# Power Flow Analysis and placement of SVC in IEEE 14 and IEEE 30 Bus Power System for Loss Minimization and Voltage Stability Enhancement

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**ABSTRACT:** This paper present SVC (Static VAR Compensation) and the voltage profile at different load buses of 14 and 30 bus system and the improvement in the voltage profile by placing SVC at different load buses in the power system. SVC is a first generation FACTS device. A variable impedance device that can control voltage at the required bus thereby improving the voltage profile of the system.SVC has inherent capability for high-speed, cycle-by-cycle control of vars , it will counter act the often hazardous voltage depressions that follow in conjunction with faults in the grid. More power can be transmitted through the existing system. The dynamic load pattern and increasing load demand, it is necessary for many electrical utilities to operate their system closer to the system operating capacity. It can be done by using facts devices- FACTS is one aspect of the power electronics revolution that is taking place in all areas of electric energy eg: TCSC, SVC, SSSC, STATCOM, UPFC etc.

***KEYWORDS:*** *SVC (Static VAR Compensation), Newton Rapson, power flow, voltage profile etc.*

## I. INTRODUCTION

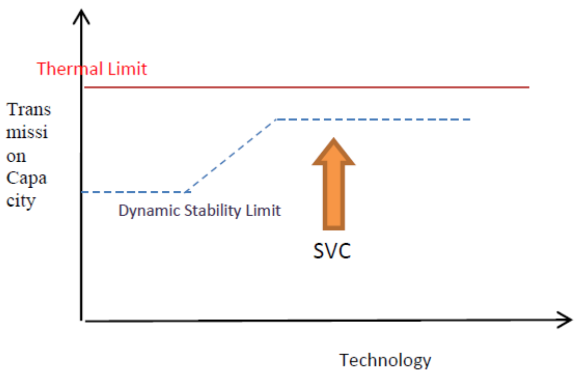
In the recent power system scenario in order to improve the capacity of transmission system with lowest cost of generation an emerging technology called FACTS has been introduced. FACTS stand for Flexible AC Transmission System. FACTS technology is a power electronics based enabled technology consists of a number of controllers. [1]

FACTS-not only offer the advantage of high speed and Utility of switching but, more importantly, the opportunities offered by a variety of innovative circuit concept based on these power devices enhance the value of electric energy.

The FACTS technology is not a single high-power Controller, but rather a collection of Controllers, which can be applied individually or in coordination with others to control one or more of the interrelated system .A well-chosen FACTS Controller can overcome the specific limitations of a designated transmission line or a corridor

This paper presents modelling and application of Static VAR compensators (SVC) for stabilizing power systems.

FIGURE 1-Increase in Transmission Capacity by SVC device. [20]

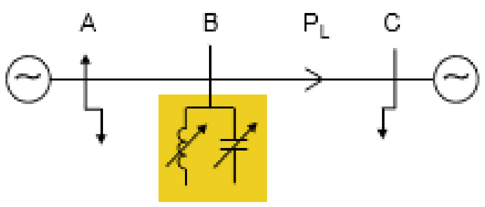



Basic SVC control strategies are examined in terms of enhancing the dynamic and transient stabilities, improving transmission capacity and damping power oscillations.

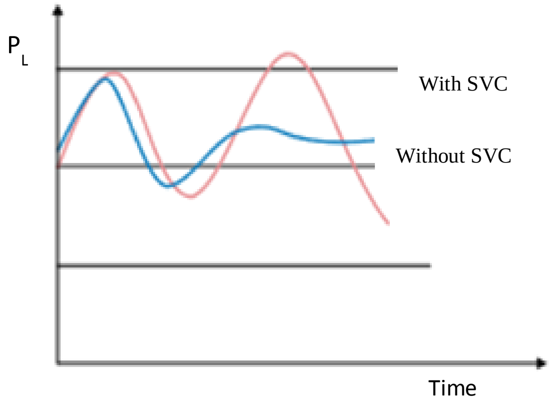
Figure 1 shows that SVC boost the transmission capacity of the line, it will ensure that the system voltage does not sag even when the power flow grows heavy. This means that more power can be transmitted through the system under stable conditions over existing lines, below thermal limits . As the current flows through the conductor increase, their temperature increases, and the line elongate, which increase the sag of conductor. The thermal limits of the conductor are set to limit the temperature attained by the energized conductors. This paper presented the placement of SVC in theIEEE 14 and IEEE 30 bus system. The effects of SVC on voltage stability of a power system. The results for the IEEE 14, 30 bus network show SVC and can be used to increase system stability in practical power systems**.** [2].Static VAR Compensator (SVC) is a first generation FACTS device that can control voltage at the required bus thereby improving the Voltage profile of the system. The primary task of an SVC is to maintain the voltage at a particular bus by means of reactive power compensation, this can be obtained by varying the firing angle of the thyristors [3].

SVC controllerhas been used for reactive power compensation to increase power transfers across limited interfaces, to dampen power oscillations and to improvethe voltage stability margins .It is achieved by dynamic control of the system voltage, the SVC is controlled to decrease the system voltage. By doing so for a limited amount of time, the power oscillations are damped out. [4].

FIGURE 2(i)-SVC connected at bus B of the system.




(ii)-Damping of power oscillations [20]




SVC is connected in shunt and its output can be capacitive or inductive current to the system that it is connected .It used for controlling reactive power and it can be used as a switch or as a continuously controlled valve by controlling the firing angle. With static VAR compensator, we find stability, security, controllability and high-quality electric power. [5]

During contingency, it provides fast acting dynamic reactive compensation for voltage support which would otherwise depress the voltage for a significant length of time. SVC also dampens power swings and reduces system losses by optimized reactive power control. The functional structure for SVC built with a Thyristor Controlled Reactor (TCR) [6] Static VAR Compensator (SVC) Static VAR systems are applied by utilities in transmission applications for several purposes. The primary purpose is usually for rapid control of voltage at weak points in a network. Installations may be at the midpoint of transmission interconnections or at the Static VAR Compensators are shunt connected static generators / absorbers whose outputs are varied so as to Control voltage of the electric power systems. The firing angle can be controlled through a PI (Proportional + Integral) controller in such a way that the voltage of the bus, where the SVC is connected, is maintained at the reference value. [7]

## II. MODELLING of SVC

It consists of one or more, switched or fixed, shunt capacitors or reactors bank. Fig 3. Shows the equivalent circuit of SVC, the model considers SVC as shunt connected variable susceptance,$B_{SVC}$ which is adapted automatically to achieve the voltage control. Figure 4. Shows the Elements of SVC , it typically included, the elements such as the thyristor-switched capacitor (TSC), the thyristor-switched reactor (TSR), the thyristor controlled reactor (TCR), mechanically-switched capacitor (MSC), and fixed filters . Filter or fixed capacitor absorbs the harmonics that generated by TCR. The objective of controlling by SVC is to maintain desired voltage at the bus, done by injecting reactive power to the bus to control its equivalent reactance.

Elements which may be used to make an SVC typically include:

- Thyristor controlled reactor (TCR), where the reactor may be air- or iron-cored.
- Thyristor switched capacitor (TSC)
- Harmonic filter(s)
- Mechanically switched capacitors or reactors (switched by a circuit breaker) [8]

FIGURE 3.Equivalent circuit of SVC [9]

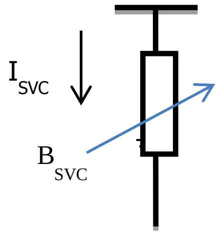



FIGURE 4.Elements of SVC

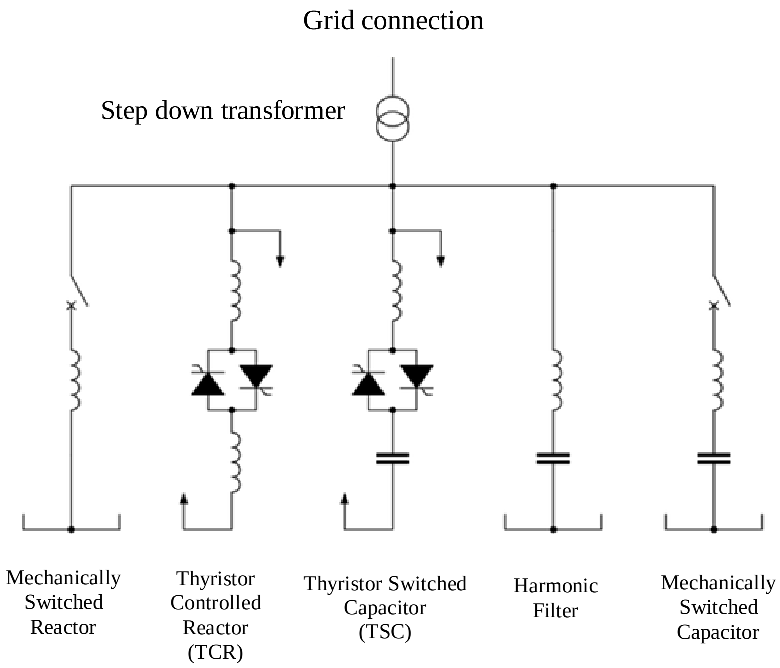
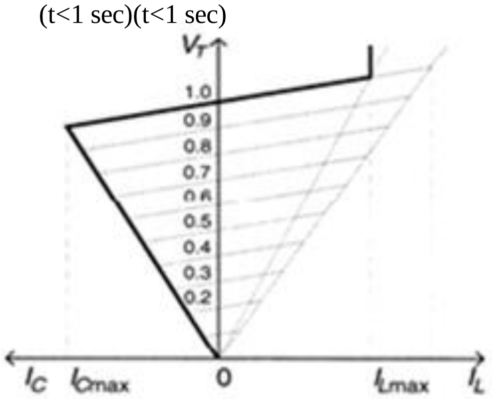



FIGURE 5- Characteristic of SVC(i)VI characteristic of SVC(ii)VQ characteristic of SVC

Fig 5(i)

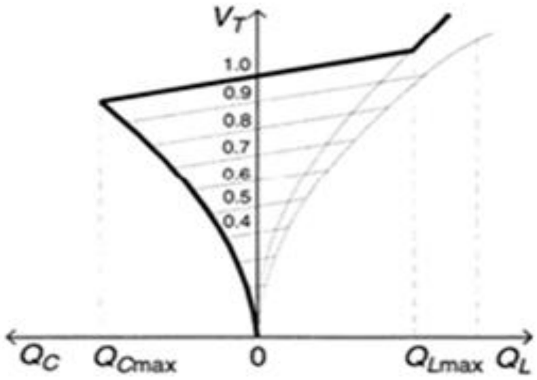
Transient rating Transient rating

(t<1 sec)(t<1 sec)




Capacitive Inductive

Fig 5(ii)




Capacitive Inductive

This circuit is used to derive the SVC nonlinear power equations and the linearized equations required by the Newton-Raphson method.

With reference to figure (1), the current drawn by SVC is given by-

$$I_{SVC}=jB_{SVC}V_k \quad (1)$$

And the reactive power drawn by the SVC, which is also the reactive power injected at bus k, is given by-

$$Q_{SVC} = Q_k = -V_k^2 B_{SVC} \quad (2)$$

The linearized equation of the SVC is given by Equation (3) where the equivalent susceptance, $B_{svc}$ is taken to be the state variable-

$$\begin{bmatrix}\Delta P_k \\ \Delta Q_k\end{bmatrix}^{(i)} = \begin{bmatrix}0 & 0 \\ 0 & Q_k\end{bmatrix}^{(i)} \begin{bmatrix}\Delta\theta \\ \Delta B_{SVC}/B_{SVC}\end{bmatrix}^{(i)} \quad (3)$$

At the end of iteration (i), the variable shunt susceptance, $B_{svc}$is updated according to Equation (4):

$$B_{SVC}^{(i)} = B_{SVC}^{(i-1)} + \left(\frac{\Delta B_{SVC}}{B_{SVC}}\right)^{(i)} B_{SVC}^{(i-1)} \quad (4)$$

The positive sequence susceptance of the SVC is given as follows:

$$Q_k = \frac{-V_k^2}{X_C X_L}\left\{X_L - \frac{X_C}{\pi}[2(\Pi - \alpha_{SVC}) + \sin(2\alpha_{SVC})]\right\} \quad (5)$$

Where $\alpha_{SVC}$ is the firing angle of the SVC. From Equation (5), the linearized SVC equation is given as-

$$\begin{bmatrix}\Delta P_k \\ \Delta Q_k\end{bmatrix}^{(i)} = \begin{bmatrix}0 & 0 \\ 0 & \frac{2V_k^2}{\pi X_L}[\cos(2\alpha_{SVC}) - 1]\end{bmatrix}^{(i)} \begin{bmatrix}\Delta\theta_k \\ \Delta\alpha_{SVC}\end{bmatrix}^{(i)} \quad (6)$$

At the end of iteration (i), the variable firing angle,$\alpha_{SVC}$ is updated according to the following Equation-

$$\alpha_{SVC}^{(i)} = \alpha_{SVC}^{(i-1)} + \Delta\alpha_{SVC}^{(i)} \quad (7)$$

And the new SVC susceptance, $B_{SVC}$ can be determined by the Equation (8), as given below-

$$B_{SVC} = -\frac{X_L - \frac{X_C[2(\pi - \alpha_{SVC}) + \sin(2\alpha_{SVC})]}{\pi}}{X_C X_L} \quad (8)$$

Equation (8) shows that the equivalent susceptance profile of SVC, as a function of firing angle, does not show the discontinuities as $B_{SVC}$ varies continuously and smoothly in both inductive and capacitive operating regions. Hence the linearization of power flow equations of the SVC, based on$B_{SVC}$.With respect to the firing angle,$\alpha_{SVC}$ shows a better numerical behavior than linearized model based on total SVC reactance. [10] [11]

## III. CASE STUDY:

IEEE-14 and IEEE 30 bus systems are considered. SVC is placed at bus number 5 in 14 bus system and at bus 17 in 30 bus system .Table No. I shows the voltage in per unit IEEE-14 bus system with and without SVC .And Table no. II shows the voltage in per unit IEEE-30 bus system with and without SVC.Comparing power flow solution of IEEE 14 and 30-bus system, without and with SVC it can be concluded that the proposed method developed in this study is efficient when power flow analysis is performed using SVC. Now SVC is placed on bus number 5 (in 14 bus system) to improve voltage on bus number 5, and bus number 17 (in 30 bus system) to improve voltage on bus number 17. Fig.6 shows IEEE 14 bus system voltage profile without SVC and Fig.7 shows voltage profile with SVC.

Fig 8 shows the comparison of voltage profile of IEEE 14-bus test system with SVC and without SVC. Which justifies it's placement in the power system.

Case –I. Voltage profile of IEEE 14 bus test system

Fig.6. Voltage profile of IEEE 14-bus test system without SVC

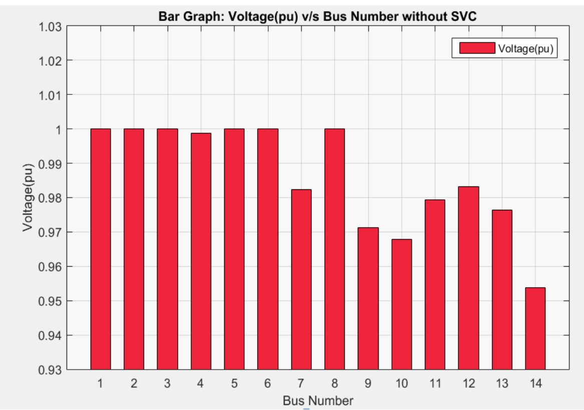



Fig.7. Voltage profile of IEEE 14-bus test system with SVC

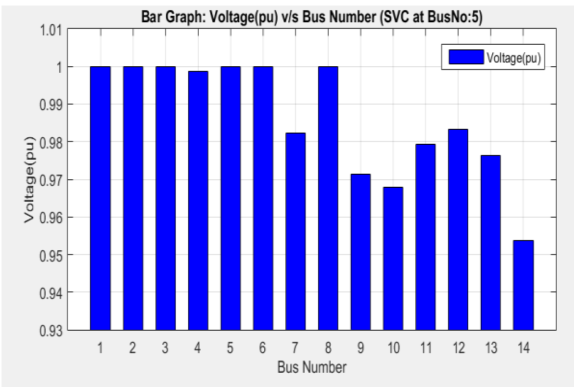


Fig.8. Voltage profile of IEEE 14-bus test system with and without SVC

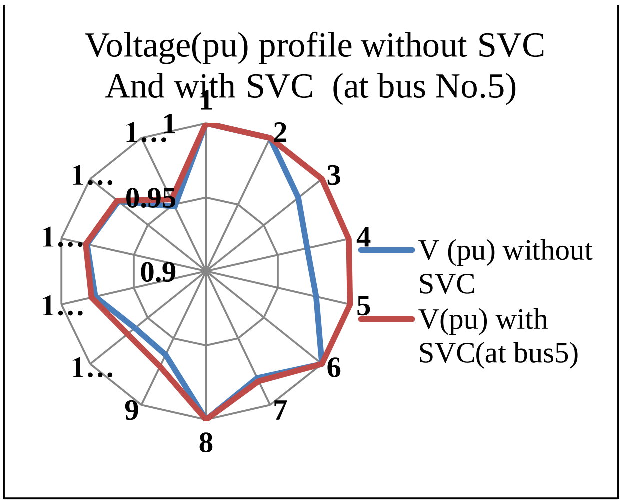



Fig9.Plot between transmission line number and Losses. (Losses at different transmission line)

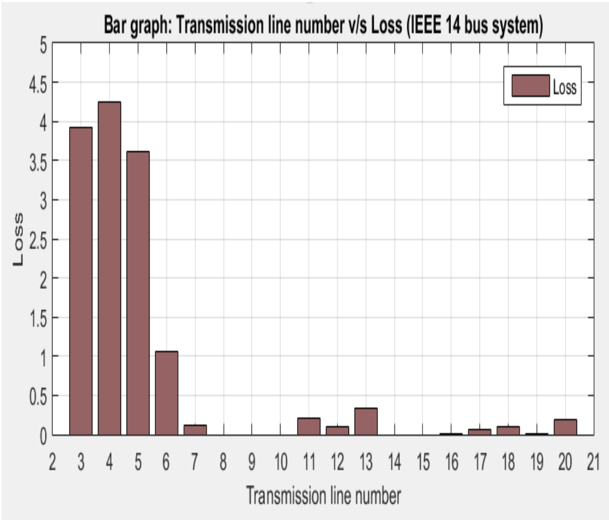
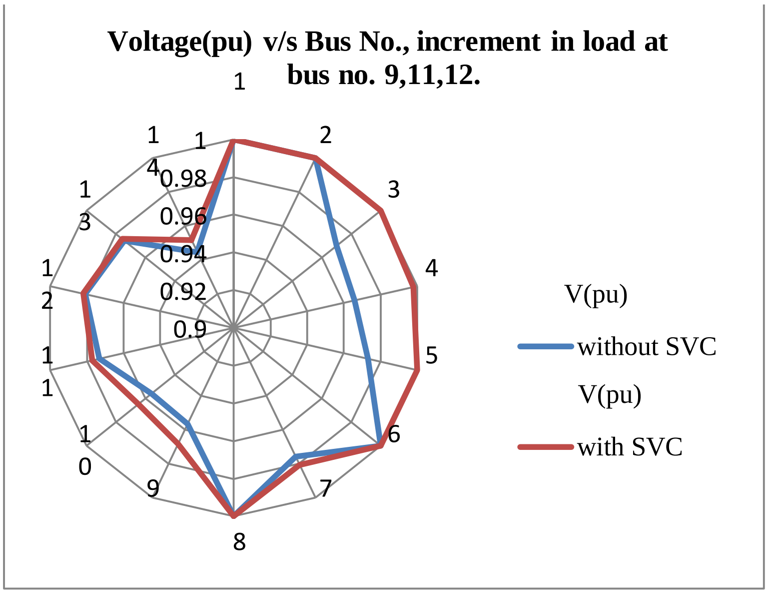



Fig 9 shows the graph between transmission lines and losses at the transmission lines. Since load is dynamic to carry out further study loadhas been increase randomly by 15%. Here the study has been performed in two stages viz. Without SVC and with SVC installed in the system. The electrical system is studied in order to determine the power flow in each of the transmission line and bus voltage. The SVC is installed at bus number 5 . An increase of loading at buses 9, 11, and 12 by 15% in IEEE14-bus test system.Fig.10 show the voltage profile of IEEE-14 bus system without SVC and the with SVC. (with 15% increment in load at bus number:9,11,12).

**Fig.10. Voltage profile of IEEE 14-bus test system with SVC and without SVC**




Now, power flow solution of IEEE 30-bus system, without and with SVC it can be concluded that the proposed method developed in this study is efficient when power flow analysis is performed using SVC. SVC is placed on bus number 17. Fig.11 shows IEEE 30 bus system voltage profile without SVC and Fig.12 shows voltage profile with SVC. Fig 13 shows the comparison of voltage profile of IEEE 30-bus test system with SVC and without SVC. Which justifies it's placement in the power system. Fig14 shows the graph for losses at different transmission line

Case –II. Voltage profile of IEEE 30 test bus system

Fig.11. Voltage profile of IEEE 30-bus test system without SVC

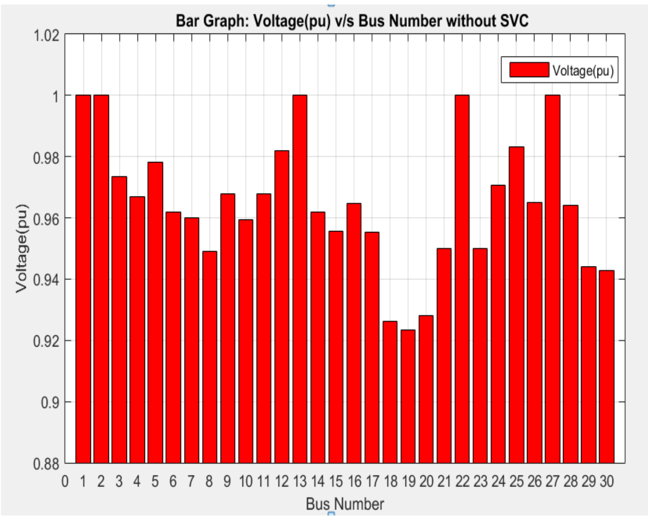



Fig.12. Voltage profile of IEEE 30-bus test system with SVC

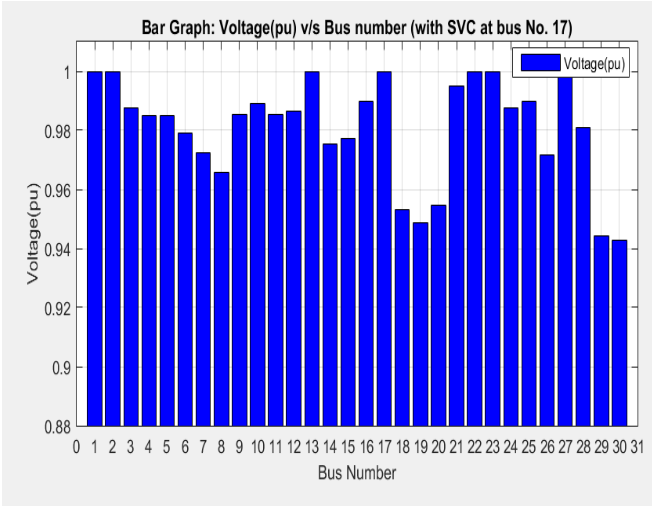



**Fig.13. Voltage profile of IEEE 30-bus test system with and without SVC**

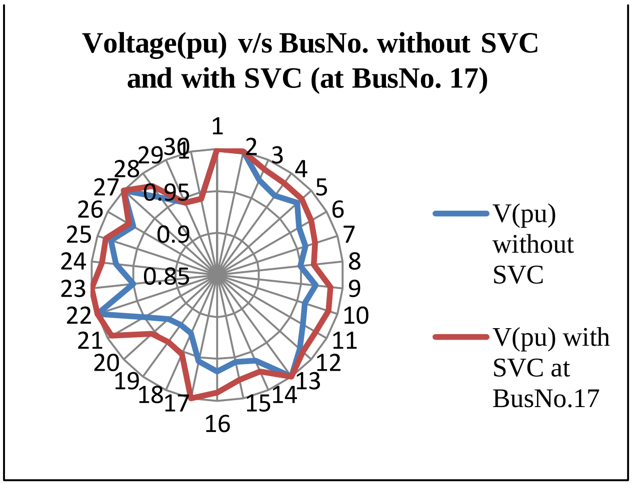
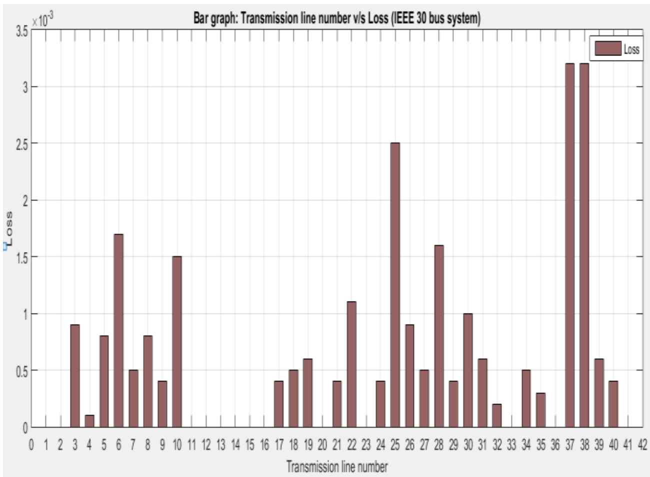



**Fig14.Plot between transmission line number and Losses. (Losses at different transmission line)**




**IV. CONCLUSION:** In this paper present modelling of SVC and voltage improvement at particular bus on which SVC is placed. A device that can control voltage at the required bus and improves the voltage profile of the system. SVC is used in IEEE 14 and IEEE 30 bus system to improve bus voltage profile of system. It is placed on bus number 5 of 14 bus system and bus number 17 of 30 bus system to improves the voltage of these buses, and stabilized voltages in weak system .Also, the results are compared between two cases i.e., with SVC and without SVC and graphs are plotted for both cases. Graph for losses at respective transmission lines are plotted which explains the advantage of SVC for reducing transmission losses that further increase transmission capacity of the system, increased damping of minor disturbances, power oscillation damping and enables better use of equipment such as transformers and cables, reduced voltage fluctuations and decreased harmonic distortion of the system.

**TABLE I. IEEE 14 BUS SYSTEM**

| Bus Number | VOLTAGE(pu) | | Angle of Voltage | |
|---|---|---|---|---|
| | Without SVC | With SVC | Without SVC | With SVC |
| 1 | 1.0 | 1 | 0 | 0 |
| 2 | 1.0 | 1 | -4.7445 | -9.0031 |
| 3 | 0.980 | 1 | -13.3244 | -19.6806 |
| 4 | 0.9702 | 0.9988 | -10.5123 | -18.1052 |
| 5 | 0.9764 | 1 | -8.9257 | -17.3572 |

**TABLE II. IEEE 30 BUS SYSTEM**

| Bus Number | VOLTAGE(pu) | | Angle of Voltage | |
|---|---|---|---|---|
| | Without SVC | With SVC | Without SVC | With SVC |
| 1 | 1 | 1 | 0.0000 | 0 |
| 2 | 1 | 1 | -0.0104 | 0.0176 |
| 3 | 0.9734 | 0.9877 | -0.6672 | -0.8465 |
| 4 | 0.9669 | 0.985 | -0.7389 | -0.9826 |
| 5 | 0.9783 | 0.9849 | -1.1541 | -1.1989 |

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