CHAPTER 3

FACTS CONTROLLERS

3.1 INTRODUCTION

Power electronics and power quality are irrevocably linked together as it strives to advance both broad areas. With the dramatic increases over the last 20 years in energy conversion systems utilizing power electronic devices, it is seen that the emergence of ‘power quality’ and simple control algorithm modification to this same technology can often play an equally dominant role in enhancing overall quality of electrical energy available to end-users.

Power electronics has given, as an industrial society, a plethora of new ways to manufacture products, provide services, and utilize energy. From a power quality impact viewpoint, applications such as

1. Switched-mode power supplies,
2. DC arc furnaces,
3. Electronic fluorescent lamp ballasts,
4. Adjustable speed drives, and
5. Flexible AC transmission components

are often cause for concern. From a utility supply system viewpoint, these converter-based systems can lead to operational and life expectancy problems for other equipment, possibly not owned or operated by the same party. It was from this initial perspective that the field of power quality emerged.
In most cases, the same devices and systems that create power quality problems can be used to solve power quality problems. ‘Problem solving’ applications such as

1. Active harmonic filters,
2. Static and adaptive var compensators, and
3. Uninterruptable power supplies

call utilize the same switching device technology as the ‘problem causing’ applications.

As the number of potentially problematic power electronic based loads has increased over time, so the attention is given to enhanced converter control to maximize power quality. Perfect examples of these improvements include:

1. Unity power factor converters,
2. Dip-proof inverters, and
3. Limited-distortion electronic lamp ballasts.

While many studies suggest increases in power electronic-based energy utilization as high as 70-80% (of all energy consumed), it is equally clear that we are beginning to realize the total benefit of such end-use technologies. Power quality problems associated with grounding, sags, harmonics, and transients will continue to increase because of the sheer number of sensitive electronic loads expected to be placed in service. At the same time, only now beginning to realize the total benefits that such loads can offer.
3.2 FACTS CONTROLLERS

3.2.1 General

With the ongoing expansion and growth of the electric utility industry, including deregulation in many countries, numerous changes are continuously being introduced to a once predictable business. Although electricity is a highly engineered product, it is increasingly being considered and handled as a commodity. Thus, transmission systems are being pushed closer to their stability and thermal limits while the focus on the quality of power delivered is greater than ever.

In the evolving utility environment, financial and market forces are, and will continue to, demand a more optimal and profitable operation of the power system with respect to generation, transmission, and distribution. Now, more than ever, advanced technologies are paramount for the reliable and secure operation of power systems. To achieve both operational reliability and financial profitability, it has become clear that more efficient utilization and control of the existing transmission system infrastructure is required. Improved utilization of the existing power system is provided through the application of advanced control technologies. Power electronics based equipment, or Flexible AC Transmission Systems (FACTS), provide proven technical solutions to address these new operating challenges being presented today. FACTS technologies allow for improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time compared to the construction of new transmission lines. Traditional solutions to upgrade the electrical transmission system infrastructure have been primarily in the form of new transmission lines, substations, and associated equipment. However, as experiences have proven over the past decade or more, the process to permit, site, and construct
new transmission lines has become extremely difficult, expensive, time-consuming, and controversial.

FACTS technologies provide advanced solutions as cost-effective alternatives to new transmission line construction. The potential benefits of FACTS equipment are now widely recognized by the power systems engineering and T&D communities. With respect to FACTS equipment, voltage sourced converter (VSC) technology, which utilizes self-commutated thyristors/transistors, has been successfully applied in a number of installations world-wide.

3.2.2 Power Transfer Limit

One or more of the following network characteristics limits power flow over a transmission system.

- Stability limit
- Thermal limit
- Voltage limit
- Loop flow

Technically limitations on power transfer can always be removed by adding new transmission and/or generator capacity. FACTS are designed to remove such limitations and meet operator’s goals without having to understand major system additions.

3.2.3 Power System Constraints

As noted in the introduction, transmission systems are being pushed closer to their stability and thermal limits while the focus on the quality of power delivered is greater than ever. The limitations of the transmission
system can take many forms and may involve power transfer between areas (referred to here as transmission bottlenecks) or within a single area or region (referred to here as a regional constraint) and may include one or more of the following characteristics:

- 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
- Others

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

### 3.2.4 Controllability of Power Systems

To illustrate that the power system only has certain variables that can be impacted by control, consider the basic and well-known power-angle curve, shown in Figure 3.1. Although this is a steady-state curve and the implementation of FACTS is primarily for dynamic issues, this illustration demonstrates the point that there are primarily three main variables that can be directly controlled in the power system to impact its performance. These are
- Voltage (V)
- Angle between Bus Voltages (\( \delta \))
- Impedance (Z)

One could also make the point that direct control of power is a fourth variable of controllability in power systems.

Figure 3.1 illustrates the controllability of power systems with the establishment of which variables can be controlled in power system and the solutions to control the variables are conventional equipment and FACTS controllers.
3.2.5 Benefits of Control of Power Systems

Once power system constraints are identified and through system studies viable solutions options are identified, the benefits of the added power system control must be determined. The following offers a list of such benefits:

- Increased Loading and More Effective Use of transmission Corridors
- Added Power flow Control
- Improved Power System Stability
- Increased System Security
- Increased System Reliability
- Elimination or Deferral of the Need for New Transmissions Lines

The advantages in this list are important to achieve in the overall planning and operation of power systems. However, for justifying the costs of implementing added power system control and for comparing conventional solutions to FACTS controllers, more specific metrics of the benefits to the power system are often required. Such benefits can usually be tied back to an area or region for a specific season and year at a defined dispatch (usually given by an ISO or equivalent) while meeting the following criteria, the examples are

- Voltage Stability Criteria
  - e.g., P-V voltage or power criteria with minimum margins
  - e.g., Q-V reactive power criteria with minimum margins
- Dynamic Voltage Criteria
  e.g., Avoiding voltage collapse
  e.g., Minimum transient voltage dip/sag criteria (Magnitude and duration)

- Transient Stability Criteria

- Power System Oscillation Damping
  e.g., Minimum damping ratio

Each of the above listed items can usually be measured in terms of a physical quantity such as power transfer through a critical transmission interface, power plant output area or region load level. This allows for a direct quantification of the benefits of adding power system control and provides a means to compare such benefits by the various solution options considered, whether they be conventional or FACTS based.

3.2.6 Conventional devices For Enhancing Power System Control

- Series Capacitor - Controls impedance
- Switched Shunt Capacitor and Reactor - Controls voltage
- Transformer LTC - Controls voltage
- Phase Shifting Transformer - Controls angle
- Synchronous Condenser - Controls voltage
- Special Stability Controls - Typically focuses on voltages control but can often include direct control of power

- Others (When Thermal Limits are Involved) - Can included reconductoring, raising conductors, dynamic line monitoring, adding new lines, etc.
3.3 **FACTS TECHNOLOGY**

The FACTS technology helps us to alleviate these difficulties by enabling utilities to get the most service from their transmission facilities and enhance grid reliability. FACTS technology is a collection of controllers which can control series impedance, shunt impedance, current voltage and phase angle.

FACTS is nothing but the Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability. FACTS technology is a collection of controllers, which can be applied individually or in coordination with others to control one or more of the interrelated system parameters mentioned above.

FACTS Controller is power electronic-based system and other static equipment that provide control of one or more AC transmission system parameters.

When the power system is controlled through mechanical switches, there is no high-speed control. Also due to the increasing complexity of the power system, the grid operator is not able to meet the dynamic swings in the power system with the help of mechanical switches. As the mechanical switches tend to wear out quickly when compared to static electronic devices, the maintenance becomes tough and the life of the entire power system gets reduced.

As most of the transmission systems are AC transmission systems, FACTS technology is necessary to pacify some but not all of these difficulties by enhancing the control over the transmission of power and to enhance the
grid reliability with the same existing line itself, unlike HVDC where new transmission system has to be installed. FACTS pave way to control the current through the line at a reasonable cost. Hence, the capacity of the line can be increased with larger conductors. The FACTS controller enables the line to carry power closer to its thermal rating

3.4 RELATIVE IMPORTANCE OF CONTROLLABLE PARAMETERS

- Control of the line impedance X can provide a powerful means of current control

- When the angle is not large, which is often the case, control of X or the angle Substantially provides the control of active power

- Control of angle, which in turn controls the driving voltage, provides a powerful means of controlling the current flow and hence active power flow is controlled when the angle is not large

- Injecting a voltage in series with the line and with any phase angle with respect to the driving voltage can control the magnitude and the phase of the line current

- When the angle is not large, controlling the magnitude of one or the other line voltages can be a very cost-effective means for the control of reactive power flow through the interconnection
Combination of the line impedance control with a series controller and voltage regulation with a shunt controller can also provide a cost effective means to control both the active and reactive power flow between the two systems.

3.5 TYPES OF FACTS CONTROLLERS

FACTS controllers can be divided into four categories.

3.5.1 Series Controller

Series Controller could be variable impedance or variable source. All series controllers inject voltage in series with the line. Variable impedance multiplied by the current flow through it, represents an injected series voltage in the line. As long as the voltage is in phase quadrature with the line current, the series controller only supplies or consumes variable reactive power.

3.5.2 Shunt Controller

Shunt Controller could be variable impedance, variable source or a combination of these. Shunt controllers inject current into the system at the point of connection. Variable shunt impedance connected to the line voltage causes a variable current flow and hence represents injection of current into the line. As long as the injected current is in phase quadrature with the line voltage, the shunt controller only supplies or consumes variable reactive power.

3.5.3 Combined Series - Series Controller

This could be a combination of separate series controllers, which are controlled in a coordinated manner, in multilane transmission system or it could be a unified controller in which series controllers provide independent series reactive compensation for each line but also transfer real power among
the lines via the power link. The term unified means that the dc terminals of all controller converters are connected together for real power transfer.

3.5.4 Combined Series-Shunt Controller

This could be combination of separate shunt and series controllers, which are controlled in a coordinated manner, a Unified Power Flow Controller with series and shunt elements. Combined shunt and series controllers inject current into the system with the shunt part of the controller and voltage in series in the line with the series part of the controller.

3.6 CONTROLLERS FOR ENHANCING POWER SYSTEM CONTROL

- Static synchronous Compensator (STATCOM) -Controls voltage
- Static VAR Compensator (SVC) -Controls voltage
- Unified Power Flow Controller (UPFC)
- Convertible Series Compensator (CSC)
- Inter-line Power Flow Controller (IPFC)
- Static Synchronous Series Controller (SSSC)

Each of the above mentioned (and similar) controllers impact voltage, impedance, and/or angle (and power)

- Thyristor Controlled Series Compensator (TCSC) -Controls impedance
- Thyristor Controlled Phase Shifting Transformer (TCPST) -Controls angle
Super Conducting Magnetic Energy Storage (SMES) - Controls voltage and power

3.7 ADVANTAGES OF FACTS TECHNOLOGY

- Rapid response
- Dynamic control of power flow in selected transmission lines within the network to enable optimal power flow conditions
- Damping of the power swings from local and inter-area oscillations
- Suppression of subsynchronous oscillations
- Decreases DC offset voltages
- Reduction of short circuit current
- Frequent variation in output
- Smoothly adjustable output

3.8 UNIFIED POWER FLOW CONTROLLER (UPFC)

The concept of unified power flow control is that injects voltage of variable magnitude and phase angle. This provides control of power system parameters, such as terminal voltage, line impedance and phase angle, thereby providing necessary real and reactive power flow control.

UPFC is a combination of STATCOM and SSSC, which are coupled via a common DC link, to allow bi-directional flow of real power between the series output terminals of the SSSC and shunt output terminals of STATCOM, and are controlled to provide concurrent real and reactive series line compensation without an external electric energy source.
• UPFC is the most comprehensive multivariable Flexible AC Transmission system (FACTS) controller

• UPFC is one of the FACTS device, which can control power system parameters, such as terminal voltage, line impedance and phase angle.

• Therefore it can be used not only for power flow control but also for power system stabilizing control

• UPFC capable of generating/absorbing both real and reactive power

UPFC are capable of directing real and reactive power flow through a designated route. Nowadays FACTS devices can be used to control the power flow and enhance system stability. They enable a line to carry power closer to its thermal rating. The salient features of a FACTS device are its multiple control functions, such as power flow control, voltage control, transient stability enhancement and oscillation damping. Voltage sag compensation is necessary for secure system operation. A well designed FACTS Controller can not only increase the transmission capability but also improves the power system stability. UPFC is the most comprehensive multivariable flexible AC transmission systems controller (Menniti et. al. 2001 and Sen and Stacey 1999).

3.8.1 Basic Circuit of UPFC

The Unified Power Flow Controller consists of two switching converters, which in the implementations considered are voltage sources inverters, as illustrated in Figure 3.2. These inverters, labeled “Converter 1” and “Converter 2” in the figure, are operated from a common dc link provided by a dc storage capacitor. This arrangement functions as an ideal ac to ac
power converter in which the real power can freely flow in either direction between the ac terminals of the two inverters and each inverter can independently generate or absorb reactive power at its own ac output terminal.

Converter 2 provides the main function of the UPFC by injecting an ac voltage $V_{pq}$ with controllable magnitude $V_{pq} (0 \leq V_{pq} \leq V_{pq\max})$ and phase angle, $\delta (0 \leq \delta \leq 360^\circ)$ at the power frequency, inserted with line via an insertion transformer. This injected voltage can be considered essentially as a synchronous ac voltage source. The transmission line current flows through this voltage source resulting in real and reactive power exchange between it and the ac system. The real power exchanged at the ac terminal (i.e. at the terminal of the insertion transformer) is converted by the inverter into dc power which appears at the dc link as positive or negative real power demand. The reactive power exchanged at the ac terminal is generated internally by the inverter.

![Figure 3.2 UPFC Connected to a Transmission Line](image)

The basic function of Converter 1 is to supply or absorb the real power demanded by Converter 2 at the common dc link. This dc link power is converted back to ac and coupled to the transmission line via a shunt
connected transformer. Converter 1 can also generate or absorb controllable reactive power, if it is desired, and thereby it can provide independent shunt reactive compensation for the line. It is important to note that whereas there is a closed “direct” path for the real power negotiated by the action of series voltage injection through Converters 1 and 2 back to the line, the corresponding reactive power exchanged is supplied or absorbed locally by Converter 2 and therefore it does not flow through the line.

Thus, Converter 1 can be operated at a unity power factor or be controlled to have a reactive power exchange with the line independently of the reactive power exchanged by Converter 2. This means that there is no continuous reactive power flow through the UPFC.

Procedure leading to the formulation of the state matrix to study the dynamic stability of multi machine power system in the presence of UPFC (Kannan sreenivasachar et. al. 2000). Two different control structure have been evaluated for closed loop stability. The improvement in dynamic stability with the different control structures has been presented for a multi machine multi UPFC power system.

(Toufan and Annakkage 1998) investigates the performance of a UPFC constructed by a back to back connection of a hysteresis current forced converter and a PWM inverter. The UPFC has been modeled at the component level using PSCAD/EMTDC program. The simulation results of the UPFC applications in steady state power flow control and dynamic stability enhancement are demonstrated in a test system.

3.8.2 Control Strategy of UPFC

3.8.2.1 Shunt Converter Control Strategy

The shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the dc link capacitor voltage. In this case,
the shunt converter voltage is decomposed into two components. One component is in-phase and the other is quadrature with the UPFC bus voltage. De-coupled control system has been employed to achieve simultaneous control of the UPFC bus voltage and the dc link capacitor voltage.

3.8.2.2 Series Converter Control Strategy

The series converter of the UPFC provides simultaneous controls of real and reactive power flow in the transmission line. To do so, the series converter injected voltage is decomposed into two components. One component of the series injected voltage is in quadrature-injected component controls the transmission line real power flow. This strategy is similar to that of a phase shifter. The in-phase component controls the transmission line reactive power flow. This strategy is similar to that of a tap changer.

3.8.3 Basic Operating Modes of the UPFC

3.8.3.1 Shunt Inverter

The shunt inverter is operated in such a way as to draw controlled current from the line. One component of this current is automatically determined by the requirement to balance the real power of the series inverter. The remaining current component is reactive and can be set to any desired reference level (inductive or capacitive) within the capability of the inverter. The reactive compensation control modes of the shunt inverter are very similar to these commonly employed in conventional static var compensators.

VAR Control Mode

In VAR control mode the reference input is an inductive or capacitive VAR request. The shunt inverter control translates the VAR reference into a corresponding shunt inverter request and adjusts the gating of the inverter to establish the desired current. The control uses current feedback
signals obtained from current transformers (CTs) typically located on the bushings of the shunt coupling transformer. A feedback signal the dc bus voltage \( V_{dc} \), is also required.

**Automatic Voltage Control Mode**

In voltage control mode, the shunt inverter current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value, with a defined droop characteristic. The droop factor defines the per unit voltage error per unit of inverter reactive current within the current range of the inverter. The automatic voltage control uses voltage feedback signals obtained from accurate potential transformers (PTs) measuring the voltage, \( V_1 \), at the substation bus feeding the shunt coupling transformer.

**3.8.3.2 Series Inverter**

The series inverter controls the magnitude and angle of the voltage injected in series with the line. This voltage injection is always intended to influence the flow of power on the line. The series voltage can be determined in different ways.

**Phase Angle Shifter Emulation Mode**

The series inverter injects the appropriate voltage so that the voltage \( V_2 \) is phase shifted relative to the voltage \( V_1 \) by an angle specified by reference input.
Line Impedance Emulation Mode

The series injected voltage is controlled in proportion to the line current so that the series insertion transformer appears as an impedance when viewed from the line. The desired impedance is specified by reference input and in general it may be a complex impedance with resistive and reactive components of either polarity. Naturally care must be taken in this mode to avoid of negative resistance or capacitive reactance that would case resonance or instability.

Automatic Power Flow Control Mode

The UPFC has the unique capability of independently controlling both the real power flow, P, on a transmission line and the reactive power, Q, at a specified point. This capability can be appreciated by interpreting the series injected voltage, $V_{\text{inj}}$, as a controllable two dimensional vector quantity. This injected voltage vector can be chosen appropriately to force any desired current vector (within limits) to flow on the line, hence establishing a corresponding power flow. In automatic power flow control mode, the series injected voltage is determined automatically and continuously by a vector control system to ensure that the desired P and Q are maintained despite system changes. The transmission line containing the UPFC thus appears to the rest of the power system as a high impedance power source or sink. This is an extremely powerful mode of operation that has not previously been achievable with conventional line compensating equipment. It has far reaching possibilities in regard to power flow scheduling. Automatic power flow control can also be used dynamically for power oscillation damping.
In general the shunt inverter will be operated in automatic voltage control mode and the series inverter in automatic power flow control mode.

3.8.4 Power Factor Corrector

In transmission line, the power factor is controlled by means of injecting a voltage across it. The transmission line consists of lumped R and L parameters. Without an injecting of voltage, the power factor is lagging in RL circuit. By injecting additional voltage across it, the angle between V and I is reduced and the power factor is improved. By appropriately selecting the value of injecting voltage, the power factor can be made to unity.

3.8.5 Basic Control of UPFC

The UPFC basic control design consists of four separate control loops grouped into series control scheme, whose objective is to control real and reactive power flow on the line, and a shunt control scheme, whose objective is the control of the sending bus voltage magnitude and the DC voltage magnitude.

UPFC is the most comprehensive multivariable Flexible AC Transmission systems (FACTS) Controller. Simultaneous control of multiple power system variables with UPFC posses enormous difficulties. In addition, the complexity of the UPFC control increases due to the fact that the controlled and the control variables interact with each other (Gyugyi et. al. 1995).

The voltage improvement resulting from the application of mitigation devices, such as STATCOM and SVC, is often distributed over the whole network or at least over the nearby buses. The selection of mitigation devices based only on evaluation of individual bus performance, therefore, is
not sufficient to reveal all of the benefits these devices can bring. The idea to comprehensively evaluate the benefits to the whole network, or at least to more than one customer, arising from the installation of FACTS devices is investigated. (Zhang and Milanovic 2006)

The added flexibility provided by FACTS controllers over the parameters and variables responsible for transmission of power, as well as the improvement of high power semiconductor devices along with cost reductions, enables a transmission line to carry power closer to its thermal rating. This improved capacity is met without lowering the power system's reliability. Some of the FACTS controllers are known as unified due to the fact that the DC links are connected together to provide real power transfer, for instance the Interline Power Flow Controller (IPFC) and the Unified Power Flow Controller (UPFC). Usually, the DC connection has a minimal storage, and can be added an extra source of energy like a battery or a superconducting magnet to replenish this link storage device. For a voltage-source converter, an unidirectional dc voltage of a DC link capacitor, use as the link storage device, is presented to the ac side as ac voltage through sequential switching of devices (Hingorani and Gyugyi 2000) Through appropriate converter and modulation topology, it is possible to vary the ac output involves reversal of current, not the voltage. One of the most complete FACTS controllers, which meets simultaneously voltage, impedance and phase angle is the Unified Power Flow Controller (UPFC)

The real power coordination discussed in it based on the known fact that the shunt converter should provide the real power demand of the series converter. In this case, the series converter provides the shunt converter control system an equivalent shunt converter real power reference that includes the error due to change in DC link capacitor voltage and the series
converter real power demand. The control system designed for the shunt converter causes excessive delay in relaying the series converter real power demand information to the shunt converter. This could lead to improper coordination of the overall UPFC control system and subsequent collapse of DC link capacitor voltage under transient conditions (Samina Elyas et al. 2008).

Although the UPFC has many possible operating modes, it is anticipated that the shunt inverter will generally be operated in automatic voltage control mode and the series inverter will typically be in automatic power flow control mode. Accordingly, block diagrams are shown in Figures 3.2 and 3.3, giving greater detail of the control schemes for each inverter operating in these modes. It must be noted that these control schemes are typical but that they may vary in detail from one installation to another. Also, for clarity, only the most significant features are shown and less important signal processing and limiting has been omitted. The control schemes assume that both the series and shunt inverters generate output voltage with controllable magnitude and angle, and that the dc bus voltage will be held substantially constant.

The automatic power flow control for the series inverter is achieved by means of a vector control scheme that regulates the transmission line current, using synchronous reference frame in which the control quantities appear as dc signals in the steady state. The appropriate reactive and real current components are determined for a desired $P_{\text{ref}}$ and $Q_{\text{ref}}$, compared with the measured line currents, and used to divide the magnitude and angle of the series inverter. In this case the controlled current is the current delivered to the line by the shunt inverter. In this case, however, the real and reactive components of the shunt current have a different significance.
3.8.5.1 Shunt Control Scheme

The reference for the reactive current, \( i_q \) shunt, is generated by an outer voltage control loop, responsible for regulating the ac bus voltage, and the reference for the real-power bearing current, \( i_p \) shunt, is generated by a second voltage control loop that regulates the dc bus voltage. In particular, the real power negotiated by the shunt inverter is regulated to balance the dc power from the series inverter and maintain a desired bus voltage. The dc voltage reference, \( V_{dc \, \text{ref}} \), may be kept substantially constant. For the shunt inverter the most important limit is the limit on the shunt reactive current as a function of the real power being passed through the dc bus. This prevents the shunt inverter current reference from exceeding its maximum rated value. The control block diagrams shown in Figures 3.3 and 3.4 are only a small part of the numerous control algorithms that are needed for all the operating conditions.
modes of the UPFC, and for protection and sequencing. The control system typically incorporates many sophisticated computer and extensive electronics.

### 3.8.5.2 Series Control Scheme

This scheme has two control loops, one for the tracking of the real power flow at the receiving bus of the line, and the second performs the same task for the reactive power flow. Specially, the objective is to track these real and reactive power flows following step changes and eliminate steady-state tracking errors. This is obtained by the appropriate selection of the voltage drop between the sending and the receiving buses, which is denoted $V_{pq}$. This voltage can be decomposed into the following two quantities which affect the tracked powers, namely

- $V_p$ - Voltage component orthogonal to the sending bus voltage (It affects primarily the real power flow on the transmission line)

- $V_q$ - Component in phase with the sending bus voltage (it affects primarily the real power flow on the transmission line)

Both voltages, $V_p$ and $V_q$, are obtained by designing classic PI (proportional-integral) controllers as illustrated in Figure 3.4. The integral controller will guarantee error free steady state control of the real and reactive line power flows.
Figure 3.4 Block Diagram of Series Inverter Control

3.9 SUMMARY

This chapter has presented power quality problems due to grounding, voltage sags, harmonics, voltage fluctuations and flicker. The concept of Unified Power Flow Controller and its operating modes are discussed in this chapter. Control Strategy of series and shunt converter of UPFC, Real and Reactive power control methods are also presented. Various types of FACTS Controllers and the advantage of the FACTS are discussed.