Placement And Coordinated Facts: An Overview

Divya B V, Dr. Archana N V

Abstract: FACTS devices are new integrated concept of power electronic switching, which enhances the transfer capability of power, power quality and stability of the system. This paper presents an extensive literature review on placement on FACTS devices and its coordination in the Power system. There could be number of FACTS devices installed in a power system to control particular quantity. Due to distributed generation, interaction between these FACTS devices becomes very important. An individually designed FACTS device has not achieved an ideal effect, with increasing demand. Hence in this paper various coordinated control techniques are reviewed, in order to enhance the quality of power in a deregulated power system.

Index Terms: Coordinated control, Flexible AC Transmission system (FACTS), Optimal Placement of FACTS devices, Power quality, Voltage stability, STATCOM, SVC, TCSC, UPFC.

1. INTRODUCTION

Due to the liberalization of electricity market and the integration of high capacity unpredictable renewable resources (e.g. wind power) yield for higher utilization of transmission networks. The capacity of transmission networks needs to be increased. In conventional Power system, the ability to transmit power is limited by several factors like thermal limit, stability limit, voltage limit, short circuit current limit. These limits define the maximum power that can be transmitted through the transmission line without causing any damage to electrical equipments and the transmission lines. The actual amount of power transferred to the load or the active power is always less than the apparent power or the net power. For ideal transmission the active power should be equal to apparent power or the power factor should be unity, this is where FACTS devices play a major role. It is a very effective way to increase the available transfer capability without changing the existing network architecture. A FACTS device in a system refers to that system consisting of power electronic devices along with conventional power system to enhance the controllability and stability of the transmission line and increases the power transmission capability:

Types of FACTS controllers classified as:-

a) Series controllers
b) Shunt controllers
c) Combined series
d) Combined series shunt

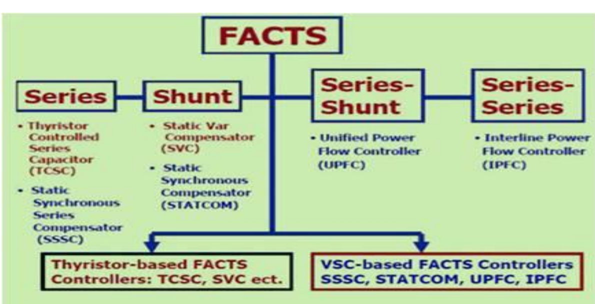

Fig1. *Choice of FACTS controllers.*

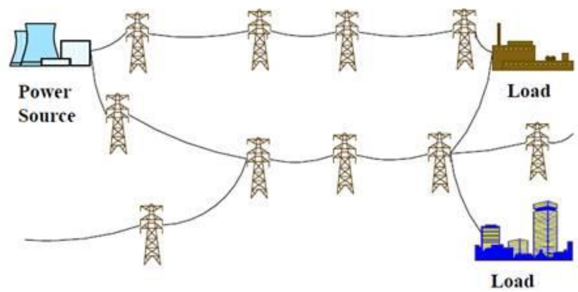

Fig2. *A large interconnected transmission system supplying power from the generating point to the loads.*

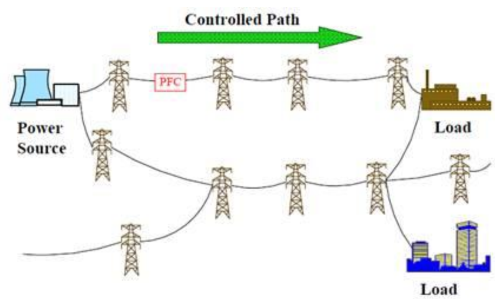

Fig3. *Power flow along the controlled path.*

Based on the different facts, the most preferred FACTS devices are tabulated in the table below considering, different power system parameters.

Table 1: *More '√' Most Preferred FACTS device*

Parameters	STATCOM	SVC	TCSC	UPFC
Reactive power	√√√√	√√	√√	√√√√
Active power	√	√	√√	
Voltage stability	√√√√	√√√	√√√	√√√√
Voltage control	√√√√	√√√	√√	√√√√
Flicker control	√√√√	√√√		√√√√
Harmonic reduction				√√√√
Power flow control			√√√	√√√√
Oscillation damping	√√√	√√	√√√	√√√√

• *Divya B V, Asst. Professor, REVA University, Bangalore India PH- 9481818664. E-mail: divya.bv@reva.edu.in*
• *Dr. Archana N V, Professor, HOD EEE Dept. NIEIT, Mysore, India PH- 9449014185. E-mail: archana@nieit.ac.in*

The above parameters are considered in the objective functions for placement of FACTS devices.

2. PLACEMENT AND CONTROL OF FACTS DEVICES IN A POWER SYSTEM

Placement of FACTS devices depend on the parameters that need to be optimised. Common optimization techniques used for placement of FACTS devices are categorized into analytical, linear programming and heuristic search methods.
Bus clusters are identified to measure bus and generator parameters and based on controllability and observability FACTS controllers are placed, to control voltage collapse and to damp low frequency inter area oscillations, considering two area control [1], it is based on control area scheme, this technique will work only with proper knowledge of control area. Optimal placement of FACTS controller considering economics of FACTS device using Genetic Algorithm (GA) is carried out [2], [3] Sensitivity – based approach has been suggested for determining the optimal placement of FACTS devices in an electricity market having pool and contracted dispatches.GA has the ability to solve multi objective problem and can also be applied for unconstrained objective function, when we consider a large power system time taken for calculation will be more. [4] Uses multi objective and GA in an open market, for minimizing the losses and power flow regulation simultaneously, considering UPFC. This technique can be used for new or restructured power system. Considering different FACTS devices such as TCSC, SVC and UPFC, Particle swarm optimization technique is used for locating these devices. Optimization is carried out considering installation cost minimization and other constraints [5], considering TNEB(Tamilnadu Electricity board) 69 bus practical system, concluded that TCSC was preferred with minimum cost and improvement in loadability. Dead zone adaptive control technique is used to damp the oscillation [6]. With maximum loading, minimum voltage deviation and minimum FACTS controllers as the constraints, optimization is carried out using Fuzzy logic and real coded GA [7], results are tested on IEEE 14 and IEEE 57 bus system, and results are promising. [8] Using TCSC as the controller for minimizing the active power loss optimization is carried out using Differential Evolution (DE) technique and the results were compared with GA algorithm, compared to GA, DE is fast, robust and easy to use. [9] DE with weighted Additive Fuzzy goal programming (WAF) to maximise the loadability and to minimize real power losses considering multi-objective power flow problems, Load Stability Index (LSI) is used to determine the critical lines which requires FACTS devices here UPFC and TCSC are chosen for steady state studies. For optimally locating TCSC to reduce line overloads Line flow overload sensitivity index (LFOSI) technique is used [10], multiple tests are carried out for best location and optimal setting of FACTS controllers. Biogeography based optimization (BBO) to solve multi objective power flow problem, objectives were reduction is fuel cost, voltage improvement and voltage stability [11] to give the best global solution. [12] Proposes SVC design for transient disturbances. A nature inspired PSO technique is used for locating UPFC to reduce power loss and improve to bus voltage [13]. [14] Self Adaptive firefly algorithm (SAFA) is used for placement of FACTS devices and optimal parameter setting. Objective is to minimise real power loss, improving voltage profile and to enhance voltage stability, SVC, TCSC and UPFC are the devices considered, and this owes to simple computation and cater to practical implementation. Model Predictive control (MPC) to improve voltage magnitude and reduce reactive power was demonstrated on 4259 bus model of Californian Electricity grid [15].

3. COORDINATED FACTS DEVICES:

When we consider a large power system several devices such as sources or generators, power system stabilisers (PSS), FACTS devices and loads comes into picture. To avoid mutual influences among several devices placed in the same grid, a coordinated control is indispensable.[16] here supervisory controller based on optimal power flow (OPF), with multi-objectives to avoid congestion, secure transmission and to minimise active power losses , here coordination between SVC, TCSC and TCPST is considered and it was observed that each device was able to influence certain parts of objective functions.

Table 2: *Control Techniques*

Techniques /Methods used for co-ordination of FACTS controllers
Sensitivity based methods
Optimization based methods
AI- based techniques

Coordination between PSS and FACTS devices is considered to damp oscillations in single machine and multi machine power system [17]. With multi shunt FACTS device in a power system Hybrid GA and Fuzzy logic rules is proposed to minimize the generator fuel cost [18]. For coordinating with already existing reactive power sources and multi type FACTS devices Gravitational Search Algorithm (GSA) is proposed for optimum coordination. FACTS devices considered are SVC, TCSC and UPFC, results were compared with GA, DE and PSO techniques [19] net saving was achieved with GSA technique. Sensitivity analysis and linear optimization is used to control and govern multiple FACTS devices in coordination with load shedding, to improve overloads caused by line outages [20], it is interfaced with load flow software to test its effectiveness, and appropriate control signals were generated. TCPST and TCSC were considered, among which TCPST gave higher performance. For highly integrated power system, decomposed GA is used to enhance optimum power flow, under sever loading condition [21], objectives are to minimize the total fuel cost, minimize voltage deviation and reactive power violation using specific number of SVC's. Decentralised coordination for optimum power flow based on multi agent system is proposed [22]. Using local controller to coordinate with Wide area signals to provide additional damping of oscillation and to improve the stability of large power system with multi area controllers [23]. [24] A set of FACTS controllers are chosen appropriately to provide security, using OPFC and multi area control, overlapping areas are determined by sensitivity analysis. [25] Coordination between TCSC and PSS to improve the efficiency of the controller for stability and damping the oscillation using Velocity update relaxation PSO (VURPSO). In an interconnected power system, low frequency oscillation can be suppressed by accurate control of absolute rotor angle [26], this is done using Phasor measurement unit (PMU) by Pulse per second (PPS). In a multi machine power system, Fuzzy logic controller is implemented in PSS, which is added to excitation system or in generator to damp low frequency oscillation [27], results are compared with conventional PID controller. In a real time environment wide area monitoring and control can be implemented [28]. To achieve optimum benefit from FACTS devices in a system where several FACTS devices are placed, coordinated control and the set points are optimised, this can be done based on Wide area measurement system (WAMS) [29]. Wide area monitoring and control is proposed [30]. Wide area monitoring and wide area neuro controllers are used [31] for power system stability. [32] Decentralized control frame work in WAMS is proposed to obtain coordinated control of multiple FACTS devices, Quantum Evolution algorithm (QEA) is used to work on time delay, result are validated on two area, four generator system.

Table 3: *Parameters being controlled*

Operating Parameters that are controlled
Damping of power system oscillations
Voltage Profile
Security of the power system
Small signal and Transient stability
Power transfer capability through the line
Dynamic performance of the power system
Load ability of the power system network

Using multiple FACTS devices to cover all the inter-area oscillatory modes is particularly beneficial in a bulk power system, as there is more than one oscillatory mode and a single FACTS device may not be sufficient to improve the damping ratios of all inter-area oscillatory modes. Besides, in a practical power system, multiple FACTS devices are often Implemented in various locations for different applications e.g. increasing power transfer capacity [33] or maintaining voltage stability during disturbances. Hence, it's essential to incorporate these FACTS devices to maintain or enhance system stability via the coordination [34].

4. CONCLUSION

The main feature of FACTS devices is to improve power system stability and to improve the power quality. In this paper an extensive review on the different techniques used for optimum location of FACTS devices is done, among these methods Heuristic search is found to be robust and fast, even though it does not provide a best or optimum solution always, solution provided will be within reasonable amount of time and memory. Among the different FACTS devices considered such as SVC, TCSC and UPFC. Even though UPFC is considered to be the most preferred cost of UPFC is very high. A compromise can be drawn between cost and performance by considering TCSC. In large power system coordination among different equipments is very important, hence in this paper along with placement, coordination of FACTS controllers is also reviewed. In a power system parameters that are need to be controlled coordinatively is tabulated in Table 3. In coordinated control of parameters, decentralized control using WAMS and AI technique to optimize the parameters is considered to be most effective and reliable.

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