# IMPACT OF STATIC VAR COMPENSATORS ON POWER SYSTEM: A CASE STUDY

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**Abstract:** With increase in load, any transmission, distribution and generating model suffers from disturbances. These disturbances effect the overall stability of the system. Criterias like voltage profile, power flows, losses tell us about the state of the system under study. Load flow analysis of the system under study is capable of providing the insight of the system. The Emergence of FACTS device is really a step forward for the flexible control or Power System Operations. FACTS is the name given to the application of the power electronics devices to control power flows and other quantities in the power system. But when it comes to implementation stage, optimizing the location becomes a great concern because of the high cost involved with FACTS devices especially converter like SVC, STATCOM etc. Static Var Compensator (SVC) is a power quality device, which employs power electronics to control the reactive power flow of the system where it is connected. It is able to provide fast-acting reactive power compensation on electrical systems. SVC is one of the methods and can be applied to obtain a system with least losses, increased power flow and healthy voltage profile. Number, location and size of SVC are the main concerns and they can be optimized to a great extent by Genetic Algorithm (GA) or any other method. Use of SVC in a system has shown considerable increase in voltage profile and power flows while decrease in losses.

**Keywords:** SVC; FACTS; distribution system; etap; genetic algorithm

## 1. INTRODUCTION

Static Var Compensator (SVC) is an electrical device for providing fast acting reactive power on high voltage electricity transmission networks. It is a power quality device, which employs power electronics to control the reactive power flow of the system where it is connected. In other words, static var compensators have their output adjusted to exchange inductive or capacitive current in order to control a power system variable such as the bus voltage.SVC is based on thyristors without the gate turn-off capability. It includes separate equipment for leading and lagging vars; the thyristor-controlled or thyristor-switched reactor for absorbing reactive power and thyristor-switched capacitor for supplying the reactive power. It is low cost substitute for STATCOM (static synchronous compensator [1]-[2].

Proper placement of SVC and thyristor controlled series compensator (TCSC) reduces transmission losses, increases the available capacity, and improves the voltage profile as suggested in [3]. Sundar and Ravikumar [4] have suggested that the optimal location of SVC is identified by a new index called single contingency voltage sensitivity (SCVS) index. Khandani et al concentrated on optimal placement of SVC controller to improve voltage profile using a novel hybrid Genetic Algorithm and Sequential Quadratic Program-ming (GA-SQP) method. This algorithm has used to determine optimal placement of SVC controller and solving optimal power flow (OPF) to improve voltage profile simultaneously. The proposed OPF has used to improve voltage profile within real and reactive power generation limits, line thermal limits, voltage limits and SVC operation limits [5]. A modified artificial immune network algorithm (MAINetA) has used for placement of SVC in a large-scale power system to improve voltage stability. To enhance voltage stability, the planning problem has formulated as a multiobjective optimization problem for maximizing fuzzy performance indices for bus voltage deviation, system loss and the installation cost [6]. Minguez et al addressed the optimal placement of SVCs in a transmission network in such a manner that its loading margin gets maximized. A multi scenario framework that includes contingencies has also considered [7].Mixed Integer Nonlinear Programming (MINLP) used as a useful technique for combinatorial optimization over integers and variables to determine optimal location of SVC in [8].

This paper presents the optimal placement of SVC in power distribution system to obtain system with least losses, increased power flow and healthy voltage profile. The results reveal the effectiveness of the GA method used.

## 2. PROBLEM FORMULATION

To find the suitable location for SVC device placement in given power system, Genetic Algorithm method is considered which will give set of values of fitness function for each case considered. The highest value of fitness function will be considered for optimum location of SVC in the given power system.
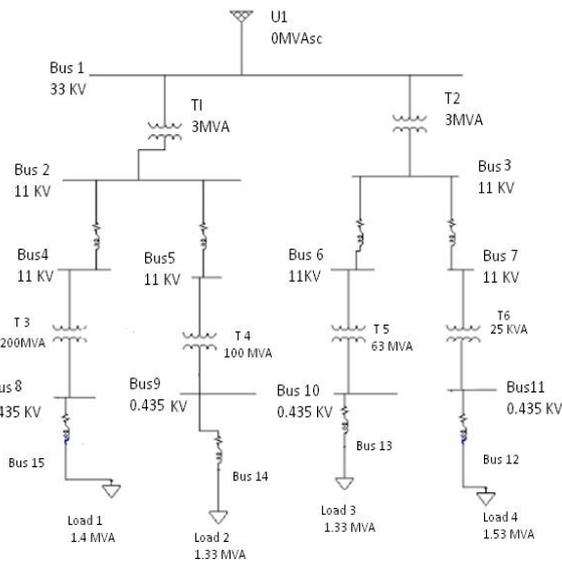
*Figure 1. Single Line Diagram*

Single line diagram of 33/11 KV Distribution Substation is taken [1] with eleven buses (from Bus 1 to Bus11) as shown in Fig. 1. It consists of two power transformers (T1 and T2), each having capacity of 3 MVA and four distribution transformers (T3, T4, T5 and T6). There are four static loads (from Load 1 to Load 4). There are two out going feeders connected to each of power transformers. Incoming voltage level is 33KV and the distribution voltage level is 11KV. Load receives a voltage of 0.435 KV.

In order to study the effect of Static Var Compensators on all these parameters, first, single SVC is considered and then two SVCs are considered in the same single line diagram and Load flow analysis is performed. The set of values of various parameters so obtained are then, used as data sheet for genetic algorithm for excel. To find the suitable location for SVC device placement in given power system, Genetic Algorithm method is considered. .GA will give set of values of fitness function for each case considered. The highest value of fitness function gives optimum location of SVC in the given power system.

## 3. LOAD FLOW ANALYSIS

The Load-flow study is an analysis of the voltages of the voltages, currents, and power flows in a power system under steady state conditions.

### 3.1 Electrical Transient Analyzer Program
ETAP allows load flow analysis in single line diagram. ETAP provides three load flow calculation methods: Newton-Raphson, Fast-Decoupled, and Accelerated Gauss-Seidel. They possess different convergent characteristics, and sometimes one is more favorable in terms of achieving the best performance. Any one of them is selected depending on system configuration, generation, loading

condition, and the initial bus voltage. Here, Newton Raphson method is considered with maximum iteration of 1000 and precision of 0.01.

### 3.2 Newton Raphson Method
The Newton-Raphson method possesses a unique quadratic convergence characteristic. It usually has a very fast convergence speed compared to other load flow calculation methods. It also has the advantage that the convergence criteria are specified to ensure convergence for bus real power and reactive power mismatches. This criterion gives the direct control of the accuracy to specify for the load flow solution. The convergence criteria for the Newton-Raphson method are typically set to 0.001 MW and Mvar. The Newton-Raphson method is highly dependent on the bus voltage initial values.

## 4. GENETIC ALGORITHM

Genetic algorithm is a search heuristic that mimics the process of natural selection. This heuristic is routinely used to generate useful solutions to optimization and search problems. Genetic Algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural selection. Genetic algorithms (GAs) are based on biological principles of evolution and provide an easy interesting alternative to "classic" gradient-based optimization methods [9]-[13]. They are particularly useful for highly nonlinear problems and models, whose computation time is not a primary concern.

The primary usefulness of the GA is that it starts by sampling the entire design space, possibly enabling it to pick points close to a global optimum. It then proceeds to apply changes to the ranked individual design points, which leads to an improvement of the population fitness from one generation to another. To ensure that it doesn't converge on an inferior point, mutation is randomly applied which perturbates design points and allows for the evaluation and incorporation of remote points.GA gives output in terms of fitness function value. The Fitness Function [Beromi *et al.* (2007)] made in GA, by considering all objectives is given by Eq. (1).

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(1)

Although a large number of modified algorithms are available, a GA typically proceeds in the following order:
- Start with a finite population of randomly chosen chromosomes ("design points") in the design space. This population constitutes the first generation ("iteration").
- Evaluate their fitness ("function value").
- Rank the chromosomes by their fitness.

- Apply genetic operators (mating): reproduction (reproduce chromosomes with a high fitness), cross-over (swap parts of two chromosomes, chosen based on their fitness to create their offspring) and mutation (apply a random perturbation to parts of a chromosome). All of these operators are assigned a probability of occurrence.
- Assemble the new generation from these chromosomes and evaluate their fitness.
- Apply genetic mating as before and iterate until convergence is achieved or the process is stopped.

## 5. RESULTS

After load flow analysis, values of various parameters so obtained are the inputs to genetic algorithm. The variation of fitness with respect to location of SVC at various buses can be represented in the form of graphs as under, where the highest value of fitness function gives optimum location for SVC. It can be seen that the value of fitness when single SVC is connected at Bus-10 is high ie.**0.035677** as shown Fig.2. Therefore, a SVC of inductive rating of 2.5 Mvar and capacitive rating of 5 Mvar must be placed at this location.
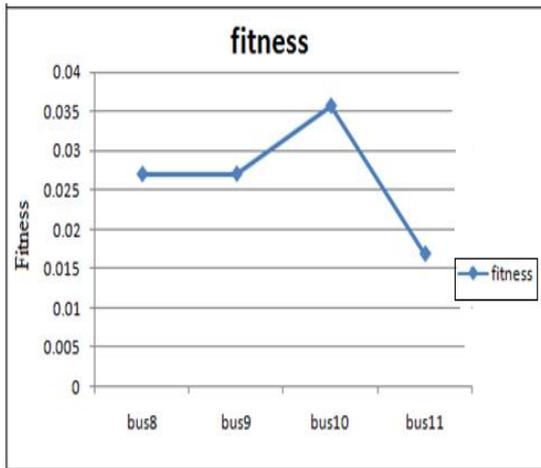


*Figure 2.  Fitness values attained when one SVC is taken*
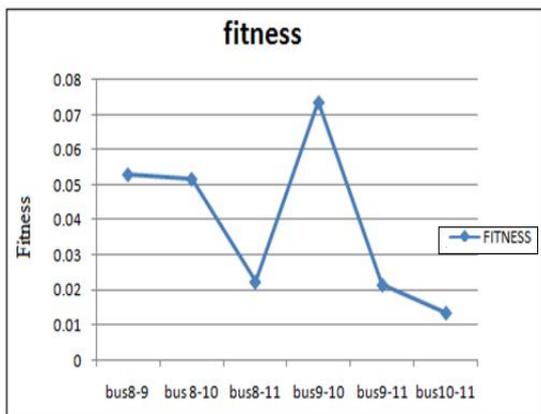


*Figure 3. Fitness values attained when two SVCs are taken*

When two SVCs are considered, the value of fitness is high at SVC location bus9-10 i.e. **0.073585**

as shown in Fig.3. Therefore, two SVCs of inductive rating of 2.5 Mvar and capacitive rating of 5 Mvar must be placed at these two locations i.e. one SVC at bus 9 and other SVC at bus 10.

Thus, we have two choices for optimum location of SVCs in given power system.

### 5.1 Single SVC

Comparison of base case with cases when a SVC is at bus location 10 is taken in terms of all parameters are discussed as below.

### Voltage Profile

When SVC is connected at Bus-10, we have improved voltage profile as shown in Fig.4. The Average voltage is increased by 1.17272 units i.e. from 94.99273 to 96.16545.
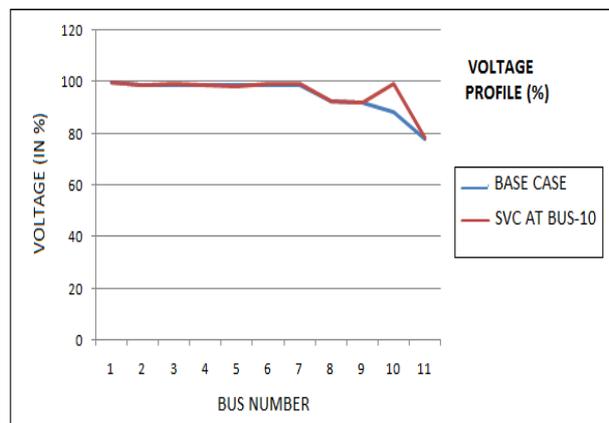


*Figure 4. Comparison of voltage profile between base case and SVC at BUS-10*

### Losses

When SVC is connected at Bus-10, we have reduction in overall losses as shown in Fig.5. The Average losses decreased by 1.48182 units i.e. from 11.88182 to 10.40.
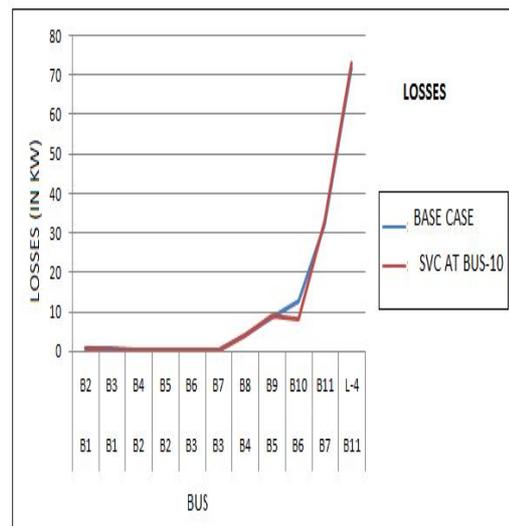


*Figure 5.  Comparison of losses between base case and SVC at BUS-10*

### Active Power

SVC connection at Bus-10 resulted in increase of average active power from 175.0909 to 184.8182 i.e. increment by 9.7273 units as shown in Fig.6.
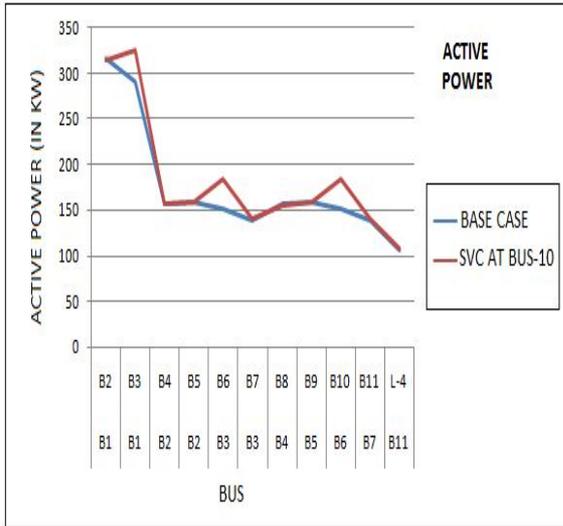


*Figure 6. Comparison of active power between base case and SVC at BUS-10*

## Reactive Power

Average reactive power is decreased from its base average value by 47.18 units with single SVC .i.e. from 235.8182 to 188.6364 as shown in Fig.7.
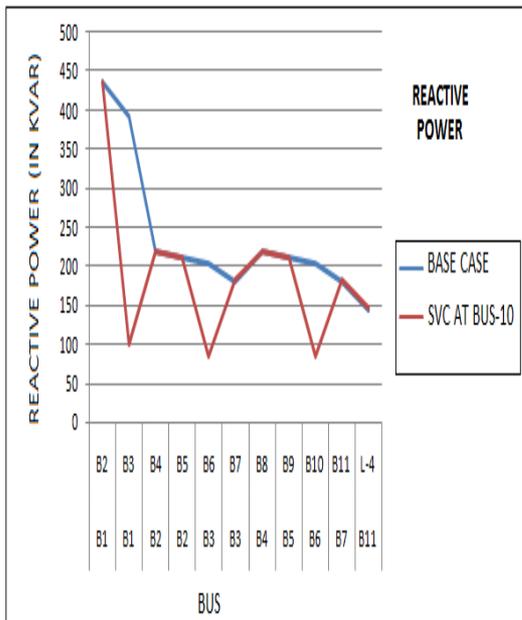


**Figure 7. Comparison of reactive power between base case and SVC at BUS-10**

## 5.2 Double SVC

Comparison of base case with cases when double SVC are at bus locations 9-10 is taken in terms of all parameters are discussed as below.

## Voltage Profile

By using two SVCs, average value of voltage is changed from 94.99273 to 96.95273 i.e. increased by 1.96 units as shown in Fig.8.
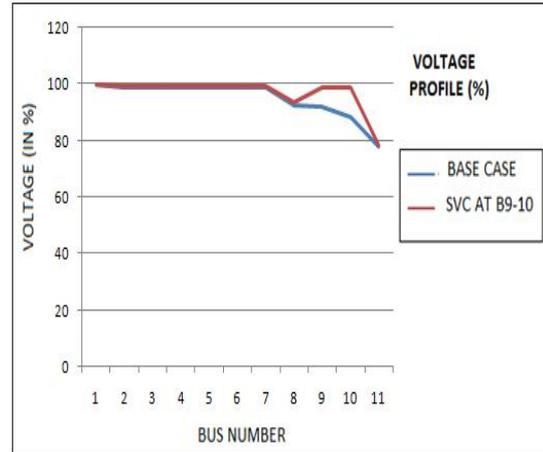


**Figure 8. Comparison of voltage profile between base case and two SVCs at BUS 9-10**

*Losses*
**When one SVC at bus 9 and other SVC at bus 10, Average losses are reduced by 0.84546 units as it is altered from 11.88182 to 11.03636 as shown in Fig.9.**



*Figure 9. Comparison of losses between base case and two SVCs at the BUS 9-10*

*Active Power*
**Two SVCs case gives increase of average active power from 175.0909 to 225.3636 .i.e. increments by 50.2727 units as shown in Fig.10.**
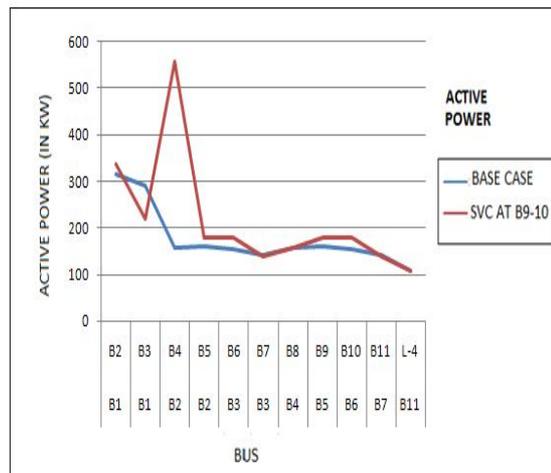


*Figure 10. Comparison of active power between base case and two SVCs at the BUS 9-10*

*Reactive Power*

By using two SVCs, there is decrease of average reactive power from its base average by 101.4546 units .i.e. from 235.8182 to 134.3636 as shown in Fig.11.
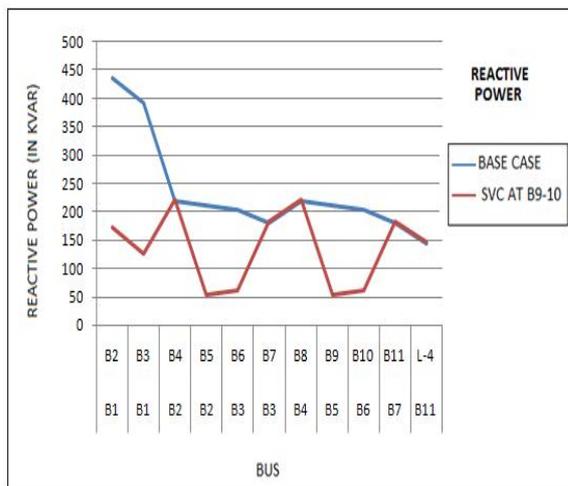


*Figure 10. Comparison of active power between base case and two SVCs at the BUS 9-10*

## 6. CONCLUSION

This paper presents a new approach using Genetic algorithm with excel for the optimal location of SVC in power distribution system. On the induction of SVC and genetic algorithm to find its location, it has found that SVC installed at all following buses where static load is present, Bus 10 gives us increased voltage profile as shown by figure 4, reduced losses as shown by figure 5 and increased active power transfer capability as shown by figure 6.

Using two SVC in the same single line diagram at different locations where static load is present, it has found that SVCs installed at Bus 9-10 gives us increased voltage profile as shown in figure 8, reduced losses as shown in figure 9 and increased active power transfer capability as shown by figure 10. Comparing this with case having single SVC, it can be said that there is appreciable increase in voltage profile, decrease in losses and increase in power transfer capability of case.

Reduction of losses, increase of power transfer capability and voltage profile can also be optimized by number of other optimization methods and instead of having ETAP as a power system solution, the same system can be simulated and the results of various indices like voltage profile, reactive power, active power and losses can be done with the help of Matlab, PSPICE and PSCAD softwares.

## ACKNOWLEDGMENT

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