International Journal of Instrumentation Science 2012, 1(2): 21-24
DOI: 10.5923/j.instrument.20120102.03

Improvement by Voltage Profile by Static Var Compensators in Distribution Substation

Guneet Kour[1], G. S. Brar[1], Jaswanti Dhiman[2,*]

[1]Department of Electrical Engineering, Baba Banda Singh Bhadur Engg College, Fatehgarh Sahib, Punjab
[2]Department of Electrical Engineering, Chandigarh College of Engineering & Technology (CCET), Chandigarh, India
vernacular12@gmail.com, gursewak.singh@bbsbec.ac.in, jaswanti98@yahoo.co.in

Abstract This paper presents the potential applications of static var compensator (SVC) as one of the FACTS(flexible alternating current transmission system) controllers, using power electronic switching devices in the fields of power transmission systems with increasing the voltage and power flow in distribution substations. Load flow analysis of 33/11 kV distribution substation is performed to calculate the various values of voltage and power flow at each bus. Low rated static var compensators are installed at load ends. Simulation of this distribution substation with SVC has been developed in the Electrical Transient Analyser Program (ETAP) Environment .The objective of the study are enhancement in voltage at various buses and the improvement in power flows with reduction in branch losses.

Keywords ETAP, Genetic Algorithm, SVC

1. Introduction

System instability, loop flows, high transmission losses, voltage limit violations, cascade tripping and high operational costs has been mentioned as a result of unregulated active and reactive power flows[1]. Upgrading existing transmission lines by using FACTS controllers is suggested as a solution to these problems[2-4]. Static var compensator is one of the solutions for these problems. It is a power quality device, which employs power electronics to control the reactive power flow of the system where it is connected. Proper placement of 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[5]. Sundar and Ravikumar[6] have suggested that the optimal location of SVC is identified by a new index called single contingency voltage sensitivity (SCVS) index. Khandani et al[7] 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. Khaleghi et al[8] proposed OPF which used to improve voltage profile within real and reactive power generation limits, line thermal limits, voltage limits and SVC operation limits[8]. 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[9].Mixed Integer Nonlinear Programming (MINLP) used as a useful technique for combinatorial optimization over integers and variables to determine optimal location of SVC[10] by Etemad et al.

This paper presents application of static var compensator in power system engineering to give improved voltage profile and increased power transfer capability.

2. Problem Methodology

A Single line diagram of 33/11 KV Distribution Substation is taken[11] 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. Bus 1is swing Bus. Buses from 2 to 7 are PV Buses and Buses from 8 to 11are PQ Buses. Power source to this system is provided by Utility, U1.

In order to see effect of two SVCs on voltage profile, losses and power flows at each bus in given single line diagram, six study cases are taken as shown in Table1.

The optimum location for two SVCs means where more increased voltage and more decreased losses are obtained is

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* Corresponding author:
jaswanti98@yahoo.co.in (Jaswanti Dhiman)

calculated by Genetic Algorithm (GA). GA gives set of values of fitness function for each case considered. The highest value of fitness function gives optimum location of SVCs in given single line diagram.

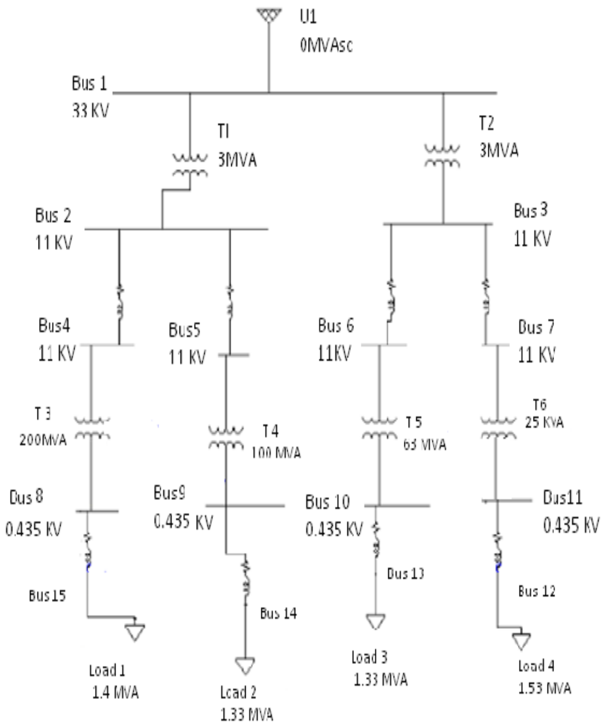

Figure 1. Single line diagram of 33/11 KV distribution substation

Table 1. Various study cases for two SVCs

Study Cases	Two SVCs location	
	Location1	Location2
1	8	9
2	8	10
3	8	11
4	9	10
5	9	11
6	10	11

3. Genetic Algorithm

Genetic algorithm (GA) is the optimization methods used which based on biological principles of evolution and provide an easy interesting alternative to "classic" gradient-based optimization methods[12-14]. Genetic algorithm is a search heuristic that mimics the process of natural selection[15]. 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[16].

Genetic Algorithm proceeds in various steps sequence wise as under,

1. Start with a finite population of randomly chosen chromosomes ("design points") in the design space. This population constitutes the first generation ("iteration").
2. Evaluate their fitness ("function value").
3. Rank the chromosomes by their fitness.
4. 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.
5. Assemble the new generation from these chromosomes and evaluate their fitness.
6. Apply genetic mating as before and iterate until convergence is achieved or the process is stopped.

The primary usefulness of 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 drawbacks of using GA are that a large number of parameters need to be set. This is simplified by information from literature, but problem-specific adjustments might need to be made. Due to the comparatively very large number of function calls, GAs requires significant computational resources. This makes them unattractive for optimization problems with computationally demanding analyses.

4. Results and Discussions

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 when two SVCs are considered, the value of fitness is high at SVC location bus9-10 i.e. **0.073585** as shown in Fig.2. 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.

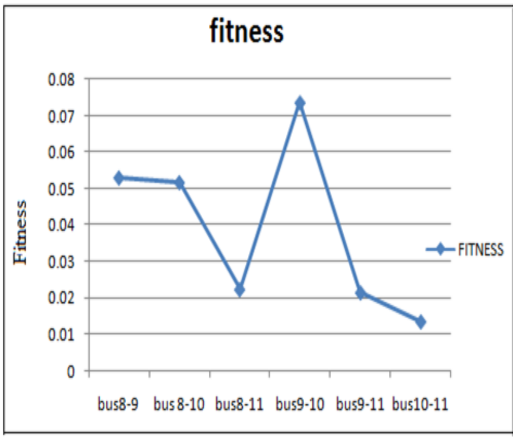

Figure 2. Fitness function values for two SVCs

After load flow analysis by ETAP, the values of branch losses without SVC and with two SVCs obtained are shown in Table 2.

Table 2. Branch losses(KW)

From	To	Without SVC	With two SVCs
Bus1	Bus2	0.6	0.3
Bus1	Bus3	0.5	0.3
Bus2	Bus4	0.2	0.2
Bus2	Bus5	0.2	0.1
Bus3	Bus6	0.1	0.1
Bus3	Bus7	0.1	0.1
Bus4	Bus8	3.7	3.7
Bus5	Bus9	8.6	4.2
Bus6	Bus10	12.6	7.0
Bus7	Bus11	32.2	32.6
Bus11	Load4	71.9	72.8
	Total	130.7	121.4
	Average	11.88	11.036

When two SVCs are considered i.e. one SVC at bus 9 and other SVC at bus 10, Average losses are reduced by 0.84546 units as it is altered from 11.88 to 11.036.

Similarly, the values of voltages without SVC and with two SVCs obtained are shown in Table3 .By using two SVCs, average value of voltage is changed from 94.992 to 96.952 i.e. increased by 1.96 units.

Table 3. Voltage profile (%)

Bus no.	Without SVC	With two SVCs
Bus1	100	100
Bus2	98.92	98.53
Bus3	99.03	99.64
Bus4	98.79	99.41
Bus5	98.8	99.52
Bus6	98.91	99.63
Bus7	98.93	99.53
Bus8	92.87	93.44
Bus9	91.96	98.74
Bus10	88.87	98.72
Bus11	77.84	78.32
Total	1044.92	1066.48
Average	94.992	96.952

The values of active power without SVC and with two SVCs obtained after performing load flow analysis are shown in Table 4.

Table 4. Active Power (KW)

From	To	Without SVC	With two SVCs
Bus1	Bus2	316	337
Bus1	Bus3	291	321
Bus2	Bus4	157	559
Bus2	Bus5	159	178
Bus3	Bus6	152	180
Bus3	Bus7	139	140
Bus4	Bus8	156	158
Bus5	Bus9	159	178
Bus6	Bus10	152	180
Bus7	Bus11	139	140
Bus11	Load4	106	108
	Total	1926	2479
	Average	175.09	225.36

By using two SVCs, we have increase of average active power from 175.0909 to 225.3636 .i.e. increment by 50.2727 units.

4. Conclusions

Using two SVCs in the single line diagram at different locations where static load is present, it has found that by genetic algorithm optimization method that when two SVCs are installed at Bus 9-10, we have highest value of fitness function as compared to other study cases as shown in Fig.2. By employing two SVCs at bus9-10 we have reduced branch losses, increased voltage profile and increased active power.

Reduction of losses, increase of power transfer capability and voltage profile can also be optimized by number of other optimization methods such as simulated annealing, fuzzy logic. Instead of using ETAP software for calculating load flow analysis, the values of various parameters like voltage profile, reactive power, active power and losses can also be calculated with the help of PSPICE and PSCAD softwares.

ACKNOWLEDGEMENTS

The authors would like to express their special thanks to Mr. Neeraj Sharma for his valuable guidance and encouragement in the work related to ETAP (Electrical Transient Analyser Program) software and to Mr.K.P.Singh for his contribution on preparing the final version of this paper. They would also like to acknowledge Department of Electrical Engineering, Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, Punjab, India for their constant support. The authors are thankful to Dr.Lakwinder Singh, Dean Academics, Baba Banda Singh Bahadur Engineering College for his interest in present work.

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