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TRANSIENT STABILITY ANALYSIS OF IEEE 6-BUS POWER SYSTEM USING POWER WORLD SIMULATOR

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Abstract: **The objective of this paper is to investigate and understand the behavior of transient stability of the power system. The intention is to check the transient stability of IEEE 6-bus system under a symmetrical three-phase fault. For this purpose, IEEE 6-bus power system is/was modeled in Power World Simulator using the given data set .When the fault is created on one of the generator bus (bus number 3 in this paper), oscillations in various electrical quantities may result. For damping out of these oscillations and regaining the system-stability ,the fault clearing time must be very short .**

Initial load flow solutions are obtained by using Polar Newton - Raphson iteration method in order to know to the pre-fault values for the symmetrical three phase fault .This is followed by the transient stability analysis.

This paper proposes the transient stability analysis by applying a symmetrical fault of 0.3 sec duration . Under fault condition, variations in rotor angles(power angles) and bus frequency are plotted against time to understand the stability status of the system. After restoration of transient stability , it is observed that the system frequency is too high which may cause some serious problems. In order to re-establish the normalcy of system frequency (drop the power system operational frequency to 50 Hz), load shedding option is provided in this paper. For solving various differential equations of the system dynamics, Runge-Kutta method is proposed in the paper.

Keywords: **Fault clearing time, polar Newton Raphson method, Runge Kutta method, Power World Simulator, load shedding,, pre-fault values.**

I. INTRODUCTION

Due to the day-by-day expansion of the power system, it becomes necessary to maintain synchronism among various parts of it . It is widely accepted that the transient stability is an important aspect in designing and upgrading of electric power system. Power system stability involves the study of the system dynamics under disturbances. Power system stability implies that its ability to return to normal or stable operation after having been subjected to some form of disturbances. From classical point of view, Power system stability can be seen as loss of synchronism.

Transient stability involves the response to large disturbances which may cause rather large changes in rotor speeds, power angles and power transfers. Transient stability is a fast phenomenon usually evident within a few seconds. The transient stability studies involve the determination of whether or not synchronism is maintained, after the machine has been subjected to any severe disturbance. This severe disturbance may be – sudden mismatch in generation-load or a fault on the system. Transient stability limit is almost always lower than the steady state stability limit and hence, it is of much importance.

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Lots of work had been done on power system transient stability in the past. Transient stability analysis of 5-bus system was performed in paper [1] using Mi-Power software. Paper [2] had provided the transient stability studies of 6-bus system using E-Tap software. While analysis of the same had been carried out on IEEE 9-bus using power world simulator. In this paper, transient stability analysis is performed with the help of a symmetrical three-phase fault on bus 3 of IEEE 6-bus system. The power angle v/s time and bus frequency v/s time plots are obtained to understand transient stability of the system.

II. PROBLEM FORMULATION

A. LOAD FLOW STUDY:-

In transient stability analysis of power system , it is necessary to know the pre-fault conditions. These pre-fault conditions can be obtained from the results of load flow solutions by Newton Raphson iteration method.

To understand the method , equations are -

$S_i = P_i + jQ_i = V_i \sum_{k=1}^{n} Y_{ik} V_k$ ……………………………………………………………………………...….[1]

$S_i = \sum_{k=1}^{n} \quad V_i V_i Y_{ik} / (\delta_i - \delta_k - \Theta_{ik})$ ……………………………………………………………………………..[2]

$P_i = \sum_{k=1}^{n} \quad V_i V_i Y_{ik} cos(\delta_i - \delta_k - \Theta_{ik})$ ……………………………………………………………...……[3]

$Q_i = \sum_{k=1}^{n} \quad V_i V_i Y_{ik} sin(\delta_i - \delta_k - \Theta_{ik})$ ……………………………………………………………...….[4]

We have- $\Delta f = J \Delta X$

If $\Delta P_i = P_{i(SP)} - P_{i(CAL)}$ ……………………………………………………………...……...[5]

Then i =1,2,…..,n , i≠ slack and

If $\Delta Q_i = Q_{i(SP)} - Q_{i(CAL)}$ ……………………………………………………………….…[6]

Then i =1,2,…..,n , i≠ slack and i≠ PV bus

Finally, equations can be written as -

$$\begin{matrix} \Delta P \\ \Delta Q \end{matrix} = \begin{matrix} H & N \\ M & L \end{matrix} \begin{matrix} \Delta \delta \\ \Delta V \end{matrix}$$ ………………………..………………………………………[7]

$\Delta P_i^{(r)} < \boldsymbol{\varepsilon}$ and $\Delta Q_i^{(r)} < \boldsymbol{\varepsilon}$

The off-diagonal and diagonal elements of sub matrices H,N,M,L are determined by differentiating equation [3] and[4] with respect to $\boldsymbol{\delta}$ and V. The power flow of various buses can be calculated by knowing the elements of Jacobian matrices (H ,N ,M ,L).

B. TRANSIENT STABILITY ANALYSIS:-

Steps for transient stability analysis in Power World Simulator are -

1. Modeling of test system , i.e., IEEE 6-bus system .

2. initial load flow calculations

3. application of a balanced (symmetrical) three-phase fault

4. settings of storage parameters – generator (rotor)speeds , rotor angles , bus frequency etc. are set to YES. 5. Prepare plots of rotor angle v/s time and bus frequency v/s time curves.

B 1:- GENERATOR MODELING

The model of the generator employed in this study is GENSAL. The parameters are the model is chosen as-

H=3 , D=0 , $X_d = 2.1$, $X_q = 0.5$, $X_{dp} = 0.2$, $X_{dpp} = 0.18$, $T_{dop} = 7$, $T_{dopp} = 0.04$, $T_{QOPP} = 0.05$, xl=0.15

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B 2:- EXCITER MODELING

Exciter model IEEE T1 type is employed in the study which have the parameters as –

$T_r = 0$, $T_f = 1.46$, $K_a = 50$, $T_a = 0.04$, $E_1 = 2.8$, $V_{rmax} = 1.0000$, $V_{rmin} = -1.0000$, $K_e = 0.06$, $T_e = 0.6$, $K_f = 0.09$, $E_2 = 3.73$, SE1 = .04 , SE2 = 0.33

C. RE-ESTABLISHMENT OF NOMINAL FREQUENCY:

By applying the load shedding of a fixed amount of 2.67 MW on each load bus of the sample system for 0.100000 sec, the nominal value of system frequency (i.e., 50Hz) may be obtained at the end of simulation process .

III. SIMULATION OF THE TEST SYSTEM

IEEE 6 Bus System is modeled on power world simulator with the given data.

The figure [1] and tables [1] , [2] and [3] represent IEEE 6-bus model on Power World Simulator .

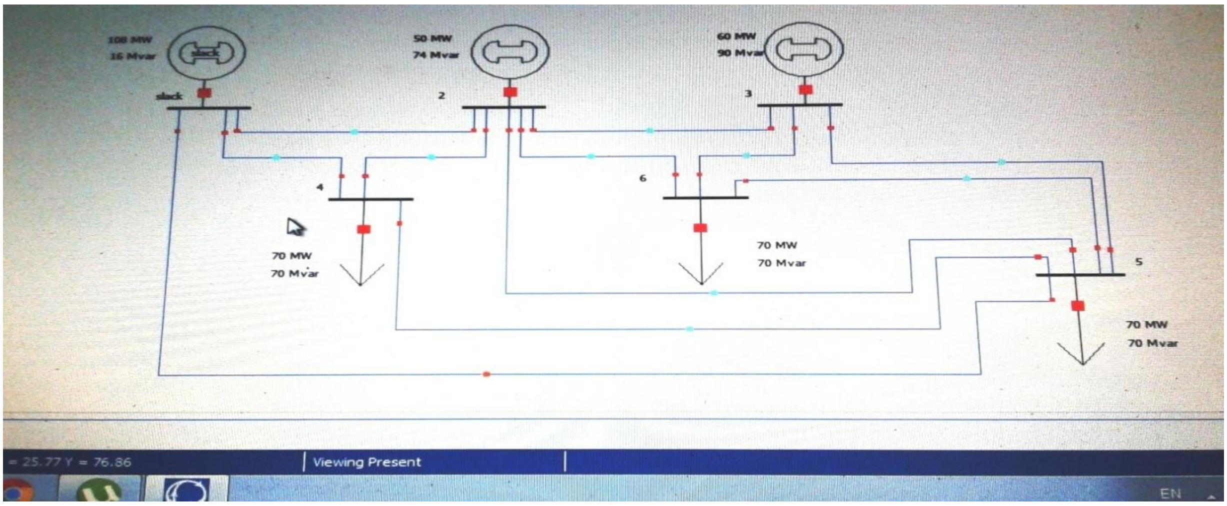

FIG 1: LAYOUT OF IEEE 6-BUS SYSTEM ON POWER WORLD SIMULATOR

IEEE 6-BUS POWER SYSTEM: DATA SET

TABLE 1: BUS DATA

BUS NO.	BUS TYPE	V(p.u.)	δ(Degrees)	LOAD MW	LOAD MVAR
1	SB (SLACK)	1.05	0	0	0
2	PV	1.05	0	0	0
3	PV	1.07	0	0	0
4	PQ	0	0	70	70
5	PQ	0	0	70	70
6	PQ	0	0	70	70

TABLE 2: GENERATOR DATA

BUS NO.	GENERATOR (P) IN MW	GENERATOR (Q) IN MVAR		P MAX	P MIN	Q MAX	Q MIN
1	0	0		200	50	100	-100
2	50	0		150	37.5	100	-100
3	60	0		180	45	100	-100

TABLE 3: TRANSMISSION LINE DATA

LINE NO.	FROM BUS NO.	TO BUS NO.	R (p.u.)	X(p.u.)	B(p.u.)	TRANSF. TAP RATIO	MAX. REAL POWER FLOW(MVA)
1	1	2	0.1	0.2	0.04	0	40
2	1	4	0.05	0.2	0.04	0	60
3	1	5	0.08	0.3	0.06	0	40
4	2	3	0.05	0.25	0.06	0	40
5	2	4	0.05	0.1	0.02	0	80
6	2	5	0.1	0.3	0.04	0	30
7	2	6	0.07	0.2	0.05	0	90
8	3	5	0.12	0.26	0.05	0	70
9	3	6	0.02	0.1	0.02	0	90
10	4	5	0.2	0.4	0.08	0	20
11	5	6	0.1	0.3	0.06	0	40

Assumed values for initial load flow using polar Newton Raphson method are – Maximum number of iterations = 04 , solution precision = 0.001 , time increment for integration steps = 0.001 , total simulation time = 05 secs .

While the assumed values for transient stability analysis are –

Nominal system frequency= 50 Hz, base kV= 20, base MVA= 100, fault creating time = 0.2 sec from the start , fault clearing time = 0.3 sec . While, for restoring the normal system frequency quickly, load shedding of 2.67 MW is applied on load buses for 0.10000 sec.

IV. SIMULATION RESULTS AND DISSCUSSION

Initial load flow calculations are tabulated in tables [4] , [5] , [6]

A. INITIAL LOAD FLOW RESULTS:-

TABLE 4: POWER FLOW RESULS FOR BUSES

Number	Name	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load MVAR	Gen MW	Gen MVAR	Area Num
1	slack	1	220	1.05	231	0			107.87	15.96	1
2	2	1	220	1.05	231	-3.67			50	74.36	1
3	3	1	220	1.07	235.4	-4.27			60	89.63	1
4	4	1	220	0.98937	217.662	-4.2	70	70			1
5	5	1	220	0.98545	216.798	-5.28	70	70			1
6	6	1	220	1.00443	220.974	-5.95	70	70			1

TABLE 5: POWER FLOW RESULTS FOR GENERATORS

Number of Bus	Name of Bus	Status	Gen MW	Gen MVAR	Set Volt	AGC	AVR	Min MW	Max MW	Min MVAR	Max MVAR	Part. Factor
1	slack	Closed	107.87	15.96	1.05	YES	YES	50	200	-100	100	10
2	2	Closed	50	74.36	1.05	YES	YES	37.5	150	-100	100	10
3	3	Closed	60	89.63	1.07	YES	YES	45	180	-100	100	10

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TABLE 6: POWER FLOW RESULTS FOR BRANCHES (LINES)

From Bus	To Bus	Status	Transformer	MW From	MVAR From	MVA From	Lim MVA	% of MVA Limit (Max)	MW Loss	MVAR Loss
1(slack)	2	Closed	NO	28.7	-15.4	32.6	40	81.4	0.9	-2.6
1(slack)	4	Closed	NO	43.6	20.1	48	60	80	1.09	0.19
1(slack)	5	Closed	NO	35.6	11.3	37.3	40	93.3	1.07	-2.2
2	3	Closed	NO	2.9	-12.3	12.6	40	31.5	0.04	-6.54
2	4	Closed	NO	33.1	46.1	56.7	80	70.9	1.51	0.93
2	5	Closed	NO	15.5	15.4	21.8	30	78.2	0.5	-2.65
2	6	Closed	NO	26.2	12.4	29	90	33.6	0.58	-3.61
3	5	Closed	NO	19.1	23.2	30	70	45.3	1.09	-2.92
3	6	Closed	NO	43.8	60.7	74.9	90	83.2	1	2.86
4	5	Closed	NO	4.1	-4.9	6.4	20	32.1	0.04	-7.73
5	6	Closed	NO	1.6	-9.7	9.8	40	24.5	0.05	-5.79
								TOTAL POWER LOSS	7.87 MW	-30.06 MVAR

B. TRANSIENT STABILITY PLOTS WITHOUT LOAD SHEDDING:-

Different plots regarding transient stability are shown in fig [2] to [5] without any load shedding.

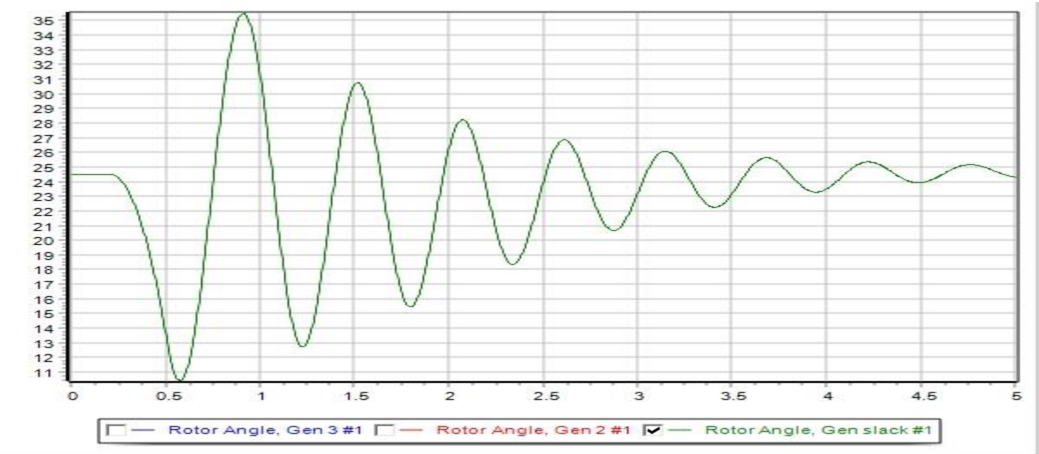

Fig 2: ROTOR ANGLE RESPONSE FOR GEN 1 (SLACK)

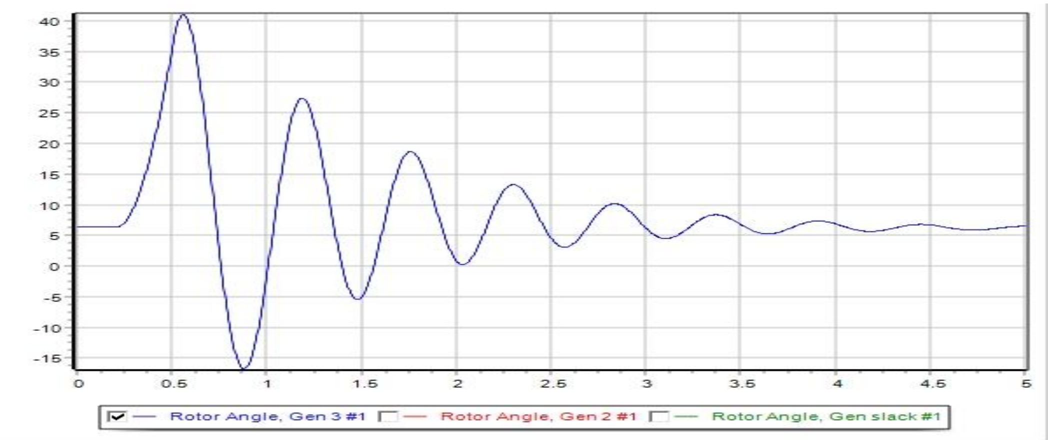

Fig 3: ROTOR ANGLE RESPONSE FOR GEN 3

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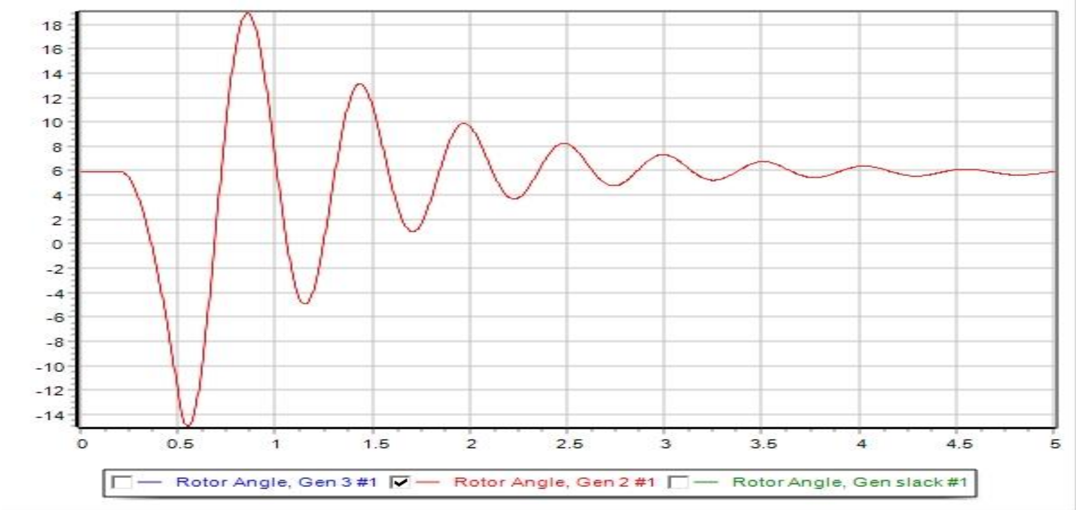

Fig 4: ROTOR ANGLE RESPONSE FOR GEN 2

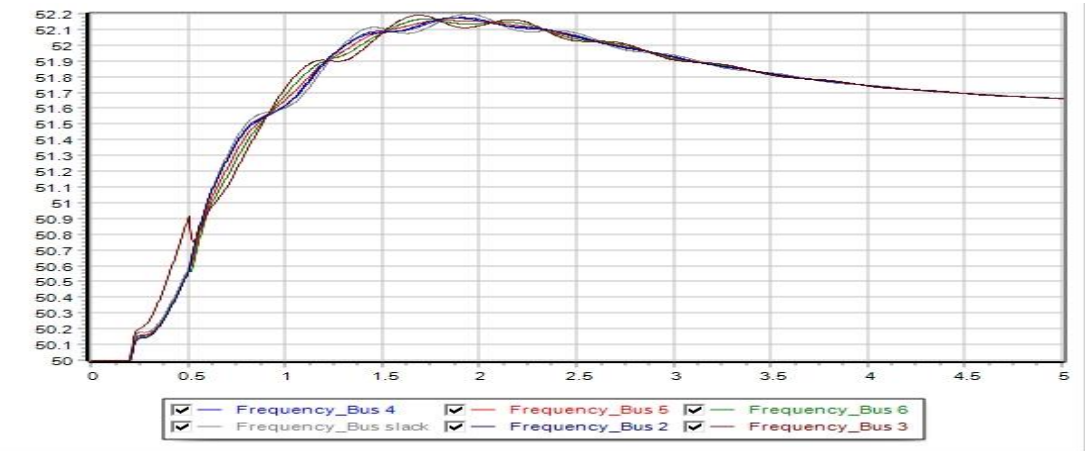

Fig 5: BUS FREQUENCY RESPONSE

C. TRANSIENT STABILITY PLOTS WITH LOAD SHEDDING OF 2.67 MW:-

Different plots regarding transient stability are shown in fig [6] to [9] with a load shedding amount of 2.67 MW for 0.10000 sec on each load bus .

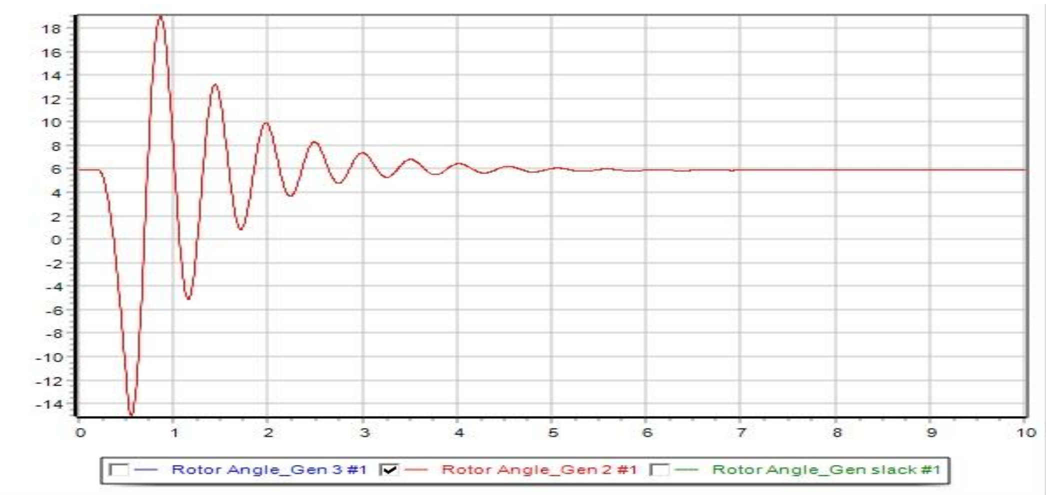

Fig 6: ROTOR ANGLE RESPONSE FOR GEN 2

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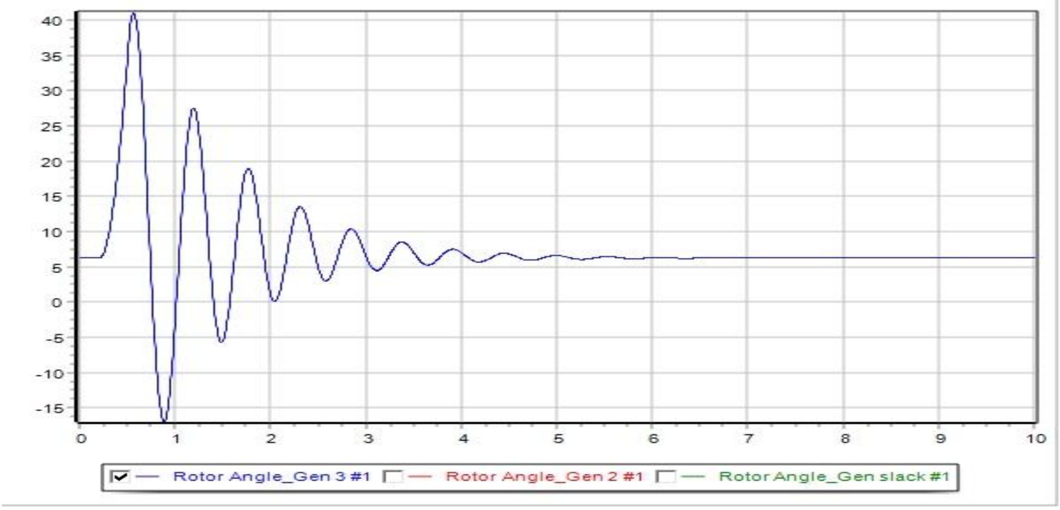

Fig 7: ROTOR ANGLE RESPONSE FOR GEN 3

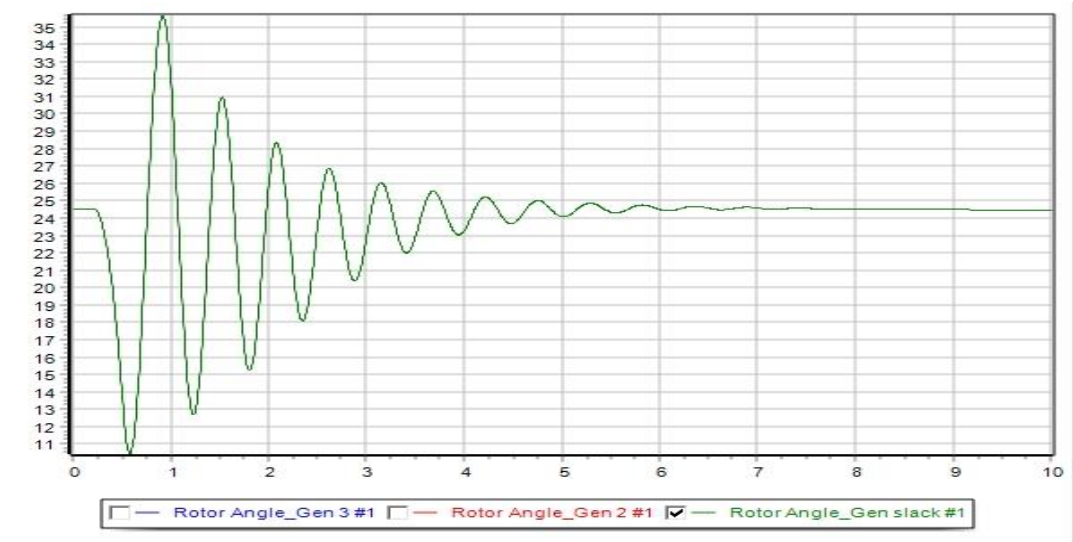

Fig 8: ROTOR ANGLE RESPONSE FOR GEN 1 (SLACK)

Fig 9: BUS FREQUENCY RESPONSE

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V. CONCLUSION

The transient stability analysis has been enhanced by creating a symmetrical three- phase fault on bus [3] and clearing within very short time in order to regain stability. It is concluded that the power system should have very low fault clearing time. Also, critical clearing time for a fault should be as low as possible to operate relays if we isolate the faulty sections with rapidity. Then only, the power system can restore stability under operating conditions. Recovering of normalcy of system frequency quickly after the completion of a major transient disturbance is always a requirement to protect the system equipment and this is obtained by the load shedding.

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