_i \frac{d^2 \delta_{m-i}}{dt^2} = P_{m-i} - P_{e-i} \quad (2)$$

where,

ω = angular rotation of generator-i

δ_{mi} = Displacement angle of mechanical generator -i

P_{m-i} = Mechanical power of generator -i

P_{e-i} = Electric power of generator -i

Suppose there are 2 micro hydro generators connected to the interconnection network, then the power of each generator is as follows,

$$P_{e1} = |E'_1|^2 |Y_{11}| \cos \theta_{11} + |E'_1| |E'_2| |Y_{12}| \cos(\theta_{12} - \delta_1) \quad (3)$$

$$P_{e2} = |E'_2|^2 |Y_{22}| \cos \theta_{22} + |E'_2| |E'_3| |Y_{12}| \cos(\theta_{23} - \delta_2) \quad (4)$$

Meanwhile, to determine the critical breaking angle, it can be solved by equations,

$$\delta_{cr} = \frac{\omega_s P_m}{4H} t_{cr} + \delta_o \quad (5)$$

or,

$$t_{cr} = \sqrt{\frac{4H(\delta_{cr}-\delta_0)}{\omega_s P_m}} \quad (6)$$

where,

δ_{cr} = critical breaking angle

H = inertia constant

t_{cr} = critical Breaking Time

To analyze the stability of the transition, it can be done using the Lyavonov method, namely,

$$\dot{V} = \sum_{i=1}^n \frac{\partial V}{\partial x_i} \dot{X}_i = \sum_{i=1}^n \frac{\partial V}{\partial x_i} f_i(x) \quad (7)$$

$$\dot{V} = \left[\frac{\partial V}{\partial x_1} \frac{\partial V}{\partial x_2} \dots \frac{\partial V}{\partial x_n} \right] \begin{bmatrix} f_1(x) \\ f_2(x) \\ \vdots \\ f_n(x) \end{bmatrix} \quad (8)$$

Simulation model,

$$J\omega_i \frac{d^2 \delta_{m-i}}{dt^2} = P_{m=i} - P_{e-i} \quad (9)$$

when, generator-1 fault, where $P_{e-1}=0$, therefore,

$$J\omega_i \frac{d^2 \delta_{m-i}}{dt^2} = P_{m=i} - 0 \quad (10)$$

In this research, several data from PT PLN (Persero) the Sulselrabar Region, especially from PT PLN (Persero), the Sulselrabar (P2B) as the Load Management Unit, requires for a certain period of time, short circuit level data, power transformer data, data for Incoming CB equipment. and 20 kV feeders, cubicle data and protection relay data. Meanwhile, from the Tombolo Pao Power Plant, data is required, including the coordinates of the location of the power house and the dam, the distance to the existing PLN distribution network and generator data obtained from the manufacturer.

4. CASE STUDY AND RESULT

4.1. Case study

In case study, Tombolo Pao Hydro Power Plant (1x2.5 MW)+(1x0.5 MW) connect to the PLN distribution system, it begins with the collection of field data which is generally obtained from the local PT PLN (Persero), namely PT PLN (Persero) Wilayah Sulselrabar, South Makassar area and Malino Rayon areas. The data required from the local PLN unit include:

- Single line distribution network diagram for the Tamaona feeder connected to the Tangka Link Substation, the Tamaona feeder connected to the Malino Substation (SS), peak load data and current peak load times and load forecast according to RUPTL 2015-2024.
- Data of distribution transformer capacity and loading and the distance between distribution transformers.
- Data on the length of the distribution network and the type of conductor used.
- Equipment data in distribution networks such as PMT, LBS/DCC, Recloser/Sectionalizer, Fuse and AVR.
- Data of types and brands of phase overcurrent protection relays and overcurrent to ground, TOC curve of relays, values of existing protection relay settings in the distribution network.

In the grid or transmission system, the thing that needs to be considered from the results of the transient stability analysis is the critical clearing time (CCT), which is the critical time limit before the out-of-step or out of sync that is expected PMT will open the line disturbed before the CCT. However, in the study of transient stability in the case of connecting renewable energy power plants to the PLN 20 kV distribution system, it is prioritized to see whether it will have an impact on the formation of an islanding operation or an isolated system so that the renewable energy power plant only supplies local loads and is not connected to the PLN system. This is because the renewable energy power plant connected to the 20 kV system has a small role in disrupting stability in the grid system which is assumed to be a swing or slack or infinite bus whose capacity is much larger and stronger (robust). The transient stability study uses ETAP 12.6 software by selecting the operating pattern at maximum load (WBP) with the assumption that the largest

noise current is obtained at maximum generation conditions. When the PLTMH operates in an islanding state, the CB at Tanka Substation (SS) which is supplied by the button feeder does not work. Likewise, with the Tamaona feeders will open CB on Tamaona substation as shown in Table 1. The short circuit current contribution of the feeder is very small due to its location which is quite far from SS Tombolo as shown in Table 2. This transient stability study, it is simulated by assuming a major disturbance, namely a 3-phase short circuit, which has an impact on the stability of the electric power system, especially to see its impact on power plant. The Governor and Exciter data for the generators of Tombolo Pao-HPP uses the existing generator data model in the ETAP 12.6 program. In this transient stability simulation, 2 scenarios were carried out by considering the location of the disturbance and its effect on the stability of TPMHPP.

Table 1. Short circuit current fault at bus#7 (SS. Tamaona)

Fault at bus:	Bus7								
Nominal kV	20.000								
Voltage c Factor	1.10 (User-Defined)								
Contribution		3-Phase Fault		Line-To-Ground Fault					
From Bus	To Bus	% V	kA	% Voltage at From Bus			kA Symm. rms		
ID	ID	From Bus	Symm. rms	Va	Vb	Vc	Ia	3I0	X0
Bus7	Total	0.00	1.833	0.00	101.28	89.39	2.019	2.019	1.16E+002
Bus6	Bus7	0.04	0.019	0.03	101.28	89.40	0.015	0.002	1.10E+005
Bus8	Bus7	3.84	1.447	3.96	100.75	89.98	1.313	0.790	2.04E+002
Bus12	Bus7	1.60	0.464	3.86	101.47	87.54	0.787	1.350	1.89E+002

Table 2. Short circuit current fault at bus#6 (SS Tombolo)

Fault at bus:	Bus16								
Nominal kV	20.000								
Voltage c Factor	1.10 (User-Defined)								
Contribution		3-Phase Fault		Line-To-Ground Fault					
From Bus	To Bus	% V	kA	% Voltage at From Bus			kA Symm. rms		
ID	ID	From Bus	Symm. rms	Va	Vb	Vc	Ia	3I0	X0
Bus16	Total	0.00	Total	0.00	98.06	2.211	2.293	0.00	98.06
Bus15	Bus16	1.25	Bus16	1.25	97.96	0.470	0.706	2.63	97.96
Bus20	Bus16	9.55	Bus16	9.55	96.95	1.797	1.640	10.29	96.95
Malino	Bus16	100.00	Bus16	100.00	100.00	0.009	0.006	100.00	100.00

4.2. Result

This scenario is carried out to determine the transient stability of the PLTMH when there is a disturbance in the Tombolo-Pao feeder at a distance of about 2 km from the TPMHPP. The simulation results of transient stability analysis can be seen in Figure 1 to Figure 7 which describes the excitation conditions of the generator, active power, rotor angle, changes in speed, magnitude and angle of voltage and frequency (%) on the Tanka Substation (SS.Tangka) and the 20 kV bus at Tombolo-Pao Substation (SS.Tombolo) as closest bus with fault location.

Figure 2 shows the excitation current in generators at the Tombolo-Pao power plant before the fault and after the bus # 7 fault. The change from initial conditions to steady state is around 0.1 second for both generators. Meanwhile, the amplitude of the excitation current increased to 1.7 pu for generator#1 and generator#2 reached 1.4 pu.

Figure 3 shows the excitation voltage in generators at the Tombolo-Pao power plant before the fault and after the bus # 7 fault. The change from initial conditions to steady state is around 0.1 second for both generators. Meanwhile, the amplitude of the excitation voltage increased to 1.2 pu (generator#1) and generator#2 reached 1.5 pu.

Figure 4 shows the speed in generators at the Tombolo-Pao power plant before the fault and after the bus # 7 fault. The change from initial conditions to steady state is around 0.1 second for both generators. Meanwhile, the amplitude of the speed generator#1 increased to 1000 rpm and generator#2 reached 1300 rpm.

Figure 5 shows the output generators at the Tombolo-Pao power plant before the fault and after the bus # 7 fault. The change from initial conditions to steady state is around 0.1 second for both generators. Meanwhile, the amplitude of the output generators#1 increased to 1.2 MW and generator#2 reached 1.2 MW.

Figure 6 shows the power angle in generators at the Tombolo-Pao Power Plant before the fault and after the bus # 7 fault. The change from initial conditions to steady state is around 0.1 second for both generators. Meanwhile, the amplitude of the power angle increased to 220-degree generator#1, generator#2 of 240 degree.

While in Figures 7 and 8, shown of the frequency and voltage system conditions of the nearest bus system when there is a disturbance on the bus closest to the Tombolo Pao Power Plant. With the operation of Tombolo Pao HPP (2x2.5 MW)+(1x0.5 MW) connected to PLN distribution system, the important thing to

note in preparing of emergency condition are: the formation of islanding operation is a condition where Tombolo Pao plant (2×2.5 MW)+(1x0.5 MW) apart from PLN system but part of distribution network load still supplied from HPP Tombolo Pao. Based on the result of protection coordination study, the possibility of forming islanding operation at Tombolo Pao plant will not occur with network configuration according to modeling in Figure 1, and with activation of anti islanding protection SMHPP Tombolo Pao which is set of 2 second. The condition of islanding operation in accordance with the provisions of the Regulation of the Board of Directors No.357.K/DIR/2014 is not permitted under normal operating conditions, except in emergency conditions established under the authority of PLN. The underlying reason for not allowing islanding operations is to safeguard both human and equipment. Therefore, any renewable energy power plant must be equipped with anti-islanding protection.

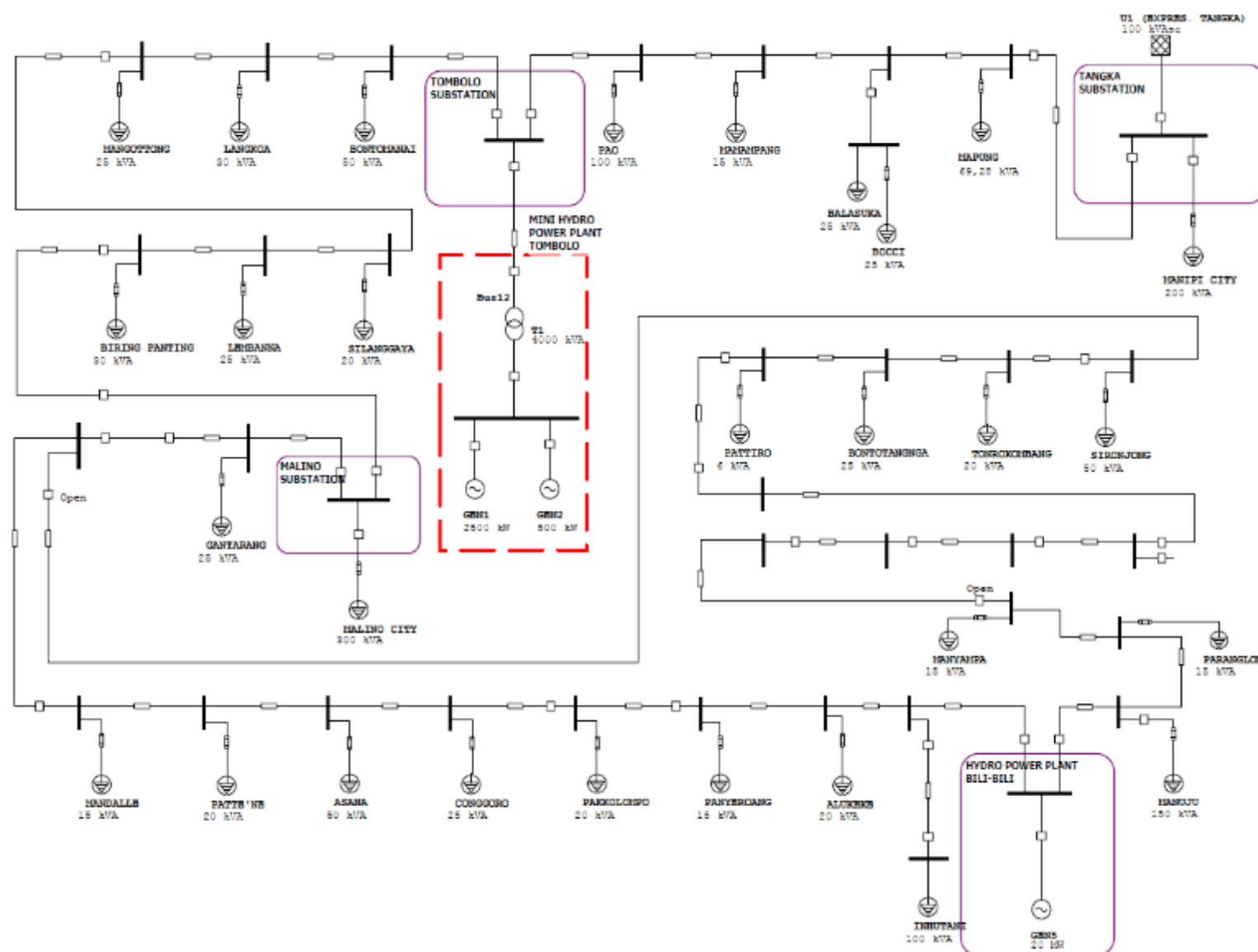


Figure 1. Single line diagram of Tombolo Pao plant interconnected with grid 20 kV system

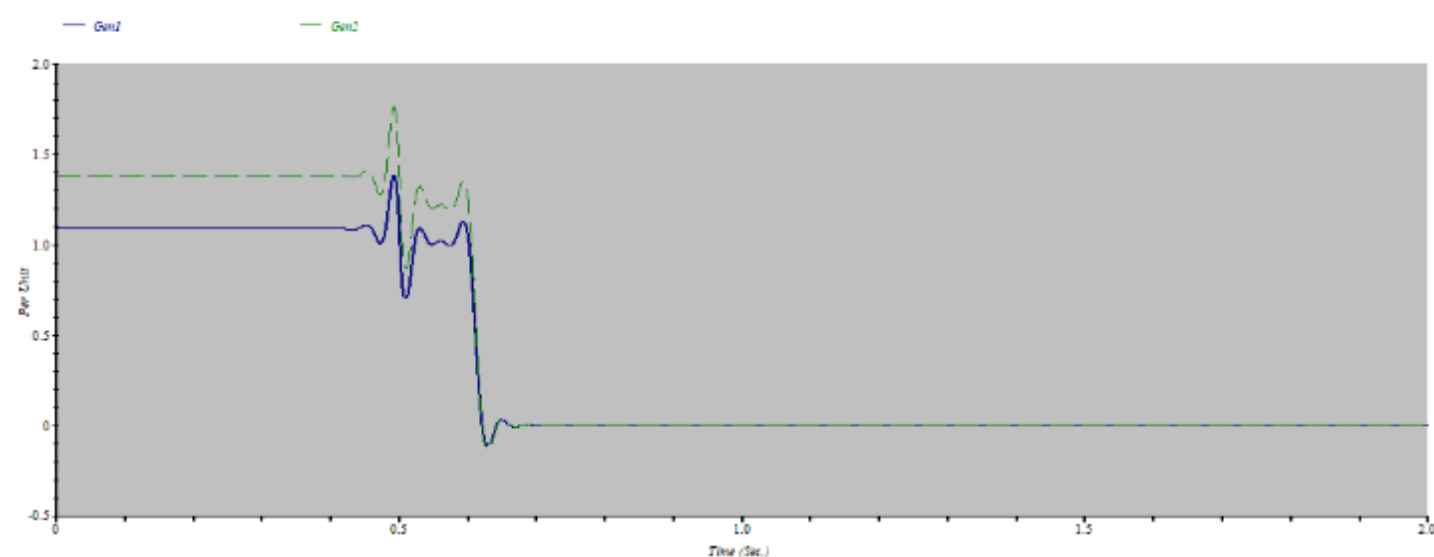


Figure 2. Excitation current on generators before and after fault

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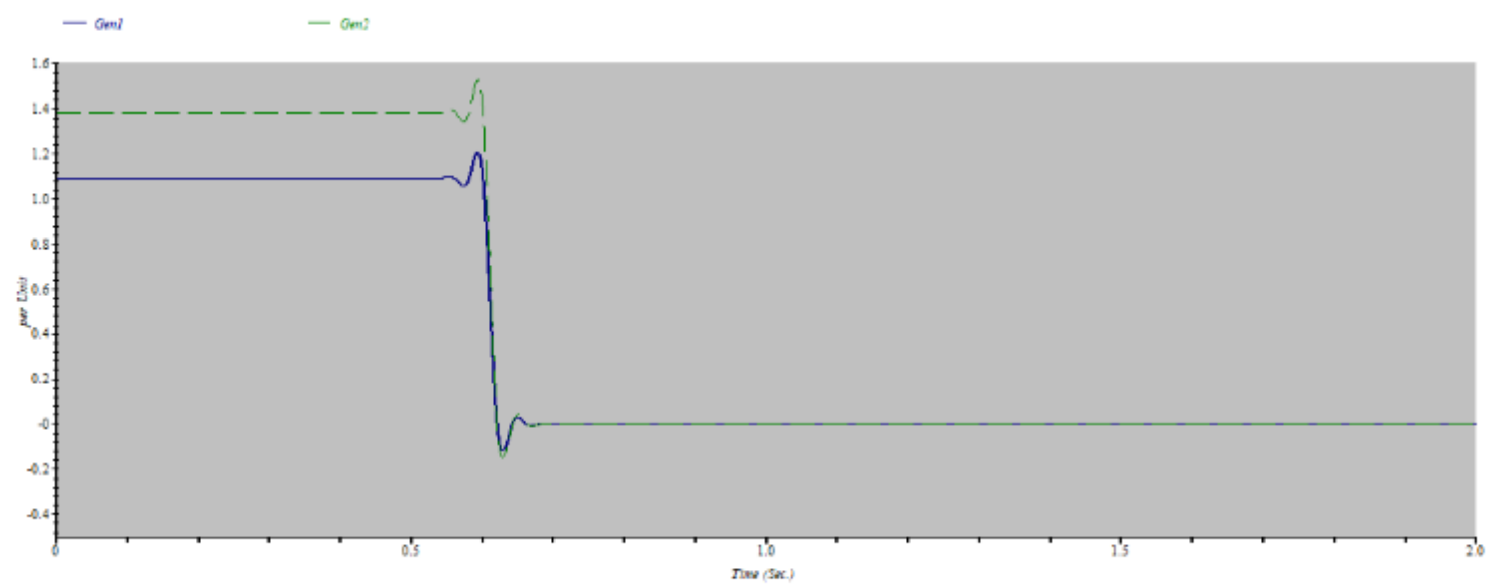


Figure 3. Excitation voltage on generators before and after fault

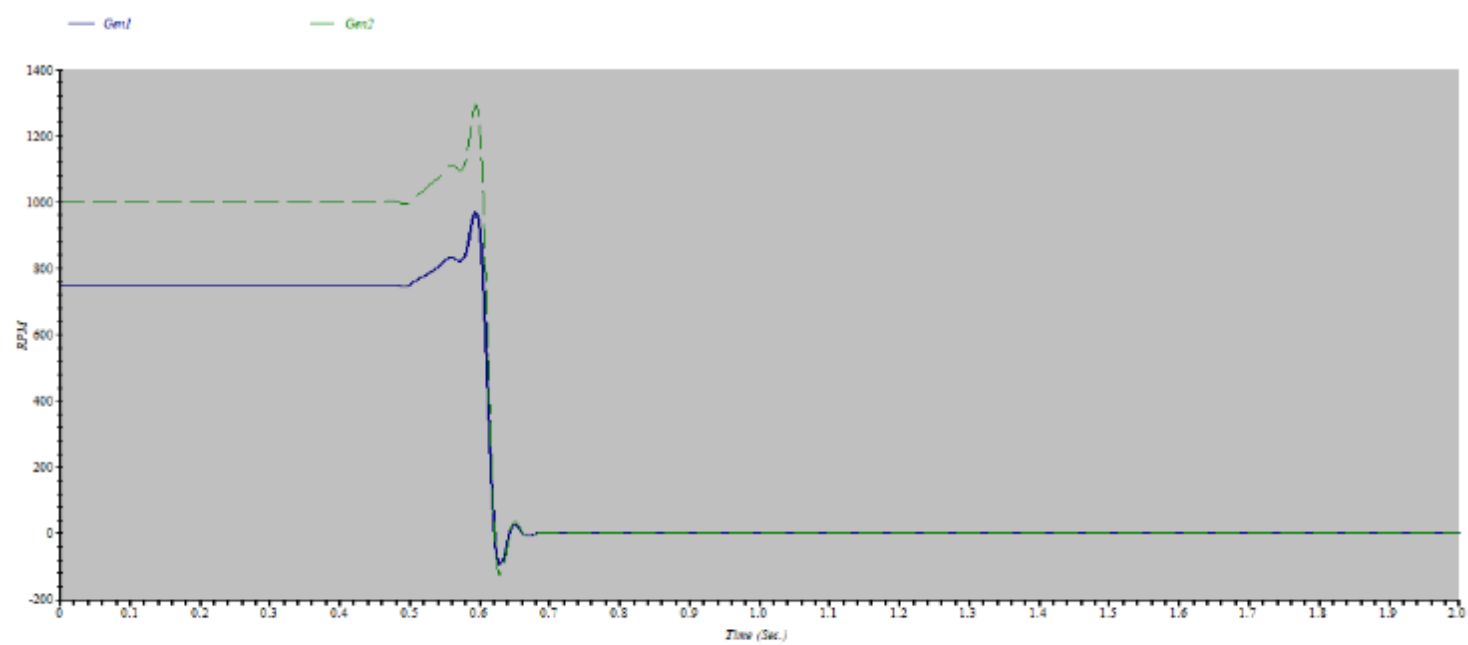


Figure 4. Generator speed on generators

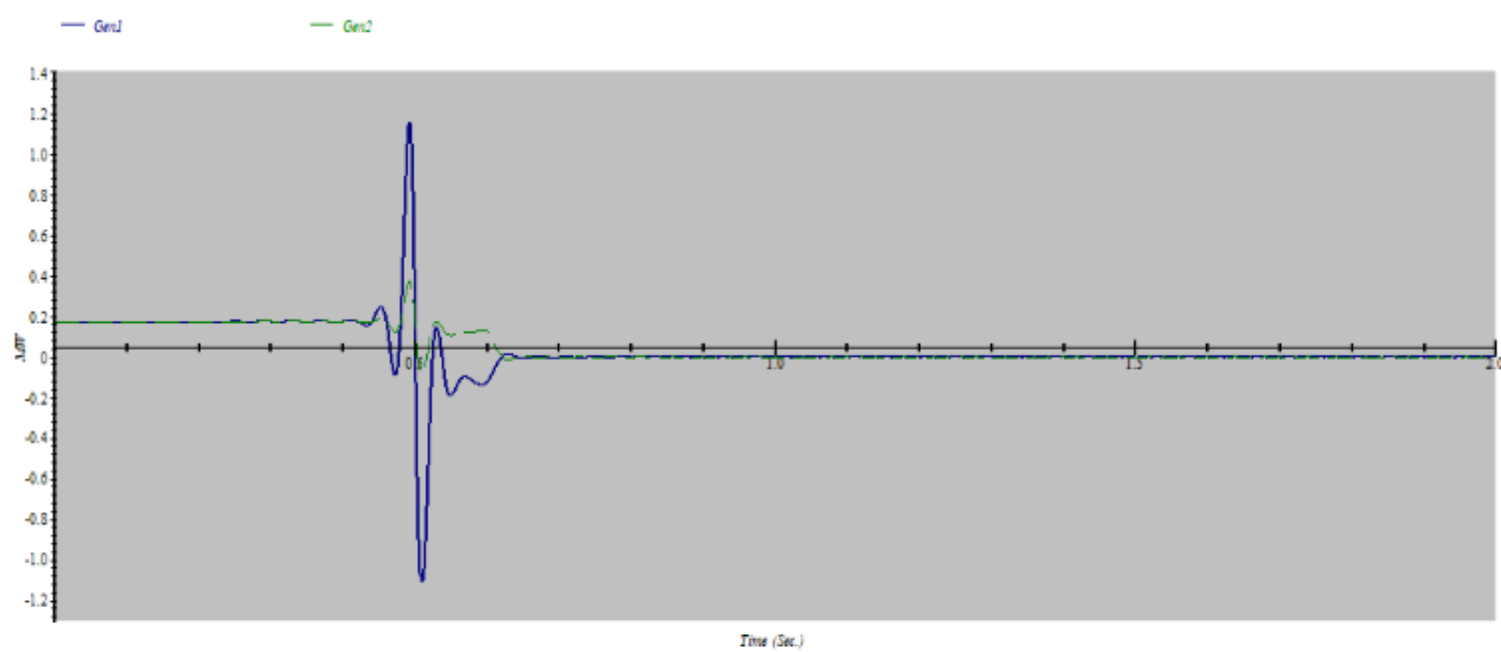


Figure 5. Output generator power before and after fault

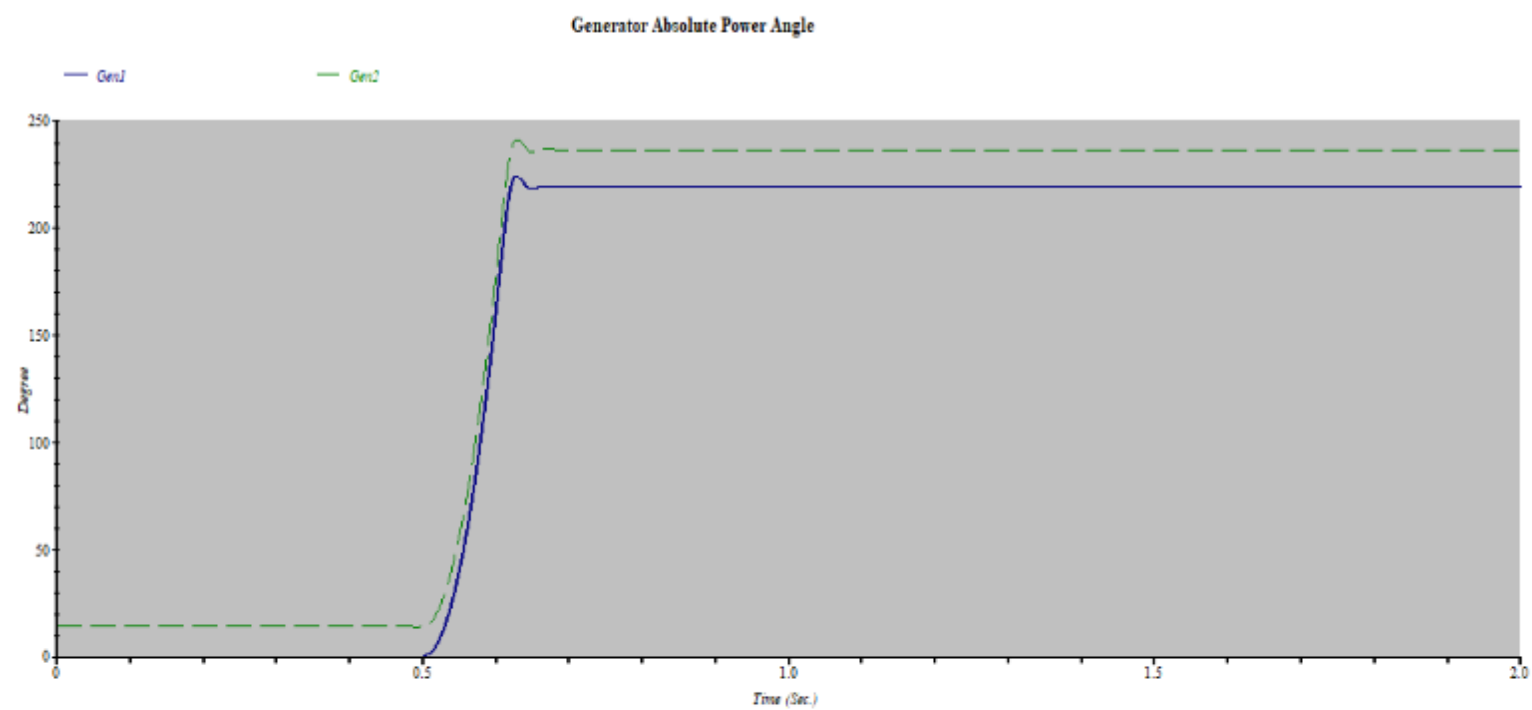


Figure 6. Power angle generator before and after fault

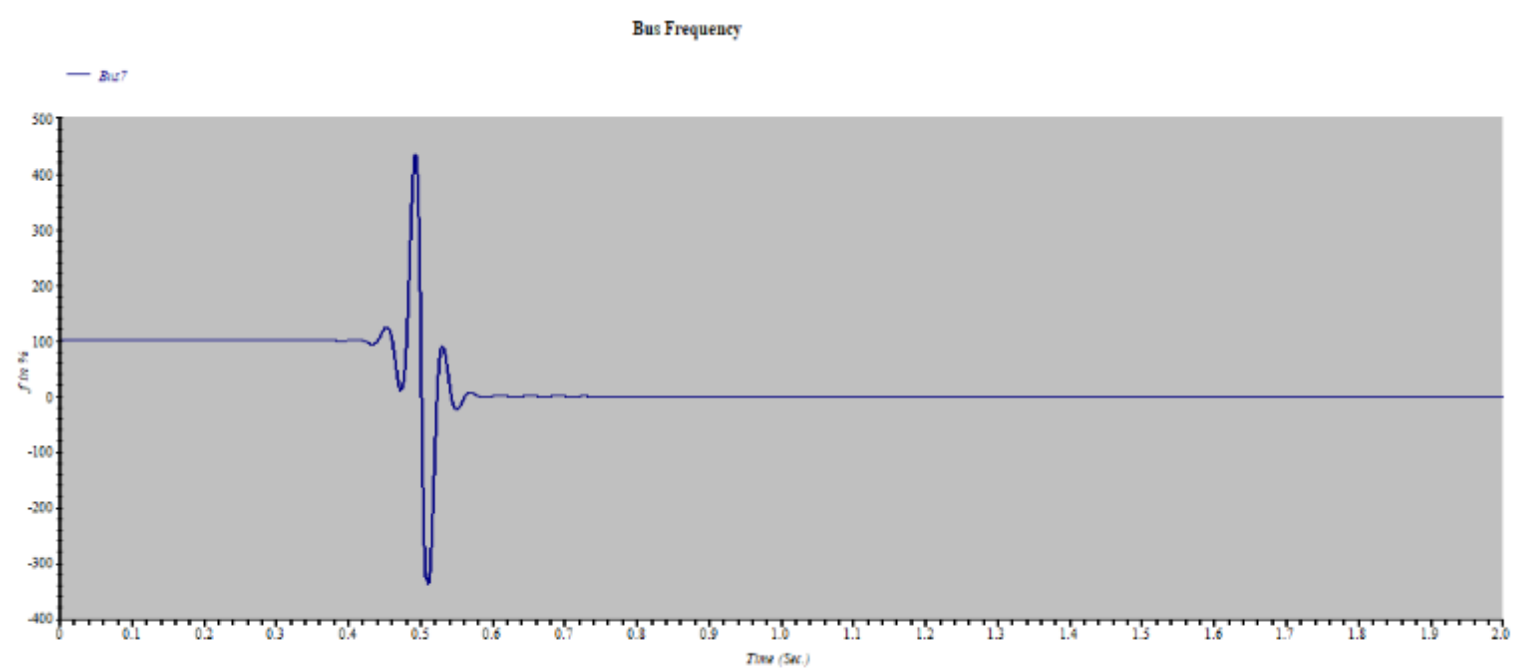


Figure 7. Frequency system on 20 kV bus closet with fault location

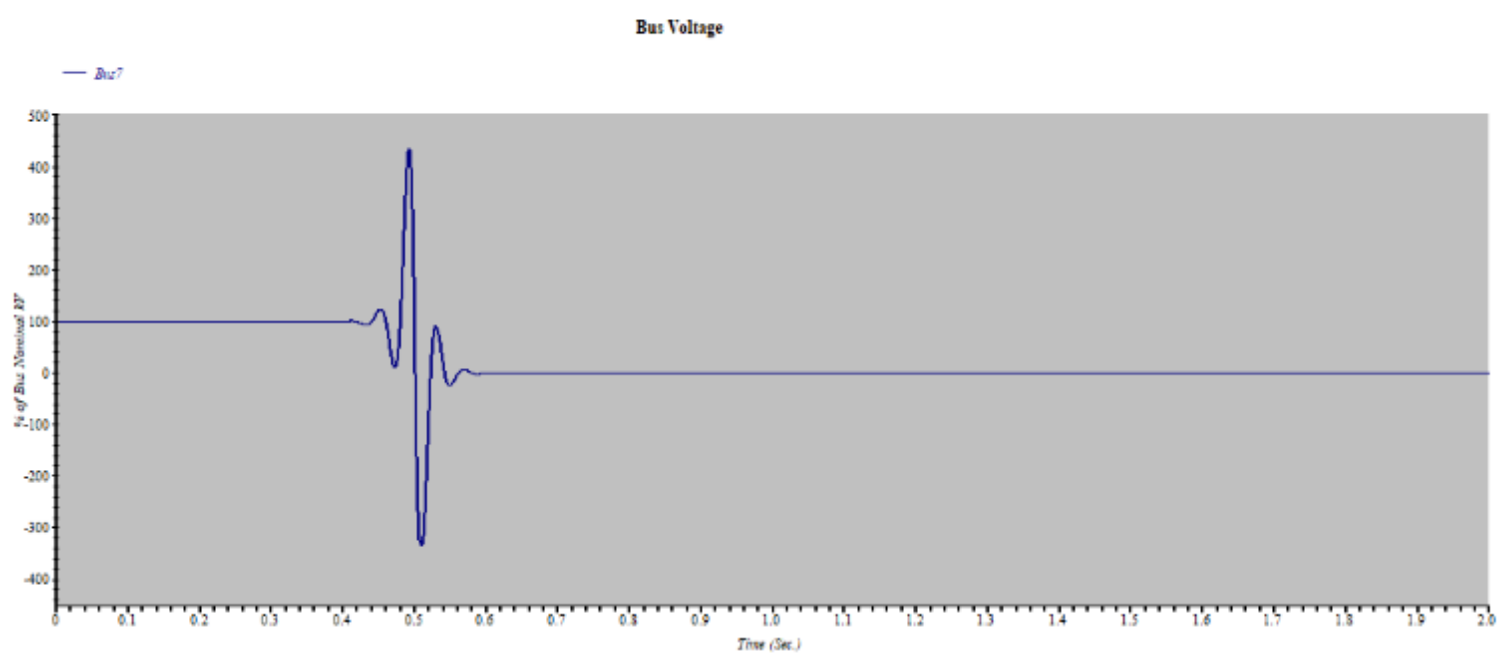


Figure 8. Voltage system (%) on 20 kV bus closet with fault location

5. CONCLUSION

The simulation results show that the location of the fault in the electric power system has a big impact on the synchronous generator synchronous speed, power angle, voltage, and frequency. Based on the simulation results, it can be seen that the transient stability of the micro-grid can be increased by the response rate of the protection system (islanding system) and load shedding immediately after disturbance of the network. In this study, the results showed that the discharge of excess load can affect the frequency stabilization until a steady-state is reached. Therefore, in the future, studies are needed that can determine the optimal load shedding based on load shedding control as a very fast and optimal solution for increasing transient stability in the micro-grid. Based on the case study of HPP Tombolo Pao, the condition of islanding operation in accordance with the provisions of the Regulation of the Board of Directors No.357.K / DIR / 2014 is not permitted under normal operating conditions, except in emergency conditions established under the authority of PLN. Based on the result of simulation study, transient stability of generators at Tombolo Pao plant about 0.1 second, will not occur with network configuration according to modeling activation of anti-islanding protection of Tombolo Pao Power Plant which is set by 2 second.

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