ORIGINAL RESEARCH PAPER

Electrical Engineering

COMPARATIVE STUDY OF FACTS DEVICES AND DIFFERENT TYPES OF FACTS CONTROLLER.

KEY WORDS: Flexible AC Transmission System (FACTS) Devices, Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator, Static Synchronous Shunt Compensator, Static Synchronous Generator (SSG), Thyristor Controlled Rectifier (TCR),

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ABSTRACT

This paper is dedicated to a comprehensive study of static synchronous compensator (STATCOM) systems. Among flexible AC transmission system (FACTS) controllers, the STATCOM have shown feasibility in terms of cost effectiveness in a wide range of problem-solving abilities from transmission to distribution levels.

I. INTRODUCTION

Among flexible AC transmission system (FACTS) controllers, the STATCOM have shown feasibility in terms of cost effectiveness in a wide range of problem-solving abilities from transmission to distribution levels. A cascade multilevel inverter is a power electronic device built to synthesize a desired AC voltage from several levels of DC voltages. A cascade multilevel inverter can be implemented using only a single DC power source and capacitors. To operate a cascade multilevel inverter using a single DC source, it is proposed to use capacitors as the DC sources. A standard cascade multilevel inverter requires 's' DC sources for 2s+1 level. To be able to operate in a high-voltage application, a large number of DC capacitors are utilized in a cascaded multilevel inverter-based STATCOM.

II. FLEXIBLE ALTERNATING CURRENT TRANSMISSION SYSTEMS (FACTS) DEVICES

- **Flexible alternating current transmission system**

It is a technology which provides a methodology for the utilities to effectively utilize their assets, enhance transmission capability by loading lines to their full transmission capability, and therefore, minimize the gap between the stability and the thermal limits, and improve grid reliability. The FACTS (Flexible alternating current transmission systems) technology is based on the use of reliable high-speed power electronics, advanced control technology, advanced microcomputers, and powerful analytical tools. The key feature is the availability of power electronics switching devices at high kV and kA levels.

- **Flexibility of Electric Power Transmission**

"The ability to accommodate changes in the electric transmission system or operating conditions while maintaining sufficient steady-state and transient margins."

III. Flexible alternating current transmission system Technology

"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."

With the advancement of power semiconductor devices , particularly the devices with turn-off capability, the cost of FACTS technology continues to decrease, and this will make the FACTS technology all the more reliable. The development of FACTS controller has followed two distinctly different technical approaches both resulting in a comprehensive group of controllers that solve some of the transmission problems.

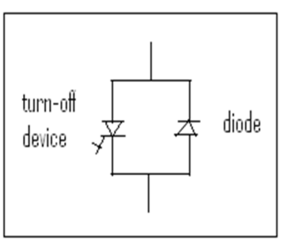


Figure-1 Valve for a voltage-sourced converter

Thus, a voltage-sourced converter is made up of an asymmetric turn-off device such as GTO with a parallel diode connected in reverse as shown in Figure 1

- **Flexible alternating current transmission system Controller**

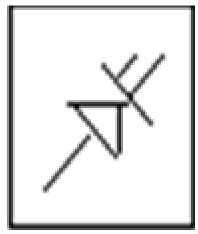


Figure-2 General Symbol of FACT

FACTS controllers are power electronic based systems and other static equipment that provide control of one or more AC transmission system parameters. A thyristor arrow inside a box, as shown in Figure 2 is the general symbol of a FACTS controller.
In general, FACTS controllers can be divided into four categories:

- **Series Controller**

The series controller may be a variable capacitor, inductor, or a power electronic based variable frequency source. The principle of operation of a series controller is that it injects variable series voltage (current x variable reactance) in the line. When the injected series voltage is in phase quadrature with the line current, the controller absorbs or consumes reactive power only; for any other phase relationship it handles both real and reactive power.

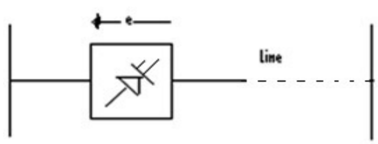


Figure-3 Series connection

There are different types of series connected controllers.
(a) Static Synchronous Series Compensator(SSSC)
(b) Thyristor-Controlled Series Capacitor(TCSC)
(C) Thyristor Controlled-Series Reactor (TCSR)

- **Shunt Controller**

Generally, a shunt controller as shown in Figure 4 is similar to a series controller.

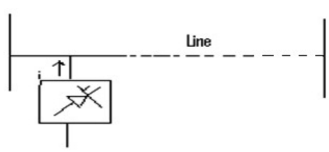


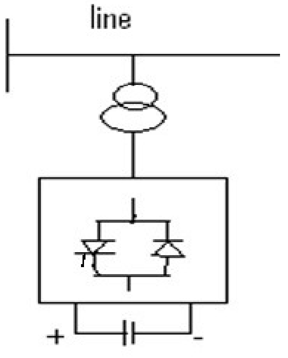
Figure-4 Shunt connection

It is however, connected in parallel and injects current into the line. Thus, a variable shunt reactance connected to a transmission line injects current into the system at the point of connection. If the injected current is in phase quadrature with the line voltage, the controller handles reactive power only; for any other phase relationship of the current with the line voltage, it handles both real and reactive power.

There are different types of shunt controllers.

(a) Static Synchronous Compensator (STATCOM)

STATCOM is one of the key FACTS controllers. It is a shunt-connected static VAR compensator and its capacitive or inductive output control is independent of the ac system voltage. A simple one line diagram of STATCOM based on voltage source converter and a current source converter is shown in Figure 5. STATCOM may be used for voltage control, VAR compensation, and damping oscillations.



(a) Static Synchronous Generator (SSG)

SSG is a combination of STATCOM and an energy source to supply or absorb power. The energy source may be a battery, large dc storage capacitor, superconducting magnet, etc. The Figure 6 shows a single line diagram of a STATCOM connected to a storage device

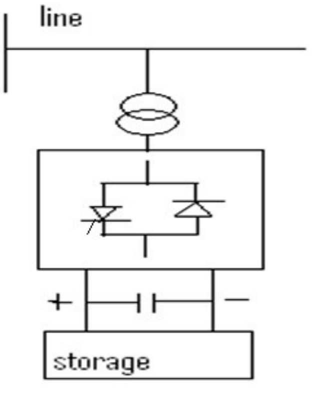


Figure-6 Static Synchronous Generator

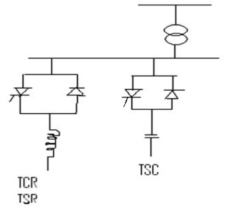
SSG may be used for voltage control, VAR compensation, and damping oscillations under steady-state and transient conditions.

(a) Static VAR Compensator (SVC)

A static VAR compensator is a shunt connected, thyristor-controlled, or thyristor-switched reactor, and/or thyristor-switched capacitor, or a combination, which inject capacitive or inductive current so as to maintain the bus voltage of the electrical power system. Figure 7 shows the schematic diagram of a SVC.

(b) Thyristor-Controlled Reactor (TCR)

A thyristor-controlled inductor is a shunt-connected device as shown in Figure 7. The effective reactance of a TCR is varied in a continuous manner by controlling the conduction of the thyristor valve by adjusting its triggering delay angle. TCRs can damp power oscillations.



- **Combined Series-Series Controller**

It is a combination of two or more separate series controllers, with each series controller connected in a transmission line, in a multi-line system, but their control is coordinated. Another variation of a series-series controller is the inter-line power flow controller (IPFC), where a unified controller is used.

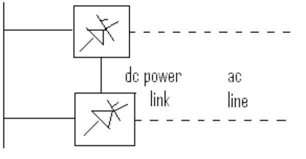


Figure-8 Unified series-series connection

- **Combined Series-Shunt Controller**

A combined series-shunt controller has separate series and shunt controllers in a transmission line whose operation is coordinated. Operationally, the series controller injects voltage in series with the line voltage and the shunt controller injects current into the system at the point of connection. The second type of this controller, where the shunt and series controllers are unified is called a unified power flow controller (UPFC).

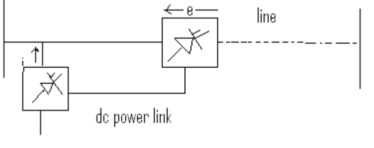


Figure-9 Unified series-shunt connection

A unified power flow controller is able to exchange real power via the dc power link in addition to performing the functions of a series-shunt controller [2].

- **Static Synchronous Compensator (STATCOM)**

The STATCOM is the first power-converter-based shunt-connected controller. Instead of directly deriving reactive power from the energy-storage components, the STATCOM basically circulates power with the connected network. The reactive components used in the STATCOM, therefore, can be much smaller than those in the SVC. STATCOM provides a superior solution for VAR control, voltage regulation, flicker compensation, and fault-ride through improvement. Also grid current harmonic filtering is possible if sufficiently high switching frequency can be used. Typical applications include flicker compensation of large industrial loads such as arc furnaces and VAR control of wind farms. Benefits of STATCOM are improved power quality and network stability, increased transmission capacity, and improved fault-ride through capability and grid code compliance of renewable generation [2].

The Figure 10 shows the basic circuit for a Static Synchronous Compensator (STATCOM) and Figure 11 shows its voltage current characteristics.

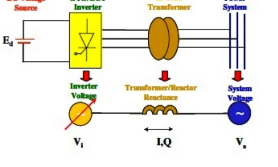


Figure-10 Static Synchronous Compensator (STATCOM)

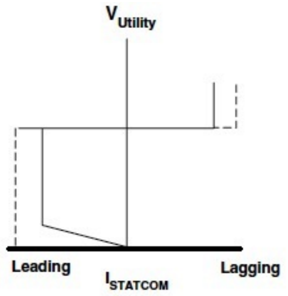


Figure 11 V-I characteristics of a STATCOM

Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. There are however, other uses, the most common use is for voltage stability. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source. For example, if the terminal voltage of the VSC is higher than the AC voltage at the point of connection, the STATCOM generates reactive current; on the other hand, when the amplitude of the voltage source is lower than the AC voltage, it absorbs reactive power. The response time of a STATCOM is shorter than that of an SVC, mainly due to the fast switching times provided by the IGBTs of the voltage source converter. The STATCOM also provides better reactive power support at low AC voltages than an SVC, since the reactive power from a STATCOM decreases linearly with the AC voltage (as the current can be maintained at the rated value even down to low AC voltage).

Relative Importance of Different Types of Controllers

- A combination of series and shunt controllers can provide the best of effect power/current flow and line voltage.
- The principle controllers are based on the dc to ac converters with bidirectional power flow capability.
- Energy storage systems are needed when active power is involved in the power flow.
- A controller with storage is more effective for controlling the system dynamics.
- A converter-based controller can be designed with high pulse order or pulse width modulation to reduce the low order harmonic generation to a very low level.

IV. CONCLUSION

STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. There are however, other uses, the most common use is for voltage stability. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source.

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