



# **Minimization of Real Power loss using Evolutionary Algorithm**

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**ABSTRACT:** In deregulated power system, load demands are continuously increasing due to growth of population. In order to meet load demand, unscheduled power flow through transmission line which results in higher real & reactive power losses and voltage instability at buses. To overcome these problems, a Flexible Alternating Current Transmission System (FACTS) devices are installed at appropriate location to get the maximum possible benefits i.e. minimize real power loss in the power network and improve voltage profile at the buses. In this paper, a new evolutionary optimization techniques have been applied namely Genetic Algorithm (GA) and Differential Evolution (DE) algorithm to select the optimal parameters setting including rating of Static Var Compensator (SVC) to minimize real power loss and improve voltage profile and compare their performances. For validation of proposed algorithm and for comparison purpose, MATLAB program is carried out on IEEE 30-bus system. The results, we have obtained, indicates that DE is an easy to use, fast, robust and powerful optimization technique compared with GA.

**KEYWORDS:** FACTS, SVC, N-R method, GA and DE.

## **I. INTRODUCTION**

In last few decades, electrical power companies are continuously increasing due to increase in demand of electrical power at load. Consequently, the power system becomes more difficult to operate, more insecure due to transfer of cheap power from generating companies to load and higher losses. These may lead to overloading of transmission lines and transformers. To alleviate these problems, utilities require to construct the new transmission line, install, and upgrade the system components. It has some problems viz. environmental issues, right of way and cost issues. Thereafter, with the development of power semi-conductor devices, it is possible to design power electronics equipment known as Flexible Alternating Current Transmission System (FACTS) devices. These devices are introduced by N.G. Hingorani in 1988. It controls magnitude and phase angle of voltage at the buses and impedance of the transmission system [1].

FACTS technologies provide the minimum infrastructure investment, environment impact and implementation time as compared to new transmission line. Among the FACTS devices, SVC is one of the effective measures for improving the voltage profile, reducing the real power loss, enhancing the transient stability and improving the dynamic characteristic of the power system [2]. The optimal parameters setting including rating of SVC is considered for the real power loss reduction, improvement in transient stability and increasing in power transfer capability. Therefore, the conventional power flow algorithm should incorporate with SVC considering one or all of the above mentioned factors [3].

This paper deals with the application of conventional method: Newton-Raphson (N-R) load flow power algorithm to solve non-linear algebraic equations. This method is used to find weakest bus considering single line outages as contingencies for optimal number and location of SVC. The disadvantages of this methods are– more time consuming, sometimes stuck in local minima and more iterations to obtain sub-optimal solution [4]-[5]. To overcome these



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problems, new evolutionary based approaches namely, GA and DE algorithm have been applied for real power loss reduction by optimal parameter setting including rating of SVC. Also, performance of GA and DE are compared.

## II. PROBLEM FORMULATION

The main objective of this paper is to determine the optimal location and optimal parameter setting of SVC to minimize real power loss and improve voltage profile, the following performance is selected:

$$\text{Min } F = \text{Min} \sum_{k=1}^{NL} P_L \quad (1)$$

Where,  $F$  = Fitness function  
 $P_L$  = Total real power loss

**Minimization of real power loss:** The real power loss ( $P_L$ ) as first term of objective function  $F_1(u,v)$  is defined as:

$$f_1(u,v) = P_L = \sum_{k=1}^{NL} g_k [(V_i)^2 + (V_j)^2 - 2V_i V_j \cos(\delta_i - \delta_j)] \quad (2)$$

Where,  $NL$  = number of transmission line,  
 $g_k$  = conductance of  $k^{th}$  line, and  
 $V_i \angle \delta_i$  and  $V_j \angle \delta_j$  = voltage and phase angle at bus  $i$  and  $j$ .

**Minimization of size of SVC:** The size of SVC as second term of objective function  $F_2(u,v)$  is defined as :

$$f_2(\text{SVC}_{\text{size}}) = \text{rating of SVC in per unit} \quad (3)$$

Subjected to following equality constraints:

$$P_{Gi} - P_{Di} - V_i \sum_{j=1}^{NB} V_j [G_{ij} \cos(\delta_i - \delta_j) + B_{ij} \sin(\delta_i - \delta_j)] = 0 \quad \text{For } i = 1, 2, \dots, NB \quad (4)$$

$$Q_{Gi} - Q_{Di} - V_i \sum_{j=1}^{NB} V_j [G_{ij} \sin(\delta_i - \delta_j) - B_{ij} \cos(\delta_i - \delta_j)] = 0 \quad \text{For } i = 1, 2, \dots, NB \quad (5)$$

Where,  $NB$  = total number of buses,  
 $P_{Gi}$  and  $Q_{Gi}$  = generator real and reactive power at bus,  
 $P_{Di}$  and  $Q_{Di}$  = active and reactive power load demand at bus  $i$ ,  
 $B_{ij}$  = transfer susceptance of line between bus  $i$  and  $j$ , and  
 $V_i$  and  $V_j$  = voltage magnitude at bus  $i$  and  $j$ .

Subjected to Inequality constraints are following:

$$\text{Reactive power generation} \quad Q_{gi}^{\min} \leq Q_{gi} \leq Q_{gi}^{\max} \quad i = 1 \dots NG \quad (6)$$

$$\text{Voltage magnitude} \quad V_i^{\min} \leq V_i \leq V_i^{\max} \quad i = 1 \dots NB \quad (7)$$

Where,  $ng$  = total number of generated bus.

## III. DESCRIPTION OF DE

Rainer Stron and Kenneth Price who was first introduced the Differential Evolution (DE) algorithm in 1995 and since then the DE algorithm has been used in many practical cases. DE is a heuristic and population based optimization technique. This algorithm is a direct search method that chooses  $N_p$  individual as fixed number of population vector for each generation ( $G$ ). DE solves a different type of global optimization problems such as dis-continuous, non-linear, non-differential, and multi-dimension objective function over a wide range of the real life application in the field of science and number of branches of engineering.

A new population of fix size is randomly generated which uses the mutation operator as a search mechanism during each iteration of the DE algorithm and uses Greedy selection. DE has three main operators – mutation, crossover and



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selection. Generally, DE algorithm uses the following notation: DE/x/y/z. Where, x stands for mutated vector, y for a number of difference vector and z for which type of crossover scheme is used- exponential crossover or binomial crossover [6]-[8].

The advantages of DE can be summarised as follows [9]-[10].

DE has the following steps [11]:

Step-1 Randomly generates an initial population of  $N_p$  individuals within the feasible space.

$$P^{(0)} = X_{ij}^{(0)} = x_i^{(L)} + rand(0,1) \times (x_i^{(U)} - x_i^{(L)}) \quad (8)$$

Step-2 Calculate the fitness value for the each individual of the each member of the population based on the objective function to be minimized.

Step-3 Generate new population by using mutation, crossover and selection operator.

Mutation- The mutation operator creates mutant or donor vector that randomly selecting three individuals or vectors  $X_{r1}^{(G)}, X_{r2}^{(G)}, X_{r3}^{(G)}$  from current population. A difference of any two individuals out of three individuals is added to third one. The mutant vector  $V_{ij}^{(G+1)}$  can be expressed as:

$$V_{ij}^{(G+1)} = X_{r1j}^{(G)} + F \times (X_{r2j}^{(G)} - X_{r3j}^{(G)}) \quad (9)$$

Where  $r1, r2, r3 \in (1 \text{ to } N_p)$  and  $F$  is real and constant number, which can take the value between 0 to 2.

Crossover- The process of crossover plays vital role in order to augment the potential diversity of the population vector. Using crossover operation, the trial vector can generated by exchanging the element or component of target vector and donor vector. The following expression for binominal crossover is:

$$u_{ij}^{(G+1)} = \begin{cases} V_{ij}^{(G+1)}, & \text{if } rand_j(0,1) \leq CR \text{ or } j = jrand \\ X_{ij}^{(G)}, & \text{otherwise} \end{cases} \quad (10)$$

Where  $i = 1 \text{ to } N_p, j = 1 \text{ to } D, jrand =$  randomly chosen index  $\in (1 \text{ to } N_p)$  that sure for trial vector get at least one parameter from mutant vector,  $rand_j(0,1)$  is uniformly distributed number within (0,1) generated for each  $j$ .  $CR$  is crossover rate. The range of  $CR$  is [0,1].

Selection- Selection specify under what condition which one of the child and parent will survive in the next generation. The selection operation is described as:

$$X_{ij}^{(G+1)} = \begin{cases} u_{ij}^{(G+1)} & \text{if } f(u_{ij}^{(G+1)}) \leq f(X_{ij}^{(G)}) \\ X_{ij}^{(G)} & \text{otherwise} \end{cases} \quad (11)$$

Step-4 Terminate process will occurs if the optimal solution is obtained or maximum number of the generation or iterations are reached; otherwise go to step-3.

Step-5 Stop the process, print the best individual.

## IV. DESCRIPTION OF GA

Conventional methods have been used to solve the problem of power system design, planning and operation for different applications. But these methods have some disadvantages- stuck in global minima, more iterations and providing sub-optimal solution. In this regard, evolutionary algorithm have been used that can give better solution in several conditions and can easily applied in field of science and number of branches engineering [12]-[13].

Genetic algorithm (GA) is a kind of evolutionary algorithm, based on the concept from natural genetics and Darwinian survival of the fittest. GA is first pioneered by Holland in the 60's and 70's. The GA control parameters- population size, crossover probability, and mutation probability are chosen and initial population is randomly generated of finite length of string. If pre-defined convergence is not satisfied, then genetic operators- selection, crossover and mutation are carried out [14]-[15]. The process of GA can described as follows:

Step-1 Inputs of GA including population size, crossover probability and mutation probability. Also, set maximum number of generations or iterations and time as stopping criterion for random generation of population.

Step-2 Calculate the fitness value for each individual of population according to objective function.

Step-3 New population is generated by selection, crossover and mutation.

- a) Selection- It is the part of GA where certain numbers of individual's genes are chosen from the current population for later breeding such as recombination and mutation.



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- b) Crossover- Crossover sometime referred as recombination. Two individuals or parents are combined with crossover operation to form child for the next generation.
- c) Mutation- Mutation operator makes small random changes in the individual in the population to create mutation children. It provides the broader space to search optimal solution in GA and as a result high diversity.

Step-4 Terminate process will occurs if the optimal solution is obtained or maximum number of the generation or iterations are reached; otherwise go to step-3.

Step-5 Stop the process, print the best individual.

## V. RESULTS AND DISCUSSION

For the simulation purpose a MATLAB codes for GA, DE and modified power flow algorithm including SVC are developed. To investigate the verification of proposed approaches, both GA and DE algorithm have been tested on IEEE 30-bus system. This system has one slack bus, 5 generator buses, 24 load buses and 41 transmission lines[16]. All the load buses i.e. PQ buses are considered as optimal location of SVC. For optimal placement of SVC obtain by applying N-R method to find most severity bus among all 30 buses. The single line outage are considered as contingency in test system. In this paper, we considered the four different cases– Base Case (without Line Outage), Line Outage 36 and Line Outage 37. The GA and DE parameters utilized in this simulation are shown in Table 1 & 2.

Table 1: parameter values for GA

Population size	26
Maximum number of generation	50
Number of variables	13
Crossover probability ( $P_C$ )	0.80
Mutation probability ( $P_m$ )	0.80

Table 2: parameter values for DE

Population size ( $N_p$ )	13*2
Dimension	2
Number of variables	13
Crossover rate (CR)	0.70
Scaling Factor (F)	0.80
DE strategy	DE/rand/bin/1
Maximum number of generation	50

**BASE CASE**– For base case, line outage is not occurred in test system. Run N-R load flow program, when SVC is not connected to find the optimal location of SVC. In this case, there are three most severe location of SVC in test system namely; bus number 30, 29 and 26. The voltages at these buses and real power loss with GA and DE are given in below Table 3 & 4:

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Table 3: Comparison of real power loss under base case with GA

Bus voltage V30 (pu)		Bus voltage V29 (pu)		Bus voltage V26 (pu)		Real power loss (pu)			Optimal value
Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	With GA	SVC
0.962	1.024	0.974	1.036	0.966	1.022	0.1821	0.1786	0.1740	0.35, 0.38, 0.18

Table 4: Comparison of real power loss under base case with DE

Bus voltage V30 (pu)		Bus voltage V29 (pu)		Bus voltage V26 (pu)		Real power loss (pu)			Optimal value
Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	With DE	SVC
0.973	0.982	0.985	1.001	0.976	1.019	0.1798	0.1679	0.1649	0.73, 0.16, 0.35

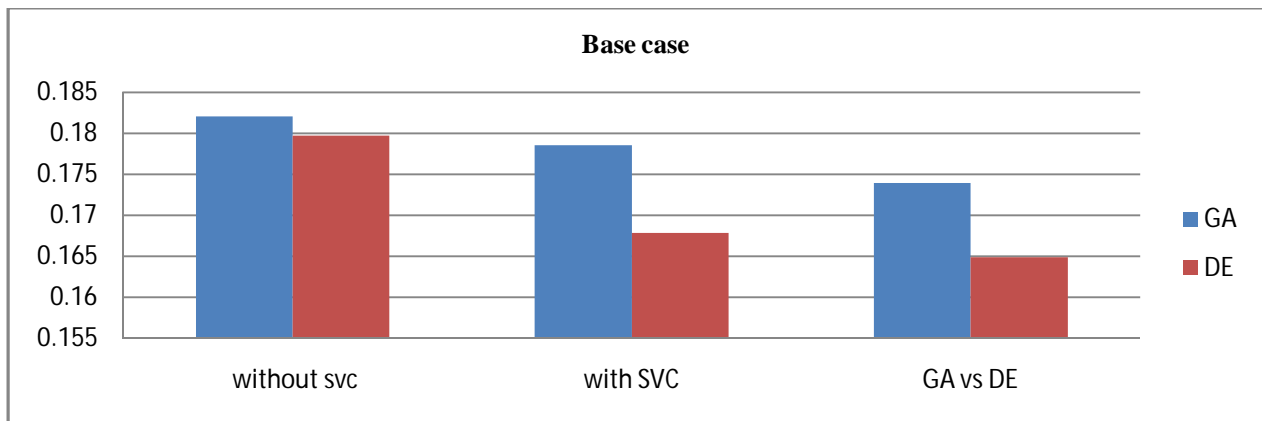


Figure1: Comparison of real power loss under base case

**Line outage 36-** Run N-R load flow, when SVC is not connected to find the optimal location of SVC. In this case, there are three most severe location of SVC in test system namely; bus number 30, 29 and 27. The voltages at these buses and real power loss with GA and DE are given in below Table 5 & 6:

Table 5: Comparison of real power loss under line outage 36 with GA

Bus voltage V30 (pu)		Bus voltage V29 (pu)		Bus voltage V27 (pu)		Real power loss (pu)			Optimal value
Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	With GA	SVC
0.799	0.915	0.814	0.928	0.838	0.949	0.2122	0.1859	0.1816	0.75, 0.12, 0.30

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Table 6: Comparison of real power loss under line outage 36 with DE

Bus voltage V30 (pu)		Bus voltage V29 (pu)		Bus voltage V27 (pu)		Real power loss (pu)			Optimal value
Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	With DE	SVC
0.815	0.966	0.829	0.979	0.853	0.992	0.2074	0.1831	0.1790	0.73, 0.10, 0.10

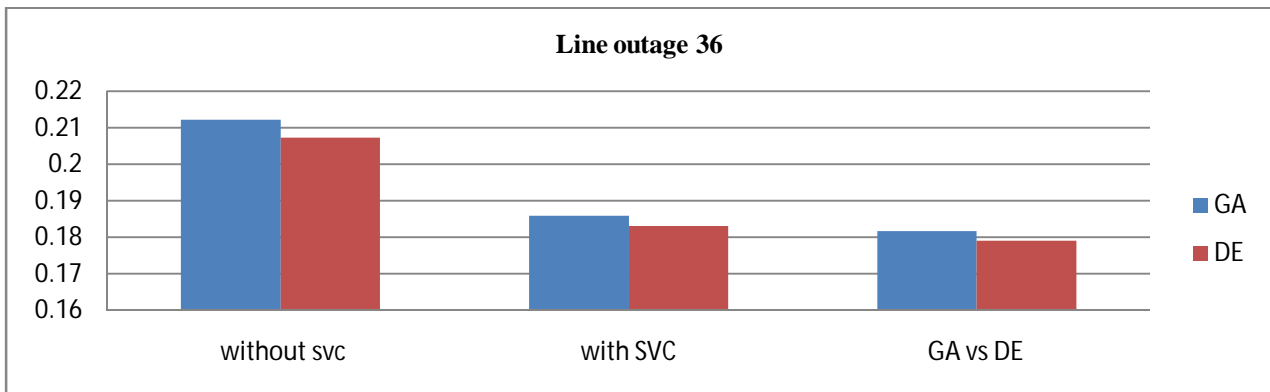


Figure 2: Comparison of real power loss under line outage 36

**Line outage 37-** Run N-R load flow, when SVC is not connected to find the optimal location of SVC. In this case, there are three most severe location of SVC in test system namely; bus number 30, 29 and 26. The voltages at these buses and real power loss with GA and DE are in given below Table 7 & 8:

Table 7: Comparison of real power loss under line outage 36 with GA

Bus voltage V30 (pu)		Bus voltage V29 (pu)		Bus voltage V26 (pu)		Real power loss (pu)			Optimal value
Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	With GA	SVC
0.925	1.019	0.914	1.011	0.963	1.043	0.1881	0.1681	0.1662	0.50, 0.03, 0.41

Table 8: Comparison of real power loss under line outage 36 with DE

Bus voltage V30 (pu)		Bus voltage V29 (pu)		Bus voltage V26 (pu)		Real power loss (pu)			Optimal value
Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC	With DE	SVC
0.938	0.973	0.927	0.980	0.974	0.998	0.1841	0.1672	0.1657	0.44, 0.10, 0.89

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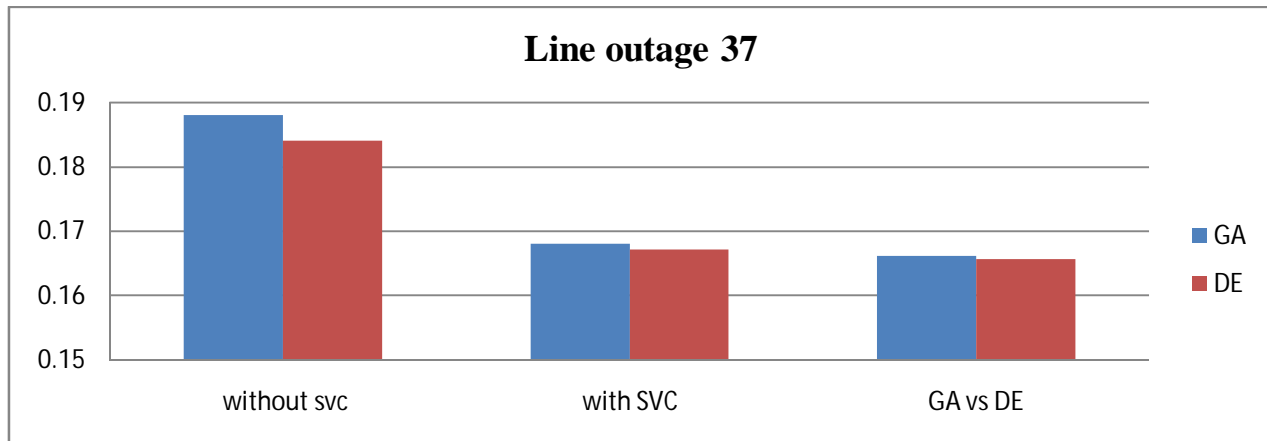


Figure 3: Comparison of real power loss under line outage 36

## VI. CONCLUSION

In this paper, the effectiveness of optimal installation of SVC for minimizing the real power losses under single line outages in the network has been investigated. Determination of optimal location of SVC was found based on weakest bus among all buses. One of the newest evolutionary techniques namely, GA and DE algorithm have been successfully applied to solve the optimization problem under consideration. Three variables were considered to be optimized i.e. voltage at voltage controlled bus, tap setting of transformer and rating of SVC. The performance of DE is compared with GA. With proposed algorithms, it is possible for real power loss reduction using placement of SVC in the network. The obtained results show that DE has superior feature including high quality solution, good computation efficiency, easy, fast, simple and robust.

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