Optimal Allocation And Sizing of TCSC Using Genetic Algorithm In Matlab

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Abstract- *In deregulated power system, load demands are continuously increasing due to growth of population. In order to meet load demand, unscheduled power flow through transmission line which results in higher real & reactive power losses and voltage instability at buses. With the help of the FACTS controllers, it is possible to reduce real & reactive power losses in the power System. Their location, type & rating have influence on system performance. Location & type chosen should be proper & rating must be optimal for economical operation of the power system. This work presents a new approach to find the optimal rating of FACTS controllers by using Genetic Algorithm (GA) & conventional Newton Raphson power flow method. Among various FACTs controllers, Thyristor Controlled Series Capacitor (TCSC) is considered in this work. Our objective is to minimize the reactive power loss in the system by placing optimum rating of the TCSC. It has used reactive power loss minimization as objective function to find the optimal rating of TCSC. The proposed algorithm is an effective & practical method in this direction. To verify the effectiveness of proposed algorithm, studies are carried out on IEEE 30bus systems To overcome these problems, a Flexible Alternating Current Transmission System (FACTS) devices are installed at appropriate location to get the maximum possible benefits i.e. minimize real power loss in the power network and improve voltage profile at the buses. In this paper, a new evolutionary optimization techniques have been applied namely Genetic Algorithm (GA) to select the optimal parameters setting including rating of Thyristor Controlled Series Capacitor (TCSC) to minimize real power loss and improve voltage profile and compare their performances. For validation of proposed algorithm and for comparison purpose, MATLAB program is carried out on IEEE 30-bus system.*

I. INTRODUCTION

Modern electric power utilities are facing numerous challenges due to ever increasing complexity in their operation and structure .In the last few years, one of the problems that got spacious concentration is the power system instabilities. With the lack of new generation and transmission facilities and over utilization of the existing facilities geared by increase in load demand make these types of problems more forthcoming in modern power systems. Demand of electrical power is continuously rising at a very high rate due to fast industrial development. To meet this demand, it is necessary to raise the transmitted power along with the existing transmission facilities. The need for the power flow control in electrical power systems is thus obvious. With the increased loading of transmission lines, the problem of transient stability after a major fault can become a transmission power limiting factor. The power system should adapt to transitory system conditions, in other words, power system should be flexible. The traditional concepts and practices of power systems have been changed. Better utilization of the existing power system to increase capacities by installing FACTS devices becomes imperative.

Genetic algorithms offer a new and powerful approach to this optimization problem made possible by the increasing availability of high speed computers at cheaper cost. Genetic algorithms are parallel and global search techniques that emulate natural genetic operators. GA is more likely to converge towards a global solution, because it simultaneously evaluates many points in the parameter space. In a power system a number of parameters such as line-flows, line overloading, real power losses, etc can be optimized. In this thesis the line overloading minimization, real power loss minimization and optimal placement and sizing of TCSC are done using Genetic Algorithms (GA).

II. OBJECTIVE OF WORK

The objectives of this Dissertation are

- To find Optimal Placement and Sizing of TCSC for Real Power Loss Minimization.
- To find Optimal Placement and Sizing of TCSC for Line Overloading Minimization.

III. TYPES OF FACTS CONTROLLER'S

A power electronic-based system and other static equipment that provide control of one or more AC transmission system parameters.

It is worthwhile to note the words “other static Controllers” in this definition of FACTS ensure that there can be other static Controllers which are not based on power electronics.

The general symbol for FACTS Controller is shown in Figure.1. FACTS Controllers are divided into four categories [21]:

(i) Series FACTS Controllers
(ii) Shunt FACTS Controllers
(iii) Combined Series-Series FACTS Controllers
(iv) Combined Series-Shunt FACTS Controllers

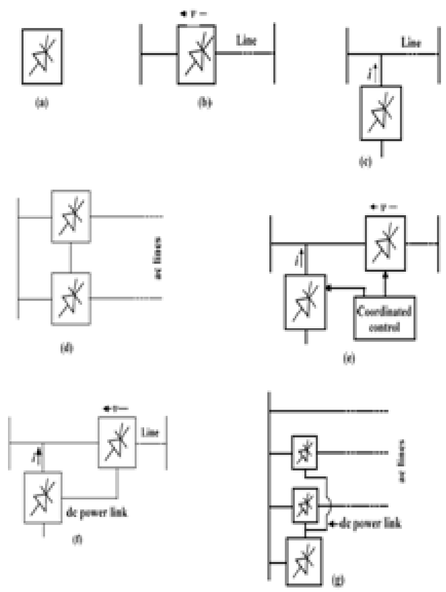


Figure 1 Basic Types of FACTS Controllers

(a) General symbol for FACTS Controller, (b) series FACTS Controller, (c) shunt FACTS Controller, (d) unified series-series FACTS Controller, (e) coordinated series and shunt Controller, (f) unified series-shunt Controller, (g) unified Controller for multiple lines

Series Compensators/ Series Facts Controllers

The series Compensator could be variable impedance, such as capacitor, reactor, etc., or a power electronics based variable source of main frequency to serve the desired need. Various Series connected FACTS devices are:

- Static Synchronous Series Compensator
- Thyristor Controlled Series Capacitor
- Thyristor Switched Series Capacitor
- Thyristor Controlled Series Reactor
- Thyristor Switched Series Reactor

Thyristor Controlled Series Compensator (TCSC)

Thyristor-controlled series compensator (TCSC) can provide many benefits for a power system including controlling power flow in the line, damping power oscillations, and mitigating sub synchronous resonance. The TCSC concept is that it uses an extremely simple main circuit. The capacitor is inserted directly in series with the transmission line and the thyristor controlled inductor is mounted directly in parallel with the capacitor. Thus no interfacing equipment like e.g. high voltage transformers is required. This makes TCSC much more economic than some other competing FACTS technologies. Thus it makes TCSC simple and easy to understand the operation. Figure 2 showed the simple diagram of TCSC.

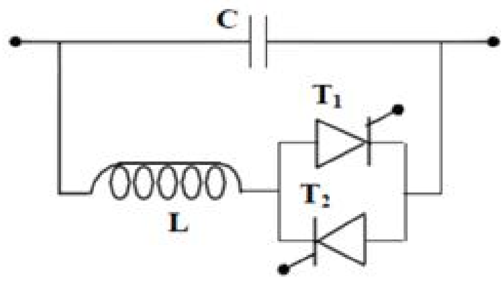


Figure 2 Basic TCSC circuit

The equivalent TCSC reactance is given by:

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

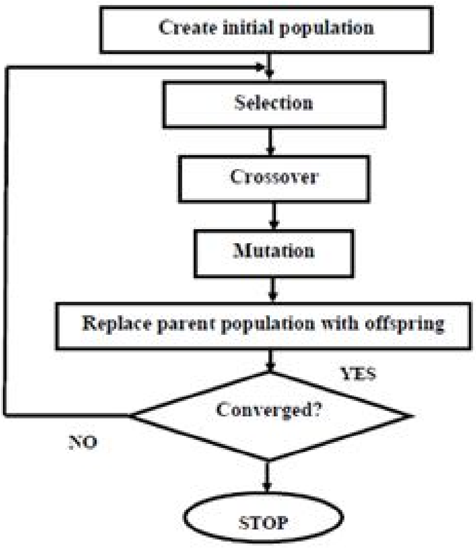
Where,

X_C = Nominal reactance of the fixed capacitor.
X_P = Reactance of inductor connected in parallel with fixed capacitor

Overloading Index (OLI)

β = Angle of advance

It is obvious that power transfer between areas can be affected by adjusting the net series impedance. One such conventional and established method of increasing transmission line capability is to install a series capacitor, which reduces the net series impedance, thus allowing additional power to be transferred. Although this method is well known, slow switching times is the limitation of its use. Thyristor controllers, on the other hand, are able to rapidly and continuously control the line compensation over a continuous range with resulting flexibility. Controller used for series compensation is the Thyristor Controlled Series Compensator (TCSC). TCSC controllers use thyristor-controlled reactor (TCR) in parallel with capacitor segments of series capacitor bank. The combination of TCR and capacitor allow the capacitive reactance to be smoothly controlled over a wide range and switched upon command to a condition where the bi-directional thyristor pairs conduct continuously and insert an inductive reactance into the line.



Line overloading is a major concern in the operation of power system. In this Dissertation, the task of overloading index is performed by optimal placement of Thyristor Controlled Series capacitor, a series FACTS device that can be used for reducing power losses and for controlling the power flows in various lines. However, due to the huge cost of the FACTS device, it is essential to find the optimal location and sizing of the device in a power system to obtain maximum benefits of the device.

The severity of a contingency can be evaluated by an overloading index:

$$OLI = \sum_{l\in nl} \frac{W}{2n}\left(\frac{\Delta Sl^{avg}}{Sl^{max}}\right)^{2n} \qquad (2)$$

Where n =2, nl is the no. of overloaded lines.

Sl^{max} is the rated capacity of line,

Sl^{avg} is the average capacity of line,

$\Delta Sl^{avg} = Sl^{avg} - Sl^{max}$

Real power loss (RPL)

Intended for Optimal placement of TCSC, a line which is not connected between two generation buses may a possible location. Except this, all other lines are to be considered as possible location of TCSC, when implementing Genetic Algorithm. In a practical power system having large number of lines, this approach will certainly require more cpu time to provide the optimal solution. Hence, in this Dissertation, for implementation of Genetic Algorithm approach for optimal placement and sizing of TCSC to minimize real power loss, first, overloading index (OLI) for various lines of a power system is computed using equation (2), then P_L computed using NR load flow method using equation(3) .

The second objective of this dissertation is to determine the optimal location and sizing of TCSC in the power system to minimize the real power loss. The real power loss describe as:

$$PL = \sum_{j=1}^{N} g_k \left[V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_i - \delta_j)\right] \qquad (3)$$

Subjected to the following equality constraints:

$$P_{gi} - P_{di} - \sum_{j=1}^{N}|V_i||V_j||Y_{ij}|\,\mathrm{Cos}\,(\delta_{ij} - \theta_{ij}) = 0 \qquad (4)$$

$$Q_{gi} - Q_{di} - \sum_{j=1}^{N}|V_i||V_j||Y_{ij}|\,\mathrm{Sin}\,(\delta_{ij} - \theta_{ij}) = 0 \qquad (5)$$

And following inequality constraints :

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \qquad \forall_i \in NG ,$$
$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max} \qquad \forall_i \in NG$$
$$V_j^{min} \le V_j \le V_i^{max} \qquad \forall_i \in NG ,$$
$$\delta_{ij}^{min} \le \delta_{ij} \le \delta_{ij}^{max} \qquad \forall_i \in NG$$
$$X_{TCSC}^{min} \le X_i \le X_{TCSC}^{max}$$

Where PL is the power loss in the k^{th} line, *ntl* is the number of lines in the system, *N* is the set of buses, NG is the set of generation buses, Y_{ij} Is the magnitude of *ij* element in admittance matrix, θ_{ij} phase angle of *ij* element in admittance matrix, P_{gi} and Q_{gi} are the active and reactive power generation at bus *i*, P_{di} and Q_{di} are the active and reactive power load at bus *i*, V_i is the voltage magnitude at bus i, δ_{ij} is the phase angle, X_{TCSC} is the reactance of TCSC.

Test System Studies

Effectiveness of the Genetic Algorithm (GA) proposed for optimal placement and sizing of TCSC method is demonstrated by applying it on IEEE 30- bus system. The IEEE 30-bus system consists of 1 slack bus, 5 generation buses, 24 load buses, and 41 transmission lines. In this dissertation work, first calculate the line over loading index, after that ranking of overloaded lines according to over loading index values, and then find the optimal placement and sizing of TCSC for total system real power loss reduction in the power system.

Line Overloading Minimization/Over Loading Index Reduction:

For over loading index reduction is by the optimal placement of TCSC. For optimal placement of TCSC, most severe line outage contingencies were found on the basis of their (Over Loading Index) *OLI* values as shown in Table 1. Line Overloading Index for various lines of a power system is computed and ranked in decreasing order. Ranking of four most critical lines is given in Table 1. As can be observed from Table 1,

Table 1 OLI Ranking for IEEE 30-Bus System

S. No.	Line outage	Overloading Index	Rank
1	10	4.2460	I
2	36	3.6751	II
3	27	2.8341	III
4	15	1.5015	IV

The four most critical lines are 10, 36, 27 and 15 respectively. Line no.10 (connected to buses 6-8) has highest value of overloading index (OLI). Therefore this line is ranked as the weakest line. For selected critical contingencies, genetic algorithm (GA) was applied for optimal placement and sizing of TCSC, so results of genetic algorithm (GA) are shown in this dissertation. The proposed genetic algorithm (GA) was implementing to find the optimal placement and proper sizing of the TCSC .The optimization parameters is given in the Table 2.

After installation of TCSC at optimal location for outage of line no.10, 36, 27, and 15 one by one, the overloading index (OLI) were minimized. Table 3 shows the optimal location and sizing of TCSC for these line outage cases of overloading in the line no.10, 36, 27, and 15 respectively. After installation of TCSC at optimal location for line outage nos. 10, 36, 27, and 15 one by one, the optimum location of TCSC in IEEE 30-bus system for overloading were found to be line nos. 13, 33, 29, and 13 respectively. Thus it can be clearly observed that TCSC optimum location for one contingency may not be optimum for other contingencies and more than one TCSC are required to minimize overloading under various contingencies. MATLAB simulation results for overloading index shows in figure 3 & 4.

Table 2 Parameters of GA

Number of variables	1
Population size	16
Number of generation	50
Pareto fraction	0.5
Stall Time Limit	100
Time Limit	200

Real power loss minimization:

For Optimal placement of TCSC, a line which is not connected between two generation buses may a possible location. Except this, all other lines are to be considered as possible location of TCSC, when implementing Genetic Algorithm. In a practical power system having large number of lines, this approach will certainly require more cpu time to provide the optimal solution. Hence, in this Dissertation, for implementation of Genetic Algorithm approach for optimal placement and sizing of TCSC to minimize real power loss, first, overloading index (OLI) for various lines of a power system is computed using equation (2), then PL computed using NR load flow method by equation(3) .

After installation of TCSC at optimal location for outage of line no.10, 36, 27, and 15 one by one, the real power loss (RPL) were minimized in tabble 4.4 shows the optimal location and sizing of TCSC for these line outage cases of real power loss in the line no.10, 36, 27, and 15 respectively. After installation of TCSC at optimal location for line outage nos. 10, 36, 27, and 15 one by one, the optimum location of TCSC in IEEE 30-bus system for real power loss minimization were found to be line nos. 13, 33, 29, and 13 respectively. Thus it can be clearly observed that TCSC optimum location for one contingency may not be optimum for other contingencies and more than one TCSC are required to minimize real power losses under various contingencies. MATLAB simulation results for real power loss shows in figure 4.7, figure 4.8, figure 4.9 and figure 4.10.

Table 3 TCSC Placement for Real power loss Reduction

S. No.	Line out	TCSC Optimal Location	TCSC Rating	Real power loss Without TCSC	Real power loss With TCSC
1	10	13	-0.1456	0.1855	0.1843
2	36	33	-0.2304	0.1984	0.1971
3	27	29	-0.0165	0.1799	0.1787
4	15	13	-0.1408	0.2035	0.2016

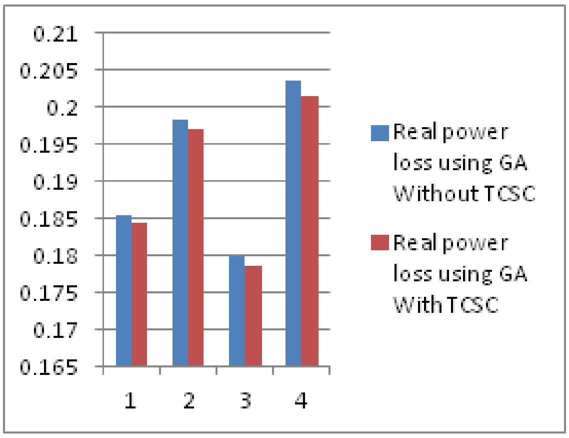


Figure 3 Results of Real power Loss with & without TCSC Placement Using Genetic Algorithm

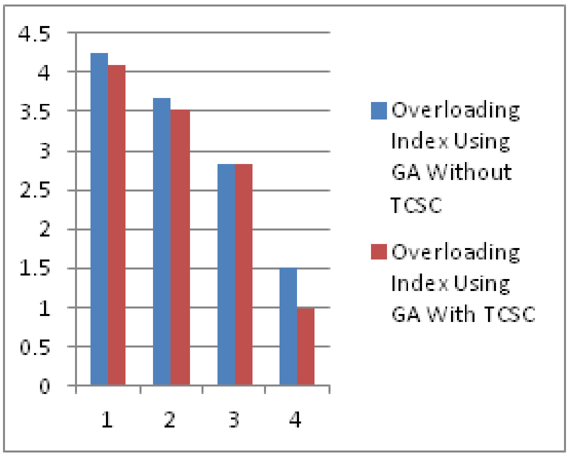


Figure 4 Results of Overloading Index with & without TCSC Placement Using Genetic Algorithm

IV. CONCLUSION AND FUTURE WORK

In this dissertation, genetic algorithm (GA) and multi-objective genetic algorithm (MOGA) has been proposed for optimal placement and sizing of TCSC for over loading index and real power loss minimization under single line outage contingencies of a power system. The effectiveness of this method has been demonstrated on IEEE 30-bus system. It has been observed that TCSC optimum location for one contingency may not be optimum for other contingencies and more than one TCSC are required to minimize over loading and power losses simultaneously under various contingencies.

As further scope of the work, the same approach may be applied for large size power system. Other FACTS devices can also be considered for loss minimization and over loading index enhancement in a power system. In this Dissertation, loss minimization and over loading index enhancement objectives are considered simultaneously and also formulated as multi-objective optimization problem. For solving such problem some other optimization technique may be implemented.

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