IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 12, Issue 4, Ver. I (Jul.-Aug. 2017), PP 62-70
www.iosrjournals.org

A Review on Stability Improvement of Electric Power Transmission SystemsUsing Shunt and Series Compensation Techniques

*Godwin Diamenu
(Ghana Technology University College, Faculty of Engineering, Takoradi, Ghana)
Corresponding Author: Godwin Diamenu

Abstract:*Electric Power demand has increased substantially while the expansion of power generation and transmission systems has been severely limited due to scarce resources and environmental restrictions. As a result, some transmission lines are heavily loaded and the system stability becomes a power transfer-limiting factor. This has resulted in a search for opportunities to increase the transmission line capacity of existing lines.With the use of series capacitors for compensating part of the inductive reactance of long transmission lines normally increases the transmission line capacity. It also increases transient stability margins, optimises load-sharing between parallel transmission lines and reduces system losses. Electric power transmission line compensation implies a modification in the electric characteristic of the transmission line with the objective of increasing the power transfer capability. In the case of series compensation, the objective is to reduce the transfer reactance of the line at power frequency by means of series capacitors. This results in an enhanced system stability, which is evidenced through an increased power transfer capability of the line. Shunt compensation technique in practical applications is often used to regulate the voltage at a given busbar against load variations, or to provide voltage support for the load when, due to generation or line outages, the capacity of the sending-end system becomes impaired.*

Keywords: *FACTS, Controllability, Static Var Compensator, Stability limit, Transmission system*

Date of Submission: 07-07-2017 Date of acceptance: 20-07-2017

I. INTRODUCTION

Society in general has grown increasingly dependent on electrical energy for economic activities and safety. As a result, electric power has become indispensable (Anon., 2016). Electricity plays an essential role in modern society, and the demand for high-qualityand reliable electrical services has increased with the advent of the technology based economy. The increased dependence on electricity means increased demand on the power system. Excessive reliance on peaking loads such as air conditioning and non-resistive loads such asinduction motors, variable speed drives, fluorescent lighting, and electronic devices changes thedemands placed on the power system (Anon., 2001). Electric Power demand hasincreased substantially while the expansion ofpower generation and transmission systemshas beenseverely limited due to scarce resources andenvironmental restrictions. As a result,some transmission lines are heavily loaded and thesystem stability becomes a power transfer-limitingfactor.

This has resulted in a search for opportunities toincrease the transmission line capacity of existing lines.The need for a new solutions and opportunities are important and critical.Flexible Alternating Current Transmission Systems (FACTS) devices has come to save the situation to some extent. FACTS devices are used to increase the transmission capacity, improvethe stability and dynamic behaviour or ensure better power quality in modernpower systems. Their main capabilities are reactive power compensation,voltage control and power flow control. Due to their controllable power electronics,FACTS devices always provide fast control actions in comparison to conventionaldevices like switched compensation or phase shifting transformers with mechanicalon-load tap changer (Mohanty and Barik, 2016; Zhan *et al*., 2006).The modern power transmission system is a complex network of transmission linesinterconnecting all the generator stations and all the major loading points in thepower system. These lines carry large blocks of power which generally can berouted in any desired direction on the various links of the transmission system toachieve the desired economic and performance objectives. Separate alternating current (ac) systemsmay be synchronously intertied with ac transmission lines to form a power pool inwhich electrical energy canbe transported among and between the systems (Anon., 2008).This paper is a reviewon series and shunt compensation techniques as applied to power transmission systems to enhance their performance.

II. THE ELECTRIC POWER SYSTEM

This section gives a brief over view of the electric power system, its controllability and constraints associated with it.

Power Generation, Transmission, and Distribution Systems

The main constituents of electric power system are generation, transmission (sub-transmission), distribution systems as well as the various loads with their related auxiliary support and protection equipment (Anon., 2008).According to Mohanty and Barik (2001), in any electric power system, the generation, transmission, and utilisation of electric power is separated intothree areas, which traditionally determines the way electric utility companies had been organised over the years.These, as given in Figure 1 and are:

- Generation
- Transmission
- Distribution

Figure 1 Block Diagram of Generation, Transmission and Distribution Systems

The electric power generation is by the use of rotating synchronous machines. The transmission, sub-transmission, and distribution lines are essentially distributed parameter, dominantly reactive networks designed to operate at high, medium and low alternating voltages respectively. The loads may be synchronous, non-synchronous, and passive, consuming in general both real and reactive power (Anon., 2008).

Electric Power System Constraints

Electric power systems worldwideare being pushed closer to their stability and thermal limits with the focus on the quality of powerdelivery. Blewushie (2013), opined that the characteristics of transmission system bottlenecks can take many forms and mayinclude one or more of the following:

- Steady-State Power Transfer Limit
- Voltage Stability Limit
- Dynamic Voltage Limit
- Transient Stability Limit
- Power System Oscillation Damping Limit
- Inadvertent Loop Flow Limit
- Thermal Limit
- Short-Circuit Current Limit

Each transmission bottleneck or constraint may have one or more of these system-level problems. The key to solving these problems in the most cost-effective and coordinated manner is thorough systems engineering analysis.

Controllability of Power Systems

A power system has certain variables that can be controlled as given by the power angle curve of Figure 2. Although this is a steady-state curve and theimplementation of FACTS is primarily for dynamicissues, this illustration demonstrates the point thatthere are primarily three main variables that can bedirectly controlled in the power system to impact itsperformance (Mohanty and Barik, 2001).These are:

- Voltage
- Angle
- Impedance

The real power, P, cannot be controlled without changingthe reactive power demand on the sending- and receiving-ends.

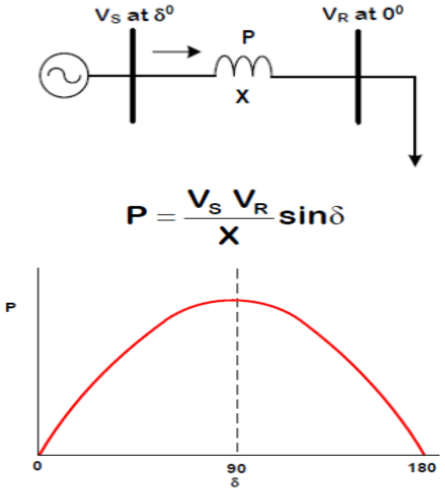

Figure 2 Controllability of Power Systems

Where, P = real power
V_S = magnitude of sending end voltage
V_R = magnitude of receiving end voltage
X = impedance
δ = phase angle between V_S and V_R

Power System Stability

Power system stability is the ability of an electric power system, for a given initial operatingcondition, to regain a state of operating equilibrium after being subjected to a physicaldisturbance, with most of the system variables bounded so that practically the entire systemremains intact.Integrity of the system ispreserved when practically the entire power system remains intact with no tripping of generatorsor loads, except for those disconnected by isolation of the faulted elements or intentionally trippedto preserve the continuity of operation of the rest of the system. The power system is a highly nonlinear system that operates in a constantly changing environment;loads, generator outputs, topology, and key operating parameters change continually. When subjectedto a transient disturbance, the stability of the system depends on the nature of the disturbance as well asthe initial operating condition.The disturbances being referred to could be faults, loadchanges, generator outages, line outages, voltage collapse or some combination of these. Powersystem stability can be broadly classified into rotor angle, voltage and frequency stability. Eachof these three stabilities can be further classified into large disturbance or small disturbance,short term or long term (Anon., 2012a; Anon., 2012b). The classification is as given in Figure 3 (Anon., 2012b).

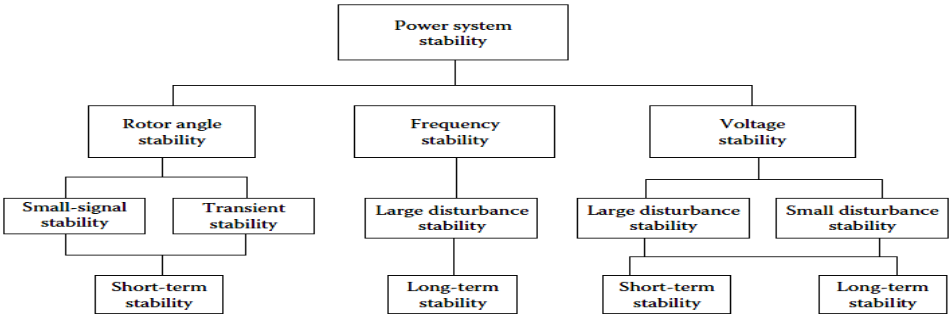

Figure 3 Classification of Power System Stability

Though, stability is classified into rotor angle, voltage and frequency stability they neednot be independent isolated events. A voltage collapse at a bus can lead to large excursions inrotor angle and frequency. Similarly, large frequency deviations can lead to large changes involtage magnitude.

2.4.1Rotor Angle Stability

The rotor angle of a generator depends on the balance between the electromagnetic torque due tothe generator electric power output and mechanical torque due to the input mechanical powerthrough a prime mover. Remaining in synchronism means that all the generators' electromagnetictorque is exactly equal to the mechanical torque in the opposite direction. If in a generator thebalance between electromagnetic and mechanical torque is disturbed, due to disturbances in thesystem, then this will lead to oscillations in the rotor angle.Rotor anglestability is therefore, the ability of the generator to remain in synchronism when subjected to a disturbance. Rotor angle stability is furtherclassified into small disturbance angle stability and large disturbance angle stability as depicted in Figure 3 (Anon., 2012a; Anon., 2012b).

Small-disturbance or small-signal angle stability

It is the ability of the system to remain in synchronism when subjected to small disturbances. If a disturbance is small enough so that the nonlinear power system can beapproximated by a linear system, then the study of rotor angle stability of that particular systemis known as small-disturbance angle stability analysis. Small disturbances can be small loadchanges like switching on or off of small loads, line tripping, small generators tripping etc. Dueto small disturbances there can be two types of instability: non-oscillatory instability andoscillatory instability. In non-oscillatory instability the rotor angle of a generator keeps onincreasing due to a small disturbance and in case of oscillatory instability the rotor angleoscillates with increasing magnitude (Anon., 2012a; Anon., 2012b).

Frequency Stability

Frequency stability depends on the ability to restore equilibriumbetween system generation and load, with minimum loss of load. Frequency instability may leadto sustained frequency swings leading to tripping of generating units or loads. It refers to the ability of a power system to maintain steady frequency following a severedisturbance between generation and load.During frequencyexcursions, the characteristic times of the processes and devices that are activated will rangefrom fraction of seconds like under frequency control to several minutes, corresponding to theresponse of devices such as prime moverand hence, frequency stability may be a short-termphenomenon or a long-term phenomenon. (Anon., 2012a; Anon., 2012b).

Voltage Stability

Unlike angle stability, voltage stability can also be a long term phenomenon. In a situation whereby voltage fluctuations occur due to fast acting devices like induction motors, power electronicdrive, High Voltage Direct Current (HVDC) etc., then the time frame for understanding the stability is within the range of 10-20 s and therefore, can be treated as short term phenomenon.On the other hand, if the voltage variations aredue to a slow change in load, over loading of transmission lines, generators hitting reactive power supply limits, tapchanging transformers etc., then time frame for voltage stability can stretch from one minute toseveral minutes. Voltage stability is the ability of the electric power system to maintain steady state voltages at all the system buseswhen subjected to a disturbance. If the disturbance is large enough, then it is known as large-disturbancevoltage stability, and if the disturbance is small, it is referred to as small-disturbance voltage stability. The main difference between voltage stability and rotor angle stability is that voltage stabilitydepends on the balance of reactive power demand and generation in the system whereas the rotor angle stability mainly depends on the balance between real power generation and demand (Anon., 2012a; Anon., 2012b).

Steady-state Limits of Power Transmission

According to Zhang *et al*., (2006), the maximum power, $P_{max}=\frac{V^2}{X}$,transmittable over a lossless line at a given transmission voltage, V, is totally determined by the line reactance X and thus sets the theoretical limit for steadystate power transmission. A practical limit for an actual line with resistance Rmay be imposed by the I^2R loss that heats the conductor. At a certain temperature the physical characteristics of the conductor could irreversibly change by being deformed with a permanent sag**.** This sets a thermal limit for the maximum transmittable power. Generally, for long lines X, and for short lines Rwould provide the main transmission limitations.AC loads are generally sensitive to the magnitude, and may as well be sensitive to thefrequency of the applied alternating voltage. Alternating current (ac) power systems are generallyoperated at a substantially constant frequency of 50 Hz or 60 Hz. The voltage levels in ac systems may moderately vary, but are not allowed to exceed typicalwell defined limits such as +5 and -10%. This tight voltage tolerance mayimpose the primary transmission limitation for long radial lines where there isno generation atthe receiving end and fortapped-lines, which feed a number ofrelatively small loads along the transmission line.Steady-state power transmission may also be limited by paralleland loop power flows. These flows often occur in a multi-line, interconnectedpower system, as a consequence of basic circuit laws which define current flowsby the impedance rather than the current capacity of the lines. These can result inoverloaded lines with thermal and voltage level problems.

Traditional Transmission Line Compensation and Power Flow Control Techniques

It has long been established that the steady-state transmittable power can beincreased and the voltage profile along the transmission line controlled by an appropriate reactivecompensationas a power system is mostly reactive.However, the lack of reactive power can cause voltage collapse in the power system. A device that is connected in parallel with a transmission line is called a shunt compensator, while a device that is connected in series with the transmission line is called a series compensator. These are referred to as compensators since they compensate for the reactive power in the ac system. The purpose of this reactive compensation is to change the naturalelectrical characteristics of the transmission line to make it more compatible withthe prevailing load demand. Thus, shunt connected, fixed or mechanicallyswitched reactors are applied to minimize line overvoltage under light loadconditions, and shunt connected, fixed or mechanically switched capacitors areapplied to maintain voltage levels under heavy load conditions (Anon., 2008).In the case oflong transmission lines, series capacitive compensation is often employed toestablish a virtual short line by reducing the inductive line impedance and for that matter the electrical length, θ, of the line given by Equation (1):

$$\theta = \sqrt{X_l + X_c} \quad (1)$$

Where, X_l = series inductive reactance
X_c= shunt capacitive reactance

Shunt Compensation Technique

Reactive power compensation technique is often the most effective way to improve both power transfer capabilityand voltage stability of the transmission line. The control of voltage levels is accomplished by controlling the production, absorption andflow of reactive power. The generating units provide the basic means of voltage control, since the automaticvoltage regulators control field excitation to maintain scheduled voltage level at the terminals of the generators. To control the voltage throughout the system,use must be made of additional devices to compensate reactive power (Akwukwaegbu and Okwe, 2013).The primary purposes of transmission system shunt compensation near load centres are voltage control and loadstabilisation.At the substation busbars where reactive power demand increases, busbar voltage can be controlled byconnecting capacitor banks in parallel with a lagging load. The capacitor banks supply part or full reactive power to the load, thus reducing the magnitudeof the source current necessary to supply the load. As a result, the voltage drops between thesending end and the load or receiving end gets reduced, improving power factor and increased activepower output is available from the source (Kiran and Laxmi, 2011).Depending upon the load demand, the capacitor banks may be permanently connected to the system or can be varied by switching on or off the parallelconnected capacitor banks either manually or automatically. Figure 4 gives a single-linediagram of an uncompensated transmission line and its voltage-phasor diagram, whereas Figure 5 gives a single diagram of a compensated transmission line and its voltage-phasor diagram (Kiran and Laxmi, 2011; Gonen, 2008).

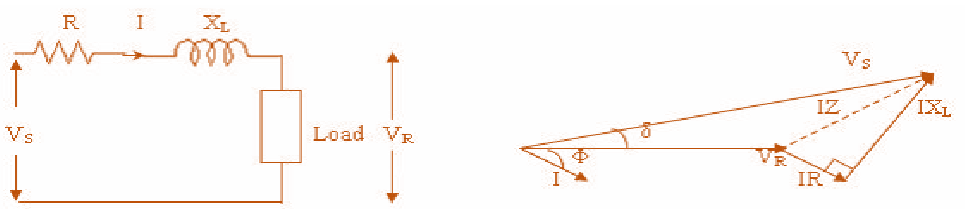

Figure 4 Uncompensated Single-line Diagram of a Transmission Line and its Voltage- phasor Diagram

The voltage drops, V_D along the line assuming a lagging power factor can be approximated from the voltage-phasor diagram by Equation (2):

$$V_D = I_R R + I_X X_L \text{ (volt)} \quad (2)$$

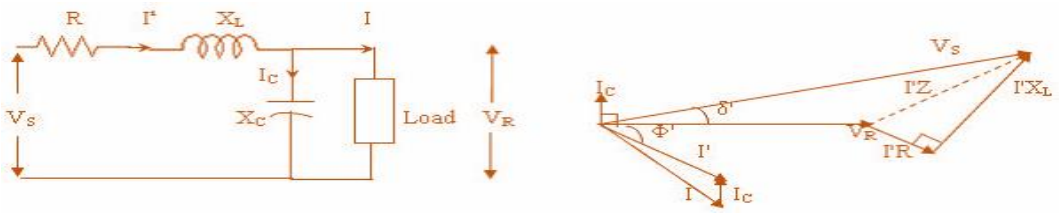

Figure 5 Compensated Single-line Diagram of a Transmission Line and its Voltage-phasor Diagram

The voltage drops,$V_D$based on the phasor diagram can be approximated by Equation (3):

$V_D = I_R R + I_X XL - I_C X_L$(volt)(3)

Where,
V_D = voltage drop
E or $V_{s\,=}$ sending end voltage
V_R= receiving end voltage
Z = circuit impedance
I_R= current flow through the resistive component of the circuit
R = resistor
I_X= current flowing through the inductive reactance component of the circuit
X_L = inductive reactance
I_C = current flowing through the capacitive reactancecomponent of the circuit
X_C= capacitive reactance
I = line current
I^1= load current
Φ or Φ^1= phase angle between V_R and I
δ or δ^1 = phase angle between V_s and V_R

Shunt compensation technique suffers from the following drawbacks (Akwukwaegbu and Okwe, 2013; Kiran and Laxmi, 2011).

- Shunt compensation do not affect current or power factor beyond their point of application
- The reactive power supplied by the shunt capacitor banks is directly proportional tothe bus voltage
- When the reactive power required is less on light loads, capacitor bank output willbe high. This problem can be eliminated by the use of switch shunt compensation technique by varying the capacitive reactance depending on load requirement
- For voltage emergencies, the reactive power output drops with the voltage squared
- For transient voltage instability, the switching may not be fast enough to prevent induction motor stalling
- Precise and rapid control of voltage is not possible

Shuntcompensation technique in practical applications is often used to regulate the voltage at agiven busbar against load variations, or to provide voltage support for the load when,due to generation or line outages, the capacity of the sending-end system becomesimpaired (Anon., 2008).

Series Compensation Technique

The basic idea behind series capacitive compensation technique is to decrease the overalleffective series transmission impedance from the sending-end to the receiving-end. The conventional view is that the impedance of theseries connected compensating capacitor cancels a portion of the actual linereactance and thereby the effective transmission impedance is reduced as if theline was physically shortened (Anon., 2008).When a load with lagging power factor is connected at the end of the transmission line, voltage drop, V_D along the transmission line is given by Equation (4):

$V_D = I(R \cos \Phi + X_L \sin \Phi)$ (volt)(4)

If a capacitance ‘C’ with reactance *Xc* is connected in series with the line, then, reduction in capacitivereactance is given by Equation (5) which results in reduction in voltage drop along the transmission line. The reactive power drawn by the line is also reduced as well (Kranti and Laxmi, 2011).

$X_L - X_C$ (5)

An equivalent circuit of a transmission line with series reactive compensation and its phasor diagram is give in Figure 6.

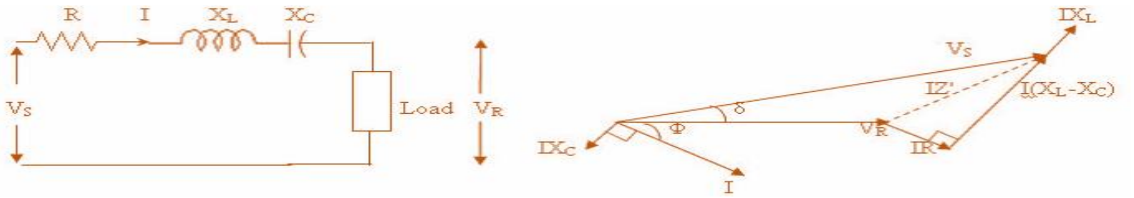

Figure 6 Single-line Diagram of a Series Compensated Transmission Line and its Voltage-phasor Diagram

Based on the phasor diagram of Figure 6, thereducedvoltage drops, V_D along a series compensated transmission line is given by Equation (6) according to (Kranti and Laxmi, 2011).

$$V_D = I(R \cos \Phi + (X_L - X_C) \sin \Phi) \qquad \text{(volt)} \quad (6)$$

There are many applications in which mechanically-switched capacitors are used to control transmission line voltage where there are slow,daily and seasonal load variations. Although these provide economical solutionsto steady-state transmission problems, their limited operating speed makes themlargely ineffective under dynamic system conditions. Also, because of restrictionsin the number of switching operations permitted, mechanically-switchedcapacitors often lack the flexibility of operation modern power systemsrequire (Anon., 2008; Joshi and Kothari, 2014).

Effects of series compensation

According to Joshi and Kothari (2014), series compensation technique has the following effects on electric power transmission lines:

1. The reduced line impedance improves stability: When the transmission line is series compensated, the rotor angle, δ reduces for the same amount of power transfer due tothe effect of the compensation. Reduction in rotor angle δ allows rotor to operate at a lower rotor angle with increased stability limit.
2. The reduced transmission line impedance improves voltage regulation: By compensating the transmission line, the net impedance of the line reduces resulting in minimal voltage drop along the transmission line resulting ina better voltage regulation.
3. Series compensation is a means of controlling the load among several transmission lines: By controlling the degree of compensation along several busbars, the amount of load shared among the lines can be controlled. It givesa better control of load among several transmission lines.
4. Increasing the loading capacity of the transmission line improves the utilisation of the transmission system, and therefore, a better return on the capital invested. Series compensated transmission lines allow power transfer at the same voltage level over longer transmission lines than uncompensated transmission lines.This results in a better utilisation of the existing transmission network, which is also cost effective compared to the construction of new or additional parallel transmission lines.
5. Increased power transfer capability: Series compensated transmission lines have reduced net transfer reactance, power transfer capability of the system greatly increases compared to an uncompensated transmission line. This method of increasing power transfer capability of an existing transmission system may eliminate the need for constructing parallel transmission lines for increased load demand.

   Despite the numerous advantages of series compensation technique, the following are the difficulties associated with it (Anon., 2014; Joshi and Kothari 2014):

- Increase in fault current
- It creates certain complexities in the over reach and under reach operation of impedance relays
- Mal operation of distance relay- if the degree of compensation and location is not proper
- Often invents the voltage and the current
- High recovery voltage of lines- across the circuit breaker contacts and is harmful
- Difficulties of ferro-resonance
- Difficulties as a result of sub-synchronous resonance

In general, the economic benefits that can be derived from applying compensation techniques to the power system can be summarised as follows according to Gonen (2008):

- Reduced generation capacity
- Reduced transmission capacity
- Reduced distribution substation capacity

  The following benefits of power system compensation applies to the distribution aspect:
- Reduced energy (copper) losses
- Reduced voltage drop and consequently improved voltage regulation
- Released capacity of feeder and associated apparatus
- Postponement or elimination of capital expenditure due to system improvement and expansion
- Increment in revenue due to voltage improvements

The EmergenceofFlexible AC Transmission Systems

Flexible AC Transmission Systems, known simply as FACTS, is a wellknownterm for higher controllability in power systems by means of power electronicdevices. Basic limitations such as distance, stability, and controllability of flow of classic ac power transmission system have necessitated the under-utilisation of transmission lines andother assets, and the potential of mitigating these limitations cost effectively bycontrolled compensation, provided the incentivestointroduce power electronics-based control for reactive compensation.Several FACTS-devices have been introduced for various applicationsworldwide. A number of new types of devices are in the stage of being introducedin practice. In most of the applications the controllability is used to avoid cost intensive orlandscape requiring extensions of power systems, for instance like upgrades or additionsof substations and power transmission lines. FACTS-devices provide a better adaptationto

varying operational conditions and improve the usage of existing installations. The FACTS initiative was originally launched to solvethe emerging system problems due to restrictions on transmissionline construction, and to facilitate the growing power export and import and wheelingtransactions among utilities, with two main objectives being:
(1) To increase the power transfer capability of transmission systems.
(2) To keep power flow over designated routes.

The basic applications of FACTS-devices are:

- Power flow control;
- Increase of transmission capability;
- Voltage control;
- Reactive power compensation;
- Stability improvement;
- Power quality improvement;
- Power conditioning;
- Flicker mitigation; and
- Interconnection of renewable and distributed generation and storages (Anon., 2008; Zhang *et al*., 2006).

Configurations of FACTS-Devices

Shunt Devices

The most used FACTS-device is the Static Var Compensator (SVC) or the version with Voltage SourceConverter called Static SynchronousCompensator (STATCOM). These shunt devices are operating as reactive powercompensators. The main applications in transmission, distribution and industrialnetworks are:

- Reduction of unwanted reactive power flows and therefore reduced network Losses;
- Keeping of contractual power exchanges with balanced reactive power;
- Compensation of consumers and improvement of power quality especially withhuge demand fluctuations like industrial machines, metal melting plants, railwayor underground train systems;
- Compensation of Thyristor converters e.g. in conventional HVDC lines, and
- Improvement of static or transient stability.

Electrical loads do generate and absorb reactive power. As the power being transmitted varies considerably from time to time, the reactive power balance in the power system varies as well. The result can be unacceptable voltage amplitude variations oreven a voltage depression, at the extreme a voltage collapse can occur. A rapidly operating Static SVC can continuously provide the reactive power requiredto control dynamic voltage oscillations under various system conditionsand thereby improve the power system transmission and distribution stability. Installingan SVC at one or more suitable points in the transmission system can increase transfercapability and reduce losses while maintaining a smooth voltage profile under differentnetwork conditions. In addition, an SVC can mitigate active power oscillationsthrough voltage amplitude modulation.

The STATCOM has a characteristic similar tothe synchronous condenser, but as an electronic device it has no inertia and is superiorto the synchronous condenser in several ways, such as better dynamics, alower investment cost and lower operating and maintenance costs.The main advantageof a STATCOM is that the reactive power provision is independent from theactual voltage on the connection point.What this means is that even during most severe contingencies, theSTATCOM keeps its full capability(Zhang *et al*., 2006).

Series Devices

SeriesCompensation is used in order to decrease the transfer reactance of a power transmission line atrated frequency. A series capacitor installation generates reactive power that in aself-regulating manner balances a fraction of the line's transfer reactance. The resultis that the line is electrically shortened, which improves angular stability,voltage stability and power sharing between parallel transmission lines. The series devices were developed from fixed or mechanically switchedcompensation devices, the Thyristor Controlled Series Compensation (TCSC) or the Voltage Source Converter based devices. The main applications are:

- Reduction of series voltage decline in magnitude and angle over a power line;
- Reduction of voltage fluctuations within defined limits;
- Improvement of system damping oscillations; and
- Limitation of short circuit currents in the transmission networks or substations;

Thyristor Controlled Series Capacitors (TCSC) is used for specific dynamical problemsin transmission systems such as:

- Increment in damping when large electricalsystems are interconnected.
- To overcome the problem of Sub-Synchronous Resonance (SSR), a phenomenon that involves an interaction betweenlarge thermal generating units and series compensated transmission systems.

The TCSC's high speed switching capability provides a mechanism for controlling transmission line power flow, which allows increased loading of existing transmissionlines, and permits rapid readjustment of transmission line power flow in response to variouscontingencies. The TCSC also can regulate steady-state power flow within its ratinglimits.

The main principles of the TCSC concept are:

- To provide electromechanical damping between large electrical systems by changing the reactance of a specific interconnecting power lines; thus, the TCSCis to provide a variable capacitive reactance.
- The TCSC shall change its apparent impedance as seen by the line current for sub-synchronous frequencies, such that a prospective sub-synchronousresonance is avoided(Zhang *et al*., 2006).

A voltagesource inverter could be connected in series with the transmission line. This device is called staticsynchronous series compensator (SSSC). In principle, an SSSC is capable of interchanging active and reactive energywith the power system. However, if only reactive power compensation is intended,the size of the energy source could be quite small. The injected voltage could becontrolled in magnitude and in phase if sufficient energy source is provided. For thereactive power compensator function, only the magnitude of the voltage iscontrolled since the vector of the inserted voltage is perpendicular to the linecurrent. In this case the series injected voltage can either lead or lag the linecurrent by 90 degrees. This means that the SSSC can be smoothly controlled atany value leading or lagging within the operating range of thevoltage source inverter (VSI). Thus, thebehaviour of an SSSC can be likened to a controllable series capacitor and acontrollable series reactor. The basic difference is that the voltage injected bySSSC is not related to the line current and can be independently controlled. Theimportance of this characteristic is that an SSSC is effective for both low and highloading (Anon., 2008).

III. CONCLUSION

This review looked at the compensation techniques available to increase the transmission line capacity of existing transmission lines. Reactive power compensation technique is often the most effective way to improve both power transfer capability and voltage stability of the transmission line. The control of voltage levels is accomplished by controlling the production, absorption and flow of reactive power. The steady-state transmittable power can be increased and the voltage profile along the transmission line controlled by an appropriate reactive compensation as a power system is mostly reactive. The basic idea behind series capacitive compensation technique is to decrease the overall effective series transmission impedance from the sending-end to the receiving-end. The primary purposes of transmission system shunt compensation near load centres are voltage control and load stabilisation. FACTS devices are used to increase the transmission capacity, improve the stability and dynamic behaviour or ensure better power quality in modern power systems. Their main capabilities are reactive power compensation, voltage control and power flow control.

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