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Optimal Location of Series FACTS Device to Reduce the Losses in a Power System

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Abstract

In recent years, continuous and reliable electric energy supply is the objective of any power system operation. Over last decade FACTS devices have become popular and are very effective solution for many power system transmission problems. FACTS controllers can be used for steady state voltage regulation and control, steady state control of power flow on a transmission line transient stability enhancement, along with this it also reduces the problem of sub synchronous resonance. In this regard, Flexible Alternative Current Transmission Systems (FACTS) devices play a key role in enhancing controllability and increasing power transfer capability of the network. Thyristor Controlled Series Compensator (TCSC) is an emerging FACTS device designated to achieve this objective. The conventional methods in solving optimization problems in power systems suffer from several limitations due to necessities of derivative existence, providing suboptimal solutions, etc. Computational Intelligence plays an important role in determining the optimal solutions for multi – objective functions. A combinatorial analysis problem in power systems can be solved by modern heuristic methods in finding optimal solution. Thus, in this paper, Genetic Algorithm, a wing of evolutionary computation encapsulated with heuristic approach, is proposed in finding optimal location of TCSC. IEEE standard 30bus system is considered to test the credibility of the proposed algorithm and the results thus obtained are subjected to analysis to determine the optimal location.

I. Introduction

The inherent power system limits restrict the power transaction which leads to the utilization of the existing transmission resources. Traditionally, fixed or mechanically switched shunt and series capacitors, reactors and synchronous generators were being used to solve much of the problem. However, there are restrictions as to the use of these conventional devices. Desired performance was not being able to achieve effectively. Wear and tear in the mechanical components and slow response were the heart of the problems. There was a greater need for the alternative technology made of solid state devices with fast response characteristics. The need was further fuelled by worldwide restructuring of electric utilities, increasing environmental and efficiency regulations and difficulty in getting permit and right of way for the construction of overhead transmission lines. The amount of electric power, which can be transmitted between two locations through a transmission network, is limited by security and stability constraints. Power flow in the lines and transformers should not be allowed to increase to a level where a random event could cause the network collapse because of angular instability, voltage instability or cascaded outages [1].

Hence, economic operation of power system along with the assurance of refined quality of power supply to consumers is a challenging task. Due to the introduction of deregulation in electricity market, installation of FACTS devices has become inevitable [3]. Because of the economic considerations, installation of FACTS controllers in all the buses or the lines in a system is not feasible. There are several sensitivity based

Doi:

methods described for finding optimal location of FACTS devices in power systems [4]. However, it is required to find the optimal location of FACTS devices by heuristic method to overcome both economical & technical barriers in accomplishing the objective. Use of Thyristor Controlled Series Compensator (TCSC) which is Flexible AC Transmission System (FACTS) device gives a number of benefits for the user of the grid, all contributing to increase the power transmission capability of new as well as existing transmission lines. These benefits include improvement in system stability, voltage regulation, reactive power balance, load sharing between parallel lines and reduction in transmission losses [2]. Optimal location of TCSC is a task assigned to Genetic Algorithm (GA) where GA is an approach to find optimal solutions for search problems through application of the principles of evolutionary biology. The optimal location of series FACTS device and series – shunt FACTS device to relieve congestion in the 57- bus system is used [7]. Different operating conditions can be simulated for determination of the optimal FACTS location [10] and also the compensation rate of TCSC can be considered for running GA program [9]. This paper is focused on optimal location of TCSC using GA for reduction of losses and to increase the power transfer capability of the transmission line in a power system. An overview of modeling of TCSC & brief description of genetic algorithm is presented in sections II and III respectively. Optimal location of TCSC using genetic algorithm is explained in section IV, which elaborates the traits of an IEEE 30-bus system under consideration. It also reveals the results obtained on applying the evolutionary strategy to solve the optimization problem. Finally, the method to locate TCSC is explained in section V.

II. Thyristor Controlled Series Compensator (Tcsc) Modeling

The IEEE TCSC a capacitive reactance compensator, consists of three main components: capacitor bank C, bypass inductor L and bidirectional thyristors SCR1 and SCR2 [4]. Series capacitive compensation is used to increase line power transfer as well as to enhance system stability. Fig. 1 shows the main circuit of a TCSC.

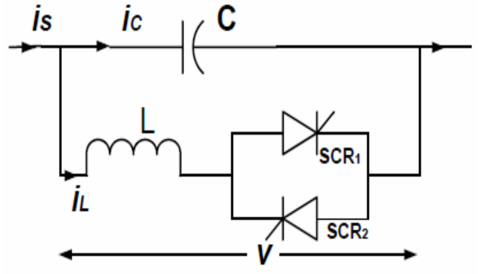

Fig. 1: Configuration of a TCSC

The firing angles of the thyristors are controlled to adjust the TCSC reactance according to the system control algorithm, normally in response to some system parameter variations. According to the variation of the thyristor firing angle, this process can be modeled as a fast switch between corresponding reactance offered to the power system. Assuming that the total current passing through the TCSC is sinusoidal, the equivalent reactance at the fundamental frequency can be represented as a variable reactance X_{TCSC}.

The TCSC can be controlled to work either in the capacitive or the inductive zones avoiding steady state resonance [4]. There exists a steady-state relationship between the firing angle α and the reactance X_{TCSC}, as described by the following equation [4]:

$$X_{TCSC}(\alpha) = \frac{X_C X_l(\alpha)}{X_l(\alpha) - X_C} \tag{1}$$

Where,

$$X_l(\alpha) = X_L \frac{\pi}{\pi - 2\alpha - \sin\alpha} \tag{2}$$

Where, α is the firing angle, XL is the reactance of inductor and Xl is the effective reactance of inductor at firing angle [4].

A model of transmission line with a TCSC connected between bus-i and bus-j is shown in Fig. 2. During steady state, the TCSC can be considered as a static reactance –jxc. The controllable reactance xc is directly used as a control variable in the power flow equations.

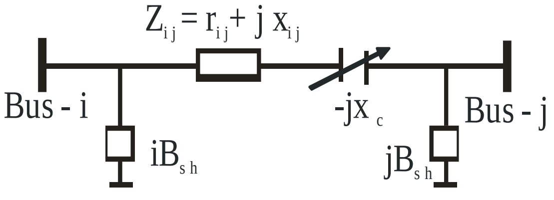

Fig. 2(a): TCSC model

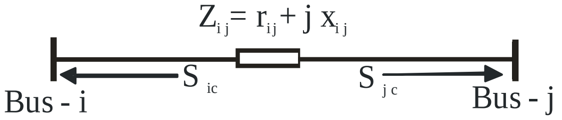

Fig. 2(b): Injection model of TCSC

The real power injections at bus-i(Pic) and bus-j(pjc) are given by the following equations[2]:

Pic=V2i ΔGij –ViVj[ΔGij cosδij + ΔBij sinδij] (3)
Pjc=V2j ΔGij –ViVj[ΔGij cosδij - ΔBij sinδij] (4)

Similarly, the reactive power injections at bus-i (Qic) and bus- j (Qjc) can be expressed as:

$Qic = - V2i\ \Delta Bij - ViVj[\Delta Gij \sin\delta ij - \Delta Bij \cos\delta ij]$ (5)

$Qjc = - V2j\ \Delta Bij + ViVj[\Delta Gij \sin\delta ij + \Delta Bij \cos\delta ij]$ (6)

Where:

$$\Delta G_{ij} = \frac{x_c\, r_{ij}\,(x_c - 2x_{ij})}{\left(r_{ij}^2 + x_{ij}^2\right)\left(r_{ij}^2 + \left(x_{ij} - x_c\right)^2\right)} \quad (7)$$

$$\Delta B_{ij} = \frac{-x_c \left(r_{ij}^2 - x_{ij}{}^2 + x_c x_{ij}\right)}{\left(r_{ij}^2 + x_{ij}^2\right)\left(r_{ij}^2 + \left(x_{ij} - x_c\right)^2\right)} \quad (8)$$

Where ΔGij and ΔBij are the changes in conductance and susceptance of the line i-j respectively.

This model of TCSC is used to properly modify the parameters of transmission lines with TCSC for optimal location.

III. Proposed Method

A. Genetic Algorithm:

Conventional methods in solving power system design, planning, operation and control problems have been extensively used for different applications. But these methods suffer from several difficulties due to necessities of derivative existence, providing suboptimal solutions, etc. In this regard, Computational intelligence (CI) methods can give better solution in several conditions and are being widely applied in the electrical engineering applications. CI is a modern tool for solving complex problems which are difficult to be solved by the conventional techniques in power system domain. Heuristic optimization techniques are general purpose methods that are very flexible and can be applied to many types of objective functions and constraints. In this research work, Genetic algorithm (GA), a main paradigm of evolutionary strategy, is applied for the optimal location of FACTS.

Genetic Algorithm is inspired by the principle of natural genetics and evolution, and mimics the process of evolution. It employs the principle of “survival of the fittest” in its search process to select and generate individuals (design solutions) that are adapted to their environment (design objectives/constraints) [4]. Therefore, over a number of generations (iterations), desirable traits (design characteristics) will evolve and remain in the genome composition of the population (set of design solutions generated each iteration) over traits with weaker undesirable characteristics It is applied to solve complex design optimization problems since it can handle both discrete and continuous variables, nonlinear objective and constraint functions without requiring gradient information [5].

In a genetic algorithm, a population of strings (called chromosomes or the genotype of the genome), which encode candidate solutions (called phenotypes) to an optimization problem, evolves towards a better solution. Solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible. The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. The algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population [6]. If the algorithm is terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached. A typical genetic algorithm requires:

A genetic representation of the solution domain

A fitness function to evaluate the solution domain.

A standard representation of the solution is as an array of bits. The main property that makes these genetic representations convenient is that their parts are easily aligned due to their fixed size, which facilitates simple crossover operations. Variable length representations may also be used, but crossover implementation is more complex in this case.

To perform its optimization-like process, the GA employs three operators to propagate its population from one generation to another. The first operator is the “Selection” operator that mimics the principal of “Survival of the Fittest”. The second operator is the “Crossover” operator, which mimics mating in biological populations. The crossover operator propagates features of good surviving designs from the current population into the future population, which will have better fitness value on average. The last operator is “Mutation”, which promotes diversity in population characteristics. The mutation operator allows for global search of the design space and prevents the algorithm from getting trapped in local minima.

The fitness function is defined over the genetic representation and measures the quality of the represented solution [4]. The fitness function is always problem dependent. Fitness function is the function that assigns fitness value to each individual. For minimization problem fitness function is an equivalent maximization problem chosen such that the optimum point remains unchanged, fitness function for loss minimization problem can be expressed as

Fitness function = 1/ objective fuction+1.

It is easy to find the maximum value of objective function using GA, the inverse function is selected to convert the objective function into a maximum one. Fig. 3 shows the flow chart of GA.

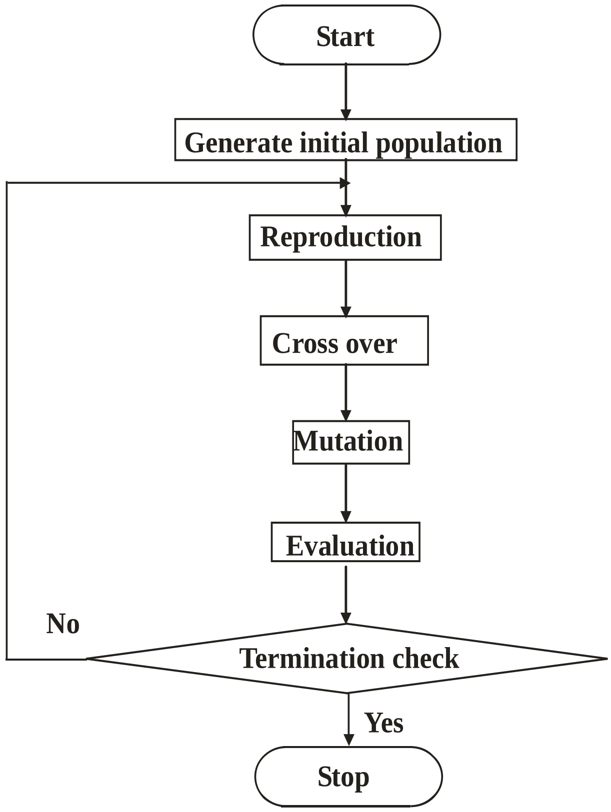

Fig. 3 : Flowchart of Genetic Algorithm

B. Problem Formulation Equations:

Equations that are considered for optimization to reduce the losses

Ploss(i) =Ploss(i) + real (conj ((V^m (n) * V^m (l))) * Ybus (n , l) * base mva) (9)

Ploss (l) = $\frac{1}{sum(P_{loss})}$ + 1 (10)

n = number of buses

V^m = Voltage magnitude of the nth bus
l = line data

$$P_{gi} - P_{di} = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\delta_i - \delta_j - \theta_{ij}) \tag{11}$$

$$Q_{gi} - Q_{di} = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij}) \tag{12}$$

$$P_{gi,\min} \le P_{gi} \le P_{gi,\max}$$
$$Q_{gi,\min} \le Q_{gi} \le Q_{gi,\max}$$

(13)

$$P_{di,\min} \le P_{di} \le P_{di,\max}$$
$$Q_{di,\min} \le Q_{di} \le Q_{di,\max}$$

(14)

$$V_{i,\min} \le V_i \le V_{i,\max}$$

(15)

PGi, QGi are the real and reactive power generation at bus i. Pdi, Qdi are the real and reactive power demands at bus i.
Vi, δi are voltage and angles at bus i.
Pgi,min, Pgi,max real power minimum and maximum generation limits at bus i.
Qgi,min, Qgi,max reactive power minimum and maximum generation limits at bus i.
Pdi,min, Pdi,max real power minimum and maximum demand limits at bus i.
Qdi,min, Qdi,max reactive power minimum and maximum demand limits at bus i.

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C. Proposed Algorithm for location of TCSC:

The steps to locate optimally a TCSC with Genetic Algorithm are as follows:

STEP-1: Read system data.
STEP-2: Run load flow to find losses using Newton Raphson method.
STEP-3: Assume suitable population size, say 100
STEP-4: Generate initial population.
STEP-5: Set counter=0.
STEP-6: Randomly generate chromosomes (Parameter xTCSC).
STEP-7: Modify admittance matrix with the help of randomly generated x^{tcsc} values.
STEP-8: Run load flow with modified admittance matrix calculated losses and evaluate fitness value i.e, Ploss
STEP-9: Increment counter function.
STEP-10: Select new population using roulette wheel selection criterion.
STEP-11: Perform crossover, mutation (if any) and evaluate objective function.
STEP-12: Add off- springs generated by cross over and mutations to the population generated by selection and replace initial population.
STEP-13: Repeat the process until minimum loss is reached which shows that convergence is achieved .
STEP-14: Place the TCSC in the line where minimum loss is obtained.

IV. Results Of Simulation

A. Case Study:

An IEEE 30-bus system is taken as a test system. Single line diagram of this system is shown in Fig. 4. The data of the system is given in Appendix- A. The system consists of 30 buses, 41 branches ,6 generators and 20 loads.

The range of TCSC is taken as -0.8% to +0.2% of the line reactance and the power flow is carried out before & after placing the TCSC to determine their benefits.

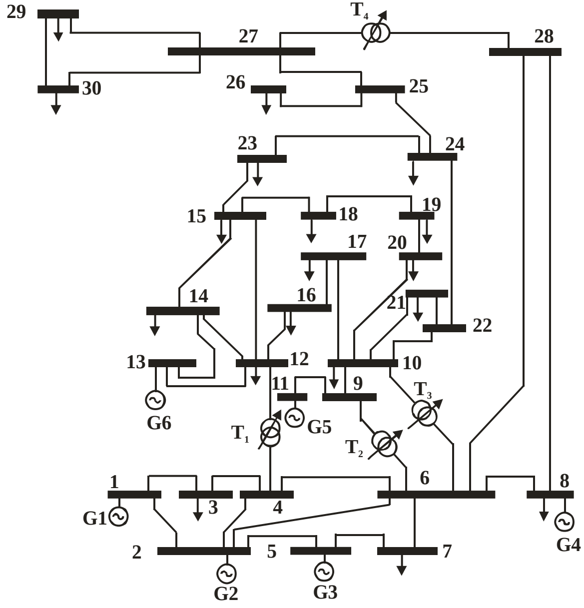


Fig. 4: Single Line Diagram of 30 Bus System

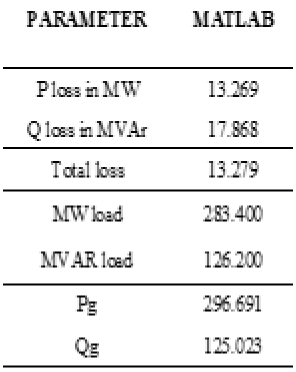
B .Load flow for 30 bus system

Load flow analysis has been carried out for IEEE 30 – bus system using MATLAB software and the results are tabulated in Tables I (a) and I(b).

Table1(b): Line flow and Line loss result for IEEE-30 bus before placement of TCSC

Branch	Line	Xold	Line losses in		Power in	
			MW	Mvar	MW	Mvar
1	1-2	0.0575	4.448	7.593	159.116	-17.846
2	1-3	0.1852	2.041	3.953	70.547	-3.116
3	2-4	0.1737	0.649	-1.912	34.558	-6.582
4	3-4	0.0379	0.553	0.703	66.121	-8.333
5	2-5	0.183	2.199	4.18	70.486	-0.713
6	2-6	0.1763	1.265	-0.096	47.916	-7.285
7	4-6	0.0414	0.4	0.455	59.219	-4.689
8	5-7	0.116	0.064	-1.902	-10.918	3.57
9	6-7	0.082	0.307	-0.799	34.086	4.607
10	6-8	0.042	0.083	-0.646	21.143	-17.02
11	6-9	0.208	0	0.911	18.992	-8.934
12	6-10	0.556	0	1.139	13.425	7.005
13	9-11	0.208	0	0.37	-10.008	-9.249
14	9-10	0.11	0	0.884	28.976	-0.606
15	4-12	0.256	0	2.955	32.65	-10.606
16	12-13	0.14	0	1.802	-12.005	-35.348
17	12-14	0.2559	0.07	0.145	7.359	2.672
18	12-15	0.1304	0.245	0.483	18.514	7.627
19	12-16	0.1987	0.064	0.135	7.572	4.011
20	14-15	0.4997	0.004	0.008	1.057	0.766
21	16-17	0.1932	0.017	0.039	4.05	2.168
22	15-18	0.2185	0.045	0.091	6.221	2.166
23	18-19	0.1292	0.006	0.012	2.914	1.027
24	19-20	0.068	0.016	0.032	-6.522	-2.247
25	10-20	0.209	0.079	0.177	8.848	3.22
26	10-17	0.0845	0.012	0.031	4.992	3.715
27	10-21	0.0749	0.11	0.237	15.356	9.814
28	10-22	0.1499	0.052	0.106	7.349	4.495
29	21-22	0.0236	0.001	0.002	-2.169	-1.489
30	15-23	0.202	0.035	0.07	4.947	3.429
31	22-24	0.179	0.038	0.059	5.073	2.787
32	23-24	0.27	0.008	0.015	1.704	1.71
33	24-25	0.3292	0.016	0.028	-1.935	-2.2
34	25-26	0.38	0.045	0.067	3.535	2.356
35	25-27	0.2087	0.055	0.105	-5.501	-4.626
36	28-27	0.369	0	1.468	18.852	9.507
37	27-29	0.4153	0.085	0.161	6.177	1.665
38	27-30	0.6027	0.161	0.303	7.091	1.657
39	29-30	0.4533	0.033	0.063	3.714	0.603
40	8-28	0.2	0.012	-4.404	1.065	1.979
41	6-28	0.0599	0.053	-1.155	17.834	2.063

Table 1(b): Matlab Parameters



PARAMETER	MATLAB
P loss in MW	13.269
Q loss in MVAr	17.868
Total loss	13.279
MW load	283.400
MVAR load	126.200
Pg	296.691
Qg	125.023

C. Optimal Location of TCSC determined by the GA Method:

Proposed GA methodology has been applied to the IEEE 30 bus system. In this paper, reactance of TCSC has been considered as chromosomes. The GA parameters are given in Table III.

From the simulation results it can be inferred that TCSC has been optimally located in one of the seven branches where minimum loss occurs. The location of TCSC and the corresponding reactance with GA are tabulated in Table II.

Table2: Line flow and line loss with and without GA

Branch	**Line**	**Xold**	**X-tcsc Added**	**X-eff = Xold + Xtcsc**	**Line losses in**		**Power in**	
					MW	**Mvar**	**MW**	**Mvar**

1	1-2	0.0575	0	0.0575	4.443	7.579	159.031	-17.826
2	1-3	0.1852	0	0.1852	2.047	3.976	70.651	-3.71
3	2-4	0.1737	0	0.1737	0.655	-1.9	34.602	-7.32
4	3-4	0.0379	0	0.0379	0.554	0.705	66.206	-8.874
5	2-5	0.183	0	0.183	2.195	4.165	70.426	-0.705
6	2-6	0.1763	0	0.1763	1.265	-0.1	47.862	-7.677
7	4-6	0.0414	0	0.0414	0.394	0.431	58.907	-3.276
8	5-7	0.116	0	0.116	0.063	-1.905	-10.971	3.228
9	6-7	0.082	0	0.082	0.308	-0.797	34.142	4.956
10	6-8	0.042	0	0.042	0.077	-0.67	21.098	-15.305
11	6-9	0.208	0	0.208	0	0.916	18.802	-9.491
12	6-10	0.556	0	0.556	0	1.091	13.322	6.51
13	9-11	0.208	0	0.208	0	0.337	-10.021	-8.345
14	9-10	0.11	0	0.11	0	0.875	28.816	-2.004
15	4-12	0.256	0	0.256	0	3.182	33.086	-13.329
16	12-13	0.14	-0.0893	0.0507	0	0.817	-11.967	-40.371
17	12-14	0.2559	0	0.2559	0.069	0.144	7.378	2.752
18	12-15	0.1304	0	0.1304	0.257	0.506	18.766	8.637
19	12-16	0.1987	0	0.1987	0.074	0.155	7.732	5.089
20	14-15	0.4997	0	0.4997	0.005	0.01	1.104	0.994
21	16-17	0.1932	0	0.1932	0.021	0.05	4.196	3.122
22	15-18	0.2185	0	0.2185	0.048	0.097	6.311	2.641
23	18-19	0.1292	0	0.1292	0.008	0.015	3.055	1.659
24	19-20	0.068	0	0.068	0.015	0.03	-6.439	-1.786
25	10-20	0.209	0	0.209	0.074	0.165	8.728	2.661
26	10-17	0.0845	0	0.0845	0.009	0.025	4.821	2.726
27	10-21	0.0749	0	0.0749	0.109	0.234	15.355	9.692
28	10-22	0.1499	0	0.1499	0.051	0.104	7.346	4.399
29	21-22	0.0236	0	0.0236	0.001	0.002	-2.182	-1.712
30	15-23	0.202	0	0.202	0.04	0.08	5.1	3.98
31	22-24	0.179	0	0.179	0.036	0.056	5.053	2.546
32	23-24	0.27	0	0.27	0.011	0.023	1.86	2.303
33	24-25	0.3292	0	0.3292	0.013	0.023	-1.811	-1.924
34	25-26	0.38	0	0.38	0.045	0.067	3.539	2.369
35	25-27	0.2087	0	0.2087	0.05	0.096	-5.373	-4.323
36	28-27	0.369	0	0.369	0	1.427	18.707	9.159
37	27-29	0.4153	0	0.4153	0.085	0.161	6.184	1.67
38	27-30	0.6027	0	0.6027	0.16	0.302	7.089	1.661
39	29-30	0.4533	0	0.4533	0.033	0.063	3.706	0.603
40	8-28	0.2	0	0.2	0.01	-4.413	1.029	1.597
41	6-28	0.0599	0	0.0599	0.052	-1.159	17.741	1.99

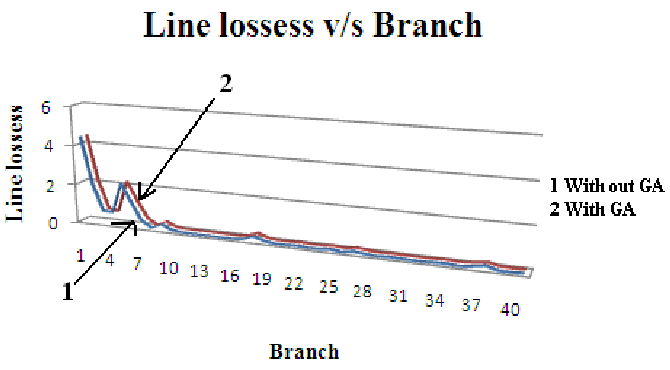


Fig.5. :Line loss verses branch.

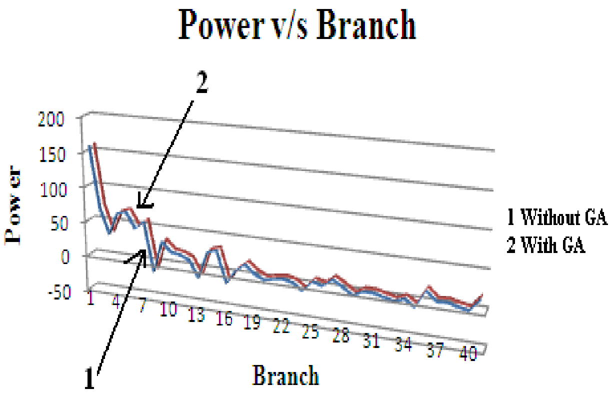


Fig 6.: Power flow verses branch

Table 3: GA parameters

Population size =100
Cross over rate = 0.8
Mutation rate = 0.02
Convergence iteration = 8
Maximum iteration = 120
Selection = Roulette wheel

The following are the benefits observed by placing TCSC in the 6th branch by genetic algorithm method into the system.

1. Reduction of total real power loss from 13.279MW to 13.27 MW.
2. Increase of real power generation

3. Increase of reactive power generation from.
4. Graph of line loss verses branch shown in Fig.5.
5. Graph of power flow verses branch shown in Fig.6.
6. Degree of compensation = 40%.

C. Summary of the Results

TABLE 4: RESULT

Parameter	Without GA	Proposed GA
Line flow 12-13	-12.005 MW	-11.967 MW
Total loss	13.279MW	13.27 MW
Line reactance 16th Branch, line 12-13	Before	After
	X_l=0.14	$X_{eff} = X_l + X_{TCSC} = 0.0507$

V. Conclusion

It can be seen from the result that , by computational intelligence method that is, genetic algorithm method , the optimized location of the TCSC is 16th branch. The degree of compensation is around 40%. The TCSC could be effectively placed in16th branch which results in the reduction of loss. The total loss effectively reduced from 13.279MW to 13.27 MW resulting in a loss reduction of 10% and it increases the power transfer capability of the line. Hence this method can be easily extended to practical systems with more number of buses.

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Bus No	V_{mag}	angle	Load data		Generator data		Q_{Min}	Q_{Max}
			MW	Mvar	MW	Mvar		
1	1.05	0	0	0	50	-30	0	150
2	1.033	0	21.7	12.7	20	-30	0	60
3	1	0	2.4	1.2	0	0	0	0
4	1	0	7.6	1.6	0	0	0	0
5	1.0058	0	94.2	19	15	-15	0	60
6	1	0	0	0	0	0	0	0
7	1	0	22.8	10.9	0	0	0	0
8	1.023	0	30	30	10	-15	0	50
9	1	0	0	0	0	0	0	0
10	1	0	5.8	2	0	0	0	0
11	1.0913	0	0	0	10	-10	0	-40
12	1	0	11.2	7.5	0	0	0	0
13	1.0833	0	0	0	12	-15	0	45
14	1	0	6.2	1.6	0	0	0	0
15	1	0	8.2	2.5	0	0	0	0
16	1	0	3.5	1.8	0	0	0	0
17	1	0	9	5.8	**0**	**0**	0	**0**
18	1	0	3.2	0.9	0	0	0	0
19	1	0	9.5	3.4	0	0	0	0
20	1	0	2.2	0.7	0	0	0	0
21	1	0	17.5	11.2	0	0	0	0
22	1	0	0	0	0	0	0	0
23	1	0	3.2	1.6	0	0	0	0
24	1	0	8.7	6.7	0	0	0	0
25	1	0	0	0	0	0	0	0
26	1	0	3.5	2.3	0	0	0	0
27	1	0	0	0	0	0	0	0
28	1	0	0	0	0	0	0	0
29	1	0	0	0.9	0	0	0	0
30	1	0	0	1.9	0	0	0	0

Line No	From bus	To bus	R	X	B/2
1	1	2	0.0192	0.0575	0.0264
2	1	3	0.0452	0.1852	0.0204
3	2	4	0.057	0.1737	0.0184
4	3	4	0.0132	0.0379	0.0042
5	2	5	0.0472	0.183	0.0209
6	2	6	0.0581	0.1763	0.0187
7	4	6	0.0119	0.0414	0.0045
8	5	7	0.046	0.116	0.0102
9	6	7	0.0267	0.082	0.0085
10	6	8	0.012	0.042	0.0045
11	6	9	0	0.208	0
12	6	10	0	0.556	0
13	9	11	0	0.208	0
14	9	10	0	0.11	0
15	4	12	0	0.256	0
16	12	13	0	0.14	0
17	12	14	0.1231	0.2559	0
18	12	15	0.0662	0.1304	0
19	12	16	0.0945	0.1987	0
20	14	15	0.221	0.4997	0
21	16	17	0.0824	0.1932	0
22	15	18	0.107	0.2185	0
23	18	19	0.0639	0.1292	0
24	19	20	0.034	0.068	0
25	10	20	0.0936	0.209	0
26	10	17	0.0324	0.0845	0
27	10	21	0.0348	0.0749	0
28	10	22	0.0727	0.1499	0
29	21	22	0.0116	0.0236	0
30	15	23	0.1	0.202	0
31	22	24	0.115	0.179	0
32	23	24	0.132	0.27	0
33	24	25	0.1885	0.3292	0
34	25	26	0.2544	0.38	0
35	25	27	0.1093	0.2087	0
36	28	27	0	0.369	0
37	27	29	0.2198	0.4153	0
38	27	30	0.3202	0.6027	0
39	29	30	0.2399	0.4533	0
40	8	28	0.0636	0.2	0.0214
41	6	28	0.0169	0.0599	0.0065