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Shunt Compensaton of the Integrated Nigeria's 330KV Transimission Grid System

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Abstract:- The Nigerian Power system is complex and dynamic, as a result of this it is characterized by frequent faults and outages resulting to none steady supply of power to the teaming consumers. This has great effect on the activities and mode of living of Nigerians. The research work was carried out on contingency analysis on the existing integrated 330KV Nigeria grid system and to carry out a shunt compensation on the violated buses, the shutdown of Eket-Ibom line being the case study so as to determine the following; uncertainties and effects of changes in the power system, to recognize limitations that can affect the power reliability and minimize the sudden increase or decrease in the voltage profile of the buses through shunt compensation of buses. Determine tolerable voltages and thermal violation of +5% and -5% of base voltage 330 KV (0.95-1.05) PU and to determine the critical nature and importance of some buses. This is aimed at bridging the gap of proposing further expansion of the grid system which is not only limited by huge sum of finance and difficulties in finding right – of- way for new lines but also which faces the challenges of fixed land and longtime of construction. The data of the network was gotten and modeled. The power flow and contingency analysis of the integrated Nigeria power system of 51 buses (consisting of 16 generators and 35 loads) and 73 transmission lines were carried out using Newton-Raphson Load Flow (NRLF) method in Matlab environment, simulated with PSAT software. Shunt compensation of the weak buses were done using Static Var Compensator (SVC) with Thyristor Controlled Reactor- Fixed capacitor (TCR-FC) technique. Results obtained showed that the average voltage for base simulation was 326.25KV, contingency 323.67KV and compensation was 322.37 KV. Voltage violations for lower limit were observed at Itu as 309KV and Eket as 306.81 KV while violations for upper limit were recorded at Damaturu as 352.85KV, Yola as 353.62 KV, Gombe as 355.98KV, and Jos as 342.97 KV. However after shunt compensation there were improvements for the violations at lower limits and that of higher limit were drastically brought down as recorded below: Damaturu 329.93 KV, Jos 330 KV, Eket 327.2 KV, Gombe 333.55KV, Itu 330KV, and Yola 330.52KV

***Keywords:-** Contingency, FACTS Controllers, Power flow study, Shunt Compensation.*

I. INTRODUCTION

The power system is dynamic, new sources of power are added to the Nigeria's power system, an over-riding factor in the Operation of the power system is the desire to maintain security and expectable reliability level in all sectors –generation, transmission, and distribution (Madueme and Nnonyelu, 2013)

The goal of a power-flow study is to obtain complete voltages angle and magnitude information for each bus in a power system for specified load and generator real power and voltage conditions (Grainger and Stervenson, 1994)

The contingency analysis of the power system using load flow method would enable the planning authority to plan for and make provision for further expansions of the grid system. The result of this analysis will be used to determine the security level of the Nigeria power system and suggestions will also be made on the level of protection to be applied on the Nigeria power system with aim of improving system security (Onojo, et al, 2013).

Flexible AC transmission systems or FACTS are devices which allow the flexible and dynamic control of power systems. . Flexible Alternating Current Transmission System (FACTS) is static equipment used for the AC transmission of electrical energy. It is meant to enhance controllability and increase power transfer capability. It is generally power electronics based device.

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II. MATERIAL AND METHODS

➢ *Shunt compensation*

Shunt compensation (inductive compensation)-This is the compensation normally carried out as a result of the long length of the transmission lines in order to limit the line voltage.

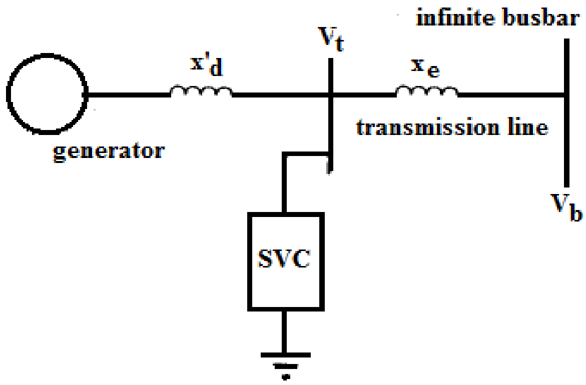

Fig 1:- Connection of SVC to the Bus

The SVC is a shunt device of the FACTS family using power electronics to control power flow and improve transient stability on power grids. It has been used for reactive power compensation since the mid-1970, firstly for arc furnace flicker compensation and then in power transmission systems. One of the first 40 MVARs SVC was installed at the Shannon Substation of the Minnesota Power and Light system in 1978 (Boudjella Houari and F.Z Gherbi, 2008)

Components of a static VAR system may include: Transformer between high voltage (HV) network bus and the medium voltage (MV) bus where power electronic equipment is connected. Usually a dedicated transformer is used, but sometimes the tertiary of an autotransformer is used. Thyristor-controlled reactors (TCRs) connected to medium voltage bus. Thyristor-switched reactors (TSRs) connected to medium voltage bus. Thyristor-switched capacitors (TSCs) connected to the medium voltage bus. Saturated reactor (SR) connected to the medium Voltage bus. Fixed capacitors (FC), harmonic filters connected to the medium voltage bus. At fundamental frequency, the filters are capacitive. Mechanically-switched capacitors (MSCs) or reactors (MSRs) usually connected at a high voltage bus, Control system, usually with a primary function of regulating the transmission voltage. (IEE special Stability control working group, 1994).

(SVC) using Thyristor controlled Reactor with fixed capacitor (TCR-FC) technique for shunt compensation, an indebt study and analysis of the SVC was carried out, results were obtained

➢ *Modeling of SVC in TCR- FC Configuration*

The particular SVC modeled in this work consists of a thyristor controlled reactor (TCR) stage to provide the lagging vars and a fixed capacitor FC which offers the leading vars. The lagging reactive power (inductive reactive power) and TCR current amplitude can be controlled continuously by varying the thyristor firing angle between 90 and 180. The TCR firing angle can be fully changed within one cycle of the fundamental frequency, thus providing smooth and fast control of reactive power supplied to the system, (Sankarbabu, P. and Subrahmanyam, J.B.V.2010) and (Oltean, S.E. 2012),.

The leading vars (capacitive reactive power) are usually provided by a different number of capacitor bank units. By combining these two components, fixed capacitor and continuously controlled reactor, a smooth variation in reactive power over the entire range can be achieved and reactance that can perform both inductive and capacitive compensation. The reactive power Injection of a SVC connected to a bus bar and the total shunt admittance of the SVC are given by:

$$Q_{SCV} = -B_{SCV}.V^2 \qquad 1$$
$$B_{SVC} = B_C - B_L \qquad 2$$

In (1) Q_{SVC} is the reactive power injection of the SVC (TCR-FC type), $B_{SVC,}$ *the* admittance of the SVC, B_C the constant admittance of the fixed capacitor and B_L the variable admittance of the thyristor controlled reactor. For a TCR-FC compensator the admittance depends on firing angle α(Karpagam, N., and Devaraj, D. (2009), and (Oltean, S.E. (2012),

$$B_{SVC} = \frac{1}{XC} - BL \qquad 3$$
$$B_L(\alpha) = \frac{2\pi - 2\alpha + \text{Sin}\ (2\alpha)}{\pi\, XL} \qquad 4$$

The inductive and capacitive reactances are X_L and Xc respectivelyThe static VAR compensator will be located at the generator busbar to provide significant damping during transient condition

➢ *Modelling of the Power system*

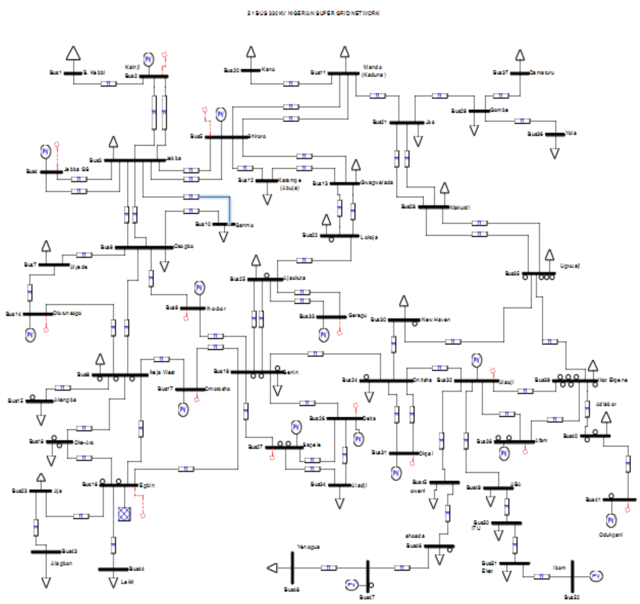

Fig 2:- Modelled the Power system

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III. RESULTS

➢ *Table of the Base simulation, Contingency and compensation*

Bus Name	Voltage (base case)	Voltage (contingency)	Voltage (compensation)
B. Kebbi	318.6460574	318.6460574	318.6460574
Ganmo	325.4356264	327.8912833	327.8757691
Mando	325.7830219	331.0310991	327.3041197
katampe	318.2364991	319.6817713	319.5944518
Gwagwalada	317.2035134	318.9370315	318.8319046
olorunsango	317.13	317.13	317.13
Akangba	318.3432778	321.819568	321.7779874
Egbin	340.23	340.23	340.23
Omotosho	330	330	330
Oke-Aro	322.0323381	324.8830914	324.8491353
Benin	314.2040674	323.1837666	322.8124964
Kainji	330	330	330
Kano	321.9708864	327.3193232	323.5213541
Jos	325.5346997	347.9693323	330
lokoja	315.9153175	319.1542851	318.9731119
aja	338.4843857	338.4843857	338.4843857
Onitcha	320.9685188	328.7579784	327.7807504
Ajaokuta	317.8304854	321.6971946	321.5022359
Delta	339.57	339.57	339.57
sapele	339.57	339.57	339.57
Markurdi	318.6684115	341.0906472	330.4367224
Gombe	327.5563674	355.9846032	333.5598267
Jebba	336.9075027	337.2986525	337.2975932
New Haven	315.498963	330.5890307	326.2109564
okpai	333.96	333.96	333.96
Alaoji	330	330	330
Geregu	330	330	330
aladji	336.5710723	336.5714168	336.5714027
Ugwuaji	314.9596212	330.8051796	326.0766686
Yola	324.3346392	353.624684	330.5289031
Damaturu	323.7185174	352.8530294	329.9375245
Afam	330.99	330.99	330.99
Ikot Ekpene	323.0078886	326.2199304	325.6261168
Jebba GS	339.9	339.9	339.9
Adiabor	325.7784075	326.4472816	326.3236257
Odukpani	328.02	328.02	328.02
Alagbon	337.7406956	337.7406956	337.7406956
Lekki	339.5419418	339.5419418	339.5419418
Owerri	330.0154721	330.0154721	330.0154721
Ahoada	331.2471616	331.2471616	331.2471616
bus47	333.96	333.96	333.96
Yenogua	330.4708621	330.4708621	330.4708621
Aba	320.9379433	315.335863	325.5322607
Shiroro	330	330	330
ITU	318.945584	309.8996079	330
Eket	321.8144402	306.8122637	327.204186
Ibom	327.03	0.00033	0.00033
oshogbo	317.9909028	322.5048138	322.4655611
Ayede	313.6793088	317.158601	317.1341359
Ikeja West	318.5874724	322.0601973	322.0186589
Ihovbor	330	330	330

Table 1

➢ *Graphs of the Results*

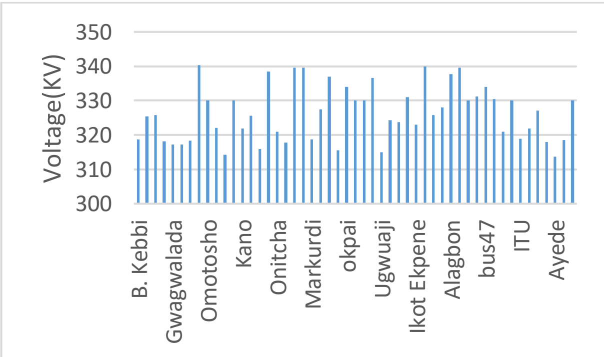

Fig 3:- Graph of Voltage against the Buses on Base Simulation

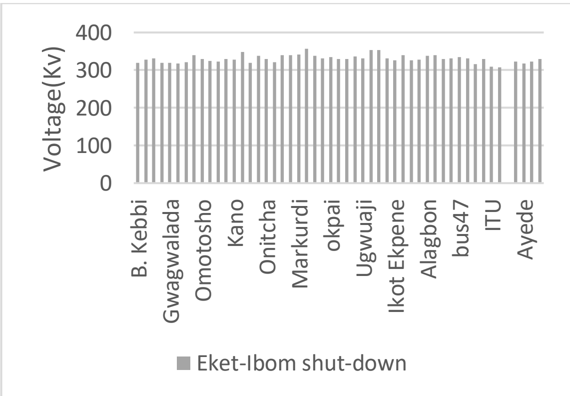

Fig 4:- Graph of Voltage against Buses when Eket=Ibom is shut down

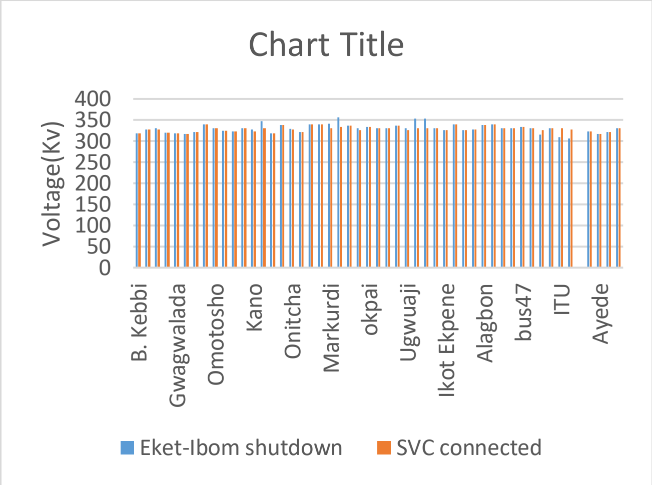

Fig 5:- Graph of Voltage against Buses when Eket-Ibom after Compensation

➢ *Discussion of Results/Summary*

The average voltage for base simulation was 326.25KV, during contingency was 323.67KV and after compensation, it was 322.37 KV. Voltage violations were at lower limit were observed at Itu as 309KV and Eket as 306.81 KV while violations for upper limit were recorded at Damaturu as 352.85KV, Yola as 353.62 KV, Gombe as 355.98KV, Jos as 342.97 KV. However after shunt compensation there were improvements for the violations at lower limits and that of higher limit were drastically brought down as recorded below thus; Damaturu 329.93 KV, Jos 330 KV, Eket 327.2 KV, Gombe 333.55KV, Itu 330KV, and Yola 330.52KV.

The improvement of the voltage profile brings about more power stability and enhance controllability and increase power transfer capability. This has been achieved at the various buses with diferent degrees of violations. There are many constraints as regards to expansion of the grid system in interconnected power systems hence the choice of shunt compensation with static Var compensator (svc) using TCS- FC technique comes to play.

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