International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 8, August - 2014

Enhancement of ATC With Facts Devices using Real-Code Genetic Algorithm

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***Abstract*—: In deregulated power systems, determination and enhancement of available transfer capability (ATC) are the important issues. The insertion of FACTS devices in electrical systems seems to be a promising strategy to enhance ATC. The proposed work aimed to investigates the use of FACTs devices, like SVC and TCSC, to maximize power transfer transactions during normal and contingency situations. Continuation Power Flow method .(CPF) is used for the computation of ATC, considering both thermal limits and voltage profile. Real-code Genetic Algorithm (RGA) is used as an optimization tool to determine the location and controlling parameters of SVC and TCSC. The suggested methodology is tested on IEEE 14-bus system and also on IEEE 24-bus reliability test system for normal and different contingency cases.**

Keywords*— *Available transfer capability (ATC), SVC, TCSC, Real-code Genetic Algorithm(RGA).

I. INTRODUCTION

The main consequence of the non-discriminatory open-access requirement is the substantial increase in power transfers. The Available Transfer Capacity 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. To ensure all economic transactions, Adequate Available Transfer Capacity (AATC) is needed. While sufficient ATC is needed to facilitate electricity market liquidity. Economical and secure operation is necessary over a wide range of system operating conditions and constraints. However, in the construction of new facilities tight restrictions due to the economic, environmental and social problem reduce the operational alternatives, sometimes lead to situation that the existing transmission facilities are intensively used [1].The power suppliers will benefit from more market opportunities with reduced possibility of network congestion. Use of existing transmission assets are maximum and will be more profitable for transmission system owners. Hence customers will receive better service with reduced prices [8].Various ATC boosting approaches have been suggested adjusting terminal voltages through under load tap changers (ULTCs) and rescheduling generation. According to NERC's definition of ATC and its thermal, voltage and stability limits. It is well recognized that introduction of FACTs devices into transmission network resulted in severe impact in system utilization. From the viewpoint of steady state power flow, networks do not normally share power in proportion to their ratings, whereas voltage profile cannot be smooth in most situations [9].Therefore 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. FACTS devices ,in theoretical can offer an effective and promising alternative to conventional methods of ATC enhancement. FACTS devices also provide new control facilities both in steady state power flow control and dynamic stability control [10].In Electric power systems, controlling power flow without generation rescheduling or topological changes, as is provided by FACTs devices can improve the network performance considerably. The effects of a TCSC and SVC with suitable location, on the ATC enhancement are studied and demonstrated through case studies. It is shown that installing SVC in proper location will improve voltage profile as well as ATC, and TCSC will improve the ATC. By improving Available Transfer Capability, Congestion management can be achieved. For ATC improvement, FACTS devices such as TCSC and UPFC have proven their utility[16].Modern techniques such as PSO have been demonstrated to be suitable approaches in solving non-linear power system problems an algorithm is developed[17].For the assessment of the feasibility of simultaneous bilateral and multilateral transactions and if they are not feasible then to find out the minimum amount of transacted power to be curtailed in order to make them feasible[18].The ATC obtained with UPFC and Sen Transformer for normal and contingency cases with constant P,Q load model and also taking impact of ZIP load model, given in[19]. A number of local and one global bifurcation observed in a small power system involving a load tap changer transformer and an induction motor [20].Real genetic algorithm (RGA) associated with analytical hierarchy process (AHP) and fuzzy sets are implemented as hybrid heuristic technique [21].

The paper is organized as follows: Section 2 provides the special need for ATC determination in deregulated operation and its computation using CPF. Section 3 gives the mathematical modelling of TCSC and SVC. Section 4 gives the Real-code Genetic Algorithm (RGA) and its applications for enhancement of ATC with SVC and TCSC. Section 5 gives the results. Finally Section 6 concludes the paper.

II AVAILABLE TRANSFER CAPABILITY

Utilities need to determine adequately their "Available Transfer Capability" to ensure that system reliability is maintained while serving a wide range of bilateral and multilateral transactions. The electric transmission utilities in the United States are required to post the information of ATC of their transmission network through the open access same time information system (OASIS) [6] for day-ahead and real-time reliable operation

2.1 ATC definitions [6]

Available Transfer Capability (ATC) is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above already committed uses. Mathematically ATC is defined as the Total Transfer Capability (TTC) less the Transmission Reliability Margin (TRM), less the sum of existing transmission commitments and the Capacity Benefit Margin (CBM) , shown in fig [6].

Total Transfer Capability (TTC) is defined as the amount of electric power that can be transferred over the interconnected transmission network in a reliable manner while meeting all of a specific set of defined pre-and post-contingency system conditions.

Transmission Reliability Margin (TRM) is defined as that amount of transmission transfer capability necessary to ensure that the interconnected transmission network is secure under a reasonable range of uncertainties in system conditions.

Capacity Benefit Margin (CBM) is defined as that amount of transmission transfer capability reserved by load serving entities to ensure access to generation from interconnected systems to meet generation reliability requirements.

Mathematically, ATC is defined as:

$$ATC = TTC - TRM - \{ETC + CBM\} \qquad (1)$$

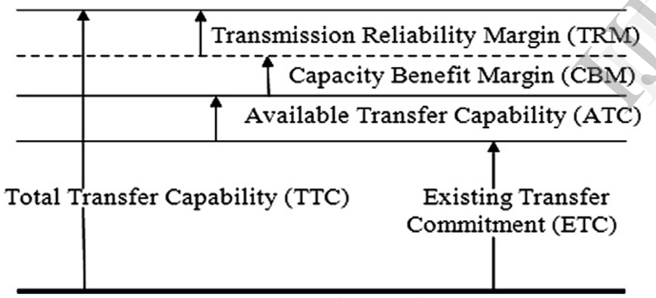

Fig: Basic Definition of ATC

2.2 ATC computation

ATC computation methods are broadly categorized as follows:

i) Methods based on distribution factors [21].
ii) Methods based on Continuation Power Flow (CPF) [3].

The method [21] based on DC power transfer distribution factors utilises DC power flow.ATC computation by this method is simple and fast and gives optimistic results. The method [21] based on AC power transfer distribution factors is simple, efficient and non-iterative to obtain ATC under bilateral and multilateral contracts.

The method based on the Continuation Power Flow (CPF) is for finding the maximum value of a scalar parameter in a linear function of changes in nodal injections of a set of buses [7]. Originally introduced for determining maximum laudability, CPF is adaptable for other applications without change in the principle. The CPF algorithm effectively increases the controlling parameter in discrete steps and solves the resulting power flow problem at each step. The procedure is continued until a given condition or physical limit preventing further increase is encountered. Even at voltage collapse CPF yields solution. CPF is performed by starting from an initial point and then increasing the load by a factor until some system limit is reached. The loads are defined as:

$$P_{Li} = \lambda P_{LOi}$$
$$Q_{Li} = \lambda Q_{LOi} \qquad (2)$$

Where P_{LOi} , Q_{LOi} are the active and reactive power respectively of bus i in the base case: λP_{LOi}, λQ_{LOi} are the active and reactive power of bus I increased by parameter λ. For specific source/sink transfer case, calculation of the ATC may be summarized as the maximum transfer power without causing a limit violation over the base case

3. Modelling of FACTS devices

With the availability of FACTS devices mitigate the effects of faults and make supply of electricity more securely by reducing the number of trips, increase in dynamic and transient grid stability and reduction in risks of line trips. FACTS devices can provide the required quality of supply to high quality electricity supply. In fact FACTS devices help to distribute electricity more economically through better utilization of existing installations thereby reducing the need for additional transmission lines [2]

3.1 Simple two-machine power system model

Consider a two-machine model that is connected through a transmission line as shown in fig below [2].

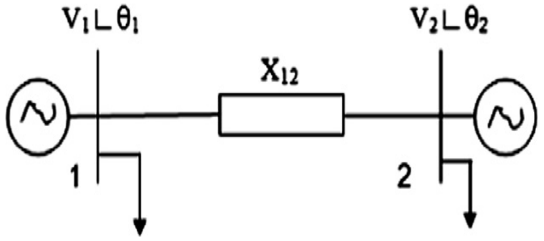

Fig. 2. Two-machine power system model.

$$P_{12} = \frac{V_1 V_2}{X_{12}} \sin\theta_{12} \qquad (3)$$

$$Q_{12} = \frac{1}{X_{12}} (V_1^2 - V_1 V_2 \cos\theta_{12}) \qquad (4)$$

Where V1 and V2 are the voltages at buses 1 and 2, X12 is the line reactance and θ12 is the angle between V1 and V2. Series Compensation permits to modify the reactance of the line X12 [12], and shunt compensation controls the voltage magnitudes of the load bus.

3.2 Modelling of TCSC

Transmission lines are represented by lumped π equivalent parameters. The series compensator TCSC is simply a static capacitor/reactor with impedance jXc [11].Fig 3 shows a transmission line incorporating a TCSC.

Where Xij is the reactance of the line,Rij is the resistance of the line.Bio and Bjo are the half-line charging susceptance of the line at bus-i and bus-j.

The difference between the line susceptance before and after the addition of TCSC can be expressed as [4]:

$$\Delta y_{ij} = y_{ij}^{'} - y_{ij} = (g_{ij}^{'} + jb_{ij}^{'}) - (g_{ij} + jb_{ij}) \qquad (5)$$

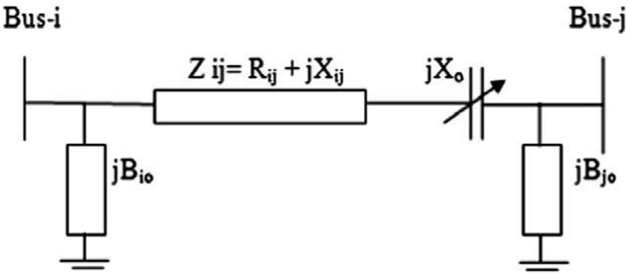

Fig 3. Equivalent circuit of a line with TCSC

$$g_{ij} = \frac{r_{ij}}{\sqrt{rij^{2} + xij^{2}}} \quad , \quad b_{ij} = -\frac{x_{ij}}{\sqrt{rij^{2} + bxij^{2}}} \qquad (6)$$

$$g_{ij}^{'} = \frac{r_{ij}}{\sqrt{r_{ij}^{2} + (x_{ij} + x_{c})^{2}}} \,, b_{ij}^{'} = -\frac{x_{ij} + x_{c}}{\sqrt{r_{ij}^{2} + (x_{ij} + x_{c})^{2}}} \qquad (7)$$

By adding the TCSC on the line between bus i and bus j of a general power system, the new system admittance matrix $Y_{bus}^{'}$ can be updated as [11]:

$$Y_{bus}^{'} = Y_{bus} + \begin{array}{c} \begin{bmatrix} 0 & 0 & 0 & \dots & 0 & 0 & 0 \\ 0 & \Delta\gamma ij & 0 & \dots & 0 & -\Delta y_{ij} & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 & 0 \\ \dots & \dots & \dots & \cdots & 0 & \dots & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 & 0 \\ 0 & -\Delta\gamma ij & 0 & \dots & 0 & \Delta y_{ij} & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 & 0 \end{bmatrix} \\ \begin{array}{ccccccc} & & Col\text{-}i & & & & Col\text{-}j \end{array} \end{array} \qquad (8)$$

$$K_{s} = \frac{X_{c}}{X_{ij}} \qquad (9)$$

Where Xc refers to the total capacitive reactance of series compensators, Xl which refers to the total inductive reactance of the line [13] and Ks refers to the degree of compensation.

As the objective is to determine the amount of series capacitor on the line, it is useful to determine the degree of compensation (Ks) in the total line impedance, which is shown:

$$Z = Rij + j\,[\,Xij\,(1 - Ks)\,] \qquad (10)$$

From the eq.(10) it is concluded that the total line impedance is reactive and is a function of control parameter Ks.

3.3 Modelling of SVC

Both Series and shunt VAR compensation are used to modify the natural electrical characteristics of ac power systems. Series compensation modifies the transmission or distribution system parameters, While Shunt compensation changes the equivalent impedance of the load. The Shunt compensation modifies the transmission or distribution system parameters, while shunt compensation changes the equivalent impedance of the load. The shunt compensator SVC is simply a static capacitor/reactor with susceptance Bsvc [12].

The reactive power injected into the bus due to SVC can be expressed as :

$$Q_{svc} = B_{SVC}\, V^{2} \qquad (11)$$

Where V is the voltage magnitude of the bus at which the SVC is connected

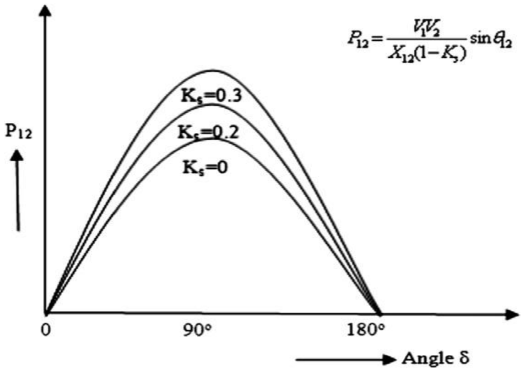

Fig 4. PowerangleVsRealpowerflow

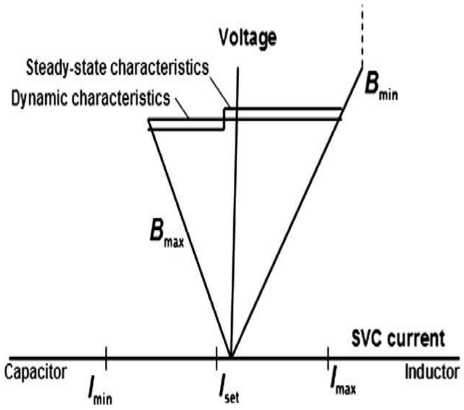

Fig 5 :SVC characteristics at high voltage bus

Fig 5.Shows the steady-state and dynamic voltage-current characteristics of the SVC portion of the system. Current/susceptance and reactive power is varied in the active control range, to regulate voltage according to slope (droop) characteristics. The slope value depends upon the desired voltage regulation. At the capacitive limit, the SVC becomes a shunt capacitor. At the Inductive limit SVC becomes a shunt reactor

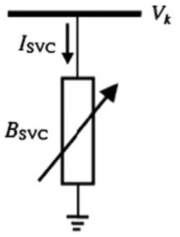

Fig 6. Variable Shunt Susceptance

An Individual chromosome

Location Code	Compensation level

Fig 7. A typical string with constant variables

After adding SVC at bus-i of a general power system, the new system admittance matrix $Y_{bus}^{'}$ is shown in eq (12)

$$\mathbf{Y'bus = Ybus +} \begin{array}{c} \left[\begin{array}{ccccccc} 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & Y_{shunt} & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ \cdots & \cdots & \cdots & \cdots & 0 & \cdots & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 \end{array}\right] \\ \begin{array}{ccccccc} & \textbf{Col –i} & & & & & \textbf{Col-j} \end{array} \end{array} \quad (12)$$

VAr (capacitive) = VAr (required) - VAr(Uncompensated) (13)

The amount of the Capacitive susceptance B_{cap} is given by the equation (14):

$$B_{cap} = \frac{\text{VAr (required) – VAr (Uncompensated)}}{V_{rms}^2} \text{Siemens} \quad (14)$$

From which the required capacitance value in farad is given by using the equation

$$\text{C (farad)} = \frac{B_{cap}}{2\pi f} \quad (15)$$

The amount of shunt reactors required on the transmission line, for determining the maximum power transfer is defined as the degree of shunt compensation (K_d).

$$K_d = \frac{B}{Im\{y\}^l} \quad (16)$$

K_d is defined as the fraction of the total inductive susceptance of shunt compensation (B) and the total charging susceptance of line

$Im\{y\}^l$ [13].

4. REAL-CODE GENETIC ALGORITHM

In this proposed work, to maximize the ATC, Real-code Genetic Algorithm (RGA) is used with the two control variables, SVC and TCSC. The Evolutionary Programming (EP) methods, which belongs to GA has special advantage over the conventional optimization methods in that EPs do not need a strict mathematical model of objective function [5]. The conventional methods like non-linear programming techniques, converge onto local optimum. Hence for power system optimization, EPs are chosen wherever possible. These are simple to programme. RGA , reduces the computational time and leads to greater accuracy of control variables. The genetic operators, crossover and mutation are also different in RGA

4.1 Presentation of Control Variables.

In GA, the term chromosome or a string refers to a candidate solution. A number of such strings form a population. In the present problem of ATC maximization, the chromosome contains two control variables for SVC / TCSC separately as shown in Fig. 7 [11]. For the location information , we use series of integrals to express different placement of TCSC/SVC. For example, if the location for TCSC/SVC has four choices, four integrals 1, 2, 3, 4 are used as candidates for control variable.

4.2 Fitness Function (FF)

To maximize of minimize the Fitness Function (FF) ,GA is designed usually which is measure of the quality of each candidate solution. The objective function will be evaluated only after the control variables are coded. These values are measures of quality which is used to compare different solutions. The better solution joins the population and the worse one is discarded. The fitness value of an individual will determine its chance to propagate its features to future generations.ATC is used as the fitness function.RGA fitness function is formed as follows [11]:

FF = maximization of ATC (17)

4.2.1 Crossover

One of the main distinguish feature of Gas is Crossover which is different from other algorithms. Its main aim is to recombine blocks on different individual to make a new one convex crossover is used as shown below:

$$\begin{gathered} x^{'} = \lambda_1 \text{x} + \lambda_2 \text{y} \\ y^{'} = \lambda_1 \text{y} + \lambda_2 \text{x} \\ \lambda_1 + \lambda_2 = 1 , \\ \lambda_1 , \lambda_2 > 0 \end{gathered}$$

Where x, y are the two parents, $x^{'}$, $y^{'}$ are their two offspring. λ_1 and λ_2 is obtained by a uniform random number generator between the range (0-1).

4.2.2 Mutation

Mutation is used to introduce some sort of artificial diversification in the population to avoid premature convergence to local optimum. An arithmetic mutation operator that has proved successful in a number of studies is dynamic and is used in this study. For a given parent x, if the gene x_k is selected for mutation, then the resulting gene is selected with equal probability from the two choices :

$$x_k' = x_k + r\,(b_k - x_k)\,(1 - \frac{t}{T})^b \quad \text{or}$$
$$x_k' = x_k + r\,(x_k - a_k)\,(1 - \frac{t}{T})^b$$

Where r is a uniform random number chosen between the range (0 , 1) , t is the current generator number , T is the maximum number of generations and b is a parameter determining the degree of non- uniformity. As the number of generations increases , the amount of mutation decreases.

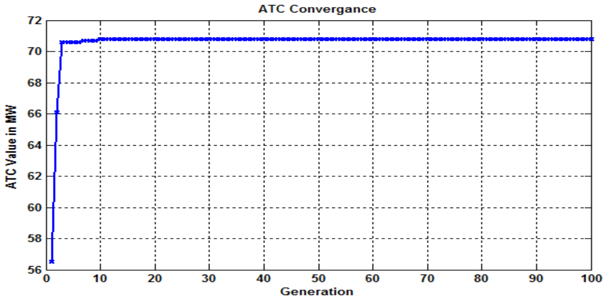

Fig 9. No. of Generations Vs Fitness profile of ATC

Table 1. ATC without FACTS Device for IEEE 14 bus system

Source/Sink bus no.	ATC (MW)	Violation Constraint (line flow/voltage)
1/9	65.5	Line-8 overflow
1/10	53.8	Line-8 overflow
1/12	30.3	Line-8 overflow
1/13	31.8	Line-8 overflow
1/14	42.3	Line-8 overflow
1/4	156.8	Bus-4 voltage deviation
1/3	158.1	Line-2 overflow

Table 2.ATCs after incorporating TCSC for IEEE 14 bus system

Source/Sink bus no.	ATC without TCSC (MW)	ATC with TCSC (MW)	TCSC Location	Compensation (p.u)
1/9	65.5	70.8	Line-8	-0.0380
1/10	53.8	60.0	Line-9	-0.0661
1/12	30.3	34.0	Line-12	-0.0666
1/13	31.8	34.2	Line-12	-0.0414
1/14	42.3	52.5	Line -12	-0.1614
1/4	156.8	168.4	Line -3	-0.0552
1/3	158.1	174.2	Line -6	-0.0475

Table 3: ATCs after incorporating SVC for IEEE 14 bus system

Source/ Sink bus no.	ATC without SVC (MW)	ATC with SVC (MW)	SVC Location	Compensation (p.u)
1/9	65.5	65.7	Bus-5	0.0485
1/10	53.8	54.1	Bus-5	0.0190
1/12	30.3	30.4	Bus-5	0.0899
1/13	31.8	31.9	Bus-5	0.0217
1/14	42.3	42.6	Bus-5	0.0840
1/4	156.8	157.3	Bus-3	0.0012
1/3	158.1	158.3	Bus-2	0.0919

Table 4: ATCs without FACTS Device during Line-16 outage for IEEE 14 bus system

Source/Sink bus no.	ATC (MW)	Violation Constraint (line flow/voltage)
1/9	71.2	Bus-14 Voltage Deviation
1/10	59.8	Line- 8 Overflow
1/12	33.6	Bus-13 Voltage Deviation
1/13	19.1	Bus-13 Voltage Deviation
1/14	25.0	Bus-14 Voltage Deviation
1/4	151.1	Bus-13 Voltage Deviation
1/3	157.7	Line-2 overflow

Table 5:ATCs after incorporating TCSC during line-16 outage for IEEE 14 bus system

Source/ Sink bus no.	ATC without TCSC (MW)	ATC with TCSC (MW)	TCSC Location	Compensation (p.u)
1/9	71.2	75.2	Line-16	-0.0764
1/10	59.8	63.1	Line-9	-0.0378
1/12	33.6	36.2	Line -16	-0.0764
1/13	19.1	21.1	Line -16	-0.0780
1/14	25.0	30.5	Line -12	-0.0444
1/4	151.1	156.4	Line -3	-0.0703
1/3	157.7	172.9	Line -6	-0.0475

Table 6 ATCs after incorporating SVC during line-16 outage for IEEE 14 bus system

Source/Sink bus no.	ATC without SVC (MW)	ATC with SVC (MW)	SVC Location	Compensation (p.u)
1/9	71.2	73.1	Bus-13	0.0904
1/10	59.8	61.6	Bus-10	0.0902
1/12	33.6	36.8	Bus-12	0.0958
1/13	19.1	21.3	Bus-13	0.0896
1/14	25.0	27.2	Bus-14	0.0992
1/4	151.1	154.7	Bus-9	0.0955
1/3	157.7	159.8	Bus-10	0.0794

Table 7 ATC without FACTS Device for IEEE 24 bus system

Source/Sink bus no.	ATC (MW)	Violation Constraint (Line flow/Voltage)
23/15	760.3	Line-24 overflow
22/9	174.5	Bus-14 Voltage Deviation
22/5	165.3	Line-12 overflow
21/6	98.2	Line-10 overflow
18/5	165.0	Line-12 overflow

Table 8 ATCs after incorporating TCSC for IEEE 24 bus system

Source/Sink bus no.	ATC without TCSC (MW)	ATC with TCSC (MW)	TCSC Location	Compensation (p.u)
23/15	760.3	807.1	Line-25	-0.0172
22/9	174.5	213.5	Line-18	-0.0090
22/5	165.3	186.4	Line -17	-0.0150
21/6	98.2	109.4	Line -5	-0.0462
18/5	165.0	187.1	Line -17	-0.0178

Table 9.ATCs after incorporating SVC for IEEE 24 bus system

Source/Sink bus no.	ATC without SVC (MW)	ATC with SVC (MW)	SVC Location	Compensation (p.u)
23/15	760.3	760.9	Bus-23	0.0864
22/9	174.5	179.2	Bus-18	0.0988
22/5	165.3	168.3	Bus-3	0.0845
21/6	98.2	98.9	Bus-10	0.0815
18/5	165.0	166.5	Bus-24	0.0926

Table 10 ATCs without FACTS Device during Line-8 outage for IEEE 24 bus system

Source/Sink bus no.	ATC (MW)	Violation Constraint (Line flow/Voltage)
23/15	756.7	Line-23 overflow
22/9	163.7	Bus-14 Voltage Deviation
22/5	60.5	Line-11 overflow
21/6	48.0	Line-11 overflow
18/5	60.4	Line-11 overflow

Table 11 ATCs after incorporating TCSC during line-8 outage for IEEE 24 bus system

Source/Sink bus no.	ATC without TCSC (MW)	ATC with TCSC (MW)	TCSC Location	Compensation (p.u)
23/15	756.7	785.3	Line-25	-0.0115
22/9	163.7	186.1	Line-15	-0.0288
22/5	60.5	150.5	Line -15	-0.0247
21/6	48.0	78.8	Line -12	-0.0545
18/5	60.4	64.1	Line -20	-0.0329

Table 12 ATCs after incorporating SVC during line-8 outage for IEEE 24 bus system

Source/Sink bus no.	ATC without SVC (MW)	ATC with SVC (MW)	SVC Location	Compensation (p.u)
23/15	756.7	757.9	Bus-16	0.0729
22/9	163.7	168.2	Bus-17	0.1000
22/5	60.5	66.8	Bus-9	0.0899
21/6	48.0	54.3	Bus-9	0.0789
18/5	60.4	61.6	Bus-24	0.0985

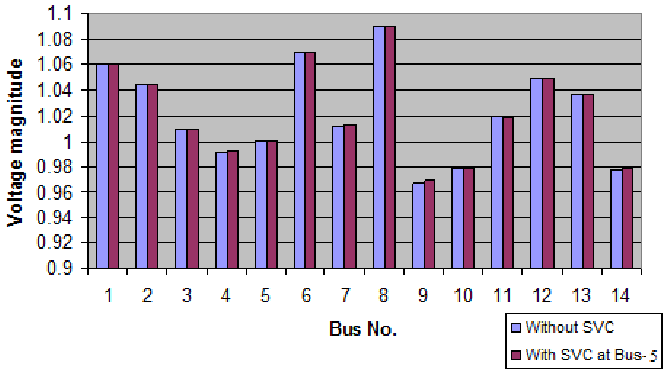

Fig 10. Bus voltage profile for without and with SVC at bus-5 for IEEE 14 bus System

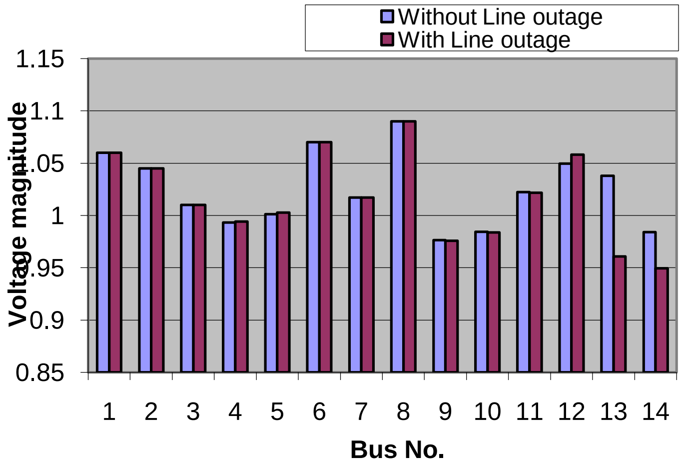

Fig. 11 Bus voltage profile for without and with line outage cases for IEEE 14 bus system

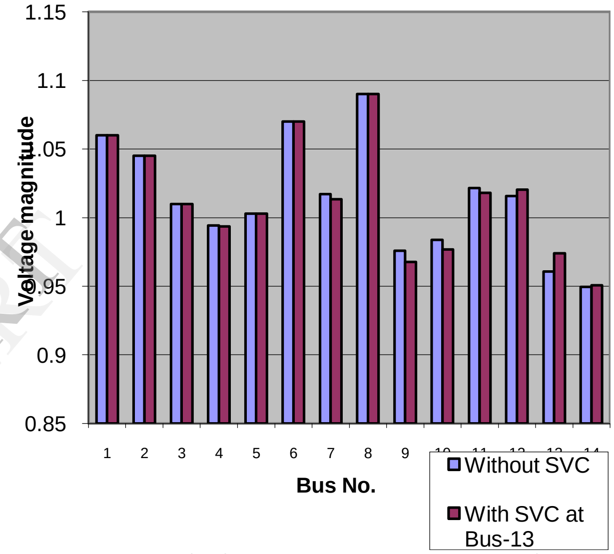

Fig. 12 Bus voltage profile for without and with SVC at bus-13 for IEEE 14 bus system

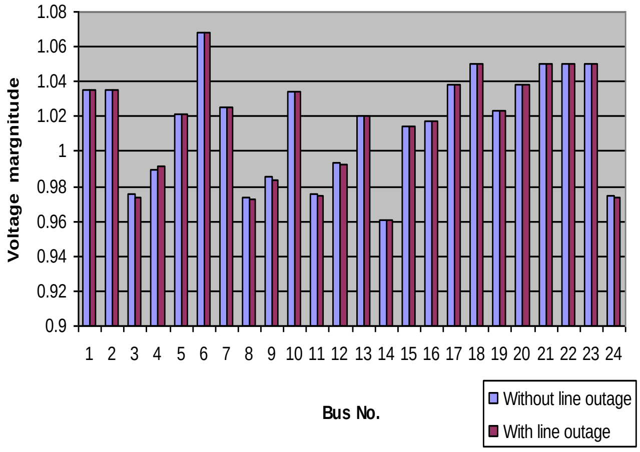

Fig. 13 Bus voltage profile for without and with line outage cases for IEEE 24 bus system

4.3 Structure of RGA

Individuals are simplified to a chromosome that includes control variable of the problem in the genetic algorithm .The value of an individual is called fitness which corresponds to the objective function value that should be optimized. Fig 8 shows the flow chart of the proposed algorithm that is implemented in this. RGA is selected for optimization process to improve the ATC including TCSC/SVC.

4.4 RGA Flow Diagram

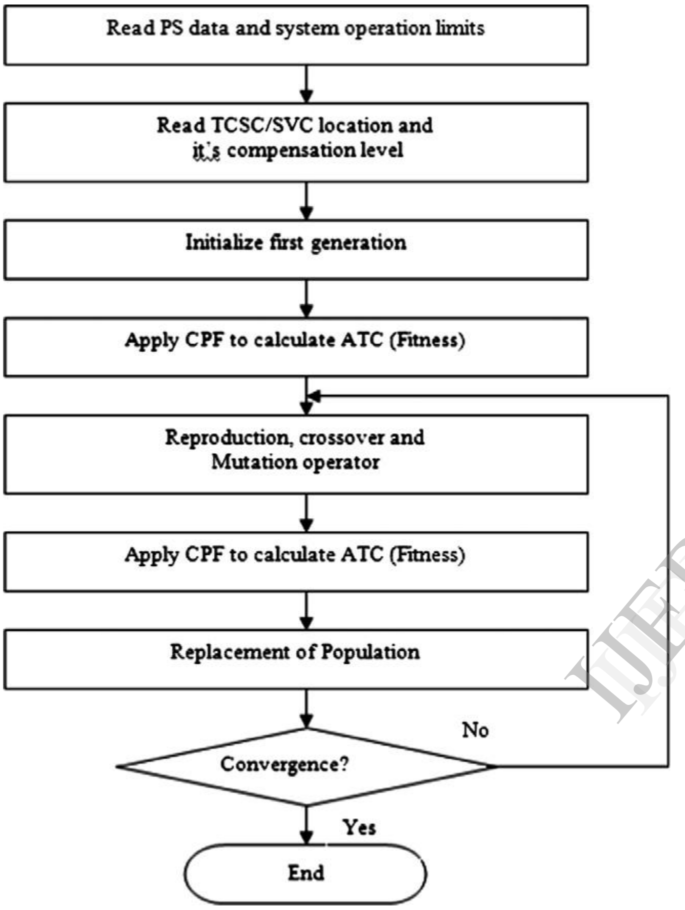

Fig. 8. RGA Flow Diagram

5. CASE STUDIES AND DISCUSSIONS

The Available Transfer Capability (ATC) for each of the stipulated source to sink power transfers on two IEEE systems (14-bus and 24 reliability test system).Studies are made with two FACTs devices [15] , TCSC and SVC to see their effectiveness on enhancing ATC. ATC values are computed in selected line outages with each of the FACTs device. In the studies, the ATC margin is limited by bus voltage magnitude in the range $0.95 \preccurlyeq V \preccurlyeq 1.15\,pu$. The amount of compensation offered by SVC (B_{avg}) is 0 – 0.19 V.Where TCSC is 0 – 40 % (K_d)

The entire study is divided into four phases:

5.1 Phase 1

The Real-code Genetic Algorithm (RGA) being the tool used for optimization. It is first tested, for population size and the GA parameters, for its convergence.The parameters selected are:

The GA parameters selected were:

(a) Population size = 40.
(b) Elitism probability = 0.15.
(c) Crossover probability = 0.60
(d) Mutation Probability = 0.01.
(e) Generations number = 100.

5.2 Phase 2

With no FACTs devices and with no line outage , the base state of the system is found for different assumed transactions. The results for 14-bus and 24-bus system are given. From the tables it can seen that there are line flow violations which is clear indication that there is a need for incorporation of FACTs devices.

5.3 Phase 3

Enhancement of ATC:

For placing of SVC, there are 13 options in 14 –bus system and 23 options in 24-bus system. For placing of TCSC, there are 19 options in 14-bus system and 38 options in 24-bus system. These are coded into RGA, optimal location and capacity of each of the device is arrived along with the enhanced value of ATC .For the relative effectiveness of the device, the same bus-to-bus transactions are chosen. Similarly computation is done on 24-bus system.

5.4 Phase 4

The base state for both the systems, the variation in ATC is studied with line outages and the results are shown in the tables for 14 –bus and 24 – bus system respectively.This is considerably improvement in ATC with FACTs devices even with line outages.

6. CONCLUSION

ATC improvement using TCSC and SVC is studied with IEE 14-bus and 24-bus reliability test systems during normal and in contingency situations. The location of the devices and the control parameters significantly affect the ATC. For enhancement of ATC, a control strategy called Real-code Genetic Algorithm is used .It is shown that SVC improves voltage profile and ATC whereas TCSC can improve ATC in thermal and voltage dominant cases. As shown it is clear that TCSC is more effective in improving ATC under both normal and contingency situations.

REFERENCES

[1] IEEE reliability test system, IEEE transactions on power apparatus and systems, vol. PAS-98, No. 6; November/December 1979.
[2] Power electronics in electric utilities: static var compensators. In: Proceedings of the IEEE, vol. 76, No. 4; April 1988.
[3] Ajarapu V, Christie C. The continuation power flow: a practical tool for tracing power system steady state stationary behavior due to the load and generation variations. IEEE Trans Power Sys 1992;7(1):416–23.
[4] Noroozian M, Anderson G. Power flow control by use of controllable series components. IEEE Trans Power Deliv 1993;8(3):1420–8.
[5] Miranda Vladimiro, Ranito JV, Proenca LM. Genetic algorithms in optimal multistage distribution network planning. IEEE Trans Power Sys 1994;9(4): 1927–33.
[6] Transmission transfer capability task force, Available transfer capability Definitions and determination, North American Electric Reliability Council,NJ; June 1996.
[7] Ejebe GC, Tong J, Waight JG, Frame JG, Wang X, Tinney WF. Available transfer capability calculations. IEEE Trans Power Sys 1998;13(4):1521–7.
[8] Dai Y, McCalley JD, Vittal V. Simplification, expansion and enhancement of direct interior point algorithm for power system maximum loadability. In:Proc 21st Int Conf Power Ind Comput Appl; 1999. p. 170–179.
[9] Christie Richard D, Wollenberg Bruce F, Wangensteen Ivar. Transmission management in the deregulated environment. Proc IEEE 2000;88(2).
[10] Xiao Y, Song YH, Sun YZ. Available transfer capability enhancement using FACTS devices. Proc 2000 IEEE/PWS Summer Meeting, Seattle 2000;1:508–15.
[11] Feng Wang, Shrestha GB. Allocation of TCSC devices to optimize total transmission capacity in a competitive power market. IEEE Trans Power Sys 2001:587–92.
[12] Gerbex Stephane, Cherkaoui Rachid, Germond Alain J. Optimal location of multi-type FACTS devices in a power system by means of genetic algorithms.IEEE Trans Power Sys 2001;6(3).
[13] Saha Tapan Kumar. Required shunt compensation for an EHV transmission line. Australia: The University of Queensland; 2003.
[14] Bansal RC, Zobaa AF, Nigim KA. Technology of VAr compensators for induction generator applications in wind energy conversion systems. J Electr Sys 2006:172–84.
[15] MATLAB genetic algorithm tutorials.
[16] Ghawghawe ND, Thakre KL. Computation of TCSC reactance and suggesting criterion of its location for ATC improvement. Int J Electr Power Energy Sys 2009;31(2–3):86–93.
[17] Farahmand H, Rashidinejad M, Mousavi A, Gharaveisi AA, Irving MR, Taylor GA. Hybrid mutation particle swarm optimisation method for available transfer capability enhancement. Int J Electr Power Energy Sys 2012;42(1):240–9.
[18] Feasibility assessment of simultaneous bilateral and multilateral transactions.Int J Electr Power Energy Sys. vol. 32, No. 8. Elsevier Ltd; 2010. p. 879–885.
[19] Kumar Ashwani, Kumar Jitendra. Comparison of UPFC and SEN transformer for ATC enhancement in restructured electricity markets. Int J Electr Power Energy Sys 2012;41(1):96–104.
[20] Sakellaridis Nikos G, Karystianos Michael E, Vournas Costas D. Local and global bifurcations in a small power system. Int J Electr Power Energy Sys 2011;33(7):1336–47.
[21] Rashidinejad M, Farahmand H, Fotuhi-Firuzabad M, Gharaveisi AA. ATC enhancement using TCSC via artificial

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