International Journal of LNCT, Vol 2(5)
ISSN (Online): 2456-9895

Improvement in voltage and power of transmission system by Static VAR compensator (SVC) and transformer tapping using MATLAB

Atul Prakash Singh[1] and Vivek Rai[2]
M.Tech (Control System) Scholar, Department of EX , LNCT, Bhopal[1]
Assistant Professor, Department of EX, LNCT, Bhopal[2]

Abstract

The Flexible AC (Facts) transmission system controllers, such as Static Var Compensator (SVC), uses the latest electronic switching equipment technology in the electrical transmission system to control voltage and power flows and improve stability short-term tension. Both Tap-changing transformers and stable VAR compensators can contribute to the stability of the supply system voltage. The combination of these two methods is the subject of this thesis. The effect of the presence of tap changing transformers is highlighted on the value required to stabilize the parameters of the constant variable compensator controller and to stabilize the load voltage on specific values. Relation between the off nominal tap ratios and the SVC controller gain and Relation of the transformer parameters with the droop slope and the SVC rating and difference between them. For all major power systems represented by two-node systems, the power / voltage curves are detected and their impact on the maximum power / significant voltage is investigated.

Several studies have found that automatic tap transformers can be used to improve voltage stability for both static and transient voltage stabilizers. Some of them were interested in the study, the new model for the tap-changer transformer used in the second, the use of static VAR compensator stable, to improve the voltage stability due to opening or recovery lines short circuit in the presence of the induction motor etc.
The main goal of this thesis is to make the effects of single-transformer is the first part of this thesis. In other study, only the effects of the static VAR compensator (SVC) are given with series capacitor. The effect of the bypass transformer, the reference voltage values and the evaluation of the advantage of the compensator are given in detail. The study system shows all major systems seen from the load node in question.

Keywords

FACTS, Voltage stability, SVC, OLTC, Static VAR compensator (SVC), thyristor controlled reactor (TCR).

1.Introduction

Mostly, if all the electricity supply systems in the world are not widely connected, then there are connections within the utilities which are their own areas which extend to inter-utility interconnections and then to inter-regional and international connections. We need these interactions because, in addition to distribution, the purpose of the transmission network is to pool power plants and load centers to reduce overall power generation capacity and fuel costs. The global transmission system is undergoing continuous change and restructuring due to the continuous increase in the demand of power, most of which should be broadcast over long distances, it has hindered connecting new plants to meet this growing demand. Apart from this, power systems are more difficult to operate in today's scenario, the reasons behind this are regulation issues, for which an open access power distribution system is required which enables power distribution between and within the regions. These trends have created extensive research interest in flexible AC transmission systems (FACTS) with the aim of developing new equipment and technologies to control the flow of electricity so that more efficient use of existing power generation and transmission power plants is permitted. These opportunities arise through the ability of factory controllers to control the operation of interpersonal relationships, which govern the operation with chain impedance. , Blurring of current, voltage, phase angle and oscillations.

2.Voltage stability and clasification of power system stability

Voltage stability is a problem in the power system, which lacks heavy weighted, defective or reactive power. The nature of voltage stability should be analyzed by examine the production, transmission and consumption of reactive power. The problem of voltage stability is related to the overall power system, although generally there is a large involvement in an important area of the power system.This chapter describes the voltage stability event. The first voltage stability, voltage instability and voltage collapse have been defined and aspects of voltage stability have been classified. Then a small pre-adequate description of the maximum transfer capacity has been described. After this, the stability of the non-linear system is introduced. Then the long-term voltage stability study describes the modeling and effect of power system components. The modeling and impact of the following components are considered: synchronous generators, automatic voltage controllers, loads, on-load tap converter, thermostatic loads, and compensation equipment. To illustrate the problem, the scenario of classic voltage collapse has also been presented.

Table 1 clasification of power system stability

Time scale	Generator-driven		Load-driven	
Short-term	Rotor angle stability		Short-term voltage stability	
	Small-signal	transient		
Long-term	Frequency stability		Long-term voltage stability	
			Small disturbance	Large disturbance

Power system stability is classified as rotor angle and voltage stability. Classification of electricity system stability based on time table and driving force norms has been presented in Table 1. Driving forces are given generator driven and load-operated names for the instability mechanism. Time scale is divided into smaller and longer time scale.

Rotor angle stability is divided into small signals and transient stability. Small signal stability is present for small disturbances in the form of under-embedded electromechanical oscillation[1-5]. The transient stability is due to the lack of torque synchronization and is started with big disturbances. The timeframe of angle stability is the electrical-dynamic mobility of the electric system. For the long-term voltage stability analysis , it required detailed modeling of long-term mobility. Long-term voltage stability is effectively analyzed by the actions of the on-load tap changer, or load-recovery through load self-restoration, corrective control functions like shunt compensation switching or load shading are delayed. Long-term mobility such as power plant control, boiler dynamics and automated generation control feedback also affect long-term voltage stability.

3.Facts controllers for power system

Flexibility of electric power transmission is “The ability to accommodate the changes in the electric transmission system or operating conditions while maintaining sufficient steady state and transient margins.”

Flexible AC Transmission system (FACTS) is “Alternating current transmission system incorporating power electronic based and other static controllers to enhance controllability and increase power transfer capability[6-8].”

FACTS Controller is “A power electronic based system and other static equipment that provide control of one or more AC transmission system parameters.”

FACTS CONTROLLERS FOR POWER SYSTEM

SHUNT CONNECTED CONTROLLERS

1 Static Synchronous Compensator (STATCOM
2 Static Synchronous Generator (SSG):
3 Battery Energy Storage System (BESS):
4 Superconducting Magnetic Energy Storage (SMES):
5 Static VAR Compensator (SVC):
6 Thyristor Controlled Reactor (TCR):
7 Thyristor Switched Reactor (TSR):
8 Thyristor Switched Capacitor (TSC):
9 Static VAR Generator or absorber (SVG):
10 Static VAR system (SVS):
11 Thyristor Controlled Braking Resistor (TCBR):

SERIES CONNECTED CONTROLLERS

1 Static Synchronous Series Compensator (SSSC):
2 Interline Power Flow Controller (IPFC):
3 Thyristor-Controlled Series Capacitor (TCSC):
4 Thyristor-Switched Series Capacitor (TSSC):
5 Thyristor-Controlled Series Reactor (TCSR):
6 Thyristor-Switched Series Reactor (TSSR):

COMBINED SHUNT AND SERIES CONNECTED CONTROLLERS

1 Unified Power Flow Controllers (UPFC):
2 Thyristor Controlled Phase Shifting Transformer (TCPST):
3 Interphase Power Controller (IPC):

Figure 1 Fact controllers

4.System for study

A large Power System which feeds a certain load or power (P+ jQ) is used in this study as shown in Figure 2. The system, at steady-state conditions can be represented by its Thevenin's equivalent seen from node 5 as shown in Figure 3

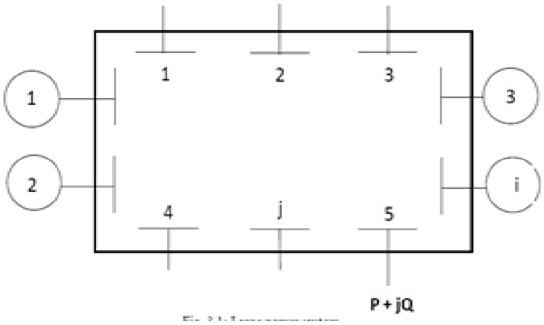


Figure 2 Large power system

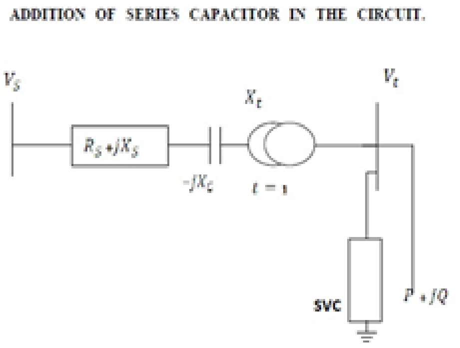


Figure 3 The venin's equivalent seen from node

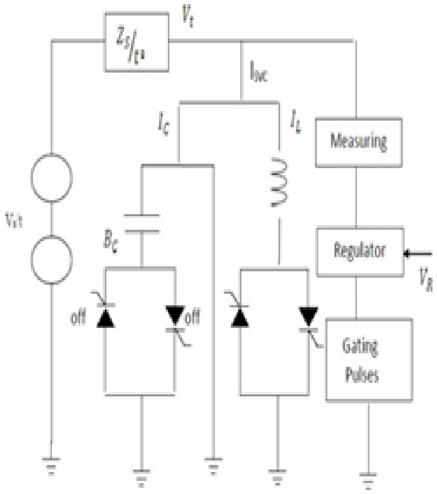


Figure 4 static VAR block diagram

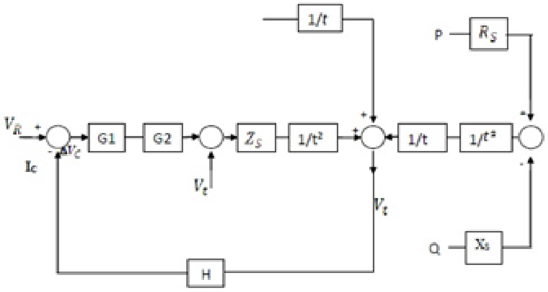


Figure 5 SVC Block Diagram

5.System equations

The controller is normally proportional element (1/slop) with certain delay T1, followed by a controller compensator circuit of the form:

$$G_1 = \frac{\left(\frac{1}{slop}\right)(1+T_2S)}{(1+T_1S)(1+T_3S)}$$

The slop is regulator droop slope equals to ΔVc/ ΔImax Volt/ampere. T1 is a delay time. T2 and T3 are the time constants of regulator compensation circuits. The controller output is given to the firing circuit which may be completely defined by a transfer function, consists of a gain Kd(nearly unity):

$$G2 = K_d\, e^{-STd} \cong \frac{K_d}{(1+T_dS)}$$

The limiter refers to the limits of the virtual compensator variable susceptance ,Bc.

The measuring circuit forms the feedback link and can be represented by a gain KH equal nearly unity and a time delay TH as:

$$H = K_H\, e^{-sT_H} \cong \frac{1}{(1+T_HS)}$$

TH of the order of 20-50 ms, While TH is usually from 8 – 16 ms. KH usually takes a value around 1.0 p.u,T2 and T3 are determined by the regulator designed for each studied system, as they are function in system parameter.

Solving block diagram of a loaded power system, series capacitor and SVC. Multiplication of B by VT yields the SVC current following in the series link (IS), which is given by: IS = BVT

The power system which is provided by a series capacitor at the load inlet can be represented by its Thevenin's voltage VS, system and capacitor reactance RS + j (XS-XC).

The load voltage drop to system equivalent series impedance and through the series capacitance link is given by:

$$\Delta V = |V_S|-|V_T| = \frac{((X_S-X_C)Q + R_S P)}{V_T}$$

Where VT is the load node and SVC terminal voltage and S is the laplace operator, which vanishes in steady-state condition.

Defining Bc =G1G2(VR-VTH) And G= G1G2VT

The compensator current Is is given by:

Is=G (VR-VTH)

And the SVC control system feedback voltage is given by: ΔVc=IsZS= G (VR-VTH) ZS

Therefore the load terminal voltage is given by:

$$V_{T1} = G(V_R - V_T H) + (V_S - \frac{R_S}{V_T} P - \frac{(X_S - X_C)Q}{V_T})$$

From which

$$V_T^2(1+GHZ_S) - V_T(V_S + GZ_S V_R) + (R_S P + (X_S - X_C)Q) = 0$$

On solving the equation

$$V_{T1} = \frac{(V_S + GZ_S V_R) + \sqrt{(V_S + GZ_S V_R)^2 - 4(1+GHZ_S)(R_S P + (X_S - X_C)Q)}}{2(1+GHZ_S)}$$

$$V_{T2} = \frac{(V_S + GZ_S V_R) - \sqrt{(V_S + GZ_S V_R)^2 - 4(1+GHZ_S)(R_S P + (X_S - X_C)Q)}}{2(1+GHZ_S)}$$

SYSTEM DATA:

Having used the system under study with the mentioned data:

V_s=1.004

X_s=0.3125 p.u

X_f=0.0126 p.u

V_f=1 p.u

H=1 p.u

R_s=0.08126 p.u

Z_s=0.3228 p.u

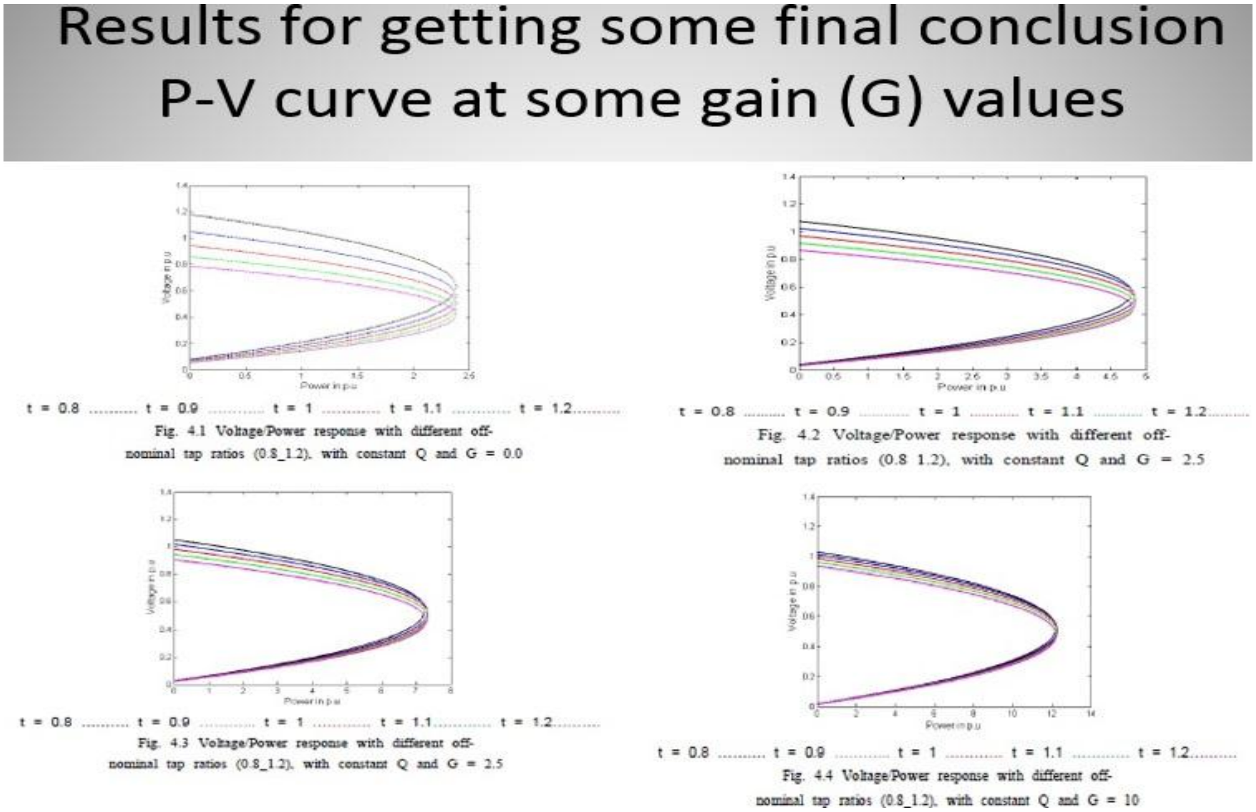
X_c=4.5 p.u

The load reactive power is assumed to be kept constant at Q = 0.18 p.u.

In order to kept the terminal voltage constant at V_f=0.8 p.u up to 1.05 p.u for different system power P.

6.Results

1.P-V curve with the presence of tap changing transformer and SVC



Results for getting some final conclusion

P-V curve at some gain (G) values

t = 0.8 .... t = 0.9 .... t = 1 .... t = 1.1 .... t = 1.2..........

Fig. 4.1 Voltage/Power response with different off-nominal tap ratios (0.8_1.2), with constant Q and G = 0.0

t = 0.8 .... t = 0.9 .... t = 1 .... t = 1.1 .... t = 1.2.........

Fig. 4.2 Voltage/Power response with different off-nominal tap ratios (0.8 1.2), with constant Q and G = 2.5

t = 0.8 .... t = 0.9 .... t = 1 .... t = 1.1............ t = 1.2..........

Fig. 4.3 Voltage/Power response with different off-nominal tap ratios (0.8_1.2), with constant Q and G = 2.5

t = 0.8 .... t = 0.9 .... t = 1 .... t = 1.1 .... t = 1.2..........

Fig. 4.4 Voltage/Power response with different off-nominal tap ratios (0.8_1.2), with constant Q and G = 10

Figure 6 Result for getting some final conclusion P-V curve at some gain(G) values

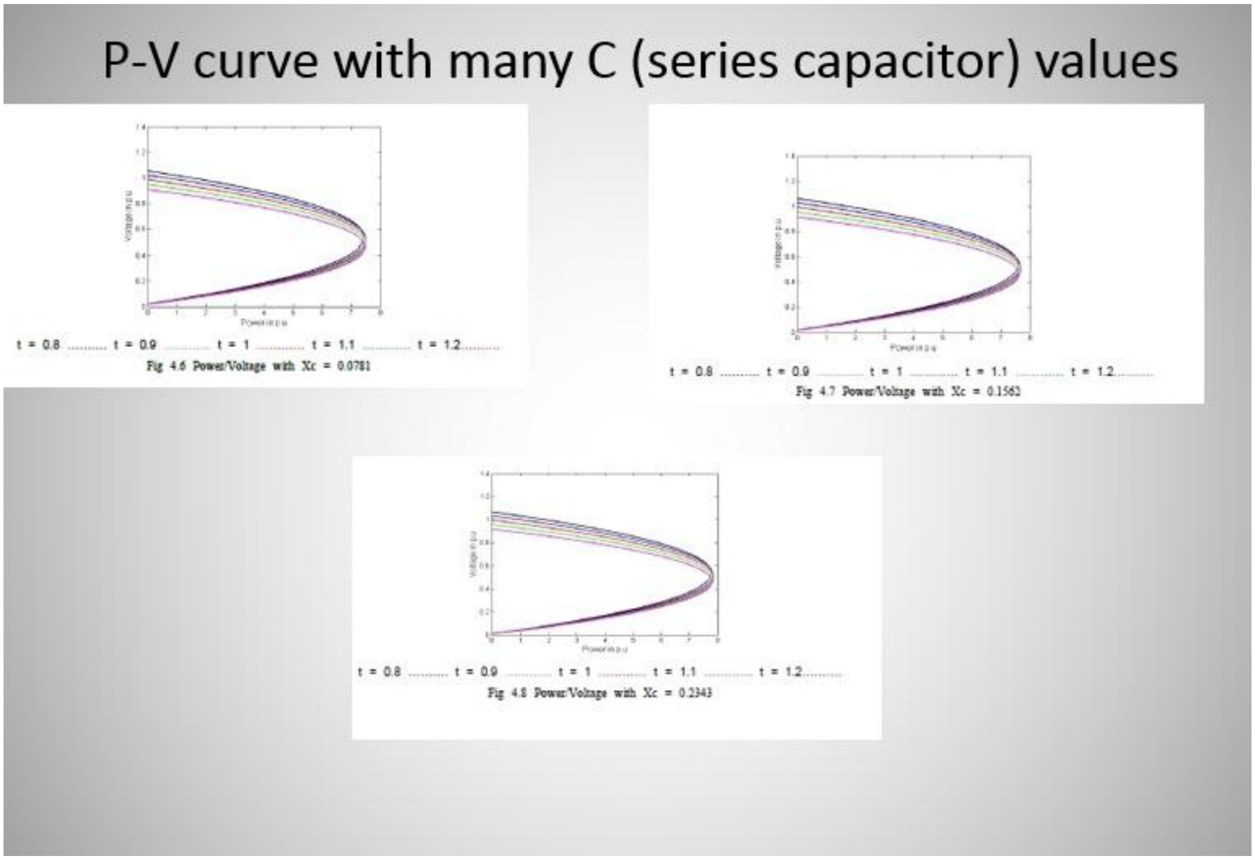
Table 2 Maximum load power as influenced by compensate or controller gains withoutseries capacitor

Compensator Gain(G)	Approximate Maximum Power
0.0	2.39
2.5	4.80
50	7.30
10.0	12.30

The compensator application increases the maximum power largely as shown in the figures 4, 5, 6, 7, for different SVC controller gains. The same previous features of their variations with different off-nominal tap ratios are noticed. The same maximum power and different critical voltages largely affect the no-load conditions than the heavy loadings.

2.P-V Curve With Some Sc Compensation Percentage :

The famous curve of the Voltage/Power relation is plotted. Having a load of constant power factor, the voltage is plotted against the load VA power, in the presence of different SC compensation percentages (0 , 25 , 50 , 75 , 90%).



P-V curve with many C (series capacitor) values

Fig 4.6 Power/Voltage with Xc = 0.0781

Fig 4.7 Power/Voltage with Xc = 0.1562

Fig 4.8 Power/Voltage with Xc = 0.2343

Figure 7 P-V curve with many C(Series capacitor)Values

As we can see in these plots that by the use of Capacitor in the circuit, the peak-load voltage can be increased by increasing the series compensation. The figure 8 shows that maximum possible critical power increases with the increase of SC series compensation percentage.

It is noticed that the critical voltage value is constant at 0.5 p.u. at all series compensation percentages . This is due to the fact that the critical voltage is independent of the value of system series reactance XS. however shows the maximum load power corresponding to various values of SVC controller gains. Therefore, at a gain of 1.0 the maximum transmitted power can be increased to 140% and a gain of 2.0 can increase it by 180% of its value without static VAR compensator. This is important result illustrates the limited effects of the series capacitor compared to the static VAR compensator, significant effects, at different controller gains.

Table 2 compensator rating at different gains(compensator rating)

Gain	**Off nominal tap ratio t=0.8**	**Off nominal tap ratio t=1.0**	**Off nominal tap ratio t=1.2**
50	1.2	0.7	0.56
70	1.7	1.08	0.75
100	2.43	1.57	1.07
150	2.7	1.74	1.2

7.Conclusion

With the stable controller advantage, the presence of a stable VAR compensator can increase the maximum stable force several times without its constant VAR compensator. In all load situations, to maintain the charge node voltage continuously, there is a conversation between the transformer out-of-band ratio and the benefit of the compensation controller and reference voltage. The price of security is influenced by the change of the band transformer, there are significant changes with the presence of the Tap changer transformer in the steady response to TCR type security. Some transformer off-load ratios reduce the essential value of SVC, i.e. in the presence of the changer transformer, requires the SVC value to keep the charging voltage constant at constant cost. Only the presence of tap changer transformer does not significantly improve the voltage stability, they affect the voltage level and slightly important voltage, but it does not affect the maximum power related to the important voltage. Therefore, the plug-in transformer at the charging terminal can contribute a bit to its voltage stability. By using series capacitors with branch transformers and SVC, the peak voltage can increase significantly.

References

[1] Yadav M, Soni A. Improvement of power flow and voltage stability using unified power flow controller. In electrical, electronics, and optimization techniques (ICEEOT), International Conference on 2016 (pp. 4056-60). IEEE.

[2] Kar P, Panda PC, Swain SC, Kumar A. Dynamic stability performance improvement of SMIB power system using TCSC and SVC. In power, communication and information technology conference (PCITC), 2015 IEEE 2015 (pp. 517-21). IEEE.

[3] Tehrani SS, Bandaghiri PS. Shunt Compensation for Improvement of Voltage Stability Using Static Var Compensator (SVC) in a Power Transmission System.

[4] Modi PK, Singh SP, Sharma JD. Fuzzy neural network based voltage stability evaluation of power systems with SVC. Applied Soft Computing. 2008; 8(1):657-65.

[5] El-Sheikhi FA, Saad YM, Osman SO, El-Arroudi KM. Voltage stability assessment using modal analysis of power systems including flexible AC transmission system (FACTS). In power engineering, 2003 large engineering systems conference on 2003 (pp. 105-8). IEEE.

[6] El-Sadek MZ, Mahmoud GA, Dessouky MM, Rashed WI. Effect of control systems on compensators ratings needed for voltage stability enhancement. Electric power systems research. 1999; 50(2):139-45.

[7] El-Sadek MZ, Dessouky M, Mahmoud GA, Rashed WI. Series capacitors combined with static VAR compensators for enhancement of steady-state voltage stabilities. Electric power systems research. 1998; 44(2):137-43.

[8] Van Overschee P, De Moor BL. Subspace identification for linear systems: Theory-Implementation-Applications. Springer Science & Business Media; 2012.

ATUL PRAKASH SINGH received the B.Tech degree in Electrical and Electronics Engineering from UNITED COLLEGE OF ENGINEERING AND RESEARCH ,Naini,Allahabad, Uttar Pradesh, India in 2012.He is currently final year student of M.Tech in CONTROL SYSTEM from , LAKSHMI NARAIN COLLEGE OF TECHNOLOGY, BHOPAL , MADHYA PRADESH,INDIA. His areas of interests are controling of power systems operation, voltage stability and applications of FACTS controllers in transmission systems.

VIVEK RAI received BE in Electrical & Electronics Engineering from Truba Institute of Engineering & Information Technology ,Bhopal India in the year 2005 and completed M.Tech in Control System in the year 2012 from LNCT, Bhopal India. Currently he is Working as an Assistant Professor in Electrical & Electronics Engineering department in LNCT Bhopal India. His areas of interest are power system, Electromagnetic Theory and power electronics.