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Transient Stability Simulation of 33 kV Power Grid

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Abstract

An example of Sandakan power grid problem is presented in this paper. Sandakan is a suburb in east coast of Sabah state of Malaysia. Stability problem occurs due to the increase in load demand, lack of generation sources and inadequate supply. The tripping disturbances occur frequently in the network which is contributing to voltage instability. In this paper dynamics stability of 33 kV power grid as related to Sandakan network is analyzed and simulated. The analysis is completed by modelling the network data in Power System Simulation for Engineering (PSS/E) software and simulate the transient stability of generator, exciter and governor during a three phase fault occurs on a far and close distance from a bus, and determine the critical clearing time as well as swing curve of rotor angle. The output values of electrical power, machine speed, rotor angle and bus voltage are observed.

Keywords

Transient Stability, PSS/E, Load Flow, Generator, Exciter, Governor, Critical Clearing Time

1. Introduction

Generally, a power system under normal operating conditions may face a contingency such as transmission element outages, generator outages, loss of transformer, and sudden change in the load or faults [1]. Transient is an event occurs when a power system subjected to large disturbances under dynamic stability [2]. Disturbances include loss of synchronism, loss of generation, loss of load in transformers or faults on transmission element and lines. Transient stability is one of major analysis in the power system in order to ensure the system stability to withstand a major disturbance and to ensure that the transmission system is operated safely, steady state and contingency analysis must be performed [7].

The round rotor generator model (GENROU) represents as solid rotor generator at sub-transient level is used to produce machine rotor angle for transient stability. Rotor angle has the ability of interconnecting the synchronous machines with power system to remain in synchronism. Stability is related to generator electromagnetic torque and mechanical torque which cause the rotor to accelerate or decelerate [1]. Voltage stability is related to change in the load. This stability is the ability of a power system to maintain steady voltages at all busses from a given initial condition after being subjected to a disturbance [6]. Voltage instability increases by load demand or change in system condition which cause the incontrollable drop in voltage. With abnormal low voltage it is lead to voltage collapse also contributes to blackout of the grid system [2]. The problems were reported with power flow and contingency in terms of blackout after main grid supply outages with overload and high fault current on distribution system [4] [6]. Critical clearing time is known as maximum time duration that a fault may occurs in a power system without loss of stability. There are three type of fault condition which pre-fault system conditions, fault structure (type and location) and post fault conditions [3]. The three-phase fault is the most serious kind of fault and its critical clearing time can reflect the transient stability of power system. Critical clearing time (CCT) can be obtained by trial and error method [4].

Synchronous generator is the source of electrical energy where in the generator the mechanical energy usually transformed into electrical energy. This transformation is provided by excitation of synchronous generator and is regulated by excitation system. An IEEE Type 2 Excitation System (IEEET2) and turbine governor such as Gas Turbine (GAST) and Turbine IEEE Type 1 Speed Governing Model (IEEEG1) are used.

Generator excitation is defined as generator output voltage and output reactive power. It means that the excitation is actually output energy of generator regulation and this can impact the stability of the power system. The use of an excitation system is for maintaining the output voltage, control the shaft's speed and enhancing the generator performance.

In this paper, PSS/E will be used for characterizes the power system transmission network and generation performance for both load flow analysis and transient analysis [5]. All the sources referred from the books, articles, research papers and journals.

2. Modelling the Network in PSS/E

The following information needed for modelling the network. This includes bus data, branch data, load data, generator data and transformer data. These data are saved in **data.sav** file in PSS/E and are given in the Appendix. All data and parameters are taken from Sandakan power grid system.

The power network consists of 26 buses, 8 generators and 22 loads. The highest bus base is 33 kV and the lowest is 6.6 kV. Figure 1 represents the existing network.

3. Transient Stability Analysis

In order to achieve stability of power system, load flow study is an important tool that gives a numerical solution. In power flow analysis a per-unit system is used for voltage magnitudes and angles, real and reactive powers.

In conducting transient analysis, there are three machine model must be taken into account such as generator, exciter and governor. These are as follows:

- Round Rotor Generator Model (GENROU)
- Exciter IEEE Type 2 Excitation System (IEEET2)
- Turbine Governor GAST
- Turbine IEEE Type 1 Speed Governing Model (IEEEG1)

Tables 1-4 show the parameters of the above models

4. Load Flow Result

The diagram Figure 1 is the operation of load flow for 26 buses divided into 1 slack bus which is BN_11 as a swing bus. The transient stability analysis requires the solution of a system of coupled non-linear differential equation. Load flow simulation on PSS/E using Newton Raphson gives the following values in Tables 5-7.

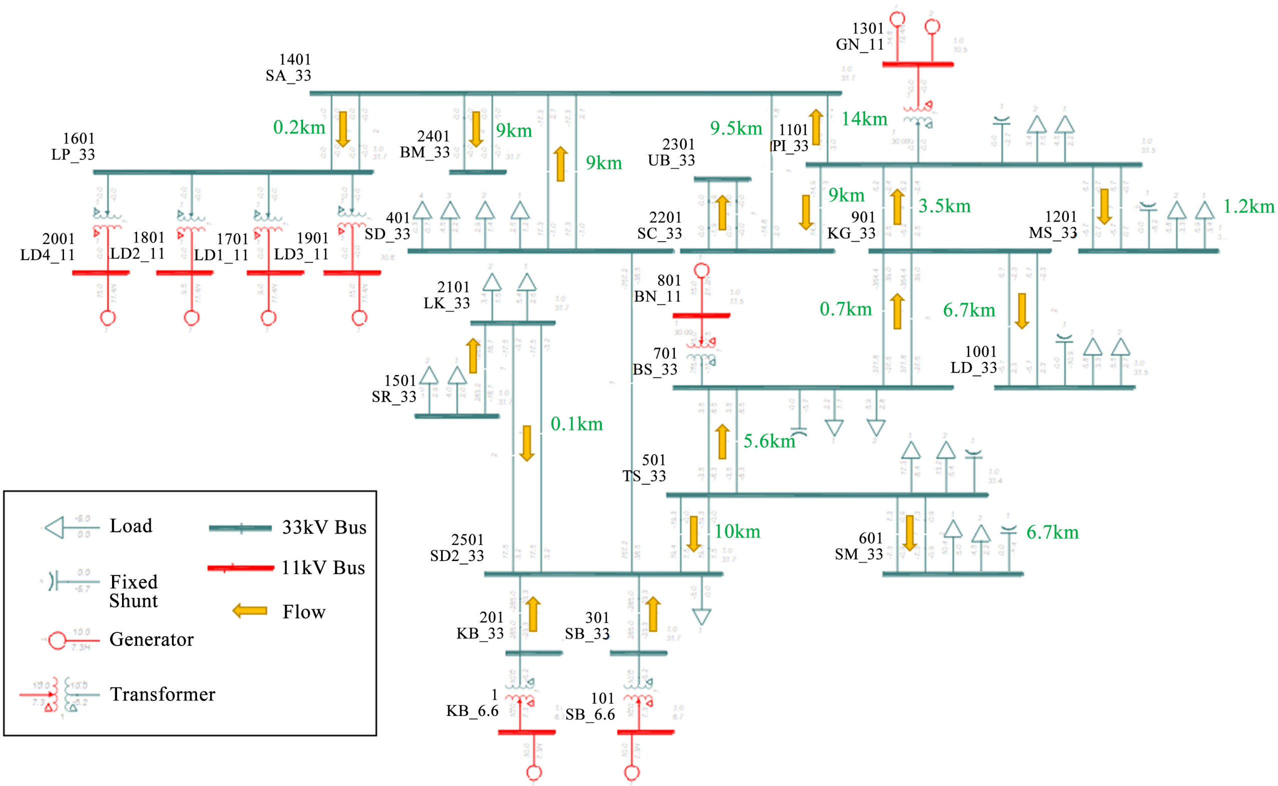

Figure 1. Sandakan power grid model in PSS/E.

Table 1. Parameters of genrou genrator model.

	Con Value			
Con Description	KB_6.6 SB_6.6	BN_11	GN_11	LD1_11, LD2_11, LD3_11, LD4_11
T'do (>0)	2.10	5.70	6.50	4.90
T"do (>0)	0.05	0.05	0.05	0.05
T'qo (>0)	1.10	0.75	0.75	0.50
T"qo (>0)	0.19	0.05	0.05	0.05
H, inertia	1.757	4.68	6.70	3.19
D, Speed Damping	0.19	0.00	0.00	0.00
Xd	1.91	2.01	2.02	1.35
Xq	1.89	1.898	1.92	0.79
X"d	0.20	0.30	0.189	0.39
X"q	1.02	0.60	0.30	0.50
X"d = X"q	0.15	0.185	0.28	0.29
Xl	0.11	0.10	0.10	0.10
S(1, 0)	0.13	0.08	0.06	0.12
S(1, 2)	0.39	0.35	0.19	0.35

Table 2. Parameters of IEEET2 exciter model.

Con Description	KB_6.6 and SB_6.6	BN_11 and GN_11	LD1_11, LD2_11, LD3_11, LD4_11
TR (sec)	0.02	0.00	0.00
KA	13.40	200.00	300.00
TA (sec)	0.00	0.50	0.50
VRMAX or zero	0.00	−2.60	−2.60
VRMIN	6.10	2.70	10.00
KE or zero	1.00	1.00	1.05
TE (>0) (sec)	0.20	1.00	0.10
KF	0.29	0.10	0.035
TF1 (>0) (sec)	1.40	0.035	0.068
TF2 (>0)	1.00	0.68	0.70
E1	0.00	0.00	0.00
SE (E1)	0.21	0.00	0.00
E2	1.00	0.00	0.00
SE (E2)	0.39	0.00	0.00

Table 3. Parameters of GAST turbine model.

Con Description	GN_11
R	0.05
T1	0.40
T2	0.10
T3	2.00
AT	1.00
KT	2.00
VMAX	0.80
VMIN	0.417
DTRUB	0.00

Table 4. Parameters of IEEEG1 governor model.

Con Description	BN_11	LD1_11, LD2_11, LD3_11, LD4_11
K	10.00	18.00
T1	0.05	20.00
T2	0.00	7.30
T3	0.25	0.80
U0	0.30	1.00
UC	−0.30	−1.00
PMAX	0.70	0.80
PMIN	0.36	−0.05
T4	0.10	0.01
T5	0.45	0.10
T6	0.00	0.10
T7	0.00	0.10
K1	0.33	1.00
K2	0.00	0.00
K3	0.67	0.00
K4, K5, K6, K7, K8	0.00	0.00

Table 5. Swing bus summary.

			MW			MVar	
Bus Name	Base (kV)	Pgen	Pmax	Pmin	Qgen	Qmax	Qmin
KB_6.6	6.6	24.7	10.0	0.0	4.8	7.3	0.5
SB_6.6	6.6	25.1	10.0	0.0	7.1	7.3	0.5
BN_11	11	27.8	20.0	0.0	7.4	21.2	−5.2
GN_11	11	4.6	19.0	10.0	2.3	12.4	−7.3

Continued

LD1_11	11	7.5	15.0	8.0	2.4	11.4	−8.5
LD2_11	11	7.5	15.0	8.0	2.4	11.4	−8.5
LD3_11	11	7.5	15.0	8.0	2.4	11.4	−8.5
LD4_11	11	7.5	15.0	8.0	2.4	11.4	−8.5

Table 6. Voltage performance under normal conditions (Pre-Disturbance).

Voltage Level	% Variation
415 V and 240 V	−10% and +5%
6.6 kV, 11 kV, 22 kV, 33 kV	±5%
132 kV and 275 kV	−5% and +10%

Table 7. Voltage performance under contingency conditions (Post-Fault).

Voltage Level	% Variation
415 V and 240 V	±10%
6.6 kV, 11 kV, 22 kV, 33 kV	+10% and −10%
132 kV and 275 kV	±10%

Table 5 shows the swing bus BN_11 holds the highest real power generation, Pgen is 27.8 MW and reactive power generation, Qgen is 7.4 MVar. This swing bus is a special generator bus serving as the reference bus. The steady-state supply voltage limits applicable for the pre-disturbance and post-fault state defined in Table 6 and Table 7. These variations of voltages are normally applied for pre and post fault

5. Bus Voltage before and after Load Flow Simulation

Table 8 shows all the voltages before load flow analysis are under normal condition which are not exceed than 105% (overvoltage) and not below 95% (under-voltage). Thus, the grid does not have any critical busses.

These parameters are found from Sandakan power grid of 26 buses. Load flow increases the voltage bus as shown.

6. Transient Stability Result

The transient stability analysis approach by applying a fault on a bus and run the simulation from time = 1 until time = breaker open. Based on the Sandakan grid's simulation in PSS/E, it can be seen from Figure 2 that all the machines in the system are in good initial condition.

The data from channel output file in PSS/E of Sandakan grid such as swing curve of rotor angle, impulse response of shaft speed, electrical power and bus voltage are plotted in Figures 3-9.

6.1. Generator

In the normal state, the machines in a power system network operate at equilibrium corresponding to the mechanical power input, Pm being equal to the electrical power output, Pe. When a fault occurs in the system at time = 1.0 seconds, the mechanical power input become greater than the electrical power output (Pm > Pe), then the speed of the machines increase as it will accelerate the rotor.

Table 8. Voltage performance before and after load flow.

			Before load flow		After load flow		
Bus Number	Bus Name	Base kV	Actual Voltage (kV)	Percentage (%)	Voltage (kV)	Percentage (%)	Condition ±5%
1	KB_6.6	6.6	6.6561	100.85	6.798	103.00	Normal
101	SB_6.6	6.6	6.6561	100.85	6.897	104.50	Normal
201	KB_33	33	31.6602	95.94	33.3881	101.18	Normal
301	SB_33	33	31.6602	95.94	33.3881	101.18	Normal
401	SD_33	33	31.6602	95.94	33.3881	101.18	Normal
501	TS_33	33	31.4292	95.24	33.1467	100.44	Normal
601	SM_33	33	31.3467	94.99	33.0737	100.22	Normal
701	BS_33	33	32.0397	97.09	33.6592	102.00	Normal
801	BN_11	11	11.539	104.90	11.539	104.90	Normal
901	KG_33	33	31.4919	95.43	33.6752	102.05	Normal
1001	LD_33	33	31.4985	95.45	33.7002	102.12	Normal
1101	PI_33	33	31.5117	95.49	33.8975	102.72	Normal
1201	MS_33	33	31.4754	95.38	33.8718	102.64	Normal
1301	GN_11	11	10.5039	95.49	11.44	104.00	Normal
1401	SA_33	33	31.7295	96.15	34.0495	103.18	Normal
1501	SR_33	33	31.6569	95.93	33.3855	101.17	Normal
1601	LP_33	33	31.7295	96.15	34.0821	103.28	Normal
1701	LD1_11	11	10.5765	96.15	11.539	104.90	Normal
1801	LD2_11	11	10.5765	96.15	11.539	104.90	Normal
1901	LD3_11	11	10.5765	96.15	11.539	104.90	Normal
2001	LD4_11	11	10.5765	96.15	11.539	104.90	Normal
2101	LK_33	33	31.6569	95.93	33.3855	101.17	Normal
2201	SC_33	33	31.614	95.80	34.0326	103.13	Normal
2301	UB_33	33	31.614	95.80	34.0327	103.13	Normal
2401	BM_33	33	31.7295	96.15	34.0495	103.18	Normal
2501	SD2_33	33	31.6602	95.94	33.3881	101.18	Normal

Bus Name	Base (kV)	Eterm (pu)	Efd (pu)	Power (MW)	Reactive (MVars)	Power Factor	Angle (degree)	Id (pu)	Iq (pu)
KB_6.6	6.6	1.0301	2.1454	10.06	3.02	0.9577	3.41	0.6008	0.4114
SB_6.6	6.6	1.0446	2.4176	10.06	5.18	0.8890	8.94	0.6742	0.3792
BN_11	11	1.0498	2.1639	24.79	7.81	0.9538	27.99	0.5766	0.3954
GN_11	11	1.0395	1.9159	17.16	2.96	0.9855	27.01	0.5565	0.4215
LD1_11	11	1.0489	1.5930	9.97	2.30	0.9744	23.47	0.2697	0.4452
LD2_11	11	1.0489	1.6057	10.48	2.26	0.9775	22.46	0.2828	0.4659
LD3_11	11	1.0490	1.7580	15.00	1.96	0.9916	13.80	0.4298	0.6380
LD3_11	11	1.0490	1.7580	15.00	1.96	0.9916	13.80	0.4298	0.6380

Figure 2. Initial condition of machines.

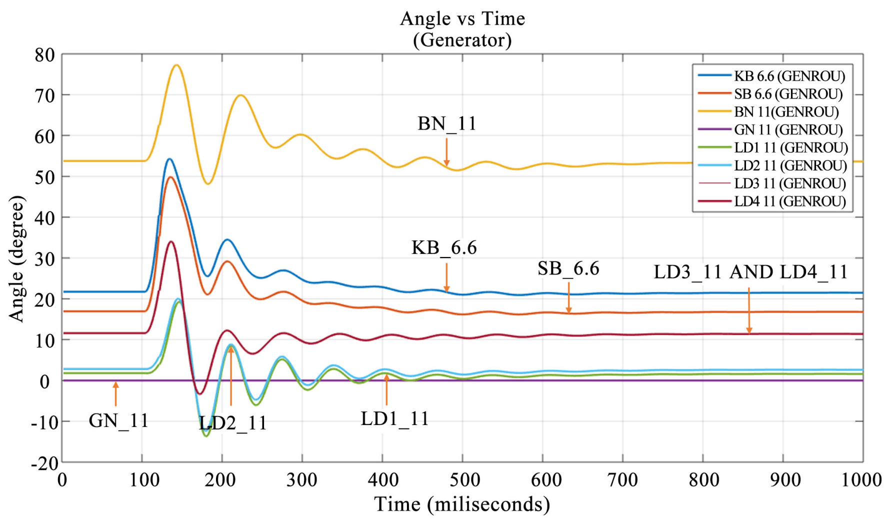

Figure 3. Swing rotor angle vs time for generators.

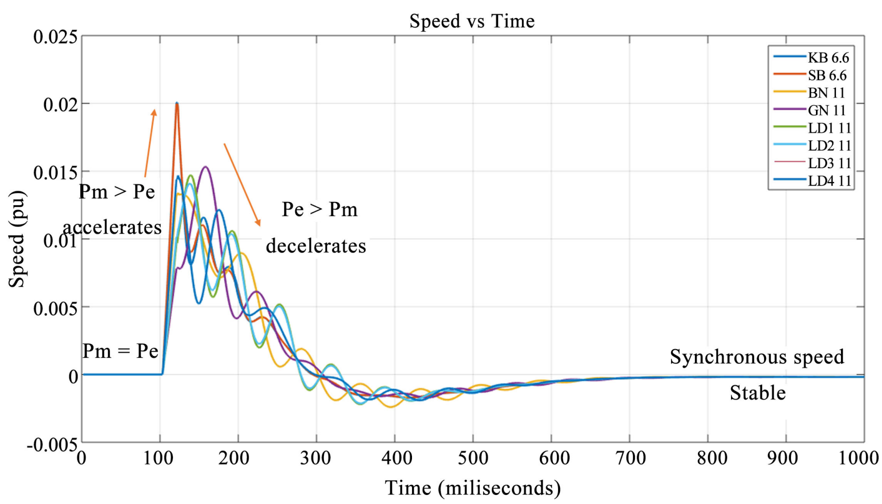

Figure 4. Impulse response of speed vs time for machines.

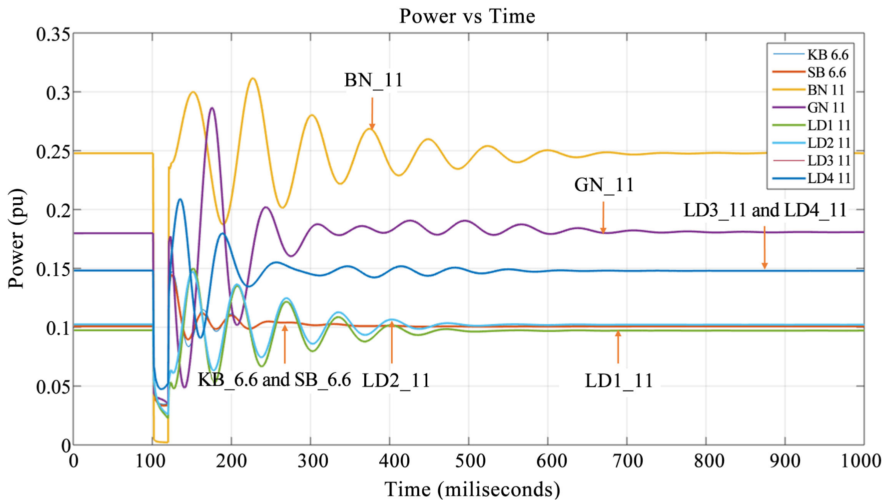

Figure 5. Active power vs time for machines.

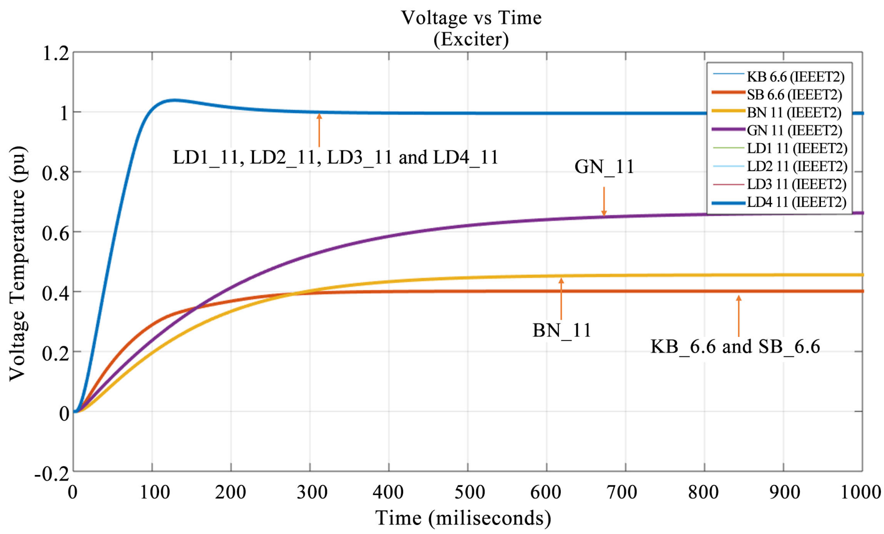

Figure 6. Terminal voltage vs time for exciters.

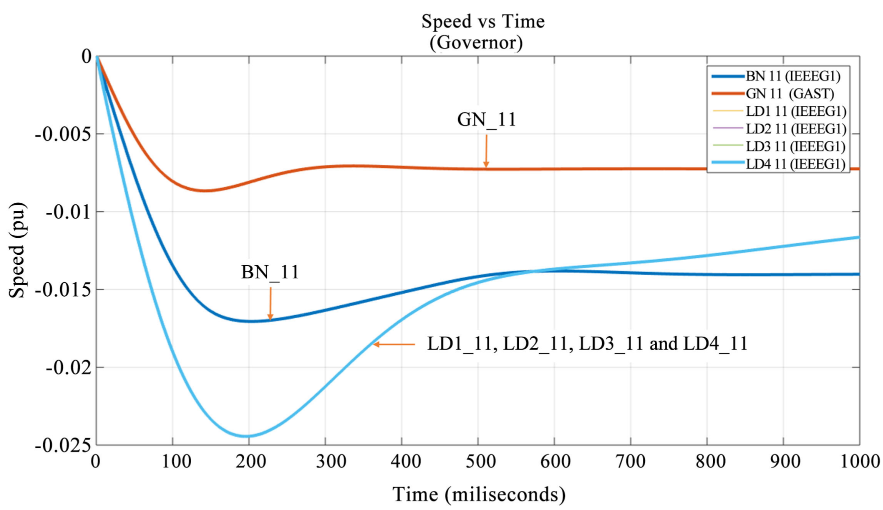

Figure 7. Step response of speed vs time for governors.

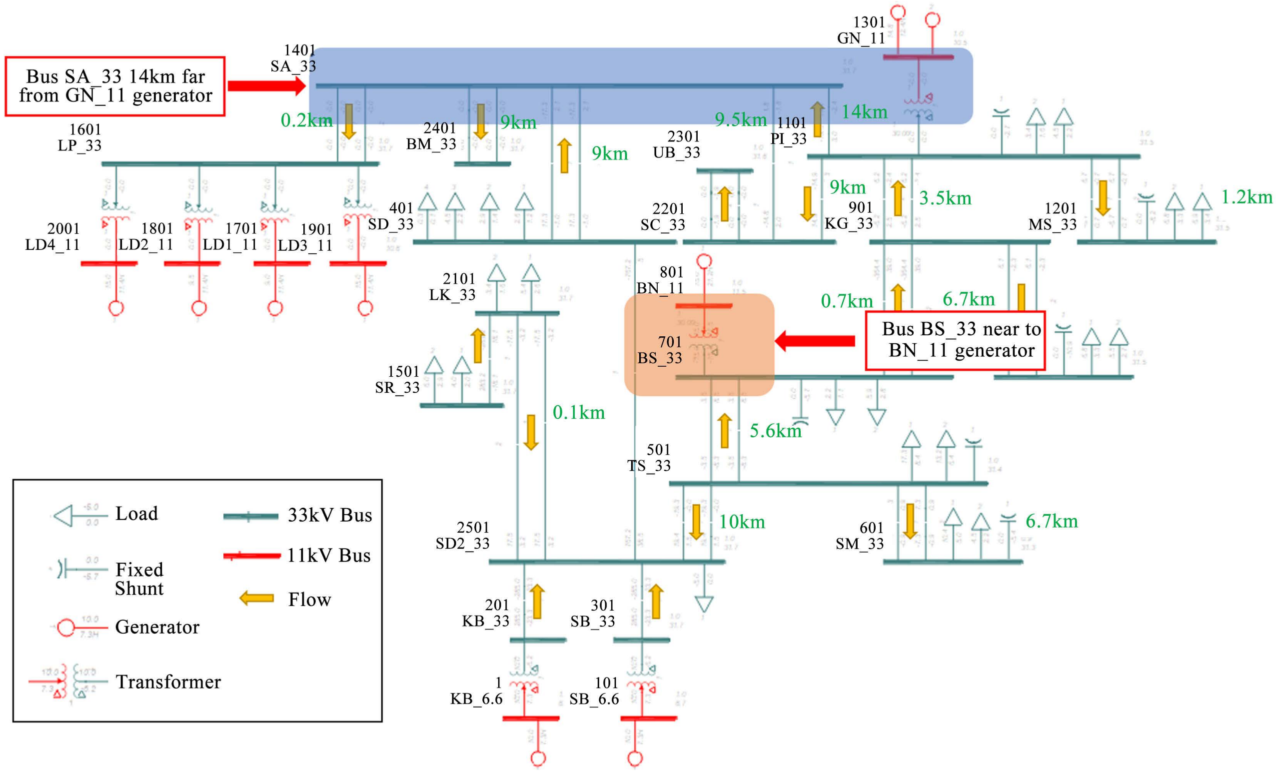

Figure 8. Bus near and far from generator.

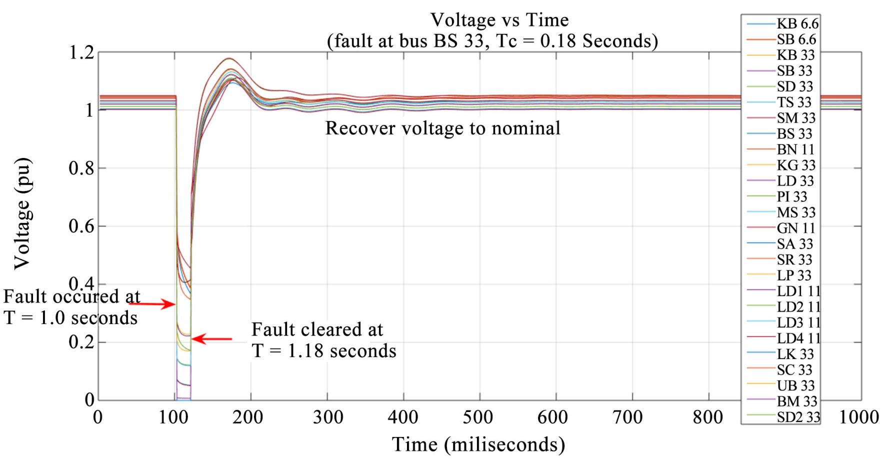

Figure 9. Voltage vs Time when faulted at bus BS_33.

With the fault cleared at time = 1.18 seconds, the electrical power becomes low but the rotor still running above synchronous speed, hence the angle and the electrical power continue to increase. When the electrical power is greater than mechanical power (Pe > Pm), it causing the rotor to decelerate toward synchronous speed until the angle reaches its critical value. When the system reached the critical value, the rotor angle will continue to oscillate back and forth at its natural frequency until it becomes stable.

In running the simulation the time of fault clear is from breaker open until 10 seconds.

6.2. Exciter

The results of the excitation system response in Figure 6, steady-state value for LD1_11, LD2_11, LD3_11 and LD4_11 are 0.994996 pu (terminal voltage). Steady-state value for GN_11 is 0.662346 pu (terminal voltage). Steady-state value for BN_11 is 0.455770 pu (terminal voltage). Steady-state value for KB_6.6 and SB_6.6 are 0.401253343 pu (terminal voltage).

Based on the results in Figure 6 indicate that GN_11, BN_11, KB_6.6 and SB_6.6 exciters perform slower than LD1_11, LD2_11, LD3_11 and LD4_11 exciters which are this exciter meet the 1 pu the excitation system voltage requirement. These bus conditions are shown in Table 9.

6.3. Governor

Figure 7 shows the variation of speed with time for governor IEEEG1 and GAST types. All final frequencies were determined by the droop, R of the responding governors, Table 10. The frequency drops depends upon the generator inertia values. The least frequency deviation occurs with high inertia and fast governors. Governor condition are given in Table 11.

6.4. Critical Clearing Time (Result)

To determine the critical clearing time when the fault occurs at bus that close and far from generator, refer to Figure 8. It shows that bus BS_33 is near to generator BN_11, while for bus SA_33 is 14 kilometers far from generator GN_11.

Figure 9 and Figure 10 have been obtained by the technique of trial and error method in order to determining the critical clearing time of the system where the fault duration was increased gradually using the step time of $\Delta t = 0.01$ seconds until the system appears to be unstable by observing machine's rotor angle as a reference point.

Figure 9 shows the variation of voltage with time for a three phase fault applied on bus BS_33 (bus near to generator). Since the three phase fault applied at time = 1.0 seconds, then the fault is clear at time = 1.18 seconds. Thus, the critical clearing time is 0.18 seconds and the system becomes stable.

Figure 10 shows the variation of voltage with time for a three phase fault applied on bus SA_33 (bus far from generator). Since the three phase fault applied at time = 1.0 seconds, then the fault is clear at time = 1.23 seconds. Thus, the critical clearing time is 0.23 seconds and the system becomes stable.

It can be seen that transient stability is greatly affected by the location of a fault from bus to generator. Table 12 shows the critical clearing times in seconds determined for all the twenty-six buses on the Sandakan Power Grid.

Transient stability analysis is run starting with a clearing time of 0.01 seconds. If the system is proved a stable condition, another analysis run is made by increasing the clearing time higher than first run. If the second run is still in stable condition, then more runs are made until the system becomes unstable. If the run showed an unstable system, then the clearing time of previous run gives the desired result.

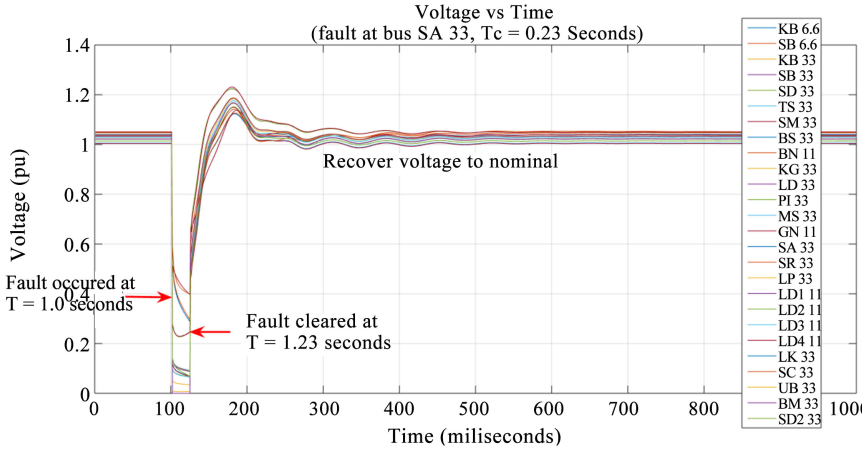

Figure 10. Voltage vs Time when faulted at bus SA_33.

Table 9. Exciter conditions.

Exciter	Condition
KB_6.6 (IEEET2) SB_6.6 (IEEET2)	Slow exciter
BN_11 (IEEET2)	Slow exciter
GN_11 (IEEET2)	Slow exciter
LD1_11 (IEEET2) LD2_11 (IEEET2) LD3_11 (IEEET2) LD4_11 (IEEET2)	Fast exciter

Table 10. Steady-state of governor.

	Steady state				
Governor	Base frequency (Hz)	Speed (pu)	Frequency (Hz)	Droop (R)	Inertia (H)
BN_11 (IEEEG1)	50	−0.01402	49.299	R = 0.1	4.68
GN_11 (GAST)	50	−0.00725	49.6375	R = 0.05	6.70
LD1_11 LD2_11 LD3_11 LD4_11 (IEEEG1)	50	−0.00808	49.596	R = 0.0556	3.19

Table 11. Governor conditions.

Governor	Condition
BN_11 (IEEEG1)	High inertia and fast governor
GN_11 (GAST)	High inertia and fast governor
LD1_11 (IEEEG1) LD2_11 (IEEEG1) LD3_11 (IEEEG1) LD4_11 (IEEEG1)	Low inertia and slow governor

Table 12. Critical clearing time with different location.

Fault at bus	Clearing time, Tc (seconds)	Location from Generator
KB_6.6	0.05	Near
SB_6.6	0.05	Near
KB_33	0.10	Near
SB_33	0.10	Near
SD_33	0.15	Near
TS_33	0.18	Far
SM_33	0.19	Far
BS_33	0.18	Far
BN_11	0.10	Near
KG_33	0.18	Far
LD_33	0.18	Far
PI_33	0.19	Far
MS_33	0.21	Far
GN_11	0.10	Near
SA_33	0.23	Far
SR_33	0.17	Far
LP_33	0.16	Far
LD1_11	0.10	Near
LD2_11	0.10	Near
LD3_11	0.10	Near
LD4_11	0.10	Near
LK_33	0.15	Near
SC_33	0.17	Far
UB_33	0.17	Far
BM_33	0.17	Far
SD2_33	0.13	Near

7. Conclusion

This paper presents a modeling and simulating case data of 26 buses, 8 generators and 22 loads 33 kV power grid that in service mode. Through load flow analysis, the voltage performance under different conditions can be determined. The desired analysis of the transient stability of the system based on output values such as machine rotor angle, electrical power, machine speed and bus voltage were found to be stable after fault is cleared. The rotor angle, power, speed and the voltage in the grid system is back to its normal condition where there is no generator set that will out of phase and when the fault is cleared. The theory of the critical clearing time (CCT) when the fault occurs close and far from the generator was proved in this paper by using trial and error method. Thus, as the distance between the bus and the generator increases, the critical clearing time also increases.

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Appendix

Table I. Buses data used in PSS/E.

Bus No.	Bus Name	Bus Code	Base kV	Voltage (pu)	Angle (deg)
1	KB_6.6	−2	6.6	1.0085	−15.28
2	SB_6.6	−2	6.6	1.0085	−15.28
3	SB_33	1	33.0	0.9594	−19.51
4	KB_33	1	33.0	0.9594	−19.51
5	SD_33	1	33.0	0.9594	−19.51
6	TS_33	1	33.0	0.9524	−23.99
7	SM_33	1	33.0	0.9499	−24.28
8	BS_33	1	33.0	0.9709	−23.60
9	KG_33	1	33.0	0.9543	−25.46
10	LD_33	1	33.0	0.9545	−25.73
11	PI_33	1	33.0	0.9549	−24.88
12	MS_33	1	33.0	0.9538	−25.07
13	TR_33	4	33.0	1.0000	0.00
14	SA_33	1	33.0	0.9615	−23.11
15	SR_33	1	33.0	0.9593	−19.52
16	LP_33	1	33.0	0.9615	−23.11
17	LK_33	1	33.0	0.9593	−19.52
18	SC_33	1	33.0	0.9580	−24.01
19	UB_33	1	33.0	0.9580	−24.01
20	BM_33	1	33.0	0.9615	−23.11
21	SI_33	4	33.0	1.0000	0.00
22	KG_11	4	11.0	1.0000	0.00
23	GN_11	2	11.0	0.9549	−54.88
24	SG2_11	4	11.0	1.0000	0.00
25	SG1_11	4	11.0	1.0000	0.00
26	SD2_33	1	33.0	0.9594	−19.51
27	BS_33	4	33.0	1.0000	0.00
28	BN_11	2	11.0	1.0490	10.42
29	LD1_11	2	11.0	0.9615	−23.11
30	BG_33	4	33.0	1.0000	0.00
31	B8_11	4	11.0	1.0000	0.00
32	LD2_11	2	11.0	0.9615	−23.11
33	LD3_11	2	11.0	0.9615	−23.11
34	LD4_11	2	11.0	0.9615	−23.11

Table II. Transformer branch data used in PSS/E.

Transformer Branches				Id	Tap Positions	Winding MVA Base
From Bus		To Bus				
No	Name	No	Name			
1	KB_6.6	4	KB_33	1	8	14.0
2	SB_6.6	3	SB_33	1	8	14.0
8	BS_33	28	BN_11	1	5	25.0
11	PI_33	23	GN_11	1	13	20.0
16	LP_33	29	LD1_11	1	5	20.0
16	LP_33	32	LD2_11	1	5	20.0
16	LP_33	33	LD3_11	1	5	20.0
16	LP_33	34	LD4_11	1	5	20.0

Table III. Machines data used in PSS/E.

Bus No.	Bus Name	Bus Code	PGen (MW)	P_{Max} (MW)	P_{Min} (MW)	QGen (Mvar)	Q_{Max} (Mvar)	Q_{Min} (Mvar)
1	KB_6.6	2	10.00	10.0	0.0	7.31	7.31	0.50
2	SB_6.6	2	10.00	10.0	0.0	7.31	7.31	0.50
23	GN_11	2	14.76	19.0	10.0	12.39	12.39	−7.35
23	GN_11	2	15.00	18.0	10.0	8.56	12.39	−7.35
24	SG2_11	4	25.00	10.0	0.0	−3.003	7.00	−5.00
25	SG1_11	4	25.00	10.0	0.0	1.525	7.00	−5.00
28	BN_11	2	15.00	20.0	0.0	17.468	21.24	−5.22
29	LD1_11	2	9.00	15.0	8.0	6.648	11.40	−8.50
32	LD2_11	2	9.50	15.0	8.0	6.603	11.40	−8.50
33	LD3_11	2	15.00	15.0	8.0	10.185	11.40	−8.50
34	LD4_11	2	15.00	15.0	8.0	7.224	11.40	−8.50

Table IV. Load data used in PSS/E.

Bus No.	Bus Name	Id	P_{load} (MW)	Q_{load} (Mvar)
5	SD_33	1	2.5730	1.2460
5	SD_33	2	2.8790	1.3950
5	SD_33	3	4.4600	2.1600
5	SD_33	4	0.2820	0.1360
6	TS_33	1	17.2890	8.3730
6	TS_33	2	13.1720	6.3790
7	SM_33	1	10.4150	5.0440
7	SM_33	2	4.4720	2.1660
8	BS_33	1	2.1810	1.0560

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8	BS_33	2	5.8810	2.8480
8	BS_33	3	0.0000	0.0000
10	LD_33	1	6.8490	3.3170
10	LD_33	2	5.5260	2.6760
11	PI_33	1	4.4970	2.1780
11	PI_33	2	3.3820	1.6380
12	MS_33	1	6.9470	3.3650
12	MS_33	2	6.8490	3.3170
15	SR_33	1	4.0310	1.9520
15	SR_33	2	6.0410	2.9260
17	LK_33	1	5.4160	2.6230
17	LK_33	2	3.3570	1.6260
26	SD2_33	99	−5.0000	0.0000
27	BS_33	99	−10.0000	0.0000
30	BG_33	99	−2.0000	0.0000

Table V. Branch/Distribution line data used in PSS/E.

Distribution Branches				Id	RATE1 (MVA)	Length (mile)	Line R (pu)	Line X (pu)
From Bus		To Bus						
No	Name	No	Name					
3	SB_33	26	SD2_33	1	36.0	36.0	0.000000	0.000100
4	KB_33	26	SD2_33	2	36.0	36.0	0.000000	0.000100
5	SD_33	14	SA_33	1	36.0	9.0	0.017631	0.333357
5	SD_33	14	SA_33	2	36.0	9.0	0.017631	0.333357
5	SD_33	26	SD2_33	1	36.0	36.0	0.000000	0.000100
6	TS_33	7	SM_33	1	35.5	6.7	0.024425	0.065831
6	TS_33	7	SM_33	2	35.5	6.7	0.024425	0.065831
6	TS_33	8	BS_33	1	18.0	5.6	0.010970	0.207422
6	TS_33	8	BS_33	2	18.0	5.6	0.010970	0.207422
6	TS_33	26	SD2_33	1	36.0	10.0	0.019590	0.370397
6	TS_33	26	SD2_33	2	36.0	10.0	0.019590	0.370397
8	BS_33	9	KG_33	1	32.6	0.7	0.005039	0.007713
8	BS_33	9	KG_33	2	32.6	0.7	0.005039	0.007713
9	KG_33	10	LD_33	1	43.7	6.7	0.020426	0.062755
9	KG_33	10	LD_33	2	43.7	6.7	0.020426	0.062755
9	KG_33	11	PI_33	1	18.0	3.5	0.059158	0.125699
9	KG_33	11	PI_33	2	18.0	3.5	0.059158	0.125699
11	PI_33	12	MS_33	1	18.0	1.2	0.020283	0.043097

Continued

11	PI_33	12	MS_33	2	18.0	1.2	0.020283	0.043097
11	PI_33	14	SA_33	1	35.5	14.0	0.051038	0.137557
11	PI_33	18	SC_33	1	35.5	9.0	0.032810	0.088430
12	MS_33	27	BS_33	1	0.0	36.0	0.000000	0.000100
14	SA_33	16	LP_33	1	18.0	0.2	0.003380	0.007183
14	SA_33	16	LP_33	2	18.0	0.2	0.003380	0.007183
14	SA_33	18	SC_33	1	35.5	9.5	0.034633	0.093343
14	SA_33	20	BM_33	1	35.5	9.0	0.032810	0.088430
14	SA_33	20	BM_33	2	35.5	9.0	0.032810	0.088430
15	SR_33	17	LK_33	1	36.0	0.0	0.000000	0.000100
17	LK_33	26	SD2_33	1	35.5	0.1	0.000365	0.000983
17	LK_33	26	SD2_33	2	35.5	0.1	0.000365	0.000983
18	SC_33	19	UB_33	1	35.5	0.0	0.000000	0.000100
18	SC_33	19	UB_33	2	35.5	0.0	0.000000	0.000100