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Reactive Power Compensation Study of Ikeja West 330kV Transmission Line for Improved Power Transmission

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ABSTRACT: *In this paper, the simulation studies are carried out on 330 kV networks of Ikeja West Transmission Company to analyse bus voltages and reactive compensation efficiency. A study of Ikeja West 330KV transmission line was carried out with special attention to contribution and effectiveness of the station Reactor Voltage Compensator. Data were obtained during site visit to the station. Ikeja West 330KV line network model was developed with aid of ETAP softwareand voltage profile on different status of station reactors was determined with a load analysis. A model of Ikeja West 330KV transmission line was perfectly implemented with ETAP simulation software showing behaviour of the network with engagement of the station reactors R1 and R2 with different combination at different time.Voltages profile on the line were observed high when none of the station reactor was engaged on the line.It was also observed that with engagement of any one of the station reactor R1 or R2. there was a slight reduction in the line voltage profile.High voltage in the system are reduced from -0.74% to 2.81% through the station system reactor. It is also seen from the computer results that the use or incorporation of system compensation will lead to control of high voltage on the line with could have resulted to ruptured terminal equipment or shattering of terminal or substation equipment especially open-ended line during system high voltage period.This work will help transmission stations nationwide to accurately calculate and determine the amount of voltage compensation required in case of voltage stability issue thereby resolving power quality problems like voltage profile maintenance at all power transmission levels, transmission efficiency and system stability.*

Keywords -*Power Transmission Lines; Reactors; Reactive Power Compensation; Transmission Line Modelling*

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I. INTRODUCTION

Now a day, nothing is possible without electricity. Without electricity modern society would cease to function. As the volume of Power transmitted and distributed increases, so do the requirements for a high quality and reliable supply. Thus, reactive power control and voltage control in an electrical power system is important for proper operation for electrical power equipment to prevent damage such as overheating of generators and motors, to reduce transmission losses and to maintain the ability of the system to withstand and prevent voltage collapse. As the power transfer grow, the power system becomes increasingly more complex to operate and the system become less secure. It may lead to large power with inadequate control, excessive reactive power in various parts of the system and large dynamic swings between different parts of the system, thus the full potential of transmission interconnections cannot be utilized.

As part of the evolution in the Power Industry in Nigeria, the Federal Government by Decree No. 24 of 1972 created the National Electric Power Authority (NEPA). This was consequent upon the merger of the Electricity Corporation of Nigeria (ECN) and Niger Dams Authority (NDA). In September 1990, the partial commercialization came into being with the appointment of a Managing Director/Chief Executive to superintend over the Corporation. Also, the Authority was divided into four autonomous divisions namely: Generation and Transmission; Distribution and Sales; Engineering; Finance and Administration. Each division was headed by an Executive Director.

The Federal Government of Nigeria (FGN) took further steps towards the Restructuring of the Nigerian Power Sector to establish an electricity supply that is efficient, reliable and cost-effective throughout the country and which will attract private investment. Subsequently, another Power Sector Reform Act was enacted in 2005, transferring the public monopoly of NEPA to Power Holding Company of Nigeria (PHCN) which was unbundled into 18 Business Units (BU); viz eleven (11) Distribution companies: - six (6) Generation companies and one (1) Transmission company[1].

The Ikeja West 330/132/33kV Transmission substation is located between coordinate points N0527520 and E 0729918 on an elevation of 120 feet above sea level in Ayobo area of Alimosho Local Government Area of Lagos state. This station was commissioned in 1979 and supplies Ikeja areas of Lagos as well as Ota, Papalanto and Abeokuta in Ogun State.

TCN has the responsibility for the management of operation, maintenance and expansion of the 132kV and 330kV transmission system NCC is also responsible for setting different codes for proper operation of electric power system in Nigeria. Hence it is important for transmission stations to have some reactive power compensation techniques. Reactors and Capacitors are installed in almost all sections of the power system from generation bus to distribution system[2].The single-line diagram of the existing 330KV Nigeria transmission existing network is as shown in Fig.1. It has 30 buses with nine generating station. The Ikeja West power station was chosen as the slack bus because of its location in the network as represented in Fig.2 as TCN Lagos Transmission Network Station Single Line Diagram.

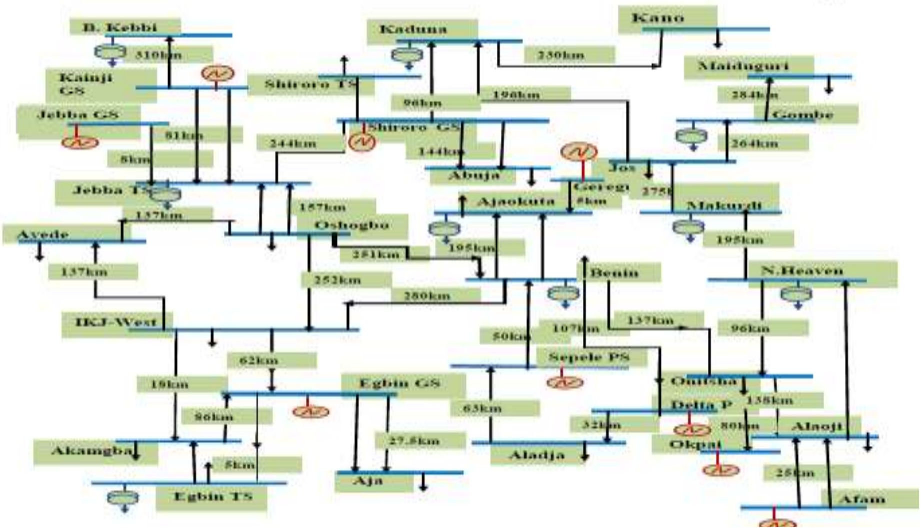

Fig. 1:One-line Diagram of PHCN 330kV 30 Bus Interconnected Network

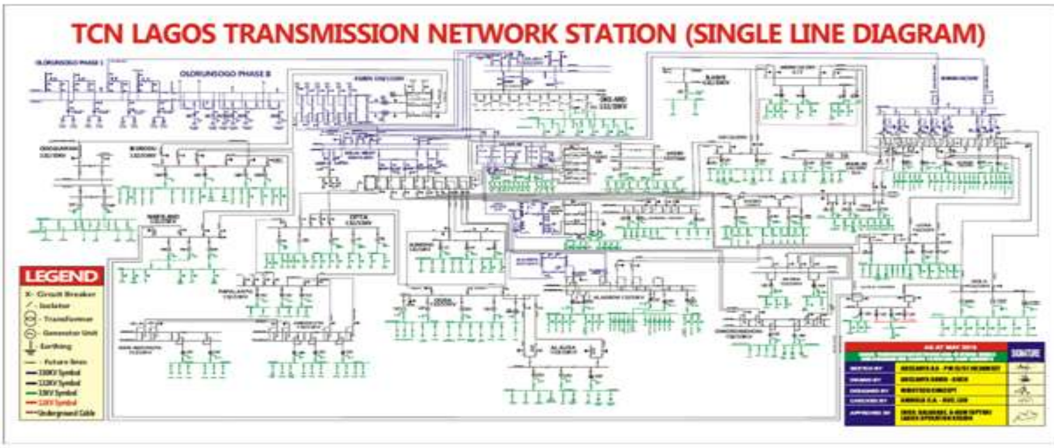

Fig.2: TCN Lagos Transmission Network Station Single Line Diagram

The Nigerian 330kV grid network is characterized with major problems like voltage instability (voltage profile violation), long transmission lines, nature of transmission lines and high-power losses which affect power generation and distribution systems. Most of the equipment used in power system especially at 330KV level and above are operated close to the limit of system design. Long transmission lines in the national grid generate considerable reactive MVARs which constitute a major source of problem in maintaining system voltage within the statutory limits especially during light load period, system disturbances or major switching.

High voltage on 330KV transmission line can lead to ruptured terminal equipment or shattering of terminal or substation equipment especially open-ended line during system high voltage period. Adequate reactive power compensation and management contributes to reducing system high voltage when occurred. This

General

study is to examine the effectiveness of reactance compensator(inductive shunt reactors) on 330kV line emanating from Ikeja West Transmission Station by using ETAP software simulation.

II. RELATED WORKS

Many surveys and literatures have been conducted on performance evaluating the reactive power compensation methods in EHV transmission line. Paper [3] proposed and presented his research on the controlled shunt reactor for bus voltage management in EHV system. As the permanent connection of the shunt reactors leads to reduced voltage levels and decreased transmission capacity of the lines during full load conditions. Thus, the paper introduces the solution of continuous voltage drop by introducing the Controlled Shunt Reactor which is a thyristor-controlled equipment offers fast response time to take care of dynamic conditions. In his research, the main equipment is RT (Reactor Transformer) is designed as single three phase unit or as three single phase unit. The simulation response shows the transients response improves using controlled shunt reactor[4-5].

Transmission lines carry bulk power from generating stations to load centres. Utility regulations limits substantial amount of voltage drop in any network to ensure efficient and reliable operation of interconnected grid. Reactive power compensation is essential for safe and efficient performance of modern power systems. Improperly managed reactive power flows result in poor voltage regulation, consumer dis-satisfaction, increased power losses and sometimes long duration system outages. The greater the reactive power moving through a transmission line, the lesser the capacity of the line. In other words, reactive power is proportional to voltage drop. Therefore, it is imperative that, the greater the reactive power flow through the transmission lines, the greater the voltage drop resulting in lower bus voltage [6-7]. This means that the low voltages at transmission system buses will lead to low voltage supply to the injection substation which is unpleasant. Furthermore, reactive power can be likened to a high-way on which active power flows. That is to say, that proper reactive power in the system leads to proper real power flow in the system [8-9].

III. METHODOLOGY

The methodology employed in this research study is two-fold. First a description of the Ikeja 330kV transmission line is obtained from the site and model in ETAP software environment and then simulation of the various state of operations of the reactors connected to the line were carried out to determine the voltage profile of the transmission line in the network at every state. The results of the simulation were then compared with the required standard voltage for the transmission line.

3.1. Ikeja West Transmission Network Model

A line network model was developed to represent the network configuration in ETAP software environment for simulation as shown in Fig.3. The network model is based on the investigation made at the site. The model considers a sub-part of the Nigeria 330kV Nation Grid. The supply voltage to Ikeja Station is 330kV while power transmission lines of 132kV emanates from the station to various other transmission stations. The 330kV transformers at the Ikeja West station normally feeds the following secondarytransmission stations:

1. Ogba 132kv T/S.2. Alimosho 132KV T/S.3. Ejigbo 132KV T/S.4. Agbara 132KV T/S.5. Alausa 132KV T/S.6. Otta 132KV T/S.7. Papalanto 132KV T/S.8. Abeokuta 132KV T/S.

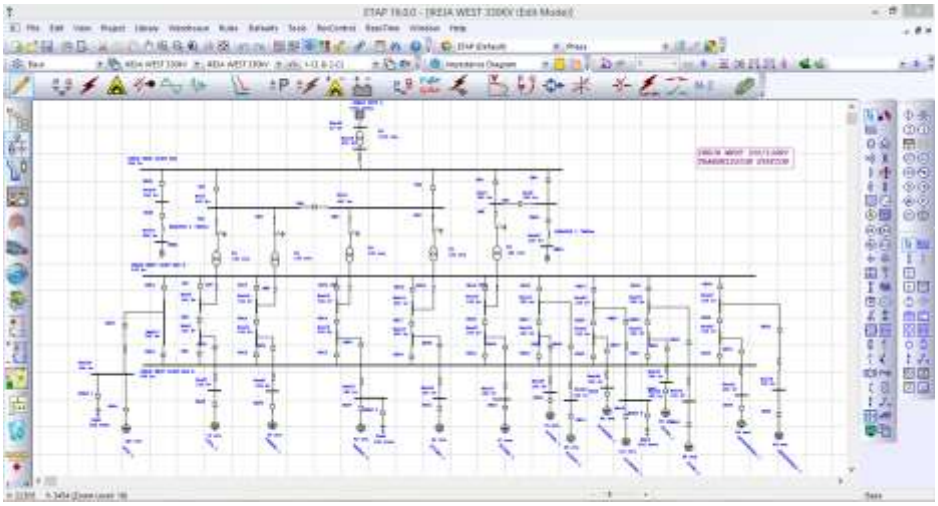

Fig.3: ETAP Model of Ikeja West Transmission Station

3.2. Different Positions of the Reactors at the Ikeja West Transmission Network

The existing network of Ikeja West 330KV/132KV is drawn using the collected data from Ikeja West database. The software graphics user interface (GUI) allows the direct input and drawing of the required network details one bit at a time. These required blocks are bus bars, transformers, transmission lines, feeder loads. The parameters required to input data each block is gotten from the Ikeja West actual report data base and the line diagram.

Fig.5 to Fig.8in the Appendix 1 show different position of reactors R1 and R2 on 330KV line with corresponding reaction on the load and the line voltage.

IV. RESULTS AND DISCUSSIONS

The simulation results obtained are summarized in Table 1 below. The Table presents the results of the voltage magnitudes at different position of the Station Reactors on 330KV line.

Table 1:Voltage Profilesof the Slack Bus (Ikeja West Station)for both Reactors R1 and R2 Position

Reactor Position	Before Reactor Compensation (KV)	Nominal Voltage (KV)	After Reactor Compensation (KV)	% Mag.
Reactor R1 Open & R2 Open	339.28	330.000	339.28	102.811
Reactor R1 Open & R2 Close	339.28	330.000	333.69	101.118
Reactor R1 Close & R2 Open	339.28	330.000	333.72	101.127
Reactor R1 Close & R2 Close	339.28	330.000	327.38	99.206

Fig.4is a chart that presents the voltage profiles of the slack bus at the different positions of the reactors during simulations operations compared with the required standard voltage of the bus (nominal voltage 330kV). The simulations represent howthe reactors operated atthe Ikeja West 330kV Transmission Station.

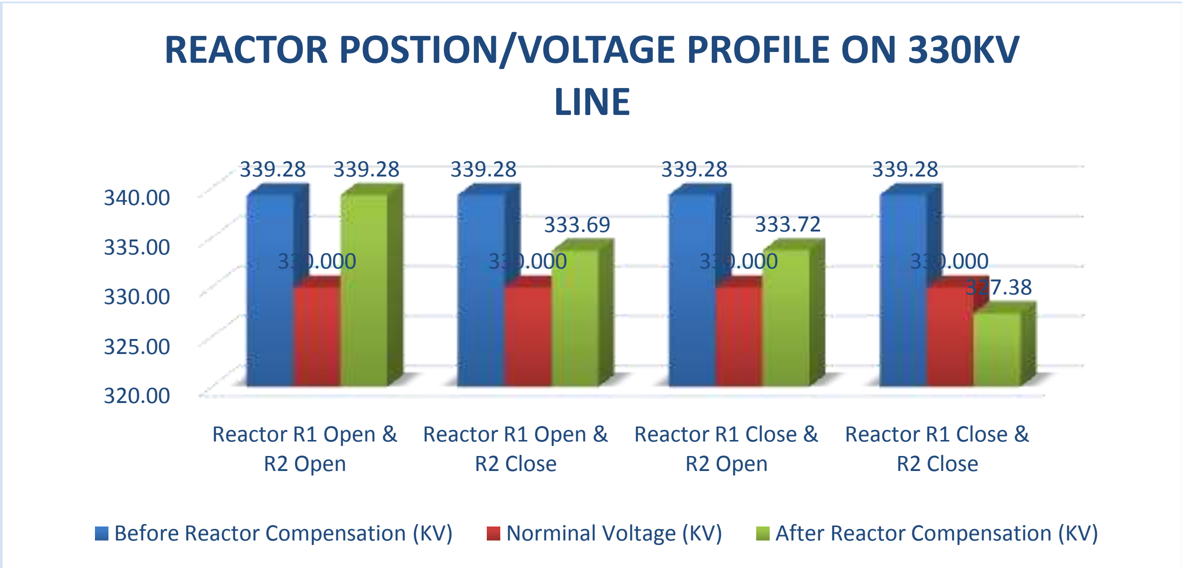

Fig.4: Reactor Position against Voltage Profile on 330kV Bus

The results obtained show a voltage profile of 102.811% of the nominal voltage when any of the station Reactor in not closed on the circuit. With the introduction of one of the station reactors, a voltage magnitude of 101.117% was recorded.It also shows a voltage profile of 99.206% of the nominal voltage with the introduction of the two station reactors on the 330KV line.It also shows a voltage profile of 99.206% of the nominal voltage with the introduction of the two station reactors on the 330KV line.Therefore, a voltage profile of 99.206% to 102.811% of the nominal voltage on 330KV Ikeja West transmission line can be achieved with combination of station reactor on the line.High voltage profile on the 330KV line can thereby be reduced with the station reactor with up to 3.605%.

V. CONCLUSION

General

A novel approach to the power transmission fault estimation and classification has been described in this research paper. We have proposed and used the Hierarchical Temporal Memory (HTM) as primary AI tool for online estimation and classification of power data obtain from a doubly fed transmission line. We have developed a simulation system in the MATLAB/SIMULINK language for implementing the transmission line and for assisting with simulation data gathering. The proposed technique is also compared with another similar classical online capable AI technique called Online Sequential Extreme Learning Machine (OS-ELM). From the results, it is obvious that the proposed HTM AI technique can outperform the OS-ELM and SVM techniques.

A model of Ikeja West 330KV transmission line has been perfectly implemented with ETAP simulation software showing behaviour of the network with engagement of the station reactors R1 and R2 with different combination at different time.Voltages profile on the line were observed to be high when none of the station reactor was engaged on the line.It was also observed that with engagement of any one of the station reactor R1 or R2. there was a slight reduction in the line voltage profile.High voltage in the system are reduced from -0.74% to 2.81% through the station system reactor.It is also seen from the computer results that the use or incorporation of system compensation will lead to control of high voltage on the line which could have resulted to ruptured terminal equipment or shattering of terminal or substation equipment especially open-ended line during system high voltage period. The use of reactorsasvoltage stabilizes in very high voltage networks shows that; drop in loads may result into increase in voltage on the line, and these high voltagesmay result to cases of partial or total system collapse.When hooking up any generating station to the 330KV line the voltage fluctuates. It is therefore recommended that more reactors be installed in other 330kV transmission line of the Nigerian 330kV Super-grid to achieve voltage stability.

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APPENDIX

Appendix 1: Load Flow Results for Different Reactor Positions (Open or Close)

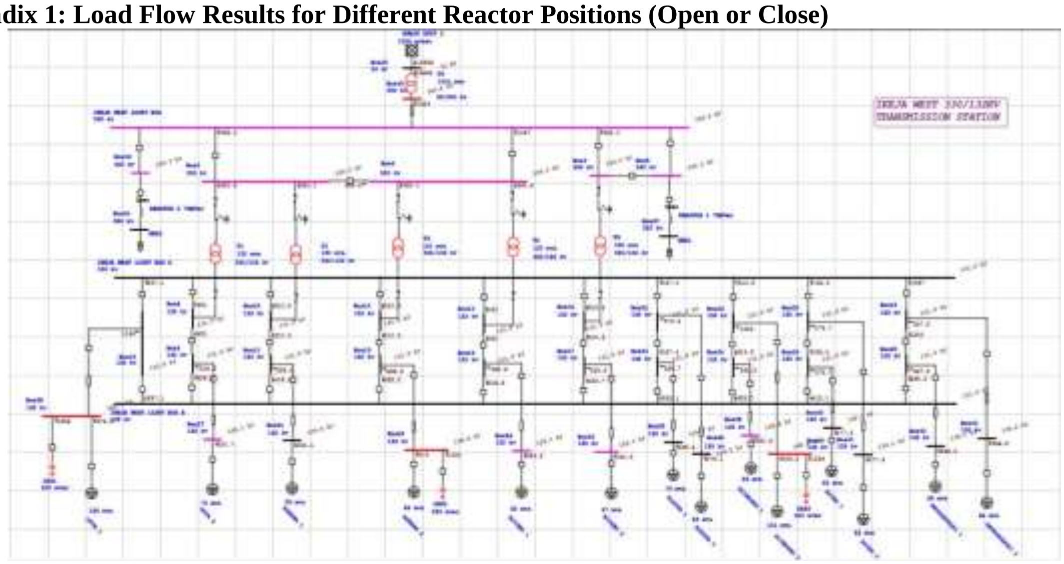

Fig.5: ETAP Simulation Line Diagram when both Reactor R1 and R2 Open

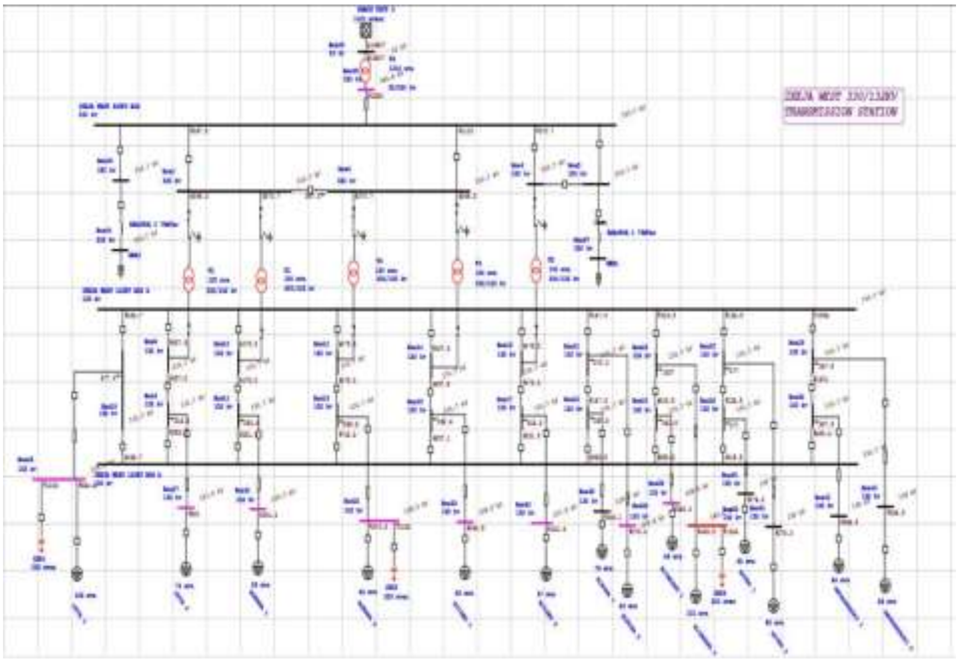

Fig.6: ETAP Simulation Line Diagram when R1 Open and R2 Closed

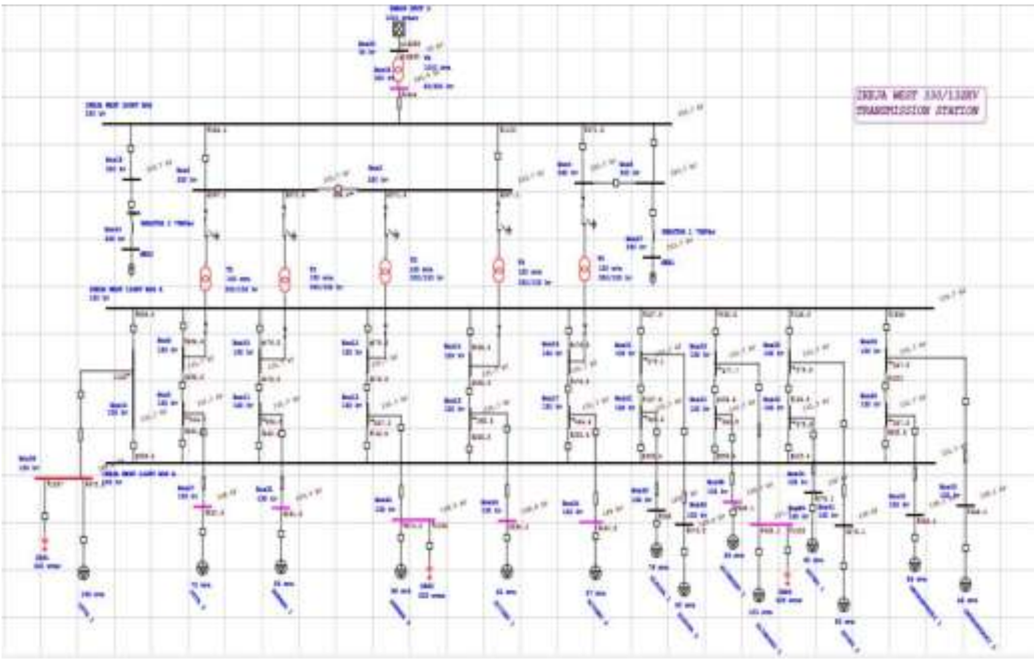

Fig.7: ETAP Simulation Line Diagram when R1 Closed and R2 Open

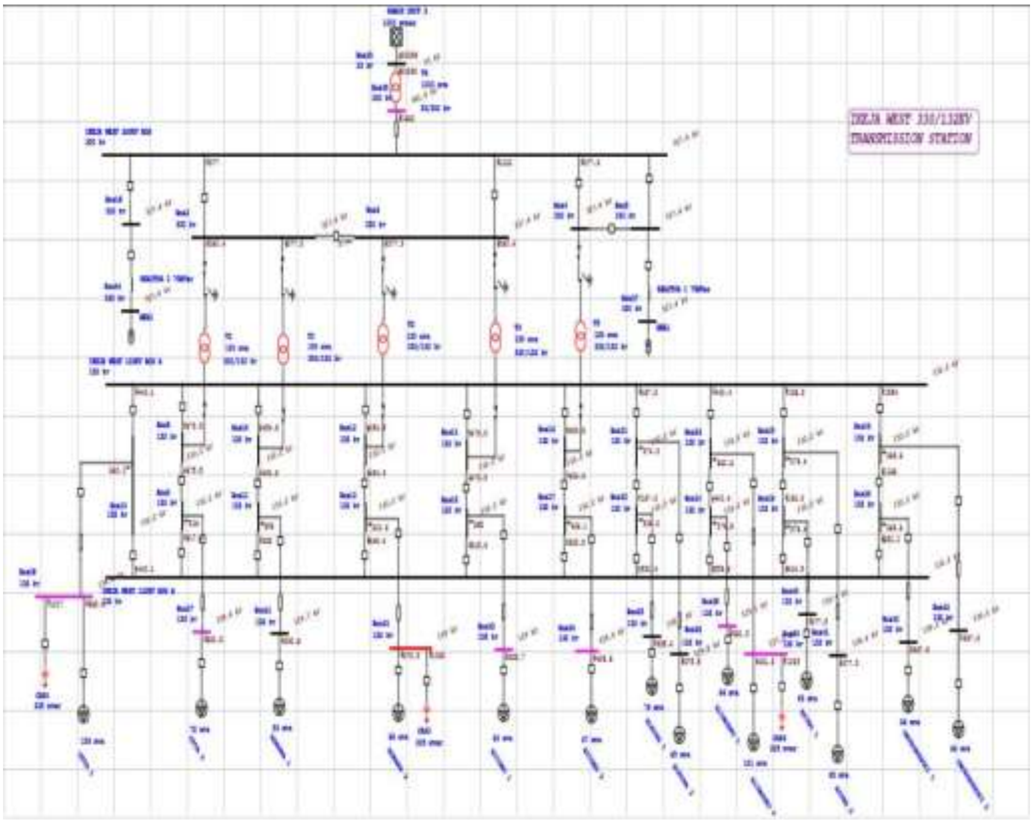

Fig.8: ETAP Simulation Line Diagram when R1 and R2 Close

Dikio C. Idoniboyeobu" Reactive Power Compensation Study of Ikeja West 330kV Transmission Line for Improved Power Transmission" " American Journal of Engineering Research (AJER), vol. 8, no. 10, 2019, pp 199-205