Optimal Placement of Multi-Type Facts Controllers Using Real Coded Genetic Algorithm

Ishit Shah[1], Dr. Jaydeep Chakravorty [2]

[1] M.E. (Electrical Power System,)

[2] Ph.D (Electrical Power System)

ABSTRACT

The objective of this paper is to enhance the Available Transfer Capability using Multi-type FACTS controllers. TCSC, SVC and UPFC controllers are implemented and included in the FLDF (Fast Decoupled Load Flow) algorithm to minimize the losses of the system. Optimal location of FACTS controllers are obtained by using Real Coded Genetic Algorithm. MATLAB coding is developed to analyze the performance of IEEE-30 bus system for different loading condition with and without FACTS device.

Keywords: FACTS Devices (TCSC, UPFC, SVC), FDLF, Elitist operation, Real Coded GA, Loadability, Losses, MATLAB.

1. INTRODUCTION

In present scenario the load demand increases. With increase in load demand the generation is not increase to that much level means the generation is not sufficient to supply the huge loads. So it is difficult to cope up with the load. It is results in the overloading of the lines. The losses also increases because of the overloading conditioned. It makes the system unstable because of the large real and reactive power demand and low voltage conditioned. It stresses the equipment into the power system and reduces its life. The solution is to place new transmission lines and extra generations. But thecost is not economical, and land problems are also occurs. So FACTS devices are suitable for these types of the problems. FACTS mean Flexible A.C. Transmission System which is based power electronic devices. It can control real and reactive power very rapidly. There are different types of FACTS devices and their working function is also different. This
technology improves the system stability by exchanging the real and reactive power with system very rapidly and also it reduces the system losses simultaneously [1-3]. FACTS controllers are used to control the current, voltage, impedance, damp the oscillations and phase angle. FACTS devices are cost effective solution. This paper focuses on the evaluation of the impact of TCSC, SVC and UPFC as FACTS devices for improving the loadability of the system and reduced the transmission losses. In a competitive (deregulated) power market, optimal the location of the device and its control can significantly affect the operation of the system [4]. The optimal placement of the device can be obtained by using Real Coded Genetic Algorithm.

This paper has been organized in the following manner. Section II discusses overview of load flow study. Section III discusses about the genetic algorithm and its parameters. Section IV presents algorithm for calculating the loadability and losses of the system for different loading conditioned. Section V presents results of load flow for IEEE- 30 bus system with and without FACTS controllers for different loading condition.

2. OVERVIEW OF LOAD FLOW

Load flow studies are very important to analyze current power system scenario. It gives the main information related to the system, like load bus voltage magnitude and its phase angle, power flow on each line and losses of the system. This information is essential to monitoring the present state of the system and for analyzing the effective future planning to cope up with the load. All the equations are non linear so this method is iterative and time consuming if we manually calculate, but now the algorithm are available to solve the load flow problems in digital computers and it is very fast and efficient. . The FLDF can be used very efficiently in optimization problem. It gives very accurate results for both real and reactive power for multiple load flow studies [i-ii].

3. GENETIC ALGORITHM

3.1 INTRODUCTION

Genetic Algorithm method was developed by John Holland in 1970. It is based on the Darwinian theory of the fittest. It is a one type of E.A. (Evolutionary Algorithm) search technique. This method gives the globally optimal solution so it is the global search method. This method doesn't require any prior knowledge related to objective function. This method always gives high quality of the solution [5]. For complex problems this method is gives trustworthy optimal solution. It is an iterative method, and very useful to find optimal location for multi objective optimization problems. In every iteration the chromosomes are selected randomly from matting pool of the current population and those parents chromosomes are used to find new offspring for next generations, and optimal solution is obtained by repeated iterations. Then the fitness of each chromosome is evaluated and new populations are generated by genetic operators like; Reproduction, Crossover and Mutation until the maximal number of generation are reached. GA can be used to solve to optimization problems with a variety of objective functions even it is highly non-linear, non-differentiable or discontinuous, new generation can be obtained through the genetic operators.

3.2 GENETIC OPERATOR

1) ENCODING AND INITIALIZATION

Firstly we have to initialize a population. Here I am working with Real coded Genetic Algorithm, So the initial population having real data. There is not required encoding operation because of real data. I initialize real data in form of srings. Each string has different data. On that basis it is generated initial population. There are main three parameters to initialize a population, namely rating of each FACTS device, its location, and Its types. These parameters are arranged as shown in figure 1 [6]. The number of column is depends on number of FACTS devices. Here In figure 1 numbers of FACTS devices=5 so the number of columns equal to 5.

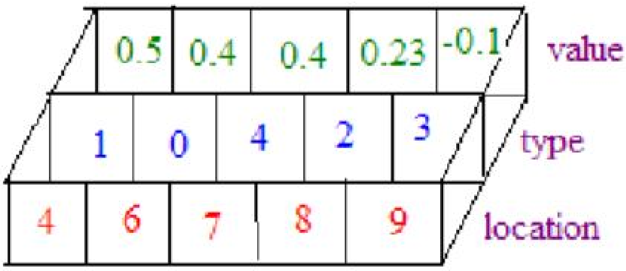

Figure 1 Individual configurations of FACTS devices

In figure 1 Values of FACTS devices indicated by first string, Type of FACTS devices indicated by second string and the location of FACTS devices indicated by the third string.

TCSC [iii-iv]:

By using Thyristor controlled Series Capacitor we can modify the transmission line reactance. TCSC working in either capacitive or inductive mode and according to that it modifies the transmission line reactance. In this work, TCSC directly adjust the reactance of the transmission line. Its rating depends on the reactance of the line where it is located:

$$X_{ij} = X_{Line} + X_{TCSC} \quad (1)$$

$$X_{TCSC} = r_{TCSC} * X_{Line} \quad (2)$$

Where,

XLine = Transmission line reactance where the TCSC is placed

rtcsc = Coefficient representing the degree of compensation by TCSC, whose working range is properly selected otherwise it provides the over compensation. So its range selected between − 0.7X Line and 0.2 X Line.

SVC [iii-iv]:

It is operated either in capacitive or inductive mode and modeled as an ideal reactive power injection at bus i. Its range selected between the values of -100 MVAR to 100 MVAR.

$\Delta Q = QSVC$ (3)

UPFC [iii-iv]:
There are the two types of model for UPFC device. First one is coupled model and the second is decoupled model. In coupled model of UPFC devices is complicated because of the modification of jacobian matrix. While in decoupled model of UPFC is modeled with two separate buses so it is easy to implement in conventional power flow algorithm and it is not required any modification in jacobian matrix. In this work decoupled model is used.

2) FITNESS FUNCTION CALCULATION
Here my objective function is related to loadability. To maximize the existing system loadability, FACTS devices are used. The initial population calculated from the rating of FACTS devices, Its types and Its location. From that the objective function is calculated for each individual. This process runs until the maximum number of population size is reach. Equation (4) is for calculating the bus loading. A term OVL is given in (5), in which Spq indicates the line flow between bus p and q and Spqmax indicates the maximum line flow limit for that particular line pq. Spq calculated by N-R load flow. If any line is overloaded then according to that penalty are given. In (4) different penalty factors are considered.
Fitness Function [6-8]:-
Busloading=OVL(k)+line_flow_penalty+voltage_penalty+gen_reactive_penalty+slack_power_penalty; (4)
If Spq ≤ Spq(max) , OVL(k) = 1
Spq > Spq(max) , OVL(k) = Equation (5)

$$OVL(k) = \exp\left(\lambda * abs\left(1 - \left(abs\left(s_{pq(k)}\right)' / s_{pqmax(k)}\right)\right)\right) \quad (5)$$

Subject to,
line_flow_penalty = penalties are applied if the line flow limits are violated.
voltage_penalty = penalties are applied if the load bus voltage limits are violated.
gen_reactive_penalty = penalties are applied if the generator reactive power limits are violated.
slack_power_penalty = penalties are applied if the slack bus active power limits are violated.

3) SELECTION TECHNIQUES
From different methods like: Rank selection, Tournament selection and Roulette selection, here I am selecting Tournament selection method. In which a loop is rotating to arrange each individual of fitness function according to their value in descending order.

4) CROSSOVER AND MUTATION
The type of crossover and mutation operation depends on genetic algorithm means whether we use binary coded genetic algorithm or real coded genetic algorithm. Because operations are varies for different types of GA. Generally these operations are used for improving the fitness value of each individual. But there can be a chance to lose best fittest chromosomes.
Real Coded Genetic Algorithm [RGA]:
This is a type of genetic algorithm which deals with real parameters values. So the genetic operators are directly applied to the real parameters values. The methods and equations for these operators are different.
Crossover for RGA [7-8]:
There are different types of crossover schemes for real coded genetic algorithm like, Discrete Crossover, Simple Arithmetic Crossover, Single Arithmetic Crossover, Whole Arithmetic Crossover, local Crossover, SBX Crossover, BLXalpha Crossover, BLX-alpha-beta Crossover, Flat Crossover and One point Crossover. Here I am using BLX-alpha Crossover. This method was proposed by Eshelman and Schaffer in 1993. It is also known as a blend crossover (BLX-α) operator.
Mutation for RGA [9]:

There are different types of mutation schemes for real coded genetic algorithm like, Usual Mutation, Mutation Clock, One mutation per solution, Fixed Strategy Mutation and Diversity based Mutation. Here I am using usual mutation scheme. u is a random number selected between 0 and 1 for every individual variable. The variable is mutated by polynomial mutation operator if u is less or equal to the mutation probability. The mutation probability is already predefined. The polynomial mutation parameter defined by Deb and Agrawal. They suggested a user-defined index parameter (ηm). If we considered here both lower bound and upper bound for a parent solution there isn't a chance to select a value outside of the limit. So for that firstly we have to define lower and upper bound limits to our variables. For example, in this work the initial population having three strings. the first one having range of the particular devices, which is between - 1 to 1. The second string is for types of the devices, which
have the values be ween 1 to 3. The third string is for the location of the devices, which has value between 1 to 41. The mutated solution Child(C) is created which based on the random number u and its range between [0,1].

Child (C) = $(p + \delta L(p-x(L)\ i)$, for $u \leq 0.5$,
$(p + \delta R(x(U)\ i -p)$, for $u > 0.5$.
Where δL and δR given by,
$\delta L = (2u)1/(1+\eta m) -1$, for $u \leq 0.5$,
$\delta R = 1-(2(1-u))1/(1+\eta m)$, for $u > 0.5$.

5) ELITIST SELECTION [10]

After evaluating the fitness function we have to arrange it in descending ordered. So from that we can find error between first and last individual of fitness function. If it is more than prescribed limit then we have to improve its fitness value by genetic operators like Elitism, Crossover and mutation. But in crossover and mutation operation there might be a chance t lose best individual chromosomes from list. So for better side firstly copy best individual from list and keep them aside for next generation. Elitist operator surely improves the performance of genetic algorithm because it prevents to lose the best chromosomes from the solutions.

4. PROPOSED GENETIC ALGORITHM

1. Read the system data.
 a. Data required for GA. (population size pop_size, Number of FACTS devices on which the string length is depend, Types of FACTS devices, Elitism Probability, Crossover Probability, Mutation Probability.
 b. Data required for load flow solution. (number of buses, number of lines, nslack, max iterations, epsilon, linedata, bus data).
2. Initial populations are randomly generated by using location, type and rated values of FACTS controllers.
3. Set maximum generation count gen=200, start it with gen=1.
4. Set maximum pop_size=60, and start it with k =1
5. Form Ybus using sparsity technique. Modification inYbus based on the positions and rated values of TCSC, UPFC and SVC.
6. Form [B'] matrix and decompose using cholesky decomposition.
7. Set maximum iteration count itermax=100, start it with iter=1.
8. Run load flow.
9. Set convergence criterion, del_pmax< Epsilon or del_qmax<epsilon then load flow is converged otherwise it runs until maximum iteration count is reach. Increment iteration count. If (iter < itermax) go to step 8 else problem is not converged in itermax iterations. STOP.
10. Calculate different parameters from converged load flow algorithm like, Power for slack bus, losses of the line, bus voltage magnitudes and its phase angles, power flow between bus p and q, loading of the lines.
11. Check for limits on load bus voltage magnitudes, generator reactive power limits, slack bus power limit, and line flow limit.
12. According to the violation in constraints the penalty is applied.
13. Evaluate the objective function.
14. Evaluate the fitness of each chromosome considering objective function, in this work the objective function is bus-loading.
15. Check if k < pop_size (population size). If yes, then increment in it, k = k+1, and go to step 4.
16. Arrange population according to their fitness value. It means in descending order.
17. Copy the portion of the best fitness values by elitism operation.

18. Apply the GA parameters to remaining population solutions. Genetic parameters are, tournament selection, uniform crossover and mutation to remaining population members.
19. Ybus is modify after every iteration.
20. Calculate the objective function values, power flow through lines, line losses and loadability.
21. Calculate that in how much generation theprogramme is converged.
22. Increment generation count. If (gen < genmax) goto step 3 else problem is not converged in genmax iterations. STOP.

5. CASE STUDY & RESULTS

To analyze IEEE 30-bus, 41-branch system is considered. Real coded Genetic Algorithm is used to determine the optimal location of FACTS controllers. Table 1 shows assumption in genetic parameters value.

TABLE 1. GENETIC PARAMETERS VALUE

Maximum Generation 200	Maximum Generation 200
Maximum no. of iteration 100	Maximum no. of iteration 100
Population size 60	Population size 60
Elitism probability 0.15	Elitism probability 0.15
Mutation probability 0.001	Mutation probability 0.001
Crossover probability 0.95	Crossover probability 0.95

The objective is to improve the system loadability by optimal location of the FACTS controllers it also reduce the losses of the system. The objective is to improve the system loadability by optimal location of the FACTS controllers it also reduce the losses of the system.

ACTIVE POWER FLOW COMPARISON

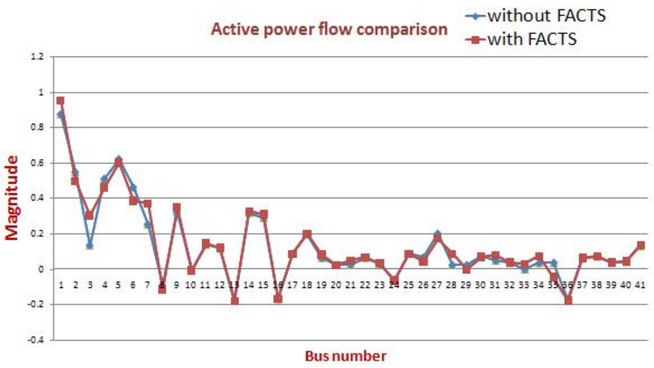

Figure 2 Normal Loading Conditioned

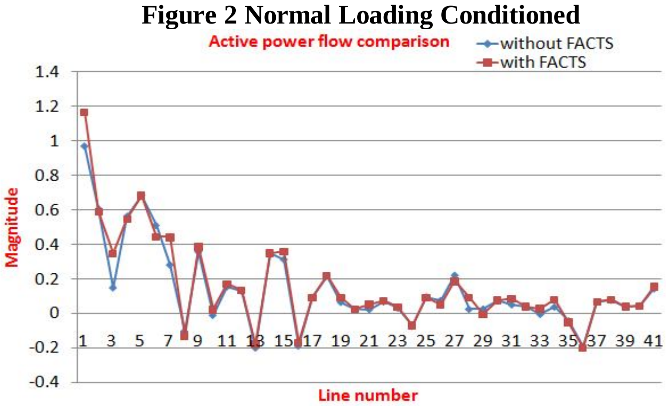

Figure 3 110% Loading Conditioned

REACTIVE POWER FLOW COMPARISON

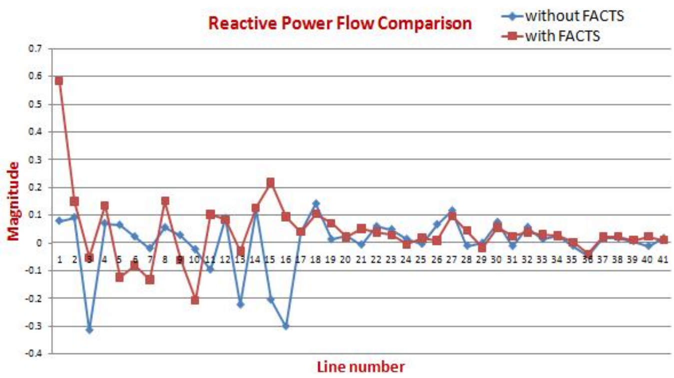

Figure 6 Normal Loading Conditioned

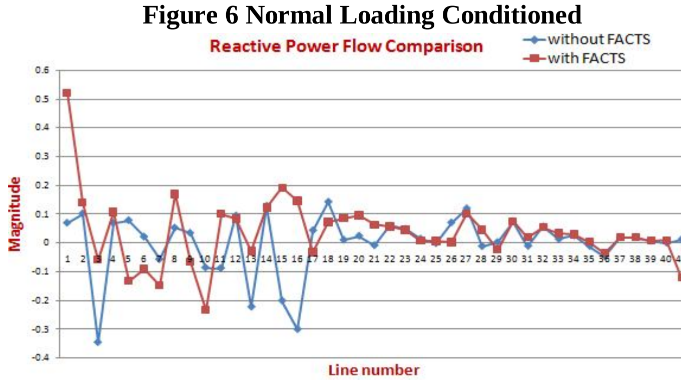

Figure 7 110% Loading Conditioned

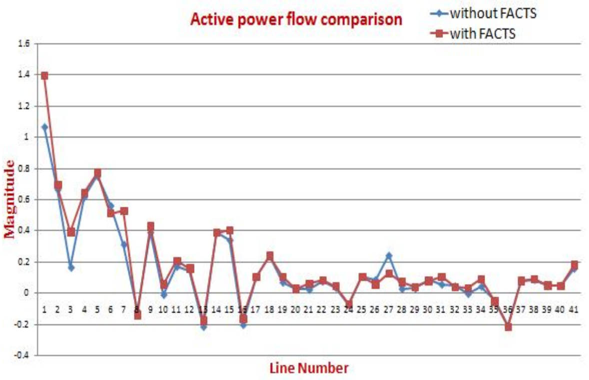

Figure 4 120% Loading Conditioned

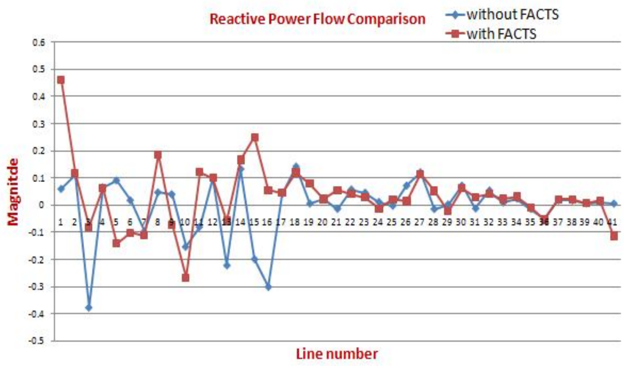

Figure 8 120% Loading Conditioned

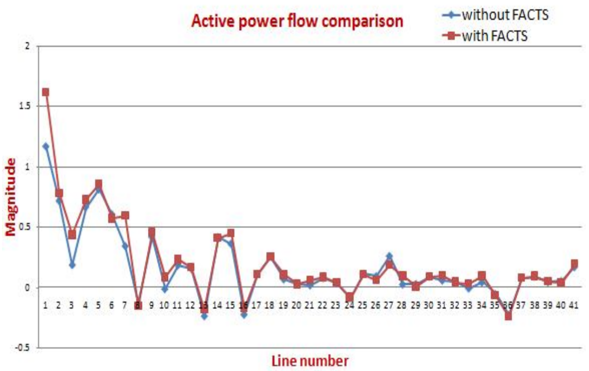

Figure 5 130% Loading Conditioned

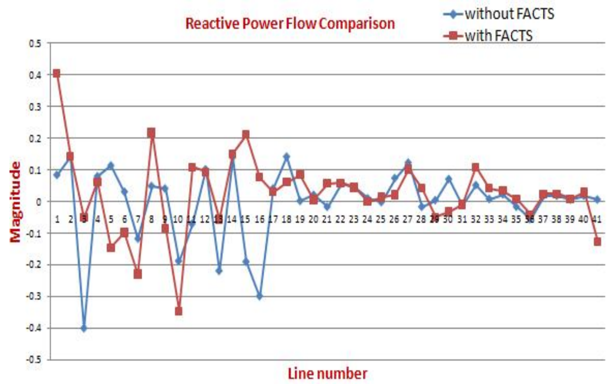

Figure 9 130% Loading Conditioned

Figure 2 to Figure 5 shows the Active power flow of each line for different loading condition with & without FACTS devices. Figure 6 to Figure 9 shows the Reactive power flow of each line for different loading condition with & without FACTS devices. Table 2 shows optimal location of different types of FACTS controllers and their parameter values. It also shows number of generations required to converge the problem. It also shows the value of bus loading fitness function. It also shows the losses for different loading condition with without FACTS devices.

Table 2. Optimal Location, Type, Parameter value of FACTS Controllers, Fitness Function Value and Losses.

Cases	Location	Type of FACTS device	Parameter value	Problem converged in generation	Bus Loading Fitness Value	Losses		
						Without FACTS Devices	With FACTS Devices	% Reduction in Losses
Normal loading	Line-11	TCSC	-0.08031	2	467.256	0.133	0.0943	29 %
	Bus-22	SVC	0.19280					
10% overloading	Line-20	UPFC	0.01781	3	711.653	0.215	0.116	46 %
	Line-24	TCSC	-0.01752					
	Line-25	UPFC	-0.04550					
20% overloading	Bus-12	SVC	0.527037	36	1093.209	0.322	0.148	54 %
	Line-26	UPFC	0.216361					
	Bus-30	SVC	0.157862					
30% overloading	Line-20	TCSC	0.8427	5	1591.271	0.458	0.196	57.2 %
	Line-23	TCSC	0.09603					
	Line-31	TCSC	-0.05850					

Conclusion

From the research work concluded that by optimal placement of FACTS controllers the loadability of the system is improved and simultaneously losses of the system is reduced. In this paper the comparisons of results is shown for different loading conditions. Real Coded Genetic algorithm based approach is proposed to determine the optimal location of different types of FACTS controllers. The proposed algorithm is an effective and practical method for the allocation of FACTS controllers.

References

Papers:

[1] El Metwally M. M., El Emary A.A., El Bendary F. M., and Mosaad M.I., "Optimal Allocation of FACTS Devices inPower System Using Genetic Algorithms", IEEE Trans., 2008.

[2] Prashant Kumar Tiwari, Yog Raj Sood "Optimal Location of Facts devices in Power System Using Genetic Algorithm", IEEE,2009.

[3] A.B.Bhattacharyya, B.S.K.Goswami, "OPTIMAL Placement of FACTS Devices by Genetic Algorithm for the Increased Load Ability of a Power System", World academy of science, engineering and technology, vol:5, 2011-02-26.

[4] Ghamgeen I. Rashed and Yuanzhang Sun(senior member IEEE), H. I. Shaheen "Optimal Location and Parameter Setting of TCSC for Loss Minimization Based on Differential Evolution and Genetic Algorithm.", Science Direct,2012

[5] Stéphane Gerbex, Rachid Cherkaoui, and Alain J. Germond, Member, IEEE "Optimal Location of Multi-Type FACTS Devices in a Power System by Means of Genetic Algorithms", IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 16, NO. 3, AUGUST 2001.

[6] K. Lokanadham,"Optimal Location of FACTS Devices In Power System by Genetic Algorithm", Global Journal of Researches in Engineering.

[7] Domagoj Jakobovic, Stjepan Picek and Marin Golub "On the Recombination Operator in the Real-Coded Genetic Algorithms"

[8] Vishnu j, Rishi menon, Tibin joseph, Sasidharan sreedharan, Chittesh v c, Vipin das p, Sebin joseph "GA based optimal facts controller for maximizing loadability with stability constraints"

[9] Kalyanmoy Deb and Debayan Deb, "Analyzing Mutation Schemes for Real-Parameter Genetic Algorithms", Indian Institute of Technology Kanpur, KanGAL Report Number 2012016.

[10] Kwong-Sak Leung and Yong Liang, "Adaptive Elitist- Population Based Genetic Algorithm for Multimodal Function Optimization", Springer-Verlag Berlin Heidelberg 2003.

Books:

i. Modern Power System Analysis by D P Kothari and I J Nagrath.

ii. Power System Analysis by Hadi Sadat.

iii. FACTS Modeling and Simulation in Power Networks by Enrique Acha, U K Claudio R. Fuerte-Esquivel, Hugo Ambriz- Perez and Cesar Angeles-Camacho.

iv. Understanding FACTS by Narain G. Hingorani and Laszlo Gyugyi