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Transient Stability Evaluation of the Power Generation under a Blackout Condition based on the Branch Tripping Scenario

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ABSTRACT

An operational condition of a power system is able to affect to stability performances after disturbed by a certain fault on the interconnection system. Moreover, this fault also gives impact to the blackout situation created by a large disturbance as disconnecting back bone lines of the interconnection system. In detail, this case is presented in this paper for evaluating transient stability performances of generating units while producing energy for the load center online the power system operation with the blackout situation designed using a branch tripping method. Furthermore, the transient stability responses are subjected to the power generation of the electric power system in Malang Raya as a real system operation for interacting the generating and demand sites. Results obtained show that voltage changes of Wlingi power station is 0.944 pu to 0.946 pu and its overshoot is 0,962. But the other overshoot of the power generation in Sutami remained to 0.968 pu at 0.5 second after appearing a blackout fault and its voltage increase to 0.952 pu from 0.948 pu at the final stable position.

Keywords *– Blackout, branch tripping, power system, stability.*

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I. INTRODUCTION

One of the important problems on the power system operation is the stability controlling system covered in voltage; power; and rotor angle. These stability performances are associated with dynamic behaviors of the power system during delivering energy from various power generations to load center areas with the individual demand at each bus. Moreover, these responses are also depended on interrupting faults at interconnected elements on power stations, transmission or distribution lines, and utility sectors. So, the stability condition is very important to know in order that it can be monitored periodically by a technical inspection to maintain the power system performance while supplying the total load with better requirements. In addition, effects of disturbances in stability responses of the power system under a disconnecting failure have been evaluated deeply in [1]. The power station which is released from an interconnection is able to interrupt to a stability position of each parts and it will remain to a new stable position. Voltage changing responses of the power system as one of operational behaviors have been also found out in [4] with its criteria for the voltage stability limit. In this case, the huge power system stability needs to watch constantly and it should be controlled in order that the stability limit could be recovered to avoid the collapse condition during establishing the interconnection operation as investigated in [3].

Many previous works have presented that the stability case is still very important to be studied because it contributes to the power system performance for presenting the normal condition; failure condition; or recovery condition, in a day all period operation. Specifically, failure and recovery conditions are more important thing to be evaluated on a striking fault or a disturbance on the power system operation. On the other hand, it can create an instability situation for shifting the stable points of voltage; frequency; power; and rotor angle for the existed generating units and buses online the power system operation as presented in [6]. In particular, these effects should be improved soon to reach a normal condition and to reduce the oscillation. Many techniques of the improvement under faulted condition have been studied and applied based on various themes for recovering stability performances [5], [8], [9], [10]. In detail, it uses small feedback signals from many parameters in transient responses of the instability condition to meet disturbing effects on the interconnecting process or the disconnecting process during maneuvering for an interruptible striking on loads, power stations or lines.

Practically, the transient stability is concerned in a large interconnection of a power system and it is divided into several areas for an inter area operation, such as in Malang Raya System (MRS). Stability behaviors of this system become a very attractive point to be analyzed because of the power delivery through one line interconnection at the north area which is connected to the back bone of Java Bali Power System (JBPS) supported by 500 kV and 150 kV systems with many types of power plants for producing energy throughout the committed scheduled power output to meet the total demand. Moreover, this paper presents an evaluation of the power station stability under a blackout condition based on a branch tripping scenario.

II. STABILITY MODEL AND METHOD

In general, power system dynamic behaviors can be described using power delivery performances and it has a maximum limit before reaching the asynchronous position or losing the system. On the other word, it can also be expressed using an oscillation of mechanical and electrical components due to power angle values or other parameters [6]. In addition, the understanding of dynamic behaviors and designing of controlling units are very important to improve stability performances of the power system and all established power stations. In principles, it can be known based on all fundamental components of the electric power system because those have a significantly contribution to the transient response as a completed structure of the power system [2]. The fundamental components of the power system are developed using turbine and governor sections; generator and rotor sections; exciter and regulator sections; transformer and transmission line sections, as illustrated in Figure 1 for the whole connection.

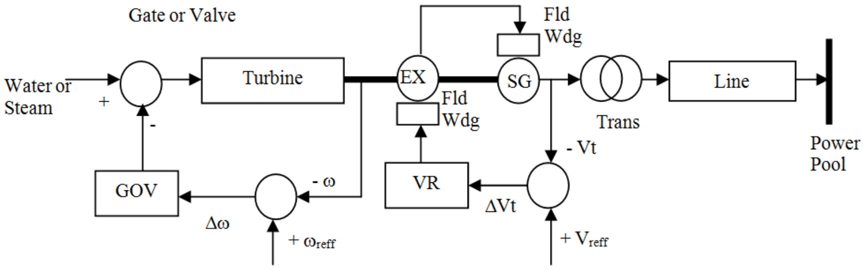

Figure 1. Fundamental components of the power system

Figure 1 shows that an interaction of turbine and governor sections gets a feedback signal from a rotation of the rotor generator as Δω after including its referenced value. Moreover, the voltage change is sent to the excitation system as ΔVt after controlling through a regulator as a feedback signal for defining the field current of the generator. As an integrated structure, the generator is connected to the power system through a transformer for conditioning each voltage level before conveying energy to the load center areas through transmission lines. This interaction will keep the power balance between a total power demand at energy users, produced power stocks at generating sites, and the total power loss at distribution and transmission lines for the interconnection system. Practically, this integrated system should be maintained every operation for keeping its performance in the normal stability and it should be recovered soon after striking a certain disturbance or a fault.

In general, disturbances or faults give impacts to the power system operation, especially the blackout condition during striking a faulted is very important to recover soon in order that the power system performance can be relocated to the other stability point to keep the normal operation. This condition is also important to prevent before interrupting the power system stability. In addition, the power system stability must be recognized in all conditions and it will be used to evaluate responses of power stations on the large system, such as in the MRS which is integrated into JBPS as an infinite bus. In detail, the JBPS connects three main islands covered Java island; Madura island; and Bali island, furthermore it is also designed for supplying to Sumatera island in future. Those are lined using submarines cables of 150 kV between each port for transferring the power output stock from Java to Madura and Bali islands.

In particular, the power system of the MRS covers Malang City and Batu City integrated using 150 kV for connecting six main areas as illustrated in Figure 2. This figure shows the MRS depicted from JBPS with individual loads and generating units at each bus interconnected to the back bone system. This system is also combined in an interconnection to Tulung Agung and Blitar Cities. In the JBPS, this system exports the power to the infinite bus which is supplied to Bali and Madura Islands through submarine line cables of 150 kV. Then, stability performances of the MRS are evaluated on 150 kV and the lower voltage systems are inserted into 150 kV with considering each load at every bus. In detail, the load condition of each area in the MRS is concentrated on 150 kV as provided in Table 1.

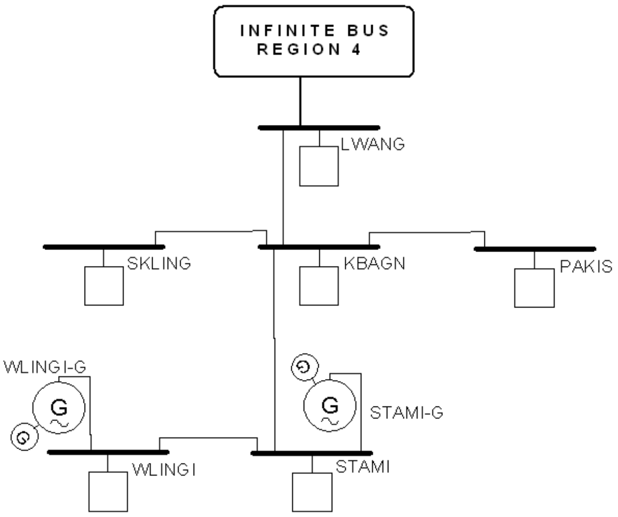

Figure 2. Power system in Malang Raya

Table 1. Load conditions in Malang Raya

No	Areas	Peak Load	
		MW	MVar
1	Kebon Agung (KBAGN)	115.0	60.0
2	Lawang (LWANG)	16.8	7.0
3	Pakis (PAKIS)	30.5	16.9
4	Sengkaling (SKLING)	58.7	34.2
5	Sutami (STAMI)	0.0	0.0
6	Wlingi (WLINGI)	58.9	38.5
Total		279.9	156.6

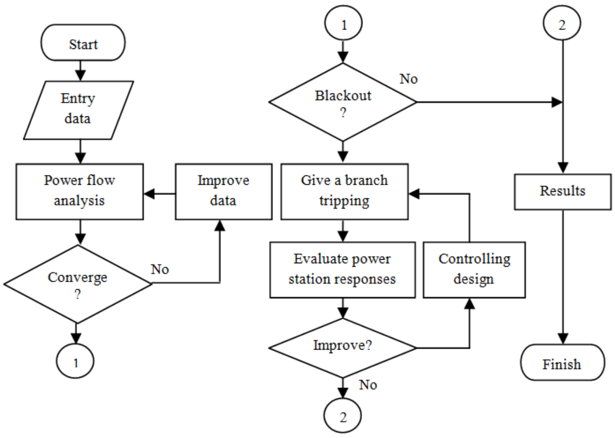

Figure 3. Analysis flow chart

In these works, the blackout condition is presented using a branch tripping placement at the main interconnection of the MRS and it describes an opening process of the transmission lines from the main interconnection and other cities caused by disturbances as disconnecting faults. Technically, these placements of the branch tripping are installed on interconnection systems of 150 kV for interrupting export/import powers through the infinite bus at the northern area and disconnecting feeders to other outside cities. In general, these procedures are presented in Figure 3 as the sequential flow chart of all the processes. These steps are also used to guide for analyzing and evaluating stability responses of the power generation.

III. RESULTS AND DISCUSSES

Stability analysis in [4] explains that it is possible to become an instability condition after losing the load center in an area or tripping power lines on cascade outages. This situation can be described using a power flow delivery process to the load and the arrow of the conveying power is very important to recognize for monitoring the power and current movements on transmission lines. In line with this evaluation, the power flow in MRS is very important to know and it is used to analysis the power delivery between load and source sites. In these works, the power flow is computed using Newton Raphson method to find out amount of power flows on transmission lines and to define the voltage for every bus. Its results are similar to the results in [3] that power flow gives an initial condition observation of the demand and generating unit interaction. Then, the power flow result of evaluation using Newton Raphson is provided in Table 2.

From Table 2, it can be clearly seen that the highest voltage drop is 1.71 % at Lawang bus or remain to 2.565 kV during the power delivery from Infinite bus to Lawang bus. Besides, the highest power lost is 1,291.4 kW while supplying to the load. It means that the power is high absorbed by the transmission line between Lawang bus and infinite bus.

Transient responses studied in [8] explain clearly that disturbances affected to the rotor angle, power and voltage. These results are also shown in this simulation throughout the branch tripping scenario while striking the power lines felt by power stations at everywhere. In this case, it is simulated to present a blackout condition in the MRS which is looked into in Sutami and Wlingi power stations. Stability responses of the Sutami power station are shown in Figure 4 and Figure 5, but the others are shown in Figure 6 and Figure 7.

According to Figure 4 and Figure 5, it is known that the Sutami power station responds the blackout condition after creating a branch tripping process. It has an oscillation of electric power and voltage performances after stroke by disturbances. These problems also generate a power decreasing during energy delivery to the load. Then, the voltage condition of Sutami power station changes is from 0.948 pu to 0.952 pu or the voltage is rose to 142.8 kV from the first level at 142.2 kV. Moreover, the overshoot voltage response of the Sutami power station is 0.968 pu or 145.2 kV which is obtained in 0.5 seconds after disconnecting the lines by the branch tripping.

Table 2. Power flow in Malang Raya System

No	From	To	Power delivery	
			MW	MVar
1	INFINITE BUS	LWANG	95.566	53.791
2	KBAGN	PAKIS	30.537	16.015
3	KBAGN	STAMI	-80.133	-35.432
4	LWANG	KBAGN	125.089	74.580
5	SKLING	KBAGN	-58.700	-34.200
6	STAMI-G	STAMI	105.000	45.600
7	WLINGI	STAMI	-23.908	-11.908
8	WLINGI-G	WLINGI	35.000	26.600

Table 3. Voltage drops and power losses in Malang Raya System

No	Location		kV Drop	Lost	
	From	To	(%)	(kW)	(kVar)
1	INFINITE BUS	LWANG	**1.71**		
2	KBAGN	PAKIS	0.13	36.7	-885.0
3	KBAGN	STAMI	0.53	337.8	-519.1
4	LWANG	KBAGN	0.87	852.4	320.9
5	SKLING	KBAGN	0.26	132.9	-523.5
6	STAMI-G	STAMI	0.06	55.8	52.2
7	WLINGI	STAMI	0.30	64.7	-1,273.0
8	WLINGI-G	WLINGI	0.02	8.3	7.8

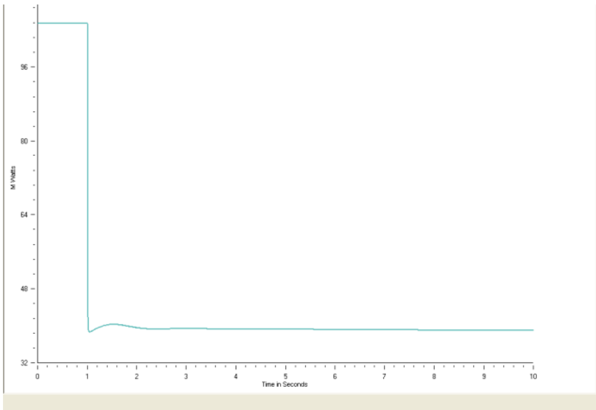

Figure 4. Power response of Sutami power station

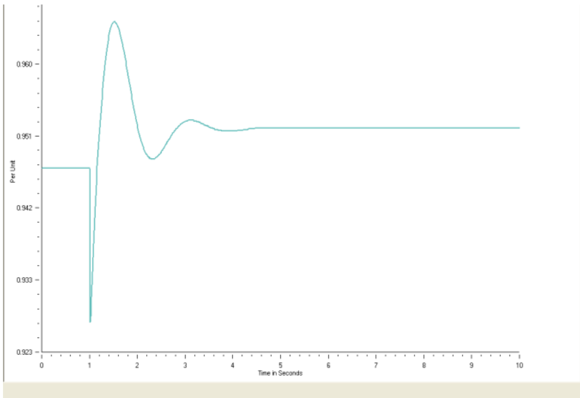

Figure 5. Voltage response of Sutami power station

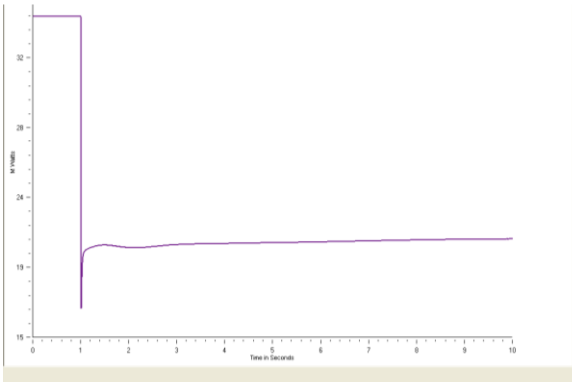

Figure 6. Power response of Wlingi power station

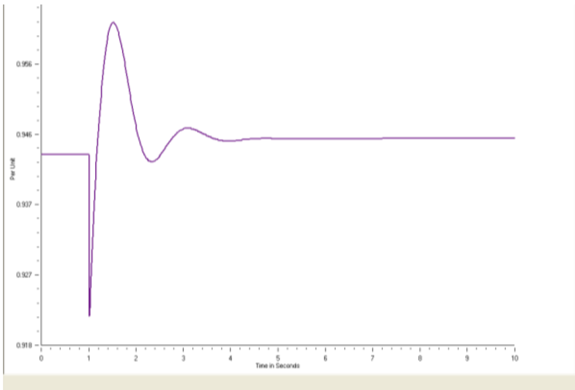

Figure 7. Voltage response of Wlingi power station

In particular, stability changed responses of the power station in Wlingi under a branch tripping scenario are given in Figure 6 and Figure 7. It can be seen that the Wlingi power station which is decreased in the power output production. Moreover, its voltage performance rises to 0.946 pu from the starting position at 0.944 pu. It means that the voltage of the Wlingi power station is associated with the disturbance effect shifted from 141.6 kV to 141.9 kV, and it has an overshoot at 0.962 pu or 144.3 kV after opening the lines in 0.53 seconds.

IV. CONCLUSIONS

The blackout condition through an outage fault created by branch tripping scenarios affects to the stabilities of power stations. These impacts influence to transient responses of each generator online the existed power system. The responses present changed levels of voltage and power performances to reach new stable points after interrupted by branch tripping faults. To recover stability performances of power stations using a controlling system application is devoted to the future research.

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