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Optimal Placement of Tcsc and Svc for Enhancement of ATC and Improvement of Contingency Using Genetic Algorithm

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Abstract: This paper determines optimal location and controlling parameter of TCSC and SVC to maximize Available Transfer Capability (ATC) and improve Contingency simultaneously using Genetic Algorithm for this purpose as the optimization tool. In this paper ATC is defined as λ varying and objective function of Contingency consists of line congestion alleviation and bus voltage magnitudes enhancement. Genetic Algorithm is carried out on IEEE 24-Bus system. ATC enhancement and improving of single line contingency are important issues in the power systems. The Available Transfer Capability (ATC) of a transmission network is the unutilized transfer capabilities for the transfer of further commercial activity, over and above already committed usage. Contingency analysis is performed to detect and rank the severest one-line fault Contingency in a power system. The obtained results show that TCSC and SVC simultaneously are very effective Devices on ATC enhancement and Contingency improvement in a power system.

Key words: ATC · Contingency · TCSC · SVC · Genetic Algorithm

INTRODUCTION

Large increase in power demand, competition and scare natural resources are some factors due to which transmission systems operate very near to their thermal limits. But because of economic, environmental and political reasons it is not preferable to build new transmission lines. So there is an interest in better utilization of existing capacities of power system by installing Flexible AC Transmission System (FACTS) Device [1]. The Available Transfer Capability (ATC) of a transmission network is the unutilized transfer capabilities of a transmission network for the transfer of power for further commercial activity, over and above already committed usage [2]. ATC values are always limited by heavily loaded buses with relatively low voltage. FACTS concept makes it possible to use circuit reactance, voltage magnitude and phase angle as controls to redistribute line flow and regulate voltage profile. They will provide new control facilities, both in steady state power flow control and dynamic stability control [3]. Contingency is considered to be the outage of a line, a transformer or a generator. Contingency occurrence results in line power flows and bus voltage magnitudes change that may cause the system enters an insecure state and become unstable [4].

Hence, by using FACTS the stability of the power network improved and the flows of heavily loaded lines reduced and help to maintain the bus voltages at desired level. Therefore, the FACTS utilization enhances the power system security in contingency for their rapid and continues control performance [5]. In [6], based on a decomposed power injection model of FACTS devices and stochastic programming, from the point view of operational planning, a novel methodology is proposed to enhance the available transfer capability (ATC) of prescribed interfaces in interconnected power networks, using control of FACTS devices. In [7], the evaluation of the impact of FACTS devices on Available Transfer Capability (ATC) and its enhancement using Genetic Algorithm is discussed. In [8, 9], various approaches for Contingency selection are investigated. In [10], Genetic Algorithm (GA) is developed to find the optimal location and setting of the TCSC to alleviate line overloads under double Contingency. A method discussed in [11], applied the optimal placement of a shunt device placed in a long line to increase the capacity of the transmissible power by improving the stability of system.

In this paper, the effect of optimal location of a combined installation of TCSC and SVC using GA on the ATC enhancement and Contingency improvement are studied. It is shown installing in the proper location will

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improve voltage profile as well ATC and Contingency. Genetic Algorithm has been tested on IEEE 24-Bus system.

Modeling of TCSC and SVC: Building new transmission lines to meet the increasing electricity demand is always limited economically and by environmental constraints and FACTS devices meet these requirements using the existing transmission systems [12]. Two types of FACTS have been used in this study namely; Thyristor Control Series Compensator (TCSC) and Static Var Compensator (SVC).

Modeling of TCSC: Transmission lines are represented by lumped π equivalent parameters. The series compensator TCSC is simply a static capacitor/reactor with impedance jxc [13]. Fig. 1 shows a transmission line incorporating a TCSC.

where X_{ij} is the reactance of the line, R_{ij} is the resistance of the line, B_{io} and B_{jo} are the half-line charging susceptance of the line at bus-i and bus-j. X_{new} is the new reactance of the line after placing TCSC between bus i and j [13].

$$X_{new} = X_{ij} - X_c \tag{1}$$

Modeling of SVC: The SVC is a shunt connected static var generator or absorber. The SVC can be used to control the reactive compensation of a system. B_{SVC} represents the controllable susceptance of SVC. It can be operated as inductive or capcitive compensation. In this study, it is modeled as an ideal reactive power injection at bus i, at where it is connected. Fig. 2 shows the equivalent circuits of SVC at bus i [14].

Objective Functions: The optimization strategy of this paper is focused on the combination of two objectives as mentioned before. The objective function of Contingency consists of line congestion and bus voltage magnitudes enhancement:

$$Min\left\{\sum_{j=1}^{n_1} w_{p_j} \times \left(\frac{P_j}{P_{j\max}}\right)^2 + \sum_{i=1}^{n_b} w_{v_i} \times \left(\frac{V_{iref} - V_i}{V_{iref}}\right)^2\right\} \tag{2}$$

Terms P_j and $P_{j_{\max}}$ show the real power flow in transmission system lines and its limits, respectively. W_{pj} and W_{vi} represent two weighting factors. In this study the value of weighting factor has been taken as 1. n_l is the number of lines and n_b is the number of buses.

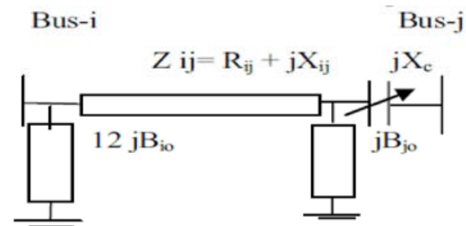


Fig. 1: Equivalent circuit of transmission line after placing TCSC

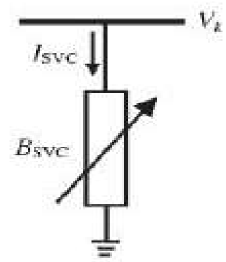


Fig. 2: Variable shunt susceptance

In this paper, the objective function of ATC is defined as λ varying and is considered in following forms [15]:

$$\begin{cases} P_{Di} = P^{\circ}_{Di}(1+\lambda k_{Di}) \\ Q_{Di} = Q^{\circ}_{Di}(1+\lambda k_{Di}) \end{cases} \tag{3}$$

where: P_{Di}, Q_{Di}: are real and reactive load demand at bus i and P°_{Di}, Q°_{Di} : are original real and reactive load demand at bus i. k_{Di}: is constant to specify the rate of changes in load as λ varies. In this paper the value of k_{Di} has been taken as 1. λ: is a scalar parameter representing the increase in load bus and is defined as ATC. In this study the first value of λ is considered as 1.

Genetic Algorithm: Genetic algorithms (Gas) were invented and developed by John Holland. Genetic algorithm is one of the more famous existing heuristic methods in the case of engineering and optimization. GA is global search methods which is able to seek several solutions at a same time independent to previous knowledge or properties of solutions [16].

Genetic Algorithm for ATC Enhancement and Contingency Improvement Using Facts Devices: Read the power system bus and line data using NR repeated power flow.

- Bus data: Bus no, Bus type, Voltage mag, Angle deg, P_{load}, Q_{load}, P_{gen}, Q_{gen}, $Q_{\max gen}$, $Q_{\min gen}$, Q_{inj}.

Table 1: ATCs and Contingencies without and with FACTS devices.

State	Location	Size	ATC	Contingency
Without FACTS	--	--	1.42	319.13
With SVC	Bus-10	Q_{SVC} = 194.95 MVAR	1.49	318.86
With TCSC	Line-26	X_{TCSC} = 0.59375 (p.u)	1.44	317.18
With TCSC & SVC	TCSC Line-5 SVC Bus-5	X_{TCSC} =0.5 (p.u) Q_{SVC} = 100 MVAR	1.51	317.13

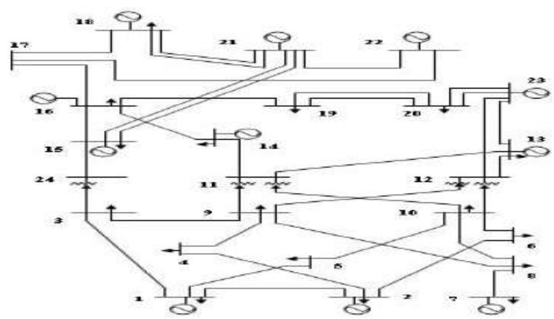


Fig. 3: IEEE 24-BUS test system

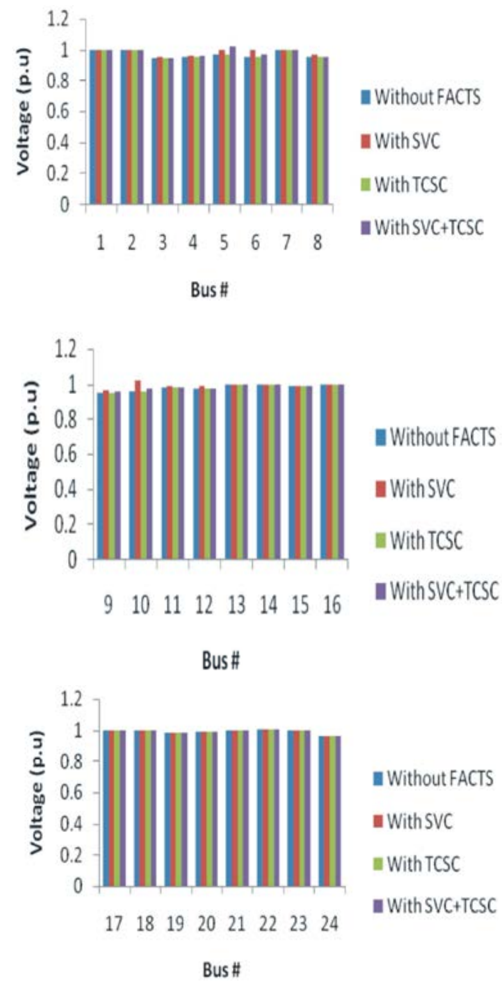
- Line data: From bus, to bus, line resistance, line reactance, half-line charging Susceptance, tap setting value.
- Read data for genetic operations.
- Read no. of control variables i.e. TCSC and SVC locations and X_{TCSC}, Q_{SVC}.
- Read line data=[ ] (for calculating Contingency) and Calculate the function that consists Contingency as (SV1).
- Read λ (for calculating ATC) and Calculate the function that consists ATC as (SV2).
- Calculate the function that consists ATC and Contingency simultataneously using NR repeated power flow as $SV = \frac{SV1}{319.13} + \frac{SV2}{1.42}$.

Generate population size of chromosomes randomly.

- Gen=1, generation count.
- K1=1, chromosome count.
- Calculate fitness (K1) = ATC (i.e. maximization) and Contingency (i.e. minimization)

IEEE 24-Bus Reliability Test System

Installation of TCSC and SVC: When one TCSC is incorporated in the system, if we consider all lines of system, there are 38 possible locations for the TCSC. The location code region are set as 38 integers as 1 to 38. Moreover, there are 24 possible locations for installing one SVC at all buses of system. The location code region of SVC are set as 24 integers as 1 to 24. Fig. 3 shows IEEE 24-BUS test system.



a) b) c)

Fig. 4: Bus voltage profile considering ATCs and Contingencies simultaneously a) bus number 1-8, b) bus number 9-16, c) bus number 17-24

ATC and Contingency values with and without FACTS Devices: Table 1 shows optimal location and setting FACTS Devices for IEEE 24-BUS system. It can be observed that by using TCSC and SVC simultaneously, ATC and Contingency values are improved more in comparison with other states. Fig. 4 shows a graph voltage profile for the system. It can be seen that by installing SVC at bus-10 and a combined installation of SVC and TCSC at their optimal places, voltage profile is improved more compared to other states.

CONCLUSIONS

ATC enhancement and Contingency improvement are two important issues in power systems. ATC can be usually limited by heavily loaded circuits and buses with relatively low voltage. It is well known that FACTS technology can control voltage magnitude, phase angle and circuit reactance. Using these devices may redistribute the load flow, regulating bus voltages. Therefore, the FACTS utilization enhances the power system security in contingency. This paper has proposed Genetic Algorithm to find optimal location and setting of the combined TCSC and SVC for maximizing ATC and minimizing Contingency of power system. Simulations were performed on IEEE 24-Bus system. Test results indicate that optimally placed TCSC and SVC by GA could increase ATC, reduce Contingency in this system. It is also shown that a combined installed TCSC and SVC will improve voltage profile as well as resulting ATC enhancement and Contingency improvement. Further studies are suggested to investigate the other types of FACTS Devices to reach this purpose.

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