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Static VAR Controller based Power Flow Control in Distribution System by GA

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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. The Static VAR compensator is designed to decrease the disturbances caused by changes in reactive power and voltage fluctuations in normal operation of transmission lines and industry distribution systems. Disturbances may be caused by line switching, line faults, non-linear components such as thyristor controls and rapidly varying active and reactive loads. These disturbances result in harmonics that load the supply network, and cause voltage fluctuations. Varying loads can also create disturbances in the form of phase unbalance and voltage flicker phenomenon as well as create a need of additional reactive power. The Static VAR Compensator increases the quality of power in many aspects. 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 - **Distribution Network, ETAP, Genetic Algorithm, Static var compensator, Voltage Profile.**

1. INTRODUCTION
Recently, environmental, economical, right of way and energy problems have delayed the construction of both new generation facilities and new transmission lines, while the demand for electric power has continued to grow. To cope up with these problems, FACTS devices such as static var compensator are one of solution nowadays. 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. As a result, it is able to provide fast-acting reactive power compensation on electrical systems. 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 [1]-[2] reactive power

and thyristor-switched capacitor for supplying the reactive power. Proper placement of static VAR compensator (SVC) and thyristor controlled series compensator (TCSC) reduces transmission losses, increases the available capacity, and improves the voltage profile as suggested by Biansoongnern et al [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 Static VAR Compensator (SVC) controller to improve voltage profile using a novel hybrid Genetic Algorithm and Sequential Quadratic Programming (GA-SQP) method. The proposed 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 static var compensators (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 static var compensators (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 [8] by Etemad et al.

This paper deals with the potential applications of static var compensator (SVC) as one of the FACTS controllers, using power electronic switching devices in the fields of power transmission systems with controlling the voltage ,losses and power flow. Number, location and size of SVC are the main concerns and they can be optimized to a great extent by Genetic Algorithm (GA).

2. PROBLEM FORMULATION

Genetic Algorithm is optimization method considered to find the suitable location for SVC device placement in given power system. GA will give set of values of fitness function. The highest value of fitness function will be considered for optimum location of SVC in the given power system.

Single line diagram of 33/11 KV Distribution Substation in ETAP [1] with eleven buses is drawn as shown in Fig. 1. It consists of two power transformers, each having capacity of 3 MVA and four distribution transformers with four static loads. 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.

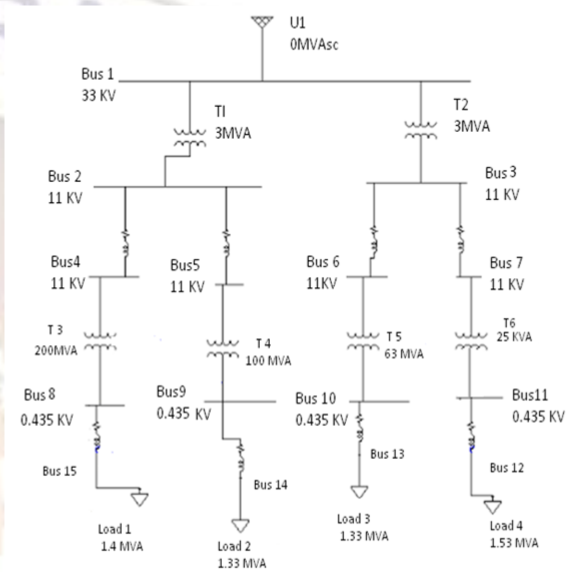

Fig.1.Single line diagram of 33/11 KV distribution system

2.1 Electrical Transient Analyzer Program (ETAP)

ETAP is a fully graphical Enterprise package that runs on Microsoft® Windows® 2000, XP, and 2003 operating systems. ETAP is the most comprehensive analysis tool for the design and testing of power systems available. ETAP's one-line diagram supports a number of features to assist you in constructing networks of varying complexities. The one-line diagram also allows you to place multiple protective devices between a circuit branch and a bus. ETAP is the foremost-integrated database for electrical systems, allowing us to have multiple presentations of a system for different analysis or design purposes.

2.1.1 Load Flow Analysis

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. 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.

Here, Newton Raphson method is considered with maximum iteration of 1000 and precision of 0.01.

3. GENETIC ALGORITHM

Genetic algorithm (GA) is meta-heuristic optimization based on biological principles of evolution and provides an easy Interesting alternative to "classic" gradient-based optimization methods. The nature of the optimization model does not need to be known [9]-[11]. This makes GAs very interesting for complex problems or for users inexperienced in gradient-based optimization techniques. The optimization model and its constraints do not have to be continuous or even real values. No simplification of a problem is necessary to accommodate it to a particular algorithm (e.g. linearization).They are readily available and easily implemented. 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.

Genetic Algorithm has three main options for any problem solution.These are, model formulation, run GA, and GA settings. In model formulation, we select excel file and design variables and constraints so as to get desired output. Run GA allows optimization of problem and GA setting includes population, constraint, main run parameters.

GA gives output in terms of fitness value. The highest value of fitness function gives idea for placement of multiple SVCs.

4. RESULTS

On the basis of optimization by GA, the values of Fitness function for various cases are tabulated in Table 1and Table 2.

Table1 Fitness values for single SVC

Case	Fitness
bus8	0.026989
bus9	0.027019
bus10	**0.035677**
bus11	0.016857

Table 2 Fitness value for double SVCs

Case	Fitness
bus8-9	0.052972
bus8-10	0.051681
bus8-11	0.022305
bus9-10	**0.073585**
bus9-11	0.021431
bus10-11	0.013448

Analysis of SVC on given system gives highest fitness of 0.035677 at BUS-10 for single SVC and 0.073585 at BUS-9 and Bus-10 for double SVC as shown in Fig.2 and Fig. 3 respectively.

Fig.2. Fitness values at various buses

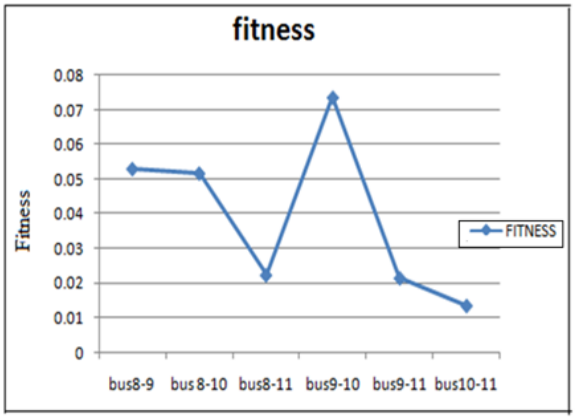

Fig.3. Fitness values for different bus pairs

Thus, we have two choices for optimum location of SVCs in given power system. The improvements in voltage profile by employing SVC are shown in Fig. 4 and Fig. 5.

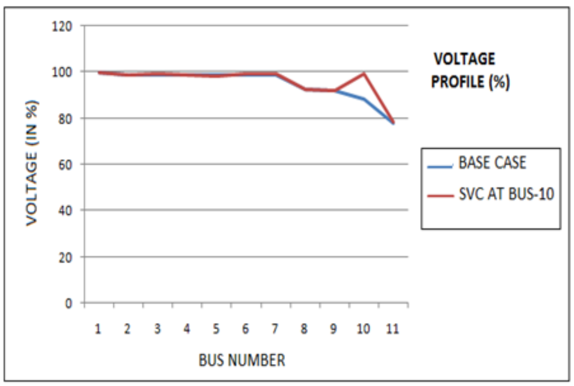

Fig.4. Voltage profile for single SVC

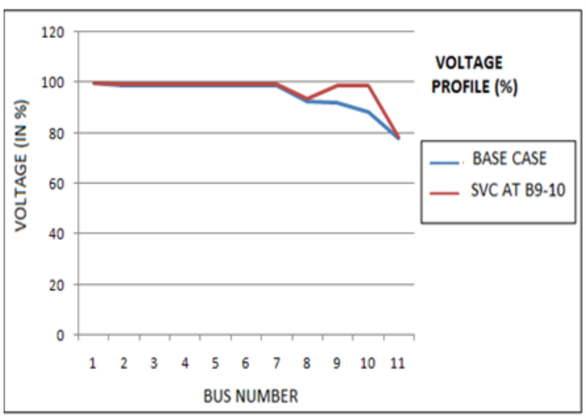

Fig.5. Voltage profile for two SVC

When SVC is connected at Bus-10, the Average voltage is increased by 1.17272 units and when two SVCs are connected at BUS9-10, then average value of voltage is increased by 1.96 units. It also has been seen that SVC gives reduced losses as shown in Fig. 6 and Fig. 7.

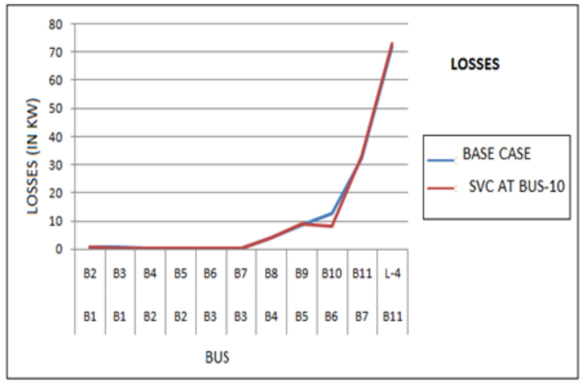

Fig.6. Losses reduction by single SVC

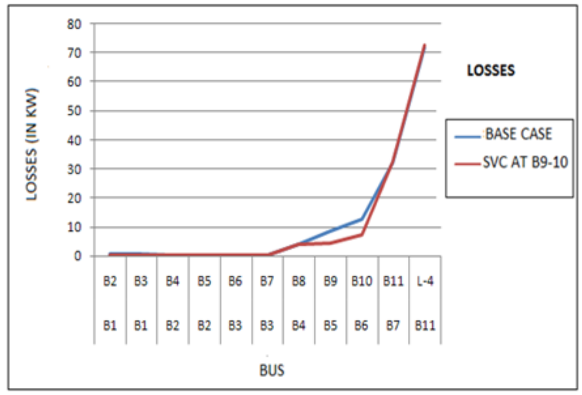

Fig.7. Losses reduction by two SVC

When SVC is connected at Bus-10, Average losses decreased by 1.48182 units and when one SVC at bus 9 and other SVC at bus 10, Average losses are reduced by 0.84546 units. It has been found that 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, 8 and 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. 9.

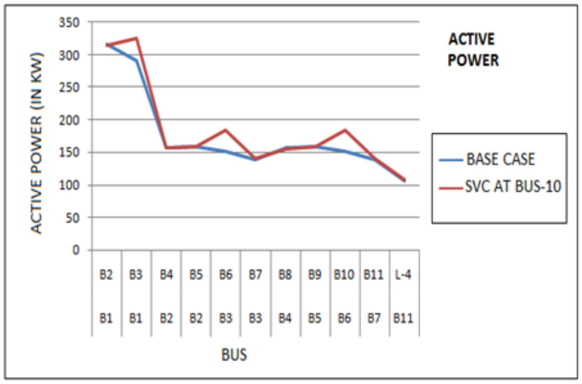

Fig.8. Active power improvement by single SVC

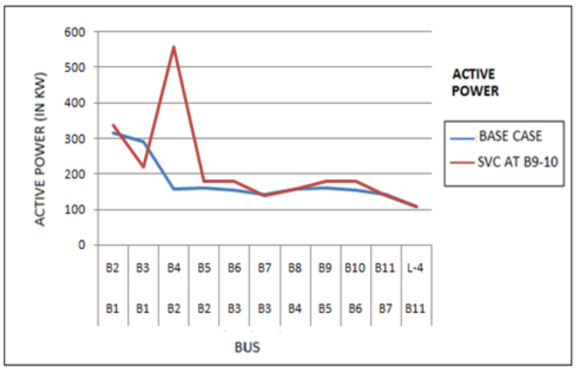

Fig.9. Active power improvement by two SVC

There is also reduction in reactive power by SVC. Average reactive power is decreased from its base average value by 47.18 units with single SVC at Bus-10 .i.e. from 235.8182 to 188.6364 as shown in Fig.10 and decrease of average reactive power from its base average by 101.4546 units .i.e. from 235.8182 to 134.3636 in case of two SVCs at bus 9 & bus10 as shown in Fig. 11.

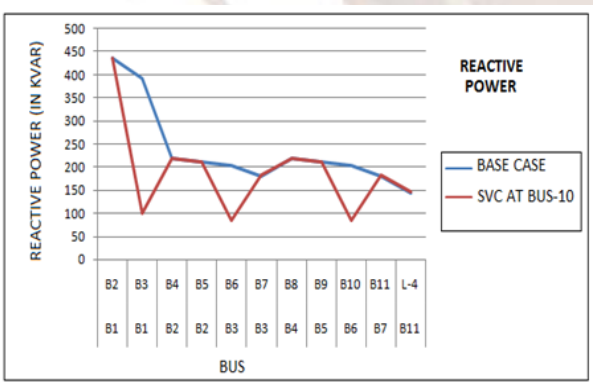

Fig.10. Reactive power obtained for single SVC

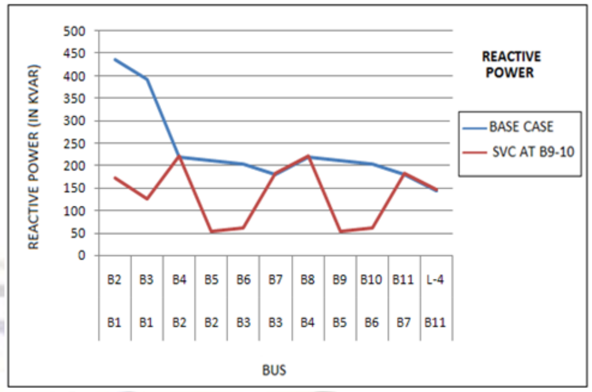

Fig. 11. Reactive power for two SVC

5. CONCLUSION

This paper represents applications of static var compensators in power system. Putting SVC and using genetic algorithm to find its location, it was 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.

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