Scientific Research and Essays Vol. 6(11), pp. 2366-2371, 4 June, 2011
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE11.370
ISSN 1992-2248 ©2011 Academic Journals

Full Length Research Paper

Optimal location of thyristor controlled series capacitor (TCSC) for loss reduction in transmission lines with genetic algorithm

Hasan Jalili[1,5]*, Ahmadreza Amirzadeh[1], Ahmadreza Montazerolghaem[2], Saeed Ezazy[3] and Mehdi Pazhoohesh[4]

[1]Neyshabur Branch, Islamic Azad University, Neyshabur, Iran.
[2]Communication and Computer Research Laboratory, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran.
[3]Shahryar Branch, Islamic Azad University, Shahr Ghods, Iran.
[4]University of Southampton, United Kingdom.
[5]No. 25, Imam Reza 12 St, Imam Reza Blvd, Dargaz, Khorasan Razavi, Iran.

Accepted 5 May, 2011

With the increasing growth of population and development of industries, huge amount of sums are spent to increase the production of electricity and installation of new units. In this paper, a new method has been presented which reduces the aforementioned costs and prevents the losses in national capitals and fuel sources. This method finds the optimal location of Thyristor controlled series capacitor (TCSC) in transmission network by using genetic algorithm. Due to the use of fossil fuels in power plants, the application of this method is necessary in countries with the high cost of electricity. The effectiveness of the proposed method has been illustrated in a 10-bus network as a case study.

Key words: Thyristor controlled series capacitor (TCSC), flexible AC transmission systems (FACTS) equipments, genetic algorithm, loss reduction.

INTRODUCTION

With the fast increase of population and development of industries, governments have been forced to invest enormous amounts of money for installation of new units as well as to increase the electricity production capacity. One way to cope with these troubles is to use the flexible AC transmission systems (FACTS) devices and semiconductor technology. These techniques yield better control of power and decrease the losses in transmission lines. Also, they enhance the usable capacity of transmission lines. The applications and capabilities of these techniques in steady-state or dynamic stability have been shown in different Studies (Taylor, 1993; Hingorani and Gyugyi, 1999). FACTS devices are able to change the apparent impedance of transmission lines; therefore they can be used for active and reactive power control, as well as voltage control.

In electricity networks, the optimal location of FACTS devices makes them able to control the power flows (Gotham and Heydt, 1998) and the system load ability is increased consequently (Griffin et al., 1996; Galiana et al., 1996). TCSC is one of the FACTS devices that nowadays are widely used in transmission networks throughout the world. The optimal location of this device for improving system load ability and voltage profile is studied in (Yang et al., 2007). Also, some literatures have studied the placement of FACTS controllers to damp out power system oscillations (Kumar et al., 2007) and transient stability assessment of power systems containing series and shunt FACTS devices (Ghosh and Chatterjee, 2007).

One of the applications of TCSC in distribution networks is the enhancement of power quality (Khederzadeh, 2007).

In this study, TCSC is used because it offers flexible control with higher response rate than the variable series

*Corresponding author. E-mail: hasan.jalili65@gmail.com. Tel: +989151584735.

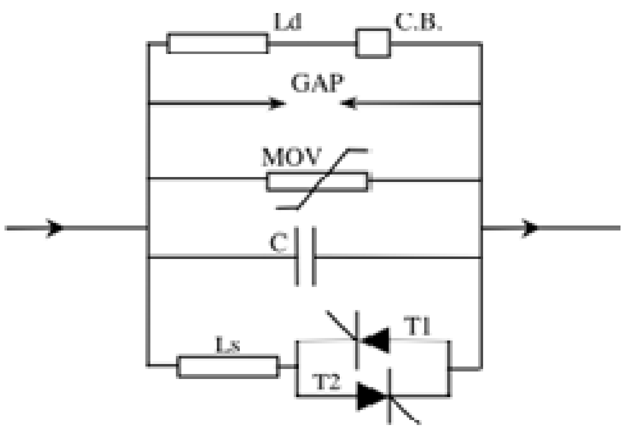

Figure 1. Configuration of TCSC.

capacitor on lines impedance (Rashed et al., 2008). To save the amount of investment for installation of new units and in order to prevent the waste of national assets, this paper proposes a new method for loss reduction in transmission lines by using TCSC associated with genetic algorithm.

OPERATING MODES OF THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC)

The structure of TCSC consists of compensating capacitor C, bypass inductance L, thyristors and metal oxide varistor (MOV). The structure of TCSC is shown in Figure 1.

The degree of TCSC compensation is controlled by the capacitor C. The main function of L is the reduction of short circuit current and absorbed energy by MOV (Khederzadeh, 2008). In the TCSC structure, thyristors are used to transform the equivalent impedance of TCSC to meet the desirable requirements in all kinds of power system conditions, such as improving the stability, increasing the transmission capability and restraining hypo-synchronization resonance. The MOV block implements a highly nonlinear resistor to protect the fixed capacitor against over voltages. For the applications which require high power dissipation, several columns of metal-oxide discs are connected in parallel. The nonlinear V-I characteristic of each column in the surge arrester is modeled by a combination of three exponential functions as follows:

$$\frac{V}{V_{ref}} = k_i \left(\frac{I}{I_{erf}} \right)^{\alpha i} \tag{1}$$

The protection voltage obtained with a single column is specified by a reference current. By adding the discs of zinc oxide in series to each column the required protection voltage is obtained. The V-I characteristic has been shown in Figure 2.

OPERATING MODES IN NORMAL OPERATION

In normal operations, there are four modes of operation: Blocking mode; bypass mode; capacitive boost mode; and inductive boost mode. When, thyristor valve is not triggered and thyristors are in non-conducting state, the TCSC operates in blocking mode and performs like a fixed series capacitor. In bypass mode, the thyristor valve is triggered continuously and thyristors stay conducting at all times. In capacitive boost mode, a trigger pulse is supplied to the thyristor which it has forward voltage just before the capacitor voltage crosses the zero line, so a capacitor discharge current pulse will circulate through the parallel inductive branch. In inductive boost mode, the circulating current in the TCSC thyristor branch is bigger than the line current. In this mode, the thyristor current is large and the capacitor voltage waveform is very much distorted from its sinusoidal shape (Khederzadeh, 2008).

OPERATING MODES DURING FAULTS

During a fault, different modes of operation could occur that incorporates the TCSC protection equipments. These modes are as follows:

1. TCSC bypass operation with/without MOV
2. Capacitive boost mode with/without MOV
3. Inductive boost mode with/without MOV
4. Blocked mode with/without MOV conduction
5. Circuit breaker bypass

The operating modes that are common in the steady state and fault conditions are bypass mode, blocked mode, capacitive boost mode and inductive boost mode without MOV conduction. TCSC bypass mode with MOV conduction is improbable because bypass mode decreases the capacitor voltage considerably, and MOV operation is not necessary (Khederzadeh, 2008).

GENETIC ALGORITHM

One method that can give us a global optimal solution is genetic algorithm. Genetic algorithm uses the principle of natural evolution and population genetics to yield an answer near to global solution. The required design variables are encoded to a binary string as a set of genes which is corresponding to the chromosomes in the biological systems. Unlike the traditional optimization techniques that require one starting point, they use a set of points as the initial conditions. Each point is called a chromosome and a group of chromosomes are called a

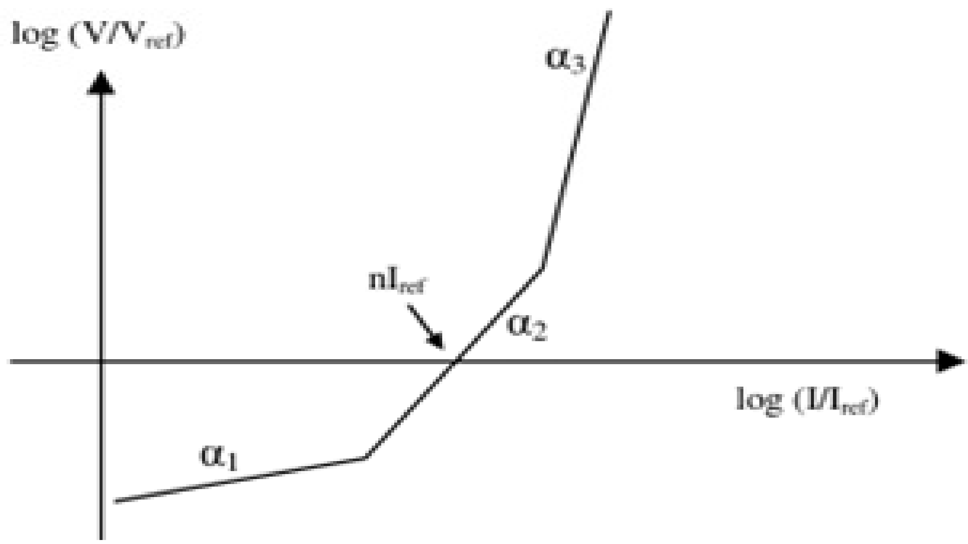

Figure 2. V-I characteristic of a MOV.

population. The number of chromosomes in a population is usually selected to be between 30 and 300. Each chromosome is a string of binary codes (genes) and it may contain sub-strings. The merit of a string is judged by the fitness function, which is derived from the objective function and it is used in successive genetic operations. During each iterative procedure (referred to as generation), a new set of strings with improved performance is generated by use of three genetic algorithm operators (namely reproduction, crossover and mutation).

In this paper, genetic algorithm for optimization of loss reduction is used.

Fitness function

Genetic algorithm is essentially unconstrained search procedures within a given represented space where the search is guided according to the fitness function. In this paper the fitness function is:

$$Loss = \sum R_i * \left| I_i \right|^2 \quad (2)$$

where, R_i is resistance in branch ith and I_i is current in branch ith.

The strings are stored according to their fitness and then they are ranked accordingly. The roulette wheel selection scheme is used for selecting the individuals for reproduction.

Genetic operators

Genetic operators are the stochastic transition rules applied to each chromosome during each generation procedure to generate a new improved population from an old one. A genetic algorithm usually consist of reproduction, crossover and mutation operators.

Reproduction

Reproduction is a probabilistic process for selecting two parent strings from the population of strings on the basis of “roulette-wheel” mechanism, using their fitness values. This fact ensures us the expected times that a string is selected is proportional to its fitness function with respect to the rest of population. Therefore, strings with the best fitness values have a higher probability of contributing offspring.

Crossover

Crossover is the process of selecting a random position in the string and swapping the characters either left or right of this point with another similarly partitioned string. This random position is called the crossover point.

Mutation

Mutation is the process of random modification of a string position by changing “0” to “1” or vice versa, with a small probability. It prevents complete loss of genetic material through reproduction and crossover by ensuring that the probability of searching any region in the problem space is never zero (Kalantar and Dashti, 2006).

Flow-chart of the optimization strategy is shown in Figure 3.

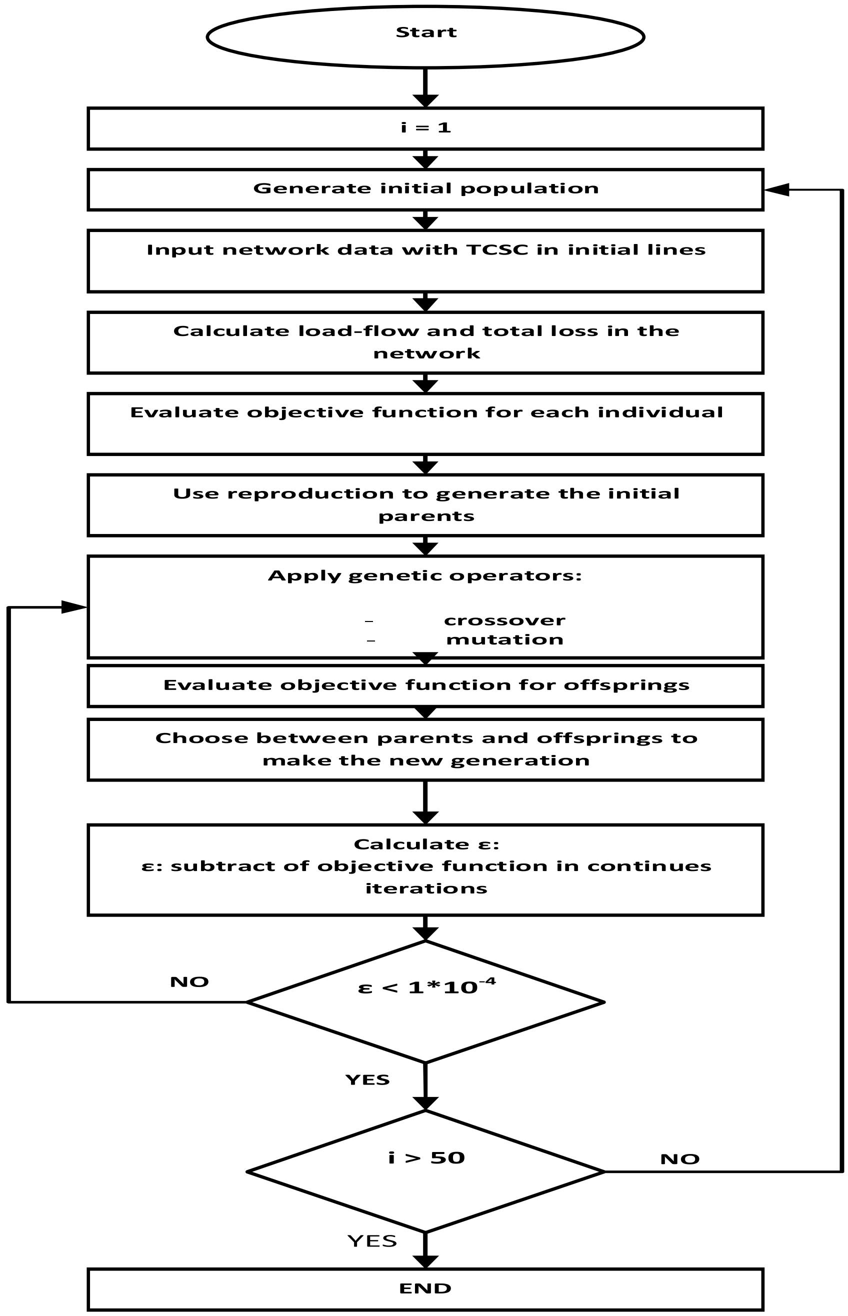

Figure 3. Flow-chart of the optimization strategy.

Case study

To investigate the validation of proposed technique, genetic algorithm has been applied to the the system in Figure 4.

Network parameters

The data for the aforementioned system is taken from (Khederzadeh, 2007).

The detailed electrical and economic parameters of the network components are given subsequently. The economical and electrical parameters of the generators are defined in Table 1. Also, the parameters of loads and lines are selected as shown in Tables 2 and 3, respectively. The basis for the p.u. calculations is 1000 MVA.

In Table 1, generators 1 and 4 are aggregated hydro units, generator 2 is aggregated nuclear and generators 3 and 5 are conventional thermal units.

In Table 2, the price sensitivity is set to be low, resulting

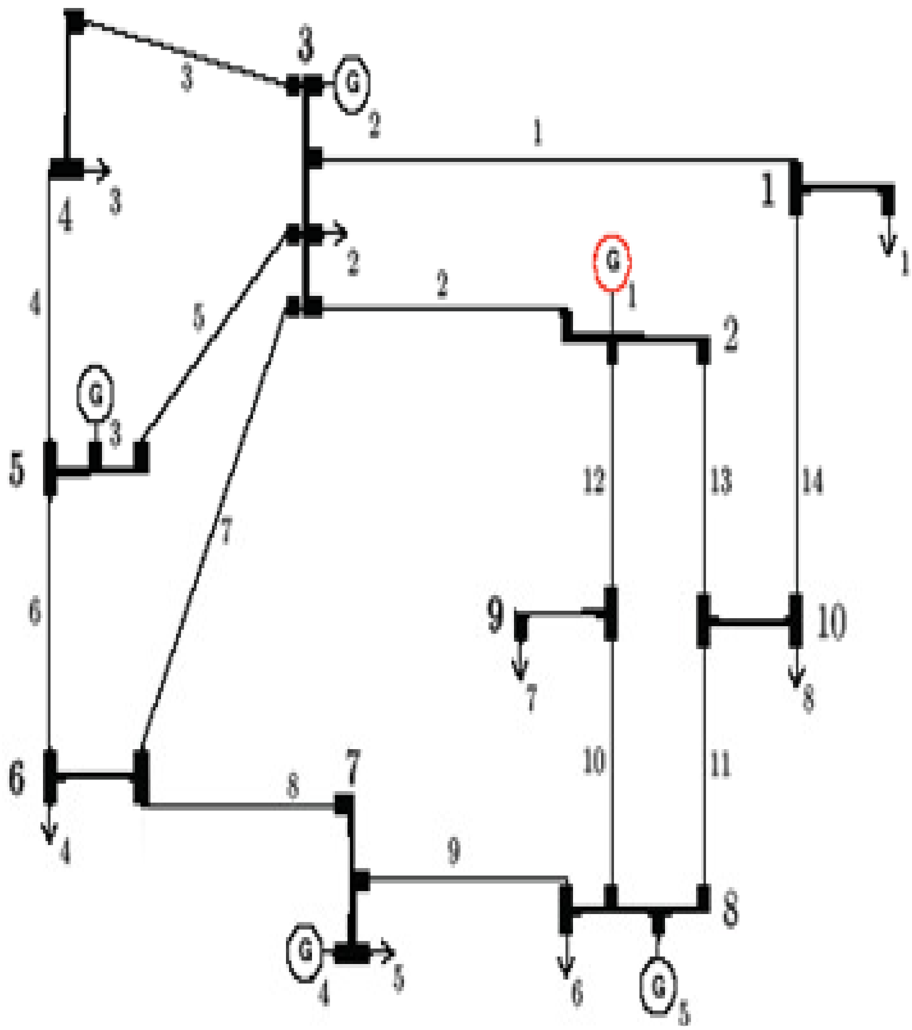

Figure 4. 10-bus network used for simulation.

Table 1. Network generators.

Nr	Pg [MW]
1	1200
2	8000
3	3000
4	800
5	2000

in a small bandwidth between P_L^{max} and P_L^{min} compared with the price difference between ρ_L^{min} and ρ_L^{max}.

Table 3 shows the link between the high price area and low price area consisting of lines 8, 12, 13 and 14 which results in a theoretical total transfer capacity of 9.3 GW.

RESULT

In this case study, the compensation rate of TCSC is considered 70%. After running genetic algorithm program, the minimum loss occurs when TCSC is installed in line 8. The amount of loss in this case will be 2.6906 p.u. that is decrease of about 6%. Annual income due to loss reduction will be 114720 $ (assuming 8 cent/Kwh).

Conclusion

This paper presented a new method based on genetic algorithm which finds the optimal location of TCSC in transmission lines. This method reduces the cost of installation of new units and prevent from the waste of fuel resources. This method is applied to a 10-bus test network. Simulation results show the amount of loss in transmission lines is reduced by 6% due to the 70% compensation in a transmission line. By applying this method to the aforementioned 10-bus network, 114720$ can be saved because of loss reduction that shows the effectiveness of this project.

Table 2. Load parameters.

Nr	$P_L^{min\ [MW]}$	$\rho_L^{min\ [€ / MW]}$	$P_L^{max\ [MW]}$	$\rho_L^{max\ [€ / MW]}$
1	90	100	110	10
2	1300	100	1300	10
3	1300	100	1300	10
4	200	100	200	10
5	2400	100	2600	10
6	3400	100	3600	10
7	900	100	1100	10
8	1700	100	1900	10

Table 3. Transmission lines parameters.

Nr	R (p. u.)	X[p.u.]
1	0.04	0.10
2	0.08	0.12
3	0.01	0.10
4	0.02	0.17
5	0.02	0.17
6	0.02	0.17
7	0.02	0.17
8	0.02	0.16
9	0.02	0.25
10	0.02	0.25
11	0.01	0.07
12	0.01	0.07
13	0.01	0.14
14	0.04	0.27

REFERENCES

Galiana F, Almeida K, Toussaint M, Griffin J, Atanackovic D (1996). Assessment and control of the impact of FACTS devices on power system performance. IEEE Trans. Power Syst., 11: 1931-1936.

Ghosh A, Chatterjee D (2007). Transient stability assessment of power systems containing series and shunt compensators. IEEE Trans. Power Syst., 22: 1210-1220.

Gotham D, Heydt G (1998). Power flow control and power flow studies for systems with FACTS devices. IEEE Trans. Power Syst., 13: 60-65.

Griffin J, Atanackovic D, Galiana F (1996). A study of the impact of FACTS on the secure-economic operation of power systems. 12th Power Systems Computation Conference, Dresden. pp. 45-51.

Hingorani N, Gyugyi L (1999). Understanding FACTS concepts and technology of Flexible AC Transmission Systems. pp. 425-429.

Kalantar M, Dashti R (2006). Combination of network reconfiguration and capacitor placement for loss reduction in distribution system with based genetic algorithm. IEEE Univ. Power Eng. Conf., pp: 308-312.

Khederzadeh M (2007). Application of TCSC to enhance power quality. IEEE Univ. Power Eng. Conf., pp. 607-612.

Khederzadeh M (2008). Power quality enhancement by TCSC application to mitigate the impact of transformer inrush current. IEEE Transmission and Distribution Conference and Exposition. pp. 1-5.

Khederzadeh M (2008). Impact of MOV operation on power quality in transmission lines compensated by TCSC. IEEE Trans. Distrib. Conf. Exposition. pp. 1-8.

Kumar BK, Singh SN, Srivastava SC (2007). Placement of FACTS controllers using modal controllability indices to damp out power system oscillations. IEEE Trans. Power Syst., 1: 209-217.

Rashed G, Shaheen H, Cheng S (2008). Evolutionary optimization techniques for optimal location and parameter settings of TCSC under single line contingency. IEEE Power Energy Society General Meeting, pp. 1-9.

Taylor C (1993). Study of system operating impacts of FACTS technologies. GE, ECC Inc. Carson Taylor Seminars, Final Report on EPRI RP, pp. 3022-3025.

Yang GY, Hovland G, Majumder R, Yang Z (2007).TCSC allocation based on line flow based equations via mixed-integer programming. IEEE Trans., 22: 2262-2269.