JCS Vol.1 No.2 Sep - Oct 2005

Micro-Genetic Algorithm based Optimal Location of FACTS Device in a Power System Network

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Abstract:

The flexible AC transmission system (FACTS) in a power system improves the stability, reduces the losses, reduces the cost of generation and also improves the loadability of the system. In the proposed work, a non-traditional optimization technique, a Micro-Genetic Algorithm (MGA) is used to optimize the various process parameters involved in introduction of FACTS devices in a power system. The various parameters taken into consideration were the location of the device, their type, and their rated value of the devices. The simulation was performed on a 30-bus power system with various types of FACTS controllers, modeled for steady state studies. The optimization results are compared to the solution given by another search method. This comparison confirms the efficiency of the proposed method which makes it promising to solve combinorial problem of FACTS device location in a power system network.

Keywords: Micro-Genetic Algorithm, Genetic Algorithm, Optimization, loadability, FACTS, optimal power flow.

1. INTRODUCTION

In recent years, with the deregulation of the electricity market, the traditional concepts and practices of power systems are changed. This leads to the introduction of Flexible AC Transmission system models (FACTS) device is only the solution such as Thyristor Controlled Series Compensations (TCSC), Thyristor controlled phase angle Regulators (TCPAR), Unified Power Flow Controllers (UPFC) and Static Var Compensator (SVC). These devices controls the power flow in the network, reduces the flow in heavily loaded lines there by resulting in an increase loadability, low system losses, improved stability of network and reduced cost of production [16,6,5,9]. It is more important to ascertain the location of these devices because of their significant costs. S.Jerbex et al [4] provides an idea regarding the optimal locations of FACTS device, without considering the investment cost of FACTS device and their impact on the generation cost. L.J.Cai et al [1] later studied about the optimal location considering the generation cost of the power plants and investment cost of the devices.

The main objective of this paper is to develop an algorithm to find and choose the optimal location of FACTS device based on power loss reductions, which is to be maximized. For the proposed objective function, the suitable types of FACTS device, their location, and their rated value must be determined simultaneously. This combinatorial analysis problem is solved by Micro-Genetic Algorithm.

This paper is organized as follows: following the introduction, different FACTS device mathematical are described in section II. Then in section III, objective functions are described. In section IV,

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the micro-genetic algorithms for optimal location of FACTS device are discussed in detail. The simulation results are given in section V. finally, a brief conclusion in section VI.

2. MATHEMATICAL MODELING

A. Facts Device

In an interconnected power system network, power flows obey the Kirchoff's laws. The active power transmitted by a line between the buses i and j may be approximated by following relationships:

$$Pij = (ViVj / Xij)\sin \delta ij \text{ .... } (1)$$

Where: Vi and Vj are voltages at buses i and j; Xij are reactance of the line;

δij angle between the Vi and Vj.

The active power flow coupled with δij and reactive power flow is linked with difference between the Vi-Vj. The control of Xij acts on both active and reactive power flows the different types of FACTS device have been chosen and located optimally in order to control the power flows in the power system network. The reactance of the line can be changed by TCSC. TCPAR varies the phase angle between the two terminal voltages and SVC can be used to control the reactive power. UPFC is the most power full and versatile device, which controls the line reactance, terminal voltage, and the phase angle between the buses. In this paper, four different typical FACTS device have been selected, and their block diagrams are shown in Fig 1. The below mentioned FACTS controllers can be applied to control the power flows by changing the parameters of power systems, so that the power flow can be optimized.

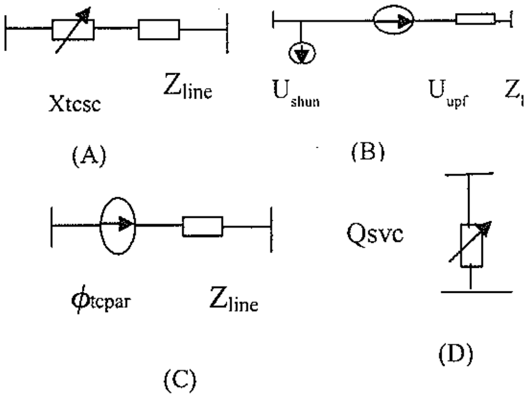

Fig.1 Block diagram of the considered FACTS controllers: a) TCSC b) UPF c) TCPAR d) SVC

The power-injected model is a good model for FACTS controller because it will handle them well in load flow computation problem. Since, this method will not destroy the existing impedance matrix Z; it would be easy while implementing in load flow programs. In fact, the injected power model is convenient and enough for power system with FACTS controller. The Mathematical models of the FACTS controller are developed mainly to perform the Steady state research. The TCSC, TCPAR, SVC and UPFC are modeled using the power injection method [1,4, 9,10].Furthermore, the TCSC, TCPAR, SVC and UPFC mathematical model are integrated into the model of the Transmission line. Fig: 1 shows a simple transmission line, the parameter are connected between bus i and bus j.The voltage and angle at the buses i and j are Vi, δi and Vj, δj respectively. The real and reactive power flow between the buses i to bus j can be written as The real and reactive power flow between the buses i to bus j can be written as

$$Pij = Vi \times ViGij - ViVj[Gij\cos \delta ij + Bij\sin \delta ij]\text{..........}(2)$$

$$Qij = -Vi \times Vi(Bij + Bsh) - ViVj[Gij\sin \delta ij - Bij\cos \delta ij]\text{....}(3)$$

Where the δij =δi-δj, similarly, the real and reactive power flow between the bus j to bus i is

$$Pji = Vi \times ViGij - ViVj[Gij\cos \delta ij - Bij\sin \delta ij]\text{.......}(4)$$

$$Qji = -Vi \times Vi(Bij + Bsh) + ViVj[Gij\sin \delta ij + Bij\cos \delta ij]\text{.....}(5)$$

TCSC

The model of a transmission line with TCSC connected between the buses i and j is as shown in fig: 1, The real and reactive power injection at buses i and j (Pic, Pjc and Qic,Qjc) can be expressed as in [9].The working range of TCSC between -0.8Xij and 0.2Xij,where Xij is reactance of transmission line, where it is located. The value can be converted in to

$$Xt\,\mathrm{csc} = Rv \times 0.45 - 0.25$$

TCPAR

The model of a TCPAR with transmission line is as shown in fig.1. The injected real and reactive power at buses i and j having the phase shifter are expressed in [9].The working range of TCPAR between -5° to +5°.It can be converted in to $\varphi tcpar = Rv \times 5(\deg ree)$

UPFC

A series inserted voltage and phase angle of inserted voltage can be modeled as the effect of UPFC on the network. The inserted voltage has a maximum magnitude of 0.1Vm, where Vm is rated voltage of the transmission line, where the UPFC is connected. It is connected to the system through two coupling transformers [6, 11]. The real and reactive power injected at buses i and j can be expressed as in [11]. The working range of UPFC between -180° to +180°.It can be converted in to

$$\varphi upfc = Rv \times 180(\deg ree)$$

SVC

The primary purpose of SVC is usually to control voltages at weak points in a network. This may be installed at midpoint of the transmission line. The given limit, the reactive power output of SVC can be expressed as in [4, 1,6] ,the working range of SVC between -100Mvar to +100 Mvar.

$$Vsvc = Rv \times 100(M\ \mathrm{var})$$

The exact loss formula of a system having N number of buses is [15].

$$Pltc = \sum_{J=1}^{N}\sum_{K=1}^{N}[\alpha jk(PiPj + QjQk) + \beta jk(QjPk - PjQk)] \qquad \ldots\ldots..(6)$$

Where Pj, Pk and Qj, Qk respectively, are real and reactive power injected at bus-j and ±jk, ^{2}jk are the loss coefficients defined by

$$\alpha jk = (Rjk / VjVk)\cos(\delta j - \delta k)$$

$$\beta jk = (Rjk / VjVk)\sin(\delta j - \delta k)$$

Where, Rjk is the real part of the j-kth element of [Zbus] matrix. If a FACTS device is used one at a time, the total loss can be written as follows [9].

$$Plk = (Plkc - [Pic + Pjc]. \qquad \ldots\ldots..(7)$$

Pic and Pjc are injected real powers.

3. OBJECTIVE FUNCTION

The aim is to utilize the FACTS device for supplying the optimal amount of power without overloaded line and with an acceptable voltage level. The optimal location of FACTS device problem is to increase as much as possible capacity of the network.i.e loadability. In this work, the FACTS device has been considered to reduce the power loss.

Objective function is

$$MinF(u), PL(V, \delta, S) = \sum_{i=1}^{N} Plt \ldots\ldots\ldots..(9)$$

Subject to F (b, v) =0, $F_1(s) < M_1$, $F_2(v) < M_2$

Where, u- set of parameters that indicate the location, devices and rated values. P_{Lt} is the power loss difference between the without FACTS device and with FACTS device in a power system network. F (b, v): conventional power flow equations, $F_1(s) < M_1$, and $F_2(v) < M_2$ are inequality constraints for FACTS device, and conventional power flows.

The FACTS device can be used to change the power system parameters. These parameters offer different results on the objective function (9). Also various FACTS device locations, rated value and types have influences on the objective function. The above-mentioned parameters are very difficult to optimize simultaneously by conventional optimization methods. To solve this type of combinatorial problem, the micro-genetic algorithm is proposed. The proposed methods are well developed and utilized effectively for this work. For which C computer coding are developed and for simulated.

4. MICRO-GENETIC ALGORITHM

Heuristic methods may be used to solve complex optimization problems. Thus, they are able to give a good solution of a certain problem in a reasonable computation time, but they do not assure to reach the global optimum [17, 1, 4]. In case of GAs (Genetic Algorithm) which is based on global search technique and the mechanisms of natural selection and genetics; they can search several possible solutions simultaneously. A simple genetic algorithm is constituted by a random creation of an initial population and a cycle of three stages, namely:

- Evaluation of each chromosome,
- Chromosomes selection for Reproduction,
- To create a new Population, this includes Crossover and Mutation. Each time, this cycle is completed, it is said that a generation has occurred.

The disadvantage of GAs is the high processing time consuming due to their evolutionary concept, based on random processes that cause the algorithm quite slow. However different methods are available for reducing the processing time, one of the method known as a Micro-genetic algorithm, reduces the processing time considerably small [7] .Most GAs produce poor results when population are small because of insufficient information about the problem and convergence to a local optimum obtained. Population size generally varies from 20 to 250 individuals. In general Micro-Genetic Algorithm (MGA) is possible to work with small population (nearly 5 to 10 individuals) and this reduces the processing time. The frequent reproductions occurring inside a small population, where the desirable genetic characteristic emerges quickly, also avoid the Mutation process because after a certain number of generations the best chromosomes are maintained and remaining are randomly selected generated ones. Accordingly, some numbers of individuals are selected for such a group, in which randomly coupled based on adoption strategy. Then, the group is repeated and individuals are selected to form couples to begin Crossover. The above work can be summarized as in flowchart.

5. SIMULATION RESULTS

The Power flows are solved with the help of AU Power software package. Simulation was carried out on IEEE 30 Bus test system, It consists of 30 Bus, 41 lines, generator are modeled as PV-node, loads are modeled as PQ- node, the line is modeled using the classical- Π scheme.The modified IEEE 30 bus test system is used to verify the effectiveness of the proposed algorithm, whose line and load data can be found in [12].The initial value of n_{facts} which indicates the number of FACTS device to be simulated, is defined as 4. TCSC for 1, TCPAR for 2, UPFC for 3 and SVC for 4.The total number of generation is 200 and there are 16 individuals in each generation with crossover and mutation rates of 70% and 5% respectively. The MGA crossover rate is 80% and their populations are constituted by 8 chromosomes, but same fitness function has been applied to both techniques. The simulation results are as shown in appendix: I

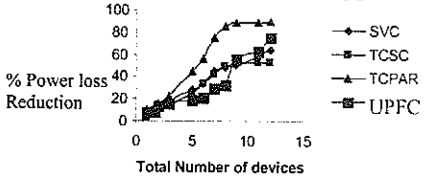

Fig 2: Number of device required for power loss reduction

In the proposed Optimization study for considering power system network, the different types of FACTS device, and their optimal location allows reducing the total real power losses. The solution found by basic MGA and GA are not the same, since the total power loss reductions are not same. The execution time of micro-genetic algorithm significantly reduces by one and half minutes when compared to GA execution time.

The figure: 2 shows the single device -type optimization results and the number of devices required for reducing power loss for consider the power system. TCPAR effectively reduces the losses up to 90%of total power loss, while UPFC, SVC and TCSC reduce up to 75%, 70% and 55%. The 8 number of TCPARs are required to obtain 90%of loss reduction as shown in appendix II. In multi type optimization, the result shows that, TCSC provides 6% relatively less additional loss reduction in real power loss reduction, while TCPAR & UPFC provides 30% and 12%more reduction respectively. The proposed method significantly increases the power loss reduction by 2% and 6% as shown in appendix: I.

6. CONCLUSION

In this paper, the proposed micro-genetic algorithm is more efficient to solve the location of given number of FACTS devices in a power system; their type and rated value are simultaneously optimized. Four different types of device are simulated: TCSC, TCPAR, UPFC and SVC. The reduction of overall system real power loss significantly improves the system performance. The simulation results clearly indicates that the efficiency of the proposed algorithm, also simultaneously optimize the location, type and rated value of the device. This algorithm is suitable to search several possible solutions simultaneously. Further, this algorithm is practical and easy to be implemented into the power system.

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VII. BIOGRAPHIES.

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Appendix-I Different Types of FACTS device locations and their reduced losses

Buses	Device		Rated value		% Reduced losses (in P.U)	
	GA	MGA	GA	MGA	GA	MGA
25 26	3	3	-88.5°	2.34°	18.36	20.8
15 23	3	3	-22.19°	-22.19°	6.5	6.9
12 14	3	3	-19.26°	128.1°	7.6	8.5
9 10	2	2	2.04°	3.2°	29.8	33.03
4 12	2	2	2.72°	0.68°	26.4	32.74
1 3	2	3	-3.82°	-19.62°	43.15	43.97
3 4	1	1	1.0885	0.01779	6.9	6.9
27 30	1	1	0.6372	0.01590	6.2	6.2
5 7	----	3	----	-33.82°	-----	12.83
12 15	----	3	-----	162.9°	-----	2.94
10 20	-----	1	-----	-0.238	----	2.23
6 28	----	4	----	-0.271	----	20.734

Appendix-II

Device:1		Device:2		Device:3		Device:4	
Line	Power loss reduction	Line	Power loss reduction	Line	Power loss reduction	Line	Power loss reduction
1	0.000060	3	0.10425	4	0.007957	3	0.085948
2	0.000015	15	0.09547	6	0.001101	5	0.065366
3	0.004874	17	0.04301	8	0.000299	8	0.053550
4	0.007037	19	0.01366	17	0.014915	10	0.012591
5	0.001298	23	0.02630	19	0.006870	11	0.059615
8	0.000316	13	0.055944	20	0.005604	12	0.099702
10	0.000218	26	0.103233	22	0.014279	14	0.076868
17	0.0003750	35	0.065992	24	0.001301	15	0.010582
27	0.000104	36	0.012910	28	0.004237	20	0.105223
28	0.000746	37	0.010878	30	0.003063	23	0.059058
31	0.000584	39	0.076629	31	0.001545	24	0.047424
36	0.032899	40	0.047849	32	0.011838	26	0.039324
34	0.000363			34	0.017735	30	0.103588
40	0.000127			36	0.009257	33	0.006998
41	0.000834			38	0.116456	34	0.024590
				39	0.107474	39	0.010787
				40	0.000165	41	0.084495
				41	0.001939	2	0.089968
				1	0.000081		