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DESIGN AND DEVELOPMENT OF UNIFIED POWER FLOW CONTROLLER USING STATCOM AND VAR COMPENSATORS

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ABSTRACT
Using MATLAB/SIMULINK, this paper indicates the theory and operation of flexible alternatingcurrent transmission system (facts) devices, namely the unified power flow controller. Two voltage source converters can be connected back to back through a common DC link capacitor in this paper's UPFC. At the point of connection, the VSC-1, referred to as STATCOM, injects a reactive current into the system. The VSC-2 also called the SSSC, injects voltage into the system in series. The unified power flow controller (UPFC) facilitates real-time control of power flow in transmission lines by adjusting line parameters such as node voltages, phase angle, and line impedance, which cover all other FACTS adjustable parameters. Static synchronous compensator (STATCOM), Static VAR Compensator (SVC), phase shifters, and thyristors are all becoming more common as technology develops.
Keywords: Flexible Alternating Current Transmission System (FACTS), Unified Power Flow Controller (UPFC), voltage source converter, Static Synchronous Compensator, Static Synchronous Series Compensator.

INTRODUCTION
In 1991, Gyugyi invented the concept of the Unified Power Flow Controller (UPFC). The UPFC was designed forreal-time control and dynamic compensation of AC transmission systems, and it provides the multifunctional flexibility needed to handle many of the difficulties that the power distribution sector faces. The UPFC may manage all of the characteristics impacting power flow in the transmission line, such as voltage, impedance, and phase angle, concurrently or selectively, within the context of standard power transmission ideas. It can also manage boththe reactive and actual power in the line independently.
Turn-on and turn-off capabilities are offered in devices such as GTO, IGBT, MCT, and so on. These devices are more costly and have higher losses than thyristors without the ability to turn off, however, can enable converter concepts that can save money and improve performance. Personality converters, as opposed to line-commuting converters, provide advantages in principle. Line-commutating converters spend reactive power and have commutation failures in the inverter mode of operation when compared to self-commutating converters. The self- commutating converter would be ideal for FACTS controllers. Self-commutating converters are split into two types.
1. current-source converters
2. voltage-source converters

Voltage-sourced converters are frequently favored over current-source converters for FACTS applications due to cost and performance.
Because the direct current in a voltage-sourced converter can flow in either direction, the converter valves must be bidirectional; additionally, because the DC voltage does not reverse, the turn-off devices do not need to be reverse-voltage capable, and these devices are referred to as asymmetric turn-off devices.

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UNIFIED POWER FLOW CONTROLLER

UPFC

On high-voltage electricity transmission networks, a unified power flow controller (UPFC) is an electrical device that provides fast-acting reactive power correction. It generates current with a pair of three-phase adjustable bridges and injects it into a transmission line via a series transformer. In a transmission line, the controller can control bothactive and reactive power flows.

As a representative of the third generation of FACTS devices, the Power Flow Controller (UPFC) is by far the most comprehensive FACTS device. In the steady-state, it can implement power flow regulation, rationally controlling line active power and reactive power, and improving the transmission capacity of the power system; inthe transient state, it can realize fast-acting reactive power compensation, dynamically supporting the voltage atthe access point, and improving the transmission capacity of the power system.

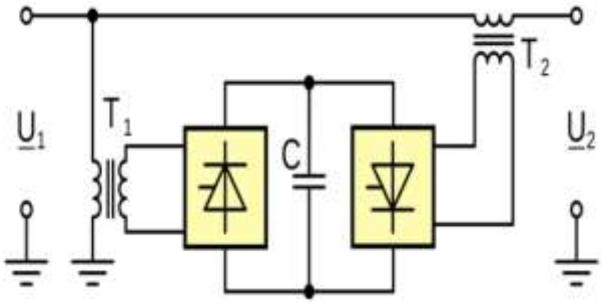

Fig.1 Basic schematic diagram of UPFC

Solid-state electronics are used in the UPFC, which provide functional flexibility not available in classic thermistor- controlled systems. A static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) are linked via a common DC voltage link to form the UPFC.

The UPFC's key benefit is that it can control both active and reactive power flows in the transmission line. The UPFC will not function if there are any disturbances or defects on the source side. The UPFC only works with a balanced sine wave source. The UPFC has three variable parameters: line reactance, phase angle, and voltage. L. Gyugyi of Westinghouse first describedthe UPFC concept in 1995. The UPFC performs a secondary but critical function called stability control, which suppresses power system oscillations and improves power system transientstability.

STATIC SYNCHRONOUS COMPENSATOR

A voltage source converter (VSC)-based device having the voltage source behind a reactor is known as a STATCOM. Because the voltage source is a DC capacitor, the STATCOM has a relatively low active power capability. However, if a suitable energy storage device is placed across the DC capacitor, its active power capabilitycan be boosted. The amplitude of the voltage source determines the reactive power at the STATCOM terminals.

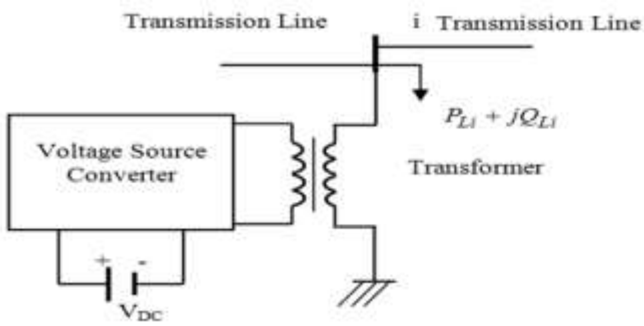

Fig. 2 Basic representation of STATCOM

STATIC SYNCHRONUS SERIES COMPENSATOR (SSSC)

A SSSC is a variable impedance type series compensator that operates similarly to a STATCOM but is serially coupled instead of using a shunt. The SSSC is also capable of compensating for real-world power.

Both STATCOM and SSSC duties can be performed by a Unified Power Flow Controller (UPFC).

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Two Voltage Source Converters (VSCs) are connected to a common DC bus in the UPFC. One VSC is wired in series with a transmission line's bus bar, while the other is wired in shunt with the same transmission line. A shared DC capacitorprovides power to both VSCs' DC links.

CONTROL OBJECTIVES OF UPFC

The UPFC's shunt compensator is typically employed with two aims.

The first is to regulate the reactive power at the point of connection, hence regulating the voltage there.

Control active power in such a way that the dc link voltage is controlled.

CONTROL SCHEME

Power electronic equipment (e.g. inverters), which provide voltage supply that is changeable in both frequency and magnitude, are used to operate ac motors at frequencies different than the supply frequency, in contrast to grid linked ac motor drives, which are scarcely variable in speed. Although there have been advances in this area for some time, a techno-economical solution was not established until the late 1980s due to space constraints, the lack of high-power devices, and the expensive cost of electronic devices and components.

To limit the effect of harmonics on motor performance, the PWM frequency should be as high as possible. However, due to switching losses and dead time distorting the output voltage, the PWM frequency is limited by the control unit (resolution) and switching device capabilities.

PWM systems come in a variety of shapes and sizes. Well-known examples include sinusoidal PWM, hysteresis PWM, space vector modulation (SVM), and "optimal" PWM techniques based on the optimization of specific performance targets such as selective harmonic elimination, enhanced efficiency, and torque pulsation minimization. While analogue approaches can be used to implement sinusoidal pulse-width modulation and hysteresis PWM, the remaining PWM techniques require the usage of a computer.

Hysteresis PWM Current Control

Hysteresis current control is a PWM technique that is relatively easy to use and handles current control directly. Three hysteresis controllers (one for each phase) implement the switching logic (figure 1.4). The three phases of the hysteresis PWM current control, often known as bang-bang control, are done individually. Each controller selects the switching state of one inverter half-bridge so that the corresponding current remains within a hysteresisband Δi.

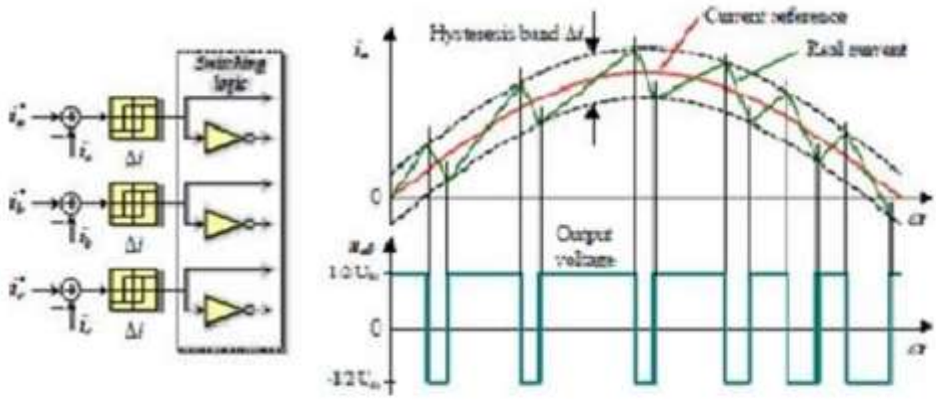

Fig. 3 Hysteresis PWM control and switching logic

The hysteresis controller generates unintentional lower sub harmonics because there is no fixed PWM frequency.

The current error is not constrained in any way. The voltage of the other two phases may cause the signal todepart the hysteresis band.

There is usually no interaction between the three phases: There is no way to make zero-voltage phasors.

Higher switching frequency (losses), particularly at lower modulation or motor speeds.

The fundamental current's phase lag (increasing with the frequency)

Sinusoidal Pulse Width Modulation

Three distinct comparators compare three-phase reference voltages of variable amplitude and

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frequency with a shared triangular carrier wave of fixed amplitude and frequency (figure 4.2). The switching state of the associated inverter leg is formed by each comparator output. The reference voltages (u*a, u*b, and u*c) are commonly determined via an extra current control loop in torque controlled ac motor drives utilizing sinusoidal PWM(FOC).

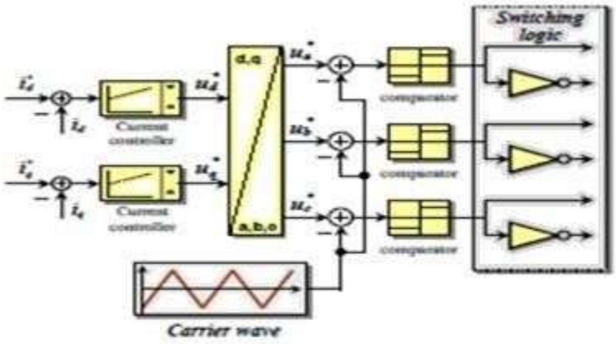

Fig. 4 Sinusoidal PWM current control and switching logic
For all three phases, a saw-tooth or triangular-shaped carrier wave is employed to determine the fixed PWM frequency. Because the pulse width is a sinusoidal function of the angular location in the reference signal, this modulation technique is also known as PWM with natural sampling.

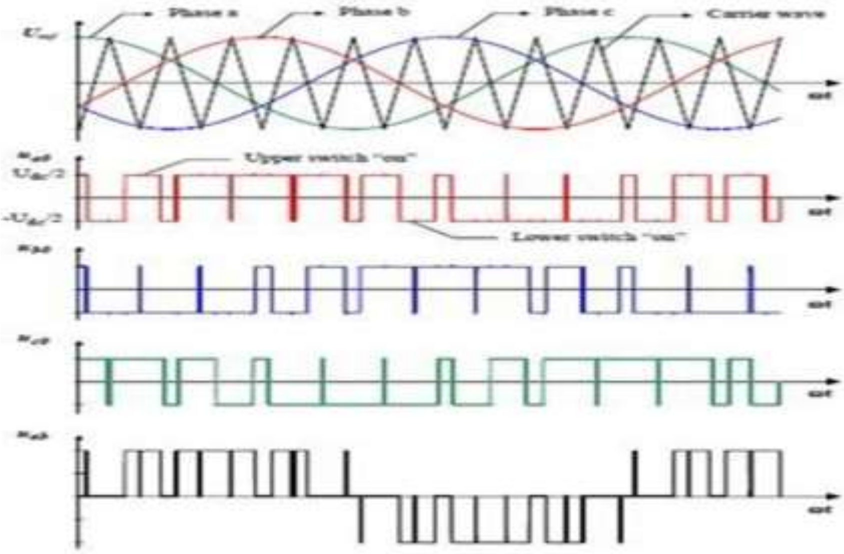

Fig. 5 Principle of sinusoidal PWM generation
The reference voltage is practically constant during one PWM period TPWM because the PWM frequency, which is equal to the carrier wave frequency, is frequently significantly greater than the frequency of the reference voltage.This is especially true when it comes to the sampled data structure of a digital control system. The positive or negative half dc bus voltage is applied to each phase depending on the switching states. The reference voltage is amplified by the inverse half dc bus voltage at the modulation stage to compensate for the switching logic's final inverter amplification into real power supply.

STRUCTURE AND CONTROL OF UPFC
The UPFC is a generalized synchronous voltage source (SVS) that communicates with the transmission system in both real and reactive power. Because an SVS can only generate the reactive power transferred, the real power mustbe provided to it or absorbed from it by a proper power supply, as previously stated. One of the end buses providesthe real power exchanged in the UPFC setup.
The UPFC is made up of two voltage-sourced converters that are connected back to back and are named "Converter 1" and "Converter 2" in fig 3.1. They are powered by a shared DC connection provided by a DC storage capacitor. This configuration serves as an excellent AC to AC power converter, allowing real power to freely flow in either direction between the two converters' AC terminals, and each converter to generate or absorb reactive power at its own AC output terminal. By

injecting a voltage with a configurable magnitude and phase angle in series with the line, the converter 2 performs the main function of UPFC. This injected voltage serves asa source of synchronous AC voltage. The current flowing via the transmission line passes through this voltage source, resulting in a reactive and genuine power exchange between the voltage source and the AC system

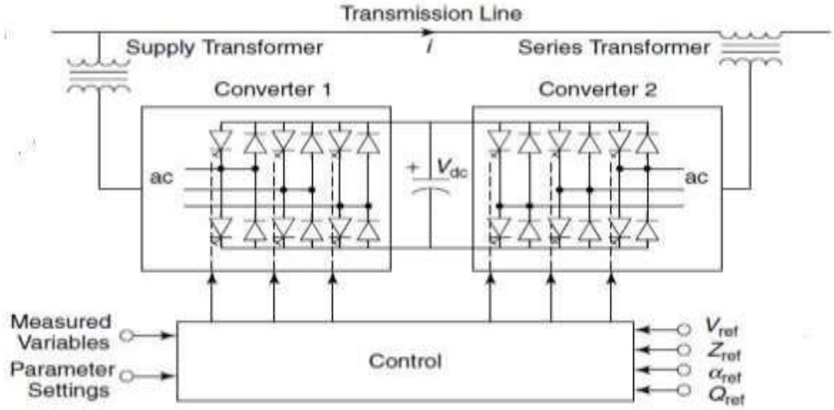

Fig. 6 Unified Power Flow Controller

Converter 1's primary role is to supply or absorb the real power required by Converter 2 at the common DC connection in order to enable the real power exchange caused by the series voltage injection. Converter 1 can generate or absorb adjustable reactive power in addition to the real power required by Converter 2. As a result, Converter 1 can be configured to have a reactive power exchange with the line that is independent of the reactive power exchanged by Converter 2.

RESULTS

STATCOM

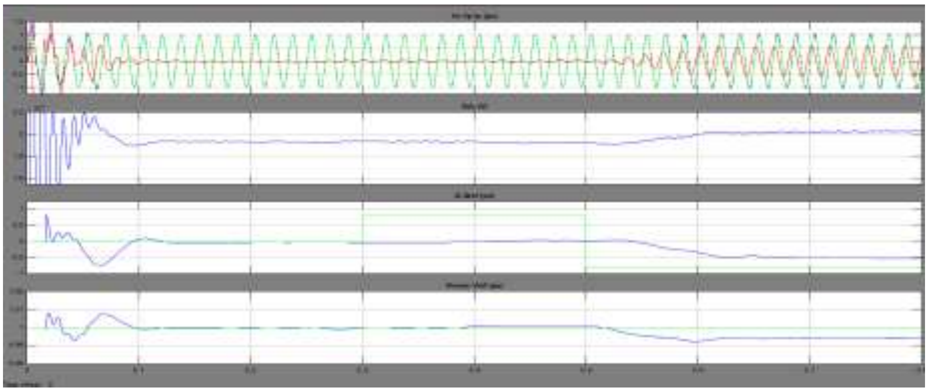

Fig. 7 Wave forms of STATCOM

SSSC

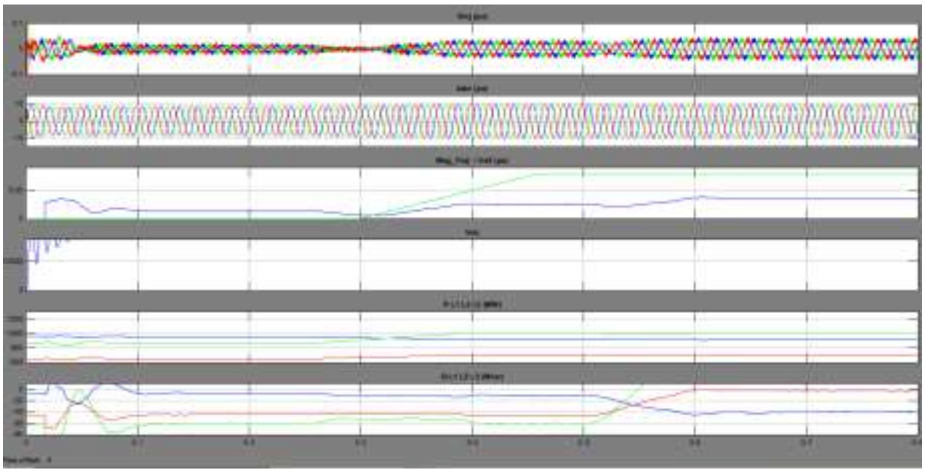

Fig. 8 Wave forms of SSSC

UPFC

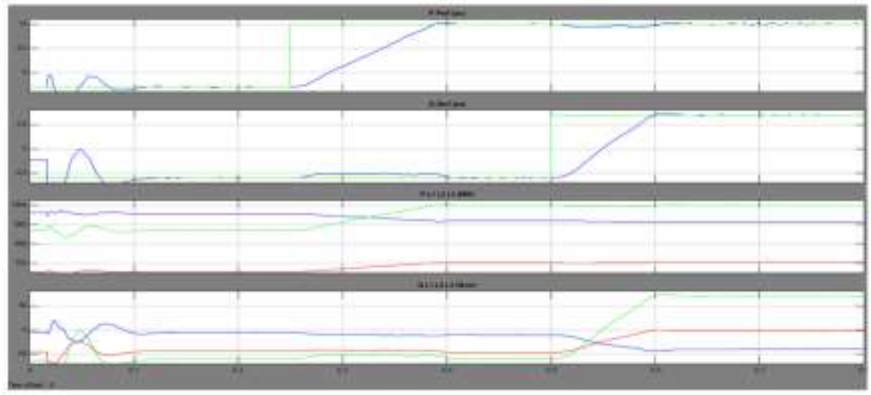

Fig. 9 Wave forms of UPFC

UPFC CONTROLLABLE REGIO

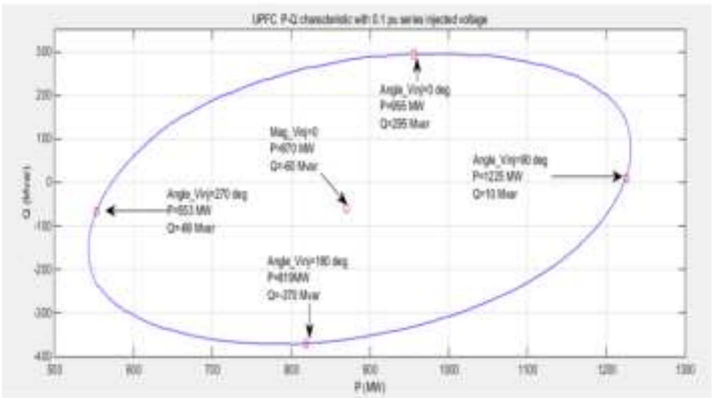

Fig 10 Controllable region of UPFC system.

CONCLUSION

The paper shows how to operate and regulate a 500kV transmission system using a Unified Power Flow Controller (UPFC). The UPFC consists of two GTO-based, 100-MVA, three-level, 48-pulse converters, one in shunt at bus B1 and the other in series between buses B1 and B2. A DC bus can transfer power between the shunt and series converters.

There are three modes of operation for this pair of converters:

Unified Power Flow Controller (UPFC) mode, which connects the shunt and series converters through a DC bus. When the switches between the DC buses of the shunt and series converters are disengaged, two new modes become available:

Shunt converter controlling voltage at busB1 as a Static Synchronous Compensator (STATCOM).

Static Synchronous Series Capacitor (SSSC) series converter regulating injected voltage while keeping injected voltage in quadrature with current.

In series with line L2, the series converter can inject up to 10% of the nominal line-to-ground voltage (28.87 kV).

When the series converter generates zero voltage, the natural power flow across bus B2 is P=+870 MW and Q=-70 MVAR. The magnitude and phase angle, as well as the series injected voltage, can all be changed in UPFC mode, allowing adjustment of P and Q. The UPFC adjustable region is obtained by adjusting the phase angle from zero to 360 degrees while retaining the injected voltage at its maximum value (0.1 pu). The P-Q trajectory that results can be seen in the "UPFC Controllable Region."

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