Energy Reports 4 (2018) 418–434

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

Research paper

# Enhancement of voltage profile by incorporation of SVC in power system networks by using optimal load flow method in MATLAB/Simulink environments

Bindeshwar Singh *, Garima Agrawal

*Kamla Nehru Institute of Technology (KNIT), Sultanpur, Uttar Pradesh, India*

ARTICLE INFO

*Article history:*
Received 22 January 2018
Received in revised form 5 July 2018
Accepted 12 July 2018

*Keywords:*
Flexible Alternating Current Transmission Systems (FACTS)
Static Var Compensator (SVC)
Distribution systems
Newton–Raphson Load Flow (NRLF)
Distributed generation (DG)

ABSTRACT

Flexible AC Transmission Systems (FACTS) controllers could be a suitable alternative to provide reactive power support at the load centers locally and hence keep the voltages within their safe operating limits. Due to high costs of FACTS devices, their proper location in the system must be ascertained. The fundamental object of this thesis work is to improve the voltage profile by reducing the real and reactive power loss in the system. The voltage profile in the system is being improved by using the FACTS device Static VAR Compensator (SVC). In this paper, studies and analyzes SVC technology for voltage enhancement, reducing system losses, suppression of fluctuations. The effectiveness of the proposed method has been tested on IEEE-9 and IEEE-30 bus systems. Optimal placement has been obtained for the base case loading and to verify its locations. To achieves the optimization of the location and the size of the power system to optimize the system performance. A Newton–Raphson Load Flow problem has been formulated with an objective to improve the voltage profile with minimization of the losses. Moreover, the effects of SVC on economic condition have also been investigated. The results obtaining is in the form of the plot and compared with the plots without SVC. This work also helpful for whose persons are working in the field of FACTS controllers planning.



## 1. Introduction

Modern power systems are becoming more vulnerable to operating limit violation and voltage instability problems due to large transmission networks, deregulation of the electricity industry and utilization of various renewable energy sources as well as different load patterns. As power systems have evolved through continuing growth in interconnections, use of new technologies and controls, and the increased operation in highly stressed conditions, different forms of system instability have emerged. For example, voltage stability, frequency stability and interred oscillations have become greater concerns than in the past. This has created a need to review the definition and classification of power system stability. Now a day's many methods are used to generate and to control the reactive power without the use of the capacitors and the reactor banks like Gate Turn-off thyristors. Other well advance technologies, Flexible Alternating Current Transmission System (FACTS) (Mithulananthan et al., 2003; Ou and Singh, 2002; Gerbex et al., 2001; Huang and Yan, 2002; Dixon et al., 2005; Singh et al., 2006; Mahdad et al., 2006; Mondal et al., 2012; Mark Ndubuka, 0000; Minguez et al., 2007; Jannati et al., 2008; Musunuri and Dehnavi, 2010; Kamarposhti and Alinezhad, 2009; Singh et al., 2011; Acha and Kazemtabrizi, 2013; Palukuru and Nee Dey, 2014; Gabbar and Abdelsalam, 2014; Singh et al., 2015; Athamneh and Lee, 2006; Ghorbani et al., 2012; Hingorani and Gyugyi, 2000; Dixon et al., 2005; Khanmohammadi et al., 2007; Venkateswara Rao et al., 2009; Srivastava, 2012; Grudinin and Roytelman, 1997; Taylor et al., 2005; Stahlkopf and Wilhelm, 1997; Grünbaum et al., 2003; Kundur, 1994; Taylor, 1994) have been discovered that are used in the transmission system to improve the power quality and to compensate the reactive power (Stahlkopf and Wilhelm, 1997; Grünbaum et al., 2003). FACTS have different devices for the above mentioned functions like Static VAR Compensators (SVC), United Power Flow Compensators (UPFC) and the Static Synchronous Compensator (STATCOM) (Kundur, 1994; Taylor, 1994).

### 1.1. Literature review

Mithulananthan et al. (2003), discussed and compares different control techniques for damping undesirable inter area oscillation in power systems by means of power system stabilizers (PSS), static VAR compensators (SVCs), and shunt static synchronous

* Corresponding author.
*E-mail addresses:* bindeshwar.singh2025@gmail.com (B. Singh), garimagrawal15@gmail.com (G. Agrawal).

https://doi.org/10.1016/j.egyr.2018.07.004

**Abbreviations**

| | |
|---|---|
| AVR | Automatic Voltage Regulator |
| FACTS | Flexible Alternating Current Transmission Systems |
| TSC | Thyristor Switched Capacitor |
| OEL | Over Excitation Limiter |
| DGs | Distributed generations |
| OPF | Optimal Power Flow |
| GA | Genetic algorithms |
| SVC | Static Var Compensator |
| LFA | Load flow analysis |
| TCR | Thyristor Controlled Reactor |
| VP | Residential load models |
| TCSC | Thyristor Controlled Series Capacitor |
| NRLF | Newton–Raphson Load Flow |
| STATCOM | Static-synchronous compensator |

**Symbols**

| | |
|---|---|
| SVC | Static Var Compensator ( p.u.) |
| $\alpha$ | Real power exponent |
| $\beta$ | Reactive power exponent |
| $P_{m\_bus}$ | Real power of static load (p.u.) |
| $P_L$ | Real power loss of the system (p.u.) |
| $AP$, $RP$ | Real and reactive power supported to the system |
| $Q_{int\,ake\_sys}$ | Reactive power intake of system (p.u.) |
| $AP_{SVC}$, $RP_{SVC}$ | Real power and reactive power delivered to the system by SVC |
| $f$ | Supply frequency (50 Hz) |
| OPF | Operating power factor |
| $Q_{m\_bus}$ | Reactive power of static load (p.u.) |
| FACTS | Flexible Alternating Current Transmission Systems |
| P,Q | Real power and reactive power supported to the system |
| $S_{int\,ake\_sys}$ | Apparent power intake of system (p.u.) |

compensators (STATCOMs). Ou and Singh (2002), discussed the Total transfer capability (TTC), which is usually limited by overloaded circuits and buses with relatively low voltage. Flexible AC transmission system (FACTS) technology can redistribute load flow and regulate bus voltage, so it is a promising method to improve TTC. Gerbex et al. (2001), presented a genetic algorithm to seek the optimal location of multi-type FACTS devices in a power system. The optimizations are performed on three parameters: the location of the devices, their types and their values. The system load ability is applied as a measure of power system performance. Four different kinds of FACTS controllers are used and modeled for steady-state studies: TCSC, TCPST, TCVR and SVC. Simulations are done on a 118-bus power system for several numbers of devices. Results show the difference of efficiency of the devices used in this context. Huang and Yan (2002), investigated the effect of thyristor controlled series capacitor (TCSC) and static VAR compensator (SVC) on power system load curtailments. An algorithm of optimal power flow (OPF) to reduce the load curtailment for installing TCSC/SVC in the system is proposed in this paper. Dixon et al. (2005), presented an overview of the state of the art in reactive power compensation technologies. The principles of operation, design characteristics and application examples of VAR compensators implemented with thyristors and self-commutated converters are presented. Static VAR generators are used to improve voltage regulation, stability, and power factor in ac transmission and distribution systems. Singh et al. (2006), presented the continuous change in power demand and supply altered the power flow patterns in transmission networks in such a way that some of the corridors are lightly loaded and some of the corridors get over loaded. To cope with these problems, flexible AC transmission systems (FACTS) are used. This paper suggests a new sensitivity based approach to locate thyristor controlled series compensator (TCSC) and unified power flow controller (UPFC) for enhancing the power system load ability. The effectiveness of the proposed method is tested and illustrated on 5-bus and IEEE 14-bus systems. Mahdad et al. (2006), focused on the first two of these requirements choosing the type of FACTS devices, deciding the installation location and control of FACTS. We presented a simple algorithm based in heuristic and practical rules to seek the optimal location of two types of FACTS, shunt compensation 'SVC' and series compensation 'TCSC'. The system load ability and loss minimization are applied as a measure of power system performance. Results show the impact of optimal operating points of FACTS (SVC and TCSC) devices under various conditions of power system. Mondal et al. (2012), investigated the optimal location and setting parameters of SVC (Static VAR Compensator) and TCSC (Thyristor Controlled Series Compensator) controllers using PSO (Particle Swarm Optimization) to mitigate small signal oscillations in a multi machine power system. Installations of FACTS devices have been suggested in this paper to achieve appreciable damping of system oscillations. However the performance of FACTS devices highly depends upon its parameters and suitable location in the power network. In this paper the PSO based technique is used to investigate this problem in order to improve the small signal stability. Mark Ndubuka (0000), investigated the effects of Static VAR Compensator (SVC) on voltage stability of a power system. The functional structure for SVC built with a Thyristor Controlled Reactor (TCR) and its model are described. The model is based on representing the controller as Variable impedance that changes with the firing angle of the TCR. Minguez et al. (2007), addressed the optimal placement of static VAR compensators (SVCs) in a transmission network in such a manner that its loading margin is maximized. A multi scenario framework that includes contingencies is considered. This problem is formulated as a nonlinear programming problem that includes binary decisions, i.e., variables to decide the actual placement of the SVCs. Jannati et al. (2008), analyzed instability is one of the phenomena which have result in a major blackout. To maintain security of such systems, it is desirable to plan suitable measures to improve power system security and increase voltage stability margins. FACTS devices can regulate the active and reactive power control as well as adaptive to voltage-magnitude control simultaneously because of their flexibility and fast control characteristics. This paper presents a Genetic Algorithm (GA) based allocation algorithm tested on IEEE 30 bus for FACTS devices considering Cost function of FACTS devices and power system losses. Musunuri and Dehnavi (2010), presented a comparison of four Flexible AC Transmission Systems (FACTS) controllers, the Static VAR Compensator (SVC), the Static synchronous Compensator (STATCOM), the Thyristor Controlled Series Compensator (TCSC) and the Static Synchronous Series Compensator (SSSC) on power system steady state voltage stability. Kamarposhti and Alinezhad (2009), presented that the growing concerns over environmental impacts, conditions for improvement of the whole distribution network, and rebate programs offered by governments have contributed to an increment in the number of DG units in commercial and domestic electrical power output. This paper introduces a sensitivity analysis to determine the optimal sitting and sizing of DG units. A new methodology PSO for the placement of DG in the radial distribution systems reduced the active power losses and to improve the voltage profile. The effectiveness of the proposed method is demonstrated through IEEE 16 bus standard test systems. Singh et al. (2011), presented the introduction of Various FACTS controllers such as SVC, TCSC, TCPAR