e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

VOLTAGE STABILITY ENHANCEMENT USING STATIC VAR COMPENSATOR

Atuchukwu, A. J*1, Okonkwo, I. I.*2, Okoye, E. O.*3

*1Associate - Professor, Dept. of Electrical/Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Nigeria.

*2Lecturer, Dept. of Electrical/Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli. Nigeria.

*3PG Scholar, Dept. of Electrical/Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli. Nigeria.

ABSTRACT

The research studied the effect of static Var Compensator (SVC) in enhancing voltage stability in power system through effective reactive power compensation. In order to achieve this, the Otowvodo 15MVA, 33/11kV injection substation was used as a case study. Power flow equations involving voltage drop with or without Static Var Compensator were developed, SVC modeling equations were also developed and used to determine its parameters. Based on the SVC parameters, ETAP 7.0 Software was the major tool used in achieving this aim. From the load flow analysis without Static Var Compensator, it was found that 108 buses fall below the allowable voltage range of within ±5% of the nominal voltage. The voltage range was between 80.94 % (0.8094 p.u) and 91.47 % (0.9147p.u) and the total loss is 0.832MW and 1.763MVAR. These weak buses were compensated. To achieve this voltage improvement and power loss reduction, the positions of the Static Var Compensator was determined as Dumex and Ovie using voltage index method. The load flow report for each of these buses was noted. The bus at which this improvement was more effective was noted. This bus signified the optimal location for the placement of these Static Var Compensators. Beyond these SVC sizes at any location or in the same location result to further loss increase. These SVCs were placed at Dumex feeder and Ovie. These locations, Dumex and Ovie were proven to be the best locations for the voltage improvement and loss reduction. The sizes of the SVC are 50MVAR and 40MVAR for Dumex and Ovie respectively using systematic sampling method. A further increase in this SVC capacity and any change in location result in increase in total network loss. After the placement of the SVC, the range was between 86.92% (0.8692 p.u) and 98.60% (0.9860p.u). The loss in the network after SVC was in operation was 0.720MW and 1.552MVAR. This confirmed that Static Var Compensator could provide the fast acting voltage support necessary to prevent the possibility of voltage reduction and voltage collapse at the bus to which it was connected. With the application of Static Var Compensator, under voltage problem was solved successfully and power factor of the system also improved. From this end consideration should be given to the use of Static Var Compensator as its presence enhances stability of voltage. The use of modern technologies (FACTS Devices) such as the Static Var Compensator should be encouraged to reduce construction of more transmission lines and reduction in losses.

Keywords: Voltage Stability, Static Var Compensator, Load Flow, Systematic Sampling And Optimal Location.

I. INTRODUCTION

Nigeria networks are characterized by many disturbances, which cause various hindrances and outages. Power losses result in lower power availability to the consumers, leading to inadequate power to operate their appliances. Increased power demand pushes the power transmission network to its upper limits and beyond, resulting to shortening of the life span of the network or total collapse. Voltage variation that occurs is a function of length of the transmission lines, change in load on the supply system, and short circuiting. Principally, the cause of voltage variation at the consumer end is the change in load on the supply system. When the load on the system increases, the voltages at the consumers' terminals fall due to the increased voltage drop in transmission line feeders and transformers impedance.

The ever-known power compensation practice is to use reactive power compensation to increase the transmittable power in AC power systems. Fixed or mechanically-switched capacitors and reactors have long been employed to increase the steady-state power transmission by controlling the voltage profile along the lines.

An inherent characteristic of electric energy transmission and distribution by alternating current (AC) is that real power is generally associated with reactive power. AC transmission and distribution lines are dominantly reactive networks, characterized by their per-unit series inductance and shunt capacitance. Thus, load and load power factor change or alter the voltage profile along the transmission lines and can cause large amplitude variations in the receiving end voltage.

As a result, the system's reactive power needs to be continuously adjusted through effective reactive power compensation if the variation in the system's voltage must be kept within the allowable range. For passive compensation, shunt capacitors have been extensively used since the 1930s. They are either permanently connected to the system, or switched, and contribute to voltage control by modifying characteristics of the network [1].

The traditional methods used include: reconfiguration of system structure, generator excitation regulation, synchronous generator, changing the voltage by transformer tap to adjust the power flow in the grid, series compensation capacitor, switching in or out the shunt reactor or shunt capacitor etc. With these methods the desired objectives were not effectively achieved with wear and tear in the mechanical components and slow response being the major problems.

Improvements in the field of power electronics have had a major impact on the development of power compensation methods. The Electric Power Research Institute (EPRI) recently carried out extensive research works leading to the discovery of Flexible Alternating Current Transmission System (FACTS) devices, which have been mainly used for solving various power system steady state control problems such as voltage regulation, power flow control, and transfer capability enhancement with near instantaneous response.

These Flexible Alternating Current Transmission System (FACTS) devices include: Static Var Compensator (SVC), Thyristor-Controlled Series Capacitor (TCSC), Thyristor-Controlled Phase Shifter (TCPS), Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC) etc.

All these FACTS devices exhibit near instantaneous response to system changes and are made up of solid semi-conductor components thereby eliminating the problems of mechanical wear and tear. One of the most important applications of these devices is to keep system voltage profiles at desirable levels by compensating for the system reactive power. By employing these devices for reactive power compensation, both the stress and the heavily loaded lines and losses are easily reduced as a consequence of line loadability, which is increased. The two main objectives of FACTS are to increase the transmission capacity of lines and control power flow over designated transmission routes [2].

Flexible AC Transmission System (FACTS) controllers, such as the Static Var Compensator (SVC), employ the latest technology of power electronic switching devices in electric power transmission systems to control voltage and power-flow, and improve voltage regulation.

Static Var Compensators are being increasingly applied in electric transmission systems to economically improve voltage control and post-disturbance recovery voltages that can lead to system instability. An SVC provides such system improvements and benefits by controlling shunt reactive power sources, both capacitive and inductive, with state-of-the-art power electronic switching devices.

When voltage security or congestion problems are observed during the planning study process, cost effective solutions must be considered for such problems. Traditional solutions to congestion and voltage security problems were to install new costly transmission lines that are often faced with public resistance, or mechanically-switched capacitor banks that have limited benefits for dynamic performance due to switching time and frequency. One approach to solving this problem is the application of "Flexible AC transmission System" (FACTS) technologies, such as the Static Var Compensator (SVC). FACTS technologies are founded on the rapid control response of thyristor-based reactive power controls

It is the aim of this study to enhance voltage stability of 33kV/11kV Otovwodo distribution line using Static Var Compensator. Otovwodo distribution is always supplying low voltage, voltage below statutory limit. Other problem are distribution losses and lack of adequate reactive power injection in the system. It has become pertinent that this abnormally must be controlled to save expensive distribution equipment like transformers, consumers appliances and resultant fault that may led to hazard to equipment and human beings.

a) APPLICATION OF STATIC VAR COMPENSATION TECHNOLOGY IN POWER SYSTEM

Biswas in [3] studied voltage level improvement by Using Static VAR Compensator (SVC). In this work, potential applications of Flexible AC Transmission System (FACTS) controllers, such the Static VAR Compensator (SVC), using the latest technology of power electronic switching devices in the field of electric power transmission systems with controlling voltage and power flow, and improving the voltage regulation was explored. Again, the Static VAR Compensators are being increasingly applied in electric transmission systems economically to improve the post-disturbance recovery voltages that can lead to system instability. A SVC performs such system improvements and benefits by controlling shunt reactive power sources, both capacitive and inductive, with high-tech power electronic switching devices. [3] proposed solution problems of poor dynamic performance and voltage regulation in 115kV and 230kV transmission system using SVC.

In [4] Avneesh, et al analyzed efficient transmission line voltage regulation using Fuzzified Soft Static VAR Compensator. The Static VAR Compensator is basically a shunt connected variable VAR generator whose output is adjusted to exchange capacitive or inductive current to the system. One of the most widely used configurations of the SVC is the FC- TCR type in which a Fixed Capacitor (FC) is connected in parallel with Thyristor Controlled Reactor (TCR). Avneesh, et al were able to prove the conventional Static VAR Compensator not able to provide an efficient voltage regulation due to the fact that, the line voltage fluctuations are very much random and imprecise. So for efficient line voltage regulation some tool is required, which can precisely handle the random line voltage fluctuations.

The best tool for handling imprecise situations is Fuzzy Logic. Hence conventional Static VAR Compensator along with Fuzzy is the best fitted combination for achieving an efficient line voltage regulation.

In [5] Roberto, et al investigated increase of voltage stability and power limits using a Static VAR Compensator. The objectives of this study were to increase the transmitted power, under the thermal capacity, through an overhead transmission line using a voltage stability criterion. The used approach has been the voltage stability, with the purpose of keeping the voltage magnitude on the main buses within the range of 0.8-1.2 p.u., during the transient state and after a fault located anywhere in the systems. In conclusion of this study, Roberto, et al stated that the application of the dynamic compensator (SVC) for increasing the power flow, under the thermal capacity, through an overhead transmission line using a voltage stability criterion to achieve the propose target. This was fulfilled by simulations carried out in the Alternative Transient Program/Electromagnetic Transient Program (ATP/EMTP) program of a model of the power system located in the southeast region of Venezuela, where exist important loads related with the oil industry using as a voltage criterion a specified range of 1.2-0.8 p.u., for the voltage variation.

In [6] Alok, et al studied enhancement of transient stability in transmission line using Static VAR Compensator FACTS controller. The paper discussed and demonstrated how Static VAR Compensator has successfully been applied to control transmission systems dynamic performance for system disturbance and effectively regulate system voltage. Static VAR Compensator is a shunt connected FACTS devices, and plays an important role as a stability aid for dynamic and transient disturbances in power systems. UPFC controller is another

FACTS device which can be used to control active and reactive power flows in a transmission line. The damping of power system oscillations after a three-phase fault is also analyzed with the analysis of the effects of SVC on transient stability performance of a power system. A general program for transient stability studies to incorporate FACTS devices is developed using modified partitioned solution approach. The modeling of SVC for transient stability evaluation is studied and tested on a 10-Generator, 39 - Bus, New England Test System [7] investigated the opportunities to install FACTS devices (Static Var Compensator) in a 132 kV transmission Network. Prakash and Sheesh modeled the network in MATLAB/SIMULINK environment and result obtained from the simulation with and without the SVC showed an increase in transmission capacity with a corresponding decrease in transmission line losses.

In [8] Pateriya, et al also carried out analysis on Transfer Capability Enhancement of Transmission Line Using Static VAR Compensator. The study employed the shunt connected compensation (SVC) based FACTS device for the control of voltage, reactive power, active power and power damping oscillations in long distance transmission line. The work dealt with determination of the optimal location of shunt Flexible AC Transmission System (FACTS) devices for a long transmission line for voltage and power transfer improvement. The result also shows that optimal location depends upon voltage magnitude and line loading and system initial operating conditions. [8] (Pateriya and Saxena, 2013) carried out test on two machine 4-bus systems, simulated using MATLAB/SIMULINK environment.

In [9] a PhD thesis on the use of Flexible AC Transmission System (FACTS) devices in enhancing the efficiency of an Electrical Network; a case study of the Nigeria 330kV transmission grid, recommended the use of FACTC devices to reduce power losses, improvement in power system stability and bus voltage magnitude instead of building more generating stations and transmission lines. The thesis further suggested the replacement of the conventional compensators (reactors, capacitors and synchronous condensers) with FACTS devices to mitigate the problem of overloaded lines due to increased electric power transmission by controlling power flows and voltage and enhance system stability.

In [10] Mark investigated the effect of Static Var Compensator (SVC) on voltage stability of a power system. Mark in his work described the functional structure for SVC built with a Thyristor- Controlled Reactor (TCR) and its model. This model was based on representing the controller as variable impedance that changes with the firing angle of TCR. Simulation which was carried out using Power System Computer Aided Design / Electromagnetic Transients confirmed that Static Var Compensator could provide the fast- acting voltage support necessary to prevent the possibility of voltage reduction and voltage collapse at the bus to which it is connected.

In [11] Naseer studied Enhancement of Power System Transient Stability Using Static Var Compensator. In his discussion and result, the SVC is connected to bus so as to control this bus voltage to a value of 1pu.

In [12] Habibur, et al researched into Stability Improvement of Power System Using a model of Static VAR Compensator (SVC) which is controlled externally by a Proportional-Integral- Derivative (PID) controller. The PID controller parameter was selected by using Ziegler-Nichols tuning rule method. Both single and three phase faults were considered. [12] simulated the network using phasor simulation method from which it was observed that SVC with PID controller is more effective to enhance voltage stability and increase power transmission capacity.

b) Overview on Static Var Compensator (SVC) Placement Techniques

Many researchers have been done research about methods of Static Var Compensator placement. [13] divided the methods into three categories: conventional method, heuristic method, and sensitivity-based method. Sensitivity-based methods use index, modal, or eigenvalue analysis. [14] used genetic algorithm-based method to determine SVC placement. [15] used novel global harmony search algorithm to optimize allocation of SVC. [16] used cuckoo search algorithm and [17] used BAT and firefly algorithm to optimize sizing and placement of SVC. [18] used particle swarm optimization method and [19] used cluster identification to determine SVC placement. [20] used dragon fly algorithm, [21] used heuristic optimization method, and [22]. use hybrid GA-PSO algorithm to optimize SVC placement. [23] – [26] used sensitivity approach to determine SVC and STATCOM placement.

II. METHODOLOGY

The methodology adopted for this research includes:

1. Power flow analysis of the network to determine the real and reactive power at each bus and its voltages without the compensator using ETAP 7.0 Software.
2. Static Var Compensator (SVC) optimal placement and sizing using voltage index method and optimum sizing of SVC using systematic sampling method.
3. Simulation of the network using ETAP 7.0 Software to obtain the power flow analysis with the compensator.
4. Graphical representation and comparison of the results for with and without SVC simulation of Otovwodo, 15MVA, 33/11kV injection.

a) Modeling of SVC

From the view point of power system operation, an SVC is equivalent to a shunt capacitor and a shunt reactor as depicted in Figure 1 that can be adjusted to control the voltage and reactive power at its terminals in a prescribed manner [1].

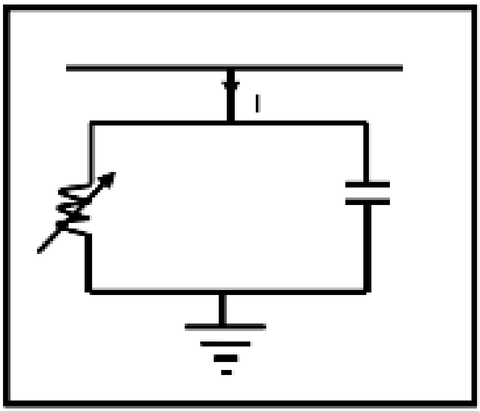

Figure 1: Ideal Static VAR System

b) Configurations of SVC/Numerical Analysis

There are two configurations of SVC

a) SVC total susceptance. A changing susceptance represents the fundamental frequency equivalent of all shunt models making up the SVC as shown in Figure 2.

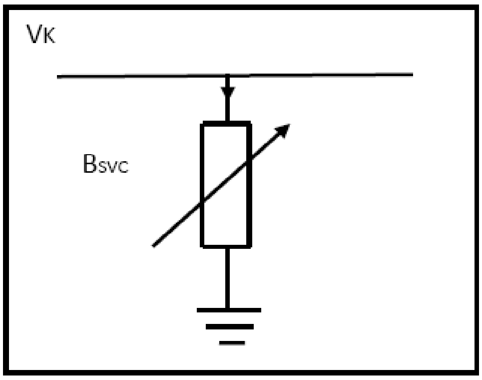

Figure 2: Variant shunt susceptance

b) SVC firing angle model. The equivalent susceptance which is a function of the firing angle α is made up of the parallel combination of TCR equivalent admittance and a fixed capacitive reactance, as shown in Figure 3.
With reference to Figure 2 and 3, the following equations can be written as in [27].

$$V = V_0 + X_{sl*} I_s \qquad (1)$$

$$I_{SVC} = jB_{SVC} * V_k \qquad (2)$$

$$Q_{SVC} = Q_k = -V_k^2 * B_{SVC} \qquad (3)$$

The linearized equation is given by equation 4, where the equivalent susceptance is taken to be the state variable.

$$\begin{bmatrix} \Delta P_k \\ \Delta Q_k \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & Q_k \end{bmatrix} \begin{bmatrix} \Delta \delta_k \\ \Delta B_{SVC} / B_{SVC} \end{bmatrix} \qquad (4)$$

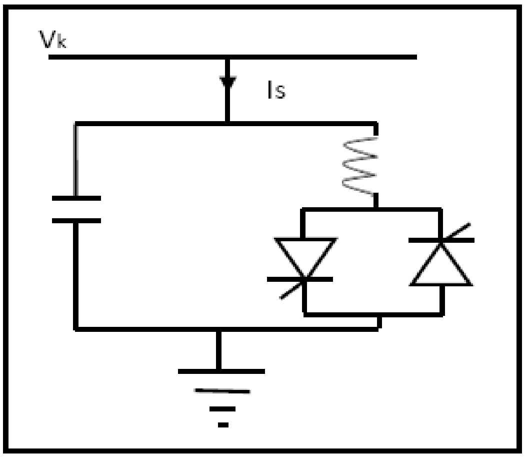

Figure 3: SVC Firing Angle Model

The changing susceptance represents the total SVC susceptance necessary to maintain the nodal voltage magnitude at the specified value.

[28] showed the mathematical implementation of firing angle model of SVC which handles the TCR firing angle as a state variable in the power flow formulation. It is expressed as follows:

$$B_{SVC} = \frac{1}{X_c X_l}\left\{X_l - \frac{X_c}{\pi[2(\pi-\alpha)+\sin 2\alpha]}\right\} \quad (5)$$

Where

$$X_c = \frac{1}{W_c} \quad (6)$$

$$X_l = W_l \quad (7)$$

α: is the firing angle

$$Q_k = \frac{-V_k^2}{X_c X_l}\left\{X_l - \frac{X_c}{\pi[2(\pi-\alpha)+\sin 2\alpha]}\right\} \quad (8)$$

From equation 8, the linearized SVC equation is given in equation 9.

$$\begin{bmatrix}\Delta P_k \\ \Delta Q_k\end{bmatrix} = \begin{bmatrix}0 & 0 \\ 0 & \frac{2V_k^2}{\pi X_l}(cos(2\alpha)-1)\end{bmatrix}\begin{bmatrix}\Delta\delta_k \\ \Delta\alpha\end{bmatrix} \quad (9)$$

At the end of iteration, the variable firing angle is updated according to equation 10

$$\alpha(i) = \alpha(i-1) + \Delta\alpha \quad (10)$$

c) Voltage Index Method for SVC Positioning

To obtain significant improvement, VAR compensator should be placed on the buses having severe voltage problems. To assess the level of voltage problem of each bus, voltage index as formulated in [26] is utilized.

$$V_{score\ i} = 1 - \frac{V_i - V_{min}}{1 - V_{min}}, \quad V_i \leq 1 \quad (11)$$

Where

Vmin= minimum permissible system voltage.

Vi = voltage at bus i.

Using the index, the severity of voltage problem at each bus can be addressed. When the voltage problem at a bus is more severe, the voltage index at that bus is higher.

d) Systematic Sampling Method of SVC Sizing

Having ranked the buses for SVC position placement using voltage index the next step is to determine the size of SVC using systematic sampling method. Systematic sampling method is a statistical method the following procedures are used.

(1) Choose 0 – N MVar as the range of the Var power of the SVC and divide the maximum Var power by n sample to get k sampling rate.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

$$\Rightarrow \quad k = \frac{N}{n} \qquad (12)$$

(2) Insert SVC in the bus with the most severity voltage problem according voltage index ranking. Start performing load flow simulations to determine the system loss by increasing the size of the SVC systematically using the sample rate k. in each sampled load flow record the system loss as SVC is still said position.

(3) System loss is a quadratic function, when it decreases upon insertion of enhancing device it will attend the minimum and then start increasing again. So, reducing the sampling within the neighborhood of the optimal size of the SVC will help obtain the closest value to the optimal size of the SVC. To achieve this, modify equation (12) as follows to get new sampling rate k around the neighborhood of the optimum size of the SVC.

$$k = \frac{N_2 - N_1}{n_1} \qquad (13)$$

Where N_1, N_2 are the left and right hand of the SVC optimum size neighborhood.

N_1 is the intend sample (simulation) around the SVC optimum size neighborhood.

III. MATERIALS FOR THE RESEARCH

Otovwodo 11 kV distribution system is the research system and is shown as a single line in figure 4, while the associated buses are shown in table 1. The data for Otovwodo 11 kV system is presented in the table 2.

Table 1: Otovwodo 11 kV Distribution System Buses

Bus Number	Bus name	Bus Number	Bus name
1	OTOVWODO SUBSTATION	55	ROBERT A TM
2	OTOVWODO 11 KV BUS	56	DORTIE TM
3	ISOKO FEEDER	57	OTOVWODO 2 TM
4	DUMEX FEEDER	58	T31
5	ODUOPHORI TM	59	OTOVWODO 4 TM
6	OVIRIOGOR 2 TM	60	BISHOP AI TM
7	OVIRI OGOR 1TM	61	BISHOP TM
8	OVIE TM	62	AGBARHA JNC TM
9	OGBALOR TM	63	AGBARHA RD TM
10	OGBALOR CR1 TM	64	UDUERE 3 TM
11	MAKOLOMI 1 TM	65	SLAUGHTER RD TM
12	MAKOLOMI TM	66	AGBARHA 1 TM
13	ONOGHARIGHO TM	67	UDUERE 2 TM
14	UTORO TM	68	AGBARHA 2 TM
15	UPPER AGBARHO 5 TM	69	UDUERE 1 TM
16	UPPER AGBARHO 1 TM	70	OPHERIN TM
17	UPPER AGBARHO 3 TM	71	OWEYWE TM
18	UPPER AGBARHO 6 TM	72	SANIKO TM
19	UPPER AGBARHO 4 TM	73	GANA JNC TM
20	UPPER AGBARHO 2 TM	74	OMABEWE 2 TM
21	UPPER AGBARHO 3 TM	75	ETEFE TM
22	SADJERE 1 TM	75	OMABEWE 1 TM
23	SADJERE TM	76	OKPHO AGARA TM

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

24	POC WATER TM	77	OTERI TM
25	WINNER TM	79	AWIRHA TM
26	NCC (AIRTEL) TM	80	MR BIGGS
27	EVWIETA TM	81	FIRST BANK TM
28	UBA AI	82	GRUBBS
29	UBA	83	OLORI EST
30	PTI AI	84	OLORI RD TM
31	PTI TM	85	OLORI RDJN TM
32	NNPC TM	86	6 MTN PL TM
33	OVIRI CR TM	87	ETI TM
34	SHELL TM	88	MUDI 2 TM
35	ECOBANK TM	89	MUD 1 TM
36	SHELL (S/S) TM	90	LOW COST
37	MTN II TM	91	HERO FAITH TM
38	MTN III BUS	92	IGHOJA TM
39	CASSIDY 1 TM	93	OMENEMU TM
40	CASSIDY TM	94	UNION BANK
41	OFOR 2 TM	95	NCC TM
42	OFOR 1 TM	96	PIPE LINE
43	D' ROSE TM	97	AFISERE TM
44	D' ROSE 1 TM	98	OGELE TM
45	MARVE SCH TM	99	ORUBU TM
46	MARVE SCH 1 TM	100	MTN 1(PL)
47	IKPRUKPRU 5 TM	101	ROUND ABT TM
48	IKPRUKPRU 6 TM	102	AMEKPA 3 TM
49	IKPRUKPRU 1 TM	103	AMEKPA 2
50	IKPRUKPRU 7 TM	104	AMEKPA TM
51	IKPRUKPRU 4 TM	105	2ND AMKPA TM
52	DANIEL 1 TM	106	HOLY SALVATION TM
53	IKPRUKPRU 3 TM	107	DANIEL TM
54	IKPRUKPRU 2 TM	108	IGHAGBOMI TM

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

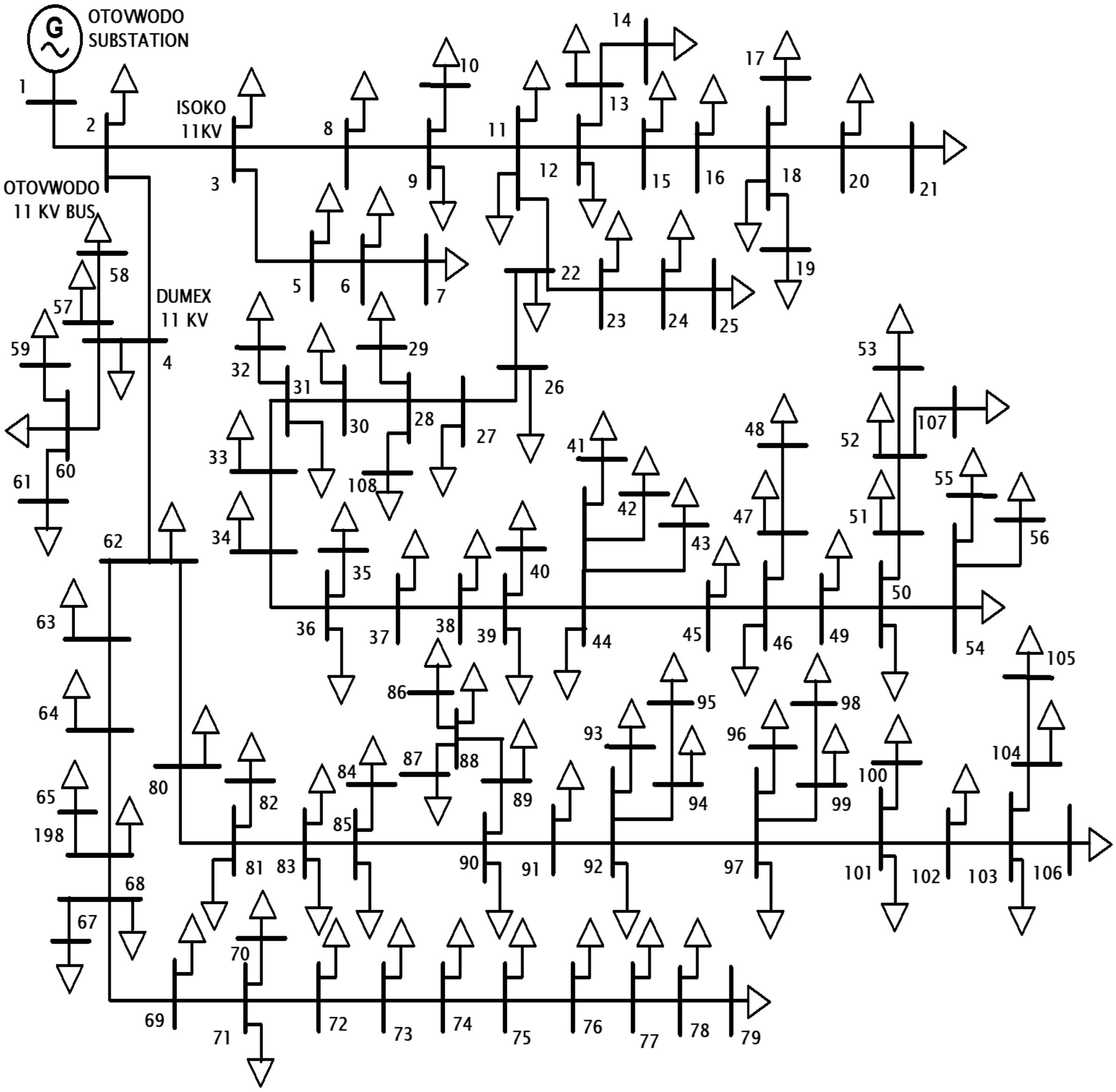

Figure 4: One Line Diagram Showing Otovwodo 11 kV Distribution System

Table 2: Line Parameters

Bus	Bus	Single Line	R	X	Z	Y
OTOVOWODO SUBSTATION	OTOVOWODO 11 kV BUS	1	15.53	22.46	27.31	0.0272043
OTOVOWODO 11 kV BUS	ISOKO FEEDER	3	2.72	3.57	4.49	5.23E-05
OLORI EST	FIRST BANK TM	12	1.17	1.53	1.93	2.24E-05
OVIE TM	ISOKO FEEDER	16	1.17	1.53	1.93	2.24E-05
GRUBBS	FIRST BANK TM	19	1.17	L53	1.93	2.24E-05
ODUOPHORI TM	ISOKO FEEDER	8	10.51	13.78	17.33	0.000202
OLORI EST	OLORI RDJN TM	11	3.50	4.59	5.78	6.72E-05
ODUOPHORI TM	OVIRIOGOR 2 TM	7	46.70	6124	77.01	0.000897

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

OLORI RDJN TM	OLORI RD TM	20	14.01	18_37	23.10	0.000249
OVIRIOGOR 2 TM	OVIRI OGOR 1TM	9	9.34	12.25	15.40	0.000179
OVIE TM	OGBALOR TM	15	8.17	10.72	13.48	0.000157
OLORI RDJN TM	LOW COST	21	7.01	9.19	11.55	0.000135
LOW COST	MUD 1 TM	34	14.01	1857	23.10	0.000269
OGBALOR TM	GRUBBS	17	8.17	10.72	13.48	0.000157
MUD 1 TM	MUDI 2 TM	36	8.17	10.72	13.48	0.000157
OGBALOR TM	MAKOLOMI 1 TM	18	4.67	6.12	7.70	8.96E-05
MUDI 2 TM	6 MTN PL TM	40	4.67	6.12	7.70	8.96E-05
SADJERE 1 TM	SADJERE TM	3	2.34	3.06	3.85	4.48E-05
SADJERE 1 TM	SADJERE TM	5	15.18	19.90	25.03	0.000291
MUDI 2 TM	ETI TM	41	7.01	919	11.55	0.000135
SADJERE TM	POC WATER TM	106	2.34	3.06	3.85	4.48E-05
POC WATER TM	WINNER TM	22	2.34	3.06	3.85	4.48E-05
IGHOJA TM	HERO FAITH TM	55	14.01	13.37	23.10	0.0002689
SADJERE 1 TM	NCC (AIRTEL) TM	4	1.17	1.53	1.93	0.0000224
NCC (AIRTEL) TM	SADJERE 1 TM	13	5.84	7.65	9.63	0.0001121
IGHOJA TM	OMENEMU TM	52	2.34	3.06	3.85	0.0000448
NCC (AIRTEL) TM	EVWIETA TM	14	3.50	4.59	5.78	0.0000672
EVWIETA TM	UBA AI	23	1.17	1.53	1.93	0.0000224
UBA AI	UBA	24	18.68	24.49	30.80	0.0003586
UBA AI	IGHAGBOMI TM	25	1.17	L53	1.93	0.0000224
NCC TM	UNION BANK	64	5.84	7.65	9.63	0.0001121
UBA AI	PTI AI	26	1.17	1.53	1.93	0.0000224
IGHOJA TM	UNION BANK	53	5.84	7.65	9.63	0.0001121
PTI AI	PTI TM	28	5.84	7.65	9.63	0.0001121
PTI TM	NNPC TM	29	3.50	4.59	5.78	0.0000672
OVIRI CR TM	SHELL TM	30	3.50	4.59	5.78	0.0000672
IGHOJA TM	AFISERE TM	54	11.68	1531	19.25	0.0002241
SHELL TM	SHELL (S/S) TM	31	2.34	106	3.85	0.0000448
SHELL (S/S) TM	ECOBANK TM	32	4.67	6.12	7.70	0.0000896
SHELL (S/S) TM	MTN II TM	33	5.84	7.65	9.63	0.0001121
MTN II TM	MTN III BUS	37	1.17	1.53	1.93	0.0000224
MTN III BUS	CASSIDY 1 TM	39	9.34	12.25	15.40	0.0001793
CASSIDY 1 TM	CASSIDY TM	42	1.17	1.53	1.93	0.0000224
CASSIDY 1 TM	D' ROSE 1 TM	43	9.34	12.25	15.40	0,0001793
AFISERE TM	PIPE LINE	69	18.68	24.49	30.80	0.0003586

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

D' ROSE 1 TM	D' ROSE TM	44	1.17	1.53	1.93	0.0000224
AFISERE TM	ORUBU TM	70	11.68	15.31	19.25	0.0002241
D' ROSE 1 TM	OFOR 1 TM	45	1.17	L53	1.93	0.0000224
D' ROSE 1 TM	OFOR 2 TM	46	3.50	4.59	5.78	0.0000672
D' ROSE 1 TM	MARVE SCH TM	47	4.67	6.12	7.70	0.0000896
MARVE SCH TM	MARVE SCH 1 TM	48	3.50	4.59	5.78	0.0000672
MARVE SCH 1 TM	IKPRUKPRU 1 TM	49	8.17	10.72	13.48	0.0001569
ORUBU TM	OGELE TM	81	8.17	10.72	13.48	0.0001569
IKPRUKPRU 5 TM	IKPRUKPRU 6 TM	50	12.84	16.84	21.18	0.0002465
IKPRUKPRU 1 TM	IKPRUKPRU 7 TM	51	8.17	10.72	13.48	0.0001569
ROUND ABT TM	MTN 1(PL)	92	16.35	21.43	26.95	0.0003138
IKPRUKPRU 7 TM	IKPRUKPRU 4 TM	56	5.84	7.65	9.63	0.0001121
ROUND ABT TM	AMEKPA 3 TM	93	8.17	10.72	13.48	0.0001569
IKPRUKPRU 4 TM	DANIEL 1 TM	58	5.84	7.65	9.63	0.0001121
AMEKPA 3 TM	AMEKPA 2	96	14.01	1837	23.10	0.0002689
DANIEL 1 TM	IKPRUKPRU 3 TM	59	5.84	7.65	9.63	0.0001121
AMEKPA 2	HOLY SALVATION TM	99	8.17	10.72	13.48	0.0001569
DANIEL 1 TM	DANIEL TM	60	10.51	13.78	17.33	0.0002017
IKPRUKPRU 7 TM	IKPRUKPRU 2 TM	57	3.50	4.59	5.78	0.0004672
AMEKPA 2	AMEKPA TM	100	18.68	24.49	30.80	0.0003586
IKPRUKPRU 2 TM	DORTIE TM	62	10.51	13.78	17.33	0.0002017
IKPRUKPRU 2 TM	ROBERT A TM	63	11.68	1531	19.25	0.0002241
AMEKPA TM	2ND AMKPA TM	105	14.01	1837	23.10	0.0002689
SADJERE 1 TM	MAKOLOMI 1 TM	6	3.50	4.59	5.78	0.0000672
MAKOLOMI 1 TM	MAKOLOMI TM	65	12.84	16.84	21.18	0.0002465
MAKOLOMI TM	UPPER AGBARHO 5 TM	66	10.51	13.78	17.33	0.0002017
UPPER AGBARHO 5 TM	UPPER AGBARHO 1 TM	68	4.67	6.12	7.70	0.0000896
UPPER AGBARHO 1 TM	UPPER AGBARHO 6 TM	71	8.17	10.72	13.48	0.0001569
UPPER AGBARHO 6 TM	UPPER AGBARHO 3 TM	72	5.84	7.65	9.63	0.0001121
UPPER AGBARHO 6 TM	UPPER AGBARHO 4 TM	73	15.18	19.90	25.03	0.0002914
UPPER AGBARHO 6 TM	UPPER AGBARHO 2 TM	74	5.84	7.65	9:63	0.0001121;
UPPER AGBARHO 2 TM	UPPER AGBARHO 3 TM	75	3.50	4.59	5.78	0.0000672
MAKOLOMI TM	ONOGHARIGHO TM	67	11.68	15.31	19.25	0.0002241

ONOGHARIGHO TM	UTORO TM	77	12.84	16.84	21.18	0.0002465
OTOVOWODO 11 kV BUS	ISOKO FEEDER	2	3.50	4.59	5.78	0.0000672
OTOVWODO 2 TM	DUMEX FEEDER	27	16.35	21.43	26.95	0.0003138
T31	OTOVWODO 2 TM	38	14.01	18.37	23.10	0.0002689
OTOVWODO 4 TM	BISHOP AI TM	61	3.50	459	5.78	0.0000672
BISHOP TM	BISHOP AI TM	76	4.67	6.12	7.70	0.0000896
BISHOP AI TM	DUMEX FEEDER	80	17.51	22.96	28.88	0.0003362
AGBARHA JNC TM	DUMEX FEEDER	84	4.67	6.12	7.70	0.0000896
AGBARHA JNC TM	AGBARHA RD TM	82	4.67	6.12	7.70	0.0000896
UDUERE 1 TM	AGBARHA 2 TM	86	3.50	4.59	5.78	0.0000672
AGBARHA RD TM	UDUERE 3 TM	85	11.68	15.31	19.25	0.0002241
SLAUGHTER RD TM	AGBARHA 1 TM	89	7.01	9.19	11.55	0.0001345
UDUERE 2 TM	AGBARHA 2 TM	90	12.84	16.84	21.18	0.0002465
UDUERE 3 TM	AGBARHA 1 TM	88	17.51	22.96	28.88	0.0003362
AGBARHA 1 TM	AGBARHA 2 TM	91	54.87	7L95	90.49	0.0010534
UDUERE 1 TM	OWEYWE TM	87	31.52	4L33	51.98	0.0006051
OWEYWE TM	SANIKO TM	95	16.35	2L43	26.95	0.0003138
OWEYWE TM	OPHERIN TM	94	7.01	9.19	11.55	0.0001345
SANIKO TM	GANA JNC TM	97	18.68	24.49	30.80	0.0003586
GANA JNC TM	OMABEWE 2 TM	98	51.37	67.36	84.71	0.0009861
OMABEWE 2 TM	OMABEWE 1 TM	101	3.50	4.59	5.78	0.0000672
OMABEWE 2 TM	OKPHO AGARA TM	102	21.15	27.73	34.87	0.0004059
OKPHO AGARA TM	OTERI TM	104	19.85	26.03	32.73	0.000381
ETEFE TM	OTERI TM	79	45.53	59.71	75.09	0.0008741
LOW COST	HERO FAITH TM	35	10.51	13.78	17.33	0.0002017
ETEFE TM	AWIRHA TM	78	45.53	59.71	75.09	0.0008741
FIRST BANK TM	MR BIGGS	103	9.34	12.25	15.40	0.0001793
AGBARHA JNC TM	MR BIGGS	83	4.67	6.12	7.70	0.0000896

IV. RESULTS AND DISCUSSION

From the data obtained, Electrical Transient Analyzer Program (ETAP) 7.0 software program was used in carrying out the load flow study. ETAP Real-Time is a fully integrated suite of electrical software applications that provides intelligent power monitoring, energy management, system optimization, advanced automation, and real-time prediction.

a) Results Presentation

The result of the voltage index ranking for the substation buses for the optimum prediction of positional placement of the SVC is shown table 3, while the result of the voltage profile of the simulation of Otowvodo 15MVA, 33/11kV distribution substation when SVC is included or not are shown in table 4 and the graphical representation is shown in figure 5. Research simulation shown in figure 5 through figure 8 and table 4 through table 7 showed the results and performance of SVC inserted 33 kV/11kV Otovwodo distribution network.

Table 3: Voltage Index Ranking for the Substation Buses

Rank	Bus	Voltage Index
1	Dumex Feeder	1.101384
2	OVIE Feeder	1.101374
3	Isoko Feeder	1.101358

The buses chosen for consideration include Dumex feeder, Isoko feeder and Ovie of Otovwodo 11kV distribution side see table 3. It was found that 50MVar and 40MVar is required to improve the voltage profile of the network, and also reduce the power losses. To achieve the voltage improvement and power loss reduction, the position and the size of the Static Var Compensator were predicted using methodology presented in section II (c) and (d) respectively.

Table 4: Simulation Result Obtained without and with SVC

Single line bus Number	Bus name	System Base bus voltage (%)	System bus phase angle	System bus voltage (%) Svc inserted	System bus phase angle (Svc inserted)
1	OTOVWODO SUBSTATION	91.48	-2.0	98.43	-1.5
2	OTOVWODO 11 KV BUS	88.51	-4.8	98.6	-4.4
3	ISOKO FEEDER	88.21	-4.8	98.41	-4.6
4	DUMEX FEEDER	88.08	-4.8	98.32	-4.6
5	ODUOPHORI TM	88.17	-4.8	98.37	-4.6
6	OVIRIOGOR 2 TM	88.07	-4.9	98.25	-4.6
7	OVIRI OGOR 1TM	88.05	-4.9	98.23	-4.6
8	OVIE TM	88.13	-4.8	98.37	-4.6
9	OGBALOR TM	87.97	-7.2	97.75	-4.8
10	OGBALOR CR1 TM	87.57	-5.0	97.75	-4.8
11	MAKOLOMI 1 TM	87.26	-5.2	97.40	-4.9
12	MAKOLOMI TM	87.00	-5.3	97.12	-5.0
13	ONOGHARIGHO TM	86.93	-5.3	97.03	-5.1
14	UTORO TM	86.90	-5.3	96.99	-5.1
15	UPPER AGBARHO 5 TM	86.88	-5.3	96.97	-5.1
16	UPPER AGBARHO 1 TM	86.83	-5.3	96.92	-5.1
17	UPPER AGBARHO 3 TM	86.78	-5.3	96.86	-5.1
18	UPPER AGBARHO 6 TM	86.78	-5.3	96.86	-5.1
19	UPPER AGBARHO 4 TM	86.76	-5.4	96.86	-5.1
20	UPPER AGBARHO 2 TM	86.74	-5.4	96.84	-5.1
21	UPPER AGBARHO 3 TM	86.73	-5.4	96.81	--5.1
22	SADJERE 1 TM	87.10	-5.2	97.22	-5.0

23	SADJERE TM	87.09	-5.2	97.11	-5.0
24	POC WATER TM	87.07	-5.2	97.19	-5.0
25	WINNER TM	87.05	-5.2	97.19	-5.0
26	NCC (AIRTEL) TM	87.05	-5.2	97.17	-5.0
27	EVWIETA TM	86.96	-5.3	97.06	-5.0
28	UBA AI	86.82	-5.3	96.91	-5.1
29	UBA	86.82	-5.3	96.91	-5.1
30	PTI AI	86.61	-5.4	96.68	-5.2
31	PTI TM	86.43	-5.5	96.44	-5.2
32	NNPC TM	86.40	-5.5	96.44	-5.2
33	OVIRI CR TM	86.99	-5.5	96.32	-5.3
34	SHELL TM	86.19	-5.5	96.20	-5.3
35	ECOBANK TM	86.12	-5.6	96.12	-5.3
36	SHELL (S/S) TM	86.12	-5.6	96.12	-5.3
37	MTN II TM	85.97	-5.6	95.96	-5.4
38	MTN III BUS	85.94	-5.6	95.92	-5.4
39	CASSIDY 1 TM	85.70	-5.7	95.66	-5.5
40	CASSIDY TM	85.70	-5.7	95.65	-5.5
41	OFOR 2 TM	85.5	-5.8	95.43	-5.6
42	OFOR 1 TM	85.5	-5.8	95.43	-5.6
43	D' ROSE TM	85.5	-5.8	95.43	-5.6
44	D' ROSE 1 TM	85.50	-5.8	95.43	-5.6
45	MARVE SCH TM	85.42	5.8	95.34	-5.6
46	MARVE SCH 1 TM	85.36	-5.9	95.04	-5.6
47	IKPRUKPRU 5 TM	85.36	-5.9	95.27	-5.6
48	IKPRUKPRU 6 TM	85.36	-5.9	95.27	-5.6
49	IKPRUKPRU 1 TM	85.21	-5.9	95.11	-5.7
50	IKPRUKPRU 7 TM	85.14	-6.0	95.03	-5.7
51	IKPRUKPRU 4 TM	85.12	-6.0	95.50	-5.8
52	DANIEL 1 TM	85.10	6.0	94.98	-5.8
53	IKPRUKPRU 3 TM	85.10	-6.0	94.96	-5.8
54	IKPRUKPRU 2 TM	85.12	-6.0	95.01	-5.7
55	ROBERT A TM	85.09	-6.0	94.97	-5.8
56	DORTIE TM	85.09	-6.0	94.98	-5.8
57	OTOVWODO 2 TM	87.93	-4.8	98.18	-4.6
58	T31	85.94	-4.9	98.10	-4.6
59	OTOVWODO 4 TM	85.05	-4.8	98.28	-4.6

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

60	BISHOP AI TM	88.05	-4.8	98.28	-4.6
61	BISHOP TM	88.04	-4.8	98.27	-4.6
62	AGBARHA JNC TM	87.68	-4.9	97.80	-4.7
63	AGBARHA RD TM	87.62	-4.9	97.80	-4.7
64	UDUERE 3 TM	87.49	-4.9	97.66	-4.7
65	SLAUGHTER RD TM	87.29	-5.0	97.44	-5.1
66	AGBARHA 1 TM	87.20	-5.0	97.45	-4.8
67	UDUERE 2 TM	86.66	-5.1	96.84	-4.9
68	AGBARHA 2 TM	86.76	-5.1	96.84	-4.9
69	UDUERE 1 TM	86.73	-5.1	96.81	-4.9
70	OPHERIN TM	86.44	-5.2	96.48	-5.0
71	OWEYWE TM	86.44	-5.2	96.49	-5.0
72	SANIKO TM	86.39	-5.2	94.44	-5.0
73	GANA JNC TM	86.30	-5.2	96.33	-5.0
74	OMABEWE 2 TM	86.21	-5.2	96.23	-5.0
75	ETEFE TM	86.13	-5.2	96.14	-5.0
75	OMABEWE 1 TM	86.21	-5.2	96.23	-5.0
76	OKPHO AGARA TM	86.19	-5.2	96.21	-5.0
77	OTERI TM	86.17	-5.2	96.19	-5.0
79	AWIRHA TM	86.10	-5.3	96.11	-5.0
80	MR BIGGS	87.36	-5.0	97.52	-4.7
81	FIRST BANK TM	86.73	-5.1	96.81	-4.9
82	GRUBBS	86.57	-5.1	98.31	-4.9
83	OLORI EST	86.65	-5.1	96.72	-4.9
84	OLORI RD TM	86.36	-5.2	97.19	-4.9
85	OLORI RDJN TM	86.57	-5.1	96.48	-4.9
86	6 MTN PL TM	85.90	-5.2	95.90	-5.0
87	ETI TM	85.91	-5.2	95.89	-5.0
88	MUDI 2 TM	85.91	-5.6	95.90	-5.0
89	MUD 1 TM	86.95	-5.5	95.94	-5.0
90	LOW COST	86.04	-5.2	96.05	-5.3
91	HERO FAITH TM	85.58	-5.3	95.23	-5.1
92	IGHOJA TM	84.96	-5.5	94.48	-5.2
93	OMENEMU TM	85.95	-5.5	94.82	-5.2
94	UNION BANK	84.96	-5.3	94.83	-5.2
95	NCC TM	84.96	-5.5	94.83	-5.2
96	PIPE LINE	84.37	-5.6	94.18	-5.3

IRJMETS
e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

97	AFISERE TM	84.48	-5.6	94.3	-5.3
98	OGELE TM	84.24	-5.6	94.03	-5.4
99	ORUBU TM	84.33	-5.6	94.14	-5.4
100	MTN 1(PL)	84.20	-5.6	93.98	-5.4
101	ROUND ABT TM	84.20	-5.6	93.98	-5.4
102	AMEKPA 3 TM	83.84	-5.7	93.58	-5.5
103	AMEKPA 2	83.63	-5.8	93.35	-5.6
104	AMEKPA TM	83.51	-5.8	93.22	-5.6
105	2ND AMKPA TM	88.08	-4.8	98.32	-4.6
106	HOLY SALVATION TM	86.59	-5.8	93.31	-5.6
107	IGHAGBOMI TM	86.77	-5.3	96.85	-5.1
108	DANIEL TM	85.08	-6.0	94.47	-5.8

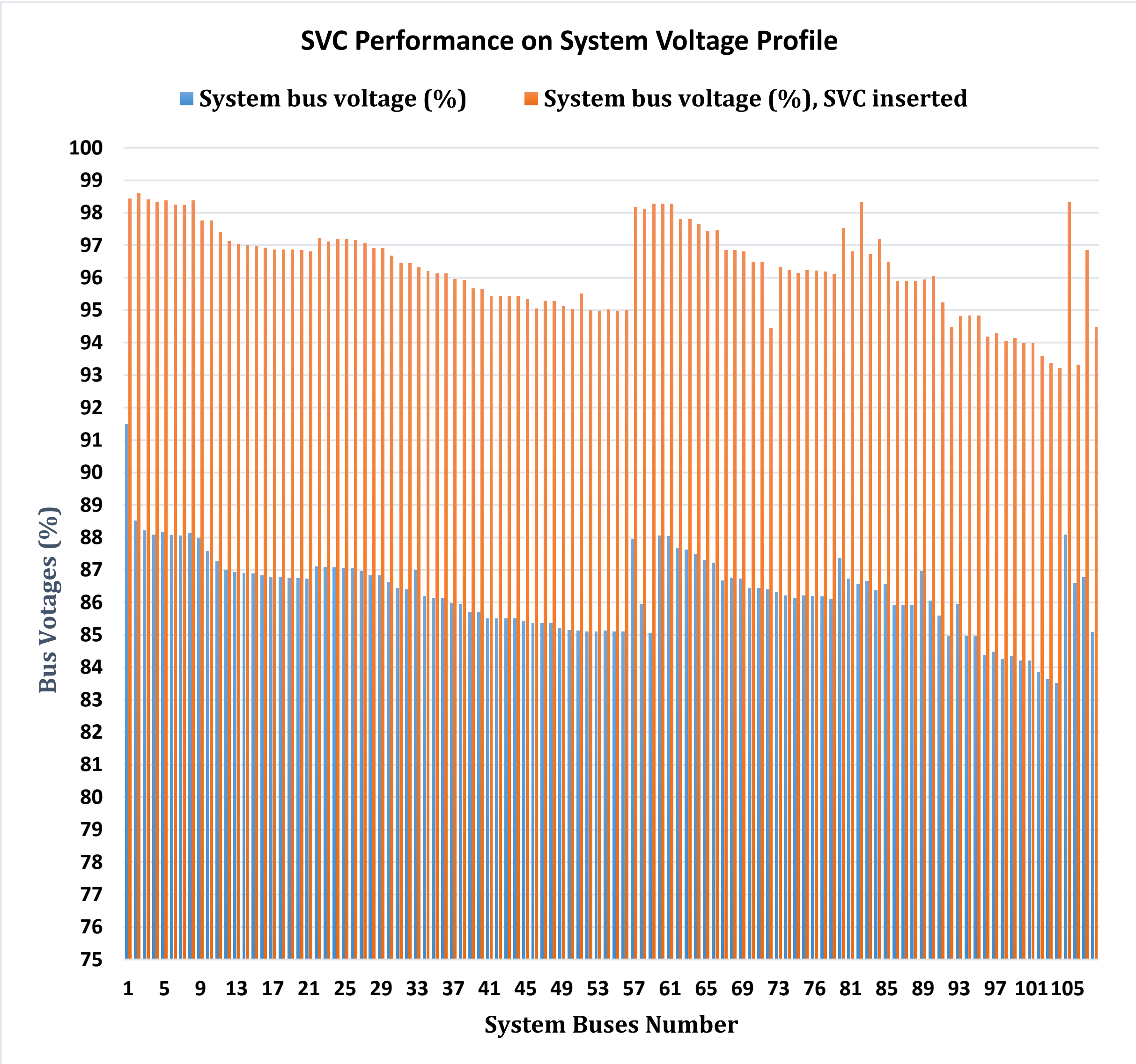

Figure 5: Graph of Simulated System Voltage with and without SVC Insertion

Table 5: Simulation Conditions and Violated Buses

Simulation Condition	No SVC	SVC at Dumex (50 MVar)	SVC at Dumex (50 MVar), Ovie (40 MVar)
Violated Buses	108	45	17

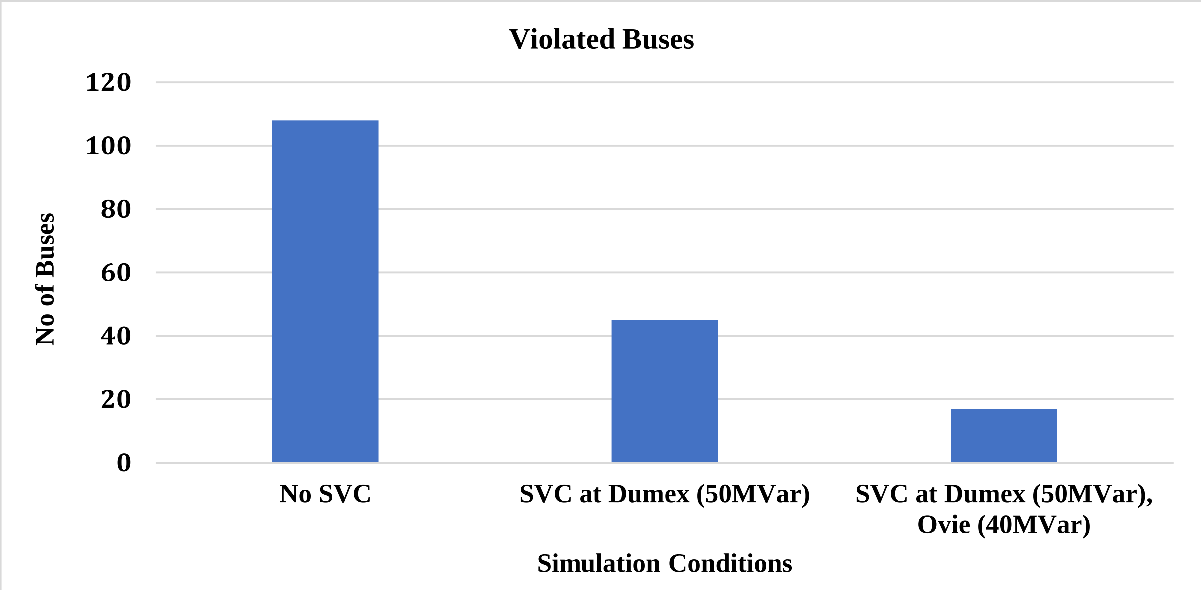

Figure 6: Graph of Violated Buses Under Various Simulation Condition

Table 6: Simulation Conditions and System Active Power Loss

Simulation Condition	No SVC	SVC at Dumex (50MVar)	SVC at Dumex (50MVar), Ovie (40MVar)
Active Power Loss (pu)	0.832	0.775	0.729

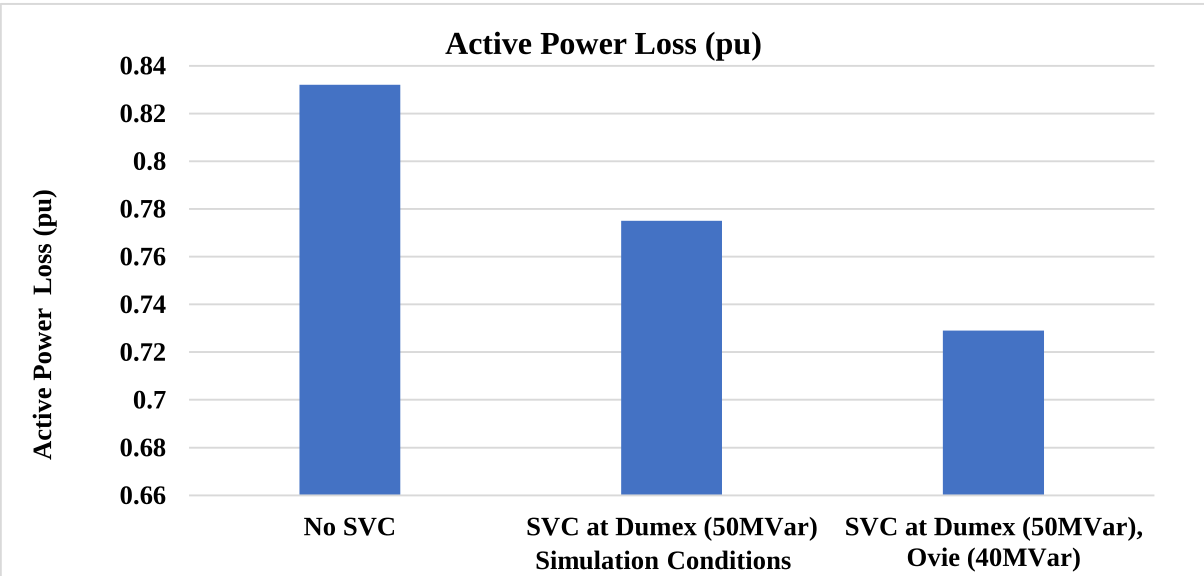

Figure 7: Graph of System Active Power Loss under Various Simulation Condition

Table 7: Simulation Conditions and System Reactive Power Loss

Simulation Condition	No SVC	SVC at Dumex (50 MVar)	SVC at Dumex (50 MVar), Ovie (40 MVar)
Reactive Power Loss (pu)	1.763	1.619	1.552

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

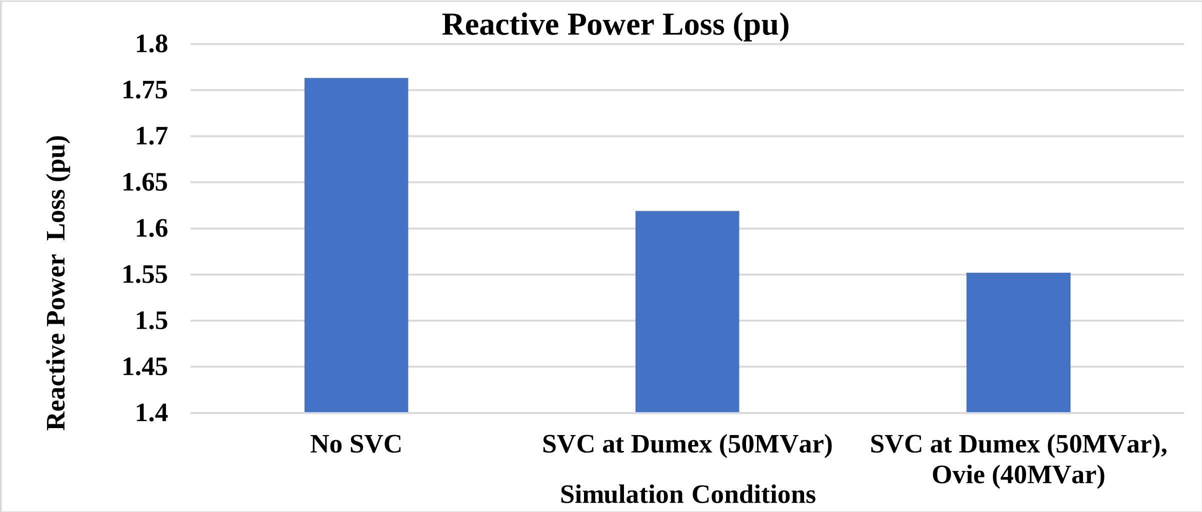

Figure 8: Graph of System Reactive Power Loss Under Various Simulation Conditions

b) Analysis of Result and Summary

From the results of load flow analysis without SVC, it was found that all buses fall below the allowable voltage range of within ±5% of the nominal voltage. The voltage range was between 80.94 % (0.8094 p.u) and 91.47 % (0.9147p.u) (table 4 and figure 5) and the total active and reactive loss are 0.832MW and 1.763MVAR (table 6, figure 7 and table 7,figure 8) respectively. The study system was compensated to achieve the voltage improvement and power loss reduction, the Static Var Compensator was placed at two positions, Dumex Bus and Ovie as suggested by voltage index simulation see table 3 and section IV(a).

The simulation conducted for SVC sizing using systematic sampling method started with the SVC placed initially at Dumex bus and it showed that the optimum of the SVC was 50MVar and the system active and reactive loss were reduced from 0.8332 MW and 1.763MVar to 0.775MW and 1.619MVar (table 6, figure 7 and table 7, figure 8) column 2 respectively. The system bus voltages range was also improved from 80.94 % (0.8094 p.u) and 91.47 % (0.9147p.u) to 82.83 % (0.8283 p.u) and 98.11 % (0.9811p.u). the violated buses were reduced from 108 to 45 buses (table 5 and figure 6), this is 58.33% bus voltage violation reduction.

On the second placement of the SVC at the bus that ranked second in the voltage index simulation, which is the Ovie, the optimum size of the SVC at this bus was 40 MVar. At this condition the system active and reactive loss were improved to 0.729 MW and 1.552 MVar (table 6, figure 7 and table 7, figure 8) column 3 respectively, and the bus voltage was enhanced to between 86.92% (0.8692 p.u) and 98.60% (0.9860 p.u) (table 4.3 , figure 4.2 and figure 4.3). this improved the bus voltage violation from initial system bus voltage violation of 108 buses to 17 buses (table 5 and figure 6) column 3, this is 85.19% bus voltage violation improvement. The placement of second SVC in Isoko feeder has less effect than placing at Ovie bus, this could only achieve 70.37% violation reduction (108 buses to 32 buses) compare to 85.19% achieved by SVC at Ovie as second placement. These results confirm the prediction made by voltage index ranking.

V. CONCLUSION

The use of Static Var Compensator in enhancing voltage stability considering Otovwodo 33/11kV distribution station, Delta State, as a case study was applied to the power system. From the simulation carried out, it can be concluded that voltage stability can be enhanced using SVC which controls the flow of reactive power in the line. The research has shown that SVC enhance system loss reduction.

VI. REFERENCES

[1] Kundur, P. (2007). Power system stability. Power system stability and control, 10.

[2] Gyugyi, L. (1994). Dynamic compensation of AC transmission lines by solid-state synchronous voltage sources. IEEE Transactions on Power Delivery, 9(2), 904-911.

[3] Biswas M, Kamol K. Das (July 2011) "Voltage Level Improving by Using Static Var Compensator (SVC)" Global Journal of researches in engineering: J General Engineering Volume 11 Issue 5 Version 1.0.

[4] Avneesh Kumar Vishwakarma, Dhaneshwari Sahu (5, May 2013) "Efficient Voltage Regulation in Three Phase AC Transmission Lines Using Static VAR Compensator" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2

[5] Roberto Alves, Miguel Montilla, Ernesto Mora (2001) "Increase of Voltage Stability and Power Limits Using Static Var Compensator.'' 85296-775-1.

[6] Alok Kumar, and Surya Bhushan Dubey (May 2013) "Enhancement of Transient Stability in Transmission Line Using SVC Facts Controller" International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-2, Issue-2.

[7] Prakash Mahela & Sheesh Ram Ola (Feb 2013) "Comparison of the Shunt Capacitors and SVC for Active and Reactive Power Flow Control in Transmission Line" International Journal of Electrical and Electronics Engineering (IJEEE) ISSN 2278-9944 Vol. 2, Issue 1 pp. 49-58. IASET.

[8] Pateriya, A., Saxena, N., & Tiwari, M. (2012). Transfer Capability Enhancement of Transmission Line using Static Synchronous Compensator (STATCOM). International Journal of Advanced Computer Research, 2(4), 83-88.

[9] Omorogiuwa Esosa, (2011) Ph.D Thesis on ''Efficiency Improvement Of The Nigeria 330kV Network Using Flexible Alternating Current Transmission System (FACTS) Devices.'' University of Benin, Benin City.

[10] Mark Ndubuka NWOHU (January-June 2009) "Voltage Stability Improvement Using Static Var Compensator in Power Systems" Leonardo Journal of Sciences 1583-0233 Issue 14, p. 167-172.

[11] Naseer M. Yasina and Mostafa Al-eedanya (June 2013) "Enhancement of Power System Transient Stability Using Static Var Compensator" International Journal of Current Engineering and Technology ISSN 2277 - 4106, Vol.3, No.2.

[12] Habibur Rahman, Ilius, Harun-Or-Rashid. (Nov.2012) "Power System Stability Improvement By Using SVC With Power System Controller.'' International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), ISSN-2278-1323, Vol.1. Issue 9, PP-37-42.

[13] Apriyanto, A. E., Virgiawan, A. R., Pariaman, H., Hisjam, M., & Hariyanto, N. (2021, March). Determination of VAR Compensator Placement for System Stability Improvement on Java Bali Network. In IOP Conference Series: Materials Science and Engineering (Vol. 1096, No. 1, p. 012133). IOP Publishing.

[14] Pisica, I., Bulac, C., Toma, L., & Eremia, M. (2009, June). Optimal SVC placement in electric power systems using a genetic algorithms based method. In 2009 IEEE Bucharest Power Tech (pp. 1-6). IEEE.

[15] Sirjani, R., Mohamed, A., & Shareef, H. (2012). Optimal allocation of shunt Var compensators in power systems using a novel global harmony search algorithm. International Journal of Electrical Power & Energy Systems, 43(1), 562-572.

[16] Nguyen, K. P., Fujita, G., & Dieu, V. N. (2016). Cuckoo search algorithm for optimal placement and sizing of static var compensator in large-scale power systems. Journal of Artificial Intelligence and Soft Computing Research, 6.

[17] Rao, B. V., & Kumar, G. N. (2015). A comparative study of BAT and firefly algorithms for optimal placement and sizing of static VAR compensator for enhancement of voltage stability. International Journal of Energy Optimization and Engineering (IJEOE), 4(1), 68-84.

[18] Sundareswaran, K., Hariharan, B., Parasseri, F. P., Antony, D. S., & Subair, B. (2010). Optimal placement of static var compensators (SVC's) using particle swarm optimization. In 2010 International Conference on Power, Control and Embedded Systems (pp. 1-4). IEEE.. Technology ISSN 2277 - 4106, Vol.3, No.2.

[19] Jumaat, S. A., Musirin, I., Othman, M. M., & Mokhlis, H. (2013, June). Cluster identification for optimal placement of static var compensator. In 2013 IEEE 7th International Power Engineering and Optimization Conference (PEOCO) (pp. 546-551). IEEE.

[20] Vanishree, J., & Ramesh, V. (2018). Optimization of size and cost of static var compensator using dragonfly algorithm for voltage profile improvement in power transmission systems. International Journal of Renewable Energy Research (IJRER), 8(1), 56-66.

[21] Dubey, R., Dixit, S., & Agnihotri, G. (2014). optimal Placement of Shunt FACTS Devices Using Heuristic Optimization Techniques. In An Overview, Fourth International Conference on Communication Systems and Network Technologies (pp. 519-523).

[22] Gacem, A., & Benattous, D. (2017). Hybrid GA–PSO for optimal placement of static VAR compensators in power system. International Journal of System Assurance Engineering and Management, 8(1), 247-254.

[23] Samimi, A., & Golkar, M. A. (2011, March). A novel method for optimal placement of STATCOM in distribution networks using sensitivity analysis by DIgSILENT software. In 2011 Asia-Pacific Power and Energy Engineering Conference (pp. 1-5). IEEE.

[24] Apribowo, C. H. B., Listiyanto, O., & Ibrahim, M. H. (2019, November). Placement Static Var Compensator (SVC) for Improving Voltage Stability Based on Sensitivity Analysis: A Case Study Of 500 KV Java-Bali Electrical Power System. In 2019 6th International Conference on Electric Vehicular Technology (ICEVT) (pp. 276-280). IEEE.

[25] Jadhao, C. W., & Vadirajacharya, K. (2015). Performance improvement of power system through static VAR compensator using sensitivity indices analysis method. In 2015 International Conference on Energy systems and applications (pp. 200-202). IEEE.

[26] Nurdin, M., Rahman, F. S., Rahmani, R., & Hariyanto, N. (2014). Placement of Shunt VAR Compensator Based on Sensitivity Analysis. International Journal on Electrical Engineering and Informatics, 6(2), 435.

[27] Erinmez Apriyanto, A. E., Virgiawan, A. R., Pariaman, H., Hisjam, M., & Hariyanto, N. (2021, March). Determination of VAR Compensator Placement for System Stability Improvement on Java Bali Network. In IOP Conference Series: Materials Science and Engineering (Vol. 1096, No. 1, p. 012133). IOP Publishing.

[28] Acha, E., Fuerte-Esquivel, C. R., Ambriz-Perez, H., & Angeles-Camacho, C. (2004). FACTS: modelling and simulation in power networks. John Wiley & Sons.