International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 13, Issue 1 [January. 2024] PP: 01-15

Investigation of Distribution System Stability with Incorporation of Capacitor Switching: A Case Study of Monatan 11 KV Distribution System

Ganiyu Adedayo Ajenikoko[1], Abass Balogun[2],Titilola Tunde Olayinka[3], Abdulbasit Oladayo Ajenikoko[4] , Jibola Mukaila Oseni[5] , Adebayo Wasiu Eboda[6.]

[1,2,3,5,6,]Department of Electronic and Electrical Engineering, Ladoke Akintola University of Technology, P.M.B, 4000, Ogbomoso, Nigeria.
[4]Department of Electrical and Computer Engineering, Kwara State University, Malete, Ilorin, Kwara State, Nigeria.
Corresponding Email: ajeedollar@gmail.com

Abstract
Effectiveness of an electrical distribution system depends on the stability of its voltage profile. Several methods in the likes of Static Compensator (SC), Thyristor Controlled Series Compensation (TCSC) and Series Capacitor have been applied for the stability of the system. However, these methods have been characterized by harmonic variation and low efficiency. Therefore, this study applied Shunt Switching Capacitor (SSC) on 11 kV distribution system located at Monatan, Ibadan, Oyo State in order to investigate the stability of the system during outages. Hourly data on bus voltage of the system were collected to determine the average bus voltage and voltage drop of the distribution system for stability evaluation using IEEE statutory limits method. Load Flow Models (LFM) of the distribution system was developed with incorporated Capacitor Switching Compensation (CSC) and solved using KCL analysis so as to improve the average bus voltage and voltage drop of the distribution system and simulation was done using MATLAB R2015a. The results of the average bus voltage and voltage drop of the distribution system were 10.5 $\pm$ sd kV and 4.2 $\pm$ sd kV, respectively. The CSC model improved the average bus voltage and voltage drop by 6 % and 33 % respectively. The study showed that incorporating capacitor switching as a compensation technique enhances the stability of the distribution systems. The research is useful in the planning and optimization of electrical distribution systems.
Keywords: *Electrical Distribution System, Voltage, Capacitor Switching Compensation, Load Flow Models, Monatan 11 kV Distribution System, Voltage Drop, MATLAB.*

Date of Submission: 20-12-2023 Date of acceptance: 03-01-2024

I. INTRODUCTION

At present, there is phenomenally increase in the demand for electricity especially in developing country like Nigeria and this persistent demand is leading to operation of the power system at its limit [1]. Therefore, the need for stable, reliable and quality power is on the rise due to electric power sensitive industries like communication, electronics and information technology among others. However, electric power demand is not the only criteria in this scenario but also the responsibility of the power system operators to provide a stable and quality power to the end users. These issues highlight the necessity of understanding the power system stability [2], [3], [4], [5].

Power system stability is that property of a power system that empowers it to stay in a condition of working balance under typical working conditions and to recover an adequate condition of balance in the wake of being exposed to an unsettling influence [3], [8],[19], [21], [23]..

In other words, power system is voltage stable if voltages after disturbances are close to voltages at normal operating conditions. A power system winds up unstable when voltages uncontrollably decrease because of outage of equipment, increase in load, decrement underway or in voltage control [5], [6], [7]. [23]. Despite the fact that the voltage stability is generally the local problem, the results of voltage instability may have a widespread impact. The consequence of this impact is voltage collapse, which results from an arrangement of possibilities rather than from one particular disturbance. It leads to really low profiles of voltage in a major part of power system [9], [11], [12], [13], [15]..

The main factors causing voltage instability are: the inability of the power system to keep voltage in the ideal range and coordination of the voltage control gadgets, load characteristics, parameters of transmission lines and transformers (Repo, 2001). Power system suffer greatly from voltage instability especially due to excessive consumption or injection of reactive power by the system elements and the consumers' loads [13], [14], [15].

1.1 Classifications of Power System Stability

Power system stability can be broadly classified into voltage, frequency and rotor angle stability. Each of these three stabilities can be further classified into large disturbance or small disturbance, short term or long term. The classification is depicted in Table 1. Analysis of stability problems, identification of essential factors that contribute to instability and devising methods of improving stable operation are greatly facilitated by classification of stability into appropriate categories. These categories are based on the following considerations [1], [3], [4], [16], [24].:

i. The physical nature of the resulting instability
ii. The size of the disturbance
iii. The devices, processes and the time span taken into consideration to determined stability
iv. The appropriate method of calculating stability.

Though, stability is classified into rotor angle, voltage and frequency stability but they are not isolated events. A voltage collapse at a bus can lead to large excursions in rotor angle and frequency. Similarly, large frequency deviations can lead to large changes in voltage magnitude. Each component of the power system such as power mover, generator rotor, generator stator, transformer, transmission lines, load, controlling devices and protection system should be mathematically represented to assess the rotor angle, voltage and frequency stability through appropriate analysis tools [4], [17], [25]. ..

Table 1: Classifications of Power System Stability [4], [11]

Power System Stability		
Type	Sub Type	
Voltage stability	Small Signal Stability Short Term Stability	Transient Stability Short Term Stability
Frequency Stability	Large Disturbance Stability	Long Term Stability
Rotor Angle Stability	Large Disturbance Stability Short Term Stability	Small Signal Stability Long Term Stability

1.2 Voltage Stability

Voltage stability is the ability of the system to maintain steady state voltage at all the system buses when subjected to a disturbance. If the disturbance is large then it is called as large disturbance voltage stability and if the disturbance is small it is called small disturbance voltage stability. Voltage stability can be a long term phenomenon [9], [18].

1.3 Voltage Collapse

Voltage breakdown is the procedure by which the grouping of occasions going with voltage insecurity prompts a low unsatisfactory voltage profile in a critical piece of the power system. It tends to be showed in a few distinctive ways [8]. At the point when a power system is exposed to an abrupt increment of reactive power request following a system possibility, the extra interest is met by the reactive power holds conveyed by the generators and compensators. As a rule there are adequate stores and the power system settles to a steady voltage level. Notwithstanding, it is conceivable, as a result of mix of occasions and system conditions, that the extra reactive power request may prompt voltage breakdown causing real separate of part of the system [8], [20] [22].

The normal voltage breakdown brought about by long haul strength is portrayed as pursues [8], [23]: some extra high voltage (EHV) transmission lines are heavily loaded, the available generation capacity of the critical area is temporarily reduced due to maintenance of unit or to market conditions, and reactive power reserves are at the minimum or are situated a long way from the critical area. Due to a fault or any other reason, a heavily loaded line is lost, immediately after the loss of EHV line, there would be decrease of voltage at adjacent load centres because of an additional reactive power demand. This would cause a load decrease and bringing about decrease of power flow in remaining EHV lines and consequently has a stabilizing effect. The voltage control of the system, in any case, rapidly restores generator terminal voltages by increasing excitation [8], [23].

1.4 Reactive Power Compensation

Leonard (2006) analyzed the requirement for reactive power compensation. It is prudent to supply this reactive power nearer to the load in the distribution system [10]. Reactive power compensation is frequently best approach to improve both power transfer capacity and voltage stability. The control of voltage levels is practiced by controlling the generation, absorption and flow of reactive power. The generating units give the fundamental methods for voltage control, because the automatic voltage regulators control field excitation to maintain planned voltage level at the terminals of the generators. To control voltage all through the system there is need to utilize extra devices to compensate reactive power [8].

Reactive compensation can be divided into series and shunt compensation. Shunt capacitors and reactors as well as series capacitors give passive compensation. They are either permanently connected to the transmission and distribution system or switched. They contribute to voltage control by modifying the network characteristics [18].

1.5 Shunt Capacitors

Shunt capacitors are employed at substation level for the following reasons:

i. **Voltage Regulation:** The main reason that shunt capacitors are installed at substations is to control the voltage within required levels. Load varies over the day, with very low load from midnight to early morning and peak values occurring in the evening between 4 PM and 7 PM. Shape of the load curve also varies from weekday to weekend, with weekend load typically low. As the load varies, voltage at the substation bus and at the load bus varies. Since the load power factor is always lagging, a shunt connected capacitor bank at the substation can raise voltage when the load is high [12]. The shunt capacitor banks can be permanently connected to the bus (fixed capacitor bank) or can be switched as needed. Switching can be based on time, if load variation is predictable, or can be based on voltage, power factor, or line current [19], [25].

ii. **Power Losses Reduction:** Compensating the load lagging power factor with the bus connected shunt capacitor bank improves the power factor and reduces current flow through the lines, transformers, generators, etc. This will reduce power losses (I^2R losses) in this equipment [6]. Shunt compensation with capacitor banks reduces kVA loading of lines, transformers, and generators, which means with compensation they can be used for delivering more power without overloading the equipment (i.e. it enhances better utilization of power equipment). Shunt capacitors have no moving parts, unlike some other devices used for the same purpose [22], [24].

Thousands of capacitor banks are installed in the entire distribution system. The primary usage for capacitor banks in the distribution system is to maintain a certain power factor at peak loading conditions. The target power factor is 0.98 leading at system peak. This figure was set as an attempt to have a unity power factor on the 69-kV side of the substation transformer. The leading power factor compensates for the industrial substations that have no capacitors. The unity power factor maintains a balance with ties to other utilities. The objective of power factor correction is to provide reactive power close to point where it is being consumed, rather than supply it from remote sources [8], [17].

Shunt capacitors banks are always connected to the bus rather than to the line. They are connected either directly to the high voltage bus or to the tertiary winding of the main transformer. Shunt capacitor banks are breaker-switched either automatically by a voltage relays or manually [8]. The capacitor requirement is developed on a per-transformer basis. The ratio of the kvar connected to kVA per feeder, the position on the feeder of existing capacitor banks, and any concentration of present or future load are all considered in determining the position of the new capacitor banks. The feeder type at the location of the capacitor bank determines if the capacitor will be pole-mounted (overhead) or pad-mounted (underground). Substation capacitor banks (three or four per transformer) are usually staged to come on and go off at specific load levels [16], [18], [20].

1.6 Series Capacitor Bank

A series capacitor bank consists of a capacitor bank, overvoltage protection system, and a bypass breaker, all elevated on a platform, which is insulated for the line voltage. The overvoltage protection comprised of a zinc oxide varistor and a triggered spark gap, which are connected in parallel to the capacitor bank, and a damping reactor. Prior to the development of the high-energy zinc oxide varistor in the 1970s, a silicon carbide nonlinear resistor was used for overvoltage protection [10]. Silicon carbide resistors require a spark gap in series because the nonlinearity of the resistors is not high enough. The zinc oxide varistor has better nonlinear resistive characteristics, provides better protection, and has become the standard protection system for series capacitor banks [5].

The capacitor bank is usually rated to withstand the line current for normal power flow conditions and power swing conditions. It is not economical to design the capacitors to withstand the currents and voltages associated with faults. Under these conditions capacitors are protected by a metal oxide varistor (MOV) bank.

The damping reactor (D) will limit the capacitor discharge current and damps the oscillations caused by spark gap operation or when the bypass breaker is closed [14].

Anderson *et al.* (1990) and Padiyar (1999), explained that series capacitor when radially connected to the transmission lines from the generation near by, can create a subsynchronous resonance (SSR) condition in the system under some circumstances [2], [20]. SSR can cause damage to the generator shaft and insulation failure of the windings of the generator. The ability to vary the series compensation will give more control of power flow through the line, and can improve the real stability limit of the power system. Varying the series compensation by switching with mechanical breakers is slow, which is acceptable for control of steady-state power flow [2], [20], [21].

1.7 Electrical Distribution System

Electrical Distribution system is the final stage in the delivery of electric power. It carries electricity from transmission system to individual consumers. Primary distribution lines carry medium voltage to distribution transformers located near the customer's premises while the distribution transformers lower the voltage to the utilization voltage of household appliances and typically feed several customers through secondary distribution lines [5], [10], [21], [25].

A typical distribution substation as shown in Figure 1 will serve from one to as many as ten feeder circuits. A typical feeder circuit may serve numerous loads of all types. A light to medium industrial customer may take service from the distribution feeder circuit primary, while a large industrial load complex may take service directly from the bulk transmission system. All other customers, including residential and commercial, are typically served from the secondary of distribution transformers that are in turn connected to a distribution feeder circuit [7], [10].

It holds a very significant position in the power system since it is the main point of the line between bulk power and consumers, and it contributes to about 2-3% of the total losses in power systems [5]. The distribution systems are usually designed to operate at specified power capability and voltage level. Operating outside the allowable tolerances of these values affect the quality of power reaching the consumers of electricity [1].

Nigeria distribution system since its inception is designed to operate radially. Electric power flows in one direction from large generating power plants to the customers load along the radial feeder. In addition, Nigeria distribution system comprises of eleven Distribution Companies (DISCOS); Electricity Distribution Companies of Abuja, Benin, Eko, Enugu, Ibadan, Ikeja, Jos, Kaduna, Kano, Port-Harcourt and Yola respectively [1]. However, for the purpose of this study data of practical 11 kV Monatan distribution substation feeder fed from Ibadan North–Adogba 132/33kV, 30MVA Transmission substation of Ibadan Electricity Distribution Company (IBEDC) will be used.

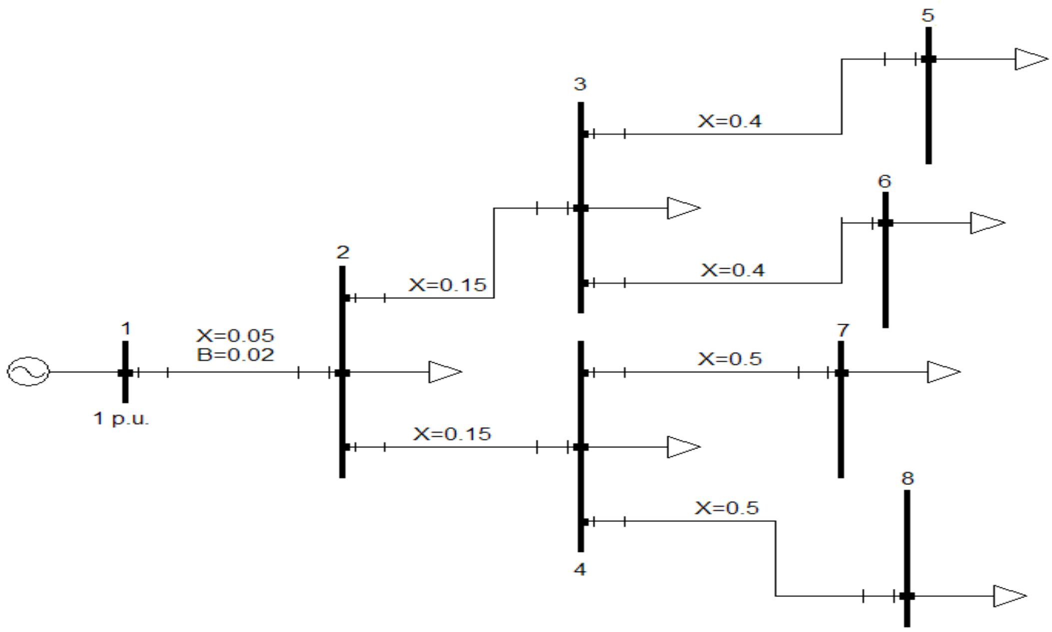

Figure 1: A Typical Electrical Distribution Network

II. MATERIALS AND METHOD

In this study a mathematical model of a distribution system with Capacitor Switching Compensation (CSC) incorporated for voltage stability of Monatan 11kV distribution system was formulated. Capacitor Switching Compensation (CSC) was included in the Load Flow Models (LFM) of the distribution system for steady state of power system and solved using KCL analysis in order to improve the average bus voltage and voltage drop of the distribution system and simulation was carried out in MATLAB environment. One day hourly recorded bus voltage data from Monatan 11 kV distribution injection substation of Ibadan Electricity Distribution Company (IBEDC) Plc were obtained to compute the voltage drop and percentage voltage drop of the distribution system without and with Capacitor Switching Compensator.

By considered the distribution system (11 kV Monatan distribution system) with incorporation of Capacitor Switching as shown in Figure 2. The distribution lines are represented by their equivalent models where impedance has been converted to per unit admittances on a common MVA base.

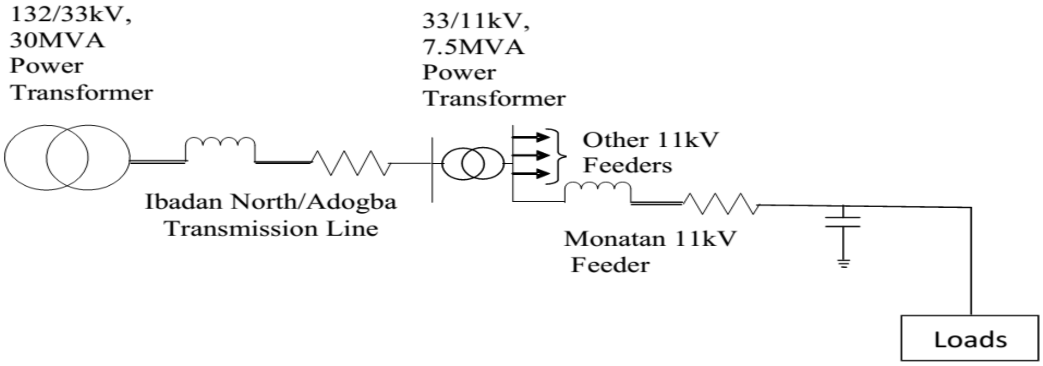

Figure 2: One- Line Diagram of Monatan 11kV Feeder with Capacitor Switching Compensator

By applied KCL at the current entering of the system, the current entering bus without capacitor placement is given as:

$$I_i = \frac{P_i - jQ_i}{V_i^*} = \frac{S_i^*}{V_i^*} \quad (1)$$

The voltage in the system without capacitor placement is given as:

$$V_i = |V_i| < \delta_i = |V_i|\,(cos\ \delta_i + j\sin\delta_i) \quad (2)$$

The real and reactive power in the system without capacitor placement is given as:

$$P_i = V_i \sum_{j=1}^{n} V_j\, Y_{ij} \cos(\theta_{ij} + \delta_j - \delta_i) \quad (3)$$

$$Q_i = -V_i \sum_{j=1}^{n} V_j\, Y_{ij} \sin(\theta_{ij} + \delta_j - \delta_i) \quad (4)$$

However, with application of Capacitor Switching on the distribution system, the feeder current is given as:

$$I_i = \frac{\sqrt{P^2 + (Q - Q_C)^2}}{V_i^*} \quad (5)$$

The voltage magnitude in the system with capacitor placement is given as:

$$V_{new} = \frac{S_{new}}{P} X\, V_{old} = \frac{V_{old}}{PF_{new}} \quad (6)$$

The real and reactive power in the system with capacitor placement is given as:

$$P_i = V_i \sum_{j=1}^{n} V_j\, Y_{ij} \cos(\theta_{ij} + \delta_j - \delta_i) \quad (7)$$

$$Q_{new} = \sqrt{S_{new}^2 - P^2} \quad (8)$$

The voltage drop in the distribution system with incorporation of Capacitor Switching Compensator can be derived as follows:

From power flow equation, current flowing from bus is:

$$I_{ij} = (V_i - V_j)Y_{ij} \quad (10)$$

where

$$V_i - V_j = V_d \text{ or } \Delta V \text{ (voltage drop)} \quad (11)$$

The voltage drop should be within IEEE statutory limits of $\pm 10\%$ [25].

Hence,

$$I_{ij} = V_d Y_{ij} \quad (12)$$

and

$$I_{ij} = \frac{P_{ij} - jQ_{ij}}{V_i^*} \quad (13)$$

Substituting equation (12) in (13)

$$V_d = \frac{P_{ij} - jQ_{ij}}{V_i^* Y_{ij}} \quad (14)$$

The voltage drop can be regulated by adjusting the system reactive power. Therefore, the voltage drop can also be written as:

$$\Delta V = IZ = I(R + jX) \quad (15)$$

since

$$I_{ij} = \frac{P_{ij} - jQ_{ij}}{V_i^*} \quad (16)$$

$$\Delta V = \frac{P_{ij} - jQ_{ij}}{V_i^*}(R + jX) \quad (17)$$

This can be approximated to

$$\Delta V = \frac{RP + XQ}{V_i^*} \quad (18)$$

This shows that voltage drop is a function of load. The percentage voltage drop in the system is given as:

$$Percentage\ voltage\ drop = \frac{Voltage\ drop}{Nominal\ voltage\ value} X\ 100 \quad (19)$$

The MVA of the network after compensation is given as:

$$S_{(C)} = \sqrt{P_{LT(c)}^2 + Q_{LT(c)}^2} \quad \text{in MVA} \quad (20)$$

The kVAr capacity of the capacitor required to carry out full compensation of the network was determined below.

$$kVAr \text{ required} = P(\tan \emptyset_1 - \tan \emptyset_2) \quad (21)$$

where ;

$P = 96100kW$ (the peak kW recorded on Monatan Feeder)

$\cos \emptyset_1 = 0.8$;

$\tan \emptyset_1 = 0.75$

$\cos \emptyset_2 = 0.95$;

$\tan \emptyset_2 = 0.325$

$kVAr$ required $= 96100\ kW\ (0.75 - 0.325)$

$= 41MVAr$

This size corresponds to value obtained from (BICC, 1965) tables for determining sizes of capacitor in kVAr per kW of load of raising the power factor. Install 41MVAr to improve power factor to 95%. The rating of the capacitor should not be greater than the no-load magnetizing kVAr. It is of advantage to locate capacitors at the power centres or feeders in order to group them (capacitors) together.

The μF capacity of the capacitor required to carry out full compensation of the network was given by

$$C = \frac{1}{2\pi f X_c} \quad (22)$$

Where;

$$X_c = \frac{V^2}{Q_c}$$

$$= \frac{(10.5\ X\ 10^3)^2}{41\ X\ 10^6}$$

$$= 2.689\Omega$$

hence,

$$C = \frac{1}{2\ X\ 3.142\ X\ 50\ X\ 2.689}$$

$$= 1183.6\ \mu F$$

Where:

Z is the impedance of the line

R is the resistance of the line

X is the reactance of the line

Q_c is the reactive power injected by the capacitor in MVAR

I_c is the current injected by the capacitor

X_c is the reactance of the capacitor

I_i is the magnitude of current in Amps

R_i is the resistance of branch i in (Ω/km/phase)

X_i is the reactance of branch i in (Ω/km/phase)

Y is the admittance of the line

V_i is the voltage at bus i

I_i^* is the complex conjugate of source current I_i injected into the bus i

P_i is the real power at bus i
Q_i is the reactive power at bus i
Q_{new} is the reactive power when capacitor is used
V_{new} is the voltage when capacitor is used
V_{old} is the voltage when capacitor is not used
P is the active power
$I_{i(C)}$ is the magnitude of current in Amps after compensation

III. RESULTS AND DISCUSSION

The test sample for the analysis was the Monatan 11 kV loaded primary radial feeder from the existing 33 kV functioning feeders in Adogba Power Transmission station, Ibadan Electricity Distribution Company Plc, Nigeria. The result of the simulation was analyses and presented without and with capacitor compensation in Figure 3 to Figure 16.

Figure 3 to Figure 5 presented the bar charts of the bus voltage, voltage drop and percentage voltage drop with time (hours) without compensation. It was observed that the voltage drop and percentage voltage drop increased with time respectively. However, the bus voltage reduced with time because the reactive power demand increased with time.

Figure 6 to Figure 8 showed the bar charts when the load in MVA was plotted with the bus voltage, voltage drop and percentage voltage drop respectively without compensation. The observation was that as load in MVA increased, voltage drop and percentage voltage drop increased while the bus voltage decreased.

In addition, Figure 9 to Figure 11 was the plots for the bus voltage, voltage drop and percentage voltage drop with time (hours) respectively when capacitor was used. The bar charts revealed that bus voltage, voltage drop and percentage voltage drop decreased with time compared to when no compensation was used.

Figure 12 to 14 showed the bar charts when the load in MVA was plotted with bus voltage, voltage drop and percentage voltage drop respectively with compensation. It was observed that the voltage drop and percentage voltage drop decreased, while the bus voltage increased. Figure 15 and Figure 16 showed the summary of the results of the bus voltage and percentage voltage drop obtained with and without capacitor switching respectively. It was observed that the effects of compensation on the power system are increase in the bus voltage and reduction in percentage voltage drop.

From the results obtained, it can be depicted that capacitor reduces the load (MVA demand) of the installation, voltage drop and increases the bus voltage. The average MVA loading on the transformer released by 16 % as it was 5.1 MVA before compensation and became 4.3 MVA after compensation. The average voltage drop reduced by 33 % as it was 4.2 kV before compensation and became 2.8 kV after compensation. The average bus voltage improved by 6 % as it was 10.5 kV before compensation and became 11.1 kV after compensation. The percentage voltage drop are within the regulatory limits of $\pm 10\%$ tolerance of the nominal voltage (IEEE statutory limits is $\pm$ 10 %) when compensation is used.

It can be deduced from the comparison between simulated results with and without capacitor that the bus voltage increased between the first and second, sixth and seventh, thirteenth and fourteenth, sixteenth and eighteenth as well as twentieth and twenty-fourth hours of the day due to decrease in load demand on the distribution system. Percentage voltage drop decreased within the same hours due to the same reason (decrease in load demand). However, the bus voltage and percentage voltage drop were constant at some hours of the day because of constant in load demand on the distribution system at those hours. Increase in load demand on the distribution system results in decrease in the bus voltage as well as increase in percentage voltage drop respectively during certain hours of the day. In a nutshell, variation in load demand on the distribution system results in variation in the bus voltage and percentage voltage drop respectively.

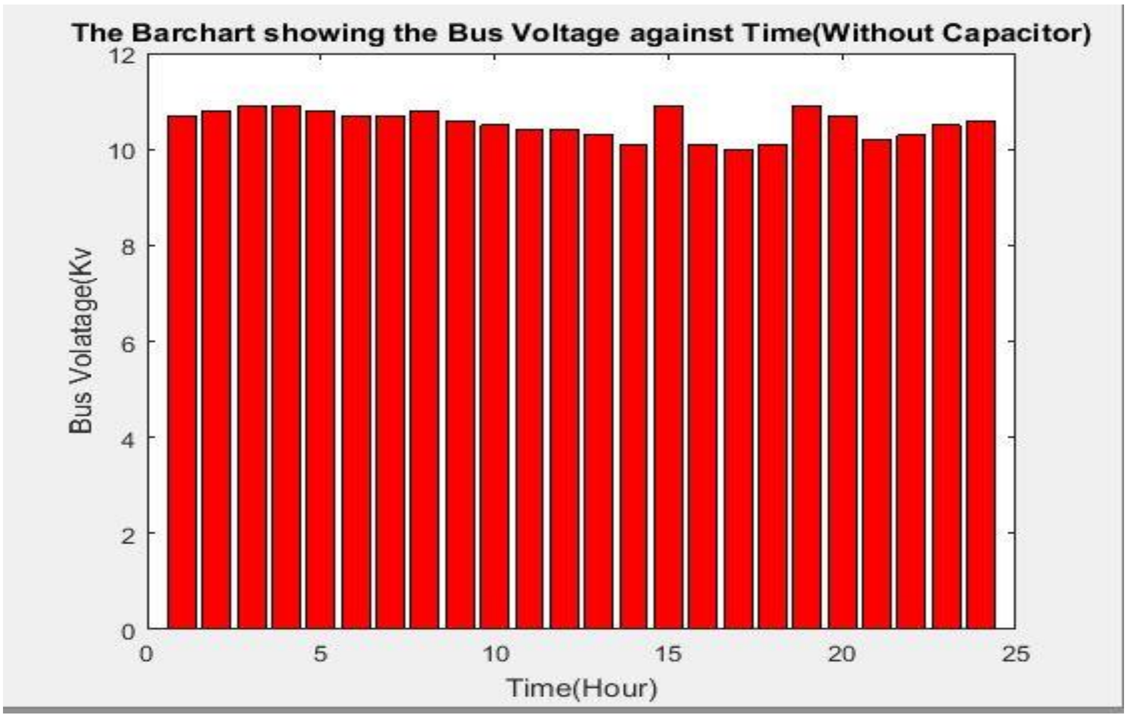

Figure 3: Bar Chart of Bus Voltage against Time without Capacitor

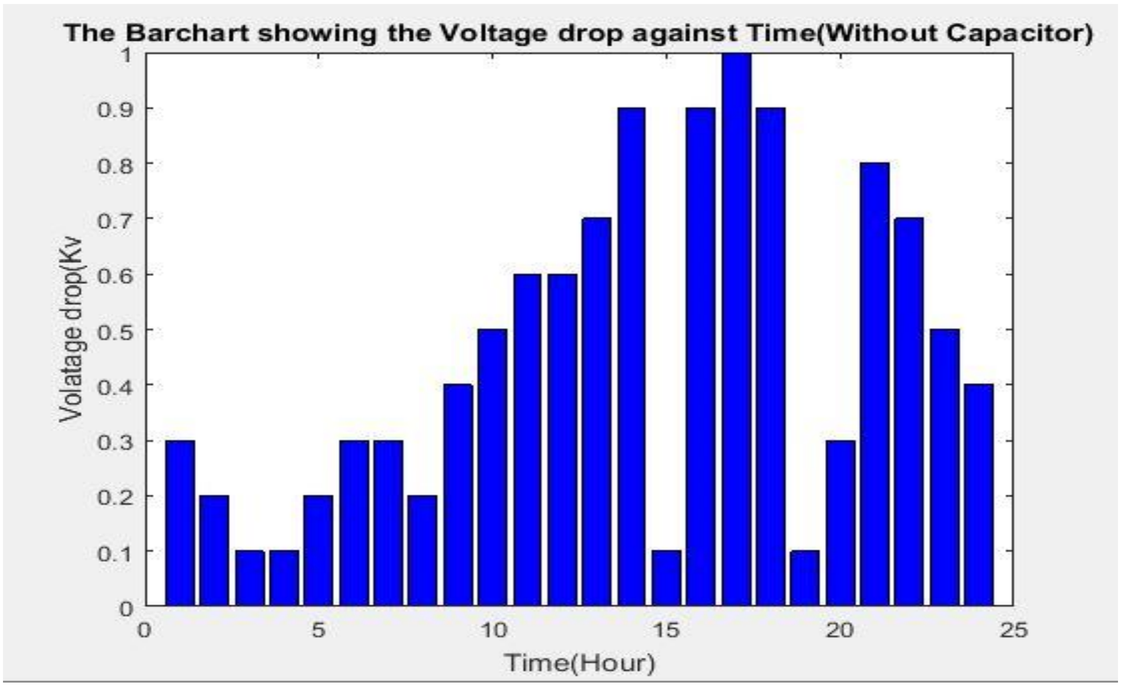

Figure 4: Bar Chart of Voltage drop against Time without Capacitor

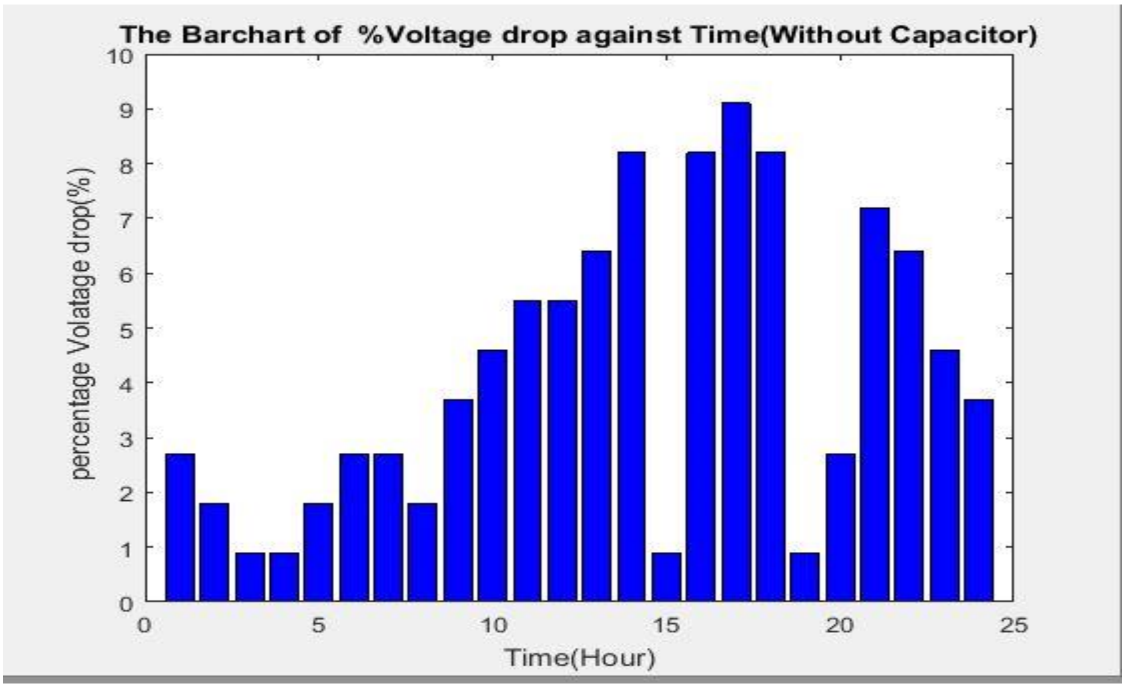

Figure 5: Bar Chart of Percentage Voltage drop against Time without Capacitor

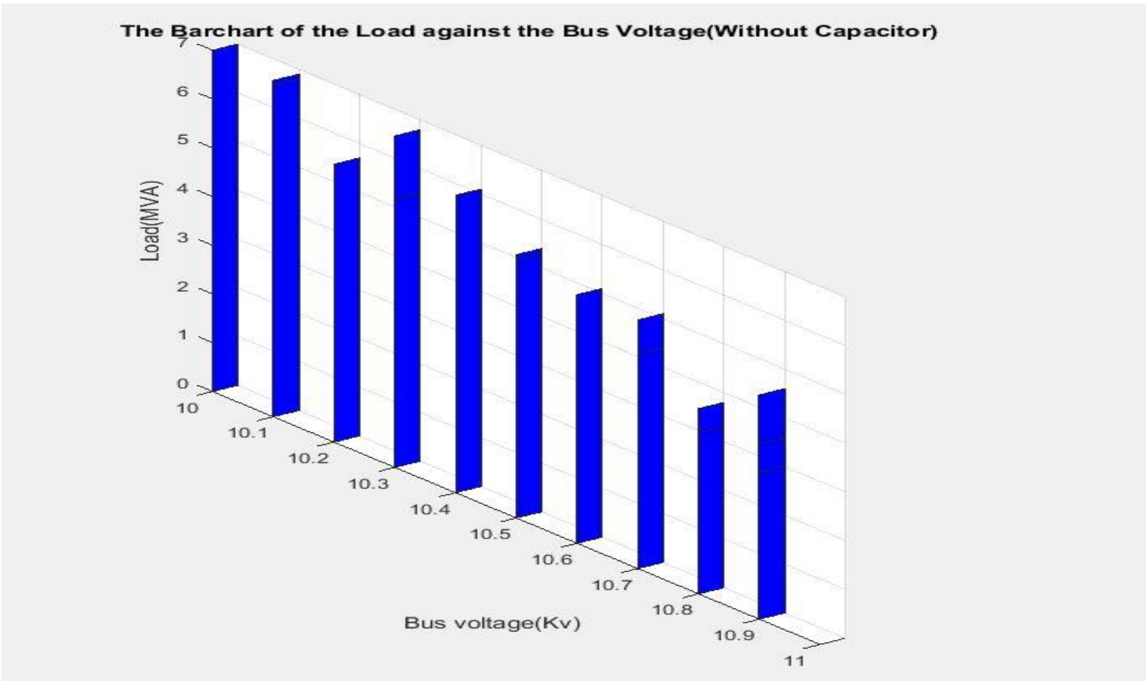

Figure 6: Bar Chart of Load against Bus Voltage without Capacitor

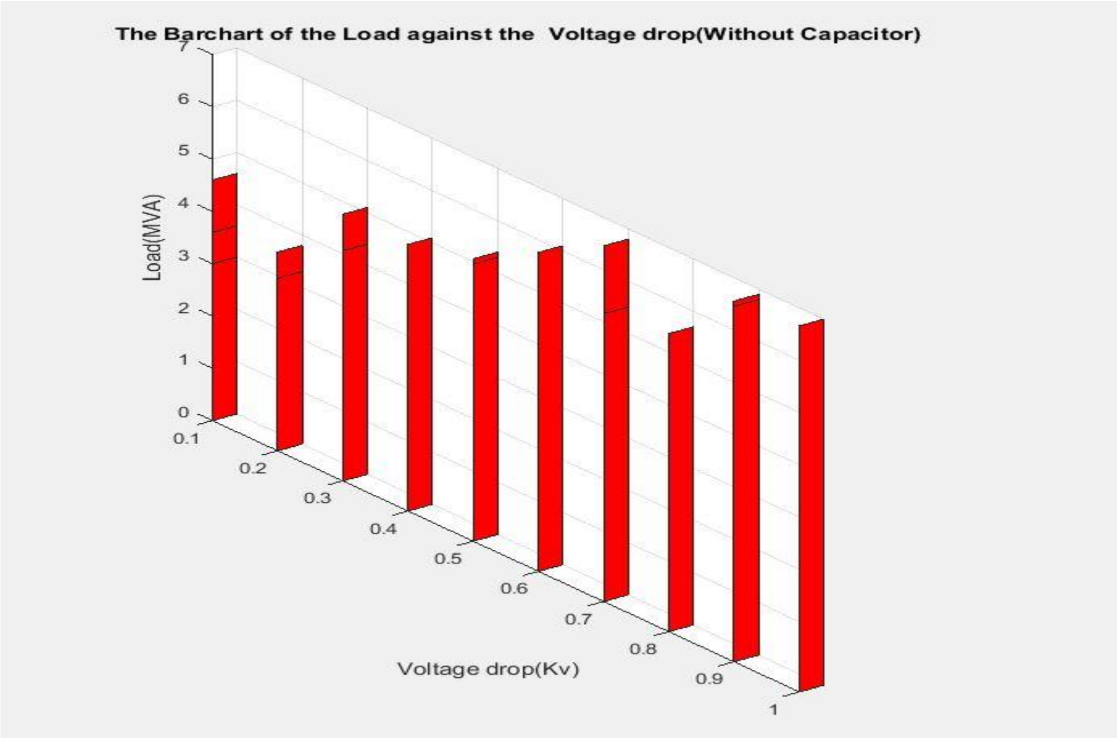

Figure 7: Bar Chart of Load against Voltage drop without Capacitor

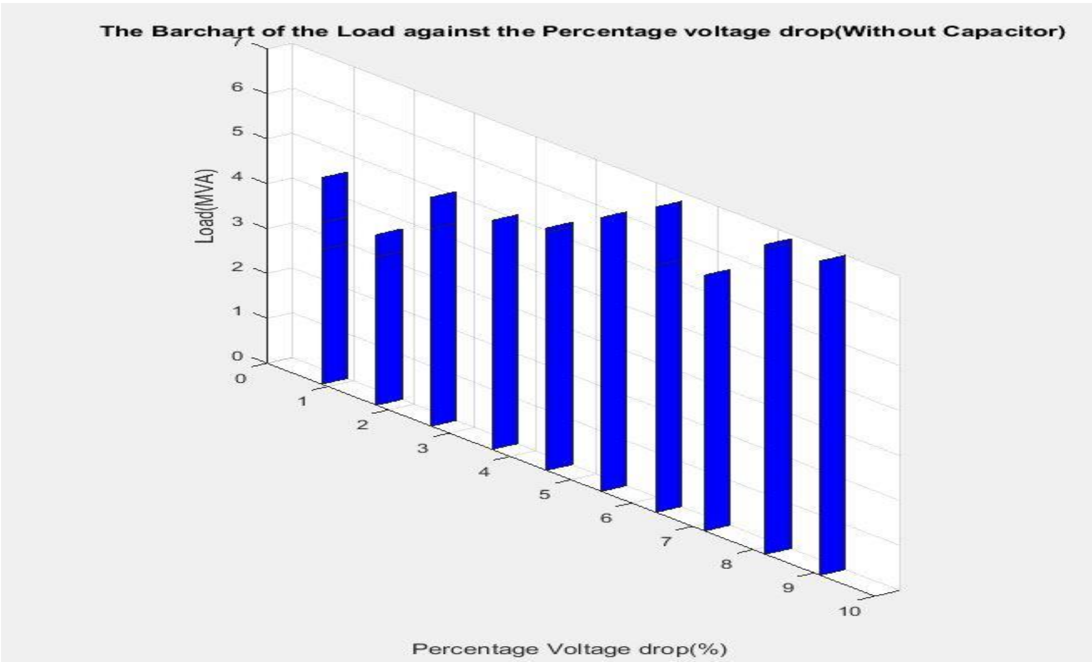

Figure 8: Bar Chart of Load against Percentage Voltage drop without Capacitor

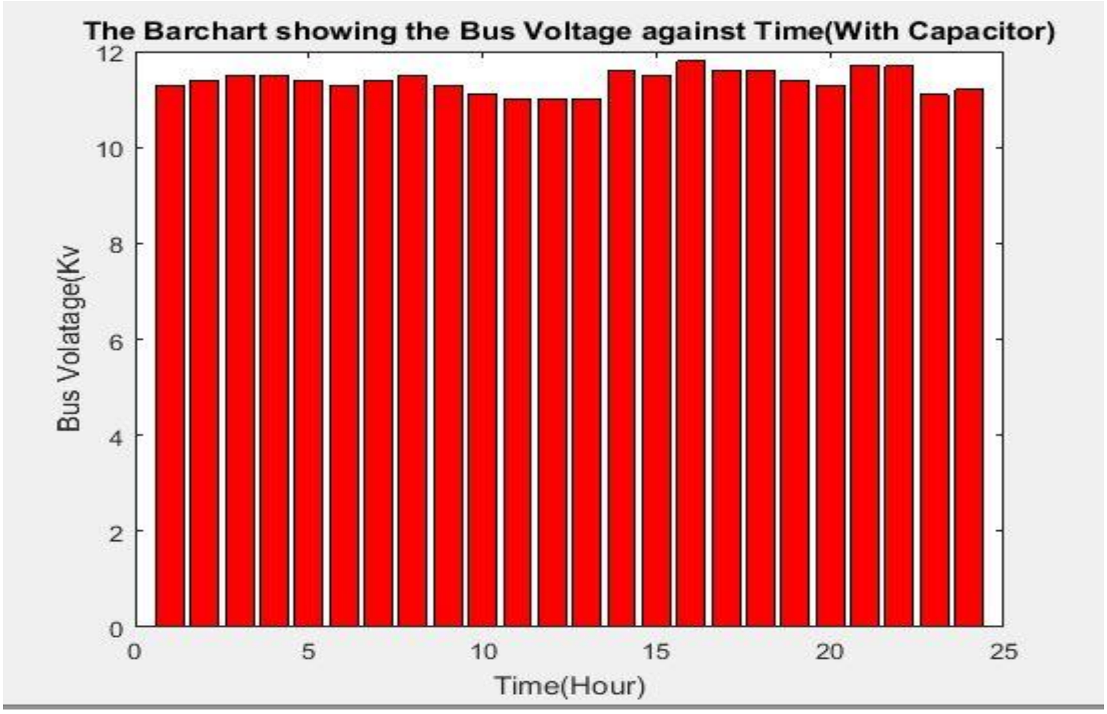

Figure 9: Bar Chart of Bus Voltage against Time with Capacitor

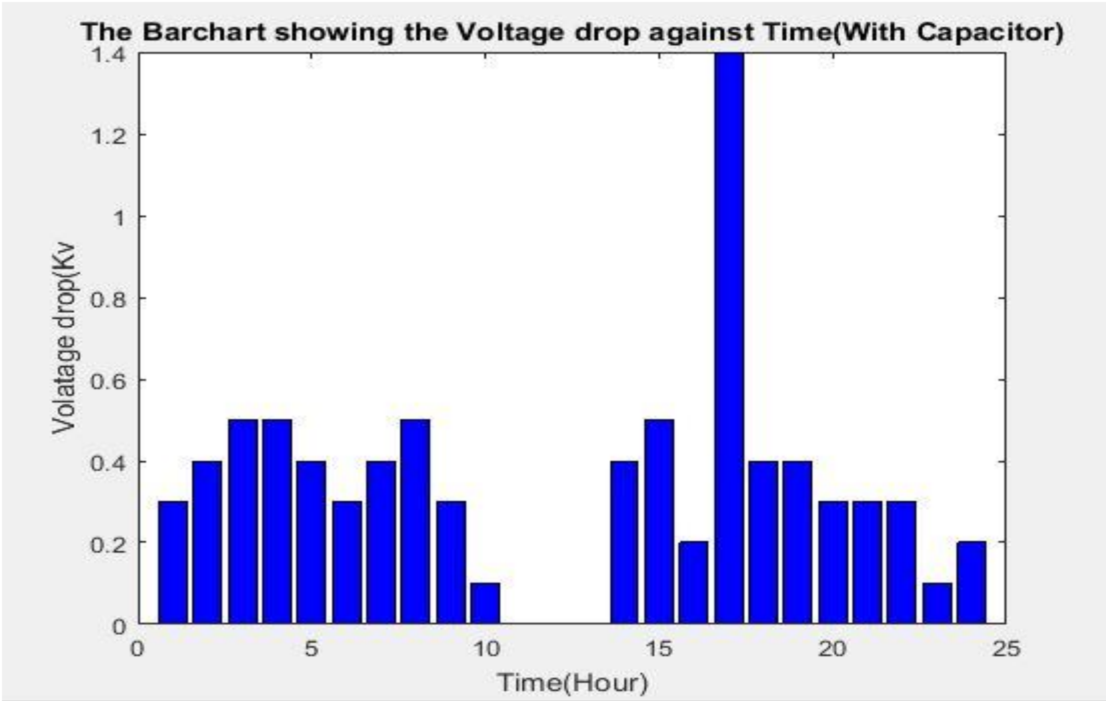

Figure 10: Bar Chart of Voltage drop against Time with Capacitor

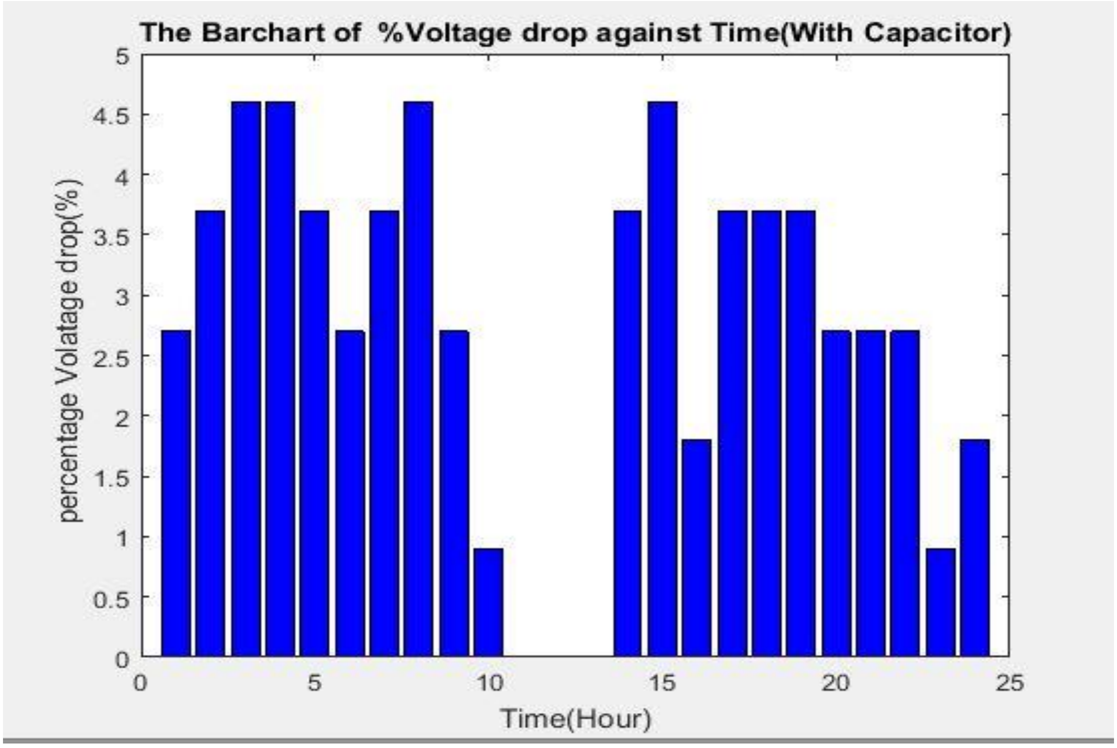

Figure 11: Bar Chart of Percentage Voltage drop against Time with Capacitor

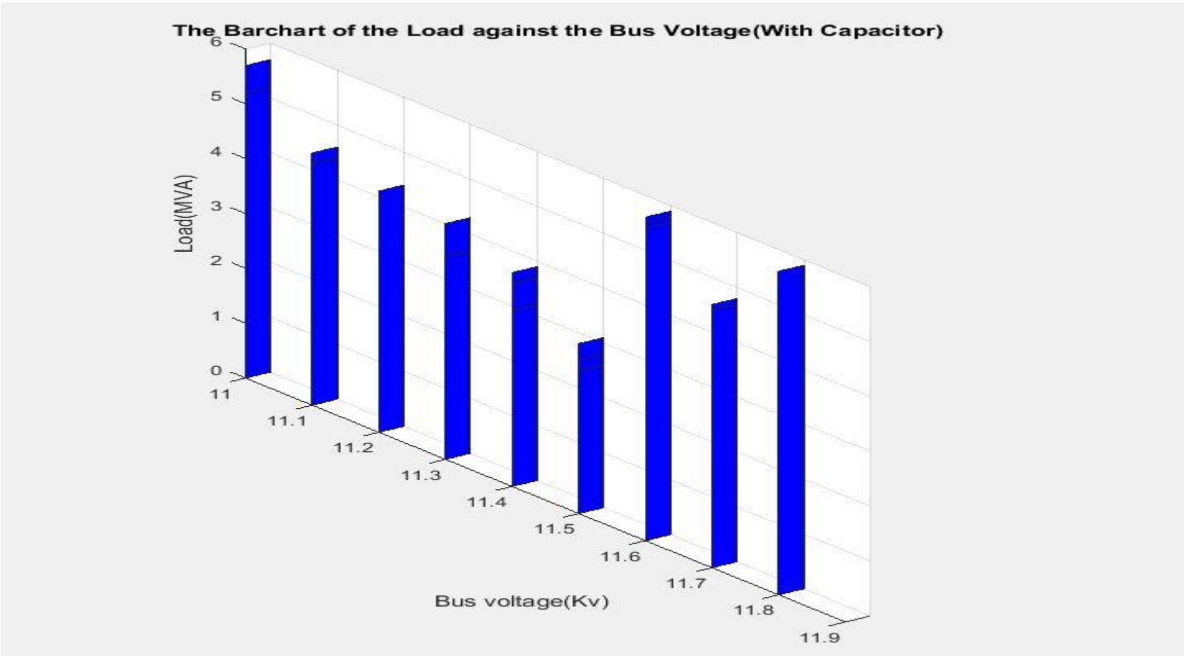

Figure 12: Bar Chart of Load against Bus Voltage with Capacitor

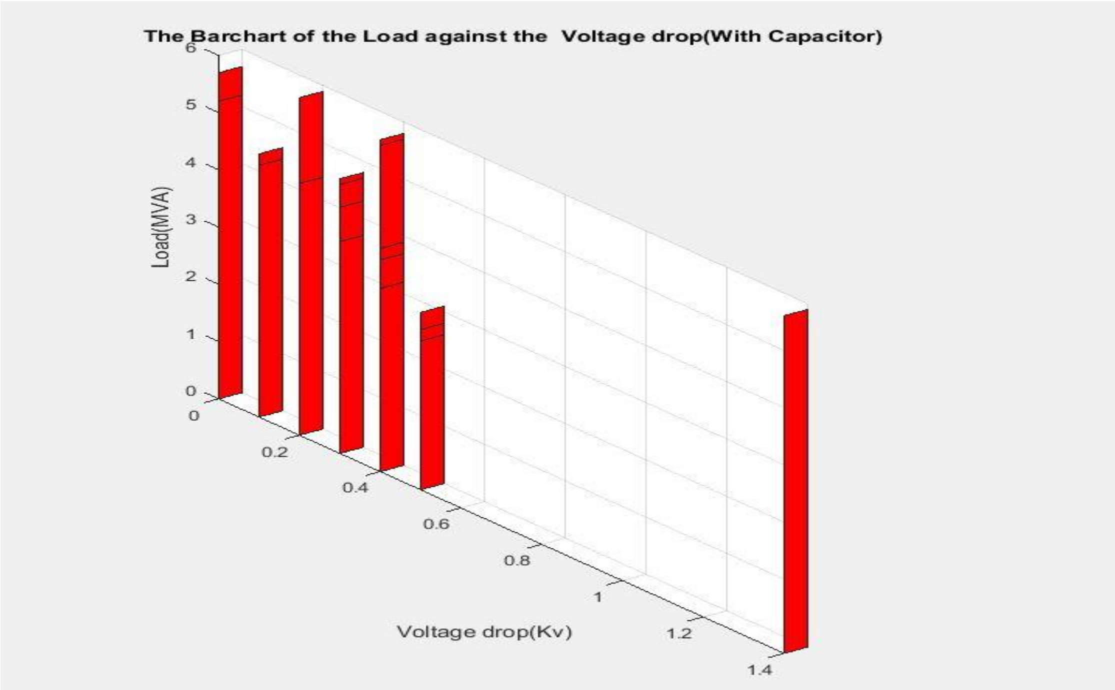

Figure 13: Bar Chart of Load against Voltage drop with Capacitor

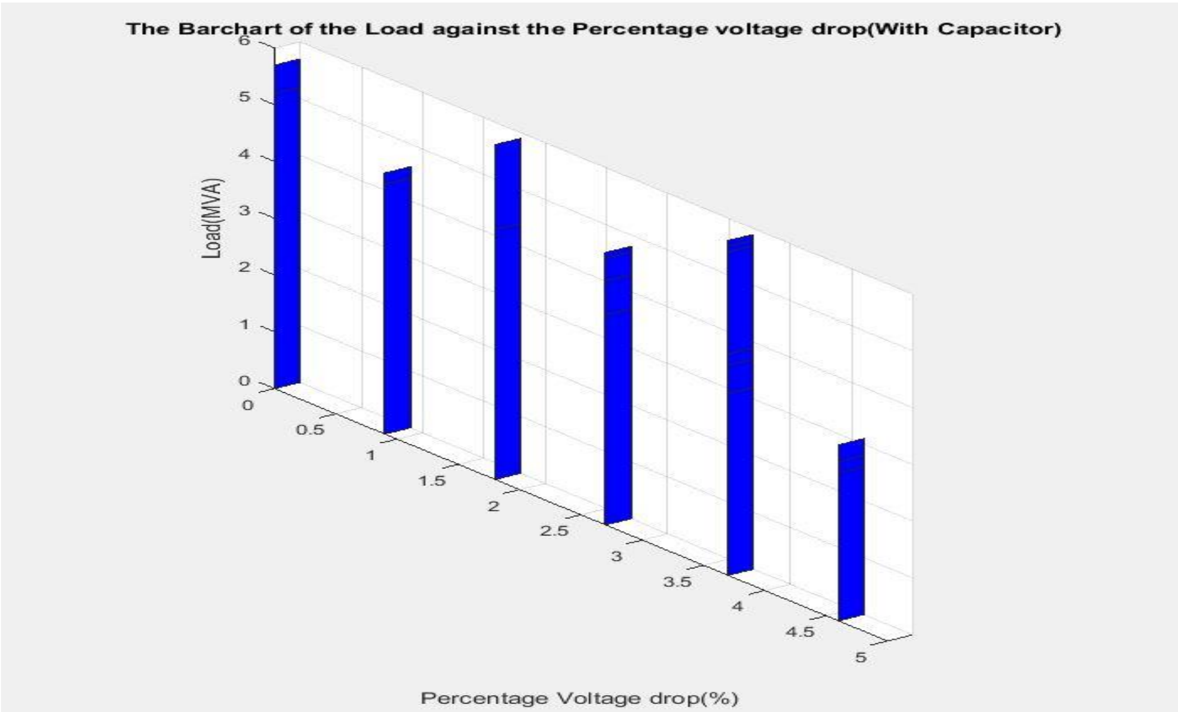

Figure 14: Bar Chart of Load against Percentage Voltage drop with Capacitor

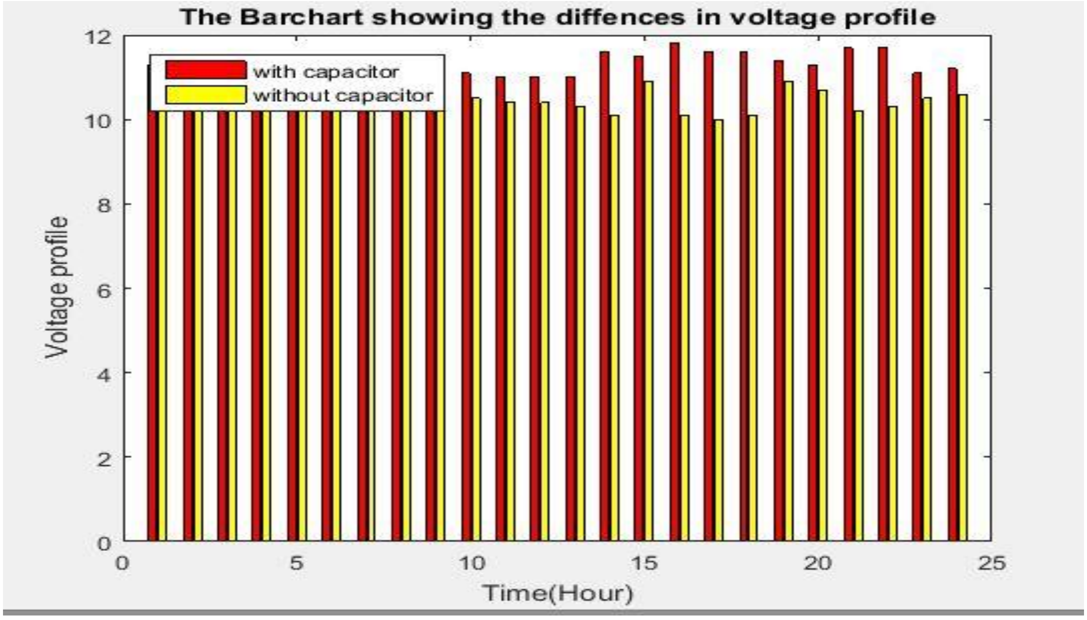

Figure 15: Bar Chart of the Voltage Profile with and without Capacitor

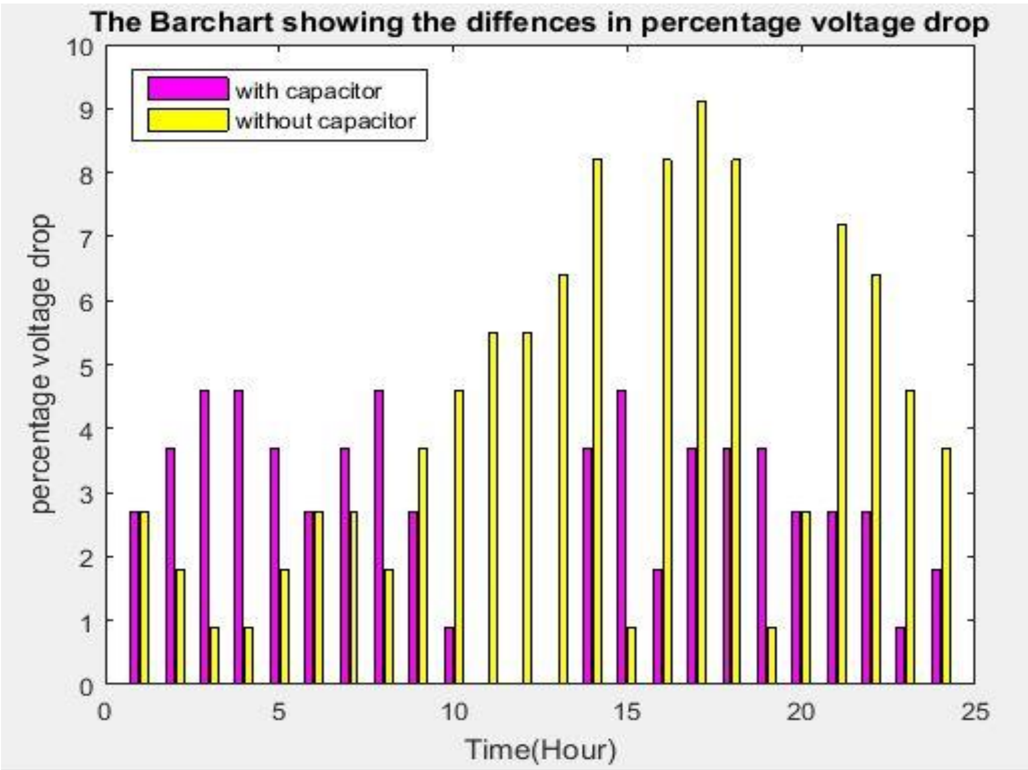

Figure 16: Bar Chart of Percentage Voltage drops with and without Capacitor

IV. CONCLUSION

This work has formulated the mathematical model of Capacitor Switching Compensator to regulate bus voltage on primary feeder of Monatan 11 kV distribution injection substation of Ibadan Electricity Distribution Company (IBEDC) Plc for the purpose of investigating the bus voltage improvement in the system. Simulations with and without capacitor were carried out by include Capacitor Switching Compensation into the Load Flow Models (LFM) of the distribution system for steady state of power system and solved using KCL analysis. Very low bus voltage was obtained from the study without voltage compensation at system feeder. The result revealed the reality of the poor power supply in distribution system. The results also, revealed that average bus voltage improved by 6 %. The average voltage drop is within the regulatory limits of $\pm 10\%$ tolerance of nominal voltage. However, installation of shunt capacitor bank and simulations carried out on Monatan 11 kV distribution feeder confirmed that capacitor switching provides improvement to the voltage level in the system.

REFERENCES

[1]. Adejumobi, I. A. and Adebisi, O. I. (2012): "Power Loss Reduction on Primary Distribution Networks Using Tap-Changing Technique", International Journal of Research and Reviews in Applied Sciences (IJRRAS), 10 (2): 272-279.

[2]. Anderson, P. M. and Farmer, R. G. (1996): "Series Compensation in Power Systems", Fred Laughter Publishing Inc. Encinitas, California, USA, pp. 112-125.

[3]. Cutsem, T. V. and Vournas, C. (1998): "Voltage Stability of Electric Power Systems", Kluwer Academic Publishers, Boston, USA, pp. 378-379.

[4]. Gargeya M. A. (2013): "A New Proposal for mitigation of power quality problems using DSTATCOM", International Journal of Scientific Engineering and Technology, Vol. 2 (5), Pp. 317-321.

[5]. Grainger, J. J. and Lee, S. H. (1981): "Optimum Size and Location of Shunt Capacitors for Reduction of Losses on Distribution Feeders", IEE Trans-PAS. 100, pp. 1105-1118.

[6]. Imad, H. I. and Marwan, M. M. (2002): "Energy Efficiency Improvement by Raising of Power Factor At Industrial Sector In Palestine", Pakistan Journal of Applied Sciences,2(9):907-912.

[7]. Jianwei, L. M., Salama, M. A. and Mansour, R. R. (2002): "An Efficient Power Flow Algorithm for Distribution Systems with Polynomial Load", International Journal of Electrical Engineering Education, 39 (4): 371-386.

[8]. Kundur, P. (1994): "Power System Stability and Control", 1st Edition, McGraw-Hill Professional Publishing, pp. 67-82, 151-168.

[9]. Ledwich G and Ghosh A. (2002): "A flexible DSTATCOM operating in voltage or current control mode", IEE Proc.-Gener. Trunsm. Disrrih, Vol. 149 (2), Pp. 215-224.

[10]. Leonard, L. G. (2006): "Electric Power Generation, Transmission and Distribution", 2nd Edition, CRC Press, Taylor and Francis Group, Boca Raton, pp. 266-277.

[11]. Mahmoud, M. E. (2018): "Power System Stability: a Technical Report and A Short Course", t: https://www.researchgate.net/publication/323073706, 1-6.

[12]. Massey, G. W. (2000): "The Impact of Installing Power Factor Improvement Capacitors: An Overview and Case Study", Proc. Electric Power Research, 56, pp. 51-60.

[13]. Matthew, S., Wara, S. T., Adejumobi, I. A., Ajisegiri, E. S. A., and Olanipekun, A. J. (2014): "Power Systems Voltage Stability Improvement Using Static Var Compensator", International Journal of Emerging Technology and Advanced Engineering (IJETAE), 4 (1): 494-501.

[14]. Miske, Jr., S. A. (1995): "Recent Series Capacitor Applications in North America", Paper presented at CEA Electricity, Vancouver Conference, pp. 1-3.

[15]. Mohamed, A. E., Samir, A. E., Dalal, H. H. and Mohamed, T. I. (2007): "The Impact of Capacitor Bank Installation on the Performance of Distribution Systems – A Case Study", 19th International Conference on Electricity Distribution (CIRED), 5 (0274): 1-4.

[16]. Molavi H and Ardehali M.M. (2013): "Application of distribution static compensator (D-STATCOM) to voltage sag mitigation", Universal Journal of Electrical and Electronic Engineering, Vol. 1 (2), Pp. 11-15.

[17]. Mynuddin, M., Roknuzzaman, K. M., Biswas, P. and Tanjimuddin. M. (2015): "Stability Study of Power System", International Journal of Energy and Power Engineering 2015; 4(2): 43-50.

[18]. Onohaebi, S. O., Odiase, O. F. and Osafehinti, S. I. (2010): "Improving the Efficiency of Electrical Equipment by Power Factor Correction – A Case Study on Medium Scale Study in Nigeria", Journal of Mathematics and Technology, (2):68.

[19]. Oodo, O. S., Liu, Y., and Sun, H. (2011): "Application of Switched Capacitor Banks for Power Factor Improvement and Harmonics Reduction on the Nigerian Distribution Electric Network", International Journal of Electrical & Computer Sciences (IJECS-IJENS),11 (6): 58-68.

[20]. Padiyar, K. R. (1999): "Analysis of Subsynchronous Resonance in Power Systems", Kluwer Academic Publishers, Boston, USA, pp.108-116.

[21]. Prashanthi M and Himani A. (2013): "Reduction of reactive power in a distribution system using D-STATCOM", Journal of Research in Electrical and Electronics Engineering, Volume 2 (4), Pp. 18-23.

[22]. Ramasamy, N. (2005): "Power System Capacitors", CRC Press, Taylor and Francis Group, Boca Raton, pp. 97-113.

[23]. Repo, S. (2001): "On-line Voltage Stability Assessment of Power System – An Approach of Black-box Modelling", Ph.D. Thesis, Tampere University of Technology Publication, pp. 344-345.

[24]. Taylor, C. W. (1994): "Power System Voltage Stability", McGraw-Hill Companies, Singapore, pp. 62-73.

[25]. United State Energy Association. (1999): "Handbook of Climate Change Mitigation Options for Developing Country Utilities and Regulatory Agencies", Property of USEA Energy Partnership Program,version 1.0, June 1999.