Recent Trends in Power, Control and Instrumentation Engineering, PCIE

Available Transfer Capability Enhancement with TCSC using Modified GA Approach in Deregulated Power Systems

[1]Dr. T.Nireekshana and [2]Dr.G.Kesava Rao
[1] Asst. Professor, EEE Department, VNR VJIET, Hyderabad, INDIA
nireekshana_t@vnrvjiet.in
[2]Sr. Professor, EEE Department, KL University, Guntur, A.P, INDIA
deanvoice@yahoo.co.in

***Abstract*—The use of TCSC to maximize Available Transfer Capability generally defined as the maximum power transfer transaction between one area to another area by limiting the constraints. Contingency analysis technique is being widely used to predict the effect of outages in power systems, like failures of equipment, transmission line etc. Practically, only selected contingencies will lead to severe conditions in power system like violation of voltage and active power flow limits. The contingency selection by calculating two kinds of performance indices; active power performance index for single transmission line outage have been done with the help of NR Method in Mi-POWER environment. A modified Genetic Algorithm approach is used as the optimization tool to determine the location as well as the parameters of TCSC simultaneously. In IEEE 30 Bus System the optimal location of the device can be decided by a new approach of Genetic Algorithm Method to enhance the ATC.**

***Index Terms*— Contingency analysis, Available transfer Capability, Thyristor Controlled Series Compensator, new approach to Genetic Algorithm.**

I. Introduction

Contingency analysis is becoming an essential task for power system planning and operation. Power system security analysis forms an integral part of modern energy management system. Security is a term used to reflect a power systems ability to meet its load without unduly stressing its apparatus or allowing variables to stray from prescribed range under the apparatus or allowing variables to stray from prescribed range under certain pre-specified credible contingencies. The contingencies are in the form of network outage such as line or transformer outage or in the form of equipment outage. The outage considered here is line outages. Outages which are important from limit violation view point are branch flow for line security or MW security and bus voltage magnitude for voltage security.

The advantage of this method it is money-making. In the context of deregulation and competitive market determination of the Available Transfer capability at any instant of time .The second in the context of optimum usage of existing resources and demand for quality power, study and implementation of means and methods to satisfy the requirement. This aspect is made true and feasible by the developments in Power

Grenze ID: 02.PCIE.2015.3.504

Electronics – FACTS devices. FACTS device like Thyristor controlled series compensator (TCSC) can be employed to increase the flows in loaded lines, results in a low system loss and improved stability of network.

II. Enrichment of ATC Using FACTS Device

According to IEEE, FACTS, which is abbreviation for Flexible AC Transmission Systems, is defined as follows: “alternating current transmission systems incorporating power electronics based and other static controllers to enhance controllability and APTC” units.

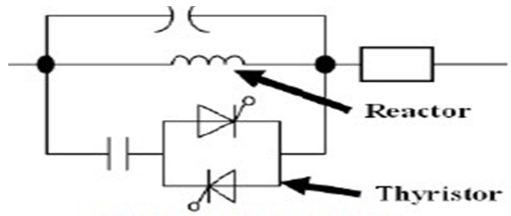

Fig.1: Simple Diagram of Thyristor Control Series Capacitor

TCSC can be defined as “A capacitive reactance compensator which consists of series capacitor bank shunted by a thyristor controlled reactor in order to provide a smoothly variable series capacitive reactance”.
Thyristor controlled series compensator (TCSC) are connected in series with transmission lines. The net transfer reactance is reduced and leads to an increase in power transfer capability. The voltage profile as also improved due to the insertion of series capacitance in the line. Series compensation is usually a preferable alternative for increasing power flow capability of lines as compared to shunt compensators as the ratings required for series compensators are significantly smaller [7-10].

Problem Formulation:
Available Transfer Capability is defined as, the maximum amount of additional MW transfer possible between two parts of a power system.
ATC can be expressed as

$$ATC = \left(\sum_{i \in load} P_{gi} - \sum_{i \in load} P_{dj} \right) - \left(\sum_{i \in generation} P_{gi} - \sum_{i \in generation} P_{dj} \right) \tag{1}$$

Where $\sum_{i \in load} P_{gi}$ is total power generated in load area

$\sum_{i \in load} P_{dj}$ is total demand is used in load area

$\sum_{i \in generation} P_{gi}$ is total power generated in generation area

$\sum_{i \in generation} P_{dj}$ is total demand used in generation area .

Available Transfer Capability problem can be mathematically formulated as follows:
Maximize

$$P_i = \sum_{j \in i} P_{kj} \tag{2}$$

Subjected to

$$P_i - \sum_{j \in i} V_i V_j Y_{ij} \cos(\theta_{ij} + \delta_i - \delta_j) = 0 \tag{3}$$

$$Q_i - \sum_{j \in i} V_i V_j Y_{ij} Sin(\theta_{ij} + \delta_i - \delta_j) = 0 \tag{4}$$

$$P_g^{\min} \le P_g \le P_g^{\max} \tag{5}$$

$$Q_g^{\min} \le Q_g \le Q_g^{\max} \tag{6}$$

$$S_{ij} \le S_{ij}^{\max} \tag{7}$$

$$V_i^{\min} \le V_i \le V_i^{\max} \tag{8}$$

The objective function is same and subject to the following device constraints in addition to the above equality and inequality constraints

TCSC constraints:

$$X_{TCSC_i}^{\min} \le X_{TCSC_i} \le X_{TCSC_i}^{\max} \qquad i=1, 2, \text{----}\ n_{TCSC} \tag{9}$$

X_{TCSC_i} = reactance of *TCSC* at line *i*

$X_{TCSC_i}^{\min}$ = Minimum reactance of *TCSC* at line *i*

$X_{TCSC_i}^{\max}$ = Maximum reactance of *TCSC* at line *i*

n_{TCSC} = number of *TCSC's*

III. Proposed Genetic Algorithm Approach

In this paper a new approach of GA is proposed for the enhancement of ATC in the power system using a series FACTS device TCSC which gives a fast result with high accuracy. The main deference in this approach is one combination is fixed and the another combination will be varied so that the time for the convergence will be reduced and the accuracy in fitness function will be increased.

Step by step procedure for proposed GA approach

Step1: Consider 10 or 20 Pseudo random numbers from 1to 8.

Step2:These are 1,3,5,1,2,4,6,7,9,5,8,3,10,12,3,10,7,11,5,4.

Step3: Apply GA Approach to obtain the best fitness function.

Step4: In the IEEE30 Bus System the Fitness function is the best possible combination of X1 (%), X2 (%) and X3(%). This combination will give the lowest loss as compared to the all off springs.

Step5:In this Proposed Algorithm the Applied Device is kept at maximum Enhancement and the left 2 TCSC the genetic Algorithm Is been applied.

TABLE I: APPLICATION OF G.A FOR IEEE 30-BUS SYSTEM

S. No	(%) Series Compensation	Binary Coding	S. No	(%) Series Compensation	Binary Coding
1	10	0000	9	55	1000
2	20	0001	10	57	1001
3	25	0010	11	61.7	1010
4	30	0011	12	62	1011
5	45	0100	13	65	1100
6	47	0101	14	70	1101
7	50	0110	15	75	1110
8	54.5	0111	16	90	1111

IV. Contingency ANAYLSIS

Contingency Analysis (CA) is one of the "security analysis" applications in a power utility control center that differentiates an Energy Management System (EMS). Its purpose is to analyze the power system in order to identify the overloads and problems that can occur due to a "contingency". Contingency analysis is abnormal condition in electrical network. It put whole system or a part of the system under stress. It occurs due to sudden opening of a transmission line, generator tripping, and sudden change in generation, sudden change in load value. Contingency analysis provides tools for managing, creating, analyzing, and reporting lists of contingencies and associated violations. Line contingency and generator contingency are generally most common type of contingencies. These contingencies mainly cause two types of violations.

A. Low Voltage Violations - This type of violation occurs at the buses. This suggests that the voltage at the bus is less than the specified value. This operating range of voltage at any bus is generally 0.95-1.05 p.u. Thus if the voltage falls below 0.95 p.u then the bus is said to have low voltage. If the voltage rises above the 1.05 p.u then the bus is said to have a high voltage problem. It is known that in the power system network generally reactive power is the reason for the voltage problems.
B. Line MVA Limits Violations – This type of contingency occurs in the system when the MVA rating of the line exceeds given rating. This is mainly due to the increase in the amplitude of the current flowing in that line. The lines are designed in such a way that they should be able to withstand 125% of their MVA limit. Based on utility practices, if the current crosses the 80-90 % of the limit, it is declared as an alarm situation

V. RESULTS

The transmission lines between the corresponding interconnecting buses of two areas are called tie-lines. Now, in this system there are six tie-lines. Three major tie-lines are selected among all of them. The criterion for this is the active power flow through the line. Major tie-lines plays a significant role in the enhancement of available transmission capacity since the active power flowing through these lines is higher when compared to the other tie-lines. Thus, the major tie-lines in this system are the tie-lines between the buses 12 & 15, 9 & 10 and 16& 17.

TABLE II: 6 TIE-LINES FROM THE 2-AREA IEEE 30 BUS SYSTEM

Tie-Line	Location of TCSC	ATC	Power Flow Direction
1	6&10	3.615MW	AREA1 TO AREA 2
2	9&10	6.320MW	AREA1 TO AREA 2
3	12&14	5.474MW	AREA1 TO AREA 2
4	12&15	9.922MW	AREA1 TO AREA 2
5	16&17	4.512MW	AREA1 TO AREA 2
6	28&27	-6.216MW	AREA1 TO AREA 2

The system is divided into two areas such that, the generation is more than the local load demand in area1 and generation is less than the local load demand in area2. This indicates that the power flow direction is from area1 to area2. The algebraic sum of power flow gives the ATC power transfer from area1 to area2. It is observed to be **23.627MW**.

TABLE III: ATC WHEN GENERATION AND LOADS ARE DOUBLED

Tie-Line	Location of TCSC	ATC	Power Flow Direction
1	6&10	11.622MW	AREA1 TO AREA 2
2	9&10	20.21MW	AREA1 TO AREA 2
3	12&14	16.437MW	AREA1 TO AREA 2
4	12&15	41.990MW	AREA1 TO AREA 2
5	16&17	19.040MW	AREA1 TO AREA 2
6	28&27	9.007MW	AREA1 TO AREA 2

The system is divided into two areas such that, the generation is more than the local load demand in area1 and generation is less than the local load demand in area2. This indicates that the power flow direction is from area1 to area2. The algebraic sum of power flow gives the ATC power transfer from area1 to area2. It is observed to be **118.417MW.**
Case (1): Placing **TCSC Device in each Major Tie-Line**
MAJOR TIE-LINE-1: **Placement of TCSC in 12 to 15 buses**

TABLE IV: TCSC PLACEMENT BETWEEN THE 12 &15 BUSES

Tie-Line	Location of TCSC	ATC	Power Flow Direction
1	6&10	19.886MW	AREA1 TO AREA 2
2	9&10	34.769MW	AREA1 TO AREA 2
3	12&14	20.778MW	AREA1 TO AREA 2
4	12&15	80.822MW	AREA1 TO AREA 2
5	16&17	44.603MW	AREA1 TO AREA 2
6	28&27	-46.682MW	AREA1 TO AREA 2

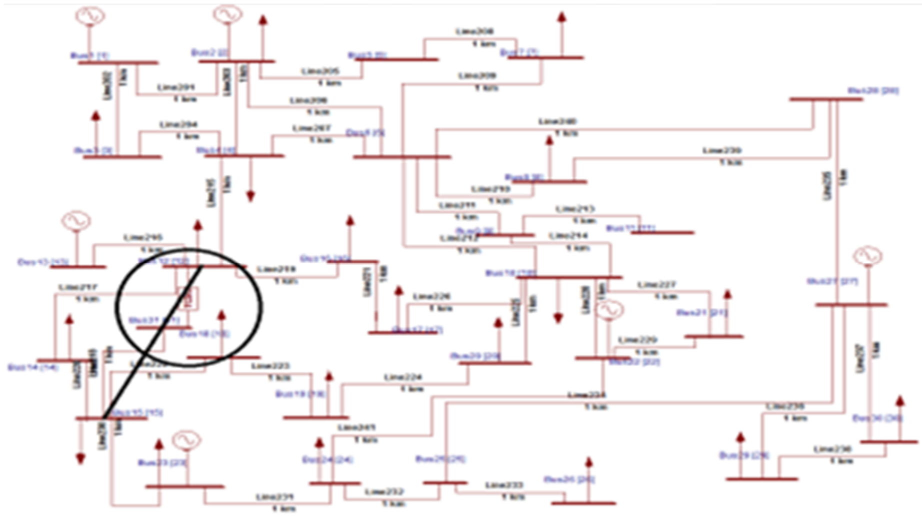

Fig 2: Placement of TCSC in 12 to 15 buses

Now, when the TCSC is implemented in the tie-line between the buses 12 & 15, the power flow through this line is enhanced from **118.417MW** to **154.176MW**. The ATC power transferred from area1 to area2 is obtained from the algebraic sum of power flows through all the tie-lines at this value.

MAJOR TIE-LINE-2: **Placement of TCSC in 9 to 10 buses**

TABLE V: TCSC PLACEMENT BETWEEN THE 9 &10 BUSES

Tie-Line	Location Between	ATC	Power Flow Direction
1	6&10	72.212MW	AREA1 TO AREA 2
2	**9&10**	**84.215MW**	**AREA1 TO AREA 2**
3	12&14	27.644MW	AREA1 TO AREA 2
4	12&15	42.965MW	AREA1 TO AREA 2
5	16&17	57.302MW	AREA1 TO AREA 2
6	28&27	-134.28MW	AREA1 TO AREA 2

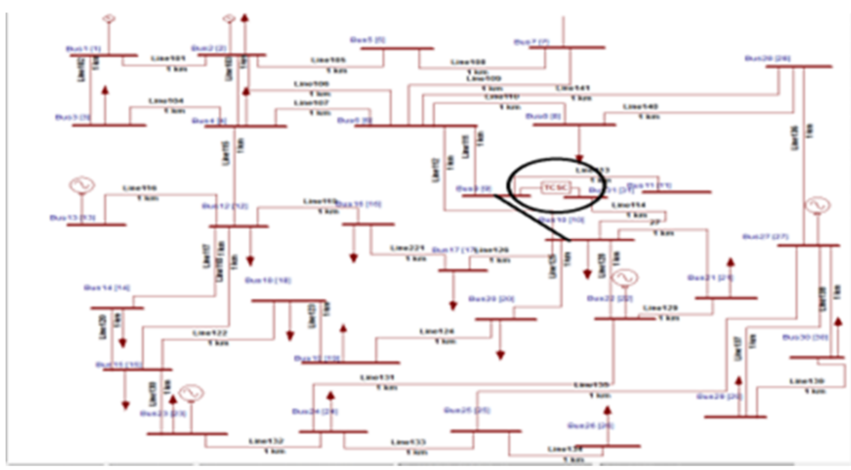

Fig 3: Placement of TCSC in 9 to 10 buses

Now, when the TCSC is implemented in the tie-line between the buses 9 & 10, the power flow through this line is enhanced from **118.417MW** to **150.058MW**. The ATC power transferred from area1 to area2 is obtained from the algebraic sum of power flows through all the tie-lines at this value.

MAJOR TIE-LINE-3: **Placement of TCSC in 16 to 17 buses**

TABLE VI: TCSC PLACEMENT BETWEEN THE 16 &17 BUSES

Tie-Line	Location between the Buses	ATC	Power Flow Direction
1	6&10	16.953MW	AREA1 TO AREA 2
2	9&10	10.557MW	AREA1 TO AREA 2
3	12&14	20.619MW	AREA1 TO AREA 2
4	12&15	57.964MW	AREA1 TO AREA 2
5	16&17	29.641MW	AREA1 TO AREA 2
6	28&27	-6.025MW	AREA1 TO AREA 2

When the TCSC is implemented in the tie-line between the buses 16 & 17, the power flow through this line is enhanced from **118.417MW** to **129.709MW**. The ATC power transferred from area1 to area2 is obtained from the algebraic sum of power flows through all the tie-lines at this value.

Case (2): Applying 3 TCSC Devices in among the 3 Major Tie-Lines by using Genetic Algorithm.

The TCSC are implemented in all the three major tie-lines at the same time and the optimal values of TCSC are obtained through Genetic Algorithm. These values are implemented and the net power transfer from area1 to area2 is obtained as follows.

TABLE VII: TCSC PLACEMENT AT THREE MAJOR TIE-LINES USING G.A

Tie-Line	Location Between The Buses	ATC	Power Flow Direction
1	6&10	10.58 MW	AREA1 TO AREA 2
2	9&10	38.562 MW	AREA1 TO AREA 2
3	12&14	18.809 MW	AREA1 TO AREA 2
4	12&15	75.423 MW	AREA1 TO AREA 2
5	16&17	31.244 MW	AREA1 TO AREA 2
6	28&27	-36.752 MW	AREA1 TO AREA 2

Now, when the TCSC is implemented in the all Major Tie-Lines, the power flow through this line is enhanced from **118.417MW** to **137.866MW**. The ATC power transferred from area1 to area2 is obtained from the algebraic sum of power flows through all the tie-lines at this value.

Case (3): Applying 3 TCSC Devices in among the 3 Major Tie-Lines by a new approach to Genetic Algorithm.

The TCSC are implemented in all the three major tie-lines at the same time and the optimal values of TCSC are obtained through Genetic Algorithm.

TABLE VIII: TCSC PLACEMENT AT THREE MAJOR TIE-LINES BY APPROACH TO G.A

Tie-Line	Location Between The Buses	ATC	Power Flow Direction
1	6&10	17.199 MW	AREA1 TO AREA 2
2	9&10	43.865 MW	AREA1 TO AREA 2
3	12&14	21.886 MW	AREA1 TO AREA 2
4	12&15	86.357 MW	AREA1 TO AREA 2
5	16&17	41.244 MW	AREA1 TO AREA 2
6	28&27	-33.173 MW	AREA1 TO AREA 2

Now, when the TCSC is implemented in the all Major Tie-Lines, the power flow through this line is enhanced from **118.417MW** to **178.066MW**. The ATC power transferred from area1 to area2 is obtained from the algebraic sum of power flows through all the tie-lines at this value.

Case (4): Contingency analysis at line outage at 12-15 buses

The TCSC implemented in 12 to 15 buses. Due to violating the constraints line is facing Outage from operating in the interconnected power system. So, implementing of TCSC in 9 to 10 bus and the concept of ATC will be implemented in these criteria.

Case (4.1): Contingency analysis without TCSC device implementation

Now, when the transmission line is been outage in between 12 to 15 bus, the active power flow is **121.954MW** .The ATC power transferred from area1 to area2 is obtained from the algebraic sum of power flows through all the tie-lines at this value.

TABLE IX: SUMMARY OF ATC'S FOR CONTINGENCY ANALYSIS

Tie-Line	Location Between	ATC	Power Flow Direction
1	6&10	15.62MW	AREA1 TO AREA 2
2	9&10	27.31MW	AREA1 TO AREA 2
3	12&14	39.529MW	AREA1 TO AREA 2
4	12&15	LINE OUTAGE	
5	16&17	26.52MW	AREA1 TO AREA 2
6	28&27	12.975MW	AREA1 TO AREA 2

Case (4.2): Contingency analysis with TCSC device implementation in between 9 to10 buses

TABLEX: CONTINGENCY ANALYSIS FOR IMPLEMENTING TCSC IN 9-10 BUS

Tie-Line	Location Between	ATC	Power Flow Direction
1	6&10	17.586MW	AREA1 TO AREA 2
2	9&10	30.748MW	AREA1 TO AREA 2
3	12&14	51.80.MW	AREA1 TO AREA 2
4	12&15	LINE OUTAGE	
5	16&17	45.342MW	AREA1 TO AREA 2
6	28&27	19.339MW	AREA1 TO AREA 2

Now, when the TCSC is implemented in the all Major Tie-Lines, the power flow through this line is enhanced from **121.954MW** to **165.339MW**. The ATC power transferred from area1 to area2 is obtained from the algebraic sum of power flows through all the tie-lines at this value.**Case (5): Comparative Analysis between different cases applied in IEEE 30 Bus System:**

TABLE XI: SUMMARY OF ATC'S FOR IEEE 30 BUS SYSTEM

S.NO	CASE STUDY	ATC (MW)
1.	Placement of TCSC in 12 to 15 buses	154.176
2.	Placement of TCSC in 9 to 10 buses	150.058
3.	Placement of TCSC in 16 to 17 buses	129.709
4.	3 TCSC's are placed at a time using GA.	137.866
5.	3 TCSC's are placed at a time using a new approached GA	178.066
6.	Contingency analysis at 12-15 buses	165.339

VI. DISCUSSIONS AND CONCLUSIONS

The results are given for standard IEEE 30 Bus system. As seen from the tables, it is noticed that the results-maximize the total active power flow is by Thyristor Controlled Series Capacitor at major tie-lines. It is observed that Search Method involves a lengthy computation requiring much iteration. Computation process is high. As Genetic Algorithm didn't meet my estimated output had been implemented in a new approach to the genetic algorithm and obtained at most of my required output.

By considering IEEE30 Bus System, this contingency analysis concept by the major line will be opened (line outage) and implementing the TCSC device in the next major tie-line and the concept of ATC will be operated under the basis of power transferred and compared with the maximum output to the contingency analysis and the effect of line outage will affect a minimum amount of power transfer when compared to maximum power transfer.

REFERENCES

[1] T. Nireekshana, Dr. G. K. Rao, Dr. S. Siva Naga Raju "Enhancement of ATC in Deregulation based on Continuation Power Flow with FACTS Devices using Real-code Genetic Algorithm" International Journal of Electrical Power and Energy Systems (IJEPES), **Elsevier**, Vol. 43, Issue 1, 2012, pg: 1276-1284.

[2] Ying Xiao, Y. H. Song, Chen-Ching Liu, Y. Z. Sun," Available Transfer Capability Enhancement Using FACTS Devices" IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 18, NO. 1, FEBRUARY 2003.
[3] T. Nireekshana, Dr. G. Kesava Rao Dr. S. Siva Naga Raju," Enhancement of ATC with STATCOM using Cat Swarm Optimization", ELSVIER TRANSACTIONS ON Proc. of Int. Conf. on Control, Communication and Power EngineeringVOL.2,NO. 1, FEBRUARY 2013,Pg NO:[422-428].
[4] Veenavati Jagadishprasad Mishra, Manisha D. Khardenvis, "Contingency Analysis of Power System" IEEE Students Conference on Electrical, Electronics and Computer Science, 2012.
[5] Transmission Transfer Capability Task Force, "Available transfer capability Definitions and determination."North American Electric Reliability Council, NJ, June 1996.
[6] Narain G.Hingorani, Laszlo Gyugyi, "Understanding FACTS: concepts and technology of flexible AC transmission systems".
[7] Ghawghawe, N. D., Thakre, K. L., "Computation of TCSC reactance and suggesting criterion of its location for ATC enhancement", Int J Electric Power Energy System, 31:86–93, 2009.
[8] Kumar, J., and Kumar, A., "Multi-transactions ATC determination using PTDFs based approach in deregulated markets", In: Proc. annual power India conference, (INDICON), pp. 1–6, 2011.
[9] Kumar, J., and Kumar, A., "ACPTDF for multi-transactions and ATC determination in deregulated markets", Int J Electr Comput Eng (IJECE), Vol. 1(1), 71–84, 2011.
[10] Pandey, S. N., Pandey, N. K., and Shashikala Tapaswi, "Neural networkbased approach for ATC estimation using distributed computing", IEEE Transactions on power systems, Vol. 25, No. 3, pp. 1291-1300, August 2010.

BIOGRAPHY OF AUTHORS

T. Nireekshana obtained her B.Tech and M. Tech from JNT University in 2002 and 2005 respectively. She got her Ph.D in Deregulated Power Systems from JNTU Kakinada in 2015. Currently, she is working as Assistant professor in department of EEE, VNR VJIET Engineering College, Hyderabad. Her areas of interest are Power System Operation and Analysis, Power System Deregulation, Optimal Power Flow.

G. Kesava Rao obtained his PhD from Moscow Power Engineering Inst. Moscow, U.S.S.R. He worked in Institute of Technology at Banaras Hindu University, Varanasi, India in various administrative and academic positions. Currently, he is working at K.L University, Guntur, A.P., India. His fields of interest are power system deregulation and renewable energy sources.