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ELECTRIC POWER STABILITY IN BOROKIRI AXIS OF TOWN AREA OF PORT HARCOURT USING CONTINUATION POWER FLOW METHOD

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ABSTRACT:Electric energy is transmitted from generation points through a complex network of interconnected transmission and distribution system. The secondary and tertiary distribution network are closer to the load centre delivering electricity to consumers. The secondary distribution network is often faced with instability challenges due to the nature of its structure and lesser stability provisions when compared to the transmission network. This study analysis the electric power network for Borokiri Axis of Port Harcourt for improved stability of the distribution network.A comprehensive gathering of essential data about the injection substations that supplies electricity to Borokiri Port Harcourt was the first task in this study. Electric Transient Simulation software (ETAP) was utilised to conduct load flow analysis in accordance withGauss-Seidel power flow method. From initial simulations, the existing distribution network is marred with low voltage profile problem at Okilopolo network. To improve the distribution network, shunt capacitors were injected into the system to enhance the voltage stability of the network. Further simulations of the improved distribution network show that the voltage profile Nsukka network has improved within the statutory limit which is between 95.0 - 105.0% and the reactive power load at Okilopolo bus 2 increased by 400% from 11.5MVar to 57.5MVar.

Keywords – *Static VAR compensation, Load Flow, FACTS, Voltage profile improvement.*

I. INTRODUCTION

How reliable a system operates depends on its capacity to restore itself to its initial state of equilibrium after it has been subjected to any form of external disturbance that may have altered its preprogramed parameters. The rate at which the system is able to return to a state of equilibrium defines its level of stability [1]. Among the factors that might lead to the system deviating from its stable state are: load variations, short circuits along the line, disconnection of power transmission lines. A stable or reliable distribution network is often provided with a specific stability margin. The parameters therein are programmed to differ from the critical values [2].

When considering stability issues of electrical systems, it is vital to differentiate between static, dynamic and overall system stability. Static stability defines the capacity of the electric system to restore itself to its expected equilibrium state after it has been subjected to minimal disturbances. Such disturbances could arise from load fluctuations and actions of automatic voltage regulators. When the system is subjected to a large disturbance, as may result from a sudden loss of power, sudden application or removal of load and line faults, transient stability comes into play values [3][4].

Haven recognized the complexities of electric power system, there is strong need to regularly monitor system operation, violation system overload, fault conditions, mismatches between power generation and power demand of the receiving-end. This operation and activities will provide and restore the events of any occurrence of instability in the power system performance in order to keep system reliability and efficiency. Provision of flexible AC controllers at determined locations can enhance the improvement of power quality, voltage profile, power factor, the violation of the affected power system components due to overload/faults and thus enhance system stability and performance.

II. RELATED WORKS

The area of transient stability studies in recent times have been very active with interesting techniques and solutions proposed at the functional, device, system and methodological levels. For instance, one technique may propose the use of intelligent/or non-intelligent algorithms for controlling/minimizing transients and accompanying oscillations while another may focus on the control technology itself e.g. Flexible AC Transmission System (FACTS) devices such as Thyristor Controlled Series Capacitor (TCSC) or Static-VAR Compensator (SVC) [5]. And yet another may focus on damping control or reduction in critical clearing time (CCT).

A few of the recent works on the effect of compensation by adding shunt capacitors to determined buses to enhances the voltage stability are stated below:

- In the paper presented in [6] the authors examined the use of an Optimal Unified Power Flow Controller (OUPFC) based on the Lyapunov Energy Function (LEF) for enhancement of the Transient Stability Limits of a test power system. Their proposed OUPFC was compared to the standard Unified Power Flow Controller (UPFC) and they were able to report significant improvements faster damping for the OUPFC. Consequently, power systems oscillations and control were reviewed in [7]. In particular the authors identifiedand described four oscillation mode classifications that can affect power system transient stabilizer (PSS). The IEEE PSS4B was highly recommended by this research due to its improved response to multi-mode oscillations; however, there may be a drawback with the complexity of the technique. For power systems considering renewable sources, adaptive PSS were specifically recommended by the authors.
- The authors in [8] adopted the use of gravitational search algorithm (GSA) for optimal static synchronous series compensator (SSSC) design for power system transient stability studies; GSA uses the law of gravity and mass interactions to tune the SSSC parameters and hence damp the oscillations in the power system. The GSA technique is compared with Genetic Algorithm (GA) and Bacteria Foraging Algorithm (BFA) and the results obtained were relative.

- In [9] a local Fuzzy based damping controller (LFDC) with a FACTS device was modelled for power system transient stability improvement; detailed thyristor model was used to eliminate the gap in existing approaches while chaotic optimization was employed for optimal design of the fuzzy controller. This was significant, but lacked the ability to predict future disturbances that may induce transient instability

III. METHODOLOGY

Considering the activities of power system behaviour, the voltages and power flows in the electrical network can be determined for a given set of loading and operating condition. The use of ETAP (Electrical transient analyser program) and power flow problem formulations were used to analyse the stability of the power system.The application of continuation power flow method is used in this analysis, the method consist of a 5-bus sample test system consisting of 5buses, 2 generators, 6 transmission lines and 5 loads.The load flow analysis using Gauss-Seidel Method was used; we assume that the voltage for all the buses except the slack bus where the voltage magnitude and phase cycle are specified and remain fixed.

3.1 Description of 132/33KV Transmission Substation

The Port Harcourt Town Transmission Substation is located at Nzimiro Amadi junction, with an installed capacity of (2×30MVA+1×60MVA+45MVA = l65MVA) The substation receives its supply via double circuit transmission line from Afam 132KV switch yard duly linked to the 330KV national grid at Aloaji substation

Table 3.1: The Installed Capacity at the Transmission Substation Rated Voltage and the Number of Feeders.

Transformer ID	Transformer Rating	Rated Voltage	No of Feeders
T1A	30MVA	132/33KV	1
T1B	45MVA	13.2/33KV	1
T1C	60MVA	132/3 3 KV	4
T1D	30MVA	132/33KV	2

Source: Port Harcourt Electricity Distribution Company (PHEDC)

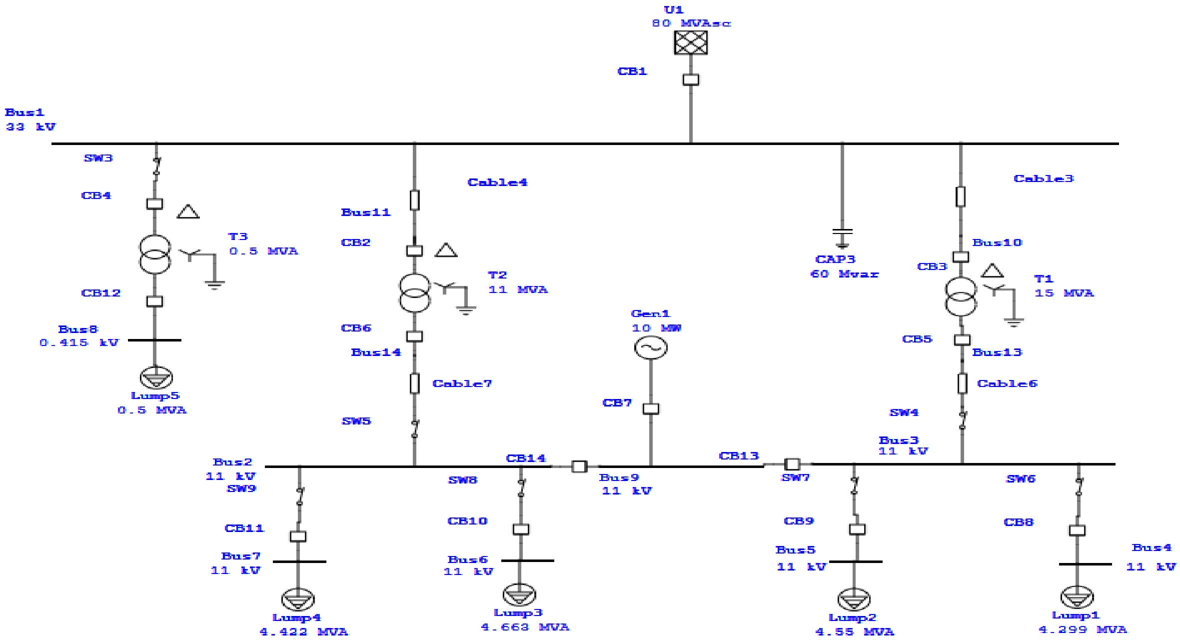

Figure 3.1: Single Line Diagram of Borokiri town axis feeder of Port Haecourt

IV. RESULTS AND DISCUSSIONS

Table 4.1: The location of transformers, rating and current reading of Borokiri town axis feeder of Port Harcourt.

S/No	NAME OF TRANSFORMER AND LOCATION	TRANSFORMER RATING	LOAD READING			
			R(A)	V (A)	B (A)	N (A)
1.	Bus – 6	500KVA	415	360	450	102
			198	118	208	
2.	Bus – 7	500KVA	265	352	414	070
			250	208		
3.	Bus – 8	500KVA	410	384	200	128
			472	420		
4.	Bus – 9	500KVA			512	040
			322	313		
					464	
			40	44		
5.	Bus – 10	500KVA			340	150
						048
			38	30		
6.	Bus – 11	500KVA			30	106
			20	14		
7.	Bus – 12	500KVA			29	8
			38	40		
8.	Bus – 13	500KVA			21	4
			20	34		
9.	Bus – 14	200KVA			33	2
10.	Bus – 15	100KVA			27	14
11.	Bus – 16	200KVA				8
12.	Bus – 17	50KVA				

Source: Port Harcourt Electricity Distribution Company (PHEDC)

Table 4.2: Presentation of Calculated Bus location, %loading, and Reactive& Active power

S/N	Bus Location	(KVA) load, SVA	% loading	Active power p	Reactive power

				(w)	p(G)
1.	Bus – 6	317.93	64.0	254.34	190.76
2.	Bus – 7	142.31	28.4	113.84	85.38
3.	Bus – 8	282.4	56.4	225.92	169.44
4.	Bus – 9	166.27	33.2	133.01	99.76
5.	Bus – 10	348.84	70.0	279.07	209.30
6.	Bus – 11	336.38	67.27	269.10	201.82
7.	Bus – 12	259.00	51.8	207.20	155.40
8.	Bus – 13	29.23	15.0	23.38	17.82
9.	Bus – 14	24.19	12.0	19.35	14.51
10.	Bus – 15	13.65	14.0	10.92	8.19
11.	Bus – 16	29.94	30.0	23.95	17.96
12.	Bus –17	21.32	43.0	17.05	12.79

The Simulated Single Line Diagram of Borokiri town axis feeder of Port Harcourt is shown in Figure 4.1 below.

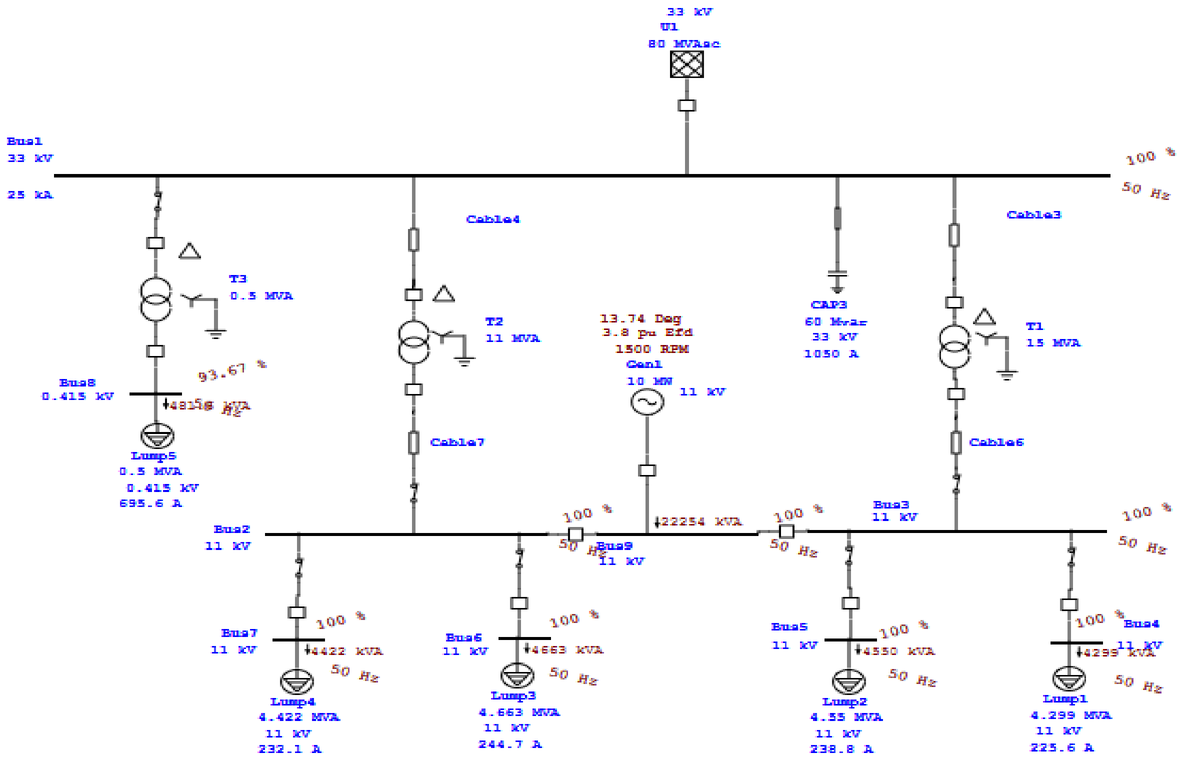

Figure 4.1: Simulated Single Line Diagram of Borokiri town axis feeder of Port Harcourt

4.1 Voltage Stability Cases and Simulation Results

The selected buses were subjected to stability analysis and the results are as seen below.

The buses were chosen based on active power higher than 15MW. The method applied considered 5 buses - Bus 2, bus4, bus5, bus6and bus10. The analysis was done by increasing the Q on bus 2. The increase inQ, the changes on the voltage magnitude of bus 2 and the changes on the voltage magnitude of buses connectedto bus 2 which are bus 4, 5 and bus 6 were analysed.

Figure 4.2:QV of Bus 2 with Reactive Power Injection

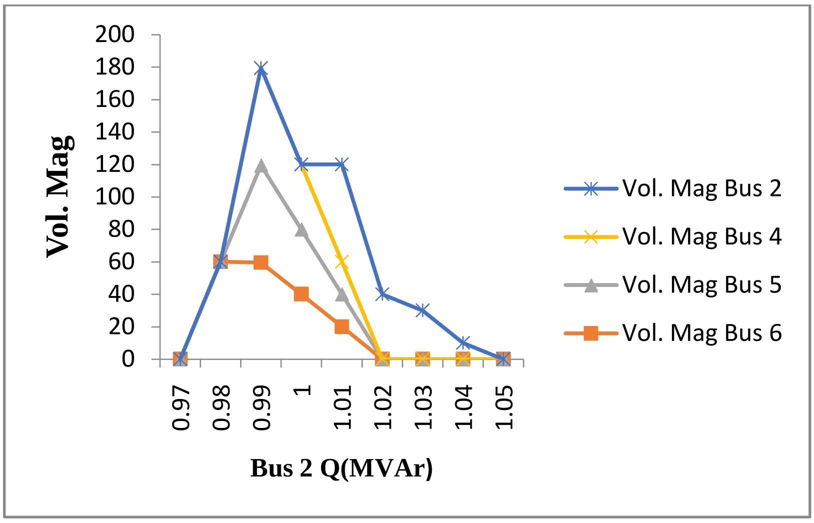

Figure 4.3: QV Comparison of Bus 2 with Reactive Power Injection

The generating bus in the network is bus 2 and it is more stable and less prone to voltage instability. Initial reactive power load at bus 2 was 11.5MVAr. This reactive power was gradually increased up to a maximum of 400% till it got to 46.0 MVAr. The result of the analysis had no significant effect on the voltage magnitude of the buses as it dropped from 1.043V to 1.013 V; meaning the buses connected to bus 2(4, 5 and 6) also experienced little changes as a result of the stable state of bus 2 Due to stable voltage at bus 2.

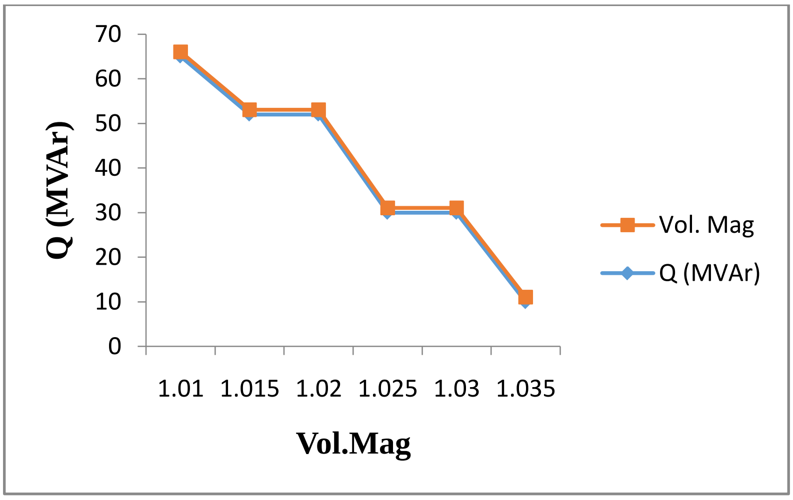

Figure 4.4: QV of Bus 2 without Reactive Power Injection

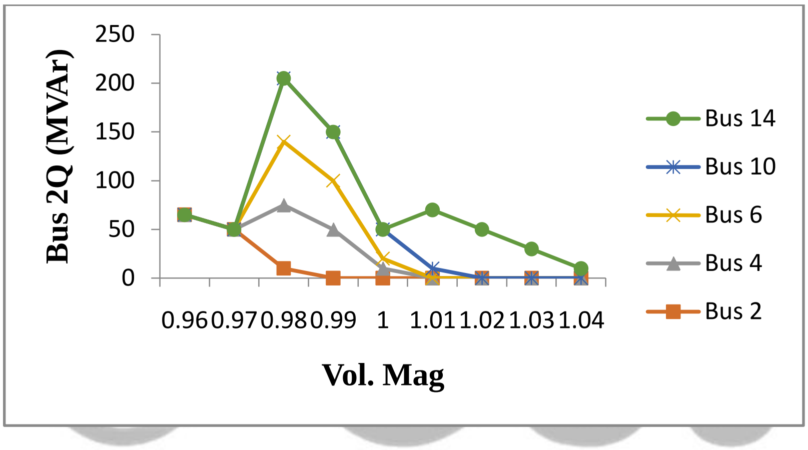

Figure 4.5: QV Comparison of Bus 2 without Reactive Power Injection

Figure 4.5 shows a significant drop in the voltage magnitude of all the analysed buses when reactive power has not been injected. Although, bus 2 is observed to be operating in a stable condition after all; If this operating condition continuous for a significant amount of time, the generator supplying bus 2 will experience some level of damage as it operates at higher load and produces more heat.

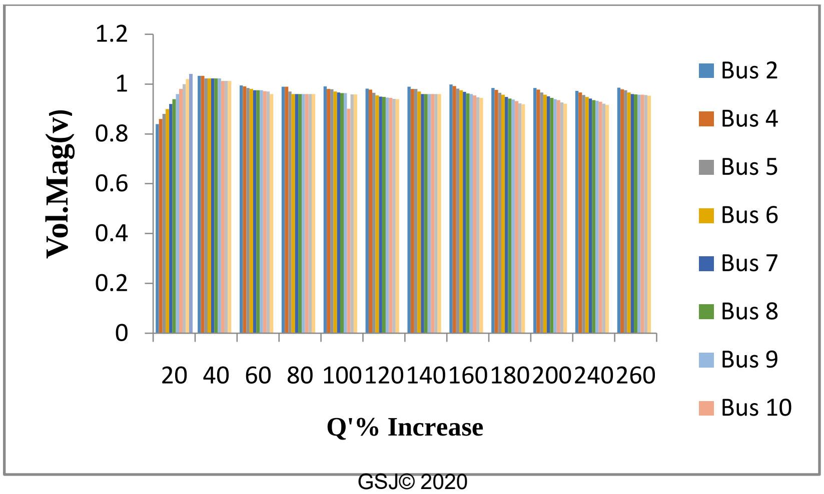

Figure 4.6: QV Comparison of all the analysed bus with reactive power injection

Figure 4.6 presents the comparison of theanalysed buses. It is seen that reactive power increased to about 200%, approximately half of the value when compared to the 400% increase in part 1 and part 2. In the analysis, the reactive power of all the 5 buseswere increased at the same time. This increased the impact on the system which in turn reduced the gain of reactive power from 400% to 200%. A further look at figure 4.6 shows that bus 6 collapses as reactive power increased more than 100% and bus 10 at 180%. Summarily, a change in the value of reactivepower of a bus does not only affects its own bus, but affects other buses connected to it.

Table 4.6: Voltage sensitivity factors of 5-Bus Test System

Bus Name	Voltage Sensitivity Factor
Navy School	0.02574
Egbema	0.02632
Kolokuma/Etche	0.02325
Bori	0.02718
Okilopolo	0.02816

In an electric network, the bus with the highest voltage sensitivity factor is often considered the weakest bus in the system. These buses are considered weakest since they are more susceptible to variations in loads. From table 4.6, it can be seen that Okilopolobus is the weakest bus in the system. Since it is not possible to exceed predetermined statutory limits, the system loses its voltage stability at the critical point where the load parameter value is 0.2816. The critical point can be taken as voltage collapse point. The System is bound to experience voltage instability leading to a sharp decrease in voltage caused primarily by insufficient reactive power in the system.

4.2 Effect of Compensation on Voltage Stability

Shunt capacitor banks ranging from 0.1 to 0.3 pu in 0.1 pu steps are connected respectively to Okilopoloto validate the effect of reactive power compensation. Continuation power flow was then performed for all cases.

In the base case, load parameter is 0.2816 whereas in 0.3 pu shunt compensation case, it increases to 0.3926. Adding shunt capacitor to powersystem enhances the voltage stability limits. Therefore, for some situations itprevents voltage collapse.Adding a shunt capacitor to Okilopolobus improves the voltage stability limit notonly in Okilopolo bus but also in other buses. Table 4.7 shows the voltage sensitivityfactors of buses for the 0.3 pu shunt capacitor case.

Table 4.7: Voltage sensitivity factors of 5-Bus Test System for 0.3 pu shuntcapacitor case

Bus Name	Voltage Sensitivity Factor
Navy School	0.01684
Egbema	0.01845
Kolokuma/Etche	0.01721
Bori	0.01938
Okilopolo	0.01835

Comparing Table 4.6 and Table 4.7, it is observed that factors in all buses decrease in the latter case which shows theenhancement in voltage stability.In addition, when both bus voltages and factor percent changes are comparedfor buses individually, it becomes obvious that the most enhancement in voltagestability occurs in Okilopolo bus. It is an expected result since shunt capacitor is connected to Okilopolo bus.

In fact, it proves the importance of local compensation.Due to the requirement of reactive power in transmission lines, most of thetime local compensation is preferred in order to improve voltage stability.

V. CONCLUSION

This study examined the existing network in Borokiri axis of Port Harcourt Township with the aim of enhancing the stability of the network by implementing the Continuous Power Flow Method. The network is simulated in ETAP to determine the stability of the network.The presented method is applied to 5-Bus sample test system. Voltage stability sensitivity factors and bus voltage versus load parameter curves are obtained for several scenarios such as Navy School, Egbema, Kolokuma/Etche, Bori and Okilopolo were used as the case study. The effect of compensation is verified by adding shunt capacitors in different per unit values to the bus defined in the system. It is observed from voltage profiles and voltage sensitivity factors that adding shunt capacitor to a bus enhances the voltage stability of the whole buses in the system. Addition of a shunt capacitor supplies more reactive power to system. Thus, critical point occurs in higher loading levels and the magnitudes of bus voltages increase.

REFERENCES

[1]. Al Marhoon, H., Leevongwat, I. & Rastgoufard, P. “A practical method for power systems transient stability and security analysis”: Transmission and distribution conference and exposition, (T & D), *IEEE PES*, *1*(6), 7-10, 2012

[2]. Nagrath, I. J. & Kothari, D. P. “Power System Engineering”. Tata McGraw Hill Pub., Delhi, India, 1994

[3]. Boribun, B. & Srithapon, C. “Development of Electrical Transient Modelling and Simulation for Electric Distribution Systems”. 2nd International Science, Social Science, Engineering and Energy Conference. 8 128-134., 2010

[4]. Ayodele, T. R., Ogunjuyigbo, A. S. O. & Oladele, O. “Improving the Transient Stability of Nigerian 330kV Transmission using Static VAR compensation”. Nigerian Journal of Technology (NIJOTECH), 35 156-166, 2016

[5]. Idoniboyeobu, D., Wokoma, B., & Evoh, S. “Reactive Power Compensation Improvement Technique for Injection Substations in Nigeria”. International Journal of Scientific and Engineering Research, *9(4)*, 1183-1190, 2018

[6]. Gupta, A. & Sharma, P. R. “Static and transient stability enhancement of power system by optimally placing Unified Power Flow Controller (UPFC) in Advanced Computing and Communication”, ACCT, Third International Conference, 121-125, 2013

[7]. Obald, Z. A., Cipcigan, Z. M. & Muhssin, M. T. “Power system oscillations and control: Classification and PSSs Design Methods: A review”, JRSER, 79, 839-849., 2017

[8]. Elazim, S. M. & Ali, E. S.“Optimal SSSC Design for Damping Power System Oscillation via Gravitational Search Algorithm”. Journalof Electrical Power and Energy System, 821, 161, 2016

[9]. Darabian, M. & Jalivand, A. “A power control strategy to improve system stability in the presence of wind farms using FACTS devise and predictive control”. Journal of Electrical Power and Energy System, 85, p50-66, 2017