THE IMPACT OF MODERN FACTS CONTROLLERS ON POWER SYSTEM PERFORMANCE- AN INVESTIGATION

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Abstract

In this paper investigation of various era FACTS gadgets have done and examination being done to know the effect of various FACTS gadgets and there use for various conditions in power frameworks. A definite review on the remuneration techniques are likewise done to comprehend arrangement, shunt topologies and consolidated topology, to understand the diverse game plan of FACTS controller in power framework. Toward the end advanced DFACTS gadgets and there study is finished.

Introduction

In present scenario, power demand is increased but its generation and utilization is restricted by power systems constraints. As a result, some transmission lines are heavily loaded and the power system stability becomes promising factors. Flexible AC transmission systems (FACTS) controllers have become one of the promising controller and compensator to the power systems [14]. FACTS devices and their journey from I-generation to modern D-FACTS controller are taken briefly in this literature. As FACTS devices are compensators so series and shunt compensators concept is also revised. In this work, impact of power system stability by the use of FACTS controllers was discussed and reviewed.

I. Compensation Method

A. Shunt compensation:

Shunt compensation are used to enhance/improve power-transfer capability and for reactive voltage drop compensation in the line (transmission/distribution) [16]

.Shunt Compensation is employed mainly at the mid-point named mid-point compensation or at the end of transmission system to improve the voltage profile and providing power quality incrementation of the line power.

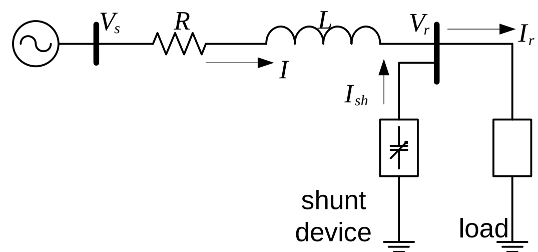


Fig.1.1 Shunt compensator located in power systems.

B. Series Compensation:

Series compensation of the power-lines are done to increase the maximum power transmission capability of the lines.

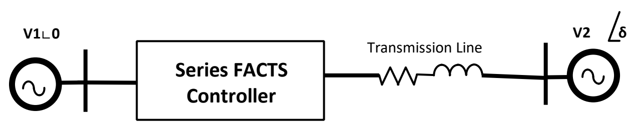


Fig.1.2 Series controller location in power systems.

By series compensation net line voltage drop would become less susceptible to line loading condition of power system, since compensation reduce the line reactance of Power transmission line by introducing the series compensators which neutralize the counter reactance effect in existing system [16] . Combination of series and shunt compensation led to combined compensation techniques also called topologies.

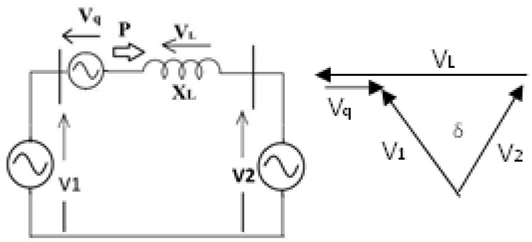


Fig.1.3 Synchronous voltage source in series with the line

II. FACTS Devices an over view

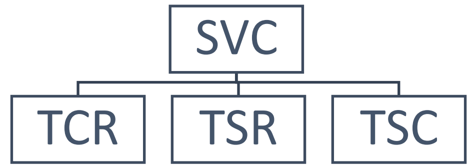
In the late 1980s, the Electric Power Research Institute (EPRI) formulated the vision of the Flexible AC Transmission Systems (FACTS) in which various power-electronics based controllers regulate power flow and transmission voltage and mitigate dynamic disturbances [16]. In present world power flow controllers are largely transforming from mechanical to electrical examples in past reactors are connected to power lines by mechanical switches and now a days they are transformed to power electronic based switching devices. Thyristor, GTO, IGBT, MCT are power electronics devices which constitute the FACTS controller for power flow management. Depending on the development stages FACTS are divided into generation of devices which include series and shunt pattern of arrangements. Now a days due to modernization one scheme is not fully capable of compensation so Distributed Flexible AC Systems DFACTS are emerging from there former designs.

A. First Generation of FACTS Devices.

First generation FACTS devices led to foundation stone in this concept as they have mechanical control which is modified to electrical and then further compatibility towards digital control, first generation devices led to foundation of mechatronics concept in one way or other, inherently they kept their motto of compensation of power lines by their characteristic behavior by injection and absorption of Reactive power. They modifies the impedance of the system by their intact time to the system for flow of power.

1. Static VAR Compensators (SVC).

SVC are shunt connected FACTS devices for the power flow control in the system, they consist of fixed or switched capacitor bank or reactors or combination of both depending on the requirement of system [14]. These compensators draws leading or lagging Reactive power from the lines, thus they regulate voltage, improve system dynamic and steady state stability. These are also termed as Static VAR Switches as they employees switching concept of control of VAR.



SVC = SVS

2. Thyristor Controlled Series Capacitor (TCSC).

Due to the developments in modern power-electronics devices such as GTO, IGBT, IGCT, MTO and Power Transistors with improved ratings of Thyristor's also, these led to efficient operation of switching control technology due to improvement of switching technology, capacitance in series bank of TCSC [14] can be controlled smoothly and in stepwise these led to following modes of operation of TCSC as mentioned bellow.

a) By passed Thyristor Mode.
b) Blocked Thyristor Mode.
c) Partially conducting Thyristor Mode; Capacitive Vernier.
d) Partially conducting Thyristor Mode; Inductive Vernier.

Due to above three modes of operation of operation utilizing efficient switching technology of modern semiconductor technology we get two variants of TCSC as

1) Thyristor Controlled Series Capacitors (TCSC).

These provide smooth and continuous control over capacitive and inductive reactance.

2) Thyristor Switched Series Capacitor (TSSC).

These provide discrete control over the capacitive reactance, TSSC are more commonly employed.

3. Thyristor Controlled Phase Shifters (TCPS)

TCPS have the ability to produce a phase shift between phasor's of terminal voltage which are independent of throughput current[14] . If we neglect the losses of the system and device action then TCPS do not consume or produce active and reactive power.

TCPS are mainly employed as Thyristor controlled phase shifting transformer which we also knows as

'Phase Angle Regulation Transformer' (TCPAR) producing phase shift in the voltage phasor's of the system for control of the active power flow in the system[14] .

B. Second Generation FACTS Devices

Next generation FACTS devices are termed as II generation due to advancement in power semiconductor devices which are used in FACTS devices mainly such as Power Transistors, IGBT, IGCT, MCT, use of these advanced power electronics devices increase power rating of the equipment's and also improve their performance.

1. Static Synchronous Compensators (SSC or STATCOM)

STATCOM is shunt compensator connected in shunt to the line thus introducing current vector control of the system. STATCOM are of two types.

a) Voltage sourced STATCOM.
b) Current sourced STATCOM.

In the former capacitors are used as energy storing components of the system thus it act as a voltage source due to storage of potential charge where as in latter inductors/reactors are used for energy storage components, which are mainly current modulation system thus termed as current sourced. Though former is used mainly due to economical and design feasibility effects. STATCOM are able to generate and absorb reactive power of the system [14] .

STATCOM improve system performance as it provide, dynamic voltage control, power oscillation damping, transient stability; it also act as active filter to absorb system harmonics.

2. Static Synchronous Series Compensator (SSSC)

SSSC is series connected device using a coupling transformer in series by which it is able to control voltage of the line and modifies line impedance, due to the power electronics controller's it has an ability to produce phase shift in relation to the line current[13].

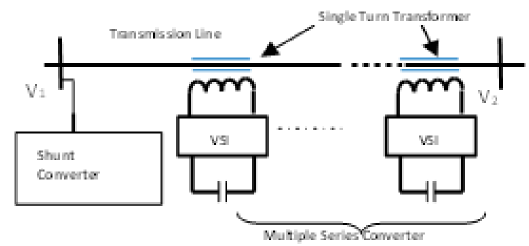
SSSC has the ability to exchange both real and reactive power in transmission system. If the injected voltage is in phase with line current then Real Power will be regulated, on the other hand if injection of voltage is in quadrature to line current then Reactive Power will be regulated (this depends on the absorption or generation).

SSSC due to its characteristic behavioral advantageous in replacing TCSC as it is capable of regulating line reactance and also line resistance in-accordance with power swing. These offer better control capability by employing proper feedback of the system parameters to the firing circuit to work by system variable change.

3. Unified Power Flow Controller (UPFC)

UPFC is combined power flow controlling device having both series and shunt component, due to this behavior UPFC able to control line impedance, line

voltage, and power angle all three parameters of power system which are essential to route the flow of power in the system networks[15].



Due to wide range of controllability these device are having dynamic behavior over the transmission system parameters. UPFC is capable of controlling directional flow of power in the system. It enhance the power transfer capability of transmission line to be within thermal loading limits of the transmission system.

C. Distributed Flexible AC Transmission Systems (DFACTS) Devices.

In modern power system interconnections of the system is common phenomenon, where as in present era distributed generation is also a part of system in past few decades which increase the complexity of the control of power and regulation.

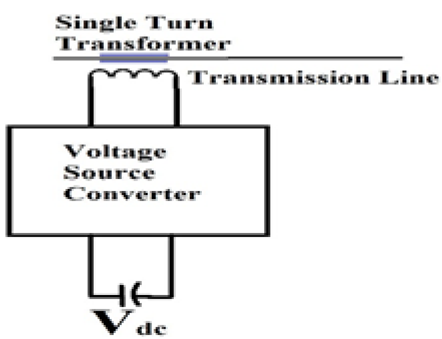
Distributed FACTS (DFACTS) are now a day getting popular due to deregulated structure and interconnection of power system. Due to better controlling ability and wider operating range of there characteristic DFACTS [9] are future as they accomplish the different present and past technology in a new encapsulated format which is efficient for the requirement of the power system at the place where it is required.

1. Distributed Static Series Compensator (DSSC)

DSSC is new generation DFACTS device derived from the parent SSSC (or S^3C) controller. DSSC is distributed device rather than to be placed centrally located at one place in system [8]. Due to this distributed components along the transmission line it is having better control capability in terms of system response improvement rather correcting at centrally compensation control. In DSSC single turn transformer is used as series element to distribute the static device which in placed at optimal location along the line.

Fig.1.5 Distributed Static Series Compensator (DSSC)

2. Distributed Power Flow Controller (DPFC)



DPFC is derived from UPFC carrying all its inherent characteristics only difference is that despite of fixed capacitor in UPFC, DPFC provides distributed capacitor and central control capability [3]. Due to this characteristic behavior it has ability to control the transmission line voltage, impedance and angle. DPFC is advantageous over UPFC as it required series convertor of small power rating which may be also of single phase, insulation level due to voltage is less than three phase convertor in single phase converter which increase reliability and reduce cost.

Fig.1.6 Distributed power Flow Controller (DPFC)

DPFC is also from the family of combined power flow controller of FACTS having wide range of control capability, it have shunt controller and series controller, whereas series controller is distributed along the line and shunt controller is located at the end of transmission line, it act as active high pass filter to eliminate harmonics.

III. Issues related to FACTS installation

For the effectiveness of the controllers, the selection of location and feedback signals of FACTS-based stabilizers should be determined. On the other hand, the robustness of the controller to the variation of power system operating conditions is equally important factor to be undertaken. Also, the coordination among different power systems stabilizers is an issue to avoid the side-effects. Additionally, performance comparison is an important factor that helps in selection of a specific FACTS device. Reactive power compensation need required by system by FACTS to be investigated. FACTS have wide influence on the system compensation so effective and proper selection to be done [15].

A. Reactive power compensation by FACTS for power transmission line led to:

1) Enhancement of transmission capacity, providing permissible line loading and influencing to work within the boundary conditions.
2) To keep voltage profile along the transmission line within acceptable limits. These led to optimization of line-insulation cost-factor.
3) Controlled compensators (Reactive power compensators) are used to improve system stability depending on their characteristic they enhance the system response (Steady state, Dynamic, Transient).
4) These are used for power oscillation damping control of the system which enhance the system stability.

B. Controller Design issues for FACTS devices.

In modern deregulated power systems, DFACTS devices providing following assistance for enhancement of power system stability.

1) Balanced power flow control over wide range of operating condition including contingencies of power system, this led to utilization of power system efficiently.
2) Balancing flow of power in parallel networks operating at different voltages.
3) Diminishing inter area power oscillations.
4) Suppuration of Sub Synchronous Resonance (SSR).
5) Avoid the construction of new transmission facilities by enhancement of power transfer capabilities of existing corridors of power systems.

6) Controllers for DFACTS device are designed on the basis of intelligent adaptive digital controllers based technique, with response capable for wide area.
7) Controller should not be designed for high level of damping, as it is not supportive way of designing for wide area system control.
8) Controller should be designed with interconnections in system should be within reliable operation region and working within security limits of power systems

C. FACTS Devices and its impacts

ISSUE	PROBLEM	CORRECTIVE ACTION	FACTS CONTROLLER
VOLTAGE LIMIT.	LOW VOLTAGE AT HEAVY LOAD	SUPPLY REAVTIVE POWER REDUCE LINE REACTANCE	SVC, STATCOM, TCSC, DSTATCOM
	HIGH VOLTAGE AT LOW LOAD	ABSORB REACTIVE POWER	SVC, STATCOM, DSTATCOM
	HIGH VOLTAGE FOLLOWING AN OUTAGE	ABSORB REACTIVE POWER, PREVENT OVERLOAD'S	SVC, STATCOM, DSTATCOM
	LOW VOLTAGE FOLLOWING OUTAGE	SUPPLY REACTIVE POWER, PREVENT OVER LOADS	SVC, STATCOM, DPFC
THERMAL LIMITS	TRANSMISSION LINE LOADING	INCREASE TRANSMISSION CAPACITY	TCSC, SSSC, UPFC, IPFC, DPFC
SHORT CIRCUIT POWER	HIGH SHORT CIRCUIT CURRENT	LIMITATION OF SHORT CIRUIT CURRENT	TCSC, UPFC, IPFC, DSSC, DPFC
LOAD FLOW	POWER DISTRIBUTION ON PARALLEL LINES AND LOAD FLOW REVERSAL	ADJUST LINE REACTANCE	TCSC, SSSC, DSSC, UPFC, IPFC, DPFC
		ADJUST PHASE ANGLE	TCSC, SSSC, DSSC, PAR,DPFC
STABILITY	LIMITED TRANSMISSION POWER	DECREASE LINE REACTANCE	TCSC, SSSC, DSSC,DPFC

In this table FACTS devices and its impact on power system with different issues related to stability and performance are taken in to considerations. Problems and its eradication are also discussed which led to quick assessments at the time of sudden disturbances and finding solution immediately. Type of FACTS controller for different purposes are also listed which helps in selection of device during designing of compensating devices.

CONCLUSION:

In the above research work it is being reasoned that the present day DFACTS gadgets are better over past era Controller. Realities gadget give extensive variety of control of force framework parameters to the stream of force in transmission and circulation frameworks of current frameworks. In FACTS controller execution of various remuneration topologies prompted to improvement of various controller, current pattern is of joined controller as they determine better properties and attributes from their parent controllers. An examination on the FACTS establishment and effect is finished.

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