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Minimization of Real and Reactive Power Loss by Incorporation of STATCOM Using Newton Raphson Load Flow Method

Priyanka Sharma[1], Manish Awasthi[2]
Department of Electrical Engineering
Jawaharlal Nehru College of Technology, Rewa, India
[1]priyankasharma7[AT]yahoo[DOT]co[DOT]in, [2]manishawa08[AT]gmail[DOT]com

Abstract: - The different problems occurring in operation and control of emerging modern restructured power systems can be resolved up to some extent by the use of flexible AC transmission system (FACTS) devices. In this paper, the injection model of STATCOM is used to investigate its effects on bus voltages and loss reduction in a power system In this paper, NRLF has been applied to obtain optimal location and sizing of static synchronous compensator (STATCOM) to minimize real & Reactive power loss, voltage deviation and sizing of STATCOM considering outage of the most critical contingencies. In first step of proposed methodology, contingency ranking has been carried out for determination of the most severe line outages by evaluating voltage. It is observed from the results that the voltage profile of the power system are increased and are within limits, also real power losses are reduced there by optimally locating STATCOM device in the power system. The proposed method is tested on IEEE 14 bus system.

Keywords: - Real power loss, Reactive power loss, Static synchronous compensator (STATCOM, Contingencies.

I. INTRODUCTION

Now a day, Modern power network are facing problem regarding stability and control, due to the increase in peak load demand and power transfer between utilities, increasing complexity in network and change in network topology. This rapid increase in load demand forces power system to operate near its critical limits due to economical and environmental pressure. It drives the power system to run as close to its stability boundary as possible to save more money. Voltage stability is one of the major problem associate with such stressed power system. Report of the occurrence of the voltage collapse is becoming more frequent and this problem has been an area of great interest to power system engineers. A power system is said to be an unstable system or in a state of voltage instability when a fault causes a progressive and uncontrollable decline in voltage. The voltage collapse is a local phenomenon and it occurs at a bus within an area of high loads and low voltage profile. Recently, FACTS-based devices have been used for power flow control and for damping power system oscillations. They can also be used to increase transmission line capacity; steady state voltage regulation; provide transient voltage support to prevent system collapse; and damp power oscillations. FACTS devices can be used in wind power systems to improve the transient and dynamic stability of the overall power system. The STATCOM is from the family of FACTS devices that can be use to provide transient voltage support to prevent system collapse. In other words a STATCOM is an electronic generator of reactive power. A review on applications of Flexible AC Transmission Systems (FACTS) controllers[1] such as Thyristor Controlled Reactor (TCR), Thyristor Controlled Switched Reactor (TCSR), Static VAR Compensator (SVC) or Fixed Capacitor. The different problems occurring in operation and control of emerging modern restructured power systems can be resolved up to some extent by the use of flexible AC transmission system (FACTS) devices [2]. Due to huge capital investment of these devices, at the planning stage of installation of these devices, an exhaustive exploration is required to attain utmost advantages of these devices. Flexible AC Transmission System (FACTS) was launched to solve the emerging system problem. It identifies alternating current transmission system incorporating power electronics based controllers to enhance the controllability increase power transfer capability. These controllers are used to regulate power flow, transmission voltage and through rapid control action can mitigate dynamic disturbances. Static Var compensator (SVC) and Static Synchronous Compensator (STATCOM) are widely used for shunt reactive compensation in order to maintain a flat voltage profile. Other FACTS controllers such as Thyristor Control Series Capacitor (TCSC) and Static Synchronous series capacitor are used to control power flow through transmission line. Power Flow Study is necessary for planning, operation and economic scheduling and exchange of power between utilities. Power Flow study is required for many other analyses such as transient stability, optimal power flow and contingency studies.

The principle information obtained from power flow study is magnitude and phase angle of voltage at each bus and real and reactive power flowing in each transmission lines. In this work, the increase in voltage profile is done through the insertion of Static Synchronous Compensator (STATCOM), a shunt connected FACTS controller which is capable of generating or absorbing reactive power in order to control the voltage magnitude of the bus where they are connected. The following objectives are hopefully to be achieved in this work: The technical literatures contributed by esteemed authors and scientists have been reviewed for this work. To develop the mathematical model of STATCOM. To develop the Newton-Raphson method of load flow in electrical power system. To use the NRLF technique for optimal location of STATCOM in electrical power system. To use the NRLF technique for optimal size of STATCOM in electrical power system. To compare the results of voltage profile obtain from Newton-Raphson method. To compare the power loss with and without STATCOM in electrical in power system.

II. PROPOSED METHODOLOGY

The FACTS devices represent a relatively new technology for power transmission systems. They provide the same benefits as conventional compensators with mechanical switches (circuit breaker) in steady state power system operation; in addition, they improve the dynamic and transient performance of the power system. This is achieved by fast switching time and repeatable operation of solid state switches as compared to mechanical switches. The switching time of solid state switch is a portion of a periodic cycle; and this is much faster than that of a circuit breaker with a switching time of a number of cycles. Generally, the main objectives of FACTS are to increase the useable transmission capacity of lines and control power flow over designated transmission routes. The power flow over a transmission line depends mainly on three important parameters, namely voltage magnitude of the buses (*V*), impedance of the transmission line (Z*)* and phase angle between buses (θ). The FACTS devices control one or more of the parameters to improve system performance by using placement and coordination of multiple FACTS controllers in large-scale emerging power system networks to also show that the achieve significant improvements in operating parameters of the power systems such as, small signal stability, transient stability, damping of power system oscillations, security of the power system, less active power loss, voltage profile, congestion management, quality of the power system, efficiency of power system operations, power transfer capability through the lines, dynamic performances of power systems, and the load ability of the power system network also increased. As FACTS devices are fabricated using solid state controllers, their response is fast and accurate. Thus these devices can be utilized to improve the voltage profile of the system by using coordinated control of FACTS controllers in multi machine power systems. The following definition for FACTS and FACTS Controllers are defined by IEEE. Flexible AC Transmission System (FACTS): Alternating current transmission system incorporating power electronic based and other static controller to enhance controllability and increase power transfer capability. FACTS Controller: A power electronic based system and other static equipment that provide control of one or more AC transmission system parameters.

III. CASE STUDY AND RESULTS

For our proposed work IEEE-14 bus for minimum power loss analysis. With the objective to bring the bus Real & Reactive Power loss nearer to 1 pu, STATCOM are implemented in these test system to improve the Real & Reactive Power loss minimum. We use the line and bus data in Newton-Raphson load flow analysis to calculate the Real & Reactive Power and voltage of each bus. A general electrical power system consists of mainly three systems, generation, transmission and utilization. In generation system we generate electrical power from mechanical power, in transmission we transmit the electrical power from generating station to utilization centre, and in utilization we use electrical power for different form of work. For good quality of power the voltage profile, frequency and continuity of electrical power is essential. In this work mainly concern with maintenance of rated voltage profile irrespective of change in load or other parameters of the electrical power system. Management of reactive power is essential for maintaining of rated voltage profile. The following power system performance indices are as follows:

a) Real Power Index (RPI)

The real power index defined as:

$$RPI = \frac{RP_{with\_STATCOM}}{RP_{without\_STATCOM}}$$

b) Reactive Power Index (RCPI)

The real power index defined as:

$$RCPI = \frac{RCP_{with\_STATCOM}}{RCP_{without\_STATCOM}}$$

c) Voltage Deviation Index (VDI)

The voltage deviation index defined as:

$$VDI = \frac{VDI_{with\_STATCOM}}{VDI_{without\_STATCOM}}$$

The *IEEE*-14 bus systems are given blow in Fig. 1 in the system there are three PV bus/generators bus systems. The parameter of the nine bus systems are given in table 2.

Parameters of IEEE-14 bus System

(I) BUS DATA

Table 1: Parameters of IEEE-14 bus System

Bus_i	Type	P_d	Q_d	G_s	B_s	Area	Vm	Va	Base kV	zone	Vmax	Vmin
1	3	0	-3	0	0	1	1.06	0	0	1	1.06	0.94
2	2	21.7	12.7	0	0	1	1.045	-4.98	0	1	1.06	0.94
3	2	94.2	19	0	0	1	1.01	-12.72	0	1	1.06	0.94
4	1	47.8	-3.9	0	0	1	1.019	-10.33	0	1	1.06	0.94
5	1	7.6	0.6	0	0	1	1.02	-8.78	0	1	1.06	0.94
6	2	11.2	7.5	0	0	1	1.07	-14.22	0	1	1.06	0.94
7	1	0	0	0	0	1	1.062	-13.37	0	1	1.06	0.94
8	2	0	0	0	0	1	1.09	-13.36	0	1	1.06	0.94
9	1	29.5	16.6	0	19	1	1.056	-14.94	0	1	1.06	0.94
10	1	9	2.8	0	0	1	1.051	-15.1	0	1	1.06	0.94
11	1	3.5	1.8	0	0	1	1.057	-14.79	0	1	1.06	0.94
12	1	6.1	1.6	0	0	1	1.055	-15.07	0	1	1.06	0.94
13	1	13.5	5.8	0	0	1	1.05	-15.16	0	1	1.06	0.94
14	1	14.9	5	0	0	1	1.036	-16.04	0	1	1.06	0.94

(II) GENERATOR DATA

Table 2: Parameters of IEEE-14 bus System

Bus	Pg	Qg	Qmx	Qmn	Vg	mBase	Status	Pmx	Pmn
1	232.4	-19.6	10	0	1.06	100	1	332.4	0
2	40	42.4	50	-40	1.045	100	1	140	0
3	0	23.4	40	0	1.01	100	1	100	0
6	0	12.2	24	-6	1.07	100	1	100	0
8	0	17.4	24	-6	1.09	100	1	100	0

3.1 Results of IEEE-14 bus System by MATLAB Programming of N- R technique

In IEEE- 14 bus system the results of real power profile from the N-R technique are given below in this table no. 3. The optimal location of the STATCOM is at bus no. 14 and the optimal size of the STATCOM is 5 (MVAR). This table shows the Real Power loss of the buses with and without STATCOM. The overall Real Power loss profile of the fourteen bus systems is minimized when STATCOM size are maximum and placed at optimal location of bus no 14. From Fig. 1 it is concluded that when the size of STATCOM is increasing Real Power Loss is decreasing. Minimum loss occurs by using 5MVAR which is maximum size at location of bus no-14 by N-R load flow technique.

3.2 Reactive Power Loss

In IEEE- 14 bus system the results of real power profile from the N-R technique are given below in this table no. 4 The optimal location of the STATCOM is at bus no. 14 and the optimal size of the STATCOM is 5 (MVAR). This table shows the Reactive Power loss of the buses with and without STATCOM. The overall Reactive Power loss profile of the fourteen bus systems is minimized when STATCOM size are maximum and placed at optimal location of bus no 14. From Fig. 3 it is concluded that when the size of STATCOM is increasing Real Power Loss is decreasing. Minimum loss occurs by using 5MVAR which is maximum size at location of bus no-14 by N-R load flow technique.

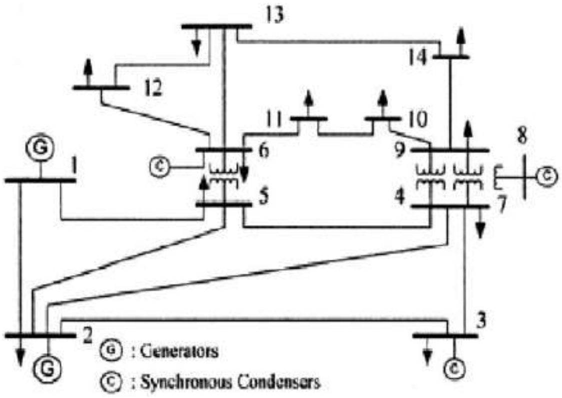

Fig.1 IEEE-14 bus system

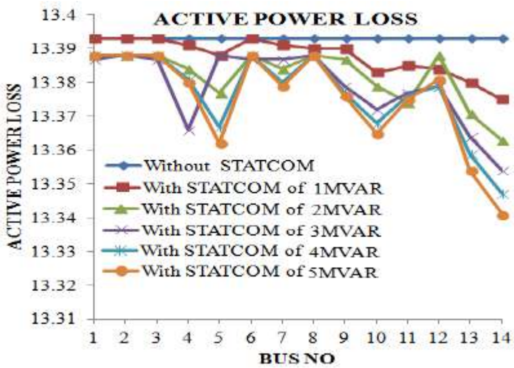

Fig. 2 Real Power loss Profile with and without STATCOM

Table 3: Real Power loss of IEEE-14 bus System

REAL POWER LOSS (MW)						
BUS NO	Without STATCOM	With STATCOM of 1MVAR	With STATCOM of 2MVAR	With STATCOM of 3MVAR	With STATCOM of 4MVAR	With STATCOM of 5MVAR
1	13.393	13.393	13.388	13.387	13.388	13.388
2	13.393	13.393	13.388	13.388	13.388	13.388
3	13.393	13.393	13.388	13.387	13.388	13.388
4	13.393	13.391	13.384	13.366	13.381	13.38
5	13.393	13.388	13.377	13.388	13.367	13.362
6	13.393	13.393	13.388	13.387	13.388	13.388
7	13.393	13.391	13.384	13.387	13.38	13.379
8	13.393	13.39	13.388	13.388	13.388	13.388
9	13.393	13.39	13.387	13.379	13.377	13.376
10	13.393	13.383	13.379	13.372	13.368	13.365
11	13.393	13.385	13.374	13.377	13.376	13.375
12	13.393	13.384	13.388	13.379	13.379	13.381
13	13.393	13.38	13.371	13.364	13.359	13.354
14	13.393	13.375	13.363	13.354	13.347	13.341

Table 4: Reactive Power loss of IEEE-14 bus System

REACTIVE POWER LOSS (MVAR)						
BUS NO	Without STATCOM	With S TATCOM of 1MVAR	With STATCOM of 2MVAR	With STATCOM of 3MVAR	With STATCOM of 4MVAR	With STATCOM of 5MVAR
1	54.54	54.54	54.52	54.52	54.52	54.52
2	54.54	54.54	54.52	54.52	54.52	54.52
3	54.54	54.54	54.52	54.52	54.52	54.52
4	54.54	54.52	54.49	54.48	54.47	54.38
5	54.54	54.52	54.48	54.45	54.45	54.44
6	54.54	54.54	54.52	54.52	54.52	54.52
7	54.54	54.52	54.49	54.47	54.46	54.45
8	54.54	54.52	54.52	54.52	54.52	54.52
9	54.54	54.51	54.47	54.46	54.44	54.43
10	54.54	54.5	54.47	54.46	54.42	54.4
11	54.54	54.5	54.47	54.47	54.46	54.46
12	54.54	54.5	54.47	54.49	54.48	54.48
13	54.54	54.5	54.48	54.4	54.44	54.43
14	54.54	54.48	54.44	54.4	54.39	54.37

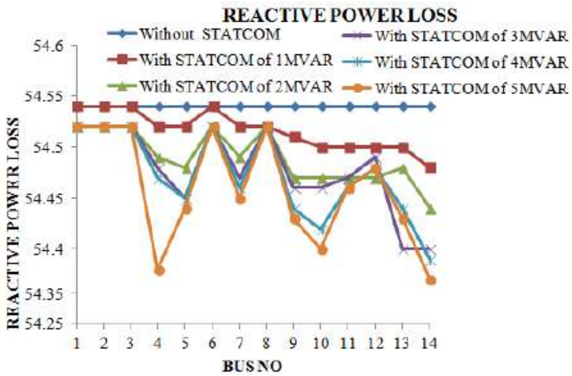

Fig. 3 Reactive Power loss Profile with and without STATCOM

IV. CONCLUSIONS

This work addresses the enhancement of voltage profile in power system environment using STATCOM for test systems in MATLAB environment. In this work we introduced the Static Synchronous Compensator (STATCOM), a shunt connected Flexible AC Transmission System (FACTS) device which is capable to increase the load ability, improve the voltage profile, minimize the active power losses, increased the available transfer capacity, enhance the transient and steady-state stability The main conclusion of the work is such as Performance of STATCOM is analyzed in Test system of IEEE-14 bus systems from power system performance point of view such as real power loss, reactive power loss are minimized and improve voltage profile of system using MATLAB tool box environment.

REFERENCES

[1]. B. Singh, K.S. Verma, Deependra Singh, C.N. Singh, "Introduction to FACTS Controllers a Critical Review", IJRIC, Vol.8, Dec. 2011.

[2]. Shishir Dixit, Laxmi Srivastava, Ganga Agnihotri "Optimal Location and Sizing of STATCOM for Minimizing Power Loss and Improving Voltage Profile using GA",IJCSNT,Vol.4,No.1,2014

[3]. A. Kumaran , A. Allirani "Location of FACTS devices for Real and Reactive Power Flow Control", 2011 International Conference on Signal, Image Processing and Applications With workshop of ICEEA 2011IPCSIT vol.21 (2011) © (2011) IACSIT Press, Singapore.

[4]. Reza Sirjani, Azah MOHAMED, Hussain SHAREEF "Optimal Placement and Sizing of Shunt FACTS Devices in Power Systems Using Heuristic Optimization Techniques: a Comprehensive Survey"

[5]. S. M. Mahaei, M. Tarafdar Hagh, K. Zare "Modeling FACTS Devices in Power System State Estimation" Department of Power Engineering, University of Tabriz, Tabriz, Iran Article history :Received Oct 29th, 2011Revised Dec 26th, 2011Accepted Jan 07th, 2012 ISSN: 2088-8708 -57Journal homepage:

[6]. Thomas John "Line loss minimization and voltage regulation using UPFC" Department of Electrical and

Electronics Engineering Velammal Engineering College, Chennai, India"Received:5 July 2011; Received in revised form: 23August 2011; Accepted: 28 August 2011;

[7]. S. Auchariyamet, S. Sirisumrannukul "Optimal Reactive Power Planning with Facts Devices by Particle Swarm Technique" King Mongkut's University of Technology North Bangkok, Thailand, 8-11 Nov. 2009. Page(s): 1 - 6. Conference Locatio: Hong Kong, China; DOI: 10.1049/cp.2009.1792; Publisher, IET.

[8]. Hirotaka Yoshida, Kenichi Kawata, Yoshikazu Fukuyama, "A Particle Swarm Optimization for Reactive Power and Voltage Control Considering Voltage Security Assessment" Vol. 15, No. 4, Nov. 2006.

[9]. K Sundareswaran, Hariharan B, Fawas Palasseri Parasseri, Daniel Sanju Antony and Binyamin Subair "Optimal Placement of Static VAr Compensators (SVC's) Using Particle Swarm Optimization" IEEE 2010.

[10]. R. Benabid, M. Boudour, "Optimal Placement of FACTS devices for Multi objective Voltage Stability Problem" Member, IEEE, and, M. A. Abido, Member, IEEE

[11]. S.Sakthivel, R. Vetrivel and V. Senthamarai Kannan "Optimal Location of SVC for Voltage Stability Enhancement under Contingency Condition through PSO Algorithm" V.R.S. College of Engg and Tech, Villupuram, Tamil Nadu, India.

[12]. Tridib K. Das, Sandhya R. Jetti, and Ganesh K. Venayaga moorthy, "Optimal Design of SVC Damping Controllers with Wide Area Measurements Using Small Population based PSO" Member *IEEE* International Joint Conference on Neural Networks July 16-21, 2006.

[13]. Abdelaziz Laïfa and Mohamed Boudour "Optimal Location of SVC for Voltage Security Enhancement using MOPSO" JES No. 1, Nov. 2009, PP: 73-78.

[14]. K. Dhananjaya Babu and M. Damodar Reddy "Optimal Placement Of SVC Using Fuzzy and PSO Algorithm" International Journal of Engineering Research and Applications (IJERA) ISSN-2248-9622, vol. 3, Issue 1, January-February 2013, pp.485-490.

[15]. Mehdi Eghbal, E. E. El-Araby, Naoto Yorino, Yoshifumi Zoka, "Application of Meta heuristic Methods to Reactive Power Planning: A Comparative Study for GA, PSO and EPSO" Systems, Man and Cybernetics, 2007. ISIC. IEEE International Conference on 7-10 Oct. 2007, ISBN- 978-1-4244-0990-7, publisher IEEE, pp. 3755-3760.

[16]. Mehdi Eghbal, Naoto Yorino and Yoshifumi Zoka, "Comparative Study on the Application of Modern Heuristic Techniques to SVC Placement Problem" JOURNAL OF COMPUTERS, VOL. 4, NO. 6, JUNE 2009, Academy Publisher, pp 535-541.

[17]. Malihe M. Farsangi , Hossien Nezamabadi-Pour, and Kwang Y. Lee, "Multi-objective AVr Planning with SVC using Immune algorithm and Guaranteed Convergence Particle Swarm Optimization" Proceeding of the 17th World Congress the international federation of Automatic Control Seoul, Korea, July 6-11, 2005, IEEE, IFAC, 2008 pp. 5599-5604

[18]. B.Singh, K.S. Verma, K.K. Singh, Anuj Kumar Shukla, Anurag Singh, and Jayant Vishnu Narlikar "Clearance of Fault in Power System Networks by SVC and STATCOM" Dept. of EE KNIT, Sultanpur-228118 (U.P.), India July6-11,2008.

[19]. Malihe M. Farsangi, Hossein Nezamabadi-pour and Kwang Y. Lee, "Implementation of GCPSO for Multi-objective VAr Planning with SVC and Its Comparison with GA and PSO" Intelligent Systems Applications to Power Systems, 2007. ISAP 2007. International Conference on Conference 5-8 Nov. 2007 ISBN-978-986-01-2607-5, pp.1-6.

[20]. S. Naga lakshmi and N. Kamaraj, "Load ability Enhancement for Pool Model with FACTS devices in Transmission System using Differential Evolution and Particle Swarm Optimization "Power Electronics (IICPE), 2010 India International Conference on Conference 28-30 Jan. 2011, pp. 1 - 8.

[21]. Vivek Kumar Jain, Himmat Singh, and Laxmi Srivastava, "Minimization of Reactive Power Using Particle Swarm Optimization" Dept. EEE, Madhav Institute of Technology and Science, Gwalior (M.P.), India, IJCER, May-June, 2012, Vol.2, Issue No.3, PP 686-691.