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Voltage Level Improvement in 33kv Power System Network Using STATCOM/ DSTATCOM : Case Study of Tungbo Feeder, Bayelsa State.

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ABSTRACT
The demand for clean and reliable electrical energy that is safe and at minimum cost is increasing due to growing energy demand by consumers. As a result of this, network injection substations, transformers and feeders are overstressed, overloaded and cannot dispatch energy to meet this continuously increase in loads. However, consumers will often experience under-voltage and epileptic power supply. In order to proffer solution to these problems ETAP version 12.6 was used to carrying out sensitivity analysis by simulating voltage loss and bus voltage profile of 33KV power system network with a peak load of 4.46MW with and without the STATCOM/ DSTATCOM using data obtained from Tungbo Feeder, Bayelsa State. An assumption of voltage limit of ± 0.6% is considered for the power flow analysis on the distribution feeder and with real and reactive demand of 0.8 and 0.6 of the transformer rating. Also, Newton Rapson load flow and Kirchoff's Law were used for the model and load equations. The simulation results showed that voltage sags were caused by faults and swell due to sudden switching of loads in the distribution system and it can be mitigated by inserting STATCOM/DSTATCOM.
Keywords: Voltage Level Improvement, Power System Network, STATCOM/DSTATCOM, Feeder

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I. INTRODUCTION

1.1 Background to the Study

The electric power system was created to be effective, dependable, simple to use, and affordable for consumers (Uhunmwangho and Okedu, 2018). Most injection substation converters and heaters are overwhelmed and unable to efficiently dispatch energy to meet the rising load demands of the consumers due to improperly sized transmission systems, load economic expansion, and frequent network growth without a correlating rise in power supply. Customers connected to the impacted substations frequently experience under-voltage and erratic power supply. The majority of feeders/ distribution lines, particularly the sub transmission networks, are overly long. Many homes and businesses now employ their own independent power generators to supplement their power demands in an effort to satisfy their daily energy needs (Hachimenum, 2015).

Between the main or source of power supply and the service switches for the customer, there is a distribution network for electricity. The bulk power generators, which can be either producing stations or electricity sub - stations supplied through transmission lines are situated in or close to the load region that the distribution system is intended to service. In general, systems may be broken down into six components: customer support connections and meters, distributing substations, principal feeders, distribution equipment, secondary networks, and sub transmission circuits.

Power system instability create problems in the customer's facility.One of the most frequent issues with power quality is voltage sags/ swell with thedepth/magnituderanging from 10% to 90% of the normal voltage, and its duration from half a cycle to one minute. They are more common in the industrialsector mostly when starting motors or transformer and result in serious issues and financial losses. Utilities frequently highlight end-user equipment disruptions as the primary source of power quality issues. Current harmonics in the distributing system can result in heating in the electrical equipment as well as harmonic distortion, poor power factor and extra losses. Additionally, it may result in machine noise and vibration as well as malfunctions of delicate equipment. Transmission and distribution system power quality issues may be improved in a number of ways. The DSTATCOM is one of these gadgets that is most efficient. The DSTATCOM's digital valves are now under control of a new Pules Width Modulation(PWM)-based control system (Gerbex et al,2011).The DSTATCOM can be established as a voltage / power support by swapping out capacitors for batteries as power storage to improve power quality problems like voltage sags/swells, harmonic distortion, and low power factor in distribution systems. It also has the additional capacity to keep reactive current at low voltage.

Custom power innovation, the low voltage equivalent of the Flexible AC Transmission System (FACTS) technology, intended for high-voltage electricity transmission applications has recently come to light as a reliable solution to many issues relating to supply continuity at the final level. Direct credit for the FACTS and bespoke power concepts goes to Electric Power Research Institute(EPRI).Custom power applications are currently seeing the emergence of a broad variety of extremely flexible controllers that make use of recently accessible power electronic parts. The analysis and modeling of these controllers for a variety of operating circumstances based on PWM control using the static var compensator DSTATCOM Voltage Source Converter (VSC) principle is described in this thesis for the DSTATCOM (Masdi et al,2014). It does not need measures of reactive power because it operates only on voltage readings. To ascertain the effect of the DC capacitor size on DSTATCOM efficiency, a sensitive analysis is conducted. The STATCOM is typically referred to as Distribution STATCOM when utilized in distribution networks (DSTATCOM).The proactive power flow is regulated by the angle between the AC system and VSC voltages, and the reactionary power flow is regulated by the differential among the magnitudes of these voltages, operating similarly to the STATCOM (FACTS controller).

1.2 Statement of the Problem

Power systems have a serious issue with voltage stability as they gradually approach the operational limits set by social and economic factors. Reactive power consumption rises whenever there is a change in load because the system voltage level lowers. If the demand for reactive power rises, bus voltage will continue to drop, which will have a cascade impact on nearby areas. Therefore, it becomes crucial to keep the voltage profile within acceptable bounds.The accessibility of power supply has become a major challenge particularly the area of case study -Tungbo feeder in Bayelsa State. Similarly, there is no adequate power supply available to meet the end user demand, making the consumers not to have efficient access to electric power supply, thereby not meeting their power requirements, this insufficiency has led to:

i. Over dependence of local demand on the already over stressed power system
ii. Dispatches between energy general capacity and energy demand requirement.
iii. Regular power outages and loads study at the receiving-end.
iv. The design of a power system with adequate control of short circuits, or faults.

The use of STATCOM/DSTATCOM on the power system networkform the bases of network reconditioning for power loss reduction and voltage profiling. Various techniques have been developed by researchers to address the stated problems. The flexibility and robustness of some of these techniques can be improved by the application of STATCOM/DSTATCOM. In view of above concern, this research seeks the need for voltage level improvement in 33kv power system network using STATCOM/DSTATCOM on Tungbo feeder, Bayelsa State.

1.3 Aim of the Study

The aim of the study is to find the voltage level improvement in 33kv power system network using STATCOM/ DSTATCOM on Tungbo feeder, BayelsaState.

1.4 Objectives of the Study

The objectives of the study are as follows:

i. To review the literatures on STATCOM/DSTATCOMfor power loss reduction and improved voltage profile.
ii. To present PHED distribution network data on Tungbo feeder.
iii. To improve voltage profile through the use of STATCOM/ DSTATCOM
iv. To compare the power loss and voltage profile of the network with and without the use of STATCOM/ DSTATCOM.
v. To make necessary recommendations based on the findings of the study

1.5Significance of the Study

In Nigeria, including Tungbo and its surroundings, electricity serves as both the primary energy source for residential consumption and the nation's businesses. The distribution network's overall efficiency will be enhanced by the deployment of STATCOM/DSTATCOM, particularly through the reduction of power losses and enhanced voltage supply. By managing tie and sectionalized switches, network reconfiguration also improves system performance. Additionally, combining various ways rather than adopting a single strategy will result in significant improvements to the system performance. In order to improve the performance of the distribution system in terms of reducing overall power loss, voltage profile improvement to cater for all customers connected to the Tungbo feeder and will be also serves as basis for improvement of similar network to PHED. The study will also be extremely helpful to research students since it will act as a resource for additional research on the subject or similar issues.

1.6Scope of the Study

The study will focus on voltage level improvement in 33kv power system network using STATCOM/ DSTATCOM. The study will limit its findings to data obtained from Tungbo feeder, Bayelsa state.

II. LITERATURE REVIEW

2.1 Conceptual Clarification

2.1.1 An Overview of the Power Sector in Nigeria

In Nigeria, the need for electric power has grown along with industrialization and population expansion. Three hydroelectric power plants, as well as steam and gas thermal stations, are the major sources of electricity in Nigeria. The majority of these facilities were run by the Power Holding Company of Nigeria (PHCN), a publicly traded utility that organized all power industry operations, including generation, transmission, and distribution as well as sales and marketing. Presently, all sectors mentioned above were privatised except the transmission companies retained by the Federal Government of Nigeria. As outlined by Sule & Anyanwu (2014), “The construction of steam thermal plants at Oji River (1956), four unit gas thermal plants at Ijora (1966–78), twenty unit gas thermal plants at Delta (1966–90), four steam thermal plants at Sapele (1978–80), another 18 unit gas thermal plants at Afam (1982), and six steam thermal plants at Egbin (1985–87)” marked the beginning of the growth of thermal plants in Nigeria. There are a total of 6 power stations, which are made up of 55 units and had a combined capacity of 5988 MW of electricity (N/B). By 2000/2002, extra power plant units were erected in certain power stations, including Afam 5. The underwhelming operation of these thermal reactors has significantly added to continued power outages and monetary loss. Sule and Anyanwu (2014) “in their report revealed that only 15 out of the 55 units were available for power generation as at 1994. The then Minister of Power and Steel, Chief Agagu” (Punch Newspaper, 2001) For the record, 20 out of 78 units (25.6%) were operational before 1999, and by 2001, after the installation of 2 more units and the restoration of 17 more, the proportion had increased to 43.8%.

High availability of the most effective and modern plant is necessary for maximum economic gain. According to Agbauduta (2018), Nigeria's economic losses from unstable electricity generation and supply were estimated to be astonishing N66 billion (about $0.55 billion). He pointed out a number of reasons for the underwhelming performance of these power plants, including a shortage of skilled maintenance engineers, a dearth of necessary replacement parts, and the volatility of the national grid. Hart(2012), reported that the development of power generation and distribution in Nigeria originally didn't entail a national grid system, therefore the producing units weren't designed with that system in mind. The absence of producing stations in a significant portion of the country necessitated the creation of the grid system.

2.2 Overview of Distribution System

Distribution System is the part of power system that is between the substation fed by transmission system and the consumer’s meters.There sole purpose is fordistributing electric power for local use by industrial, commercial, residential and transportation customers at required voltages .Distribution system is generally classified into three- radial, loop or network but with six basic interconnected components, viz;

- Sub transmission Circuits
- Distribution substation
- Distribution or primary feeders
- Distribution transformers
- Secondary circuits
- Connections and meter or consumers’ services.

2.3Statcom/ Dstatcom

The DSTATCOM is a reactive power compensation device with a power electronic foundation that is shunt-connected to a specific bus in the electrical distribution system (Taher and Asfari,2014). The three-phase matrix converter serves as the fundamental structural component of the suggested capacitor-free architecture. To the converter's output side are nine bidirectional switches, a 3 different filter, and output chokes. The suggested capacitor-free DSTATCOM configuration linked at the terminal bus in the distribution network is depicted in a simplified manner in Fig. 2.1. A three-phase source with impedances is modeled upstream, towards to the substation (Zs). The model for downstream consists of two blocks: the harmonic generating block and the consumer and enterprise block (producer-consumer) and as a photovoltaic system with a three-phase inverter and other rotherhithe loads like personal computers, televisions, and energy-efficient bulbs (fluorescent and LED), it will produce current harmonics to depict the overall behavior of the system (Saeidpour,2015). The second load is the corresponding R-L load for the linear loads that are grouped together. In order to make sure that the power flow from the upstream source (Is) is sinusoidal and in phase with the voltage, the suggested DSTATCOM is resistive element and injects current (Ic) to make up for the downstream activity. The controllers unit of the DSTATCOM in the picture comprises of the line voltage generator and the predicted values control, together with the matrix converter (MC) unit linked to the output chokes (MPC).Both the Current Source Inverter (CSI) architecture and the Voltage Source Inverter (VSI) topology may be used to build DSTATCOM devices (Sumpavakup et al,2013). No matter the architecture, a regulator is made up of a number of semiconductors (such as IGBT, GTO, IGCT, etc.) with turn-off ability that are linked to the feeder by a tiny reactive filter. The VSI conversion contains a dc voltage (capacitor CD) on the DC side and is coupled to the feeder through reactor LF. The CSI converter contains a constant current (inductor LD) on the DC side and is coupled to the AC side through capacitor CF. DSTATCOM does not often employ CSI topology.This is because the DC reactor of CSI has greater losses than the DC capacitor of VSI. Furthermore, CSI converters use reverse-blocking switching devices, which have larger losses than VSI converters' reverse conducts switches. Finally, the VSI-based topology has an advantage since the capacitance of an AC filter can be partially or entirely made up of the capacitance of a step - up transformer (Tr), if one is present. The features of DSTATCOM based on VSI topology will only be covered in the following paragraph, however they are largely the same as those of CSI-based controls. The multi-level topology on which the VSI converters for DSTATCOM are built can be used with or without the usage of a transformer. These solutions offer assistance for operations requiring a high level of terminals security.Additionally, in order to obtain higher rated power or smaller PWM-related current ripples, DSTATCOM controllers can be a compound of many converters tuned to different topologies. In a parallel setup, converters are controlled to distribute the electricity generated equitably or at a predetermined ratio, such as proportionate to the converter's power rating.

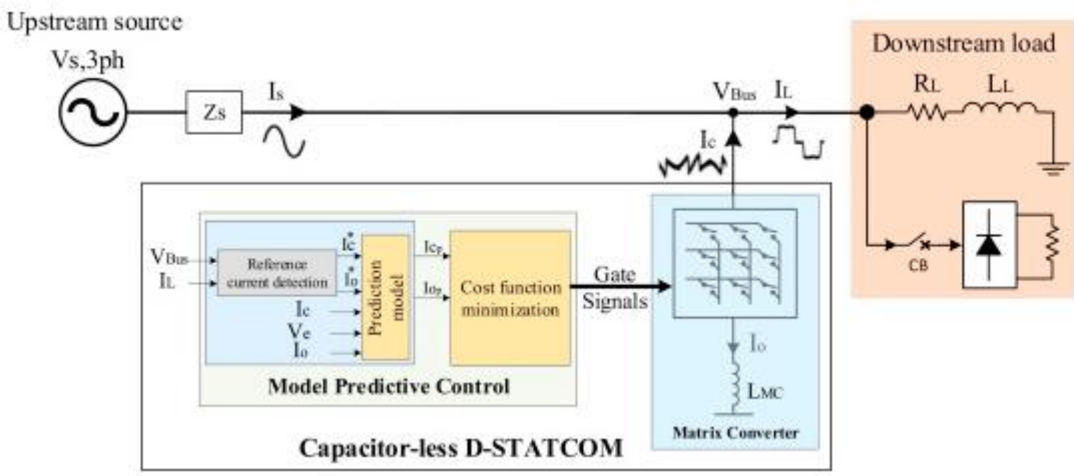

Fig 2.1 DSTATCOM

2.4Review of Related Literature

In 2014, Vanishree and Ramesh looked at how power systems may improve their voltage profiles. Voltage Stability, they observed, is a serious issue in power systems, which slowly approach operating thresholds imposed by social and economic factors. The system voltage level fluctuates whenever the load varies. The need for reactive power rises as voltage levels decline. If the reactive power requirement is not satisfied, the bus voltage will continue to drop, which will have a cascade impact on nearby areas. Therefore, it becomes crucial to keep the voltage stability within acceptable bounds. In order to maintain the voltage level, their study discussed a variety of ways and techniques, each with pros and disadvantages. Sensitivity-based control strategies were one of these methods,involves the design and optimum placement of FACTS devices employing a variety of optimization techniques for VAR replacement, voltage gain control schemes, and structural parameters of the power system as the basis for the control.

In order to preserve the Static Voltage Characteristics (SVC) VAR reserve and keep the voltage profile at the desired level, Henghu Li et al. (2014) suggested a methodology based on sensitivity for efficient dispatch of VAR. The elements governing the Static VAR Compensator's controllability include the reference voltage, the static var characteristics of the system, the margin of control, and slopes. Critical Static VAR Comparator is that component that is outside the boundaries of control and coordinate the SVC output at various places. It is detected by system that is designed to increase during compensating.

Gowtham (2015) looked at DSTATCOM's Power Loss Prevention and Voltage Profile Methods.

III. MATERIALS AND METHOD

3.1 Materials

This chapter presents the methodology in carrying out voltage level improvement in 33kv power system network on Tungbo feeder in Bayelsa State using the STATCOM/ DSTATCOM approach, as a method for power loss reduction and voltage profile improvement with considerations of the single and combined effect of the proposed models. The results will determine the model which is better for power loss reduction and Voltage profile improvement. The methodology presents a detailed mathematical model equation for computing parameters of the distribution network, load model, distributed generation model, problem formulation and a detail of the developed genetic algorithm (GA) approach are presented.

3.1.1 *Case Study*

The case study adopted as a test case is the Tungbo 33kv feeder which start from Yenagoa 132/33KV Transmission Station and running through route length of about 35km to various distribution substations where power is step down through Delta/Star transformation and evacuated via upriser cables and the Low-tension lines to feed the consumers or customers. The peak load on Tungbo feeder is 40.5 amperes (4.46MW). The adaptation of proposed scheme to the existing feeder along with the load growth for two years is considered. An assumption of voltage limit of ± 6% is considered here in power flow analysis of the distribution feeder.

3.2 *Data Collection*

The Data was collected from PHEDC, Bayelsa Business unit. The data captures the network diagram, rating of each transformer, capacity of the feeder and route length between each connected transformer. The load data that was utilized was based on the following assumption:

i. The real and reactive demand at each node is taken as (0.8*kVA and 0.6*kVA) of the transformer ratings respectively.

ii. The network was assumed to be a balance system with a power factor of 0.8

iii. Effect of line charging capacitance was neglected due to short nature of distribution network. The line and load data were converted into case data

3.3Model Equation for Load Flow Analysis of the Power System

Given the size of the distribution network under consideration, which has roughly 26 nodes, computation time is crucial, and layering and integration approaches call for an effective load flow calculation algorithm. The system is a radial network that is only minimally meshed and has a small number of closed systems. Here we consider the n-bus distribution network reduced to a two-bus network topology as shown in figure 3.1:

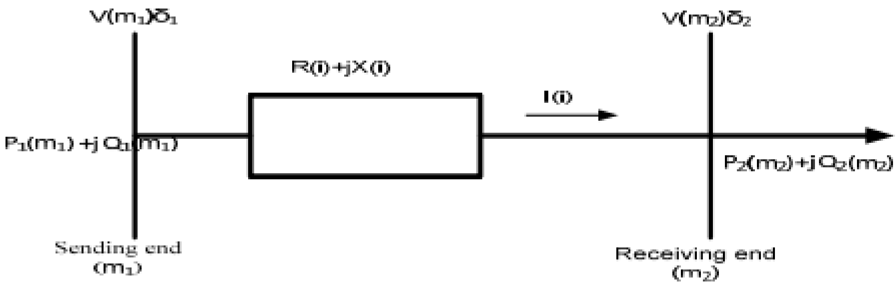

Figure 3.1 Single-Line Diagram of a Two Bus Distribution Network

Using Newton Raphson load flow method and Applying Kirchhoff's law to the network above; The first step is to compute the voltage at bus2.

$$|V(m_2)|\angle\delta_2 = |V(m_1)|\angle\delta_1 - I(i)(R(i) + jX(i)) \tag{3.1}$$

The load flow algorithm's subsequent step is to determine the power at each junction using the continuity formula.

$$I(i) = \frac{P_2(m_2) - jQ_2(m_2)}{V^*(m_2)} \tag{3.2}$$

The PSO approach for solving optimal sizing of DSTATCOM to minimize the power loss and to improve the voltage profile takes the following steps:

Step 1: Get the inputs which are the line impedance and the bus data.
Step 2: Initially [nop x n] number of particles are generated where nop is the number of population and n is the number of DSTATCOOM devices.
Step 3: Generate initial [nop x n] number of velocities randomly between the limits. Iteration count is 1. load flow analysis is performed by placing all the „n‟ DSTSATCOM devices at the particular candidate locations and power losses PL DSTATCOM are calculated. Same procedure is repeated for „nop‟ number of particles to find the total real power loses.
Step 4: For maximum loss reduction, fitness function can be calculated by the following formula: Fitness FA= PL- PL DSTATCOM, where PL is total real loss before placement. PL DSTATCOM is the total real loss after placement of DSTATCOM. Fitness with negative value is replaced with minimum and the respective particle position also assign with minimum from equation. Initially all the fitness values are copied to pbest fitness, maximum pbest fitness gives the gbest fitness. Which is a measure of maximum loss reduction and the respective particles represents gbest particles.
Step 5: Using equations (3) and (4), updated particle locations and new velocities are determined for all particles included inside the boundaries.
Step 6: After doing a load flow study and calculating a new exercise value utilizing equation (6). The relevant particle is relocated to the pbest particles if the new fitness is higher than the pbest fitness.
Step 7: The particle in question will be saved as the gbest particle when the maximal pbest fitness results in the gbest fitness.
Step 8: Using pbest fitness, maximum fitness and average fitness are computed. Equation is used to determine error (9). Error is equal to (max.fitness - avg.fitness) (9) Proceed to step 10 if the estimated error is less than the chosen tolerances.
Step 9: If the repetition could not reach its maximum, the current iteration count was increased; otherwise, move on to step 5.
Step 10: Total loss reduction and ideal sizes of DSTATCOM are provided by gbest fitness and the gbest particle, accordingly.

IV. RESULTS AND DISCUSSION

4.1 Description of the Work

This chapter presents the data onTungbo Feeder and analyzes the voltage level improvement in 33kv power system network using STATCOM/DSTATCOM on Tungbo feeder, Bayelsa state. The use of ETAP version 12.6 is used to simulated the case study.

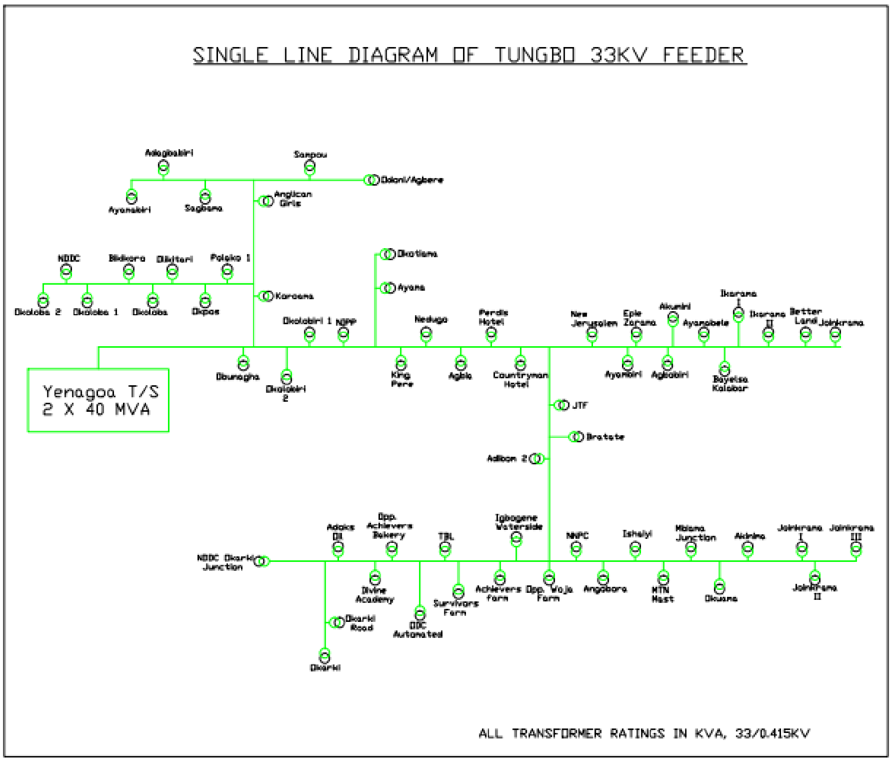

Fig 4.1 Single Line diagram for TUNGBO 33kv feeder

Table 4.1: Station Identification showing the Reactance, Impedance and Admittance (TUNGBO)

Identification Station	R	X	Y
Adagbabiri	0.236536	0.143000	0.0000637
Ayamabiri	0.236536	0.143000	0.0000637
Sagbama	0.236536	0.127000	0.0000660
Sampou	0.236536	0.143000	0.0000637
Anglican girls	0.327145	0.151000	0.0000581
Bolani/Agbere	0.236536	0.143000	0.0000637
Nddc	0.236536	0.143000	0.0000637
Bikkoro	0.637122	0.150000	0.0000498
Polako 1	0.236536	0.143000	0.0000637
Okoloba 2	0.637122	0.150000	0.0000498
Okoloba 1	0.236536	0.143000	0.0000637
Okoloba	0.236536	0.143000	0.0000637
Okpos	0.236536	0.143000	0.0000637
Koroama	0.236536	0.143000	0.0000637
Okolobiri 1	0.236536	0.143000	0.0000637
Nipp	0.236536	0.143000	0.0000637
Ayama	0.236536	0.127000	0.0000660
Nedugo	0.236536	0.143000	0.0000637
Peros Hotel	0.236536	0.143000	0.0000637
New jerusalem	0.236536	0.143000	0.0000637
Ikarama	0.236536	0.143000	0.0000637
Bratate	0.327145	0.151000	0.0000581
JTF	0.236536	0.143000	0.0000637
BayelsaKalabar	0.236536	0.143000	0.0000637
Mbiama Junction	0.236536	0.143000	0.0000637
Mtn Post	0.236536	0.143000	0.0000637
Achievers farm	0.236536	0.127000	0.0000660
Divine academy	0.236536	0.143000	0.0000637
Woja farm	0.236536	0.143000	0.0000637
NNPC	0.236536	0.143000	0.0000637
Ishayi	0.236536	0.143000	0.0000637
Igbogene waterside	0.236536	0.127000	0.0000660
NDDC Junction	0.236536	0.143000	0.0000637
Adoks oil	0.236536	0.143000	0.0000637
ODC automated	0.236536	0.143000	0.0000637
Joinkrama	0.236536	0.143000	0.0000637
Joinkrama II	0.236536	0.143000	0.0000637

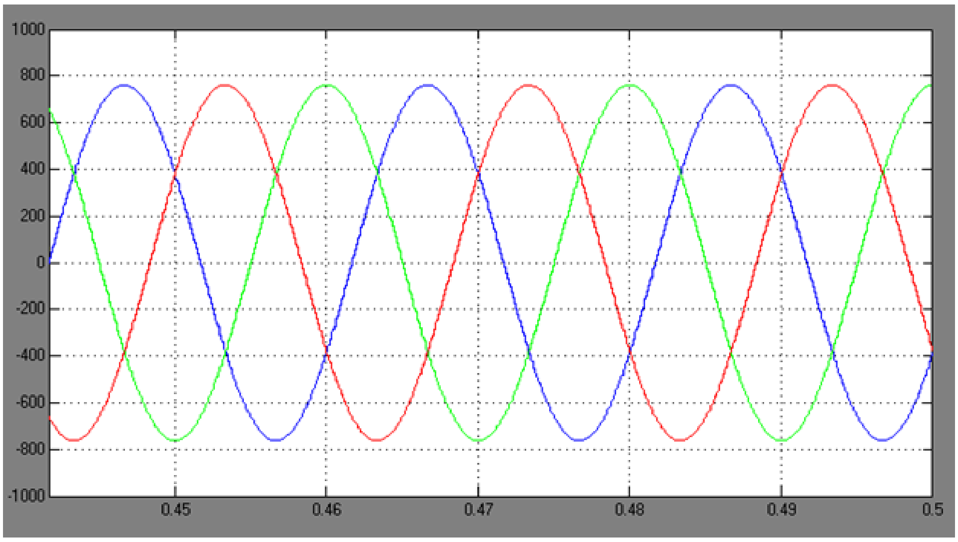

Fig 4.1 (a) Simulation circuit without STATCOM/DSTATCOM

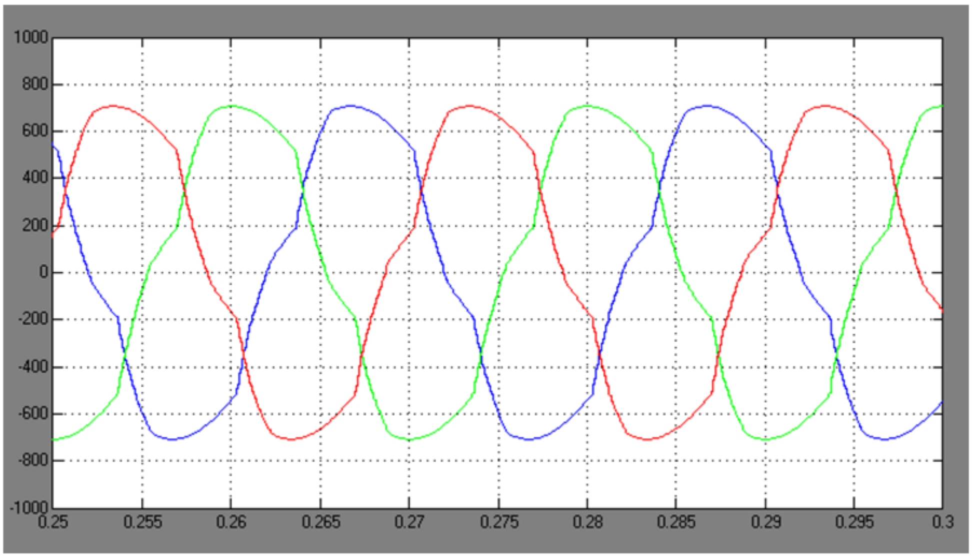

Fig 4.1 (b) Source Voltage Waveform without STATCOM/DSTATCOM

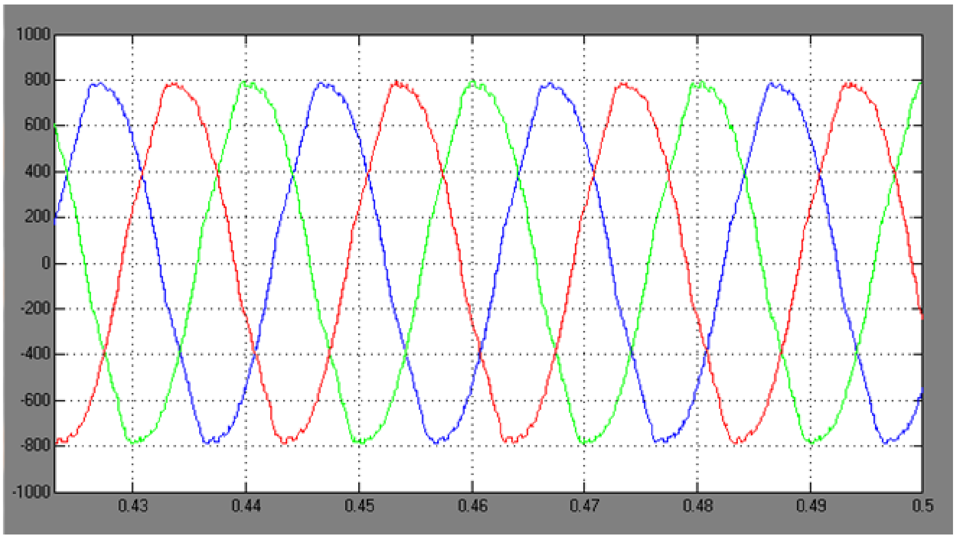

Fig 4.1 (c) load voltage waveform without SATCOM/DSTAT COM

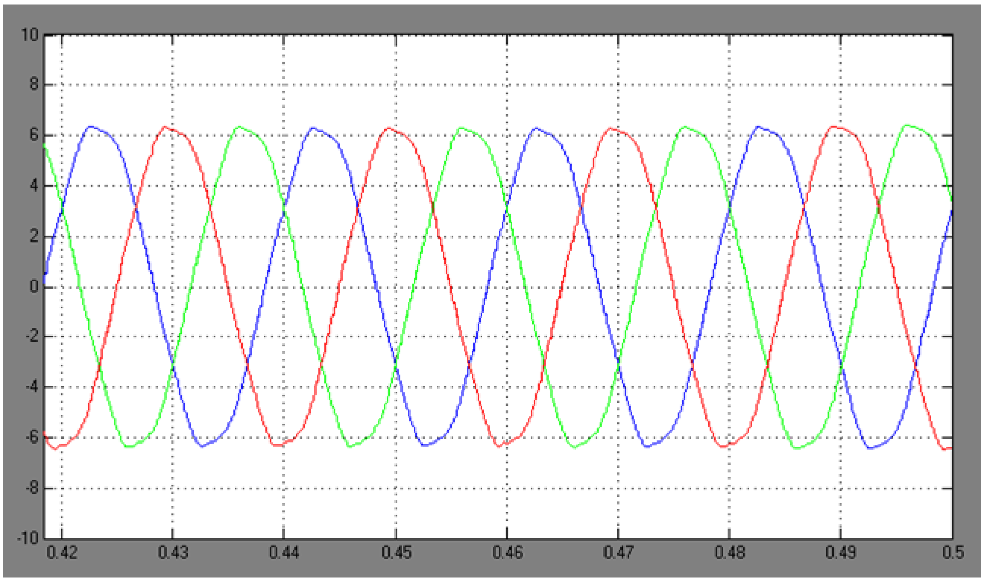

Fig 4.1 (d) load voltage waveform with STATCOM/DSTATCOM

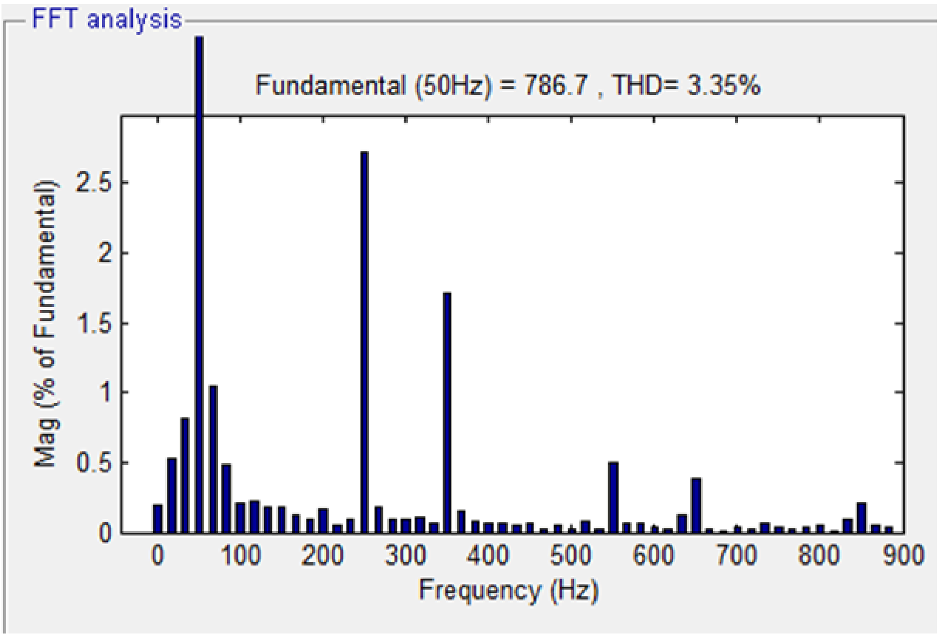

Fig 4.1(e) FFTAnalysis of load voltage with STATCOM/DSTATCOM

4.2 Simulation response

The system parameters considered for the study of voltage level improvement in 33kv power system network using SATCOM/DSTAT comis given below in Table 4.2

COMPONENTS	SPECIFICATIONS
AC Source	V_s=415v , f=50HZ , R_s=3.6$_S$Ω=5.8Mh,L
Non Linear Load	R_L=40Ω $_L$=50mH, L
Passive Filter	L_5=13.5mH C_5=30F , L_7=6.75mH $C_{5=}$50F

4.2 Simulation Response without STATCOM/DSTATCOM

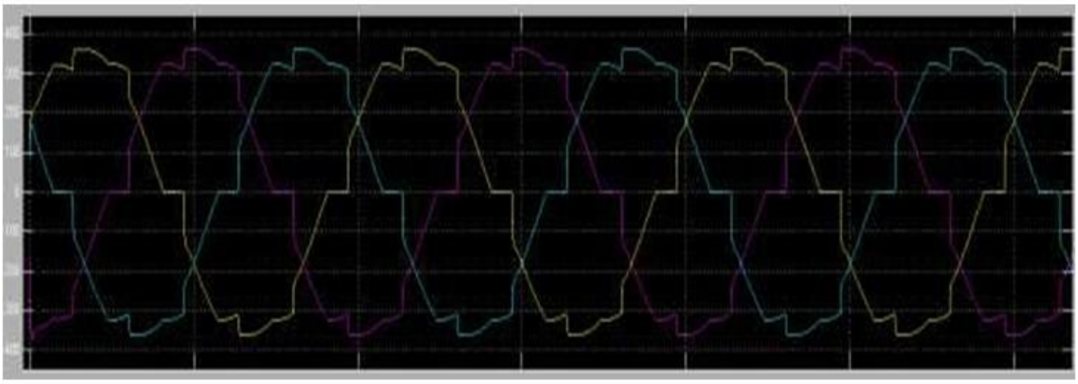

Figure-4.2(a) Waveforms of source voltage without STATCOM/DSTATCOM

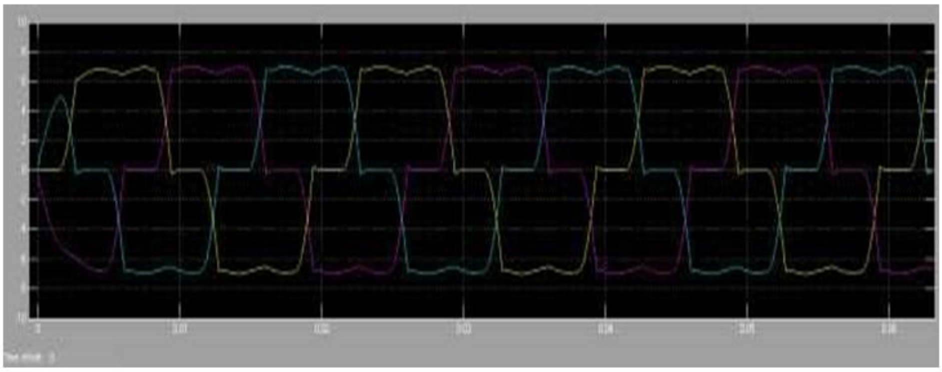

Figure-4.2(b) Waveforms of source current without STATCOM/DSTATCOM

4.2i Simulation Response with SATCOM/DSTAT COM

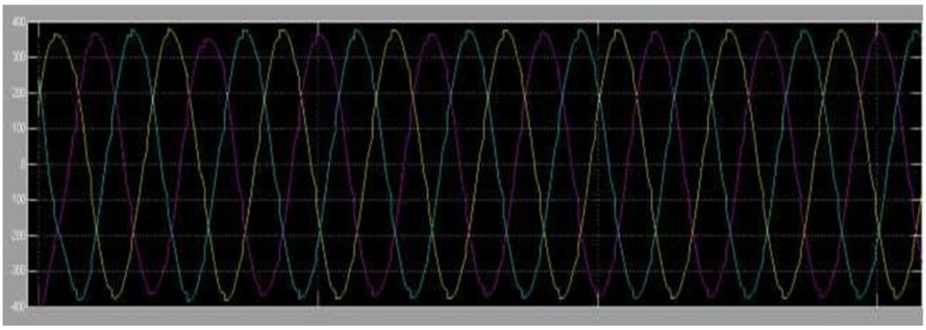

Figure 4.2© Waveforms of load current with SATCOM/DSTAT COM

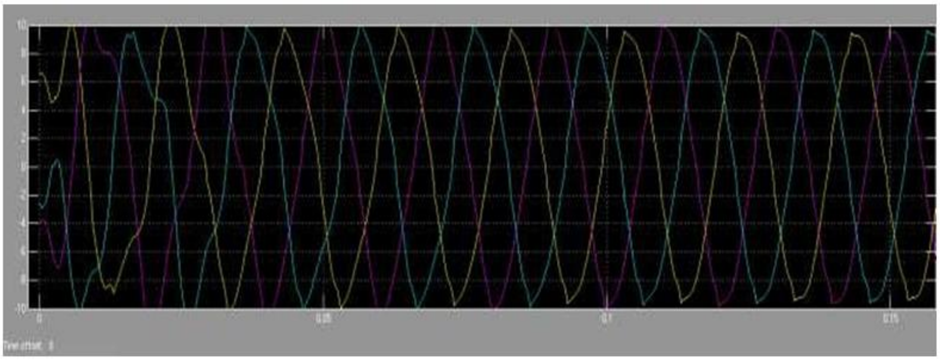

Figure 4.2(d) Waveforms of source voltage with SATCOM/DSTAT COM

4.5 Discussion of findings

Voltage sags and swells are examples of the power quality issues that our study has highlighted. The presentation included compensation methods for the STATCOM/DSTATCOM bespoke power electrical device. The design, applications, and thorough findings of DSTATCOM for voltage sags and swells were given. The simulation findings demonstrate that power losses resulting by faults and surges from unexpected load switching in the distribution system may be reduced by incorporating STATCOM/DSTATCOM. With the aid of Sinusoidal Pulse Width Modulation, the Voltage Source Convert (VSC) was put into operation (SPWM). The control strategy was evaluated in a variety of operational scenarios, and it was shown to be extremely reliable in each one.MATLAB/highly SIMULINK's developed visual capabilities were employed for the modeling and simulation of a DSTATCOM. The simulations run here demonstrated that the voltage control capabilities of the STATCOM/DSTATCOM are comparatively superior.

V. CONCLSUION AND RECOMMENDATIONS

5.1 CONCLUSION

The aim of this research project was to explore the effectiveness of STATCOM/ DSTATCOM at improving under-voltage problems due to load growth inTungbo feeder, Bayelsa state. The focus on Tungbo feeder is due to the high expense of upgrading them in the conventional manner to address voltage control issues brought on by load increase. The following aspects of STATCOM/ DSTATCOM installation and operation were explored in detail: (a) their location (b) VAR circulation avoidance (c) reactive power prioritizing (d) four quadrant operation and (e) the timing of installation and operation. The DSTATCOM control applied was with active power voltage drop and reactive power voltage drop characteristics that were implemented in a load flow study with modified Jacobian matrix elements.

5.2 FURTHER WORK

Given the relatively low cost of kVar injection relative to kW injection, it is very likely that a more economical approach would be to have STATCOM/ DSTATCOM rated so that Q-injection is not limited by the rating of the STATCOM/DSTATCOM. More investigations are needed to explore STATCOM/ DSTATCOM control schemes that accommodate Q-injection limits (Qmax) that are not due to the rating of the STATCOM/ DSTATCOM being reached.

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