Damping of SSR oscillations with STATCOM and TCSC

J. Sreeranganayakulu[1,]
Research Scholar, Department of EEE,
JNTUA, Ananthapuramu
Andhra Pradesh, INDIA

Dr. G. V. Marutheswar[2]
Professor, Dept. of EEE, SV University,
Tirupati, Andhra Pradesh.,
INDIA

Dr. P. Sujatha[3]
Professor, Dept. of EEE,
JNTUA CEA, Anantapuramu,
Andhra Pradesh, INDIA

***Abstract* - Subsynchronous Resonance is a serious issue in power system transmission lines because of which the mechanical multi-mass model encounters shaft harms. This problem can be solved by controlling the deviations of mechanical oscillations which for the most part happen amid a symmetrical shut circuit fault on the power system network ought to be eliminated by a some mechanism. This paper shows about the IEEE SBM model which is modeled and simulated in MATLAB Simulink. The outcomes are analyzed when STATCOM is incorporated and furthermore with those when Thyristor controlled arrangement capacitor (TCSC) included for their adequacy in moderating the Subsynchronous Resonance oscillations.**

Keywords - Flexible AC Transmission systems, SSR, STATCOM, TCSC

I. INTRODUCTION

The existing electric power system transmission networks, sub synchronous resonance (SSR) is a significant issue which makes the transmission network unstable in case of faults because of the insertion of power factor correction capacitor. This leads to the dangerous swinging of the shaft mechanism which is undamped. This in turn add up to permanent shaft damage. Theoretically it happens, when the electric system exchanges energy with a turbine generator at least one of the characteristic frequencies of the consolidated network beneath the synchronous frequency of the system [1].

For the purpose of analysis of SSR, the IEEE SSR task force has prepared standard test cases [2-3]. This system consists of six masses coupled to the same shaft namely ‘HP’, ‘IP’, ‘LPA’, ‘LPB’, ‘Generator’ and ‘Exciter’. These are interconnected to the transmission line viz. a 600 MVA, 22/500 kV transformer.

For controlling the Subsynchronous Resonance oscillations, Flexible AC Transmission System controllers like STATCOM and TCSC can be included in series with the series capacitor.

V versus I graph of a Static Compensator is similar to that of a synchronous condenser, but it has no inertia and is advantageous in various aspects over the synchronous condenser, such as better dynamics, a low investment cost and reduced operating and maintenance costs.

STATCOM is comprised of Thyristors with great turn-off capacity, for example, GTO or an IGCT or with more number of IGBTs. STATCOM has a merit since its reactive power variation is independent of the actual voltage. This perspective is seen in the figure 1 where the peak currents are independent of the voltage variation in comparison to the Static Var Compensator. This implies, that although there is a severe short circuit fault, the Static compensator (STATCOM) operates with full capability.

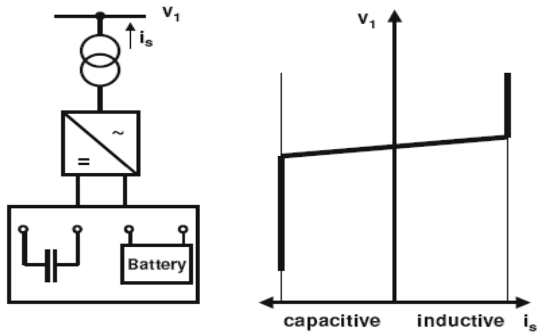


Figure 1. STATCO model, V / I characteristic.

II. STATCOM OPERATING PRINCIPLE

Fig.2 depicts a three phase six pulse STATCOM. It is to be observed that, if STATCOM voltage ‘Vs’ is greater than bus voltage, ‘Es’, then capacitive or leading VArs are produced and if ‘Vs’ is smaller than ‘Es’ then inductive or lagging VArs are generated.

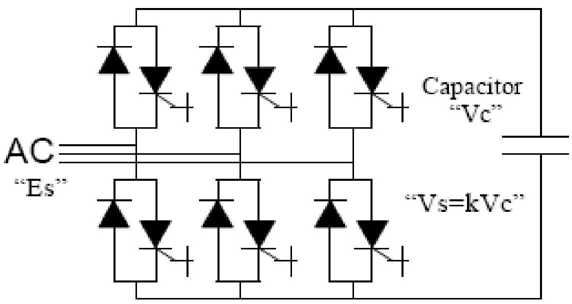


Fig 2. Structure of Statcom

The operation of STATCOM given in Fig. 2 is such that, for a three phase power system network operating at fundamental frequency in steady state, the power at any instant entering a pure reactive element should be zero.

Here, each phase receives reactive power which can be provided by circulating the real power at any instant between the phases. This requires proper firing of the switches (GTO or diode) such that, it maintains the difference in phase angle between ‘E_S’ and ‘V_S’ at every instant.

It is possible to construct a device based on circulating instantaneous power which has no energy storage device.

IEEE Second benchmark system is first developed in this research work, using MATLAB including the Static Synchronous Compensator (STATCOM) and is connected in parallel with the compensating series capacitor [4].

This model comprises of multi mass system including an alternator, a transformer, breaker, transmission line parameters, series capacitor, and an infinite bus. The simulation circuit for the IEEE second benchmark system is modeled in MATLAB is shown in Fig. 3 which includes the ‘FACTS’ controller ‘**STATCOM**’.

During the three phase to ground fault condition which is applied from t=0.5sec to t=0.67 sec, the simulation results are shown in Fig. 4. From the figure, it seems that the SSR oscillations between LP-HP turbines are gradually decreased and are made to lie within 1 p.u. This graph indicates that with inclusion of STATCOM the SSR currents are reduced and hence the torque remains within the prescribed limits.

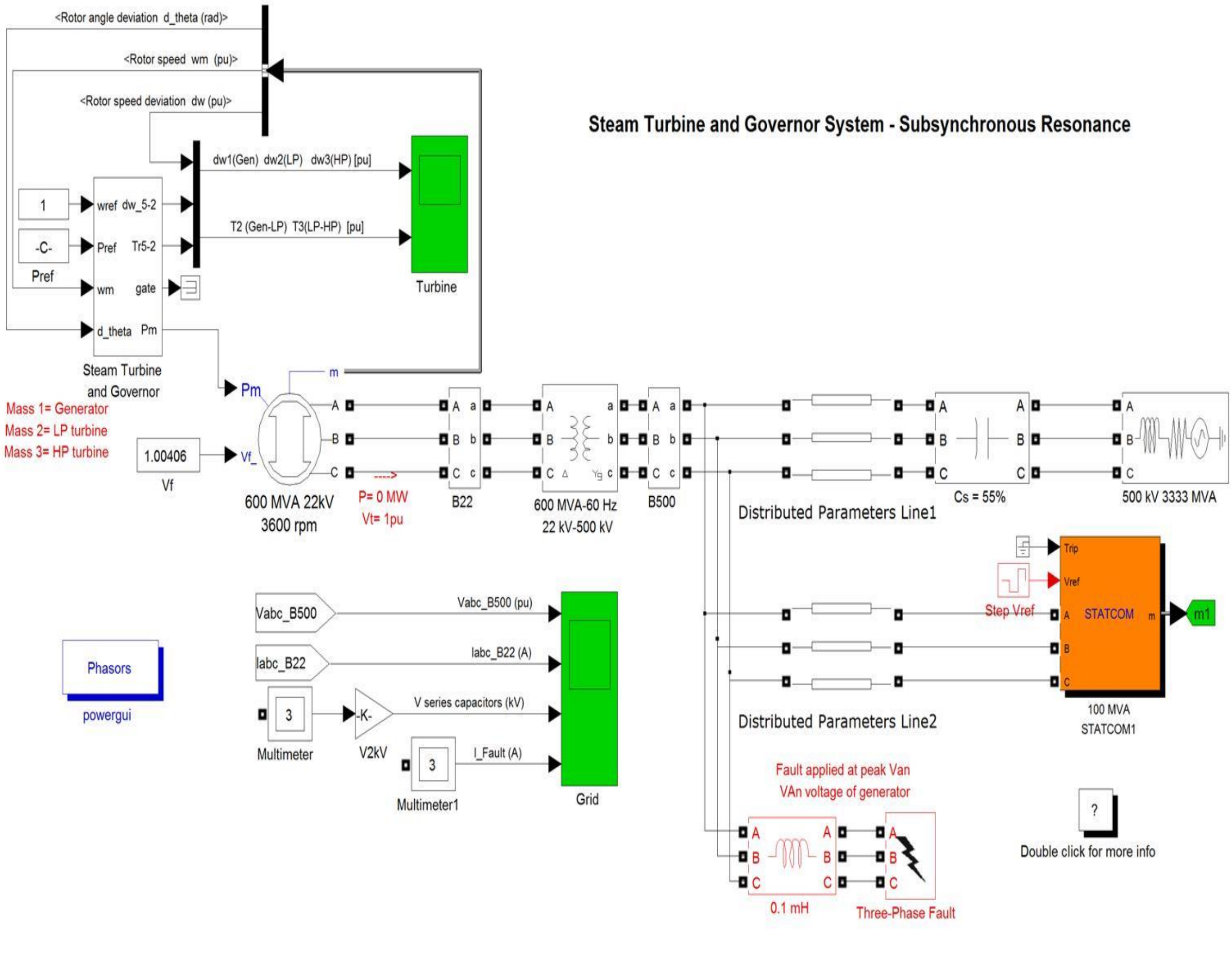


Fig. 3: Second benchmark model including static synchronous compensator

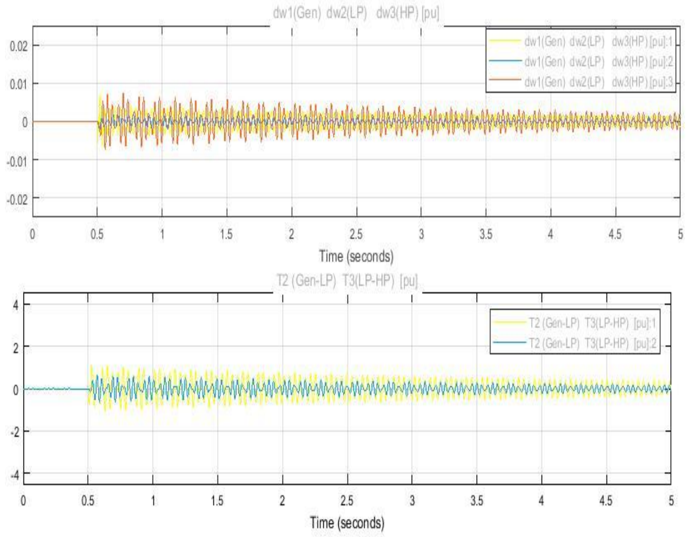


Fig 4: Generator, LP, HP turbine torque variations with respect to time.

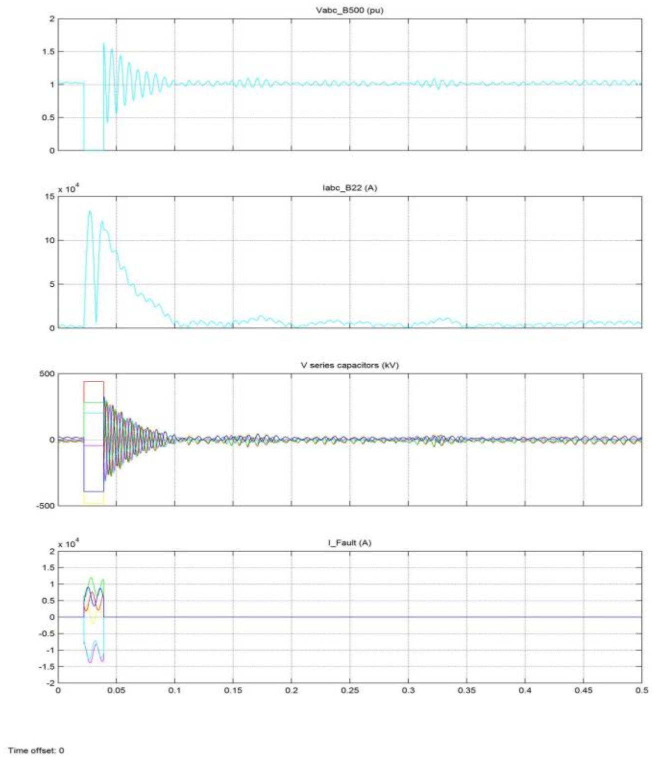


Fig 5: V_L(p.u.), I_L(A), V_C and I_f wave forms with respect time

III. PRINCIPLE OF TCSC

TCSC is such a compensator utilized for transmission lines compensation, which can give numerous advantages to a power system along with power flow control in the line, suppressing power oscillations and damping SSR oscillations.

TCSC arrangement is basically as shown in figure 6. Here, a capacitor is embedded legitimately along with transmission line and the thyristor controlled inductor is placed in across the capacitor.

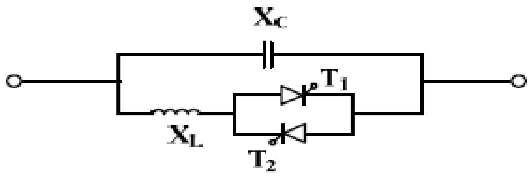


Fig 6. TCSC basic configuration

IV. TCSC OPERATION:

TCSC amplifies the capability of power transfer a transmission network in addition to several other functions. It provides a fast, constant control of the series compensation level for transmission line thus progressively controlling the power flow in the line.

For present scenario, the TCSC is assumed to be primarily in use for controlling line reactance and thus power flow control. The SSR damping function is added through constant current control for this study.

A TCSC while functioning at fundamental frequency offers a pure capacitive reactance to enhance the power transfer capability of the network. Then again, the equivalent TCSC offers resistive impedance at Subsynchronous frequencies which should be damped.

The resistive impedance of the TCSC raises with the increase in the boost factor. It is the proportion of the capacitive reactance offered by the TCSC and the total line reactance. Thus, the TCSC also provides a resistive damping to the SSR oscillations.

For the arrangement shown in figure 6, the corresponding TCSC reactance is given by following expression

$$X_{TCSC} = X_C - \frac{X_C^2}{X_C - X_L}\frac{2\beta + \sin 2\beta}{\pi} + \frac{4X_C^2}{X_C - X_L}\frac{\cos^2\beta}{k^2 - 1}\frac{k\tan k\beta - \tan\beta}{\pi}$$

Here β = Angle of advance = π – α, α is firing angle of the thyristors.

Figure 7 shows the substitution of TCSC with that of STATCOM to compare the performance of the network under transient condition. Figures 8 and 9 depicts results of simulation which implies that TCSC gives better performance in reducing of the torque pulsations and angular speed deviations along with voltage profile improvement.

V. RESULTS

The simulation outputs are tabulated in Table I. It compares the magnitudes of reduction in peak torque and the speed deviations without inclusion of FACTS controllers where the SSR oscillations are uncontrolled.

These output results in turn verified with the inclusion of STATCOM and TCSC. Observing these results, it is obvious that the effectiveness in damping SSR oscillations is more as the magnitudes of oscillations are gradually reduced with inclusion of TCSC compared to STATCOM.

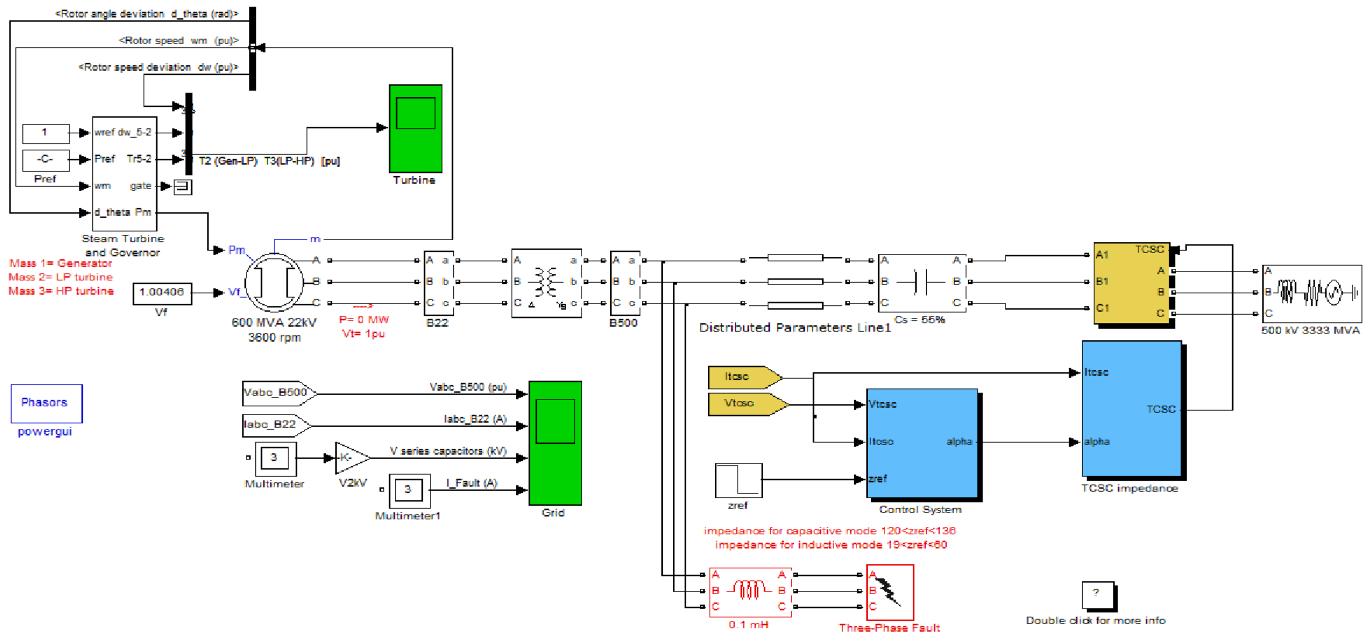
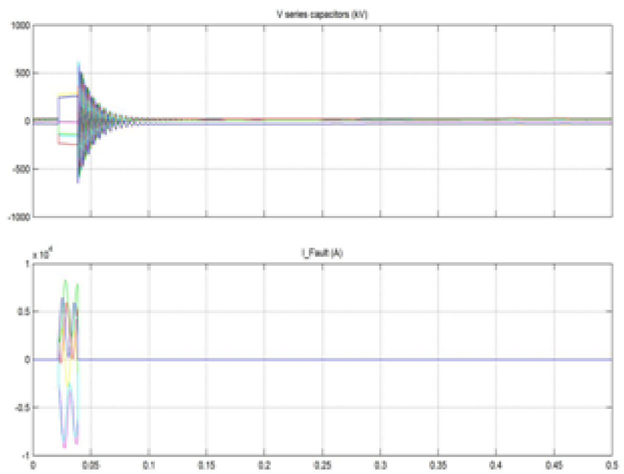
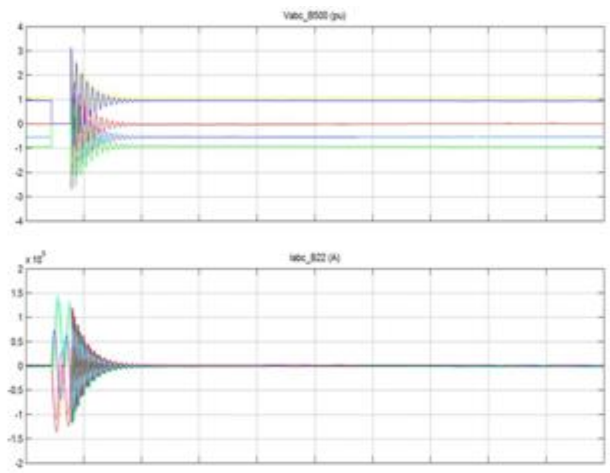


Fig 7: IEEE SBM model with Thyristor controlled series capacitor (TCSC)

TABLE I. PEAK TORQUES AND SPEED DEVIATIONS OF THE THREE CASES

Case	Gen-LP Torque (p.u.)		LP-HP Torque (p.u.)		dω (Gen) p.u.		dω (LP) pu		dω (HP) pu	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Without FACTS device	-2.4	2.5	-1.1	1.15	-0.012	0.0097	-0.0072	0.0058	-0.0145	0.0145
With STATCOM	-1.035	1.07	-0.58	0.652	-0.0061	0.00715	-0.0025	0.002	-0.0074	0.0072
With TCSC	-1.08	1.22	-0.653	0.737	-0.00682	0.0075	-0.00263	0.0033	-0.00831	0.0082





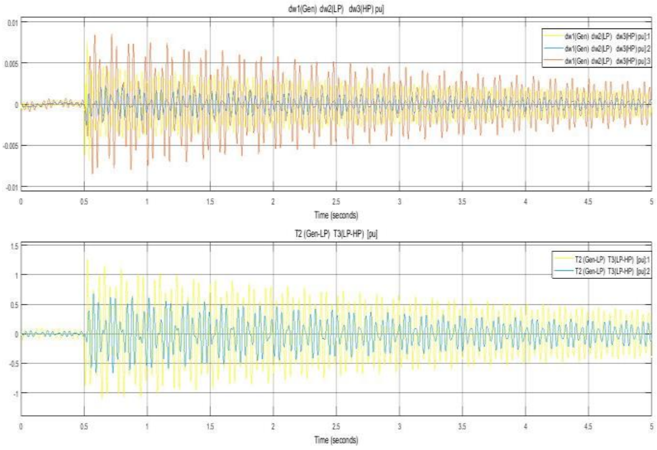


Fig 9: V_L(p.u.), I_L(A), V_C and I_f with respect time with Thyristor controlled series capacitor.

VI. CONCLUSIONS

This work illustrates the comparison in effectiveness of TCSC and STATCOM in damping the sub synchronous resonance oscillations that are observed in large multi mass model. Two test cases are observed the variation of turbine torques and change in angular speeds:

1. Without the inclusion of any FACTS controller.
2. When STATCOM is included and
3. When TCSC is included.

The results shown in section IV clearly indicates how the STATCOM can reduce the torque pulsations between various shafts of the multi mass model, as well as changes in angular speeds in generator, low pressure and high pressure turbines more effectively than TCSC. Enhancement in the power system network transients reduction is noted with insertion of STATCOM compared to the case of TCSC.

REFERENCES

[1]. IEEE SSR working group, "proposed terms and definitions for sub synchronous resonance," IEEE symposium on countermeasures for sub synchronous resonance, IEEE Pub.81TH0, p086-9 PWR,1981 p 92-97.

[2]. IEEE SSR working group,"First benchmark model for computer simulation of sub synchronous resonance".IEEE transactions on power apparatus and systems, vol.

[3]. PAS-96, pp. 1565-1572,September/october 1977.IEEE SSR working group, "Second benchmark model for computer simulation of sub synchronous resonance ". IEEE transactions on power apparatus and systems,vol. PAS-104, pp. 1057-1066,may 1985.

[4]. Dr. Narendra Kumar, Sanjiv Kumar and Vipin Jain,"Damping Sub synchronous Oscillations In power systemusing shunt and series connected FACTS controllers",IEEE transactions on power delivery, vol.2, Sep2010.

[5]. P.M. Anderson, B.L. Agrawal, J.E. Van Ness, "Subsynchronous Resonance in Power Systems", IEEE Press, New York, 1990, pp.31-93. N.G. Hingorani & L. Gyugyi, "Understandingf FACTS", IEEE Press. J.Guo, M.L.Crow, J.Sarangapani "An improved UPFC Control for Oscillation Damping" IEEE Transactions on Power Systems, Vol. 24,No. 1, Feb. 2009,pp.288-296.

[6]. J.Sreeranganayakulu, N.Chinna Alluraiah, "Simulation of first benchmark model for analysis of sub synchronous resonance in power systems using SEQUEL", IJERA ISSN: 2248-9622, Dec 2011.

[7]. J.Sreeranganayakulu,Dr.G.V.Marutheswar, Dr.K.S.R.Anjaneyulu, "Mitigation of Subsynchronous Resonance oscillations using UPFC", Global Journal of Trends in Engineering, Vol.2, Issue.3, March 2015.

[8]. J.Sreeranganayakulu,Dr.G.V.Marutheswar, Dr. P.Sujatha, "Reduction of SSR Oscillations in power system network with STATCOM and UPFC",International Journal of Engineering and Technology, Vol.7, Issue.2.8, March 2018

Mr. **J.Sreeranganayakulu** has completed his B.Tech degree from INTELL Engineering College, Anantapur, M.Tech from Sri Venkateswara University College of Engineering, S V University, Tirupati in the years 2005 and 2008 respectively. He is presently working as Assistant Professor in Sreenivasa Institute of Technology And Management Studies, Chittoor, Andhra Pradesh, India. He is pursuing his Ph.D. from JNTUA, Anantapuramu. His areas of interests in research are power system protection, FACTS and Fuzzy systems.

Dr. **G.Venkata Marutheswar** has completed his B.Tech, M.Tech and Ph.D. in Elecectrical and Electronics Engineering, ICS and EEE from Sri Venkateswara University in the years 1985, 1992 and 2008 respectively. He Joined as Lecturer in SVUCE, SV University, Tirupati in 1992. Currently he is working as Professor in SVU College of Engineering, Tirupati from 2012. His areas of interests in research includes control systems, FACTS, power systems.

Dr. **P.Sujatha** has completed her B.Tech, M.Tech and Ph.D. degree in Electrical Engineering from JNTUA Anantahapuramu, AP, India. She has joined in Department of Electrical Engineering, Jawaharlal Nehru Technological University, Anantapur, AP, India as a lecturer in 2001. Currently she is Professor in Electrical Engineering in JNTUA College of Engg,Anantapur, India. Her research interest includes Electrical Power Systems.