Voltage Stability Improvement By Optimal Location Of SMES In A Power System

Siva Kumar M
PG Student,
Department of EEE, SVEC,
Tirupati, India

Lakshmikantha Reddy M
Asst. Professor,
Department of EEE, SVEC,
Tirupati, India

Abstract

Now-a-day's voltage instability problems in a power system have become one of the most important concerns in the power system. Superconducting magnetic energy storage (SMES) system is an equipment that can help to improve the voltage stability of power system. Location of SMES in multi-node power network plays a significant role for the stability improvement level. In this paper, based on the quantitative voltage stability index (L-index), genetic algorithm (GA) is used for optimization of the SMES location. In GA, voltage stability index is used as the fitness function. The GA mathematical parameters and optimal flow chart are presented. The proposed algorithm is tested in an IEEE 14-bus system.

1. Introduction

Superconducting magnetic energy storage (SMES) system stores energy in the superconducting coil and regenerates it to the utility through power conversion circuits. Because of the difference of gird scales, fault styles and running duties, one may have different choices for the locations of the SMES systems leading to various performances and costs [1]. Thus, it is important to investigate the optimization of the SMES location in different situations.

It has two major advantages, rapid response and high power efficiency, which makes them valuable for improving power system stability in a transmission grid [2]. The most important advantage of SMES is that the time delay during charge and discharge is quite short. Power is available almost instantaneously and very high power output can be provided for a brief period of time. Other energy storage methods, such as pumped hydro or compressed air have a substantial time delay associated with the energy conversion of stored mechanical energy back into electricity. Thus if a customer's demand is immediate, SMES is a viable option. Another advantage is that the loss of power is less than other storage methods because electric currents encounter almost no resistance. Additionally the main parts in a SMES are motionless, which results in high reliability.

An indicator of voltage stability called Voltage Stability Index is defined [3], and loss sensitivity index in [4], with this indicator it is easy to find the most vulnerable area in a power system. From the indicator, it is also allowed to predict the voltage instability or the proximity of a collapse. The advantage of this method lies in the simple numerical calculation and strong adaptation in steady state and transient process. The quantitative voltage stability index varies in the range between 0 (no-load of System) and 1(voltage collapse) is typically used as a criterion for optimization problem.

Various methods and criteria, expressed from a multi-objective optimization perspective, were proposed and used for optimal allocation of FACTS devices in power systems [5],[6], including Pareto optimal solutions, genetic algorithm and particle swarm optimization technique [7].

This paper introduces the application of a genetic algorithm for optimal location of SMES to improve the voltage stability in a power system. It is organized as follows, Section 2 gives information about SMES, In Section 3 quantitative voltage stability index, In Section 4 the flow chart of the optimization is described. In Section 5 simulation results are presented, followed by the conclusion.

2.About SMES

Superconducting magnetic energy storage (SMES) system is an energy storage system that stores energy in the form of dc magnetic field, by passing current through the superconductor. The conductor for carrying the current operates at cryogenic temperatures, where it becomes superconductor and thus has virtually no resistive losses as it produces the magnetic field. Consequently, the energy can be stored in a persistent mode, until required.

In general, an SMES system consists of four parts, which are the superconducting coil with the magnet (SCM), the power conditioning system (PCS), the cryogenic system (CS), and the control unit (CU), as shown in Fig.1.

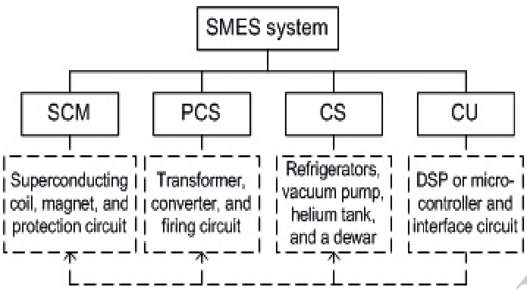

Fig 1. Block diagram of an SMES system.

SMES consists of isolated transformers, voltage source converters (VSC), DC converters (DC/DC), and a superconducting magnet coil, as shown in Fig.2.

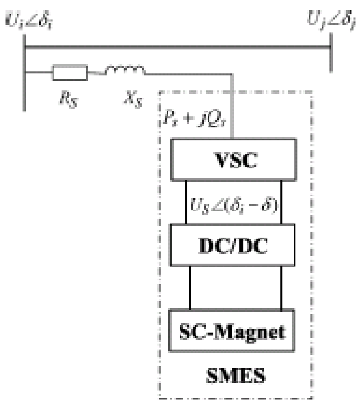

Fig. 2 : A schematic of a SMES system connected to a power system. The SMES system is shown within the dashed line.

1. Voltage Stability Index

In power system, the stability level of all buses and the weakest bus among them are identified with the help of the stability indices. Voltage Stability Index (L-Index) is one among them.

The minimum singular value of the power flow Jacobian matrix has been used as a static voltage stability index. VSI indicates the distance between the studied operating point and the steady-state voltage stability limit. Operators can use the index to know how close the system to voltage collapse, or how much power that the system can supply to loads. This index can be used on-line or off-line to help operators in real time operation of power system or in designing and planning operations [8].

Voltage Stability Index is used to calculate the stability indices for all the load buses connected in an IEEE 14 bus network. For a given system operating condition, by using the load flow results obtained from Newton- Raphson Technique, the Voltage Stability index (L- index) for load buses is to be computed as:

$$L_j = \left| 1 - \sum_{i=1}^{g} F_{ji} \frac{V_i}{V_j} \right| \qquad (1)$$

Where g is the no of generators connected in the system. And j=g+1….n. Where n is the total number of buses.
The values of F_{ji} can be obtained from Y bus matrix.

$$F_{ji} = [Y_{LL}]^{-1}[Y_{LG}] \qquad (2)$$

Where Y_{LL}, Y_{LG} are corresponding partitioned portions of the Y-bus matrix. The L-indices for a given load condition are computed for all load buses and the maximum of the L- index gives the proximity of the load bus to voltage collapse.

2. Algorithm and Implementation

Genetic Algorithm (GA) is an efficient search technique used in computing to find exact or approximate solution to optimization and search problems [9]. They are being applied successfully to find acceptable solutions to problems in business, engineering, and science. GAs are generally able to find good solutions in reasonable amounts of time, but as they are applied to harder and bigger problems there is an increase in the time required to find adequate solutions. Here, the optimal objective is to reach the best transient voltage stability. The Fig.3 below shows the flow chart for SMES optimal locationn.

The implementation of GA is as follows.

1) Set SMES parameters and prepare to solve the stability problem in transmission grid.
2) Define GA parameters
   Such as the number of individuals (NIND=20), the maximum number of generations (MAXGEN=100), the generation gap (GGAP), the precision of variables (Preci), etc.
3) Initial population
   The SMES location rules shown below can guide the chromosome selection.
   a. A minimal number of devices should be installed to minimize the cost.
   b. Generator buses where voltages are regulated do not need SMES installation.
   c. If the bus voltage is above 0.95 p.u., then none of the SMES systems will be installed.

   A binary coding, also known as a chromosome, represents the solution of optimal problem, one bit is considered for presenting the SMES on node.
4) Assign fitness values
   The fitness value of each chromosome is the voltage stability index for the transient voltage stability in the related transmission grid. So the stability is calculated for each transmission grid. The result is the fitness value of the chromosome
   Fitness= a*L
   where 'a' is coefficient and L is the transient voltage stability index.
5) GA operators
   Selection and crossover operators are carried out on the chromosome with the pre-specified probabilities.

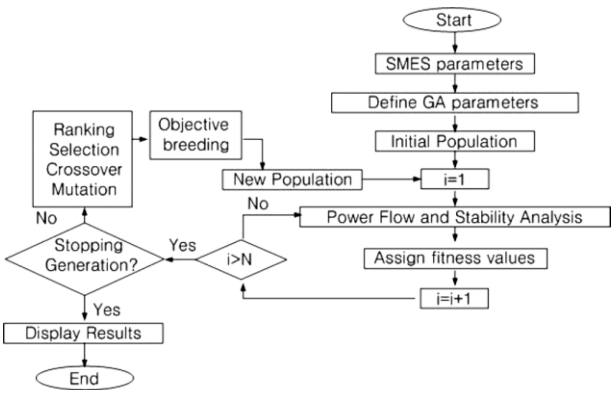

Fig. 3. The flow chart of SMES optimal location.

a) Selection

A selection method known as roulette-wheel is chosen [10]. The selection ratio P_J is

$$p_i = \frac{f_i}{\sum_{j=1}^{N} f_j} \tag{3}$$

where f_i is the fitness of i^{th} element in the population and N is the population number.

b) Crossover

Arithmetic crossover is chosen based on the following formulas:

$$\left.\begin{aligned} O_1 &= \lambda P_1 + (1-\lambda) P_2 \\ O_2 &= \lambda P_2 + (1-\lambda) P_1 \end{aligned}\right\} \tag{4}$$

Where P_1, P_2 are the two parents.O_1, O_2 are two Children .λ_1 , λ_2 are two random numbers.

3. Results

The application is carried out on the IEEE 14-bus test system [11] shown in Fig.4, which consists of two generators, Three synchronous compensators are set at buses 3, 6 and 8.Nine load buses and 20 transmission lines.

ISSN: 2278-0181
Vol. 2 Issue 5, May - 2013

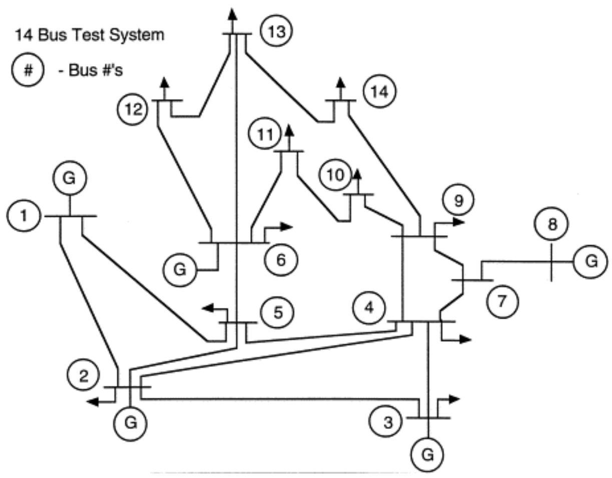

Fig 4: IEEE 14 bus test system

Table I shows the initial operating condition of the network. The generating and regulated buses are ignored. Simulations are performed under a three phases ground fault as an example starting at t=0s on the line between bus 2 and 3, and fault is cleared at t=0.1s.

TABLE I
INITIAL CONDITION OF THE 14-BUS NETWORK

Bus	Voltage		Bus Power	
Number	Mag (pu)	Ang (pu)	P(MW)	Q (MVAR)
4	1	0	57.8	23.9
5	1	0	47.6	1.6
7	1	0	0	0
9	1	0	29.5	16.6
10	1	0	29.5	5.8
11	1	0	13.5	5.8
12	1	0	36.1	1.6
13	1	0	23.5	5.8
14	1	0	14.9	5

The load flow is performed for an IEEE-14 bus test system. By substituting the corresponding load flow results in the equations (1) and (2) to obtain the VSI. These are shown in bellow table II

Table I
Voltage Stability Index Values at Load Buses.

Load Bus No.	Voltage Stability Index Value
4	0.7270
5	0.7260
7	0.7020
9	1.0000
10	1.0000
11	0.5070
12	0.4710
13	0.4470
14	1.0000

The L index gives a scalar number to each load bus. If the index value (L index) is moving towards zero, then the system is considered as stable and also improves system security. When this index value moves away from zero, the stability of system is relatively decreases then the system is considered as unstable.

In this test case, VSI at load buses 9, 10 and 14 is 1. So voltage at these buses is about to collapse for any small disturbance. To avoid this, SMES are placed at optimal location. This optimal location is given by Genetic Algorithm using voltage stability index as fitness function.

The buses calculating for location of SMES systems are 10, and 14. Voltage profiles with and without the optimally positioned SMES systems are compared in Fig. 5. It can be seen that voltage stability is enhanced when SMES systems are settled on the best site through GA optimization.

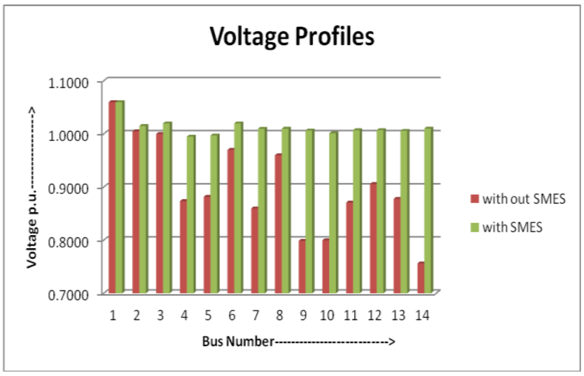

Fig. 5 Voltage profiles with and without SMES systems.

1. CONCLUSION

The paper has demonstrated the application of GA on location of SMES systems in transmission grid, for the aim of voltage security enhancement. Simulation results through an IEEE 14-bus test system show the significantly voltage stability enhancement and validate the efficiency of the optimal location of SMES. Cost-benefit of SMES systems as fitness function will be considered in the future work.

REFERENCES

[1] Z.L.Lin and Y.Min,"*On-line steady state security assessment of power systems based on SMES*," Automation of Electric Power Systems, vol.27, pp.40-44, Apr.2003.

[2] Arsoy, and Y. Liu, "*Energy storage systems for advanced power applications*," *Proceedings of the IEEE*, vol. 89, no. 12, pp. 1744–1756, Dec. 2001.

[3] I.Kumaraswamy, W.V.Jahnavi, T.Devaraju, P.Ramesh "*An* P. F. Ribiero, B. K. Johnson, M. L. Crow, A. *Optimal Power Flow (OPF) Method with Improved Voltage Stability Analysis*" proceedings of the world congress on Engineering , WEC 2012,July 4-6, 2012, London, U.K.

[4] S.J.Lee,"Location of superconducting device in a power grid for system loss minimization using loss sensitivity" IEEETrans. Applied superconductivity, vol.17, no 2, pp.2351-2354, jun.2007.

[5] M.K.Verma and S.C.Srivastava," *Optimal placement of SVC for static and dynamic voltage security enhancement*, "International Journal of Emerging Electric Power Systems, vol.2, no.2, 2005, Article 1050.

[6] M.F.Malihe, N.P.Hossien, and K.Y.Lee,"*Multi-objective VAR planning with SVC for a large power system Using PSO and GA*," in 2006 power system conference & Exposition, pp.174-279.

[7] M.A.Abido," *Multiobjective evolutionary algorithms for electric power dispatch problem*," IEEE Trans. Evolutionary computation, vol.10.no.3, pp.315-329, jun.2006.

[8] P. Kessel and H. Glavitch, "*Estimating the voltage stability of a power system*," *IEEE Trans. Power Delivery*, vol. PWRD-1, pp. 346–354, 1986.

[9] S. Grossberg, "Competitive learning: From interactive activation to adaptive resonance," *Cognitive Science*, vol. 11, pp. 23–63, 1987.

[10] D. E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*. Reading, MA: Addison-Wesley, 1989.

[11] Power System Test Archive-UWEE (University of Washington). [On-line]. Available: http://www.ee.washington.edu/research/pstca.