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Power System Stability Studies for Port Harcourt Electricity Distribution Company Network

Ahiakwo, C. O[1]., Braide, S. L.[2] and Aferonkhai, J. E[3]
1,2 &3 *Department of Electrical Engineering ,Rivers State University ,Port harcourt .*

ABSTRACT: *This paper presents different numerical techniques with better faults clearing time in cases of fault conditions that is before, during and after faults in a typical power system network. Overloading of electric power system component (generations, transmission, distribution, utilizations) has seriously become a major challenge because of the increasing needs of power consumption for man and society, thereby constituting major system imbalance and constant transient characterised by dynamic behaviour resulting into diverse faults scenario as stipulated in the study cases under investigation. Different numerical techniques including conventional swing equations, modified euler techniques and fourth-order Runge-Kutta techniques that showed faster or better response in terms of faults clearing time were employed. Sudden transient behaviour of different rotor angles using different numerical techniques with respect to time were characterised, examined and analysed for the purpose of determining faster response to clear faults condition were applicable in the study cases. The study considered the Afam Power Station to Port Harcourt Main (zone) network. The numerical data collected from the network were implemented into the formulated numerical techniques for purpose of determining faster convergence characteristics of the faults clearing time. With the Runge-Kutta techniques, a fault clearing time of 0.81 seconds was obtained, while conventional swing equation and modified eulers techniques obtained 0.26 seconds and 0.20seconds respectively, as corresponding fault clearing time for the same fault conditions by the mutual relationship of the circuit breaker and relay actions before and after the restoration of faults scenario*

KEYWORDS –*Power System; Transient Stability; Fault Clearing Time; Rotor Angle; Transient and Dynamic Stability Limit; Swing Equation;*

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I. INTRODUCTION.

Modern city expansionis as a result of rural to urban migration, and it has resulted in the stretching of infrastructural facility, it hasbeenlinked to the reason for increasing demand for power supply. The continuous rise in the power demand and the limitations of the installed capacity of power supply system often result in system instability. Instability in power system be caused by short-circuits, loss of power utility (generators) connections, starting of a lager motor, switching operations (lines or capacitors), impact loading on motors etc. Sudden large change in load and generation most often result into instability of power system [1].Transient Stability also known as Rotor Stability or Dynamic Stability is an electromechanical phenomenon that ensures all synchronous machines must remain in synchronism with one another. It is among the power system studies/analysis conducted to ensure optimum stability of a power system network [2]. The consequences of instability may include among others things damage to equipment, maloperation of protective devices and area wide blackout. The general model for transient stability studies takes into account the basic nature and source of instability on the power system and to develop a model which will reflect the swing operation and synchronization of generators.The restoration of transient stability after loss of components or achieving enhanced transient stability at very minimum time, so as to maintain improved system security and reliability is what differentiate most of the models considered for stability of a system[3]. There is need to carryout adequate load flow analysis especially using numerical techniques to determine the permitted voltages, currents, active power, reactive power, bus angle, bus magnitudes etc. on the buses in the network [4].

Transient stability of a system will be influencing by the generator loading prior to disturbance experience by the network. When the loading is closer to the maximum power the system becomes unstable during acceleration. The generator internal reactance also influences the transient stability as the reactance, peak power and the dissipation time during deceleration increases while the initial rotor angle decreases. The duration of the fault clearing time also influence the transient stability of the system [5].

The objectives of this paper are focused on transient stability analysis of the power system with emphasis on the 330KV Sub-station in Alaoji. The stability of the Alaoji station following transient disturbance is desirable to prevent a progressive increase in angular separation of generator rotors, or a progressive decrease in bus voltages due to increase in reactive power.

Transient stability analysis is required therefore to evaluate the critical clearing time as well as the rotor angle of the machines which are essential to establish the conditions necessary to achieve stability. It is important therefore that maintaining system security and performance cannot also he achieved without achieving transient stability.

II. RELATED WORK.

In papers [6-7] transient stability of typical Nigeria networks were investigated. Authors considered transient stability of 33KV and 132KV power transmission line. Computational models were examined. Different methods were considered. Of concern is the trapezoidal method. The trapezoidal numerical technique for data analysis was adopted while an electrical transient analysis tool was employed. The authors investigated the power angle, angular velocity, rotor angle differential changes among other things. In their work it was showed that when a symmetrical three-phase short circuit fault occur at one or any of the feeders, the fault must be cleared as quick as possible through the coordination of the circuit breakers and protective relay. 17 cycles corresponding to relay time setting of t = 0.34 s were recommended and at each cycle, changes in time with respect to changes in rotor angle, angular velocity, rotor differential and angular velocity differential were calculated on the power network simultaneously.

In [8-9], the use of compensators to improved stability were experimented. Thyristor controlled series capacitor (TCSC) to improve transient stability of power systems were demonstrated. In order to implement the proposed scheme, detailed model of TCSC, based on actual behaviour of thyristor valves, is adopted. Paper [10-11] presented the use of artificial intelligence (AI) technique in transient stability improvement. The techniques are geared towards evaluating critical clearing time and the rotor angle position required to open during abnormal condition without damage to generators under synchronism.

III. METHOD

The materials used in this research include line diagram of the study case, line reactance, impendence and route length of conductors etc.The research work will adopt the application of modified ruler technique as form of the numerical formulations.

3.1Procedure for Transient Analysis, Based on Swinging Operation of the Electric Machine

Define model network parameters: machine – H constant, generator transient reactance, transform short-circuit reactance.

a) Series reactance impedance of the interconnecting line.
b) Compute initial machine cycle angular velocity
c) Compute initial angle speed
d) Compute pre-fault reactance
e) Compute the maximum pre-fault active power (p) that is deliverable from Afam power generating system

Perform transient stability simulation using E-tap platform, when creating fault time (t_1 = 10.5 sec), fault clearing time (t_2 = 10.7 sec). The total simulation period for the activity of the fault lasted for time (t_3 = 200 second)

3.2 Assumption of Swing Model for Machine Rotor

a) Constant mechanical power input during the period of transient
b) Neglect damping of the machine
c) Representation of the machine by constant voltage source
d) Synchronous power may be calculated from steady-state solution of the network.

The bus loading condition for the network under study are the maximum and minimum load ranges from PHEDC and PHCN data etc.

3.3 Parameters of the Network System under Study

Generator reactance:

$$x_d = 0.276\, pu$$

$$P_e = 382MW, P_m = 384MW$$

$$X_t = X_{T1} + X_{T2}$$

$$X_t = j0.023 + j0.074 = j0.097$$

$$X_L = j0.0405$$

Rated inertia constant for **Afam 4**: 1.41MJ/MVA each

$$H_1 = 1.41 \times 2 = 2.82MJ/MVA$$

Rated inertia constant for **Afam 5**:

$$H_2 = 2.12 \times 2 = 4.24MJ/MVA$$

Converting to pu system:

$$pu = \frac{Actual\ value}{base\ value}$$

$H_{1new} = H_{1old} \times \frac{S_{1old}}{S_{1new}}$ and same for H_{2new}

$$H_{1new} = 2.4816MJ = 2.4816MJ/MVA$$

$$H_{2new} = 5.6MJ/MVA$$

$$H_{eq} = H_{1new} + H_{2new}$$

$$H_{eq} = 2.4816 + 5.6$$

$$H_{eq} = 8.80MJ/MVA$$

Line Network Parameter

$$S = \frac{P}{PP} < \cos^{-1}(\emptyset)$$

$$S = \frac{1.524}{0.8} < \cos^{-1}(0.8)$$

$$S = 1.915 < 36.87$$

The current is computed as

$$I = \frac{S^*}{V^*} = \frac{1.915 < -36.87}{1.0 < -0}$$

$$I = 1.915 < -36.87$$

Excitation voltage is as:

$$E_g^1 = V + JX_d^1 I$$

$$E_g^1 = 1 < 0 + (J0.4125)(1.915 < -36.87)$$

$$E_g^1 = 1.6036 < 23.2pu$$

From the calculation, initial operating power angle is as:

$$\delta_0 = 23.2^0 = 0.4049\, rad$$

$$E_g^1 = 1.6036\, pu$$

Using base of 250MVA

$$P_e = \frac{381}{250} = 1524pu$$

$$P_m = \frac{383}{250} = 1532pu$$

$$X = j0.275 + j0.097 + j\frac{0.081}{2}$$

$$X = j0.275 + j0.097 + j.0.0405$$

$$X = j0.275 + j0.1375$$

$$X_{eq} = j0.4125\, pu$$

$$\delta_0 = \delta_L = 23.2^0 = 0.4049\, rad$$

$$\omega_0 = \omega_L = 2\pi f = 314.1593$$

3.4 Modified Euler Analysis

The two first order differential equations are:

$$\frac{d\delta}{dt} = \omega_t - \omega_s$$

where,

ω_L = is the latest angular velocity

ω_s = is the synchronous speed

δ_L = is the latest torque angle

$$\frac{d\omega}{dt} = \frac{50\pi}{H}(P_m - P_e)$$

where,

H = is the inertial constant

P_m is the mechanical power

P_e = is the electrical power

During fault condition $P_e = 0$

IV. RESULTS AND DISCUSSION

Results are presentation which is based on numerical technique. The analysis was mainly to investigate the stability limits of a power system, before, during and after the system changes or experienced disturbances in the occurrence of faults. The system behaviour when faults are created and captured in terms of voltage magnitude and rotor angle the turbine.

Fig. 1 shows thesingle line diagram of 132/33KV Injection Substation model before simulation while Fig. 2 shows thesingle line diagram of 132/33KV Injection Substation model simulated.

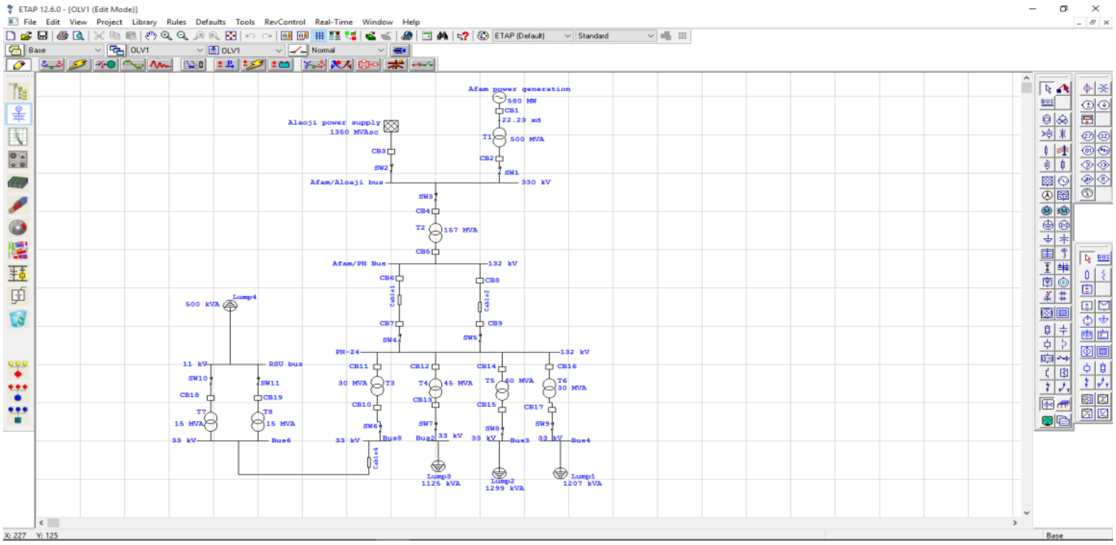


Figure 4.1: Single Line Diagram of 132/33KV Injection Substation at zone 4 (Not Simulated)

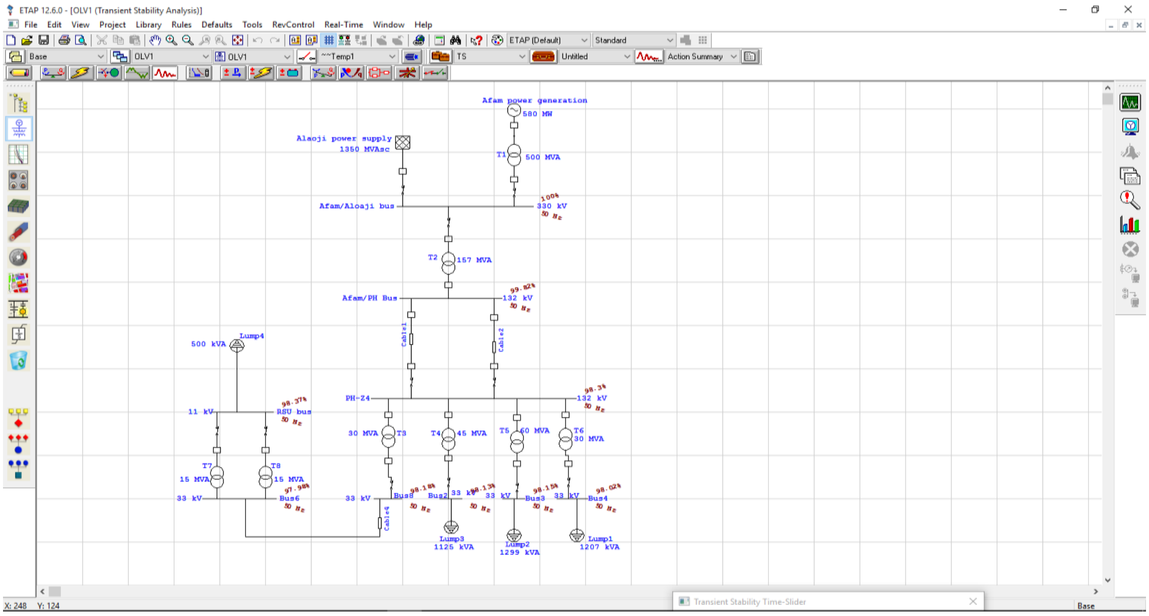


Figure 4.2: Single Line Diagram of 132/33KV Injection Substation at Zone 4 (Simulated)

4.1 Discussion

Table 4.1 to Table 4.14 presents some of the output result from generated data derived from the numerical technique: modified Euler. In Table 4.3 and Table 4.4 noticeable variance is observed for the degree change derived from swing equation technique and that of modified euler technique.

Table 4.1: Shows the incremental time (t) with changes in machine rotor angle (δ_1)

t	δ_1	δ_1(deg)
0	0.4049	23.2
0.02	0.4049	23.5
0.04	0.4347	24.9
0.06	0.5658	32.4
0.08	0.9053	51.9
0.10	1.5962	91.5
0.12	1.6642	95.32
0.14	0.8568	49.1

Table 4.2:Shows the incremental time (t) with changes in machine rotor angle (δ_2)

T	δ_2	δ_2(deg)
0	0.4049	23.2
0.02	0.4109	23.5
0.04	0.4586	26.3
0.06	0.6194	35.5
0.08	1.0006	57.3
0.10	1.4271	81.8
0.12	1.3401	77.0
0.14	0.4276	24.5

Table 4.3:Shows the incremental time (t) with changes in machine rotor angle (δ_2) for swing equation technique and modify euler.

T	δ_2 (swing, deg)	δ_2(modify, deg)
0	23.2	23.2
0.02	23.4	23.5
0.04	24.1	26.3
0.06	25.2	35.5
0.08	26.8	57.3
0.10	28.8	81.8
0.12	31.2	77.0
0.14	34.1	24.5

Table 4.4:Shows the incremental time (t) with changes in machine angular (w_1) velocity.

T	w_1
0	314.1593
0.02	314.755
0.04	315.9463
0.06	317.7333
0.08	320.1159
0.10	316.732
0.12	310.7339
0.14	304.5763

Table 4.5:Shows the incremental time (t) with respect to change in rotor angle $\frac{d\delta_1}{dt}$.

T	w_1
0	0
0.02	0
0.04	0.5957
0.06	1.787
0.08	3.574
0.10	5.9566
0.12	1.9761
0.14	-3.4524

Table 4.6:Shows the incremental time (t) with respect to change in rotor angle $\frac{d\delta_2}{dt}$.

t	$\frac{d\delta_2}{dt}$
0	0
0.02	0.5957

0.04	1.7887
0.06	3.574
0.08	5.9566
0.10	2.5728
0.12	-3.4254
0.14	-9.583

Table 4.8:Shows the incremental time (t) with changes in machine rotor angle δ_1, δ_2, δ_3, δ_3,

T	δ_1	δ_2	δ_3	δ_4
0.00	21.64	24.21	21.64	20.64
0.05	24.21	24.21	24.21	23.22
0.10	31.59	29.54	31.59	30.34
0.15	42.89	34.10	42.89	40.56
0.20	56.87	36.70	50.09	45.08
0.25	72.30	37.72	51.63	48.88
0.30	88.28	34.16	47.28	42.12
0.35	104.44	29.64	37.85	35.45
0.40	121.021	24.33	25.50	22.22
0.45	138.90	19.73	13.50	14.55
0.50	159.65	17.73	5.37	4.28

Table. 4.9: Show incremental time (t) with changes in machine rotor angle (r_1)

time,t	rotor, δ_1 (rad)
0	0.4049
0.02	0.4049
0.04	0.4347
0.06	0.5658
0.08	0.9053
0.1	1.5962
0.12	1.6642
0.14	0.8568

The result of the above table is simulated for different cases of instability and stability. Fig. 4.3 to Fig. 4.6 presents pictorial representation of the behaviour of the moto rotor angle and with respect to time.

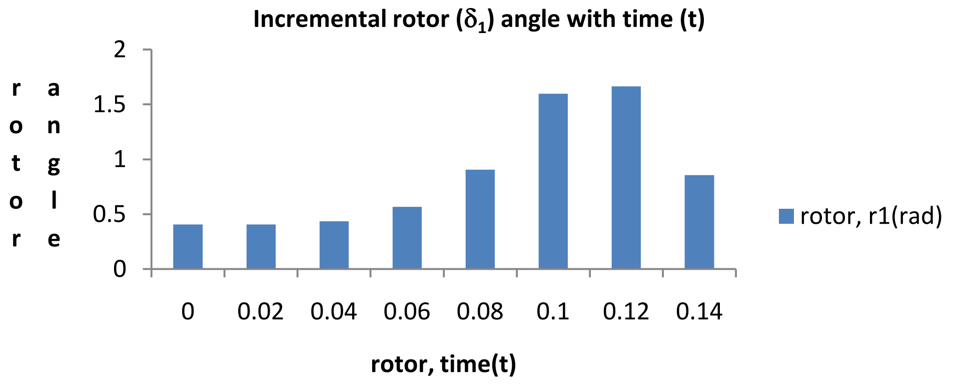


Fig. 4.3: The behaviour of rotor angle (δ_1) with time, t

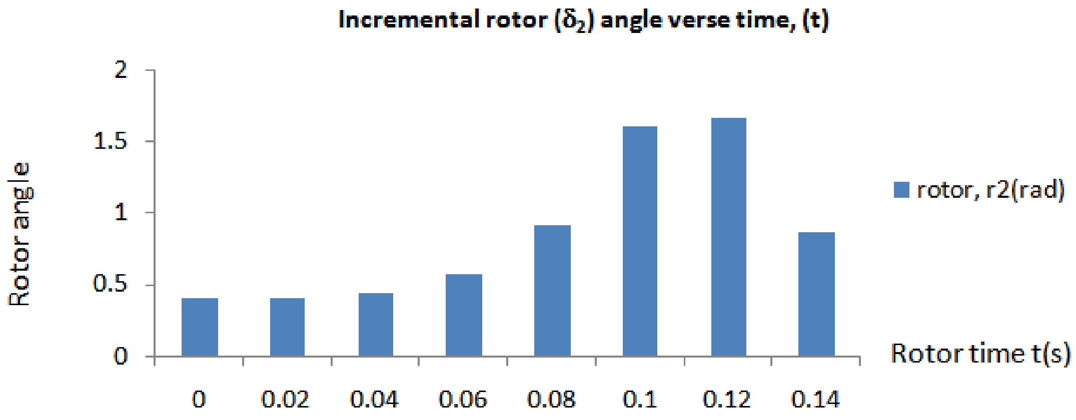


Figure 4.4: presentation of rotor-angle (δ_2) with time, t.

Table 4.10: Shows the incremental time (t) with changes in machine motor (r_2)

time,t	rotor, δ_2 (rad)
0	0.4049
0.02	0.4049
0.04	0.4347
0.06	0.5658
0.08	0.9053
0.1	1.5962
0.12	1.6642
0.14	0.8568

Table 4.14: shows incremental time changes with four(4) machine rotor angle (δ_1, δ_2, δ_3, δ_4) using swing equation, modified euler and Runge-Kutta fourth –order for circuit – breaker fault clearing time.

time,t	rotor(r1)	rotor,r2	rotor,r3	rotor,(r4)
0	21.64	24.21	21.64	20.64
0.05	24.21	24.21	24.21	23.22
0.1	31.59	29.54	31.59	30.34
0.15	42.89	34.1	42.89	40.56
0.2	56.87	36.7	50.09	45.08
0.25	72.3	37.72	51.63	48.88
0.3	88.28	34.16	47.28	42.12
0.35	104.44	29.64	37.85	35.45
0.4	121.02	24.33	25.5	22.22
0.45	138.9	19.73	13.5	14.55
0.5	159.65	17.73	5.37	4.28

Table 4.15: Machine rotor and rotor time, (t)

time(s)	rotor(r1)	rotor(r2)	rotor(r3)	rotor(r4)
0	21.64	24.21	21.64	20.64
0.05	24.21	24.21	24.21	23.22
0.1	31.59	29.54	31.59	30.34
0.15	42.89	34.1	42.89	40.56

0.2	56.87	36.7	50.09	45.08
0.25	72.3	37.72	51.63	48.88
0.3	88.28	34.16	47.28	42.12
0.35	104.44	29.64	37.85	35.45
0.4	121.021	24.33	25.5	22.22
0.45	138.9	19.73	13.5	14.55
0.5	159.65	17.74	5.37	4.28

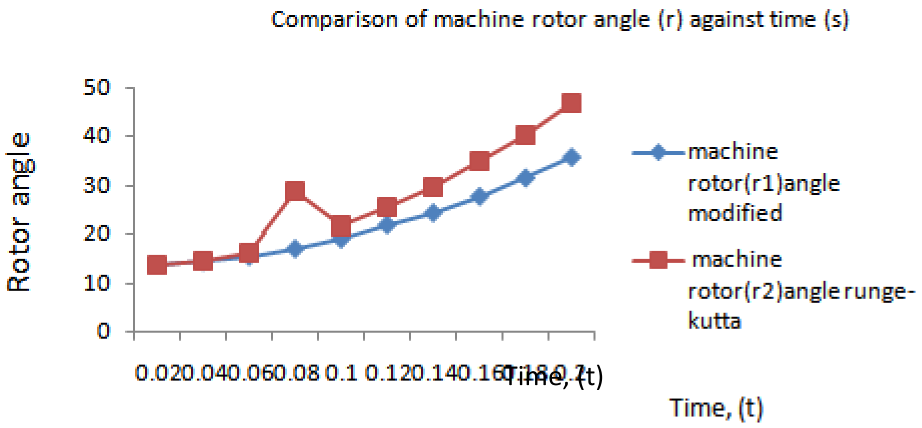


Figure 4.5: Machine rotor angle with fault clearing time t (s)

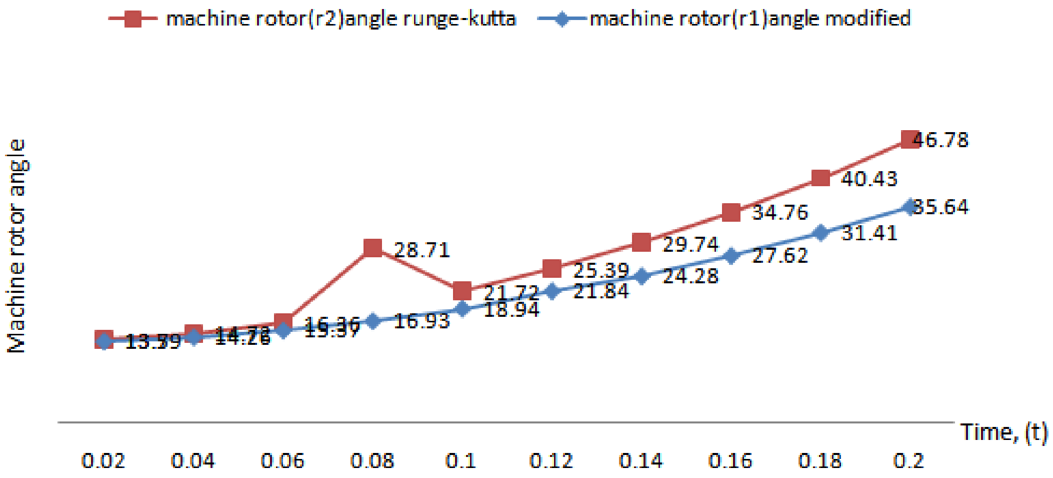


Figure 4.6: Comparison of machine rotor angle using modified euler and Runge-Kutta

V. CONCLUSION

5.1 Conclusion

This work attempted providing an insight into the power system transient stability issue in a growing economy with emphasis on the behaviour of the synchronous machine following a large sudden disturbance on the transmission network. In theearly part of this paper, definitions and type of power system stability were presented; major reasons were discussed to justify the need to the study area. The data collected included generation and transmission line data, which was then analysed.

An Etap software was used to model the network and also used to the analysis after which results were generated. The time to power angle and time to angular velocity was strongly investigated using analytical tool. The swing equation model was also applied using the Euler Model to determine the accelerating power of the synchronous generator when the load was suddenly removed. Stability was achieved for 5 cycles at a power angle of 86^0 above 5 cycles any swinging due to disturbance can cause instability.Theswing curves plotsgenerated using the Etap analysis tool were presented as appendix in this paper.

REFERENCES

[1]. Al Marhoon, H. H., Leevongwat, I., & Rastgoufard, P. (2012, May). A practical method for power systems transient stability and security analysis. In *PES T&D 2012* (pp. 1-6). IEEE.

[2]. Ayodele, T. R., Ogunjuyigbe, A. S. O., & Oladele, O. O. (2016). Improving the Transient Stability of Nigerian 330kv Transmission Network Using Static VAR Compensation Part I: The Base Study. *Nigerian Journal of Technology*, *35*(1), 155-166.

[3]. Wokoma, B. A., Idachaba, A. O.,&Osegi, E. N. (2019).Predicting Voltage Stability Indices of Nigerian 330kV 30 Bus Power Network Using an Auditory Machine Intelligence Technique. *2019 IEEE African Conference (IEEE AFRICON 19), Accra*.

[4]. Ojuka, E. O., &Wokoma, B. A. (2019). Cascaded Swarm Intelligence Algorithm for Automated Power Flow Studies. *Iconic Research and Engineering Jourrnals*, *3*(6), 51-55.

[5]. Oluseyi, P. O., Adelaja, T. S., & Akinbulire, T. O. (2017). Analysis of the Transient Stability Limit of Nigeria's 330kV Transmission sub-network. *Nigerian Journal of Technology*, *36*(1), 213-226.

[6]. Elechi, P., Ahiakwo, C. O., & Okwu, U. N. (2020). Transient Stability Analysis of 33 KV Transmission Network of Egi Community, Nigeria. *Journal of Power and Energy Engineering*, *8*(3), 18-35.

[7]. Chikezie, B. U. Computational Model for Transient Stability Analysis of Power System in Nigeria.

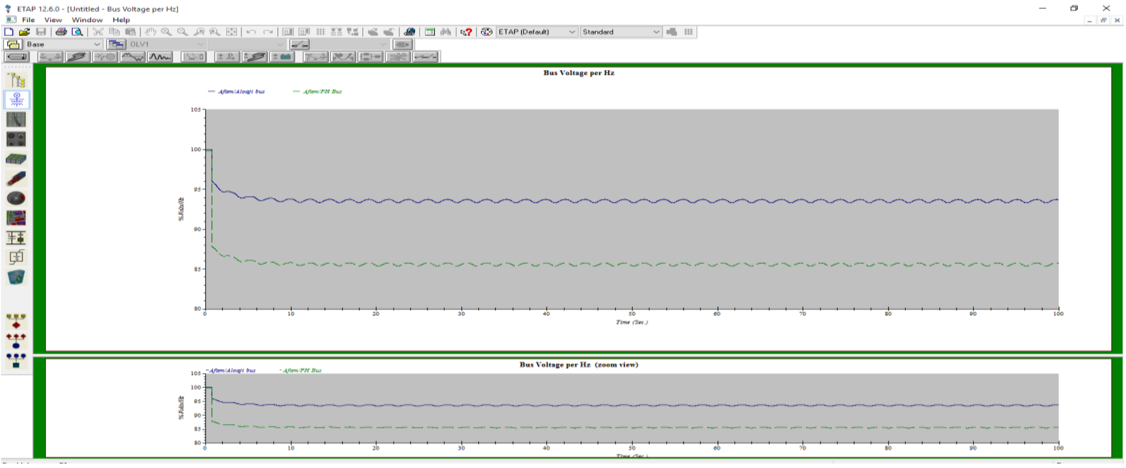
[8]. Idoniboyeobu, D., Wokoma, B., & Evoh, S. (2018). Reactive Power Compensation Improvement Technique for Injection Substations in Nigeria.

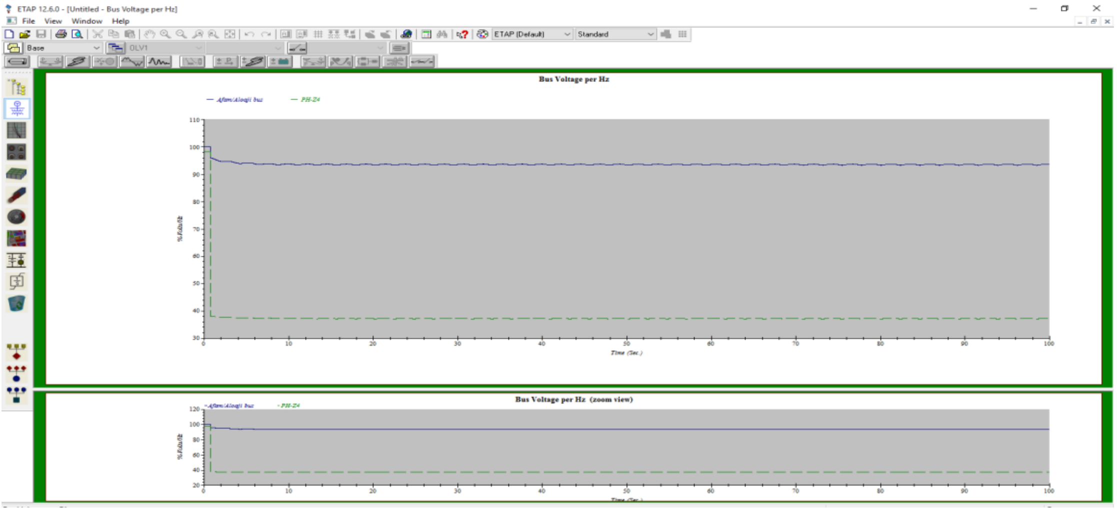
[9]. Dhaval, N. T.; Bhavesh, B.; & Vijay, M. (2012). Role of PSS and SVC for Improving the Transient Stability of Power System; *International Journal of Engineering and Advanced Technology*,*1*(13), 7-140

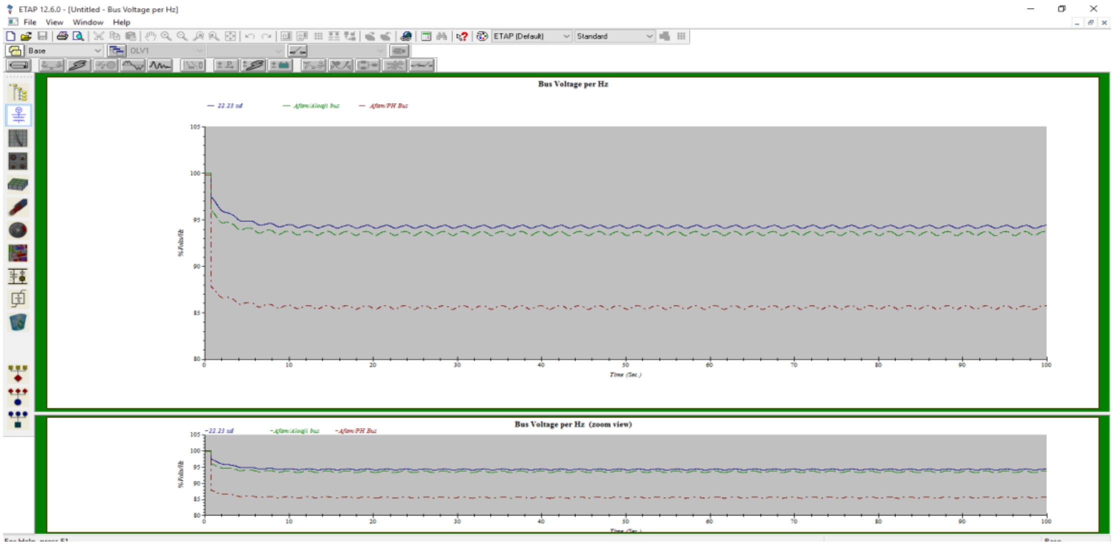
[10]. Bala, T. K., Amesi, C. I., & Ndubisi, S. N. (2018). Feed-forward Neural Network Based Transient Stability Assessment of 132KV Sub-transmission Power System Network: Case Study Afam to Port-Harcourt Town (Z4), Nigeria.

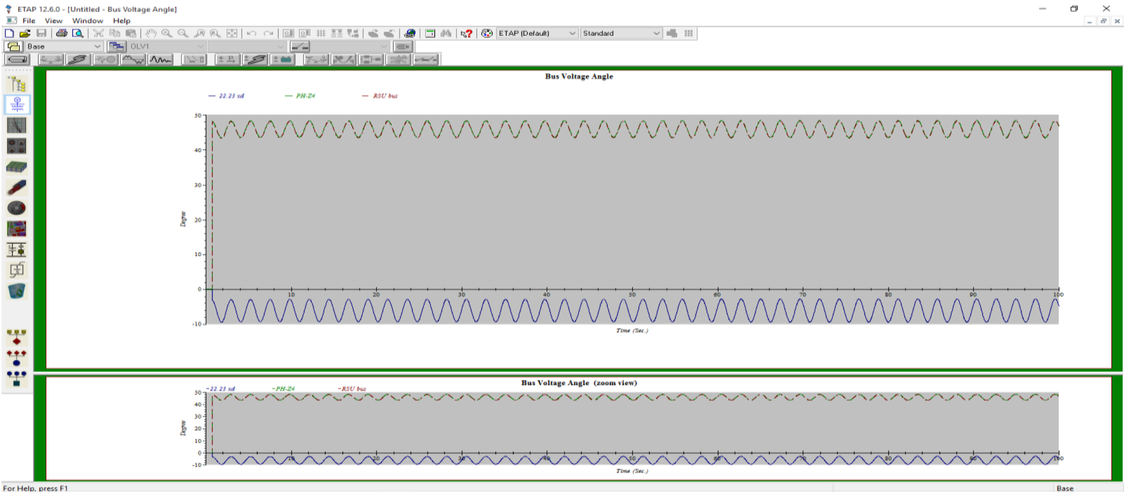
[11]. Bakhshi, M., Holakooie, M. H., & Rabiee, A. (2017). Fuzzy based damping controller for TCSC using local measurements to enhance transient stability of power systems. *International Journal of Electrical Power & Energy Systems*, *85*, 12-21.

APPENDIX









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