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Flexible Alternating Current Transmission Systems

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ABSTRACT
Flexible AC Transmission System (FACTS) refers to a family of power electronics-based devices designed to increase power transfer capability of power transmission system. The main objective of FACTS is to obtain AC systems with a high level of flexibility just as in high-voltage DC systems. FACTS uses power electronics for controlling power flow in a transmission system. This paper provides a brief introduction to FACTS devices or controllers.

KEY WORDS: *flexible AC transmission system, power electronics, voltage source converters*

INTRODUCTION

In conventional AC transmission system, the amount of power that can be sent over a transmission line is limited by many factors such as the length of the line, overheating, and system stability, transient stability limit, voltage limit, and short circuit current limit. For ideal transmission the active power should be equal to the apparent power so that the power factor can be unity. This is where the role of flexible AC transmission system (FACTS) comes in. The use of FACS devices can potentially overcome the limitations by using advanced solutions based on modern power electronics.

A flexible alternating current transmission system (FACTS) consists of static equipment used to overcome certain limitations in the static and dynamic transmission of electrical energy. IEEE defines FACTS as "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" [1]. In a power system, FACTS devices enable control of active and reactive power flow. Using the devices opens up the potential of reducing power losses of a transmission line.

The concept of FACTS was introduced by Hingorani in 1988 [2]. Since then, FACTS applications have increased significantly. The number of FACTS devices installed in practical power systems has steadily increased. It is expected that FACTS will play a significant role in the next generation of electric power grids.

FEATURE OF FACTS

The objectives of FACTS include [3]: (i) to increase the transmission capabilities while maintaining the stability of power systems, (ii) to control power so that if flows on the desired routes, (iii) to increase loading capacity of transmission lines, (iv) to prevent blackouts.

The design of FACTS devices is based on the combination of traditional power system components (such as inductors, capacitors, transformers, and, switches) and power electronics elements (such as transistors and thyristors). FACTS controllers used in power systems are illustrated in Figure 1 and explained as follows [4]:

- *STATCOM*: The static synchronous compensator (STATCOM) is a shunt-connected FACT device which is used in controlling the bus voltage by varying impedance. It is also used for reactive power compensation of the transmission line.
- *SVC:* The static VAR compensator (SVC) is the first generation of FACTS controllers. It is often used to stabilize the load voltage in the power system and to improve the power factor of the load.
- *SSSC:* The static synchronous series compensator (SSSC) is a VSC-based serial FACTS device that can provide capacitive or inductive compensation. It has the same power electronic topology as STATCOM except that it is incorporated through

a series coupling transformer instead of the shunt transformer as in the STATCOM.

- *UPFC*: The unified power flow controller (UPFC) is a versatile FACTS device which can provide simultaneous control of all basic parameters of the power system. It can provide both power flow and voltage control. It can control both the real and the reactive power flow. Although UPFC can be installed in different location in the power system, it is more effective when it is located at some optimal location.

Other FACTS devices include thyristor controllable series capacitor (TCSC), thyristor controllable phase-shifting transformers (TCPST), dynamic flow controller (DFC), and the super conducting magnetic energy storage (SMES) unit. These FACTS controllers are capable of changing the parameters of the transmission lines in a fast and effective manner. They can be connected to the power system in series, shunt or hybrid.

APPLICATIONS

FACTS devices have been used for controlling the voltage, impedance, and phase angle of high voltage AC lines. They can be used to increase transient stability of the transmission systems and for balancing three phase arc furnace loads. Modern FACTS devices are based on using voltage source converter (VSC) to inject a controllable AC waveform into the power system. The VSC is a basic element of the modern FACTS.

Other applications include power flow control, reactive power compensation, power quality improvement, and interconnection of renewable and distributed power generation.

BENEFITS

Using FACTS devices in power systems provides a number of benefits. These include [5]:

- It enhances the reliability of AC grids
- It increases power transmission capability and improves transient stability
- It provides dynamic reactive power support and voltage control
- It improves power quality and transmission efficiency
- It reduces operation and transmission investment cost
- It reduces power delivery costs
- It facilitates the connection of the renewable generation to the grid

Other benefits of FACTs include cost (which outweighs other consideration), convenience, and environmental impact [6].

CHALLENGES

Although FACTS devices can solve several power system problems, they have their own challenges and limitations. They are not widely used in the power industry. Their cost and complexity of the devices have prevented their deployment and integration into the electric transmission system [7]. The introduction of FACTS devices has raised concern on stability since FACTS increases the stress level of the system. Power flows in a power network are not easily controlled due to the fact that the line parameters are not easily changed. As more FACTS technologies are deployed, the coordination problem complexity increases [8]. Proper placement of the FACTS controllers is crucial in order to obtain good performance.

CONCLUSION

FACTS is a technology that is based on power electronics. Advances in power electronics technology now offer fast FACTS devices. The devices are used to enhance transient stability, controllability and power transfer capability of transmission systems. It is expected that FACTS devices will be used in smart grids for various control purposes. For more information about FACTS, one should consult [9,10].

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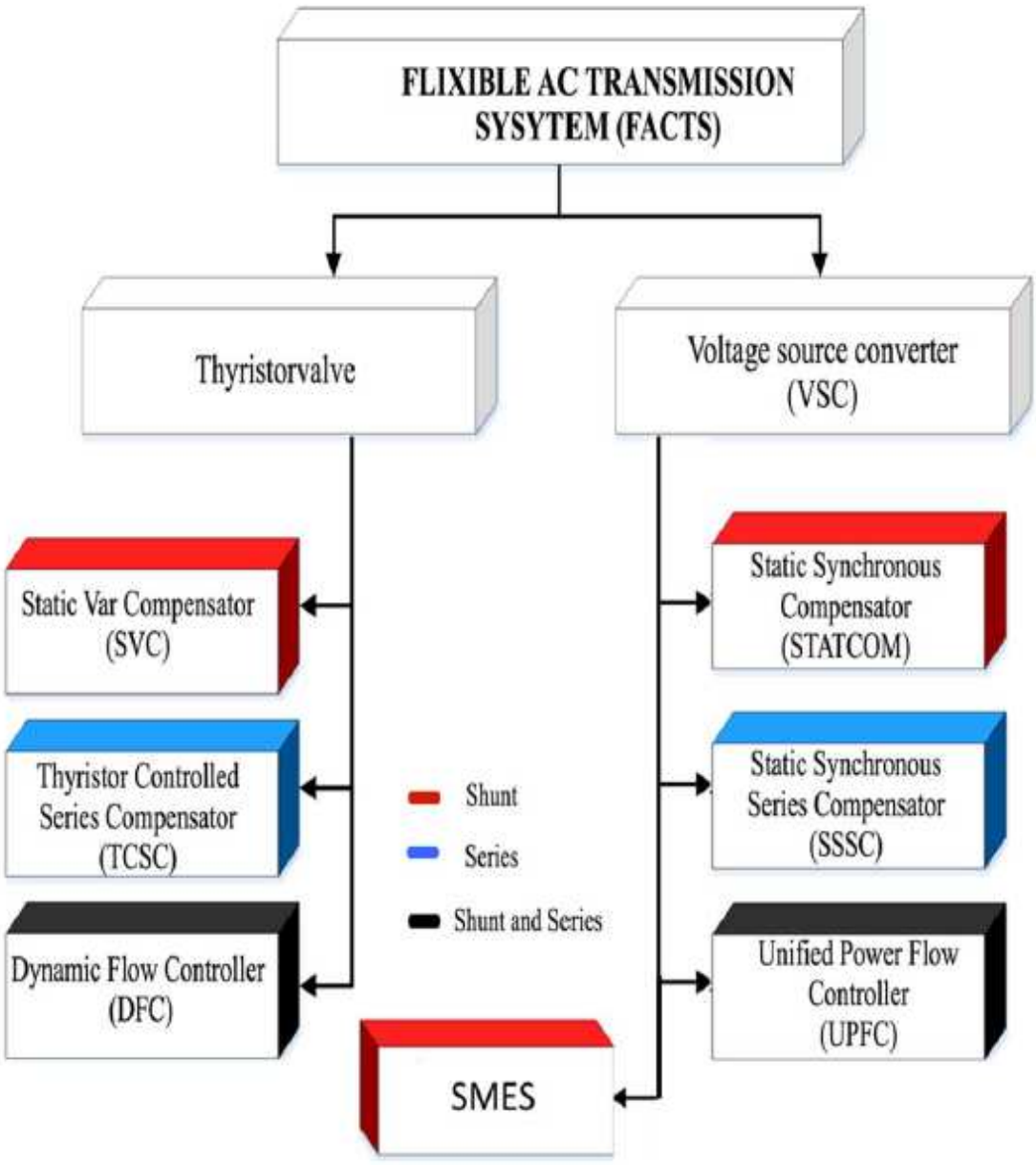

Figure 1 Major FACTS devices [4].