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OPTIMAL LOCATION OF SVC, TCSC AND UPFC DEVICES FORVOLTAGE STABILITY IMPROVEMENT AND REDUCTION OF POWERLOSS USING GENETIC ALGORITHM

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ABSTRACT

Improving of ATC is an important issue in the current de-regulated environment of power systems. 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. Power transactions between a specific seller bus/area and a buyer bus/area can be committed only when sufficient ATC is available. Transmission system operators (TSOs) are encouraged to use the existing facilities more effectively to enhance the ATC margin. In this paper, the use of TCSC and SVC to maximize Available Transfer Capability (ATC) generally defined as the maximum power transfer transaction between a specific power-seller and a power-buyer in a network during normal and contingency cases. In this thesis, ATC is computed using Continuous Power Flow (CPF) method considering both line thermal limit as well as bus voltage limits. Real-code Genetic Algorithm is used as the optimization tool to determine the location as well as the controlling parameter of TCSC or SVC simultaneously. The performance of the Real-code Genetic Algorithm has been tested on IEEE 14-Bus System and IEEE 24-Bus Reliability Test System.

I. INTRODUCTION

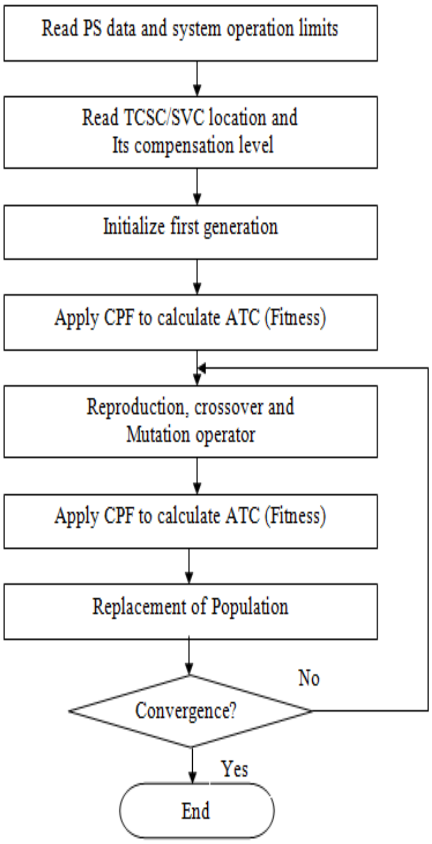
The focus of electric industry reorganize is to encourage vying electric power markets merchandise. Under the new domain, main outcome of the open-access need is the considerable growth in the transfer. The ATC (A - Available, T - Transfer, and C -Capability) of transference network is unused transfer abilities of a network dispatch for further commercial business power transference, in addition to pledged use. Adequate ATC is required to protect all cost effective undertakings, while adequate ATC is desired to smoothen availability of market for electricity. It is essential to sustain inexpensive and reliable performance over a broad spectrum of the system working condition and restrictions. Though, limitations in building latest amenities due to the inexpensive, nature and societal issues, lowers the action possibilities. It may occasionally lead to a state that the prevailing transmission provisions are extremely used [8]. According to NERCs interpretation of ATCs calculations [6], conveyance network can be limited by voltage, stability and thermal controls. In contrast, it is thoroughly altered that, with the ability of pliable power flow [9], FACTS knowledge has established acute influence to the conveyance system using effectively with considering those 3 limitations. From stable flow of state point of view, network does not usually power share in relative amount to its rating, where in majority circumstances, voltage profiles could not be even. Hence, ATC merits are always constrained by extremely loaded bus with comparatively small voltage. Idea of FACTS makes it feasible to utilize reactance of circuit, phase angle as sways and voltage magnitude to reorganize flow of line and profile of voltage are managed. Conceptually, devices of FACTS could offer an efficacious and assured substitute to traditional ATC methods intensification. These devices will give latest authority provisions; in active stability sway and stable flow of power sway. Maintain flow of power in systems of electricity in the absence of production postpones or topology can enhance network achievement considerable. With acceptable position, the impact of SVC and TCSC on ATC improvement is considered and illustrated via case studies. Lodging SVC in actual position would enhance potential profile additionally TCSC and ATC will enhance ATC.

II. OBJECTIVE OF PAPER

The foremost objective is augmenting the ATC from source (generating) zone to sink (accepting) zone in an uncontrolled abode system utilizing uninterrupted Flow of Power technique in usual and unpredictable occasions with flawless position and regulate parameters of Devices of FACTS of a kind that SVC or TCSC on IEEE14-bus and IEEE 24-bus reliability check system. TCSC or SVC Regulating and Location parameter is measured via the utilization of RGA. ATC is reliant on numerous factors for example system working base case, network configurations, system working limits, description of contingency etc. Due to restrict on ATC, it has lesser influence on transmission system uses when compared to FACTS technology. Therefore, extreme prevailing transmission resource use would be extra worth for operators of transmission system (TSO) and consumers will get best assistance with minimized expenditure.

III. STRUCTURE OF REAL GENETIC ALGORITHM

In genetic algorithm, individuals are simplified to a chromosome that includes control variables of the problem. The value of an individual is called fitness which is corresponding to the objective function value that should be optimized. Figure. 5.2 shows the flow chart of the proposed algorithm that is implemented in this research. As it is mentioned RGA is selected for optimization process to improve the ATC including TCSC/SVC.



IV.CASE STUDIES AND DISCUSSION

The Available Transfer Capability (ATC) are computed for a set of source/sink transfers on IEEE 14-bus system and IEEE 24 reliability test system. The ATC margin can be further increased by proper location and control parameter of FACTS devices. In this thesis, TCSC and SVC are used as FACTS devices. Real-code Genetic Algorithm is used to find optimal location and control parameter of TCSC and SVC for maximizing of ATC. In this thesis, the total study is divided into two cases as:

1. ATC calculation without line outage.
2. ATC calculation with line outage.

The ATC margin is limited by bus voltage magnitude and line flow rating. The voltage magnitude limits of all buses are set to V_{min}=0.95 (p.u) and V_{max}=1.15 (p.u). The line ratings of IEEE 14-bus system and IEEE 24-bus system are given in appendix A and B respectively.

IJARSE
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IV.1 IEEE 14-bus system

Without line outage case

Table.-1: ATC without FACTS Device

Source/Sink bus no.	ATC (M.W)	Violation Constraint (line flow/voltage)
1/9	53.0	Line-8 overflow
1/10	44.0	Line-8 overflow
1/12	30.0	Line-8 overflow
1/13	31.5	Line-8 overflow
1/14	42.0	Line-8 overflow
1/4	222.0	Line-1 overflow
1/3	157.5	Line-2 overflow

The Available Transfer Capability (ATC) are computed for a set of source/sink transfers using Continuous Power Flow (CPF). Table-1 shows the ATCs for IEEE 14-bus system without FACTS device.

Incorporation of TCSC

When TCSC is incorporated in the system, if we consider all lines of system, there are 20 possible locations for the TCSC. The location code region are set as 20 integers as 1 to 20. The amount of compensation offered by TCSC is 0 to 40% (K_d). After using Real Genetic Algorithm proposed in this work, the results obtained are shown in Table-2. It shows that with the flow control function TCSC increased the ATC significantly.

Table - 2: ATCs after incorporating TCSC

Source/Sink bus no.	ATC without TCSC (M.W)	ATC with TCSC (M.W)	TCSC Location	Compensation (p.u)
1/9	53.0	68.5	Line-9	-0.088
1/10	44.0	62.0	Line-12	-0.075
1/12	30.0	47.0	Line -9	-0.130
1/13	31.5	48.5	Line -9	-0.128
1/14	42.0	57.0	Line -12	-0.110
1/4	222.0	250.0	Line -3	-0.070
1/3	157.5	210.5	Line -6	-0.081

Figure-1 is the convergence characteristic of Real-code Genetic Algorithm and it shows a graph between generation and fitness function i.e., ATC (M.W) when source/sink transfer is between bus 1 and bus 9. After 89 generations, the optimal value of TCSC location and compensation value are found. It shows a goodconvergence of this algorithm.

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IJARSE
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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.

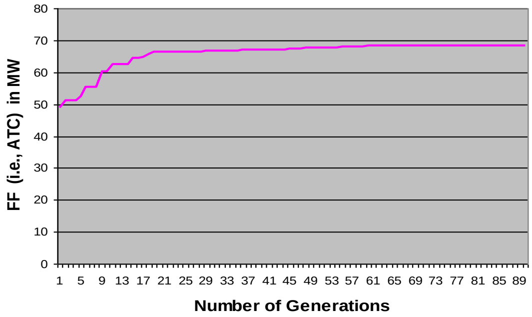

Fig -1: No. of Generations Vs Fitness profile of ATC

Incorporation of SVC

When one SVC is incorporated in the system, if we consider all buses of system, there are 14 possible locations for the SVC. The location code region are set as 14 integers as 1 to 14. The amount of compensation offered by SVC is 0 to 0.1 (p.u) i.e., B_{svc}. After using Real Genetic Algorithm, the results obtained are shown in Table-3. It shows that with the flow control function SVC increased the ATC significantly. Figure - 2 shows the voltage profile for IEEE 14-bus system without and with SVC at bus-9, when ATC is computed for a transaction 1/9.

Table -3: ATCs after incorporating SVC

Source/Sink bus no.	ATC without SVC (M.W)	ATC with SVC (M.W)	SVC Location	Compensation (p.u)
1/9	53.0	61	Bus-10	0.081
1/10	44.0	49	Bus-10	0.081
1/12	30.0	40.5	Bus-12	0.097
1/13	31.5	42	Bus-12	0.091
1/14	42.0	57	Bus-12	0.097
1/4	222.0	228	Bus-9	0.091
1/3	157.5	160.5	Bus-13	0.075

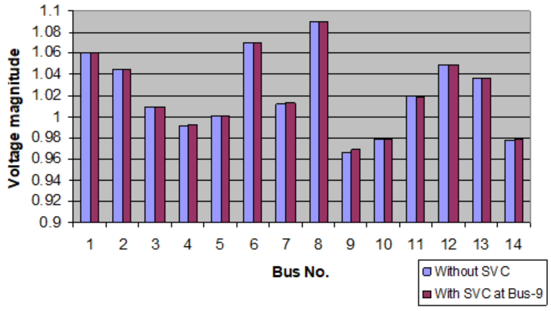

Fig -2: Bus voltage profile for without and with SVC at bus-9

With line outage

The Available Transfer Capability (ATC) are computed for a set of source/sink transfers using Continuous Power Flow (CPF), when line-16 is physically removed from the system that is connected between bus-13 and bus-14. Table-4 shows the ATCs for IEEE 14-bus system without FACTS device, when line-16 is outage. Figure-3: Shows a graph voltage profile for the IEEE 14-bus system with and without outage cases.

Table-4: ATCs without FACTS Device during Line-16 outage

Source/Sink bus no.	ATC (M.W)	Violation Constraint (line flow/voltage)
1/9	45.0	Bus-14 voltage limit
1/10	44.0	Bus-10 voltage limit
1/12	34.5	Line-8 overflow
1/13	22.5	Bus-13 voltage limit
1/14	36.0	Bus-14 voltage limit
1/4	217.0	Line-7 overflow
1/3	157.5	Line-2 overflow

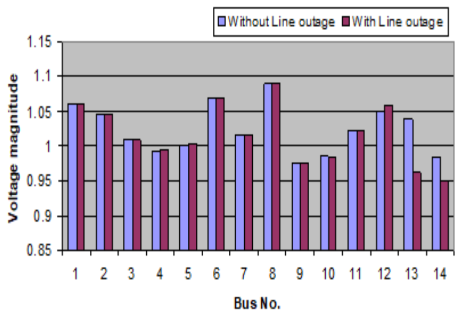

Fig -3: Bus voltage profile for without and with line outage cases

Incorporation of TCSC

When one TCSC is incorporated in the system, if we consider all lines of system, there are 19 possible locations for the TCSC. The location code region are set as 20 integers as 1 to 20 except line 16. The amount of compensation offered by TCSC is 0 to 40% (K_d). After using Real Genetic Algorithm proposed in this work, the results obtained are shown in Table-5. It shows that with the flow control function TCSC increased the ATC significantly even under line outage.

Table-5: ATCs after incorporating TCSC during line-16 outage

Source/Sink bus no.	ATC without TCSC (M.W)	ATC with TCSC (M.W)	TCSC Location	Compensation (p.u)
1/9	45.0	61.0	Line-6	-0.089
1/10	44.0	56.5	Line-6	-0.100
1/12	34.5	46.0	Line -12	-0.055
1/13	22.5	39.0	Line -9	-0.084
1/14	36.0	51.0	Line -12	-0.066
1/4	217.0	230.0	Line -8	-0.100
1/3	157.5	187.5	Line -6	-0.102

Incorporation of SVC

When one SVC is incorporated in the system, if we consider all buses of system, there are 14 possible locations for the SVC. The location code region are set as 14 integers as 1 to 14. The amount of compensation offered by SVC is 0 to 0.1 (p.u) i.e., B_{svc}. After using Real Genetic Algorithm, the results obtained are shown in Table-6. It shows that with the voltage control function SVC increased the ATC significantly during line-16 outage. Figure-4 shows the voltage profile for IEEE 14-bus system without and with SVC at bus-13, when ATC is computed for a transaction 1/13.

Table-6: ATCs after incorporating SVC during line-16 outage

Source/Sink bus no.	ATC without SVC (M.W)	ATC with SVC (M.W)	SVC Location	Compensation (p.u)
1/9	45.0	51.0	Bus-14	0.0984
1/10	44.0	46.0	Bus-10	0.0781
1/12	34.5	45.0	Bus-12	0.0940
1/13	22.5	31.5	Bus-13	0.0890
1/14	36.0	45.0	Bus-14	0.0970
1/4	217.0	226.5	Bus-9	0.0940
1/3	157.5	160.5	Bus-10	0.0960

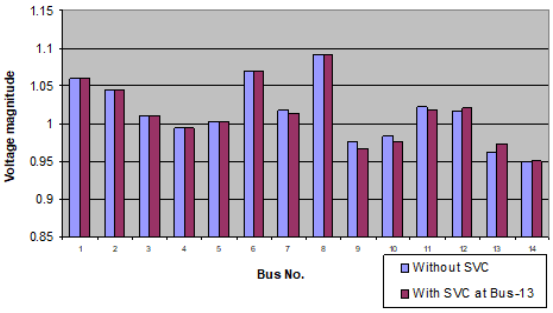

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Fig -4: Bus voltage profile for without and with SVC at bus-13

IV. II IEEE 24-bus Reliability Test System

Without line outage case

The Available Transfer Capability (ATC) are computed for a set of source/sink transfers using Continuous Power Flow (CPF). Table-7 shows the ATCs for IEEE 24-bus system without FACTS device.

Table -7: ATC without FACTS Device

Source/Sink bus no.	ATC (M.W)	Violation Constraint (Line flow/Voltage)
23/15	770.0	Line-24 overflow
22/9	395.0	Line-38 overflow
22/5	260.0	Line-38 overflow
21/6	105.0	Line-10 overflow
18/5	260.0	Line-38 overflow

Incorporation of TCSC

Table-8: ATCs after incorporating TCSC

Source/Sink bus no.	ATC without TCSC (M.W)	ATC with TCSC (M.W)	TCSC Location	Compensation (p.u)
23/15	770.0	810.0	Line-28	-0.0103
22/9	395.0	420.0	Line-12	-0.0635
22/5	260.0	270.0	Line -15	-0.0239
21/6	105.0	120.0	Line -5	-0.0669
18/5	260.0	270.0	Line -15	-0.0283

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. The amount of compensation offered by TCSC is 0 to 40% (Kd). After using Real Genetic Algorithm proposed in this work, the results obtained are shown in Table-8. It shows that with the flow control function TCSC increased the ATC significantly

Incorporation of SVC

When one SVC is incorporated in the system, if we consider all buses of system, there are 24 possible locations for the SVC. The location code region are set as 24 integers as 1 to 24. The amount of compensation offered by SVC is 0 to 0.1 (p.u) i.e., B_{svc}. After using Real Genetic Algorithm, the results obtained are shown in Table-9. It shows that with the flow control function SVC increased the ATC significantly.

IJARSE
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Table-9: ATCs after incorporating SVC

Source/Sink bus no.	ATC without SVC (M.W)	ATC with SVC (M.W)	SVC Location	Compensation (p.u)
23/15	770.0	790.0	Bus-20	0.099
22/9	395.0	405.0	Bus-5	0.086
22/5	260.0	265.0	Bus-11	0.081
21/6	105.0	110.0	Bus-11	0.082
18/5	260.0	262.0	Bus-5	0.091

With line outage

The Available Transfer Capability (ATC) are computed for a set of source/sink transfers using Continuous Power Flow (CPF), when line-8 is physically removed from the system that is connected between bus-4 and bus-9. Figure.-5 shows a graph voltage profile for the IEEE 24-bus system with and without outage cases.

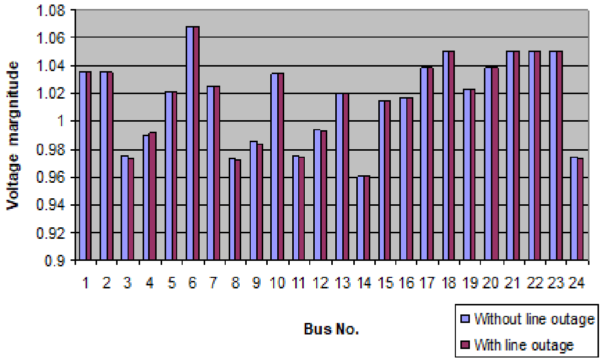

Fig-5: Bus voltage profile for without and with line outage cases

Table - 10 shows the ATCs for IEEE 24-bus system without FACTS device, when line-8 is physically removed.

Table-10: ATCs without FACTS Device during Line-8 outage

Source/Sink bus no.	ATC (M.W)	Violation Constraint (Line flow/Voltage)
23/15	765.00	Line-24 overflow
22/9	385.00	Bus-9 voltage limit
22/5	214.20	Line-9 overflow
21/6	86.70	Line-10 overflow
18/5	214.20	Line-9 overflow

Incorporation of TCSC

When one TCSC is incorporated in the system, if we consider all lines of system, there are 19 possible locations for the TCSC. The location code region are set as 20 integers as 1 to 20 except line-8. The amount of compensation offered by TCSC is 0 to 40% (Kd). After using Real Genetic Algorithm proposed in this work, the results obtained are shown in Table-11. It shows that with the flow control function TCSC increased the ATC significantly even under line outage

Table-11: ATCs after incorporating TCSC during line-8 outage

Source/Sink bus no.	ATC without TCSC (M.W)	ATC with TCSC (M.W)	TCSC Location	Compensation (p.u)
23/15	765.00	801.20	Line-25	-0.0101
22/9	385.00	413.10	Line-14	-0.0652
22/5	214.20	229.50	Line -2	-0.0304
21/6	86.70	91.80	Line -7	-0.0730
18/5	214.20	229.50	Line -2	-0.0328

Incorporation of SVC

When one SVC is incorporated in the system, if we consider all buses of system, there are 24 possible locations for the SVC. The location code region are set as 24 integers as 1 to 24. The amount of compensation offered by SVC is 0 to 0.1 (p.u) i.e., B_{svc}. After using Real Genetic Algorithm, the results obtained are shown in Table-12. It shows that with the flow control function SVC increased the ATC significantly during line-8 outage.

Table-12: ATCs after incorporating SVC during line-8 outage

Source/Sink bus no.	ATC without SVC (M.W)	ATC with SVC (M.W)	SVC Location	Compensation (p.u)
23/15	765.00	785.40	Bus-10	0.084
22/9	385.00	392.70	Bus-23	0.099
22/5	214.20	219.30	Bus-14	0.092
21/6	86.70	88.20	Bus-6	0.081
18/5	214.20	224.40	Bus-16	0.098

V.CONCLUSION

In unregulated power systems, available transfer capability (ATC) analysis is currently a critical issue either in the operating or planning because of raised area interchanges among utilities. Adequate ATC should be guaranteed to support free market trading and maintain a cost efficient and secure operation over a wide range of system conditions. Nevertheless, tight restrictions on the construction of new facilities due to the rising difficult economic, environmental, and social problems, have led to a much more rigorous shared use of the existing transmission facilities by utilities and independent power producers (IPPs). Based on operating drawbacks of the transmission system and control capabilities of FACTS technology, technical feasibility of applying FACTS devices to boost ATCs are analysed and identified.The ATC is computed for various transactions using Continuous Power Flow method on IEEE 14-bus test system and IEEE 24-reliability test system during normal and contingency cases considering line thermal limit as well as bus voltage limit. The enhancement of ATC using TCSC or SVC is studied and demonstrated with IEEE14-bus test system and

IJARSE
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IEEE24 reliability test system during normal as well as contingency cases.The location and control parameter of TCSC and SVC in the system also affects the enhancement of ATC. Implementation of the proposed Real code Genetic Algorithm has performed well when it is used to determine the location and compensation level of TCSC or SVC with the aim of maximizing the Available Transfer Capability. From the results, it is shown that installing SVC as FACTS device will improve voltage profile as well as resulting ATC enhancement, whereas TCSC can improve ATC in both thermal dominant case and voltage dominant case. Finally, it is clearly shows from the results that TCSC is more effective than SVC in improving ATC under both normal and contingency conditions.

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