FACTS devices in Distributed Generation

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ABSTRACT: *The FACTS devices control the interrelated parameters that rule the operation of the transmission systems, including the serial impedance, the derivation impedance, the current, the tension, the phase angle and the muffling of oscillations to different frequencies under nominal frequency. The FACTS technology has a collection of controllers, that can be used individually or co-ordinated with other control installed in the network, thus permitting to profit better of the network's characteristics of control.*

The configurations of compensators based on switched inverters, called static compensators of reactive power, are today the most used in the electric current transmission systems. The application of high powered electronic converters makes possible the generation or absorption of reactive power without using banks of condensers or inductors.

The STATCOM is a device used on alternating current electricity transmission networks. It is based on a power electronic voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide AC power. It is a member of the FACTS family of devices. The function will depend on the type of network in which it will be installed; it could fulfill functions of reactive power control and power factor regulator, or other functions as shock absorber of system oscillations or filtering of harmonics, depending on the system applications.

KEYWORDS: FACTS, STATCOM, Custom power, Active filter.

1. INTRODUCTION

The solutions to improve the quality of supply in the electrical networks with distributed generation go through the application of the developments in semiconductor power devices, that is to say, the utilization of static power converters in electrical energy networks. The technological advances in power semiconductors are permitting the development of device that react more like an ideal switch, totally controllable, admitting high frequencies of commutation to major levels of tension and power.

On the other hand, large advances in auxiliary technologies devices of digital control, DSP's, circuits of programmable logic and in techniques of advanced control. These technological developments, united to a tendency of reduction of cost of the power semiconductors, are permitting to undertake a new practical way to practice topologies of conversion of capable energy to give competitive solutions to the related problems, with the interconnection of new energy sources in the networks of high and medium tension and with improved the quality of the electricity supply.

The concept of distributed generation is generally associated to the development of the renewable energy sources and other alternative sources as the fuel piles, is another factor to keep in mind in the development and configuration of the electrical system, that will need an important electronic equipment based on power converters that facilitate the integration of these sources of energy, without damaging over the reception quality of the users connected to the electricity network.

The use of static power converters in electricity networks has the potential of increasing the capacity of transmission of electric lines and improving the supply quality of the electric energy. The devices used to achieve this, are the FACTS.

According to the IEEE the definition of these FACTS devices is the following: "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability."

The FACTS controllers offer great opportunities to regulate the transmission of alternating current (AC), increasing or diminishing the power flow in specific lines and responding almost instantaneously to the stability problems. The potential of this technology is based on the possibility of controlling the route of the power flow and the ability of connecting networks that are not adequately interconnected, giving the possibility of trading energy between distant agents.

2. FACTS in Active Distribution Systems

In the new market of Active Distribution, the flexibility of the transmission depending on the prices of the electric energy in each moment is imposed. The fact that the energy can vary dynamically in the way from generation to consumption requires a bigger margin of the lines design, or at least, a major control of the energy they transmit.

Narrowly related to the FACTS term is that of CUSTOM POWER, controllers based on solid state technologies that are designed to operate in medium and low tension levels, whose main objective is to improve the quality of service in distribution networks. The solutions to improve the energy quality at the load side is of great important when the production processes get more complicated and require a bigger liability level, which includes aims like to provide energy without interruption, without harmonic distortion and with tension regulation between very narrow margins.

Among the FACTS, but that is different to them because of their final use. In fact the topologies that they employ are identical to the ones in the FACTS devices with little modifications and adaptations to tension level; therefore they are most oriented to be used in distribution networks of low and medium tension, sometimes replacing active filters.

A. Advantages and operability of FACTS devices

The following features resume the main advantages of the FACTS devices:

Better utilization of existing transmission system assets: Cost of FACTS generally lower than that of new transmission lines.

Increased transmission system reliability and availability: FACTS provide transmission systems with robustness to endure contingencies.

Increased dynamic and transient grid stability: Lower vulnerability to load changes, line faults.

Increased quality of supply for sensitive industries: Through mitigation of flicker, frequency variations.

Environmental protection: Smaller impact than the installation of new lines. No waste production.

There are three factors to be considered before installing a FACTS device:

- The type of device
- The capacity required
- The location that optimize the functioning of the device

Of these factors, the last one is of great importance, because the desired effect and the proper features of the system depend on the location of FACTS.

B. Classification

Depending on the type of connection to the network. The FACTS device can differentiate four categories;

Serial controller

Derivation controller

Serial to serial controller

Serial derivation controllers

Depending on technological features, the FACTS devices can be divided into two generations:

First generation: uses thyristors with ignition controlled by door (SCR).

Second generation: semiconductors with ignition and extinction controlled by door (GTO, IGBT, etc.).

FACTS devices	Attributes of control
Satatic compensator of VAR's (SVC ,TCR,TCS,TRS)	Voltage control and stability, compensation of VAR's, muffling of oscillations
Thyristor controlled series compensation(TCSC,TSSC)	Current Control , muffling of oscillations, transitory, dynamics and of tension stability, limitation of fault Current
Thyristor controlled Reactor series (TCSR,TSSR)	Current Control , muffling of oscillations, transitory, dynamics and of tension stability, limitation of fault Current
Thyristor controlled Phase shifting transformer (TCPST OR TCPR)	Control of active power, muffling of oscillations, transitory, dynamics Transformer and of Voltage stability
Thyristor controlled voltage regulator (TCVR)	Control of reactive power, voltage control muffling of oscillations, transitory, dynamics Transformer and of Voltage stability
Thyristor controlled Voltage limited (TCVL)	Voltage Limited Limit of transitory and dynamic voltage
Synchronous static compensator (STATCOM without storage)	Voltage control, compensation of VAR's, muffling of oscillations, stability of voltage
Synchronous static compensator (STATCOM with storage)	Voltage control and stability, compensation of VAR's, muffling of oscillations, transitory, dynamics and of tension stability
Static Synchronous series compensator (SSSC without storage)	Current Control, muffling of oscillations, transitory, dynamics and of Voltage stability, limitation of fault Current
Static Synchronous series compensator (SSSC with storage)	Current Control , muffled of oscillations, transitory, dynamics and of tension stability
Unified power flow controller (UPFC)	Control of active and reactive power, voltage control, compensation of VAR, limitation of fault current
Interline power flow controller (IPFC) or back to back (BtB)	Control of reactive power, voltage control, muffling of oscillations transitory, dynamics and of voltage stability

First Generation	Second Generation

TABLE 1

These two classifications are independent, existing for example; devices of a group of first classification that can belong to various groups of the second classification. In the table 1.you can see the summary of the main devices.

C. Types of network connection

Serial controllers:

It can consist of variable impedance as a condenser, a coil, etc. or a variable electronics based source at a fundamental frequency. The principle of operation of all the serial controllers is to inject a serial tension to the line. Variable impedance multiplied by the current that flows through it represents the serial tension. While the tension is in quadrature with the line current the serial controller only consumes reactive power; any other phase angle represents management of active power.

A typical controller is serial synchronous static compensator (SSSC).

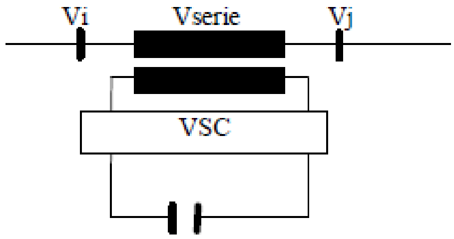

Fig. 1. Serial Controllers

Controllers in derivation:

As it happens with the serial controller, the controller in derivation can consist of a variable impedance variable, variable source or a combination of both. The operation principle of all controllers in derivation is to inject current to the system in the point of connection. Variable impedance connected to the line tension line causes variable current flow, representing an injection of current to the line. While the injected current is in quadrature with the line tension, the controller in derivation only consumes reactive power; any other phase angle represents management of active power. A typical controller is Synchronous Static Compensator (STATCOM).

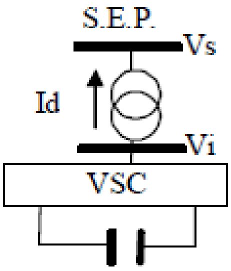

Fig. 2. Controllers in derivation.

Serial-serial controllers:

This type of controller can be a combination of co-ordinated serial controllers in a multiple transmission system, or can also be an unified controller in which the serial controller provide serial reactive compensation for each line also transferring active power transmission capacity that presents a unified serial-serial controller or line feed power controller. A typical controller is the interline power flow compensator (IPFC).

Serial-derivation controllers:

This device can be a combination of serial and derivation controllers separated, co-coordinately controlled or a unified power flow controller with serial and derivation elements. A typical controller is unified power flow controller (UPFC) which incorporating functions of filtering and conditioning, becomes a universal power line conditioner (UPLC).

3. Second generation FACTS devices

The first generation FACTS devices work like passive elements using impedances or tap changer transformers controlled by thyristors. The second generation FACTS devices work like angle and module controlled voltage sources. The main difference between first and second generation devices is the capacity to generate reactive power and to interchange active power. In the first generation, these abilities are exclusive for SVC and TCSC, are compensators of reactive but are not capable exchanging active power with the system, or in the case of the TCSP, the can exchange active or reactive power, but are not capable of generating reactive power. The second generation has the inherent capacity, as a synchronous machine, to exchange active and reactive power and with the system, furthermore, to generate or absorb it automatically, having as consequence reactive compensation without condensers or alternating current coils. The real power has to be exchanged through the AC system.

Simplifying, the difference between these generations of FACTS devices is the flexibility and the response dynamic. The second generation of FACTS devices adapt to improve to changes in the topology or in the point of work of the network and the response dynamics is faster. Nevertheless, the second devices of this generation of FACTS are more complex and expensive.

The following controllers belong to this second generation:

- STATCOM (Static Synchronous Compensator)

- SSSC (Static Synchronous Serious Compensator)

- UPFC (Unified Power Flow Controller).

The SSSC is identical to the STATCOM (in equipment and operation) but employs them in a different disposition (serial) and UPFC has two STATCOM one serial and the other in derivation.

A. STATCOM (Static Synchronous Compensator)

It is a device connected in derivation, basically composed of a coupling transformer, that serves of link between the electric Power system (SEP) and the voltage synchronous controller (VSC), that generates the voltage wave comparing it to the one of the electric system to realize the exchange of reactive power.

In its most general way, the STATCOM can be modelled as a regulated voltage source Vi connected to a voltage bar Vs through a transformer, as the figure below shows in Fig. 3.

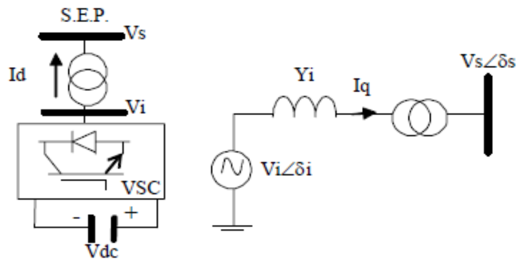

Fig. 3. STATCOM

There can be a little active power exchange between the STATCOM and the SEP. The exchange between active power between the inverter and the AC system can be controlled by adjusting the output voltage angle from the inverter to the voltage angle of the AC system. This means that the inverter cannot provide active power to the AC systems from the DC accumulated energy if the output voltage of the inverter goes before the voltage of the AC system. On the other hand, the inverter can absorb the active power of the AC system if its voltage is delayed in respect to the AC systems voltage.

Figure 4. Shows a simplified configuration of a STATCOM with a source of energy coupled to the DC side. The interface provides the coupling between the DC side of the STATCOM and other energy sources that can be of any kind of energy accumulation device or DC source: battery banks, DC generators, photovoltaic systems, or other power electronics device, where P_{mCD} represents the active power of the DC source.

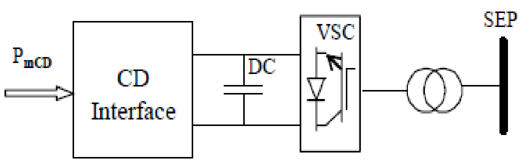

Fig.4. STATCOM with a source of energy

When this FACTS device is applied in distribution systems is called D-STATCOM (Distribution STATCOM) and its topology is the same one with small modifications and adaptations, oriented to a possible future amplification of its possibilities in the distribution network at low and medium voltages, implementing the function so that we described as flicker damping, harmonic filtering and hole and short interruption compensation.

B. SSSC (Static Synchronous Series Compensator)

This device works the same as the STATCOM. It has a voltage source converter serially connected to a transmission line through a transformer. It is necessary an energy source to provide a continuous voltage through a condenser and to compensate the losses of the VSC. A SSSC is able to exchange active and reactive power with the transmission system. But if our only aim is to balance the reactive power, the energy source could be quite small. The injected voltage can be controlled in phase and magnitude if we have an energy source that is big enough for the purpose.

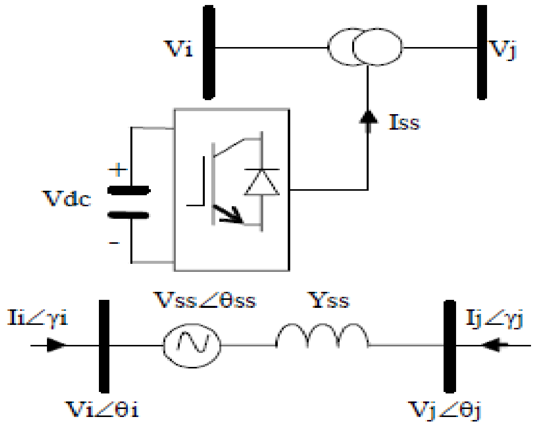

Fig. 5. SSSC

Thus, a SSSC can work like a controllable serial condenser and a serial reactance. The main difference is that the voltage injected through a SSSC is not related to the line intensity and can be controlled independently. This important feature means that the SSSC can be used with excellent results with low loads as well as with high loads.

C. UPFC (Unified Power Flow Controller)

The most complete FACTS device is the unified energy flow controller. It is the only device with serial and parallel compensation operated by a common link of direct current. The serial compensator has a three-phase inverter and voltage source (2) that gives a serial-to-the-line voltage through the winding of a serial transformer .The derivation compensator (basically a STATCOM) has an inverter(1) connected to a point of the line through a shunt transformer.

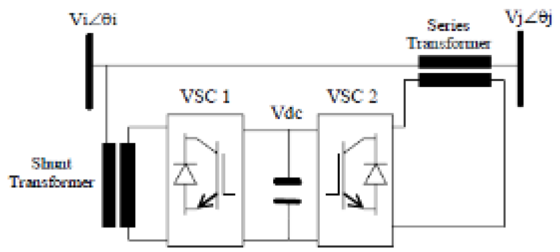

Fig. 6. UPFC

The converter 2 has the main function of the UPFC; it injects an AC voltage to the transmission line, which magnitude and angle are controllable through a serial transformer. The basic function of the converter 1 is to give or absorb the real power that the converter 2 demands in the common DC link. The converter 2 supplies or absorbs locally the required reactive power and exchanges the active power as a result of the serial injected voltage which varies in module and angle, as we can see in figure 7.

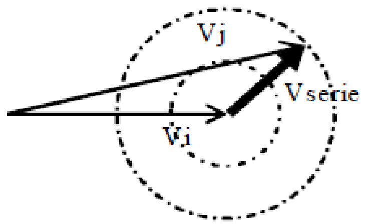

Fig. 7. Vj variation through Vserie

A UPFC system can regulate the active and reactive power at the same time. Generally it has three control variables and can operate in different modes. The converter connected in derivation regulates the distribution bar voltage and the serial connected converter regulates the active, reactive power and the voltage of the serial connected point.

4. Conclusions

Due to the every time higher requirements of the liability and quality of the electricity, the implantation of devices capable of guaranteeing these requirements will keep increasing. The power electronic systems with a Voltage Controlled Source (VSC) topology connected to the network have the ideal features to improve the capacity of the electric energy transmission of the networks.

Even though these kinds of systems have been applied in transport systems of high and medium voltages, the actual challenge it to implement these very same topologies in the electrical energy distribution networks. This is of important interest in lines that make a strong use of distributed generation, in which the quality of the transmission could be maimed by the connection of generation systems with low or null performances to ensure the energy supply under certain circumstances.

The development of high power inverters (more than 100MVA) of high performances at low cost is necessary to consolidate compensators such as STATCOM (Static Synchronous Compensator), SSSC (Static Synchronous Series Compensator) and UPFC (Unified Power Flow Controller). The developments spoil the potentialities of the multi-level converters to implement FACTS devices using the newest power semiconductor device technology. The multi-level converters are especially suitable to work at high voltages and low switching frequencies. The areas to improve would be these three: the converter topology, the basic control strategies and the applications of multi-level FACTS devices.

References

[1] Narain G. Hingorani and Laszlo Gyugyi. “Understanding FACTS. Concepts and Technology of Flexible AC Transmission Systems”. IEEE Press, (1999).

[2] M. Aredes, G. Santos Jr., “A Robust Control for Multiples STATCOMs”, Proceedings of IPEC 2000, Vol. 4, pp. 2163-2168, Tokyo, 2000.

[3] Y.H. Song, A.T. Johns, Flexible ac transmission systems (FACTS). IEE Power and Energy Series 30, 1999.

[4] H. Fujita, S. Tominaga, H. Akagi, “Analysis and Design of a DC Voltage- Controlled Static Var Compensator Using Quad-Series Voltage Source Inverters,” IEEE Trans. on Industry Applications, Vol. 32, No. 4, 1996.