e-ISSN: 2278-8875
p-ISSN: 2320-3765

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

Volume 10, Issue 9, September 2021

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.282

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 9, September 2021 ||

DOI:10.15662/IJAREEIE.2021.1009001 |

Improving the Performance of 132kV Transmission Line Using Static Load Model and Shunt Capacitive Compensation Technique

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ABSTRACT: The need to carry out a comprehensive analysis of 132kV compensated alternating current transmission line has become inevitable to maintain an efficient system devoid of voltage instability. Voltage instability is a serious challenge in the power system and therefore, the transmission line most especially desires to be compensated. Uncompensated alternating current transmission line may generally possess high risk of voltage instability shifting its voltage outside the statutory value. Appropriate data to carry out the analysis of 132kV alternating current transmission line were collected from Afam power station and Port Harcourt Mains transmission station. These became the input data in ETAP 12.6 software using static load model to conduct analysis on the transmission network without compensation in the first case. A second case of analysis was done in conjunction with capacitor banks modelled using shunt capacitive compensation method. The analysis showed that after compensation, voltage improvement occurred on buses 4, 21 and 23. The voltage improved from 131.87kV to 131.89kV for bus 4, 131.86kV to 131.88kV for each of buses 21 and 23. Voltage stability was achieved as compensation brought the voltage closer to 132kV value. IEEE regulation on voltage stability enforcement validates this result as a good step in creating an efficient system.

KEYWORDS: Static Load Model, Transmission Line, Shunt Capacitive Compensation, Load Bus, Capacitor Bank, Voltage Magnitude.

I. INTRODUCTION

In AC power transmission system compensation is the management of reactive power to improve the quality of power supply and this is geared towards increasing the system reliability, stability, efficiency, and cost effectiveness. The demand on transmission network has grown in recent years and will continue growing. Due to the problems associated with constructing new transmission lines, it is important to examine the other possible options of increasing the transmission capability on present sites and making maximum use of existing transmission systems [1]. The impedance of transmission lines and the need for lagging reactive power by most machines in generating system results in the consumption of reactive power, thus disturbing the stability limits of the system as well as transmission lines. Unnecessary voltage drops lead to bigger losses which need to be supplied by the source and in turn leading to faults in the line due to increased stress on the system.Shunt compensation can be installed near the load, in a distribution sub-station or transmission sub-station [2].

It is necessary to improve the maximum limit of power transfer of an existing power transmission system to overcome the challenges related to constructing new transmission infrastructure [3].In power system, the reactive power compensation is important for system voltage profile. This is also helpful to power factor improvement and loss reduction [4].

II. RELATED WORKS

The reactive power in a system keeps on varying and if the reactive power generated is simultaneously controlled, a flat voltage profile could be maintained [5].However, most high voltage transmission systems are operating below their thermal rating due to such constraints as stability limits, on an alternating current power system voltage is controlled by managing the production and absorption of reactive power.

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Load compensation is the management of the reactive power to improve the power system [6]. The voltage can be controlled by providing reactive power control margin to modulate the supply needs through compensations.

According to Anyalebechi & Anyaka [7], application of reactive power devices at all levels of power transmission, improves stability by increasing the maximum transmissible power and/or supply the reactive power requirements in the most economical way.The three main objectives of load compensation are: better voltage profile, Power factor correction, and load balancing. It is not possible to load longer lines even to their natural loadings without compensation [8].

III. MATERIALS AND METHODS

Research materials such as transmission line data, bus data, station data and other relevant data were obtained at the Afam Power Station and Port Harcourt Mains Transmission Station. Others were computed for the purpose of the analysis. The network for this study was the medium transmission line since it measured up to 100km. Static Load Model was used to model the network and load flow conducted on the network to ascertain the network's real power, reactive power, voltage magnitude and voltage angle with reference to Afam/Port Harcourt 132kV transmission lines 1 and 2 .

In a second case of load flow, Shunt capacitive compensation method was used to model capacitor bank and placed on the load buses. With this, real power, reactive power, voltage magnitude and voltage angle are realized. Static load model calculation on the 3-bus 132kV transmission lines 1 and 2 becomes:

BUS 21
Following that

$$P = P_0\left(\frac{V}{V_0}\right)^{np}$$

Where
P_0=350KVA

$np = 1$
$V = 0.415KV$ for bus 14
$V = V_O$ at unity pf for power distribution
Then,

$$P = 350\left(\frac{0.415}{0.415}\right)^1$$

$P = 350KVA$
BUS 23
Following that

$$P = P_0\left(\frac{V}{V_0}\right)^{np}$$

Where
P_0=350KVA

$np = 1$
$V = 0.415KV$ for bus 13
$V = V_O$ at unity pf for power distribution
Then,

$$P = 350\left(\frac{0.415}{0.415}\right)^1$$

$P = 350KVA$
Having gotten the data needed using static load model, load flow analysis was conducted on the 3-bus 132kV transmission lines 1 and 2 in ETAP 12.6 software environment as the data were used as input data for an operation without compensation.

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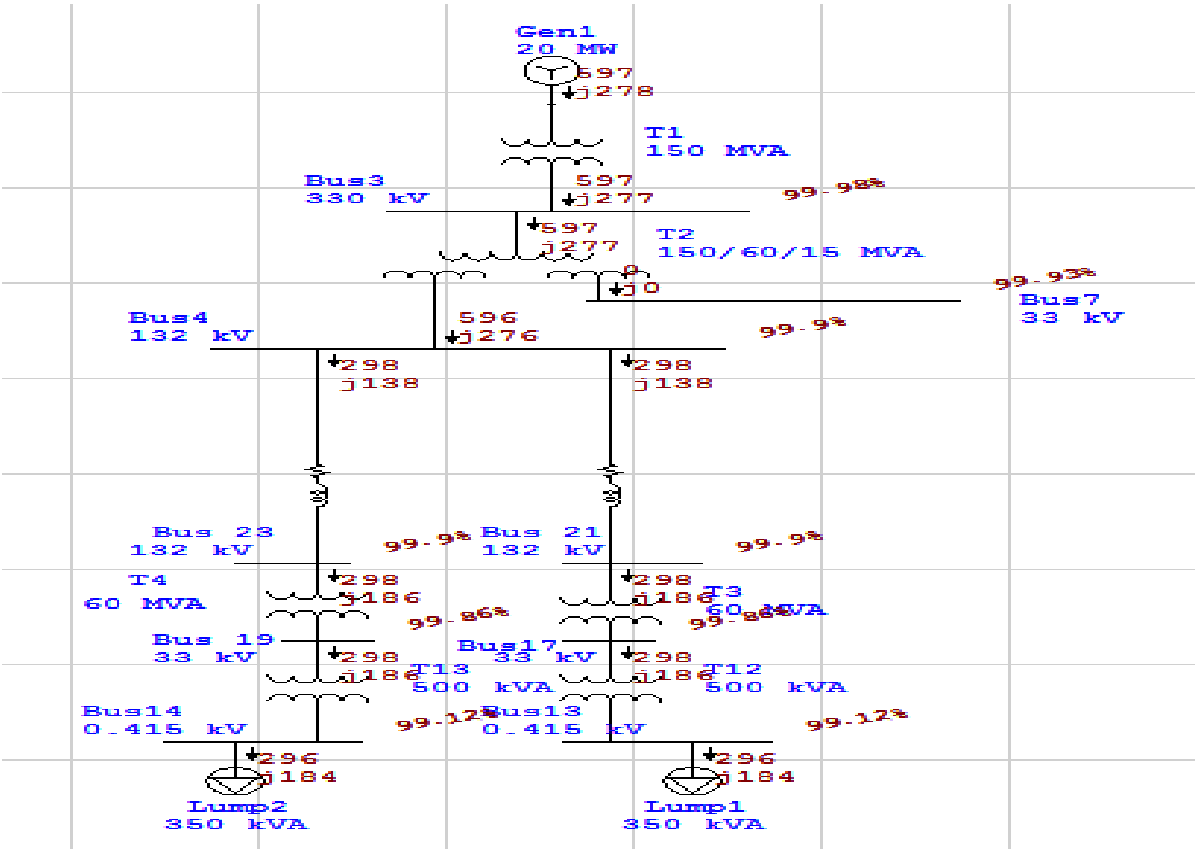

Fig.1 3-Bus 132kV Transmission Lines 1 and 2 modelled in ETAP 12.6 Software (Without Compensation)

For capacitor banks rating calculation, considering that

$$Q_C = {}^{P}/_{Pf_1}\ X\ Sin(Cos^{-1}(Pf_1)) - {}^{P}/_{Pf_2}\ X\ Sin(Cos^{-1}(Pf_2))$$

Where

$Q_C = Rating\ of\ capacitor\ bank$

$P_{f1} = 0.85$

$P_{f2} = Unity$

$P = Total\ load\ in\ KVA$

BUS 21

$Q_C = {}^{350}/_{0.85}\ X\text{Sin}(Cos^{-1}(0.85)) - {}^{350}/_{1}\ XSin(Cos^{-1}(1))$

$Q_C = 216.9105184KVAr$

$Q_C = 0.022MVAr$

BUS 23

$Q_C = {}^{350}/_{0.85}\ X\text{Sin}(Cos^{-1}(0.85)) - {}^{350}/_{1}\ XSin(Cos^{-1}(1))$

$Q_C = 216.9105184KVAr$

$Q_C = 0.022MVAr$

The capacitor banks were modelled using shunt capacitive compensation method and placed at the end buses to the load in ETAP 12.6 software environment for the purpose of analysis of the 132kV transmission lines. The 3-bus 132kV transmission lines 1 and 2 after compensation was subjected to a second case of load flow analysis using static load model as follows:

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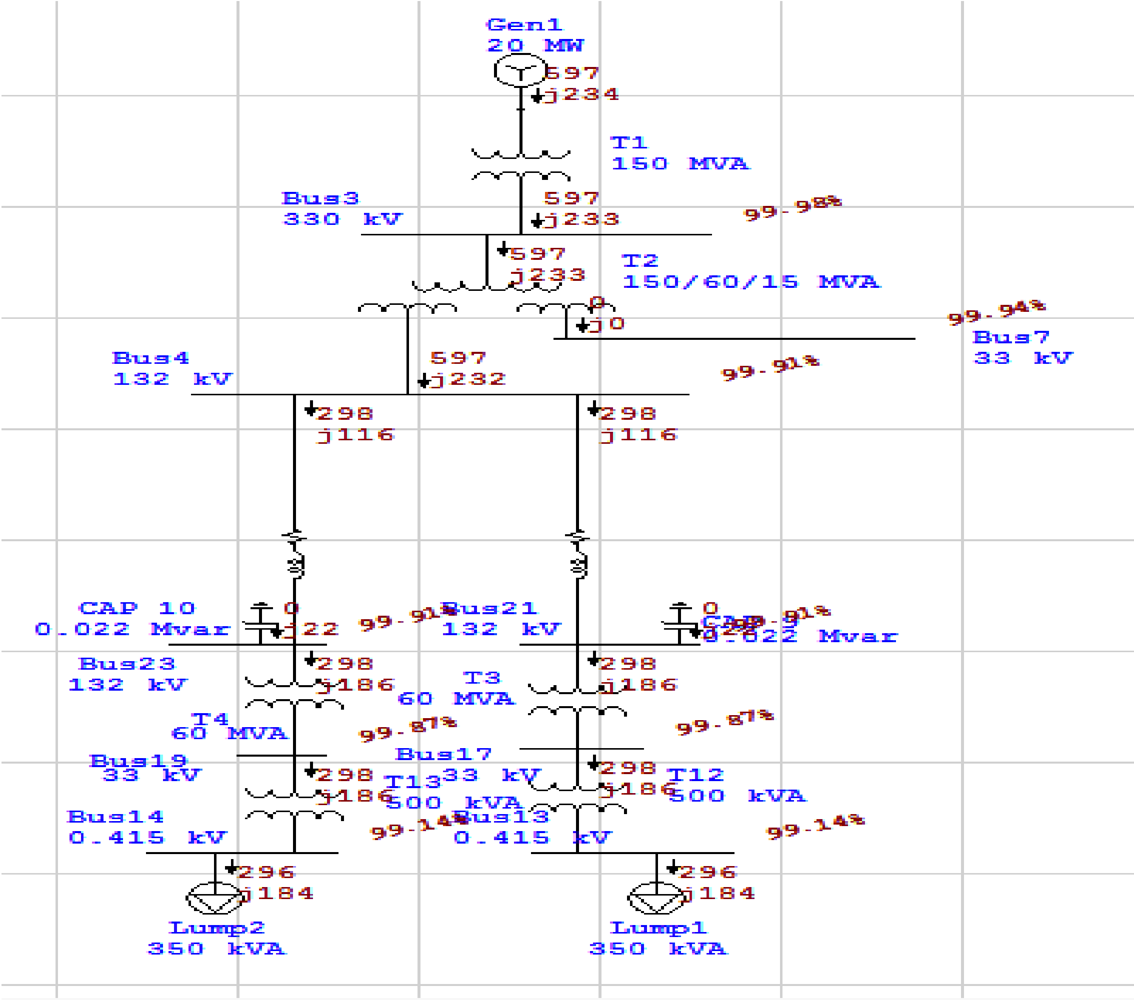

Fig.2 3-Bus 132kV transmission Lines 1 and 2 Modelled in ETAP 12.6 Software (With Compensation)

IV. RESULTS AND DISCUSSION

Results realized from the load flow without compensation and load flow with compensation are indicated in Tables 1-6 and Figs.3-8.

Table 1 Summary of Voltage Magnitude without Compensation

Buses	Voltage Magnitude (%)
4	99.902
21	99.897
23	99.897

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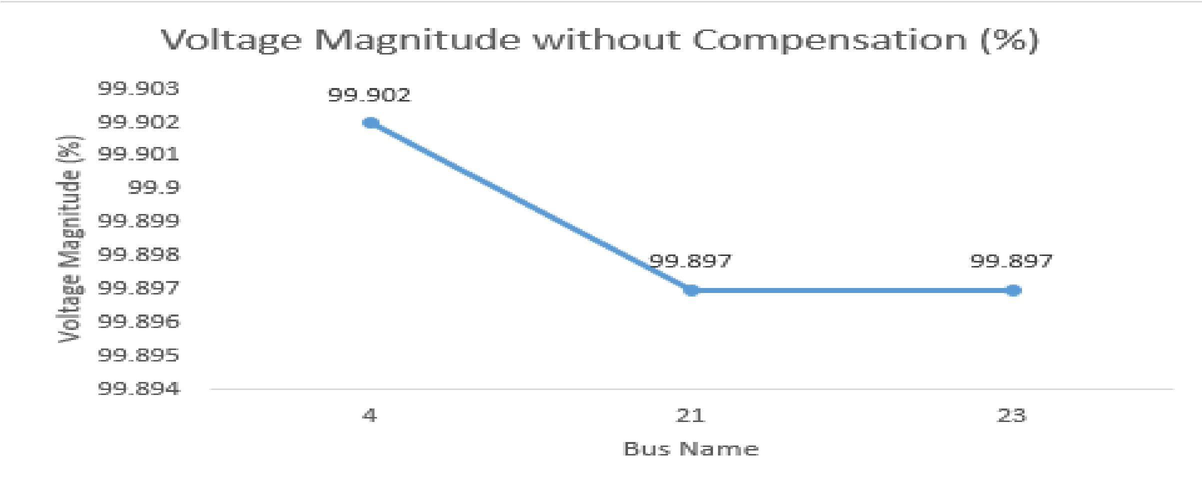

Figure 3 Plot of Voltage Magnitude without Compensation

Table 2 Summary of Reactive Power without Compensation

Buses	Reactive Power (MVAr)
4	0.278
21	0.138
23	0.138

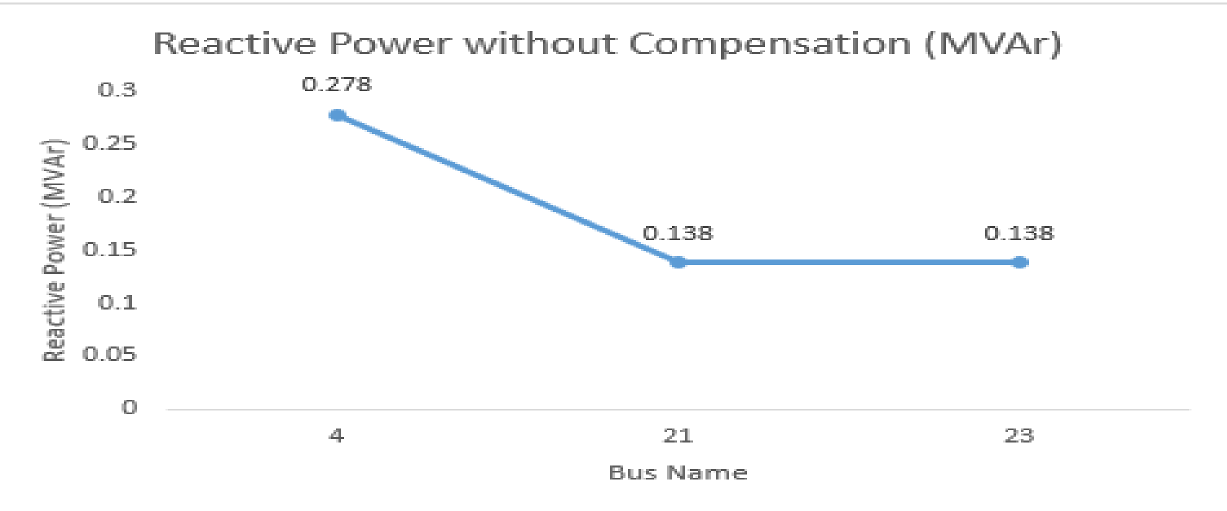

Figure 4 Plot of Reactive Power without Compensation

Table 3 Summary of Voltage Magnitude with Compensation

Buses	Voltage Magnitude (%)
4	99.915
21	99.910
23	99.910

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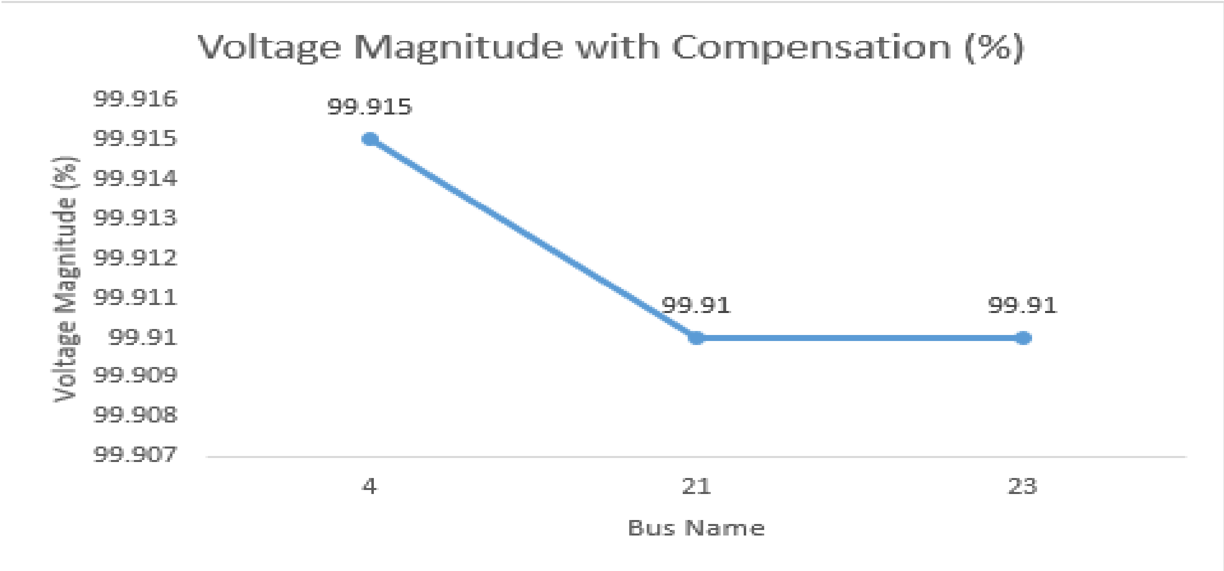

Figure 5 Plot of Voltage Magnitude with Compensation

Table 4 Summary of Reactive Power with Compensation

Buses	Reactive Power (MVAr)
4	0.234
21	0.116
23	0.116

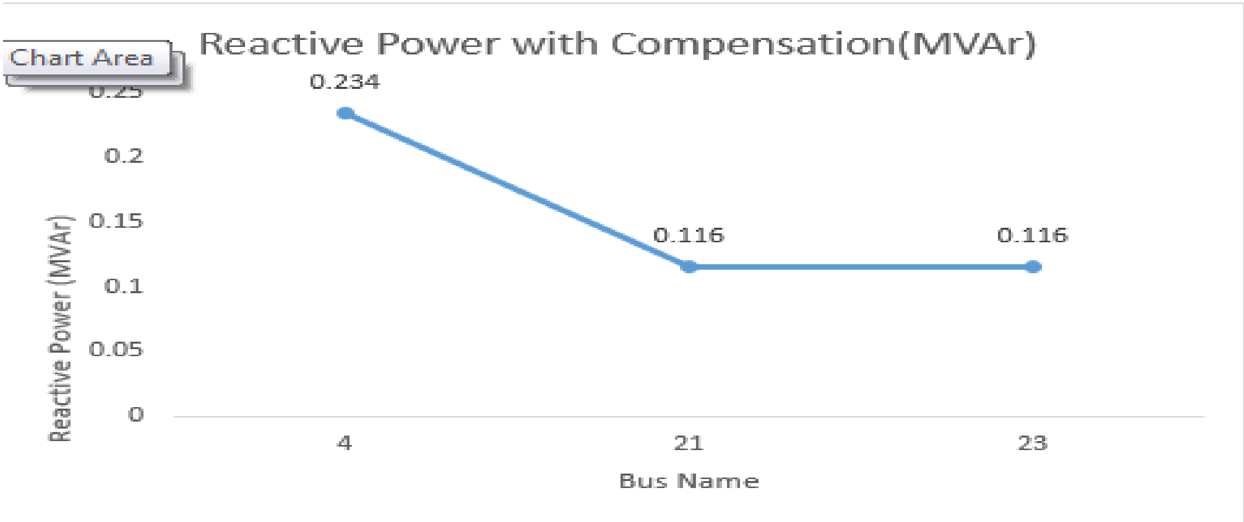

Figure 6 Plot of Reactive Power with Compensation

Table 5 Voltage Magnitude, with and without Compensation

Buses	Voltage Magnitude without Compensation (%)	Voltage Magnitude with Compensation (%)
4	99.902	99.915
21	99.897	99.910
23	99.897	99.910

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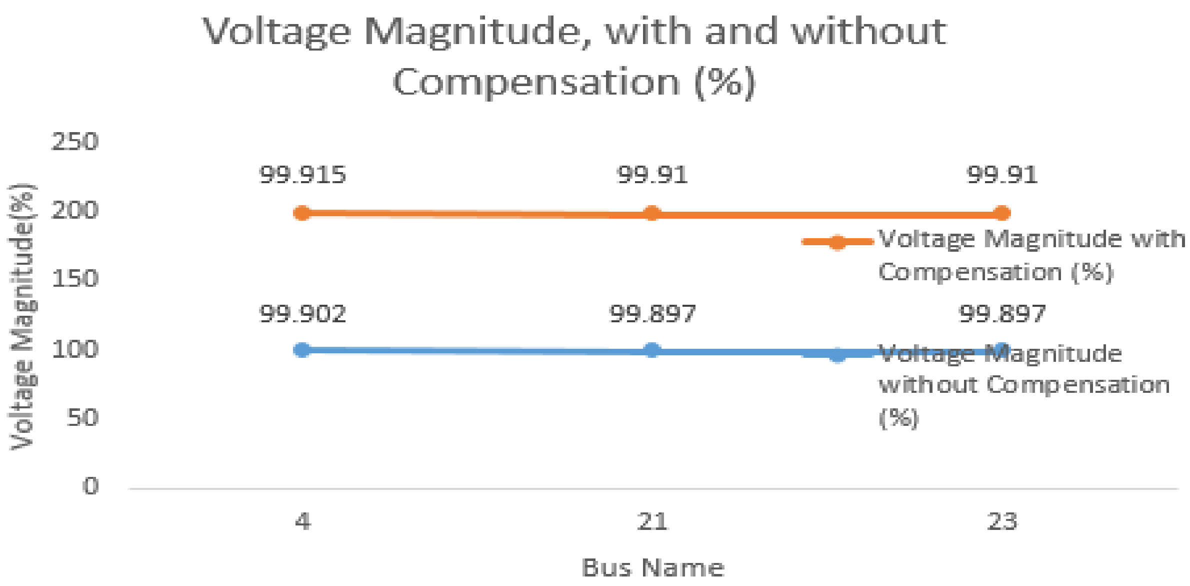

Figure 7 Plot of Voltage Magnitude, with and without Compensation

Table 6 Reactive Power, with and without Compensation

Buses	Reactive Power WithoutCompensation (MVAr)	Reactive Power with Compensation (MVAr)
4	0.278	0.234
21	0.138	0.116
23	0.138	0.116

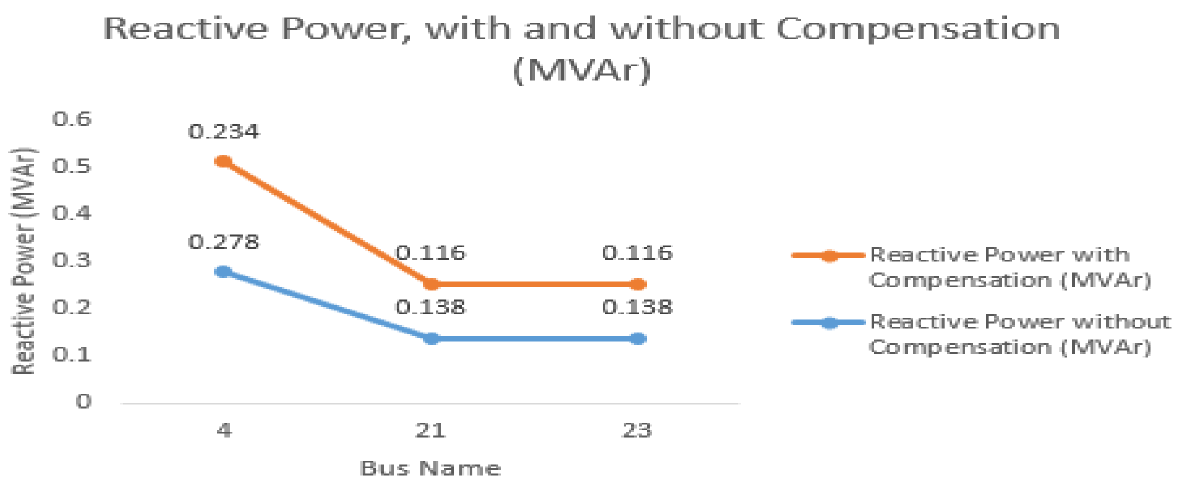

Figure 8 Plot of Reactive Power without Compensation

V. CONCLUSION

Static load model as a method was employed in the modelling of 3-bus 132kV transmission lines 1 and 2 in ETAP 12.6 software. This was performed to analyze the performance of the transmission lines without compensation.The transmission lines were subjected to load flow analysis with static load of 350KVA for each of buses 17 and 19. The load flow analysis showed that without compensation, buses 4, 21 and 23 have voltage magnitudes of 99.902, 99.897

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and 99.897. these represent 131.87kV, 131.86kV and 131.86kV as against 132kv for buses 4, 21 and 23. Also, reactive powers available are 0.278MVAr, 0.138MVAr for each of buses 21 and 23.

With the use of shunt capacitive compensation, capacitor bank was modelled and placed on the two transmission load buses. This modelling was to provide compensation on the transmission network.After capacitor bank modelling and placement, the 3-bus 132kV transmission lines 1 and 2 was subjected to a second case of load flow analysis. This indicates voltages of 99.915 for bus 4 and 99.910 for each of buses 21 and 23 representing 131.89kV, 131.88kV and 131.88kV as against 132kV for buses 4, 21 and 23.Also, reactive powers available are 0.234MVAr for bus 4 and 0.116MVAr for each of buses 21 and 23.

In comparison, the 3-bus 132kV transmission lines 1 and 2 proved to be more stable when compensated as the voltage magnitudes improved from 99.902 to 99.915 for bus 4 and 99.897 to 99.910 for each of buses 21 and 23 representing voltage improvement from 131.87kV to 131.89kV, 131.86kV to 131.88kV and 131.86kV to 131.88kV for buses 4, 21 and 23. The reactive power reduced from 0.278MVAr to 0.234MVAr for bus 4 and 0.138MVAr to 0.116MVAr for each of buses 21 and 23. Improvement in voltage magnitude is 0.013 for each of buses 4, 21 and 23. This improvement in voltage magnitude has shifted the working voltage closer to the nominal voltage of 132kV by 0.02kV for each bus than when not compensated.

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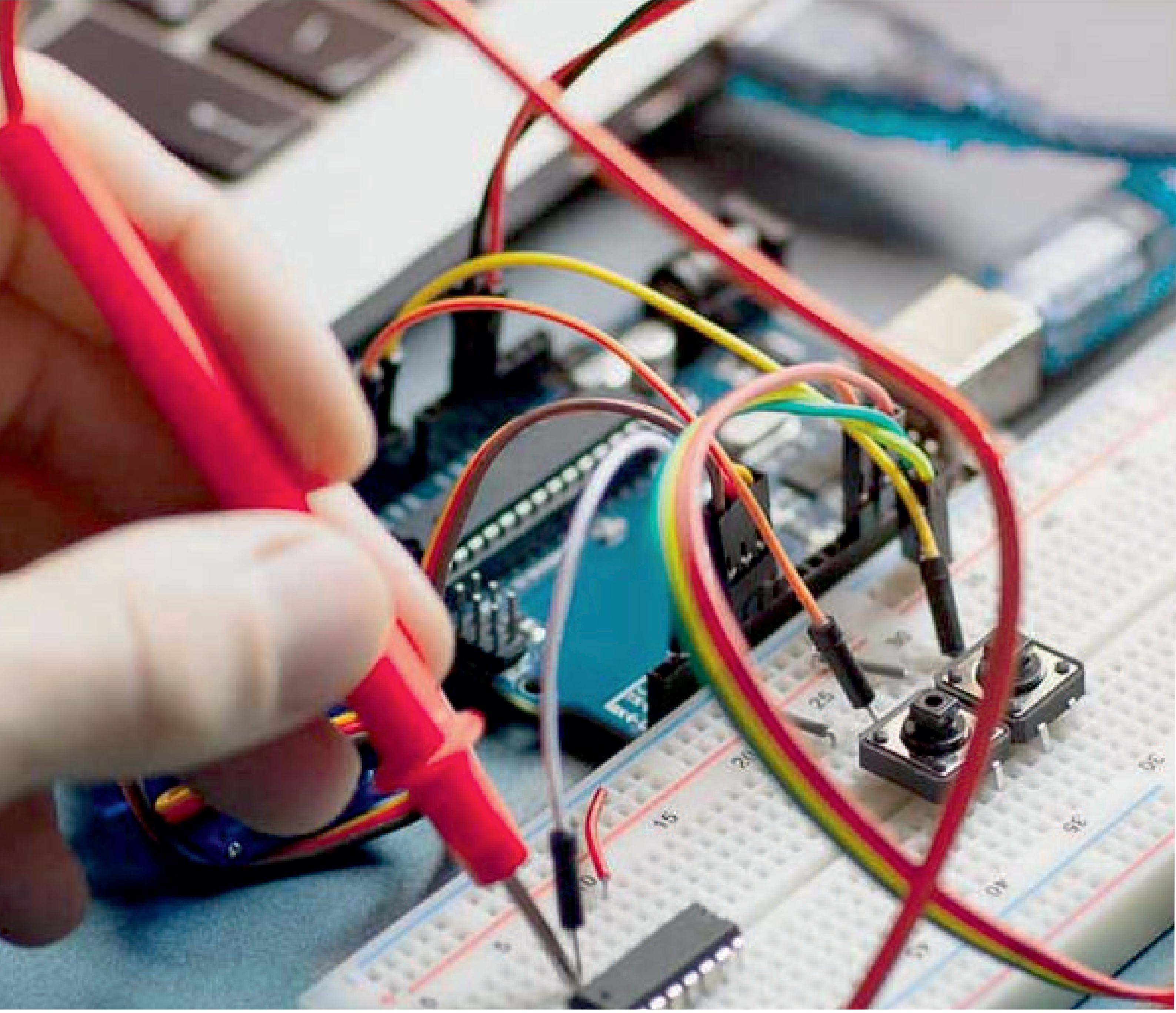

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