A MODIFIED PARTICLE SWARM OPTIMIZATION TECHNIQUE FOR SOLVING IMPROVEMENT OF VOLTAGE STABILITY AND REDUCE POWER LOSSES USING UPFC

[1]Kiran Kumar Kuthadi and [2] M. Suresh Babu

[1]Dept. of EEE, Sree Vahini Institute of Science & Tech., Tiruvuru, Krishna Dist, Andhra Pradesh.
[2]Dept. of EEE, V.R.S & Y.R.N College of Engg, & Tech, Chirala, Guntur Dist, Andhra Pradesh.

ABSRACT: *The loss minimization is a major role in Power System (PS) research. Transmission line losses in a Power System can be reduced by Var compensation. After the establishment of power markets with transmission open access, the significance and use of Flexible AC Transmission Systems (FACTS) devices for manipulating line power flows to relieve congestion and maximize the overall grid operation have been increased. The Modified Particle Swarm Optimization (MPSO) algorithm for solving power flow problem through the application of UPFC. UPFC is one of the most promising FACTS devices for power flow control. The location of UPFC is placed based on VSI. The modified PSO technique is used to set the parameters of UPFC. This result is obtained using modified PSO, to show the validity of the proposed technique and for comparison purpose, simulation carried out on IEEE 9-bus and IEEE 30-bus test systems.*

Index Terms: *- Flexible AC Transmission Systems (FACTS), Unified Power Flow Controller (UPFC), Voltage Stability Index (VSI), Modified Particle Swarm Optimization (MPSO.)*

1. INTRODUCTION

Most of the large power system blackouts, which occurred worldwide over the last twenty years, which are caused by heavily stressed system with large amount of real and reactive power demand and low voltage condition. When the voltages at power system buses are low, the losses will also to be increased. This study is devoted to develop a technique for improving the voltage and minimizing the losses and hence eliminate voltage instability in a power system. Application of FACTS devices are currently pursued very intensively to achieve better control over the transmission lines for manipulating power flows. There are several kinds of FACTS devices. Thyristor-Controlled Series Capacitors (TCSC), Thyristor Controlled Phase Shifting Transformer (TCPST) and Static Var Compensator (SVC) can exert a voltage in series with the line and, therefore, can control the active power through a transmission line. On the other hand UPFC has a series voltage source and a shunt voltage source, allowing independent control of the voltage magnitude, and the real and reactive power flows along a given transmission line.

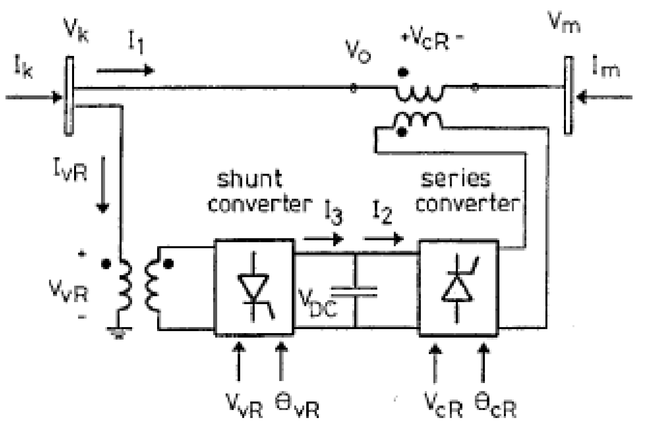
The UPFC was proposed for real-time control and dynamic compensation of AC transmission systems, providing the necessary functional flexibility required to solve many of the problems facing the utility industry. The UPFC consists of two switching converters, which in the implementations considered are voltage sourced inverters using Gate Turn-Off (GTO) thyristor switch.

Many Heuristic optimization methods like Evolutionary Programming (EP), Simulated Annealing (SA), and Genetic Algorithm (GA) have been employed to overcome the drawbacks of conventional techniques. In 2002, Abido employed a new approach called as Particle Swarm Optimization (PSO) which was inspired by the social behaviours of animals such as fish schooling and bird flocking. PSO approach utilizes global and local exploration. He has obtained the results for different objective function of the power flow problem and compared it with the reports available in the literature. The results of his work were promising and had shown effectiveness and superiority over classical techniques and Genetic Algorithms. The other main advantages of using PSO algorithm is that it requires only few parameters to be tuned.

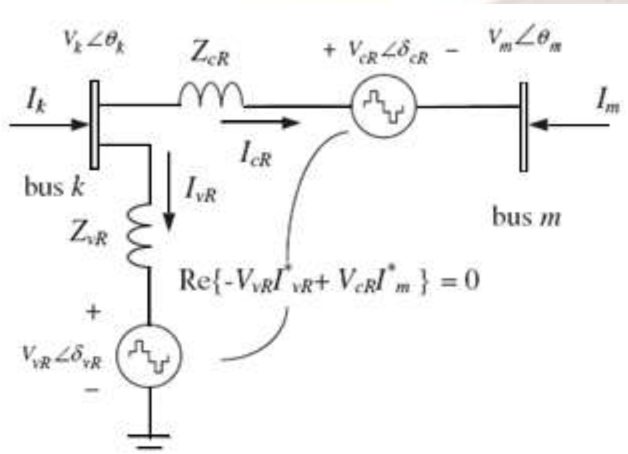
This Papers deals with the application of Modified Particle Swarm Optimization (MPSO) for finding the optimal placement and initial parameters setting of the Unified Power Flow Controller with considered of total loss reduction and improving voltage stability in power system.

2. MATHEMATICAL MODEL OF UPFC

The UPFC may be seen to consist of two voltage source converters sharing a common capacitor on their DC side and a unified control system. A simplified schematic representation together with its equivalent circuit of the UPFC is given in Fig.1. The UPFC allows simultaneous control of the active and reactive power flow, and voltage magnitude at the UPFC terminals. Alternatively, the controller may be set to control one or more of these parameters in any combination or to control none of them.



(a)



(b)

Fig.1. Block diagram of the UPFC system:
(a) Two back-to-back voltage source converters.
(b) Equivalent circuit of a UPFC.

The active power demanded by the series converter is drawn by the shunt converter from the AC network and supplied to bus m through the DC link. The output voltage of the series converter is added to the nodal voltage, say bus k, to boost the nodal voltage at bus m. The voltage magnitude of the output voltage V_{cR} provides voltage regulation, and the phase angle δ_{cR} determines the mode of power flow control. For specified nodal powers at node m, P_{mref} and Q_{mref}, the solutions of the active and reactive power equations at this node give,

$$\theta_{cR}^0 = arctan\left(P_{mref}/C_1\right)$$

$$V_{cR}^0 = \left(X_{cR}/V_m^0\right)\sqrt{(P_{mref}^2 + C_1^2)}$$

Where $C_1 = Q_{mref} - \frac{V_m^0}{X_{cR}}(V_m^0 - V_k^0)\ if\ \ V_m^0 \neq V_k^0$

$$C_1 = Q_{mref} \quad if\ V_m^0 = V_k^0$$

X_{cR} is the inductive reactance of the series source and superscript 0 indicates initial value.

An equation for initializing the shunt source angle can be obtained by solving Eqn. and it is given by,

$$\theta_{vR} = -arcsin\left(\frac{(V_k^0 - V_m^0)V_{cR}^0 X_{cR}\sin(\theta_{cR}^0)}{V_{vR}^0 V_k^0 X_{cR}}\right)$$

Where X_{cR} is the inductive reactance of the shunt source. When the shunt converter is acting as a voltage regulator, the voltage magnitude of the shunt source is initialized at the target voltage value and then it is updated at each iteration. Otherwise, if the shunt converter is not acting as a voltage regulator, the voltage magnitude of the shunt source is kept at a fixed value within prescribed limits,$(V_{vRmin} \leq V_{vR} \leq V_{vRmax})$, for the whole iterative process.

3. VOLTAGE STABILITY INDEX

Voltage stability is becoming an increasing source of concern in secure operating of present-day power systems. The problem of voltage instability is mainly considered as the inability of the network to meet the load demand imposed in terms of inadequate reactive power support or active power transmission capability or both. It is mainly concerned with the analysis and the enhancement of steady state voltage stability based on L-index.

Consider an n-bus system having $1, 2, 3, \ldots n$, generator buses(g), and $g+1, g+2, \ldots n$, the load buses$(r = n - g - s)$. The transmission system can be represented by using a hybrid representation, by the following set of equations

$$\begin{bmatrix} V_L \\ I_G \end{bmatrix} = H \begin{bmatrix} I_L \\ V_L \end{bmatrix} = \begin{bmatrix} Z_{LL} & F_{LG} \\ K_{GL} & Y_{GG} \end{bmatrix} \begin{bmatrix} I_L \\ V_G \end{bmatrix}$$

It can be seen that when a load bus approaches a steady state voltage collapse situation, the index L approaches the numerical value 1.0. Hence for an overall system stability condition, the index evaluated at any of the buses must be less than unity. Thus the index value L gives an indication of how far the system is from voltage collapse. The $L-$ indices for a given load condition are computed for all load buses. The equation for the $L-$index for j^{th} node can be written as,

$$L_j = \left|1 - \sum_{i=1}^{i=g} |F_{ji}| \frac{|V_i|}{|V_j|}(F_{ji}^r + jF_{ji}^m)1 - \sum_{i=1}^{i=g} |F_{ji}| \frac{|V_i|}{|V_j|}\angle\theta_{ji} + \delta_i - \delta_j\right|$$

$$L_j = \left|1 - \sum_{i=1}^{i=g} |F_{ji}| \frac{|V_i|}{|V_j|}(F_{ji}^r + jF_{ji}^m)\right|$$

$$F_{ji}^r = |F_{ji}| \cos(\theta_{ji} + \delta_i - \delta_j)$$

$$F_{ji}^m = |F_{ji}| \sin(\theta_{ji} + \delta_i - \delta_j)$$

It can be seen that when a load bus approaches a steady state voltage collapse situation, the index L approaches the numerical value 1.0. Hence for an overall system voltage stability condition, the index evaluated at any of the buses must be less than unity. Thus the index value L gives an indication of how far the system is from voltage collapse.

4. PARTICLE SWARM OPTIMIZATION

i. General Particle Swarm Optimization

Kennedy and Eberhart developed a PSO concept through simulation of bird flocking in two-dimension space. The position of each agent is represented by XY axis position and also velocity is expressed by V_x (the velocity of X axis) and V_y (the velocity of Y axis). Modification of the agent position is realized by the position and velocity information.

Bird flocking optimizes a certain objective function. Each agent knows its best value so far (P_{best}) and its XY position. Moreover each agent knows the best value so far in group (G_{best}) among P_{bests}. Namely, each agent tries to modify its position using the following information:

- The distance between the current position and P_{best}.
- The distance between the current position and G_{best}.

This modification can be represented by the concept of velocity. Velocity of each agent can be modified by the following equation:

$$V_i^{k+1} = WV_i^k + C_1 \times rand1 \times \left(P_{besti} - S_i^k\right) + C_2 \times rand2 \times \left(G_{besti} - S_i^k\right)$$

Where V_i^k = Velocity of agent i at k^{th} iteration

V_i^{k+1} = Velocity of agent i at $(k+1)^{th}$ Iteration

W = the inertia weight

$C_1 = C_2$ = Weighting factor (0 to 4)

S_i^k = Current position of agent at k^{th} Iteration

S_i^{k+1} = Current position of agent at $(k+1)^{th}$ Iteration

$iter_{max}$ = Maximum iteration number

$rand1, rand2$ = The random numbers selected between 0 and 1.

P_{besti} = P_{best} of agent i

G_{besti} = G_{best} of the group

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} \times iter$$

The above Equation is called "inertia weights approach (IWA)". Using the above equation, diversification characteristic is gradually decreased and a certain velocity, which gradually moves the current searching point close to P_{best} and G_{best} and can be calculated. The current position (search point the solution space) can be modified by the following equation:

$$S_i^{k+1} = S_i^k + V_i^{k+1} \times \Delta t$$

Where S_i^k = Current position of agent at k^{th} iteration

S_i^{k+1} = Current position of agent at $(k+1)^{th}$ iteration

Δt is change in time step from two successive iterations.

ii. Modified Particle Swarm Optimization

In this approach we remove worst particle in population and replace it by new particle. This is important that how to determine worst particle and how to generate new particle for current population.

The particle is selected with worst local best value at generation. Then we randomly choose two particles from the population and use crossover operator to generate two new particles. Then select the best one from two newly generated particles and the selected particles and the selected particle and replace the worse particle with it.

In other hand we combine GA operator and PSO algorithm to modify it. This modification make converges faster than basic algorithm.

iii. UPFC Cost and Fitness Function

Using Siemens AG Database [12], cost function for UPFC is developed as follows:

$$C_{UPFC} = 0.0003S^2 - 0.2691S + 188.22 \ US\$/kVAR$$

Where, S is operating range of UPFC in MVAR

$S = |Q_2 - Q_1|$

Q_1 - MVAR flow through the branch before placing FACTS device.

Q_2 - MVAR flow through the branch after placing FACTS device.

The goal of optimization algorithm is to place FACTS devices in order to enhance voltage stability margin of power system considering cost function FACTS devices. So these devices should be place to prevent congestion in transmission lines and transformer and maintain bus voltages close to their reference.

Fitness function is expressed as below:

$$F = \frac{1}{\alpha(maxL_j) + \beta(TIC) + \gamma(PL)}$$

Where $maxL_j$ = maximum value for VSI

TIC= Total cost of Investment

PL= Loss in the system

The coefficient $\alpha\,\beta\,\gamma$ are optimized by trial and error to 2.78, 0.1 and 2.05 respectively.

5. SIMULATION RESULTS

For the validation of the proposed techniques, both PSO and Modified PSO algorithms have been tested on the following IEEE 9-Bus and IEEE 30- Bus test System. A MATLAB code for both techniques was developed for simulation purpose.

5.1 IEEE 9-Bus Test System

The Problem of Placement of the UPFC has been solved of the IEEE 9-Bus test system. By considering the voltage stability index value, it observed that Bus-4 is more sensitive towards system security. An additional node Bus-10 is used to connect the UPFC. The modified original network is including a UPFC between nodes Bus-4 and Bus-10. After Placing UPFC voltage stability index is improved.

The Proposed algorithms were implemented to find out the proper setting and installation cost of the UPFC in IEEE 9-Bus test system. Comparisons of two proposed algorithms are shown in Table. 1and Figs. 1 to 3, it is observed that fitness function is minimized in Modified PSO compared to PSO

Table 1 Summary of results of IEEE-9 Bus Test System

Aspect	GA	PSO	Modified PSO
Total power loss without UPFC (MVA)	19.736	19.736	19.736
Total power loss with UPFC (MVA)	18.012	15.874	15.847
Cost of UPFC (Rs/ kVAr)	184.07	178.10	178.10
Fitness Value	55.037	50.040	34.554
Elapsed Time in Sec	7.54	7.44	5.84

Table 2 Comparison of VSI with & without UPFC

Bus No	Before UPFC Placement	After UPFC Placement
3	0.0328	0.0376
4	0.0483	0.0316
5	0.0425	0.0250
6	0.0178	0.0264
8	0.0282	0.0096
9	0.0309	0.0125
10	------	0.0096

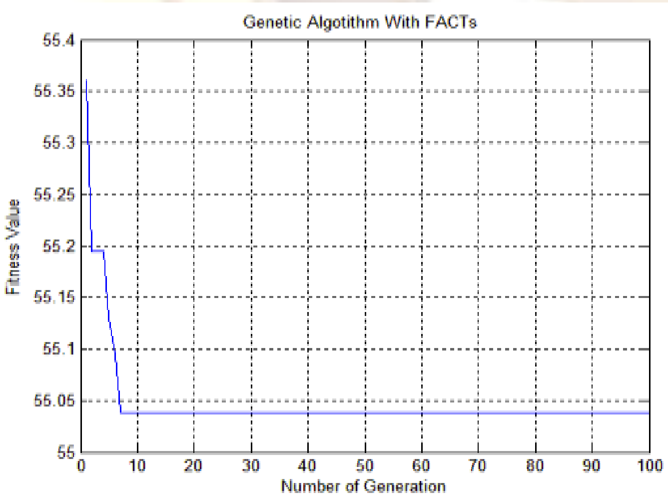


Fig. 1 Fitness function is minimized by using GA for IEEE 9-Bus Test System

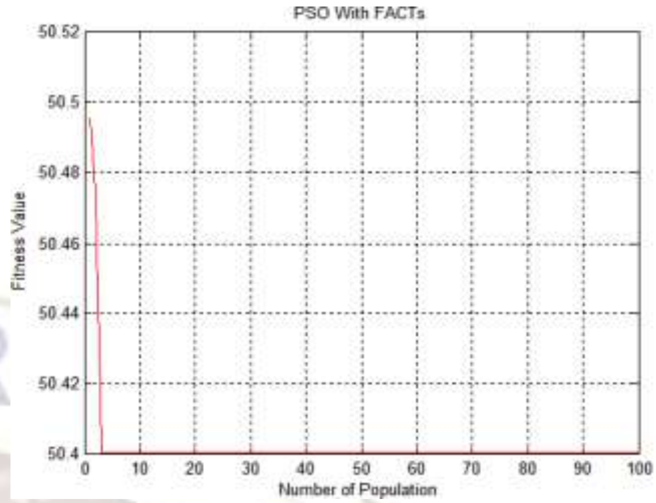


Fig. 2 Fitness function is minimized by using PSO for IEEE 9-Bus Test System

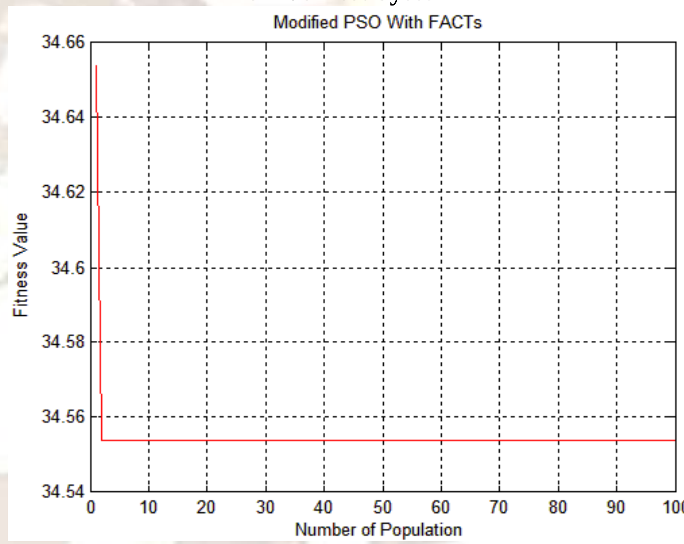


Fig. 3 Fitness function is minimized by using MPSO for IEEE 9-Bus Test System

5.2 IEEE 30-Bus Test System

The Problem of Placement of the UPFC has been solved of the IEEE 30-Bus test system. By considering the voltage stability index value, it observed that 30-Bus is more sensitive towards system security. An additional node 31-Bus is used to connect the UPFC. The modified original network is including a UPFC between nodes 30-Bus and 31-Bus. After Placing UPFC voltage stability index is improved.

Table 3 Summary of results of IEEE-30 Bus Test System

Aspect	GA	PSO	Modified PSO
Total power loss without UPFC (MVA)	55.933	55.933	55.933
Total power loss with UPFC (MVA)	53.082	53.112	51.121
Cost of UPFC (Rs/ kVAr)	188.06	188.012	187.01
Fitness Value	127.80	127.80	127.79
Elapsed Time in Sec	43.50	40.12	35.12

The Proposed algorithms were implemented to find out the proper setting and installation cost of the UPFC in IEEE 30-Bus test system. Comparisons of two proposed algorithms are shown in Table 3 and Figs. 4 to 6, it is observed that fitness function is minimized in Modified PSO compared to PSO

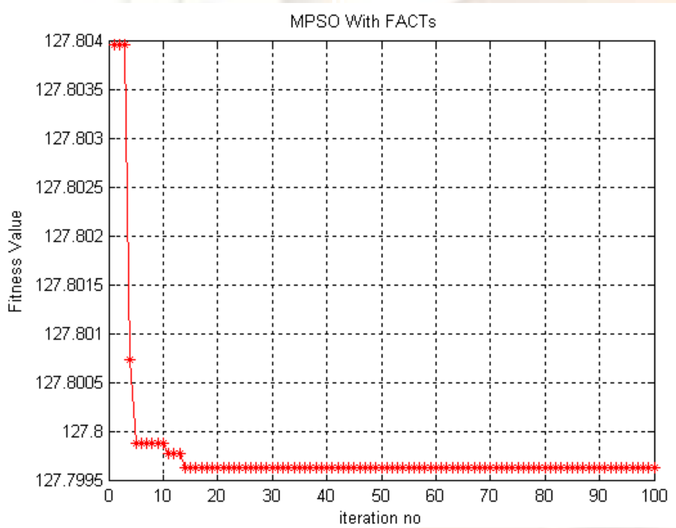


Fig. 4 Fitness function is minimized by using MPSO for IEEE 30-Bus Test System

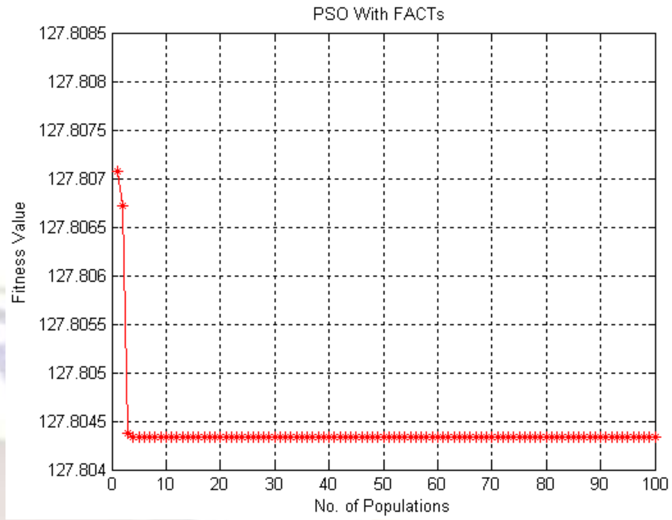


Fig. 5 Fitness function is minimized by using PSO for IEEE 30-Bus Test System

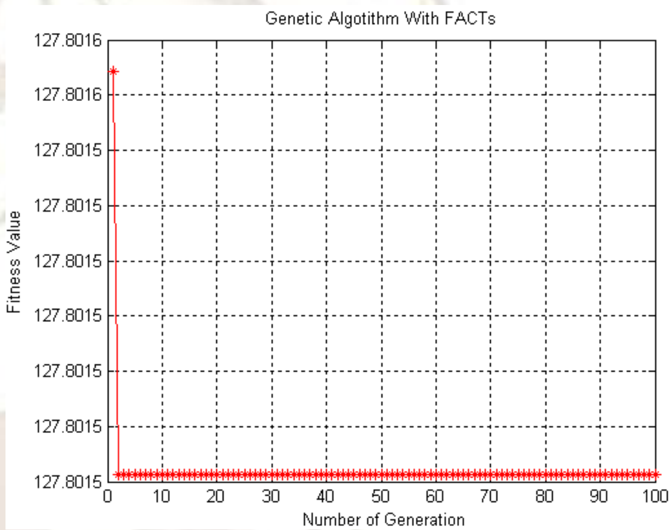


Fig. 6 Fitness function is minimized by using GA for IEEE 30-Bus Test System

6. CONCLUSION

This paper presents the application of Modified Particle Swarm Optimization (MPSO) technique in power system with and without UPFC. The unified power flow controller provides simultaneous or individual controls of basic system parameters like transmission voltage, impedance and phase angle, there by controlling the transmitted power. The Modified Particle Swarm Optimization (MPSO) technique is used to compute the power flow. The power loss occurring in the various branches and state variables of IEEE 9-bus and IEEE 30--bus systems are evaluated using Modified Particle Swarm Optimization (MPSO). From the results it is concluded that the system performs better when the UPFC is connected i.e., the state variables are improved and the total losses are minimized.

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8. BIOGRAPHIES

Kiran Kumar Kuthadi *recived his B.Tech degree in Electrical Engineering from Lakireddy Balireddy College of Engineering, Mylavaram, A.P and his M.Tech degree in Electrical Power Systems from J.N.T. University Anantapur, Anantapur, A.P in 2009. His special research of interest is its application to power system, FACTS devices and their control. He is working as Asst. Professor in Sree Vahini Institute of Science & Technology, Tiruvuru. Andhra Pradesh.*

M. Suresh Babu *recived his B.Tech degree in Electrical & Electronics Engineering from V.R.S & Y.R.N College of Engg & Tech, Chirala, A.P and his M.Tech degree in Control Systems from J.N.T. University Anantapur, Anantapur, A.P in 2010. His special research of interest is its application to Control system Power Systems, FACTS devices and their control. He is working as Asst. Professor in V.R.S & Y.R.N College of Engg, & Tech, Chirala, Guntur Dist, Andhra Pradesh.*