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The Impact of Fault on an Excerpt of Nigeria Synchronous 330KV Power System Equipped with Genetic Algorithm Based Power System Stabilizer with Emphasis to Critical Clearing Time

Nwagu Chukwukadibia C
Department of Electrical Electronic Engineering, Enugu State University of Science and Technology, Enugu
Email address: lordcondusresources1 @ yahoo.com

Abstract— *Disturbance in Nigeria Power system generation and transmission has contributed majorly to instability in power supply to the end users. Disturbance can be as a result of fault, application of load, rejection of load, sudden load removal, loss of generating unit component, loss of transmission line or outright loss of generating unit at a particular station or substation. These disturbances result into total outage, low voltage and voltage fluctuation tantamount to causing serious damages in industries, factories, offices and household in Nigeria. These damages and their effects necessitated this research on impact of fault and its relationship to critical clearing time on an excerpt of Nigeria synchronous bus system equipped with genetic algorithm based power system stabilizer. The excerpt of Nigeria Synchronous system is Okpai, Alaoji and Afam generating stations which formed nine bus systems.*

Keywords— *Nine Bus System, Genetic algorithm based power system Stabilizer, Critical Clearing Time and Impact of fault on Afam-Okpai-Alaoji generating stations.*

I. INTRODUCTION

Recently, Nigeria power system has proven to be very difficult in stabilization, handling and management due to the geometric growth in the population which created sudden high demand of stable power supply across board. Power supply is meant to strike balance between the generation and the demand. And when the power supply is not in consonance with the demand from the end users, there are high possibilities of the machine within the local area mode, intra area mode or inter area mode to start swinging against each other with tendency of pulling out of synchronism, which will eventually lead to power supply fluctuation in the affected localities. And any fluctuations in power supply do cause changes in the operation of household appliances and industrial equipment. The change in the operation of the appliances and equipment may lead to high generation of internal heat within the equipment leading to loss of the said equipment. Analyzing the impact of fault on an excerpt of Nigeria synchronous power system equipped with genetic algorithm based power system stabilizer with emphasis to critical clearing time will aid to know how long a network can withstand disturbance before it will pull out of synchronism. The Determination of the critical clearing time of the network will help to calculate a proportionate delay time of any protective device on the power system to enable it isolate the faulty area quickly so as to keep the network stable.

II. NETWORK UNDER STUDY

The excerpt of Nigeria synchronous power system under study, comprise of Okpai, Alaoji and Afam generating stations. These three generating stations formed a Nine bus system, which is part of the total bus system of Nigeria power system. The formed nine bus systems has three generator buses, six load buses and five transmission lines as shown with a single line diagram in figure 1.

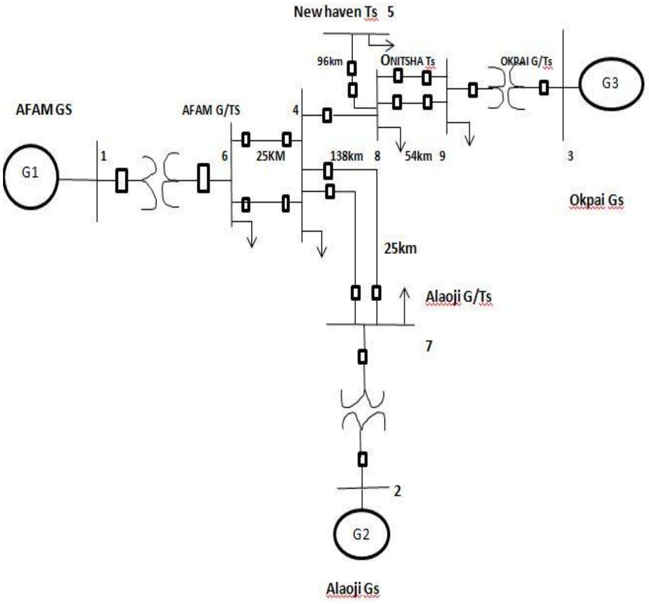

Fig. 1. Single line diagram of 330KV 9-bus power system

The diagram as shown in figure 1 depicted distances covered within the load buses as well as the transmission lines as displayed in Table 1. The installed and available capacities of each of the generating stations are enumerated in a table 2 while other pieces of information as displayed in Table 3.

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TABLE 1. Distances of the transmission line of the network

S/N	Buses	Distance of the transmission lines
1	4-------6	25KM
2	4--------7	25KM
3	4---------8	138KM
4	5---------8	96KM
5	8---------9	54KM

TABLE 2. Capacities of 3-machine 9-bus System

S/No	Power Station	Installed Capacity (MW)	Available Capacity (MW)
1	Afam	987.2	65.8
2	Alaoji	1074	360.2
3	Okpai	480	421.2

(NIPP FINAL REPORT)

TABLE 3. Details of the three generating stations under study (NIPP FINAL REPORT)

STATION	NOMENCLATURE	FUEL USED	MAKE	MVA	TERMINAL VOLTAGE(KV)	P.F
ALAOJI	GT 1	GAS		141.25	15	0.85
	GT 2	GAS		141.25	15	0.85
	GT 3	GAS		141.25	15	0.85
OKPAI	GT 1	GAS	ALSTOM	210	15.75 +/-5%	0.85
	GT 2	GAS	ALSTOM	210	15.75+/-5%	0.85
	ST 1	STEAM		210	15.75+/-5%	0.85
AFAM IV	GT 13	GAS	BBC	110	10.5+/- 7.5	0.8
	GT 14	GAS	BBC	110	10.5 +/- 7.5	0.8
	GT 15	GAS	BBC	110	11.5+/-5	0.8
	GT 16	GAS	BBC	110	11.5+/- 5	0.8
	GT 17	GAS	BBC	110	11.5+/- 5	0.8
	GT 18	GAS	BBC	110	11.5+/-5	0.8
AFAM V	GT 19	GAS	SIEMENS	162.69	15.75+/-5%	0.85
	GT 20	GAS	SIEMENS	162.69	15.75 +/- 5%	0.85

III. MODEL OF THE NETWORK UNDER STUDY

The network comprising Okpai, Alaoji and Afam generating station was modeled as a two-axis fifth order model. The vector state variables, state vectors and input vector were considered in the modeling.

$\dot{X} = f(X,U)$

X = vector state variables $[\Delta\delta, \Delta\omega, E'_q, E'_d, \Psi]$

Where $\Delta\delta$ = Change in rotor angel

$\Delta\omega$ = Change in rotor speed

E'_q = stator voltage along quadrature axis

E'_d = stator voltage along direct axis

Ψ = stator flux

X and U stand for state vector and input vector as well as PSS output signal

In the model, genetic algorithm based power system stabilizer was incorporated in each generating station to enhance the critical clearing time of the network at any occurrence of disturbance.

The model of the network as shown in figure 2 was built with the following assumptions below;

1-A group of machines are represented by an equivalent as they are assumed to be coherent

2-Identical speed governors, turbines and AVRs are on all the generators

3-Identical genetic algorithm based power system stabilizers are on all the generators

4-Input powers are same throughout the simulation with pre-fault bus voltage while all loads with equivalent admittance to ground, all remain constant.

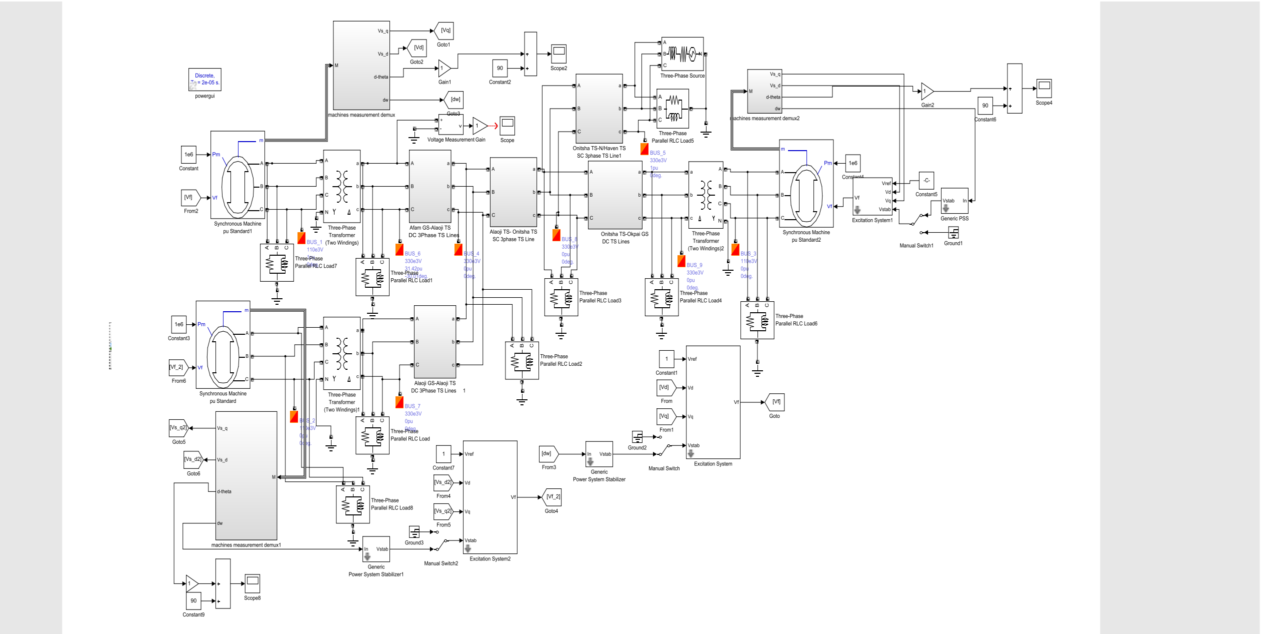

Fig. 2. Complete Model of the network

IV. INITIAL STEADY STATE OF THE NETWORK BEFORE FAULT THROUGH LOAD FLOW ANALYSIS

The data collated from the network was processed and placed in a matlab file to form the data bank of the network. The data bank file performed call to functions as embedded in it. The first function to be called was 'Lfybus' to form the bus admittance matrix of the network as needed for power flow. The next function called was 'Lfnewton' to perform load flow based on Newton-Raphson iterative technique. For the power flow solution to be displayed, another function known as 'Busout' was called to enable the power flow solution displayed after five iterations. Lineflow function helped the line flow to be shown on the screen. From the load flow results, the bus voltage and their corresponding angles are readily available.

Table 4 Power Flow Solution by Newton-Raphson Method

```
              Maximum Power Mismatch = 6.59041e-08
                      No. of Iterations = 5
Bus  Voltage  Angle    ------Load------    ---Generation---   Injected
No.  Mag.     Degree     MW       Mvar       MW       Mvar      Mvar
 1   1.000    0.000     0.000     0.000    65.856   -90.606     0.000
 2   1.010   -0.156     0.000     0.000    30.200   130.456     0.000
 3   1.030    4.248     0.000     0.000   421.000    23.428     0.000
 4   1.005   -0.219   289.400   179.400     0.000     0.000     0.000
 5   1.021    1.125   107.000    44.600     0.000     0.000     0.000
 6   1.002   -0.075     4.800     3.600     0.000     0.000     0.000
 7   1.005   -0.216     6.000     2.500     0.000     0.000     0.000
 8   1.023    1.919    98.000    60.700     0.000     0.000     0.000
 9   1.029    3.679     9.000     5.600     0.000     0.000     0.000
Total                 514.200   296.400   517.056    63.278     0.000
                          Line Flow and Losses
--Line--  Power at bus & line flow    --Line loss--  Transformer
from  to     MW      Mvar     MVA       MW      Mvar      tap
          1        65.856  -90.606  112.011
          6   65.856  -90.606  112.011    0.000    0.251
          2        30.200  130.456  133.906
          7   30.200  130.456  133.906    0.000    0.615
          3       421.000   23.428  421.651
          9  421.000   23.428  421.651    0.000    4.190
          4      -289.400 -179.400  340.495
          7  -12.093  -65.606   66.711    0.007   -1.936
          7  -12.093  -65.606   66.711    0.007   -1.936
          6  -30.505   37.475   48.321    0.023   -9.754
          6  -30.505   37.475   48.321    0.023   -9.754
          8 -204.204 -123.137  238.458    1.078 -103.190
          5      -107.000  -44.600  115.923
          8 -107.000  -44.600  115.923    0.180  -77.784
          6        -4.800   -3.600    6.000
          4   30.528  -47.228   56.236    0.023   -9.754
          4   30.528  -47.228   56.236    0.023   -9.754
          1  -65.856   90.857  112.214    0.000    0.251
          7        -6.000   -2.500    6.500
          4   12.100   63.670   64.810    0.007   -1.936
          4   12.100   63.670   64.810    0.007   -1.936
          2  -30.200 -129.841  133.307    0.000    0.615
          8       -98.000  -60.700  115.276
          9 -205.231  -23.731  206.598    0.769  -16.912
          9 -205.231  -23.731  206.598    0.769  -16.912
          4  205.282   19.947  206.249    1.078 -103.190
          5  107.180  -33.184  112.199    0.180  -77.784
          9        -9.000   -5.600   10.600
          8  206.000    6.819  206.113    0.769  -16.912
          8  206.000    6.819  206.113    0.769  -16.912
          3 -421.000  -19.238  421.439    0.000    4.190
   Total loss                              2.856 -233.122
   Prefault reduced bus admittance matrix
                     Ybf =
   0.1202 - 2.3855i   0.0562 + 1.5684i   0.0061 + 0.7825i
   0.0562 + 1.5684i   0.0907 - 2.2871i   0.0123 + 0.6859i
   0.0061 + 0.7825i   0.0123 + 0.6859i   0.1380 - 1.4622i

        G(i)   E'(i)    d0(i)    Pm(i)
          1    0.9834   0.7060   0.0659
          2    1.0399   0.2162   0.0302
          3    1.0412   9.8780   0.4212
```

V. THE IMPACT OF FAULT ON THE NETWORK WITH EMPHASIS TO CRITICAL CLEARING TIME

Generating units tend to lose synchronism with the rest of the power system following a large disturbance like loss of a circuit or disconnection done by their own protective systems, if a fault persists on the power system beyond a critical period. The critical clearing time is a maximum time interval by which the fault must be cleared in order to preserve the system stability. The critical clearing period usually depend on number of factors like;

- Nature of fault
- Location of the fault with respect to a generation unit, and
- The characteristics and capability of the generating units

The calculation of the critical clearing time for generating units for a particular fault is determined by carrying out a set of simulations in the time domain in which the fault is allowed to persist on the power system for increasing amounts of time before being cleared.

After confirming the stability of the network, a three phase fault was simulated along Alaoji generating station and Alaoji transmission station, which is between bus 4 and 7. At the start of the simulation, when t= 0sec, all circuit breakers were to toggle from open to close position. The fault on the circuit was simulated with the aid of a time based fault connected to the designated circuit. The fault was switched to the circuit after start of simulation. The clearing times of the fault were varied and the swing equation was solved using RUNG-KUTA numerical analysis of non-linear equations.

To disable the fault, the faulted circuit was isolated by simultaneously opening of the breakers at the two ends of the circuit. For different clearing times of the fault and constant simulation time of 5 seconds ,the swing curves for the Alaoji and Okpai power stations are as shown under ,noting Afam as the datum or reference station, that is swing bus. The table 5 below shows the various clearing times and their corresponding clearing angles in the network with AFAM generating station set as reference or slack bus. It is apparent that the critical clearing times and angles for Alaoji generating stations and Okpai generating stations are[10.03°,0.60s] and [111.80°,0.60s] respectively. The fault was usually cleared by isolating the faulted circuit from the network; it is apparent that fault on the designated circuit should be cleared on or before 0.6 seconds, to maintain the system integrity. The graphs below in figure 3-11, illustrated when a fault is allowed on the network to ascertain the critical clearing time. From these graphs, the network operate better with the fault from 0.2 seconds till 0.6 seconds and beyond 0.6 seconds the network started pulling out of synchronism gradually. The pulling out of the synchronism became obvious at 0.68 seconds at this time, the generating stations at Okpai and

Alaoji started swinging against themselves causing serious inter-area mode oscillation

TABLE 5. Generator rotor relative angles for different fault clearing times

Clearing time (s)	**Gen 2 relative rotor angle (deg.)**	**Gen. 3 relative rotor angle (deg.)**
0.20	0.739	20.81
0.40	4.22	54.93
0.60	**10.03**	**111.80**
0.65	11.84	129.6
0.66	12.22	133.30
0.67	12.61	137.10
0.68	13.00	140.90
0.70	13.80	148.80
0.80	18.15	191.40

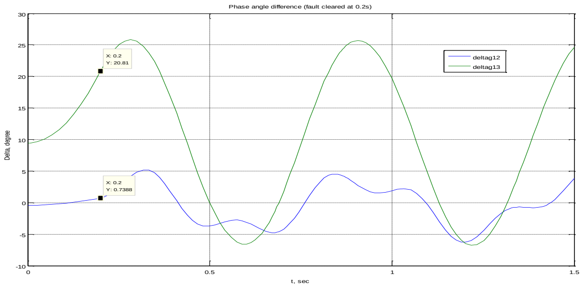

Fig. 3. Phase angle difference for a fault clearing time of 0.2sec.

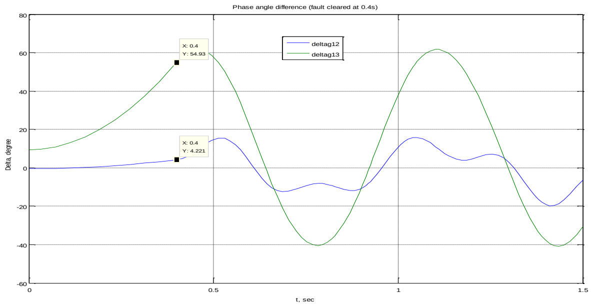

Fig. 4. Phase angle difference for a fault clearing time of 0.4sec.

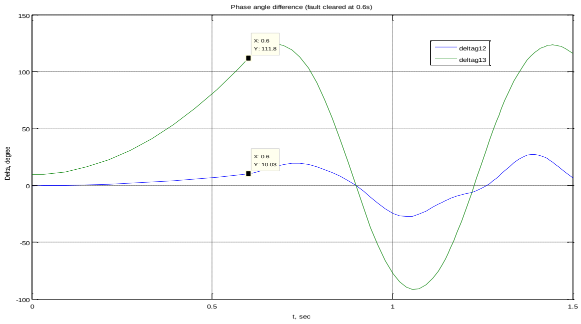

Fig. 5. Phase angle difference for a fault clearing time of 0.6sec.

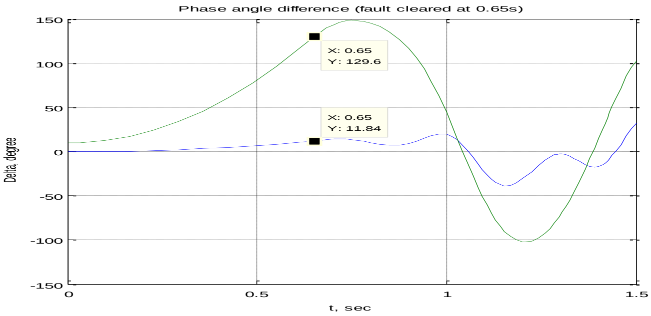

Fig. 6. Phase angle difference for a fault clearing time of 0.65sec.

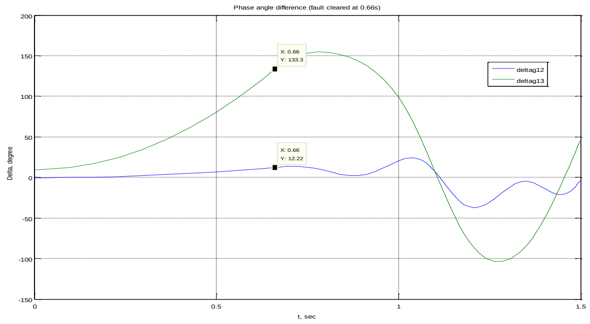

Fig. 7. Phase angle difference for a fault clearing time of 0.66sec.

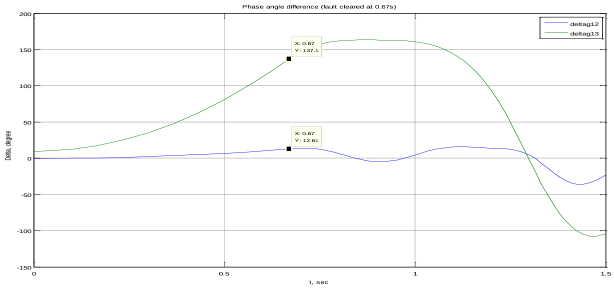

Fig. 8. Phase angle difference for a fault clearing time of 0.67sec.

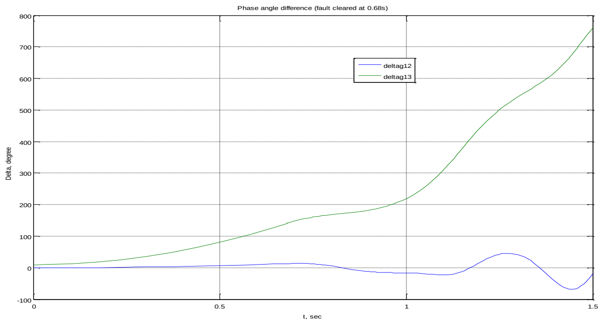

Fig. 9. Phase angle difference for a fault clearing time of 0.68sec.

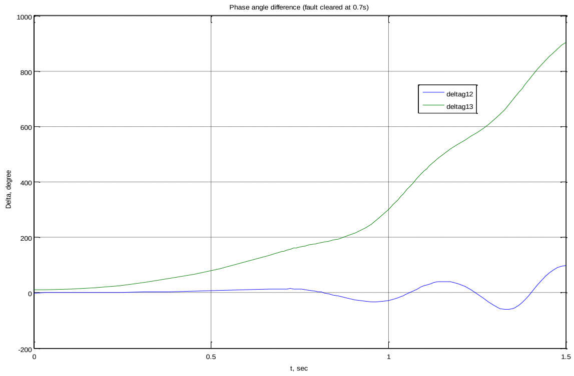

Fig. 10. Phase angle difference for a fault clearing time of 0.7sec.

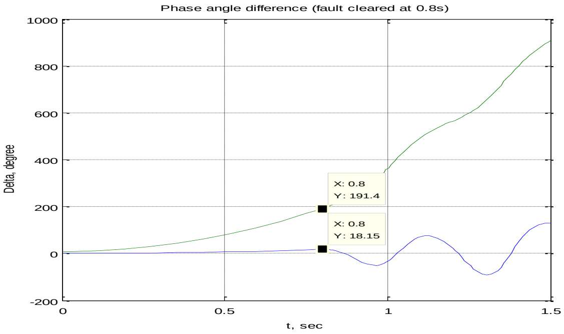

Fig. 11. Phase angle difference for a fault clearing time of 0.8sec.

VI. CONCLUSIONS

The critical clearing time is a vital parameter as regards the fault duration on the network. It is essence to be known so as to decide or calculate the delay time of the protective devices on the network. These devices will isolate the entire network from the faulty circuit so as to maintain the synchronism of the network, otherwise the entire network will be affected which will lead to the outage in the areas where the network is covering. From the results as contained in this simulation, the critical clearing time was 0.6seconds and beyond this critical clearing time, the network starts swinging against each other. Therefore, from 0.2 seconds to 0.6 seconds the network was able to contain the faulty circuit.

REFERENCES

[1] Somolu F.A, (April, 2007) “Integration and evacuation Study for National integrated Power Projects” Final report of In-house study, Vol.1.