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Transient Stability Analysis of Power Station (A Case Study of Nigeria Power Station)

V. C. Ogboh, K. C. Obute, A. E. Anyalebechi
Department of Electrical Engineering, Nnamdi Azikiwe University, Awka, Nigeria
Department of Electrical Engineering, Nnamdi Azikiwe University, Awka, Nigeria
Corresponding Author: V. C. Ogboh

-ABSTRACT-
Transient stability, the stability of a power system subjected to a large, sudden and severe disturbance such as the occurrence of fault, sudden outage of a line or sudden application or removal of loads to maintain steady flow. Techniques are available to obtain an approximate solutions of such kinds of faults that could occur on the power system. In this work, simulation of faulted power station was performed, numerical computation techniques was applied, critical clearing angle and time was obtained for the Jebba power station / Jebba – Oshogbo – Ikeja West test transmission line connected to an infinite bus. The result show different graphs generated per simulated fault type and swing curve for sustained and cleared fault.
KEYWORDS *- Matlab, Transient Stabilty, Critical angle, Prime mover, Swing Equation*.

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I. INTRODUCTION

Power stations or power generating stations is an industrial facility built for electric power generation.

Power system comprises of these major components namely; the generation, transmission and distribution components. Each of the components experiences a transient (sudden disturbance) of different kind. These disturbances cause severe damage to the system equipment and therefore needs to be protected against any of the disturbances.

In this work, we are concern with the power generating station transient stability in Nigeria. The generating stations are hydro, gas and steam power generating stations.

A typical power generating station comprises of the following units depending on the type of generation; turbine, generator, transformer and the bus-bar through which the power is transmitted to the consumers via the transmission line.

The turbine and generator are responsible for production of power which when transmitted through the transmission line reaches the consumers [J. B. Gupter, 2008].

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II. TRANSIENT STABILITY OF THE POWER STATION

Transient stability refers to the stability of a power system subject to a large, sudden and severe disturbance such as the occurrence of fault, sudden outage of a line or sudden application or removal of loads.

Transient stability analysis is needed in the power stations and system at large to ensure that the system can withstand the transient conditions following a major disturbance.

It is also important to perform this analysis when new power plants and transmitting stations are planned. In the analysis, such conditions as the nature of the relaying system needed, critical clearing time of circuit breakers, voltage level of the systems and transfer capability between the systems.[H. Saadat, 2006]

However, the practical approach to the transient stability problems is to list all important severe disturbances along with their possible locations to which the system is likely to be subjected according to the experience and judgment of the power system analyst. Then the numerical solution of the swing equation in the presence of all these disturbances is then computed giving the results as the plots of the δ (power or torque angle) verses t (time) which is called the swing curve.[Nagrath and Kothari, 2004].

2.1 SWING EQUATION

Under normal operating conditions, the relative position of the rotor axis and the resultant magnetic field axis is fixed. The angle between the rotor and the resultant magnetic field is called the power angle or torque angle δ. During any disturbance, the rotor speed will decrease or accelerate with respect to the synchronous rotating air gap mmf, and results to a relative motion of the rotor. The equation describing this relative motion is called the swing equation. Figure 1, illustrates the power angle of a two pole cylindrical rotor generator.

Here, the power angle δ is the angle between the rotor mmf F_r, and the resultant air gap mmf F_{sr}. Both of them are rotating with synchronous speed. It is also the angle between the no load generated emf E and the resultant stator voltage E_{sr}. If the generator armature resistance and leakage flux are neglected, the angle between E and the terminal voltage V, which is δ, is considered to be the power angle.

Since we are considering the synchronous operation of the turbine (prime mover) and the generator, therefore, if the Tm is the driving mechanical torque of the turbine shaft to generator rotor, Te is the electromagnetic torque of the synchronous generator running at the same speed w_{sm} with the turbine shaft. Then, under steady state operation with the losses neglected, we have that;

$$Tm = Te \tag{1}$$

But if a disturbance is introduced causing the system to lose it synchronism and no more under steady state but on transient condition. This causes the system acceleration (Tm > Te) or decelerate (Tm < Te). Thus, acceleration Torque Ta becomes;

$$Ta = Tm - Te \tag{2}$$

Taking J to be the combine moment of inertia of the turbine-shaft (prime mover) and the generator, neglecting frictional and damping torques, the Ta becomes;

$$Ta = Tm - Te = J\frac{d^2\theta_m}{dt^2} \tag{3}$$

$$\theta_m = w_{sm}t + \delta_m \tag{4}$$

Where θ_m is the angular displacement of the rotor with respect to the stationary reference axis on the stator. w_{sm} is constant angular velocity of the rotor. δ_m is the rotor position before the disturbance at t = 0;

$$w_{sm} = \frac{d\theta_m}{dt} = w_{ms} + \frac{d\delta_m}{dt} \tag{5}$$

Rotor acceleration becomes;

$$\frac{d^2\theta_m}{dt^2} = \frac{d^2\delta_m}{dt^2} \tag{6}$$

Therefore, putting equation 7 into 4, we have;

$$Tm - Te = J\frac{d^2\delta_m}{dt^2} \tag{7}$$

Multiplying by w_m;

We have

$$w_m Tm - w_m Te = w_m J\frac{d^2\delta_m}{dt^2} \tag{8}$$

Since the product of angular velocity and torque gives the power, therefore;

$$w_m J\frac{d^2\delta_m}{dt^2} = P_m - P_e \tag{9}$$

However, Jw_m is called the inertia constant and is denoted by M.
Thus, the swing equation in terms of the inertia constant becomes;

$$M\frac{d^2\delta_m}{dt^2} = P_m - P_e \tag{10}$$

The swing equation in terms of the electrical power can be written as;

$$\frac{H}{\pi f_0}\frac{d^2\delta}{dt^2} = P_m - P_e \quad (11)$$

is in electrical radians;

$$\frac{H}{180 f_0}\frac{d^2\delta}{dt^2} = P_m - P_e \quad (12)$$

is in electrical degrees;

f_0 is the fundamental frequency of the system output. [H. Saadat, 2006]

2.2 NUMERICAL SOLUTION OF SWING EQUATION

The transient stability analysis requires the solution of a system of coupled non-linear differential equations. In general, no analytical solution of these equations exists. However, techniques are available to obtain an approximate solution of such differential equations by numerical methods and one must therefore resort to numerical computation techniques commonly known as digital simulation. Some of the commonly used numerical techniques for the solution of the swing equation are:

Euler modified method
Forth-Order Runga – Kutta method
Point by point method

The swing equation can be transformed into state variable form. And the two first order differential equations to be solved to obtain solution for the swing equation are: [C. S. Sharma, 2014 and T. Z. Mon, Y. A.Oo]

$$\frac{d\delta}{dt} = \Delta\omega \quad (13)$$

$$\frac{d\omega}{dt} = \frac{Pa}{M} = \frac{Pm - Pmax\sin\delta - D\Delta\omega}{M} \quad (14)$$

Where;

$$M = \frac{H}{\pi f_0} \quad (15)$$

2.21 APPLYING MODIFIED EULER'S METHOD

we have;

$$\Delta\omega^{P}_{i+1} = \frac{d\delta}{dt}\Big|_{\Delta\omega^{P}_{i+1}} \quad (16)$$

$$\text{Where } \Delta\omega^{P}_{i+1} = \Delta\omega_I + \frac{d\Delta\omega}{dt}\Big|_{\delta i}\Delta t \quad (17)$$

$$\frac{d\Delta\omega}{dt}\Big|\delta^{P}_{i+1} = \left[\frac{Pa}{M}\right]\Big|_{\delta^{P}_{i+1}} \quad (18)$$

$$\text{For } {}_{\delta}{}^{P}_{i+1} = {}_{\delta i} + \frac{d\delta}{dt}\Big|_{\Delta\omega i}\Delta t \quad (19)$$

$${}_{\delta}{}^{c}_{i+1} = {}_{\delta i} + \left[\frac{d\delta}{dt}\Big|_{\Delta\omega i} + \frac{d\delta}{dt}\Big|_{\Delta\omega^{P}_{i}}\right]\Delta t \quad (20)$$

$${}_{\Delta\omega}{}^{c}_{i+1} = {}_{\Delta\omega i} + \left[\frac{d\Delta\omega}{dt}\Big|_{\delta i} + \frac{d\Delta\omega}{dt}\Big|_{\delta^{P}_{i}}\right]\Delta t \quad (21)$$

2.22 APPLYING RUNGE – KUTTA'S FOURTH ORDER METHOD TO THE EQUATIONS
We have, starting from initial value δ_0, ω_0, t_0 and step size of Δt, the formula becomes;

$$K_1 = \omega_0 \Delta t \tag{22}$$

$$I_1 = [\frac{Pm - Pmaxsin\delta 0}{M}] \Delta t \tag{24}$$

$$K_2 = [\omega_0 + \frac{I1}{2}]\Delta t \tag{23}$$

$$I_2 = [\frac{Pm - Pmaxsin[\delta 0 + \frac{K_1}{2}]}{M}]\Delta t \tag{24}$$

$$K_3 = [\omega_0 + \frac{I2}{2}]\Delta t \tag{25}$$

$$I_3 = [\frac{Pm - Pmaxsin[\delta 0 + \frac{K_2}{2}]}{M}]\Delta t \tag{26}$$

$$K_4 = (\omega_0 + I_3)\Delta t \tag{27}$$

$$I_4 = [\frac{Pm - Pmaxsin[\delta 0 + K3]}{M}]\Delta t \tag{28}$$

$$\delta_1 = \delta_0 + \frac{1}{6}[K_1 + 2K_2 + 2K_3 + K_4] \tag{29}$$

$$\omega_1 = \omega_0 + \frac{1}{6}[I_1 + 2I_2 + 2I_3 + I_4] \tag{30}$$

δ_1 and ω_1 are used as initial values for the successive time step.

2.23 APPLYING POINT BY POINT METHOD
The following

$$P_{a(n-1)} = P_s – P_{e(n-1)} \tag{31}$$

$$\alpha_{(n-1)} = \frac{Pa(n-1)}{M} \tag{32}$$

$$\Delta\omega_n - \frac{1}{2} = \omega_n – a_n - 1\Delta t \tag{33}$$

$$\omega_n - \frac{1}{2} = \omega_n - \frac{3}{2} + a_n - 1\Delta t \tag{34}$$

$$\Delta\delta_n = \omega_n - \frac{1}{2}\Delta t = \omega_n - \frac{3}{2} + a_{n-1} \Delta t \tag{35}$$

$$= \Delta\delta_{n-1} + a_{n-1} \Delta t2 \tag{36}$$

$$= \Delta\delta_{n-1} + \frac{Pa(n-1)\Delta t2}{M} \tag{37}$$

$$\delta_n = \delta_{n-1} + \Delta\delta_n \tag{38}$$

3. EQUAL AREA CRITERION

In a system where one machine is swinging with respect to an infinite bus, it is possible to analyze transient stability of the power station using equal area criterion without going through the numerical solution of swing equation. Considering the swing equations below;

$$\frac{d^2\delta}{dt^2} = \frac{1}{M} = Pm - Pe = \frac{Pa}{M} \tag{39}$$

Where Pa is the accelerating power;

$$M = \frac{H}{\pi f} \tag{40}$$

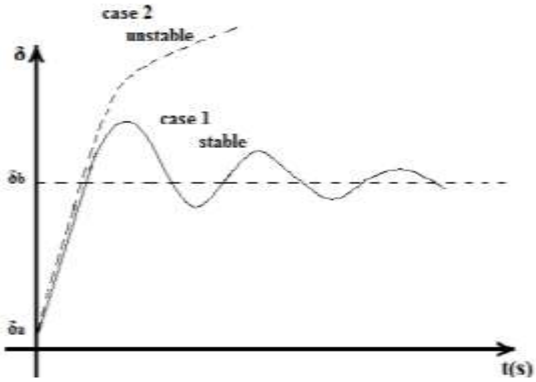

Figure 1: Plot of δ against t for stable and unstable systems.

If the system is unstable, δ will continue to increase indefinitely with time and the system loses synchronism.
However, if the system is stable, $\delta(t)$ will perform nonsinusoidal oscillations whose amplitude decreases in real practice due to damping. These two conditions are shown in the above figure x.

$$\frac{d\delta}{dt} = 0 \text{ System is table} \tag{41}$$

$$\frac{d\delta}{dt} > 0 \quad \text{System unstable} \tag{42}$$

The stability criterion for power systems can be applied to a single machine infinite bus system as shown below;

$$\left(\frac{d\delta}{dt}\right)^2 = \frac{2}{M}\int_{\delta 0}^{\delta} Pa\, d\delta \tag{43}$$

$$\left(\left(\frac{d\delta}{dt}\right)^2 = \frac{2}{M}\int_{\delta 0}^{\delta} Pa\, d\delta\right)^{0.5} \tag{44}$$

$$\left(\frac{2}{M}\int_{\delta 0}^{\delta} Pa\, d\delta\right)^{0.5} \tag{45}$$

Thus, the system is stable, if the area under Pa verses δ curve reduces to zero at certain value of δ.
However, it means that, the positive (acceleration) area under the Pa verses δ curve must be equal the negative (deceleration) area, thus the name equal area criterion.
Considering various disturbance conditions of faults in a single machine infinite bus bar, we can illustrate the stability the system using equal area criterion.

3.1 SUDDEN CHANGE IN MECHANICAL INPUT

The electrical power transmitted is given by;

$$Pe = \left[\frac{|E||V|}{X'd+Xe}\right]\mathrm{Sin}\delta = P_{max}\mathrm{Sin}\delta \tag{46}$$

Under steady operating condition

$P_{m0} = P_{e0} = P_{\mathbf{max}}\mathrm{Sin}\delta$ (47)

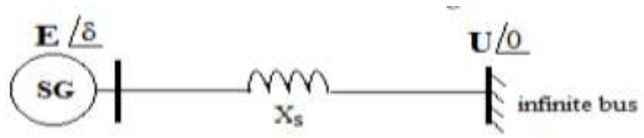

Figure 2. Single machine tied to infinite bus bar

When mechanical input to the rotor is suddenly increased to $P_{\mathbf{m1}}$ (i.e. opening the steam valve). The acceleration power $P_a = P_{\mathbf{m1}} - P_e$ cause the rotor speed to increase ($\omega > \omega_s$) and so does the rotor angle. Also at the angle $\delta_{\mathbf{1}}$, $P_a = P_{\mathbf{m1}} - P_{\mathbf{e}}$ (= $P_{\mathbf{max}}$ $\mathrm{Sin}\delta_{\mathbf{1}}$) = 0, but the rotor angle continues to increase as
$\omega > \omega_s$.

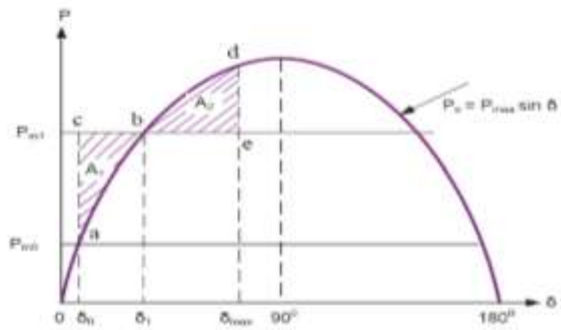

Figure 3. Sudden increase in mechanical input to the generator

As the rotor speed and angle is increasing, $\omega > \omega_s$. But, when they are decreasing, $\omega < \omega_s$. The P_a becomes negative (decelerating) and the rotor speed begins to reduce while the angle $\delta_{\mathbf{2}}$, $\omega = \omega_s$. at this point, the decelerating area A2 is equal to the acceleration area $A_{\mathbf{1}}$.
Thus,

$$\int_{\delta 0}^{\delta 2} \mathrm{Pa}\ d\delta = 0 \tag{48}$$

The deceleration of the rotor causes the rotor speed to reduce below ω_s making the rotor angle to start to reduce. According the above diagrams, one can easily see that the system oscillates about the new steady state point where $\delta = \delta_{\mathbf{1}}$. These oscillations are similar to the simple harmonic motion of an inertia spring system.
The system settles for a new steady state when the oscillation decays out due to unavoidable system damping. Here,

$P_{m1} = P_e = P_{\mathbf{max}}\mathrm{Sin}\delta_{\mathbf{1}}$ (49)

As area A1 and A2 are given by

$$A_{\mathbf{1}} = \int_{\delta 0}^{\delta 1} (\mathrm{Pm1} - \mathrm{Pe})d\delta \tag{50}$$

$$A_{\mathbf{2}} = \int_{\delta 1}^{\delta 2} (\mathrm{Pe} - \mathrm{Pm1})d\delta \tag{51}$$

The figure 3 is for a limiting case of transient stability with mechanical input suddenly increased. Here,

$\delta_2 = \delta_{max} = \pi - \delta_1 = \pi - \sin^{-1}\frac{Pm1}{Pmax}$ (52)

For stability purpose, the rotor speed of both the turbine and generator should be running in synchronism (at the same speed), but when the rotor speed of the turbine r_{trpm} or ω_t is not in synchronism with that of the synchronous generator r_{Grpm} or ω_s , there will be fluctuation in output power supply of the generator. Thus, the turbine rotor angle is not equal to the generator rotor angle. This condition will result to instability in power supply of the generator. The effect can easily be seen as the variation in rotor angle of the turbine and generator.

3.2 EFFECT OF CLEARING TIME ON STABILITY OF POWER SYSTEM

Considering that the figure 3 is operating with mechanical input Pm at a steady angle of δ_0 ($P_m = P_e$) as shown by the point a on figure 4. If a 3-phase fault be allowed to occur at the point P, the electrical output of the generator will instantly be reduced to zero ($P_e = 0$) and the state point drops to b. The acceleration area A1 will begin to increase and so does the rotor angle while the state point moves along b_c. At time t_c corresponding to angle δ_c the faulted line is cleared by the opening of the line circuit breaker.
However, t_c and δ_c are known as clearing time and clearing angle. Thus, the system becomes stable and transmits

$P_e = P_{max}\sin\delta$.

(53)

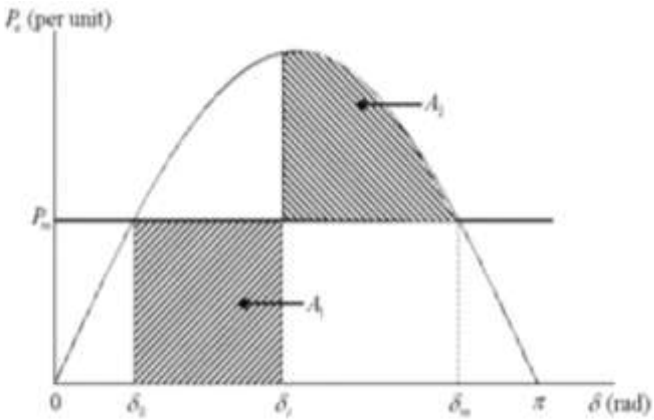

Figure 4 critical clearing angles.

δ_C is the critical clearing angle.
At this point, A2 =A1, system is said to stable, and finally settles down to the steady operating point a in an oscillatory manner due to damping influence.

3.3 SIMULATION OF THE MODELED POWER STATION

A typical steam power plant can be modeled using Matlab 2013 to represent a Nigerian power station. Figure 5 below is the model of Nigerian steam power plant modeled using a typical Nigeria steam power plant data obtained from Osogbo Power Station, Osun State Nigeria.
The Nigerian national grid system can also be used. The simulation can be done concentrating on the fourteen (14) generation systems. Therefore, the result obtained will be for these generating stations.
A typical generating station is shown below on figure 5 and figure 6 illustrates the Nigerian national grid network.

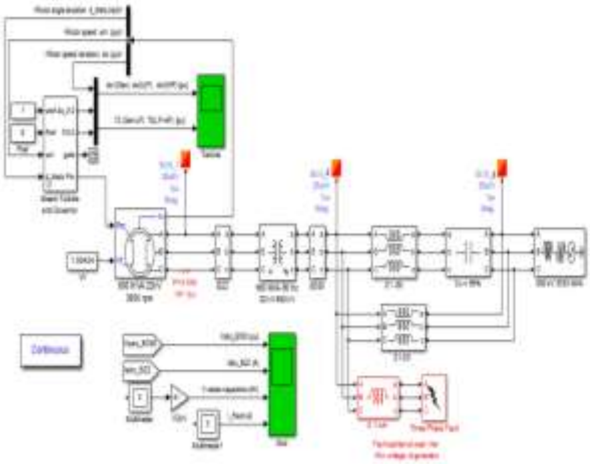

Figure 5: Modeled Nigerian Power Station

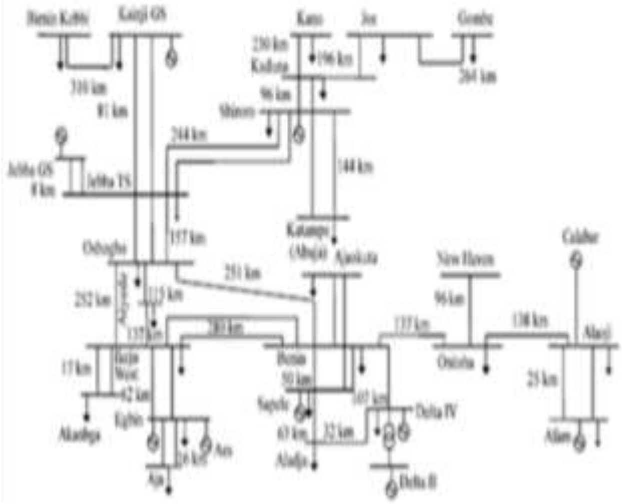

Figure 6: Nigerian national grid network

The transmission line of Jebba - Oshogbo – Ikeja West is used as test line to compute the Critical Clearing time, t_C and angle, δ which can be obtained using the following equations:

Angular momentum, $M = \frac{GH}{180f}$ (54)

Rotor angle at time

$$\delta_n = \delta_{n-1} + \Delta\delta_n \quad (55)$$

Change in rotor angle

$$\Delta\delta_n = + \Delta\delta_{n-1} + 4.464P_A. \quad (56)$$

Where P_A is the accelerating power and 150MVA, 140MW supply, frequency of 50Hz, line reactance, X_L of 0.4pu, transient reactance 0.2pu.

Table1. Step by step solution of swing curve for sustained fault.

S/NO	T (Secs)	P_{max} (pu)	Sinδ	P_E=P_{max}sinδ (pu)	P_A=0.96-P_E (pu)	4.464P_A Electrical Degree	Δδ Electrical Degree	δ Electrical Degree
1	0^-	0.26	0.3657	0.9600	0.0000	0.0000	-	21.45
2	0^+	1.05	0.3657	0.3840	0.5760	2.5690	-	21.45
3	0_{Ave}	-	-	-	0.2747	1.2252	1.2252	21.45
4	0.05	1.05	0.3651	0.3834	0.5766	2.5739	2.4517	22.68
5	0.10	1.05	0.3856	0.4049	0.5551	2.4779	5.0256	27.71
6	0.15	1.05	0.4650	0.4883	0.4715	2.1048	7.1304	34.84
7	0.20	1.05	0.5713	0.5999	0.3601	1.6075	9.2352	44.08
8	0.25	1.05	0.6956	0.7304	0.2296	1.0249	10.8427	54.92
9	0.30	1.05	0.8184	0.8593	0.1007	0.4495	11.8676	66.79
10	0.35	1.05	0.9191	0.9650	-0.0050	-0.0223	12.3171	79.11
11	0.40	1.05	0.9819	1.0311	-0.0711	-0.3174	11.2948	90.40
12	0.45	1.05	1.0000	1.0500	-0.0900	-0.4018	11.6306	102.03
13	0.50	1.05	0.9780	1.0269	-0.0669	-0.2986	11.2288	113.26

Table 2. Swing Curve computation for Fault cleared in 0.10 seconds.

S/NO	T (Secs)	P_{max} (pu)	Sinδ	P_E=P_{max}Sinδ (pu)	P_A=0.96-P_E (pu)	4.464P_A Electrical Degree	Δδ Electrical Degree	δ Electrical Degree
1	0^-	0.26	0.3657	0.9600	0.0000	-	-	21.45
2	0^+	1.05	0.3657	0.3840	0.5760	2.5713	-	21.45
3	0_{Ave}	-	-	-	0.2747	1.2252	1.2252	21.45
4	0.05	1.05	0.3657	0.3834	0.5766	2.5739	2.4517	22.68
5	0.10^-	1.05	0.3856	0.4049	0.5551	-	-	27.71
6	0.10^+	1.75	0.4650	0.8137	0.1463	-	-	27.71
7	0.10_{Ave}	-	-	-	0.3507	1.5655	6.2625	27.71
8	0.15	1.75	0.4650	0.8137	0.1463	0.6531	7.8280	35.54
9	0.20	1.75	0.5812	1.0172	-0.0572	-0.2553	8.4811	44.02
10	0.25	1.75	0.6950	1.2161	-0.2561	-1.1432	8.2258	52.25
11	0.30	1.75	0.7907	1.3837	-0.4237	-1.8914	7.0826	59.33
12	0.35	1.75	0.8601	1.5052	-0.5452	-2.4340	5.1912	64.52
11	0.40	1.75	0.9027	1.5798	-0.6198	-2.7668	2.7572	67.28
12	0.45	1.75	0.9223	1.6142	-0.6542	-2.9202	-0.0096	67.27
13	0.50	1.75	0.9223	1.6142	-0.6542	-2.9202	-2.9298	64.34

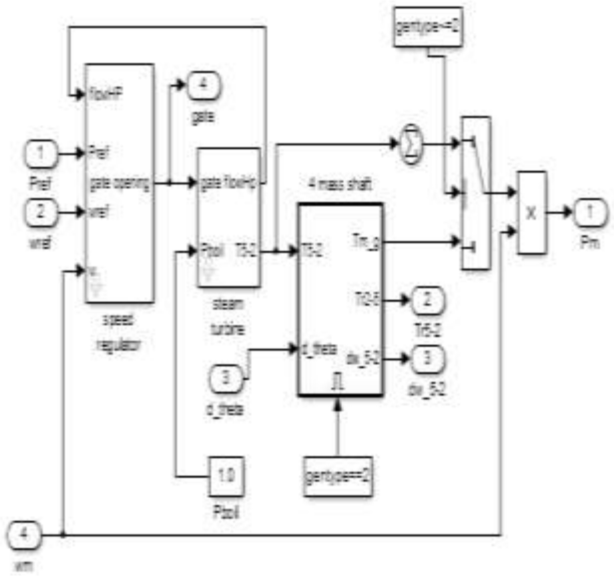

Figure 7 Internal model of the steam turbine

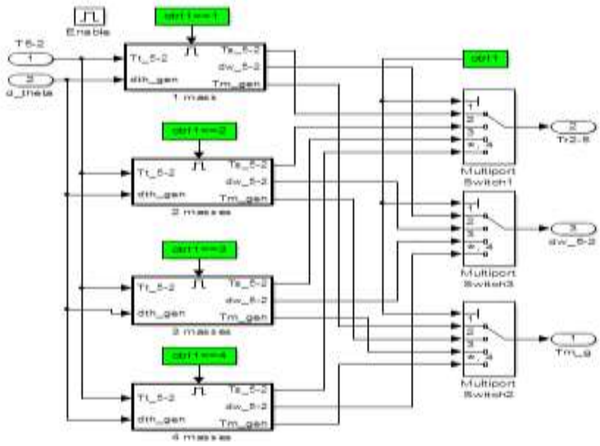

Figure 8 Four mass shaft of the turbine.

A three phase fault was allowed or tested on the above modeled powper station.
The following graphs where obtained after simulating the simpowersystem matlab 2013 modeled steam power station.

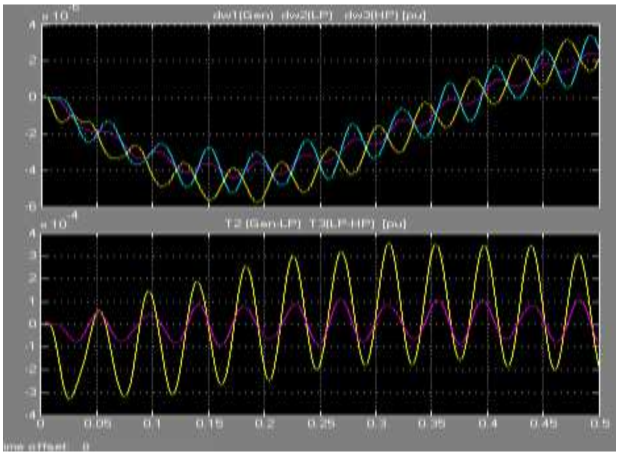

Figure 9: Three phase wave form of the turbine and generator speed in pu before fault.

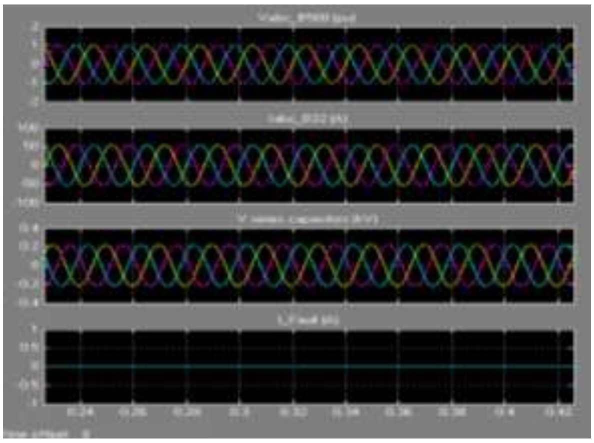

Figure10: Per unit three phase voltage, current (A) and fault current (A) verses time graph under normal or steady state on the power station.

One can see from figure11 above that, at steady state condition, the amplitudes of the wave form are constantly uniform. It means there is no instability or transient in the system, rather, the system is stable. This stability corresponds with the graph of stable condition using equal area criterion shown on figure 10.

Also, the wave form of fault current under no fault condition shows that there is no fault in the system. The wave form shows a straight line running from zero to infinity.

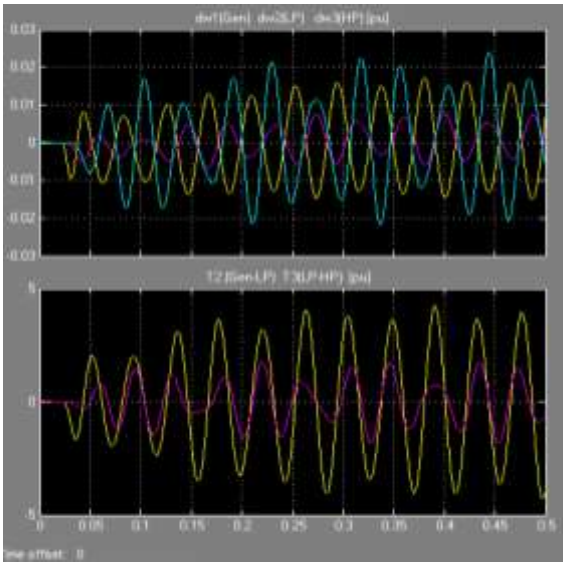

Figure13a: Per unit three phase generator speed deviation d_w and turbine torque constant T time graph during faulty or transient condition on the power station.

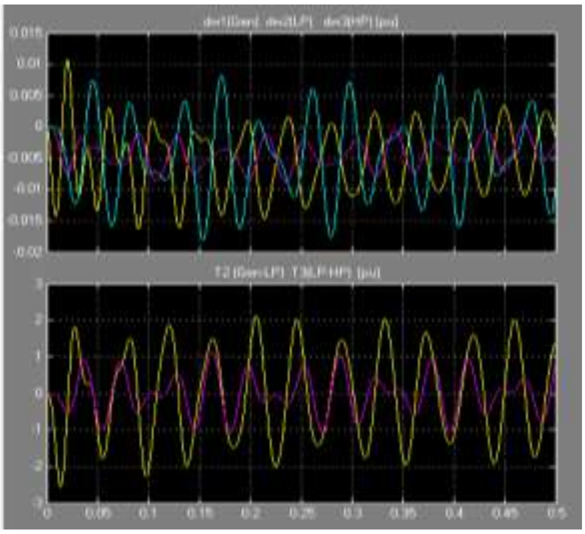

Figure 13b: Per unit three phase generator speed deviation d_w and turbine torque constant T time graph during faulty or transient condition on the power station.

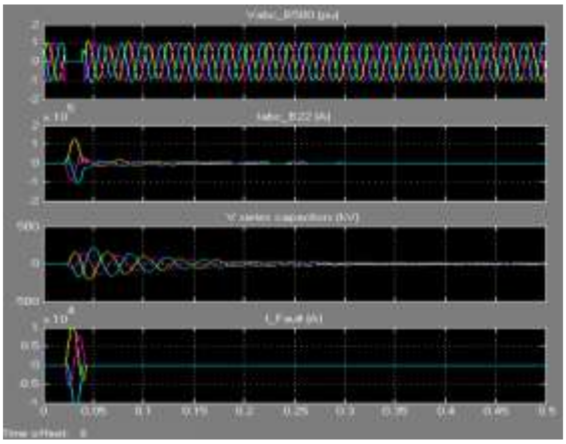

Figure14: Per unit three phase voltage, current (A) and fault current (A) verses time graph under faulty or transient condition on the power station.

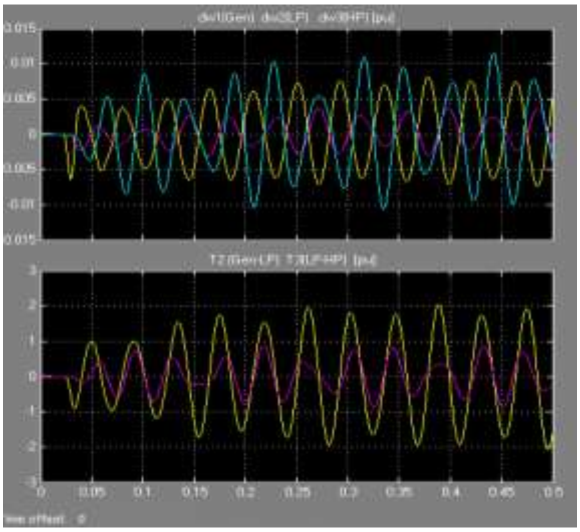

Figure 15: Per unit three phase generator speed deviation d_w and turbine torque constant T time graph during faulty or transient Line to ground fault condition on the power station.

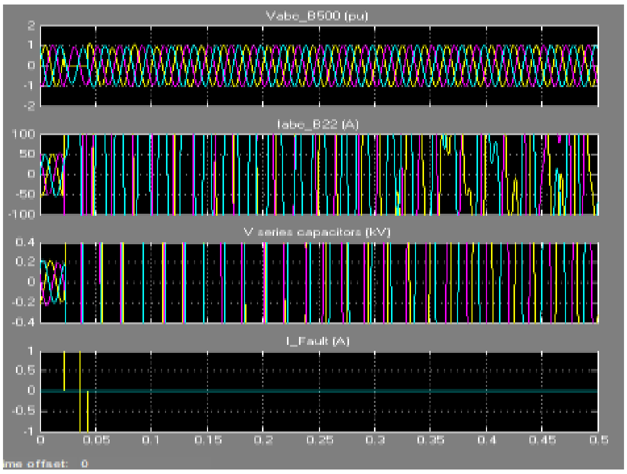

Figure 16: Per unit three phase voltage, current (A) and fault current (A) verses time graph under faulty or transient Single Line to ground fault condition on the power station.

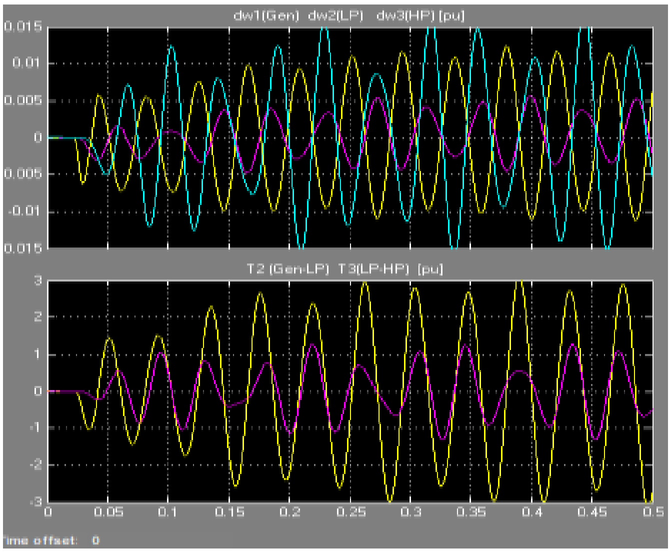

Figure 17: Per unit three phase generator speed deviation d_w and turbine torque constant T time graph during faulty or transient Double line to ground fault condition on the power station.

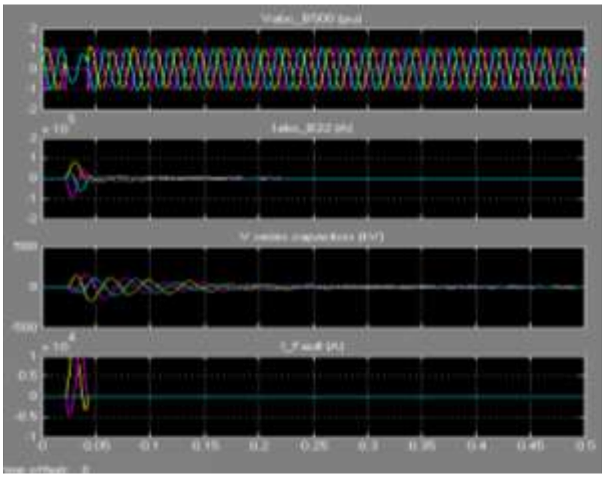

Figure 18: Per unit three phase voltage, current (A) and fault current (A) verses time graph under faulty or transient double line to ground fault condition on the power station.

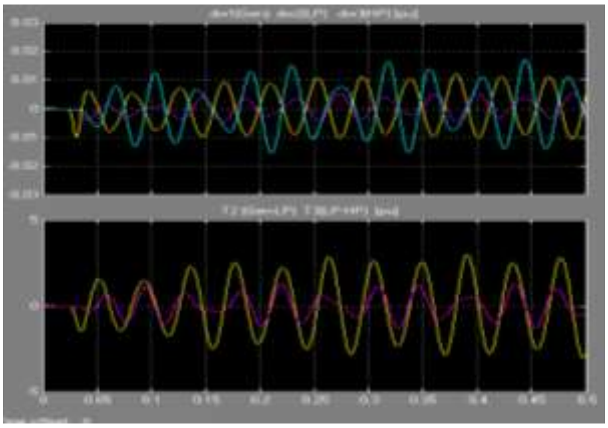

Figure 19: Per unit three phase generator speed deviation d_w and turbine torque constant T time graph during faulty or transient Line to line fault condition on the power station.

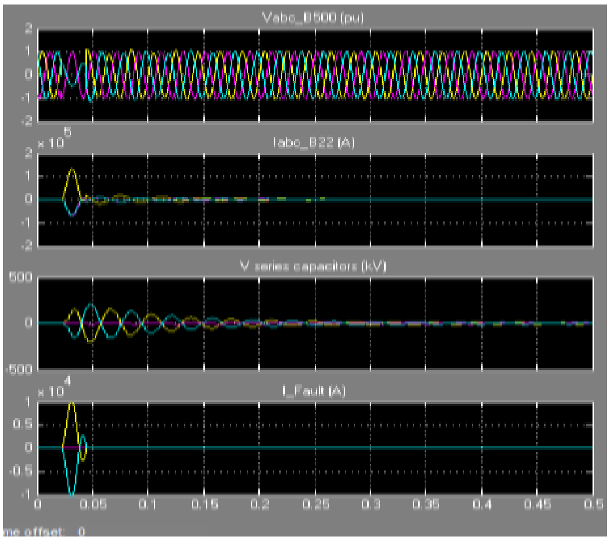

Figure 20: Per unit three phase voltage, current (A) and fault current (A) verses time graph under faulty or transient Line to line fault condition on the power station.

Table 1 above show the step by step solution of the swing curve for sustained fault. While Table 2 show the computation the swing curve for the fault cleared 0.10 seconds. More so, figure 10 is the swing curve which the instability of the system and that the cause of the instability (fault) is cleared in 0.10seconds after the occurrence of the fault.

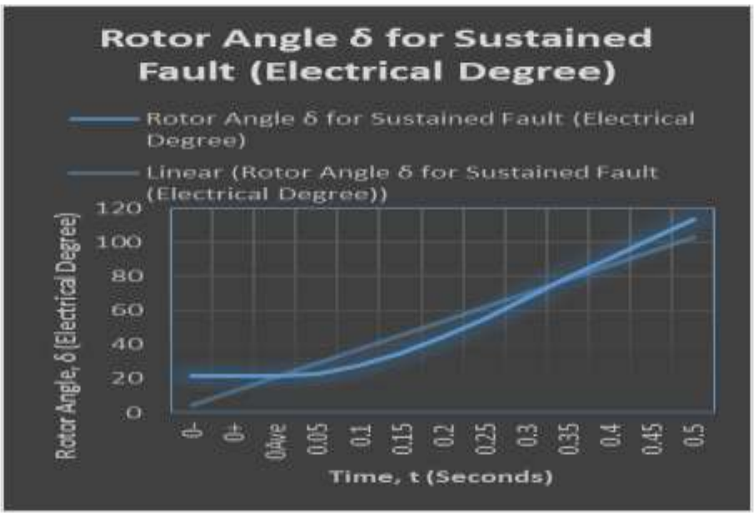

Figure 21. Swing Curve for Sustained Fault.

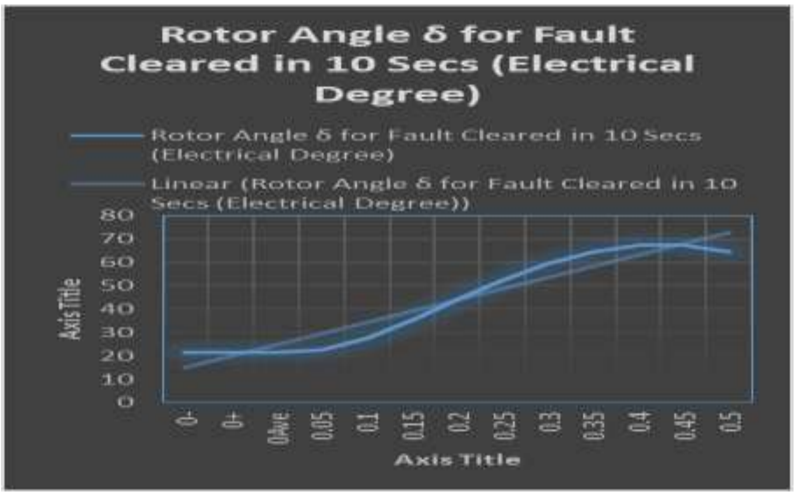

Figure 22. Swing Curve for Fault cleared in 0.10 seconds

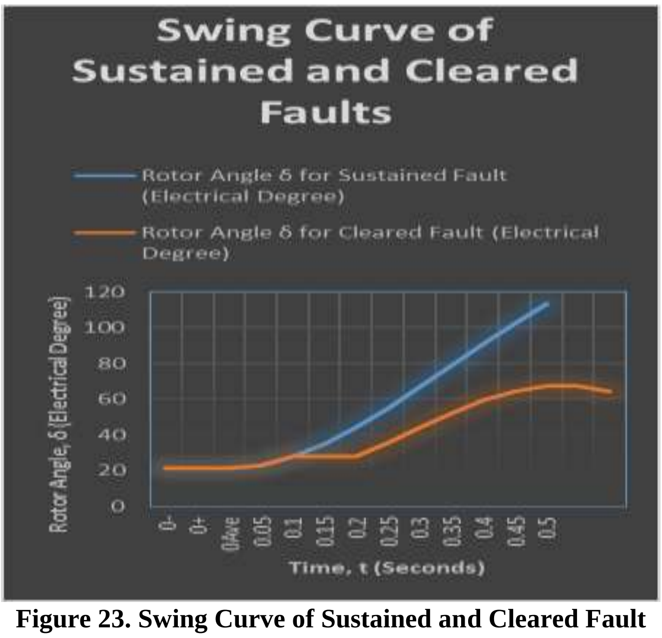

Figure 23. Swing Curve of Sustained and Cleared Fault

III. RESULT ANALYSIS

Different faults were simulated, tested and allowed to occur in the system. The figures 9 – 10 and 13-20 illustrates the steady state and faulty conditions of the system respectively. The compensator was use to restore the system operation after the occurrence of fault. Also the figures 21 and 22 illustrates the characteristic behavior of the power system generator during faulty conditions. While figure 23 shows that the maximum swing occurred at 68 (electrical degree), finally starts decreasing and the system became stable again.
However, from the figure 23, the critical clearing angle δ_C of 119^o corresponds to the critical clearing time t_C of 0.475seconds.

IV. CONCLUSION

The advantages of this paper is that, it brings to researchers the knowledge of transients in the power plants. Various methods and their applications to the stability of the power plant against transients. This paper also exposed various graphs illustrating waveform or nature of the power plant signals when the plant is under transients. Some limitations are that, we were not able to include the software aspect of the numerical application due to large data space needed.

REFERENCES

[1]. J. B. Gupter, A Course in Power System. Fifth Edition Sanjeev Kumar Kataria, 2008.
[2]. H. N. Ikeli, Critical Analysis of Transient Stability.
[3]. I. J Nagrath and D. P. Kothari, Power System Engineering. Fourth Edition Tata McGraw – Hill, 2004.
[4]. H. Saadat, Power System Aanalysis. Sixth Edition Tata McGraw – Hill, 2006
[5]. S. S. Chandra ‘’Transient Stability Analysis of Single Machine Infinite Bus System using Numerical Method. International Journal of Electrical and Electronics Research ISSN 2348-6988 (online) Vol. 2, Issue 3, pp: (158-166), Month: July - September 2014,
[6]. Matlab 2013 version

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