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APPLICATION OF STATIC VAR COMPENSATOR (SVC) IN 33kV DISTRIBUTION NETWORK

[1]Chizindu Stanley Esobinenwu and [2]Oniyeburutan, Ebakumo Thomas.

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Abstract:

Reliable and efficient electric power transmission and distribution constitute part of the major challenges in a power system. Proper management and control of reactive power proffer solutions to power quality problems, improved system efficiency and stability, reduce losses, improve power factor, maintained a balanced voltage profile at all power transmission and distribution levels. This paper present application of Static Var Compensator (SVC) in reactive power compensation in the 33kV Distribution Network to improve performance of AC transmission and distribution systems. The simulation of the 132/33kV, 20-bus Port Harcourt distribution power network was carried out in Electrical Transient Analyzer Program. It was observed from the result of the analysis that most of the buses in the network have weak voltage profile, consequent to the absorption of reactive power flow at each of the buses. The weak buses were compensated by the incorporation of Static VAr Compensator at bus 3 (PH Mains) and bus 19 (Yenagoa). Voltage control in an electrical power system is very essential as it seeks to minimize real power losses, improve power factor, maintained a balanced voltage profile, improved system efficiency and stability at all levels of the power system network.

I. INTRODUCTION

The need for reactive power management and voltage control in alternating current transmission and distribution system is of utmost importance as it constitutes part of the major challenges in the power system. Management and effective control of reactive power enhance the performance and stability of the AC system (Esobinenwu & Oniyeburutan, 2023). The portion of power flow that is temporarily stored in the form of magnetic or electric fields, due to capacitive or inductive network elements and then returned to the source is called "reactive power."

[1] Electrical and Electronic Engineering Department, University of Port Harcourt, Rivers State, Nigeria.
Email:chizindu.esobinenwu@uniport.edu.ng
[2] Electrical and Electronic Engineering Department, University of Port Harcourt, Rivers State, Nigeria.
Email: *ebasonis@yahoo.com*

Reactive power compensation is simply by injecting or absorbing reactive power. This injection or absorption helps maintain the voltage level within given statutory limits. Reactive power is a vital component of a power system network. Without it, transmission lines could not transmit active power or machines could not rotate (Gandoman et al., 2018).

Reactive power compensation in the transmission line increases transmission efficiency, enhances AC system stability by increasing the maximum active power that can be transmitted. It also helps to retain a substantially flat voltage profile at all levels of power transmission, controls steady-state dynamics, and temporary overvoltage (Agber1 et al., 2015).

This work is focused on the application of Static Var Compensator (SVC) in reactive power compensation in the 33kV Distribution Network to enhance the performance of AC transmission and distribution systems. The objectives for carrying out this research are, but not limited to: Improve the quality of power delivery, minimization of losses in the network, increase power availability, improve system power factor, and maintain voltage profile within acceptable rated value.

II. LITERATURE REVIEW

2.1 Theoretical Review

Over the years, several approaches have been used by researchers in reactive power compensation in AC transmission and distribution systems. In Esobinenwu and Oniyeburutan's (2023) work on reactive power compensation in high voltage transmission lines, different reactive power compensation techniques were highlighted with an emphasis on static var compensation techniques as a reliable approach in high voltage transmission systems. In Agber1 et al.'s (2015) work on power flow control analysis of transmission line using SVC, the capability of SVC in stabilizing the power system was investigated. Power flow equations involving voltage drop with/without SVC were developed. The Nigeria 330kV, 28 buses power network was used for the study using MATLAB/SIMULINK software. It was concluded that SVC is an effective method of reactive power compensation. The Nigeria 330kV, 57 buses transmission network was modeled in ETAP by the researchers in Nnanedu et al.'s (2019) work on reactive power compensation for the reduction of Losses in Nigeria 330kV Network Using STATCOM; the weak buses observed were substantially improved to 85 percent by the application of STATCOM. A review was carried out by Neha and Bhandakkar (2016) in their work on reactive power compensation in the transmission line using FACTS technology; various FACTS devices used in RPC compensation were discussed. The researchers in Kumar et al.'s (2013) use static synchronous series compensator for series compensation of EHV Transmission line. They commended the application of STATCOM in reactive power management. The principle of series capacitor compensation of the inductive reactance of long transmission lines to enhance the quality of long-distance transmission lines' voltage was analyzed in Obiuwevwi et al.'s (2020) work. In this work, the Nigeria 330kV, 30 buses network was considered, and the system reliability, efficiency, and stability were improved..

2.2 Static VAR Compensator (SVC)

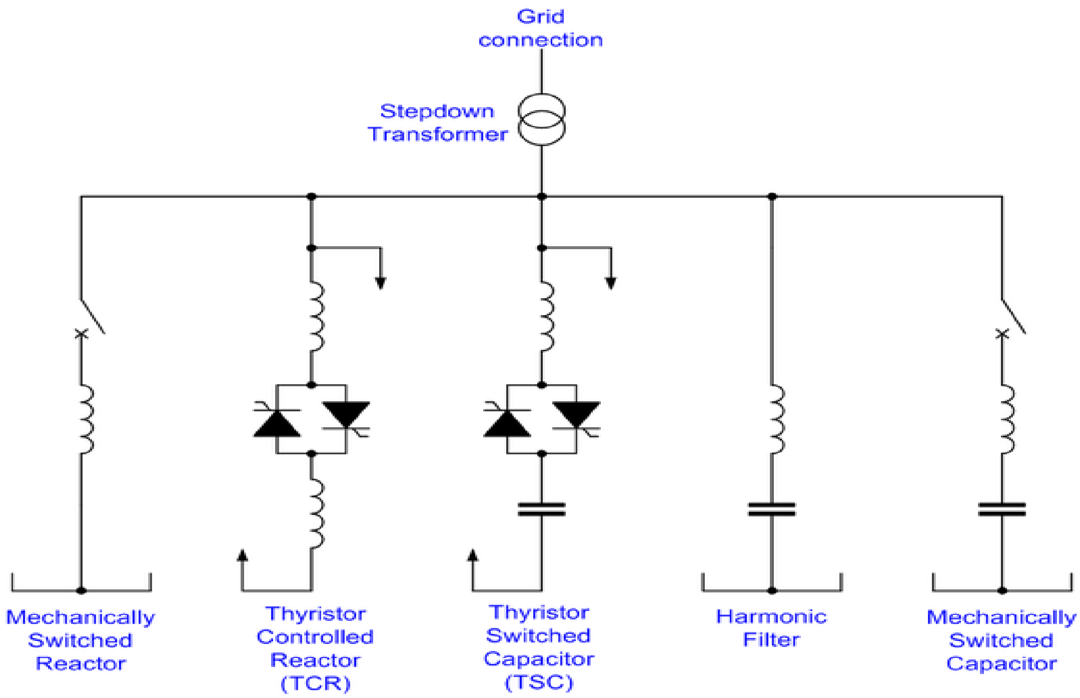

Fig 1: Thyristor switched reactor

A Static Var Compensator (SVC) is a shunt-connected electrical device whose output is adjusted to exchange capacitive or inductive current to control or maintain specific parameters of the electrical power system, typically, the bus voltage (Gandoman et al., 2018). The SVCs are part of the families of flexible alternating current transmission system (FACTS) devices regulating voltage, power factor, harmonics, and stabilizing the system. It is designed to bring the power system network closer to unity. Typical SVCs can be classified as Thyristor-Controlled Reactor (TCR), Thyristor-Switched Reactor (TSR), and Thyristor-switched capacitors (TSCs) (Cetin, 2007). In TCR, reactors are connected in series with a bidirectional thyristor valve; in TSR, reactors are also connected in series with a bidirectional thyristor valve, but the thyristor is either in zero or full connection, while in TSC, capacitors are connected in series with a bidirectional thyristor valve.

The reactive power in SVC increases when TSC is switched on, indicating that SVC supplies reactive power to the AC power source. In the same vein, when TCR firing angle is decreased, reactive power in SVC increases, showing that SVC absorbs more reactive power from the AC power source, thereby regulating voltage, power factor, and stabilizing the system (Neha & Bhandakkar, 2016). There are two ways to operate a static VAR compensator: In voltage-controlling mode, where voltage is regulated within certain thresholds, and in VAR regulation mode, where the susceptance of the SVC is kept constant.

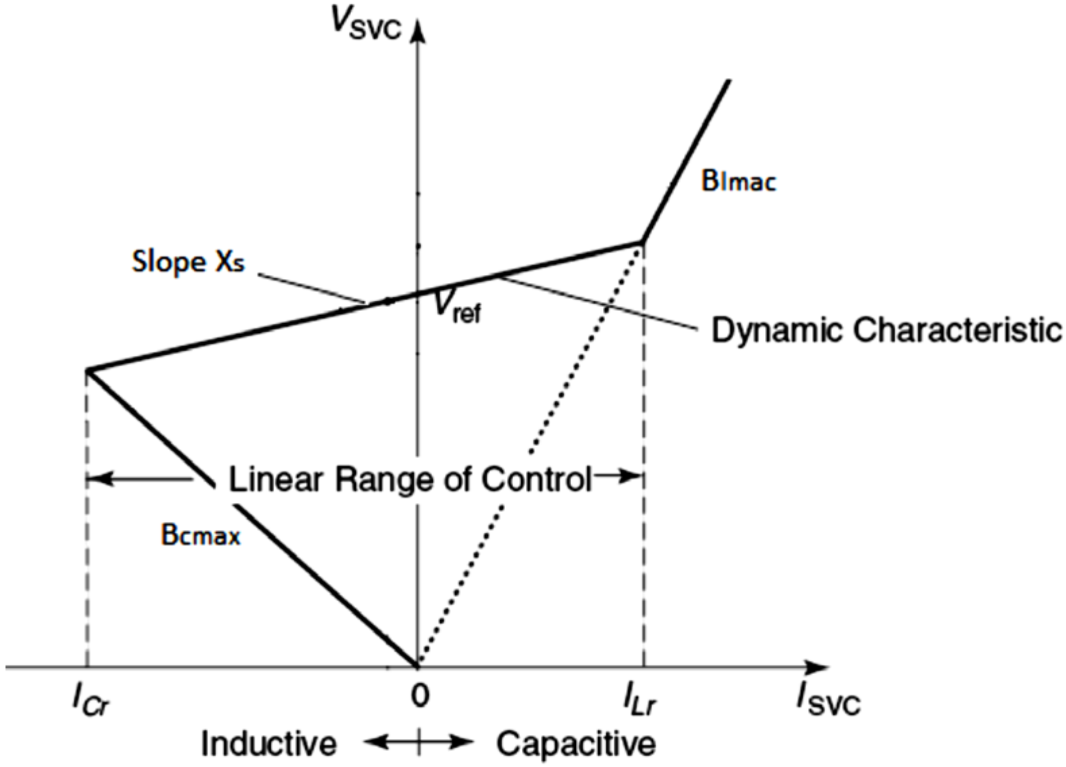

Fig 2. SVC V-I Characteristic Curve

The SVC's V-I characteristic curve, shown in Figure 2, shows that the voltage is regulated by the reference voltage Vref as long as the SVC susceptance B is kept within the maximum and minimum susceptance limits set by the total reactive power of the capacitor banks (BCmax) and reactor banks (BImax) (Cetin, 2007).

III. MATERIALS AND METHODS

3.1 Description of Existing 132/33kV Port Harcourt Networks,

3.1 Description of Existing 132/33kV Port Harcourt Networks In Nigeria, the primary transmission line voltage is 330kV, while the secondary transmission line voltage is 132kV. The 132kV transmission networks are very large; hence, it is regionalized into eight (8) regions, namely; (1) Kano region, (2) Kaduna region, (3) Lagos region, (4) Ibadan region, (5) Oshogbo region, (6) Benin region, (7) Port Harcourt region, and (8) Enugu region for improved service delivery and identification (Federal Ministry of Power, Works and Housing, 2013). The Port Harcourt region is also subdivided into six (6) sub-regions, namely Port Harcourt Mains, Port Harcourt Town, Elelewon, Rumuosi, Ahoada, and Yenagoa.

The network parameters of the 132/33kV, 20-bus transmission network of the Transmission Company of Nigeria, Port Harcourt Region, are used for this work—the generator, transformer, load, and line data of the Port Harcourt transmission system as used in this work were obtained from Transmission Company of Nigeria (2020) and are shown in tables 1.

The network under use consists of 6 transmission stations, (Port Harcourt Mains, Port Harcourt Town, Elelewon, Rumuosi, Ahoada and Yenagoa), 15 transformers, 20 buses, 13 transmission lines and 60 lump loads [12].

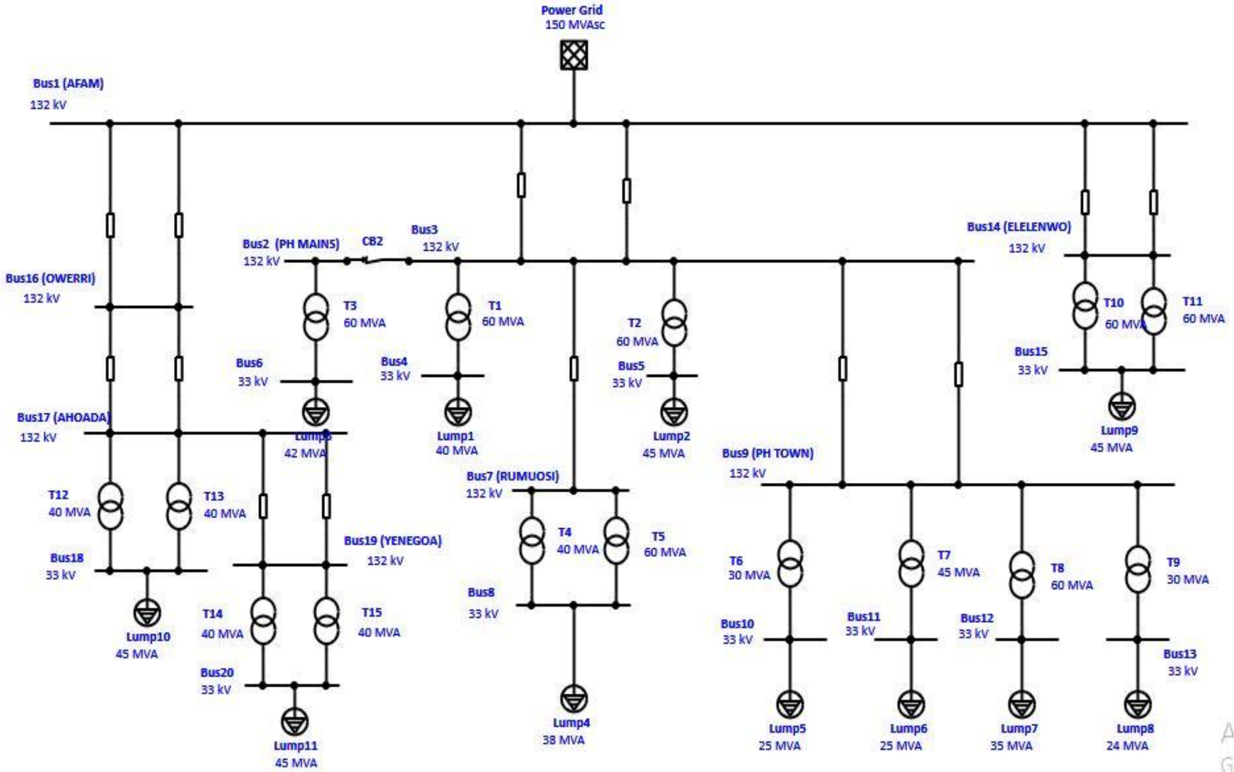

Fig 6: 132/33kV, 20 bus Single line diagram of Port Harcourt Region Transmission Stations

Table 1: Port Harcourt region transmission stations and their loading capacity

S/N	Transmission Stations	Location	Transformer Name	Transformer Size (MVA)	Load (MW)
1.	Port Harcourt Mains	Rumuobioakani	T1A T2A T3A	60 60 60	36 40.5 37.8
2.	Port Harcourt Town	Nzimiro/Amadi Junction	T1A T1B T2A T2B	60 30 30 45	31.5 22.5 21.6 22.5
3.	Rumuosi	Rumuosi	T01 T01	40 60	15 20
4.	Elelewon	Elelewon	T01 T02	60 60	40.5
5.	Ahaoda	Ahaoda	T1 T2	40 40	20 20.5
6.	Yenagoa	Yenagoa	T1 T2	40 40	20 20.5

Source: Transmission Company of Nigeria, Rumuobioakani, Port Harcourt [11]

IV. RESULTS AND ANALYSIS

The system was model in Electrical Transient Analyzer Program (ETAP) and simulations were carried out at all the load buses within the 132/33kV, 20-bus Port Harcourt distribution power network. Simulations of each load bus in the system without the SVC were done and the system voltage magnitudes at each of the load bus were obtained as shown in figure 7. Also, simulations of each load bus in the system with the incorporation of SVC were carried out and the system voltage magnitudes at each of the load bus were also obtained as shown in figure 8. The system voltage magnitudes at each of the load bus with SVC and Transformer tap changing is shown in Figure 9. The system voltage differential at each of the load bus with and without SVC, were computed to verify the performance of the SVC. The comparative results of the voltage profile with/without the incorporation of SVC are shown in Table 2. Table 3 shows the SVC device input data.

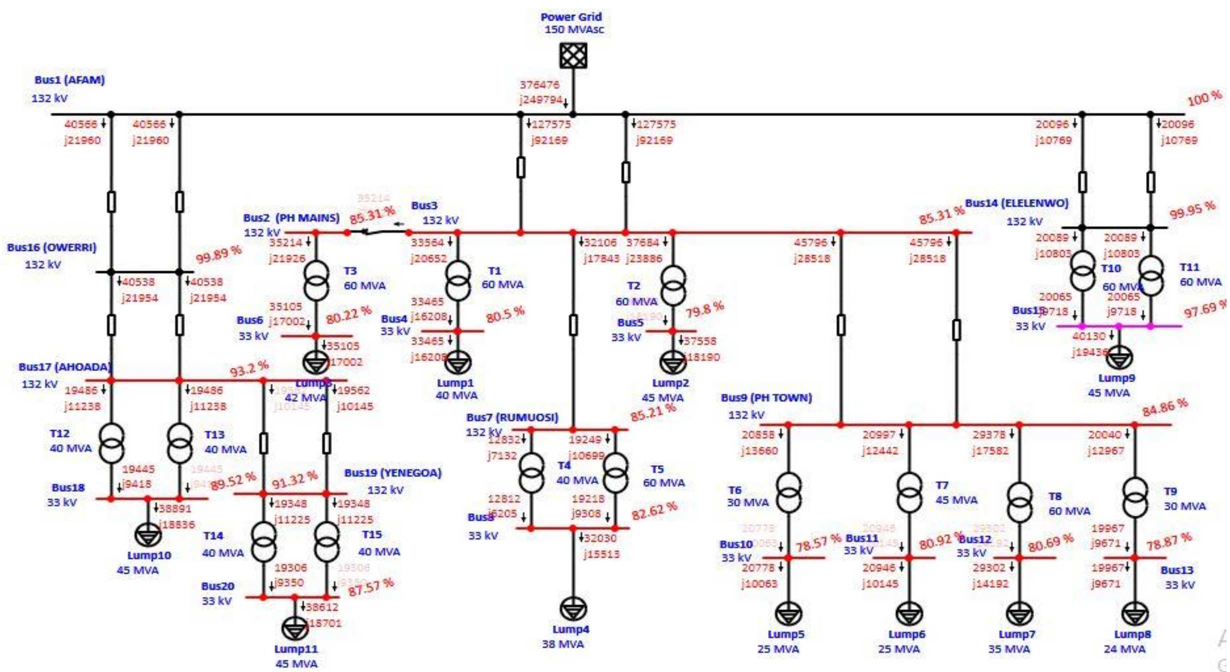

Figure 7: Port Harcourt Region 132/33kV Transmission Stations Simulation Result without SVC

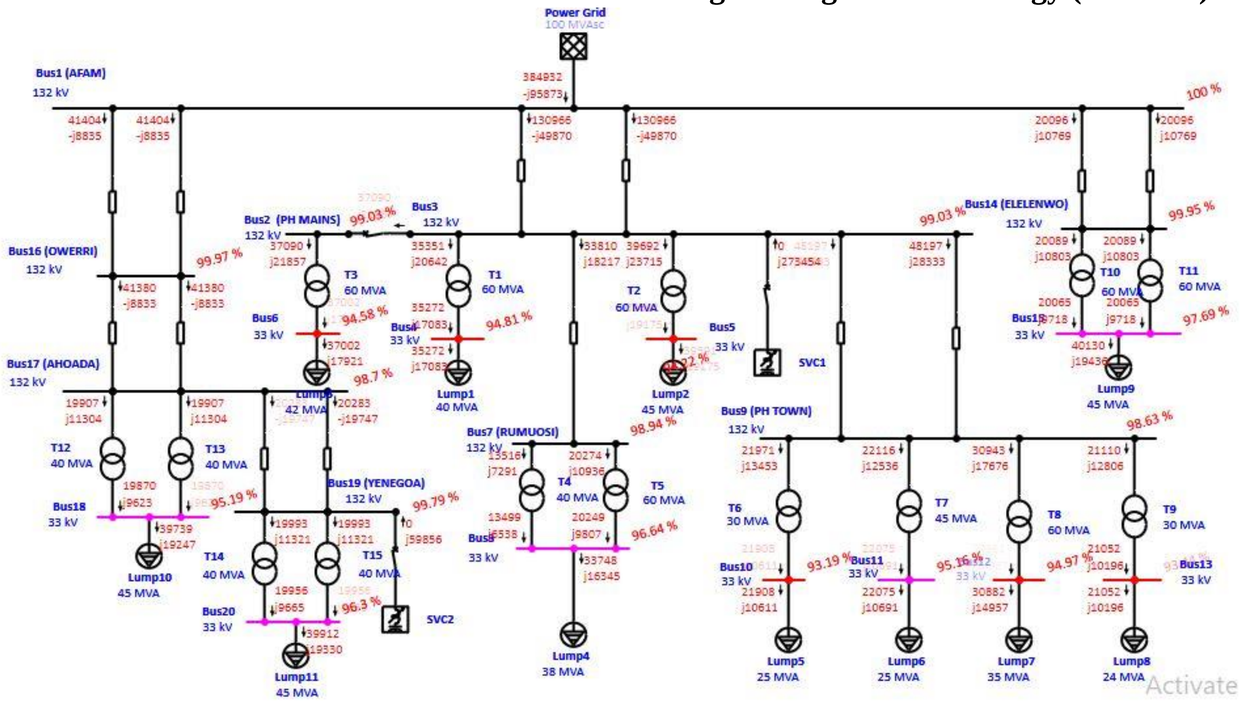

Figure 8: Port Harcourt Region 132/33kV Transmission Stations Simulation Result with SVC

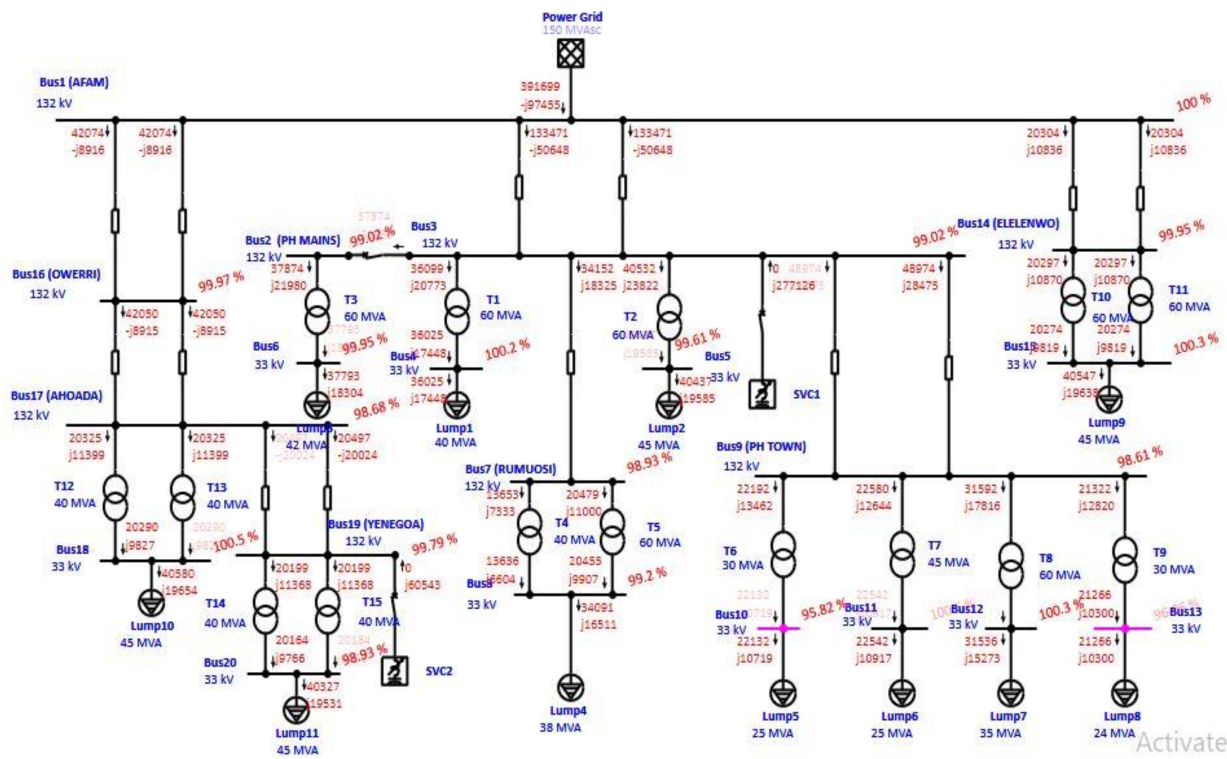

Figure 9: Port Harcourt Region 132/33kV Transmission Stations Simulation Result with SVC and Transformer Tap Changing.

Table 2: Comparative Simulation Result of the Voltage Profile with/without SVC

S/N	Sub-Transmission Stations	Bus ID	Voltage Profile Without SVC (%)	Voltage Profile With SVC (%)
1	Port Harcourt Mains	2	85.31	99.02
2.	Port Harcourt Town	9	84.86	98.61
3.	Rumuosi	7	85.21	98.93
4.	Elelewon	14	99.95	99.95
5.	Ahaoda	17	93.20	98.68
6.	Yenagoa	19	91.32	99.79

Table 3: SVC Device Input Data

Static Var Compensator Input Data

	Voltage Rating				Inductive Rating						Capacitive Rating					
SVC ID	kV	Vmax %	Vmin %	Vref %	QL Mvar	QLmax Mvar	IL Amps	ILmax Amps	BL Siemens	SLL %	Qc Mvar	Qcmax Mvar	Ic Amps	Icmax Amps	Bc Siemens	SLC %
SVC1	132.000	130.00	70.00	100.00	200.000	4000.000	874.8	13458.1	0.136	1.95	300.000	6000.000	1312.2	37490.3	0.703	1.05
SVC2	132.000	130.00	70.00	100.00	200.000	4000.000	874.8	13458.1	0.136	1.95	300.000	6000.000	1312.2	37490.3	0.703	1.05

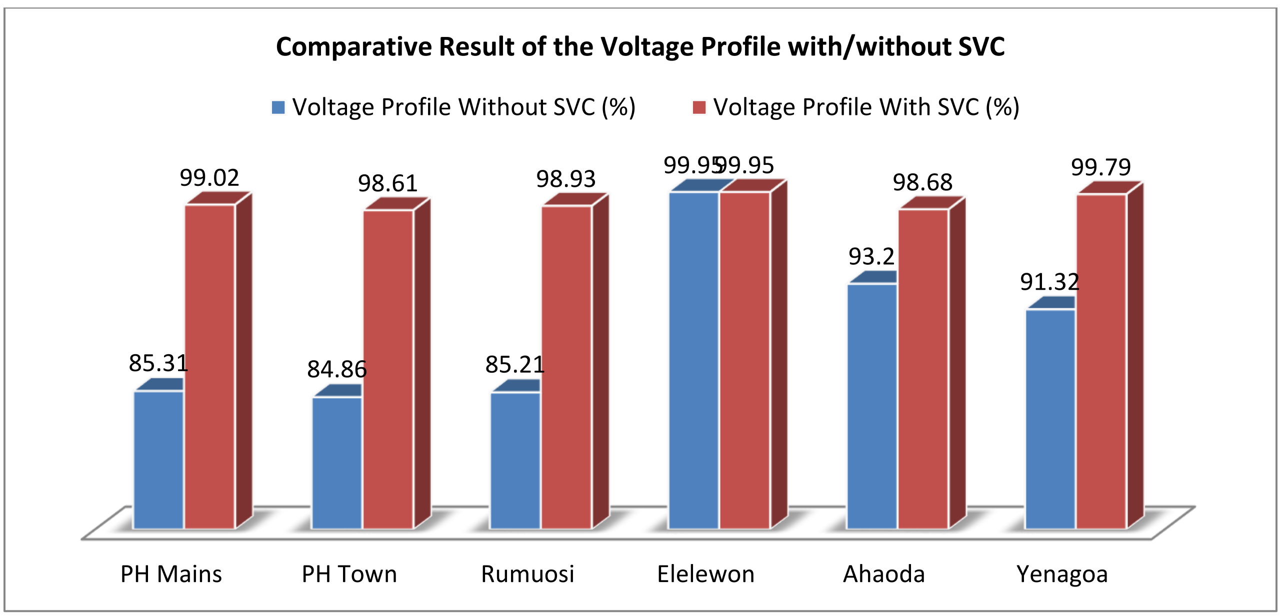

Figure 10: **Comparative Simulation Result of the Voltage Profile with/without SVC**

V. CONCLUSION

The simulation of the 132/33kV, 20-bus Port Harcourt distribution power network was carried out in Electrical Transient Analyzer Program. It was observed from the result of the analysis that most of the buses in the network have weak voltage profile, consequent to the absorption of reactive power flow at each of the buses. The weak buses were compensated by the incorporation of Static VAr Compensator at bus 3 (PH Mains) and bus 19 (Yenagoa). Voltage control and management in an electrical power system is very important for proper operation for electrical power equipment to prevent damage. It maintains adequate voltages throughout the transmission and distribution system for both current and contingency conditions. It reduces real power losses, improves power factor, maintained a steady voltage profile, improved system stability and efficiency at all levels of the power system network.

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