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# OPTIMAL LOCATION OF TCSC AND SVC FOR ATC ENHANCEMENT IN A DEREGULATED ENVIRONMENT USING REAL 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. ATC can be limited usually by heavily loaded circuits and buses with relatively low voltages. 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, it is worthwhile to investigate the impact of FACTS controllers on the ATC. This paper focuses on the evaluation of the impact of TCSC and SVC as FACTS devices on ATC and its enhancement during with and without line outage cases. In a competitive (deregulated) power market, optimal the location of these devices and their control can significantly affect the operation of the system and will be very important for ISO.*

*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 paper, 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 24-Bus System.*

**KEYWORDS:** ATC, TCSC, SVC, FACTS, CPF

## I. INTRODUCTION

The aim of electric industry restructuring is to promote competitive markets for electric power trading. Under new environment, the main consequence of the nondiscriminatory open-access requirement is the substantial increase in power transfers. 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. Adequate available transfer capacity (AATC) is needed to ensure all economic transactions, while sufficient ATC is needed to facilitate electricity market liquidity. It is necessary to maintain economical and secure operation over a wide range of system operating conditions and constraints. However, tight restrictions in the construction of new facilities due to the economic, environmental, and social problems, reduces the operational alternatives. It may sometimes lead to a situation that the existing transmission facilities are intensively used. On the other hand it can be said that power suppliers will benefit from more market opportunities with reduced possibility of congestion incorporating power systems security enhancement. Maximum use of existing transmission assets will be more profitable for transmission system owners; and customers will receive better services with reduced prices [8]. Various ATC boosting approaches have been experienced via adjusting generators' terminal voltages, under load tap changers (ULTCs) and rescheduling generator outputs. Based upon the NERC's definition of ATC and its determination [6], transmission network can be restricted by thermal, voltage and stability limits. On the other hand, it is highly recognized that, with the capability of flexible power flow [9], FACTS technology has introduced a severe impact to the transmission system utilization with regards to those three constraints. From the steady state power flow viewpoint, networks do not normally share power in proportion to their ratings, where in most situations, voltage profile cannot be smooth. 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. Theoretically FACTS devices can offer an effective and promising alternative to conventional methods of ATC enhancement. They will provide new control facilities, both in steady state power flow control and dynamic stability control [10]. Controlling power flow in electric power systems without generation rescheduling or topological changes can improve the network performance considerably. With suitable location, the effect of a TCSC and SVC on the ATC enhancement are studied and demonstrated through case studies. It is shown that installing SVC in the proper location will improve voltage profile as well as ATC, and TCSC will improve the ATC.The main objective of the paper is to enhance the Available Transfer Capability (ATC) from Generating/ Source area to Sink area in a De-regulated environment system using Continuous Power Flow method during normal and contingency cases with optimal location and control parameter of FACTs Devices such as TCSC or SVC on IEEE 24 reliability test system. Real-code Genetic Algorithm is used to determine location and control parameter of TCSC or SVC. ATC is dependent on many factors, such as the base case of system operation, system operation limits, network configuration, specification of contingencies etc. FACTs technology has a severe impact to the transmission system utilization with regards to those constraints on ATC. Hence, maximum use of existing transmission assets will be more profitable for Transmission System Operators (TSO) and customers will receive better services with reduced prices.

## II. Available Transfer Capability

In a deregulated power system structure, power producers and customers share a common transmission network for wheeling power from the point of generation to the point of consumption. All parties in this open access environment may try to produce the energy from the cheaper source for greater profit margin, which may lead to overloading and congestion of certain corridors of the transmission network. This may result in violation of line flow, voltage and stability limits and thereby undermine the system security. Utilities therefore need to determine adequately their "Available Transfer Capability (ATC)" 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].

The ATC of a transmission network has been defined as the unutilized transfer capability of the 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 can be committed only when sufficient ATC is available for that interface. Thus, such transfer capability can be used for reserving transmission services, scheduling firm and non-firm transactions and for arranging emergency transfers between seller bus/areas or buyer bus/areas of an interconnected power system network. ATC among areas of an interconnected power system network and also for critical transmission paths between areas are required to be continuously computed, updated and posted to OASIS following any change in the system conditions

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.

## III. ATC Computational Methods

The ATC is calculated by the following methods.

1. Method based on Continuation power flow (CPF).
2. Method based on distribution factors.

The method based on the Continuation Power Flow incorporates the limits of reactive power flows, voltage limits as well as voltage collapse and line flow limits. However, with this method the computational effort and time requirement are large.

The method based on DC power transfer distribution factors utilizes the DC power flow based formulation. Computation of ATC by this method is very simple and fast. However, this method gave more optimistic results.

The method based on AC power transfer distribution factors is a simple and efficient non-iterative method to calculate ATC under bilateral and multilateral contracts.

### 3.1 Algorithm for ATC Calculation Using CPF

(i) a) Read the system line data and bus data

**System data:** From bus, To bus, Line resistance, Line reactance, half line charging, Off nominal turns ratio, maximum line flows.

**Bus data**: Bus no, Bus type, $P_{gen}$, $Q_{gen}$, $P_{Load}$, $Q_{Load}$, $P_{min}$, $P_{max}$, $V_{sp}$ shunt capacitance data.

b) Cal $P_{shed}(i)$, $Q_{shed}(i)$, for i=1 to n
Where $P_{shed}(i)= P_{gen}(i)-P_{Load}(i)$
$Q_{shed}(i)= Q_{gen}(i)-Q_{Load}(i)$
c) Form $Y_{bus}$ using sparsity technique
(ii) a) iter=1 iteration count
b) Set $|\Delta P_{max}| = 0$ and $|\Delta Q_{max}| = 0$
c) Calculate $P_{cal}(i) = \sum_{q=1}^{n} |V_i||V_q||Y_{iq}| \cos(\delta_{iq} - \theta_{iq})$
$Q_{cal}(i) = \sum_{q=1}^{n} |V_i||V_q||Y_{iq}| \sin(\delta_{iq} - \theta_{iq})$
d) Calculate
P (i) = $P_{shed}(i) - P_{cal}(i)$
Q (i) = $Q_{shed}(i) - Q_{cal}(i)$
for i=1 to n
Set $P_{slack}=0.0$, $Q_{slack}=0.0$
e) Calculate $|\Delta P_{max}|$ and $|\Delta Q_{max}|$ form [Δp] and [ΔQ] vectors

f) Is $|\Delta P_{\max}| \le \in$ and $|\Delta Q_{\max}| \le \in$
If yes go to step (vii), problem converged case
Form Jacobian elements
a) Initialize A[i][j]=0,for i=1 to 2n+2
j=1 to 2n+2
b) Form diagonal elements for i=1 to n

$$H_{pp} = \frac{\partial P_p}{\partial \delta_p} = -Q_p - B_{pp}|V_p|^2$$

$$N_{pp} = \frac{\partial P_p . |V_p|}{\partial V_p} = P_p + G_{pp}|V_p|^2$$

$$M_{pp} = \frac{\partial P_p}{\partial \delta_p} = P_p - G_{pp}|V_p|^2$$

$$L_{pp} = \frac{\partial Q_p |V_p|}{\partial V_p} = Q_p - B_{pp}|V_p|^2$$

c) Formation of off diagonal elements

$$H_{pq} = \frac{\partial P_p}{\partial \delta_p} = |V_p||V_q|(G_{pq} \sin\delta_{pq} - B_{pq}\cos\delta_{pq})$$

$$N_{pq} = \frac{\partial P_p |V_q|}{\partial V_q} = |V_p||V_q|(G_{pq}\cos\delta_{pq} + B_{pq}\sin\delta_{pq})$$

$$M_{pq} = \frac{\partial Q_p}{\partial \delta_q} = -N_{pq}$$

$$L_{pq} = \frac{\partial Q_p |V_q|}{\partial V_q} = H_{pq}$$

d) Modification of Jacobian elements for slack bus and generator buses For slack bus
$H_{pp} = 10^{20}$
$L_{pp} = 10^{20}$
For PV buses $L_{pp} = 10^{20}$
e) Form right hand side vector
B[i] = ΔP[i], B [i+n] = ΔQ[i]
for i=1 to n Jacobian correction mismatch vector
(iv) Use Gauss-elimination method for solving $[A][\Delta X] = [B]$ Update the phase angle and voltage magnitudes for i=1 to n
$\delta_i = \delta_i + \Delta X_i$
$V_i = V_i + \{\Delta X_{i+n}\} V_i$
(v)One iteration over Advance iteration count iter=iter+1, If (iter>itermax) go to step (ii) (b)Else go to step (vi).
(vi) NR is not converged in "itermax" iterations
(vii) NR is converged in 'iter' iterations calculate
a. Line flows
b. Bus powers, Slack bus power.
c. Print the converged voltages, line flows and powers.
(viii) Read the sending bus (seller bus) *m* and the receiving bus (buyer bus) *n*.
(ix) Assume some positive real power injection change Δtp (=0.1) i.e. λ -factor at seller bus-*m* and negative injection Δtp (=0.1) i.e. λ -factor at the buyer bus-*n* and form mismatch vector.
(x) Repeat the load flow (i.e., from steps (ii) to (vii)) and from the new line flows check whether any of the line is overloaded. If yes stop the repeated power flow else go to (ix).
(xi) The maximum possible increment achieved above base-case load at the sink bus is the ATC.

## IV. Modeling of TCSC and SVC

### 4.1 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 [11]. Fig. 1 shows a transmission line incorporating a TCSC.

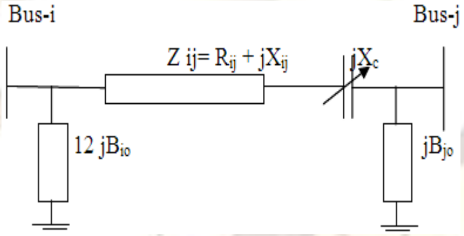

Fig. 1: Equivalent circuit of a line with TCSC

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.

### 4.2 Modeling of SVC

The shunt compensator SVC is simply a static capacitor/reactor with susceptance $B_{svc}$ [12]. Fig. 2 shows the equivalent circuit of the SVC can be modeled as a shunt-connected variable susceptance $B_{SVC}$ at bus-i.

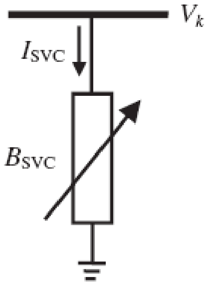

Fig. 2: Variable shunt susceptance.

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

$$Q_{svc} = B_{svc} V^2 \quad (3.9)$$

Where V is the voltage magnitude of the bus at which the SVC is connected. Fig. 3 shows the steady-state and dynamic voltage-current characteristics of the SVC portion of the system. In the active control range, current/ susceptance and reactive power is varied to regulate voltage according to a slope (droop) characteristic. The slope value depends on the desired voltage regulation, the desired sharing of reactive power production between various sources, and other needs of the system. The slope is typically 1-5%. At the capacitive limit, the SVC becomes a shunt capacitor. At the inductive limit, the SVC becomes a shunt reactor (the current or reactive power may also be limited). The response shown by the dynamic characteristic is very fast (few cycles) and is the response normally represented in transient stability simulation. Some SVCs have a susceptance/current/reactive power regulator to slowly return the SVC to a desired steady-state operating point. This prevents the SVC from drifting towards its limits during normal operating conditions, preserving control margin for fast reaction during disturbances. During normal operation, voltage is not regulated unless the voltage exceeds a dead band determined by the limits on the output of the susceptance regulator.

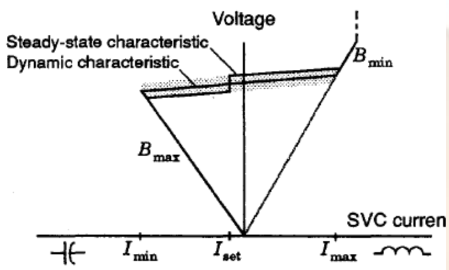

Fig. 3: SVC static characteristics at high voltage bus.

## V. Algorithm RGA for enhancement of ATC using FACTs Devices

i) Read the power system data

a) Read system line and bus data.

**System data**: From bus, To bus, line resistance, line reactance, half –line charging susceptance, off nominal turns ratio, maximum line flow.

**Bus data**: Bus no, Bus type, $P_{gen}$, $Q_{gen}$, $P_{load}$, $Q_{load}$, $P_{min}$, $P_{max}$, $V_{sp}$ Shunt capacitor data.

b) Read data for genetic operations i.e ***population size, elitism probability, cross-over probability, mutation probability***

c) Read no. of control variables i.e. TCSC/SVC location and reactance/susceptance

d) Read maximum line flow limits, load bus voltage limits.

e) Read the sending bus (seller bus) *m* and the receiving bus (buyer bus) *n*.

f) Calculate $P_{shed}(i)$, $Q_{shed}(i)$, for i=1 to no. of buses Where $P_{shed}(i)=P_{gen}(i)-P_{load}(i)$
$Q_{shed}(i)=Q_{gen}(i)-Q_{load}(i)$

g) Form $Y_{bus}$ using sparsity technique

h) E=complex ($V_{sp}$,0)

(i) Generate population size of chromosomes randomly

(ii) gen=1, generation count

(iii) (a) k1=1, chromosome count

(b) Using the line no./bus no. and reactance/susceptance information modify Ybus

(iv) Calculate ATC using NR repeated power flow

(v) Calculate fitness (k1) = ATC (i.e. maximization)

(vi) If (k1< population size)
k1=k1+1
go to (iv)(b)
Else go to (vii)

(vii) Check the termination criteria i.e. the difference between first chromosome fitness value and last chromosome fitness value will be certain tolerance. If the condition is satisfied stop the process otherwise go to step (ix)

(viii) Arrange chromosomes in descending order of their fitness values

(ix) Copy elitism probability of chromosomes to next generation and perform roulette wheel reproduction technique for parent selection.

(x) If (r<Pc) perform cross over to obtain children of next generation using the following equation, where r is a randomly generated number between 0 and 1 and Pc is the cross over probability.

where x, y are the two parents, x', y' are their two offspring. $\lambda_1$ and $\lambda_2$ is obtained by a uniform random number generator between the range (0~l).

$x^I = \lambda_1 x+\lambda_2 y$
$y^I = \lambda_1 y+\lambda_2 x$
$\lambda_1+\lambda_2=1,$
$\lambda_1,\lambda_2>0$

(xi) Perform mutation i.e.

If ($r_1$<Pm) perform mutation to inject new information using the following equation, where $r_1$ is a random number between 0 and 1, and Pm is the mutation probability. Finally, replace old population by new population.

$$x_k' = x_k + r(b_k - x_k)\left(1 - \frac{t}{T}\right)^b$$

Or

$$x_k' = x_k + r(x_k - a_k)\left(1 - \frac{t}{T}\right)^b$$

(xii) If (gen < genmax)
gen = gen+1 and go to step (iv)(a)
Else go to step (xiv)

(xiii) Print optimized values i.e. line no, compensation and ATC values for each transaction.

## VI.Case studies and Discussion

The Available Transfer Capability (ATC) are computed for a set of source/sink transfers on IEEE 24-bus system. The ATC margin can be further increased by proper location and control parameter of FACTs devices. In this paper, 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 paper, 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 24-bus system are given in appendix A .

### 6.1 IEEE 24-bus Reliability Test System

### 6.1.1 without line outage case

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 24-bus system without FACTs device.

Table-1: 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 |

### 6.1.1.1 Incorporation of TCSC

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) |
|---|---|---|---|---|
| 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-2. It shows that with the flow control function TCSC increased the ATC significantly

### 6.1.1.2 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-3. It shows that with the flow control function SVC increased the ATC significantly.

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) |
|---|---|---|---|---|
| 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 |

### 6.1.2With 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. Fig. 4 Shows a graph voltage profile for the IEEE 24-bus system with and without outage cases.

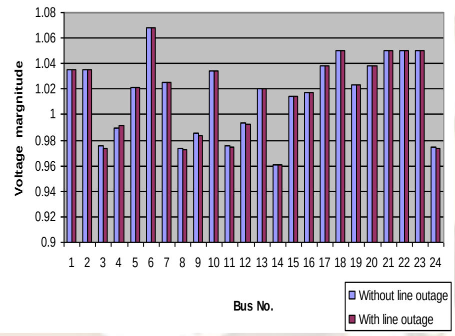

Fig. 4: Bus voltage profile for without and with line outage cases

Table-4 shows the ATCs for IEEE 24-bus system without FACTs device, when line-8 is physically removed.

Table-4: 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 |

### 6.1.2.1Incorporation 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% ($K_d$). 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-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 |

### 6.1.2.2 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-6. It shows that with the flow control function SVC increased the ATC significantly during line-8 outage.

Table-6: ATCs after incorporating SVC during line-8 outage

| **Source /Sink bus no.** | **ATC without SVC (M.W)** | **ATC with SVC (M.W)** | **SVC Loca -tion** | **Compensation (p.u)** |
|---|---|---|---|---|
| 23/15 | 765.00 | 785.4 | Bus-10 | 0.084 |
| 22/9 | 385.00 | 392.7 | Bus-23 | 0.099 |
| 22/5 | 214.20 | 219.3 | Bus-14 | 0.092 |
| 21/6 | 86.70 | 88.20 | Bus-6 | 0.081 |
| 18/5 | 214.20 | 224.4 | Bus-16 | 0.098 |

**Results after Simulation of TCSC and SVC using GA**

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THE NUMBER OF BUSES ARE 24
THE NUMBER OF LINES ARE 38
THE SLACK BUS 13
THE CONVERGENCE CRITERION IS BUS 0.001000
THE MAXIMUM NUMBER OF ITERATIONS ARE 350

24th line limit has exceeded
ATC IS 9.486000 MW for transaction between bus 23and 15

V(1)=1.035000 /_-0.320237
V(2)=1.035000 /_-0.326183
V(3)=0.985110 /_-0.245682
V(4)=0.991301 /_-0.413867
V(5)=1.019500 /_-0.339462
V(6)=1.064396 /_-0.376491
V(7)=1.025000 /_-0.639190
V(8)=0.971774 /_-0.544103
V(9)=0.983208 /_-0.242075
V(10)=1.030092 /_-0.302447
V(11)=0.978681 /_-0.118518
V(12)=0.979423 /_-0.053399
V(13)=1.020000 /_0.000000
V(14)=0.966795 /_-0.071397
V(15)=1.014000 /_-0.084595
V(16)=1.017000 /_0.001367
V(17)=1.039652 /_0.042192
V(18)=1.050000 /_0.048564
V(19)=1.011010 /_0.112162
V(20)=1.029170 /_0.239954
V(21)=1.050000 /_0.047355
V(22)=1.050000 /_0.158783
V(23)=1.050000 /_0.319600
V(24)=0.996268 /_-0.066086
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## Conclusions

In deregulated power systems, available transfer capability (ATC) analysis is presently a critical issue either in the operating or planning because of increased area interchanges among utilities. Sufficient ATC should be guaranteed to support free market trading and maintain an economical and secure operation over a wide range of system conditions. However, tight restrictions on the construction of new facilities due to the increasingly difficult economic, environmental, and social problems, have led to a much more intensive shared use of the existing transmission facilities by utilities and independent power producers (IPPs). Based on operating limitations of the transmission system and control capabilities of FACTS technology, technical feasibility of applying FACTS devices to boost ATCs are analyzed 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 improvement of ATC using TCSC or SVC is studied and demonstrated with IEEE 14-bus test system and IEEE 24 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 a FACTS device will improve voltage profile as well as resulting ATC enhancement, where as 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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