ENHANCEMENT OF VOLTAGE STABILITY USING BY UPFC

(UNIFIED POWER FLOW CONTROLLER)

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***Abstract*—Owing to increase in power demand, many instability problems are experienced by power system in every year. Voltage stability is one of the main problems in power systems that must be treated using suitable mitigation techniques. Under heavy load conditions due to insufficient reactive power causes the voltage drop and under lightly loaded condition due to surplus amount of reactive power causes voltage rise, finally it leads to voltage instability. The enhancement of voltage stability in transmission line is done by Unified Power Flow Controller. In this project voltage stability improvement using UPFC is analyzed. Voltage stability improvement is shown and analyzed using MATLAB/ Simulink.**

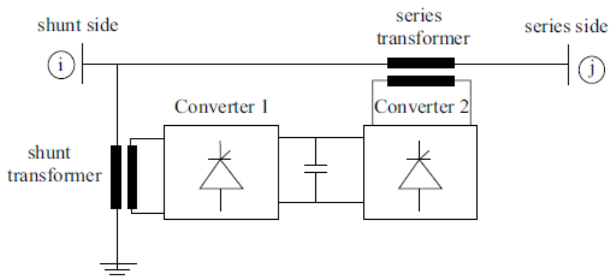
Keywords*—Unified Power Flow Controller(UPFC); Flexible AC Transmission System (FACTS); proportional-integral-derivative controller (PID controller); Static Compensator (STATCOM).

I. INTRODUCTION

Besides transformers, the general structure of UPFC contains also a "backto back" AC to DC voltage source converters operated from a common DC link capacitor, First converter (CONV1) is connected in shunt and the second one (CONV2) in series with the line. The shunt converter is primarily used to provide active power demand of the series converter through a common DC link. Converter 1 can also generate or absorb reactive power, if it is desired, and thereby provide independent shunt reactive compensation for the line. Converter 2 provides the main function of the UPFC by injecting a voltage with controllable magnitude and phase angle in series with the line via an voltage source,The reactance xs describes a reactance seen from terminals of the series transformer and is equal to (in p.u. base on system voltage and base power)

$x_s = x_k r^2_{max} (S_B = S_S)$

Where xk denotes the series transformer reactance r_{max} the maximum perunit value of injected voltage magnitude, SB the system base power, and SS the nominal rating power of the series converter. The UPFC injection model is derived enabling three parameters to be simultaneously controlled. They are namely the shunt reactive power, Qconv1, and the magnitude, r, and the angle, , of injected series voltage $\bar{V}se$.



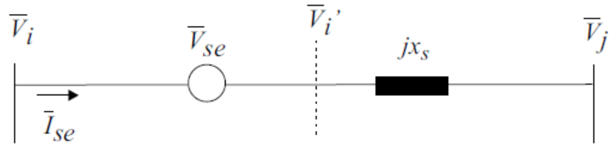
Series connected voltage source is modeled by an ideal series voltage V se which is controllable in magnitude and phase, that is,

$\bar{V}se = r\bar{V}\ k^{ej\alpha}$ where

$0 \leq r \leq r_{max}$ and $0 \leq \alpha \leq 2$.

A.INJECTION MODEL OF UPFC

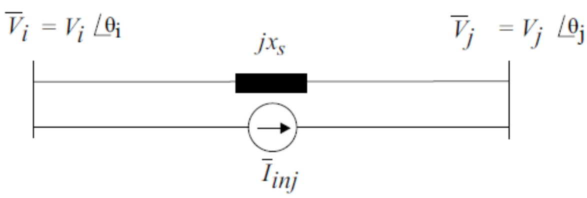
To obtain an injection model for UPFC, it is first necessary to consider the series voltage source



Representation of series voltage source

The injection model is obtained by replacing the voltage source V se by a current source

$\bar{I}_{ini} = -jbs\bar{V}se$ in parallel with xs



Transformer series voltage source

The current source $\bar{I}inj$ corresponds to injection powers $\bar{S}i$ and $\bar{S}j$ which are
Defined by

$$\bar{S}_i = \bar{V}_i(-\bar{I}_{inj})^* = -rb_s\ V_i^2\sin(\alpha) - jrb_s\cos(\alpha)$$

$$\bar{S}_j = \bar{V}_j(\bar{I}_{inj})^* = rb_s\ (V_iV_j\sin(\Theta_{ij}\alpha) + jrb_sV_iV_j\cos(\Theta_{ij}-\alpha)$$

$$\Theta_{ij} = \Theta_i - \Theta_j$$

$$B_s = 1/X_s$$

$$P_i = -real(\bar{S}_i), Q_i = -imag(\bar{S}_i)$$

$$P_j = -real(\bar{S}_j), Q_j = -imag(\bar{S}_j)$$

II. UPFC CONSTRUCTION

The UPFC be made up of of dual voltage source converters; series and shunt converter, which are associated to respectively other with a communal dc link. Series converter or Static Synchronous Series Compensator (SSSC) is charity to add well-ordered voltage magnitude and phase angle trendy arrangements by the line, while shunt Converter or Static Synchronous Compensator (STATCOM) is secondhand to make accessible reactive power to the ac system, besides that, it will deliver the dc power essential for both inverters. Each of the kindling contains of a transformer and power electronic converter. These dual voltage source converters cohesive a mutual dc capacitor.

The energy storage capability of this dc capacitor is generally small. Therefore, active power drained by the shunt converter ought be equal to the active power made by the series converter. The reactive power trendy the shunt or series converter be able to be chosen individualistically, benevolent greater elasticity to the power flow control. The coupling transformer is used to associate the device towards the system.

The UPFC operates with constraints on the following variables:

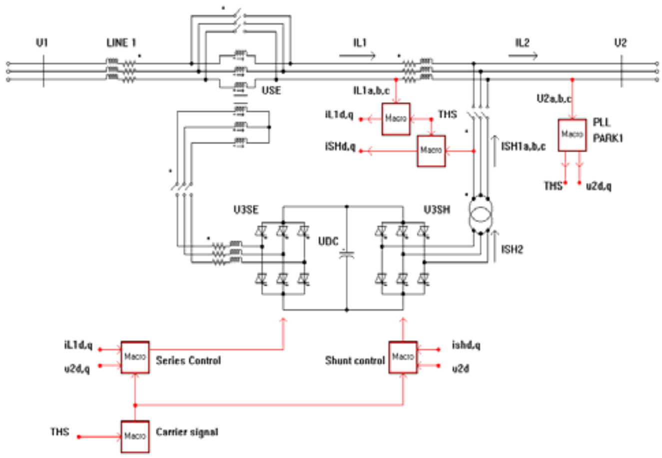
- The series-injected voltage magnitude
- The line current through series converter;
- The shunt-converter current;
- The minimum line-side voltage of the UPFC;
- The maximum line-side voltage of the UPFC; and
- The real-power transfer between the series converter and the shunt converter.

III. VOLTAGE STABILITY IMPROVEMENT USING UPFC

The power systems operation becomes more important as the load demand increases all over the world. This rapid increasing of load demand forces power systems to operate near critical limits due to economic and environmental constraints. The objective in power systems operation is to survey energy with capable voltage and frequency to consumers at minimum cost. In this paper, voltage stability is studies by using continuation power flow method. Also steady state modeling of Static VAR Compensator (SVC) and Unified Power Flow Controller (UPFC) for continuation of power flow controller .The effects on static voltage collapse or maximum loading level.

IV. BASIC TOPOLOGY OF UPFC

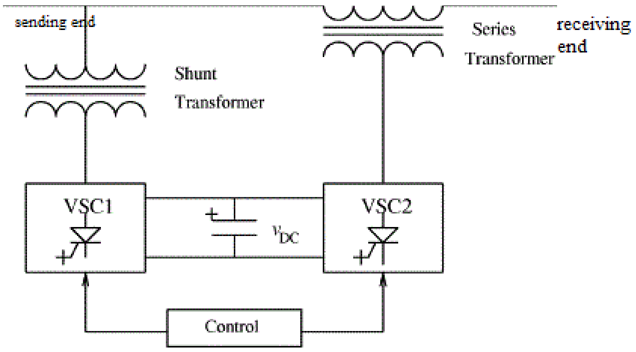
The converter on the right side is called shunt compensatorand is connected to the bus 2 through the shunt transformer,whose role is to produce or consume reactive power in order to support the voltage at this bus. Another function of theshunt compensator is to control the DC voltage of theconverter. The other converter, on the left side, is called series compensator and is connected to the transmission line through a special transformer, whose function is to insert a voltage Use in series with the transmission line in order to control the active and reactive power flows through the line.



Basic topology of UPFC

V. BASIC PRINCIPAL OF UPFC

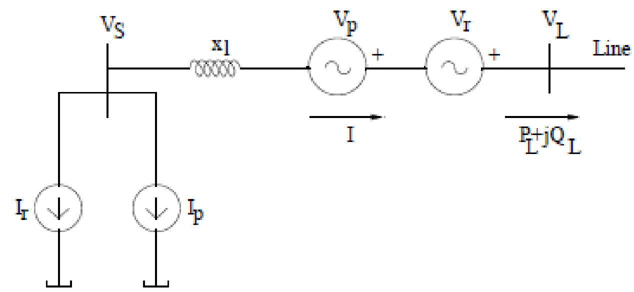
As the figure shows, UPFC enclose of two reverting converters named VSC1 and VSC2, are produced from a DC foundation as long as by a dc stowage capacitor. These schedules activate convert to ultimate ac to ac converter in which the real control energy can at liberty flow both in direction in the middle of the ac terminals of the dual converts and separately converter be able to self-reliantly generate or engage reactive power as its private ac output mortal.



Basic UPFC scheme

One VSC is connected to in shunt to the transmission line via a shunt transformer and other one is connected in series through a series transformer. The DC terminal of two VSCs is coupled and this creates a path for active power exchange between the converters. VSC provide the main function of UPFC by injecting a voltage with controllable magnitude and phase angle in series with the line via an injection transformer. This injected voltage act as a synchronous ac voltage source. The transmission line current flows through this voltage source resulting in reactive and active power exchange between it and the ac system. The reactive power exchanged at the dc terminal is generated internally by the converter. The real power exchanged at the ac terminal is converted into dc power which appears at the dc link as a real power demand. And VSC1 is to supply or absorb the real power demanded by converter2 at the common dc link to support real power exchange resulting from the series voltage injection. This dc link power demand of VSC2 is converted back to ac by VSC1 and coupled to the transmission line bus via shunt connected transformer. in addition, VSC1 can also generate or absorb controllable reactive power if it is required and thereby provide independent shunt reactive compensation for the line. Thus VSC1 can be operated at a unity power factor or to be controlled to have a reactive power exchange with the line independent of the reactive power exchanged by VSC1. Obviously, there can be no reactive power flow through the UPFC dc link.

A.EQUIVALENT CIRCUIT OF UPFC



Equivalent circuit of UPFC

The shunt converter draws both active (Ip) and reactive current (Ir). The active current (Ip) is not independent and is related to Vp by the relation in steady state.

V Ip = IVp

The equivalent circuit of the UPFC can be viewed as a two port network. The shunt converter is connected at one port while the Series converter is connected in series with the line at the other port. The voltage at the latter port is denoted by. If the series injected voltages, Vp and Vr are controlled to regulate the power and reactive power in the line; these quantities are conveniently measured at the line side port of the UPFC.

VI. CONTROL OF UPFC

As the UPFC consists of two converters that are coupled on the DC side, the control of each converter is explained below:

A.CONTROL OF THE SHUNT CONVERTER

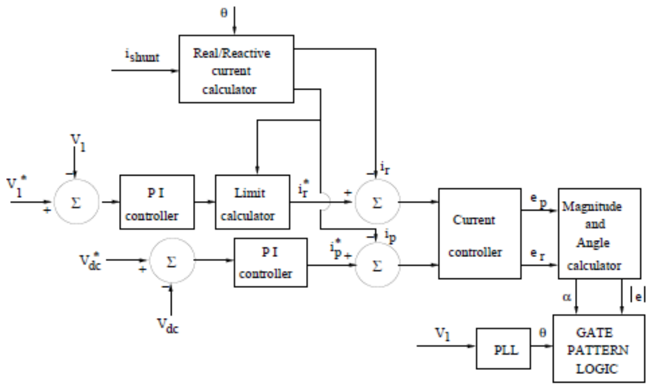
The shunt converter draws a controlled current from the system. One component of this current is Ip which is automatically determined by the requirement to balance the real power supplied to the series converter through the DC link. This power balance is enforced by regulating the DC capacitor voltage by feedback control.

The other component of the shunt converter current is the reactive current, Ir which can be controlled in a similar fashion as in a STATCOM.

There are two operating (control) modes for STATCOM or the shunt converter. These are,

1. VAR control mode where the reactive current reference is determined by the inductive or capacitive VAR command. The feedback signals are obtained from current transformers (CT) typically located on the bushings of the coupling (step down) transformer.

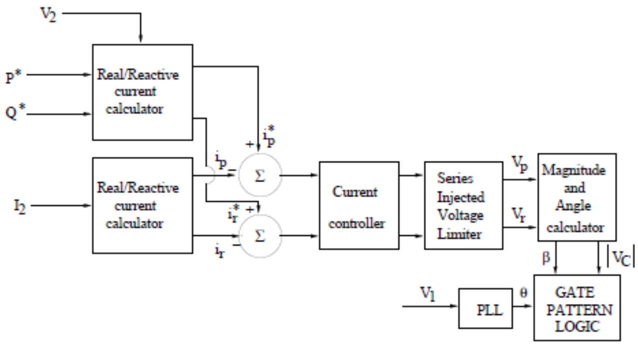
2. Automatic voltage control mode where the reactive current reference is determined by the output of the feedback voltage controller which incorporates a droop characteristic (as in the case of a SVC or a STATCOM). The voltage feedback signals are obtained from potential transformers (PT) measuring the voltage V1 at the substation feeding the coupling transformer.



Control of the shunt converter

B.CONTROL OF THE SERIES CONVERTER

In this control mode, the series injected voltage is determined by a vector control system to ensure the flow of the desired current (phasor) which is maintained even during system disturbances (unless the system control dictates the modulation of the power and reactive power).



Series controller

Although the normal conditions dictate the regulation of the complex power flow in the line, the contingency conditions require the controller to contribute to system stability by damping power oscillations.

The different control modes for the series voltage are given :

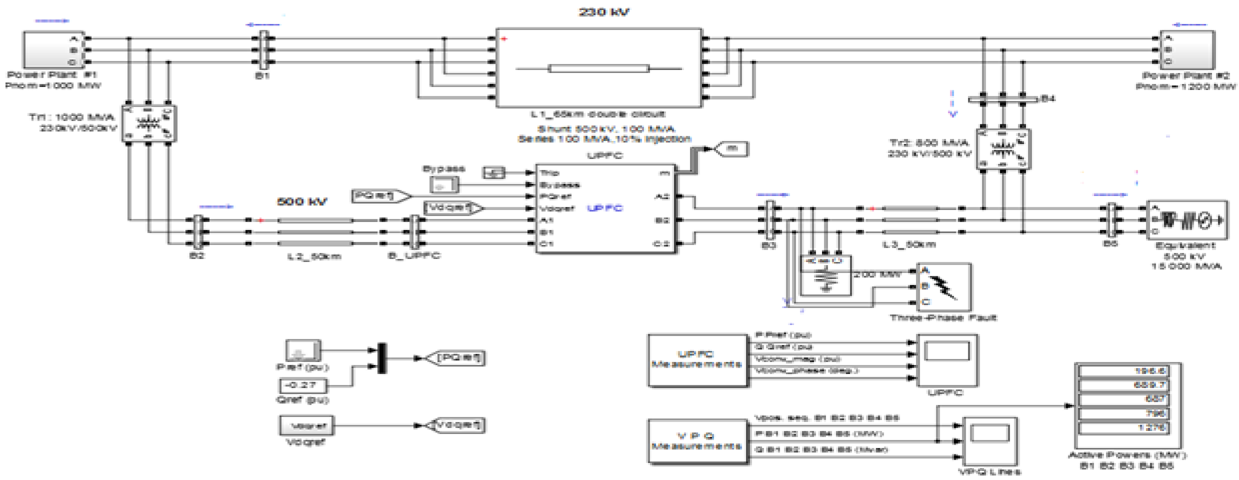
1. Direct voltage injection mode where the converter simply generates a voltage phasor in response to the reference input. A special case is when the desired voltage is a reactive voltage in quadrature with the line current.
2. Phase Angle Shifter Emulation mode where the injected voltage is Vc phase shifted relative to the voltage V_1 by an angle specified by the reference input.
3. Line impedance emulation mode where the series injected voltage is controlled in proportion to the line current.
4. Automatic power flow control mode where the reference inputs determine the required real power (P) and the reactive power (Q) at a specified location in the line.

VII. SIMULATION DOMINO EFFECT FOR UPFC CONTROLLER

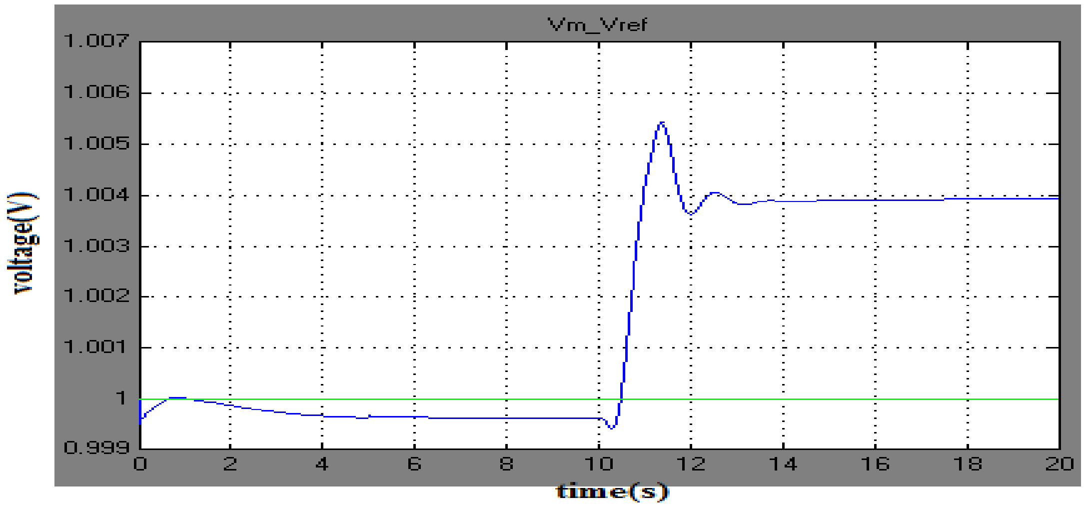
The method of improving voltage Stability by using UPFC is tested on Multi-machine system. The system consists of 2 generators, 2 transformers and buses. A UPFC is used to control the power flow in a 500 kV /230 kV transmission systems. The system consists essentially of five buses (B1 to B5) interconnected through transmission lines (L1, L2, L3) and two 500 kV/230 kV transformer banks Tr1 and Tr2. The plant models include a speed regulator, an excitation system as well as a power system stabilizer (PSS). In normal operation, most of the 1200-MW generation capacity of power plant 2 is exported to the 500-kV equivalent through three 400-MVA transformers connected between buses B4 and B5.

Data table for UPFC

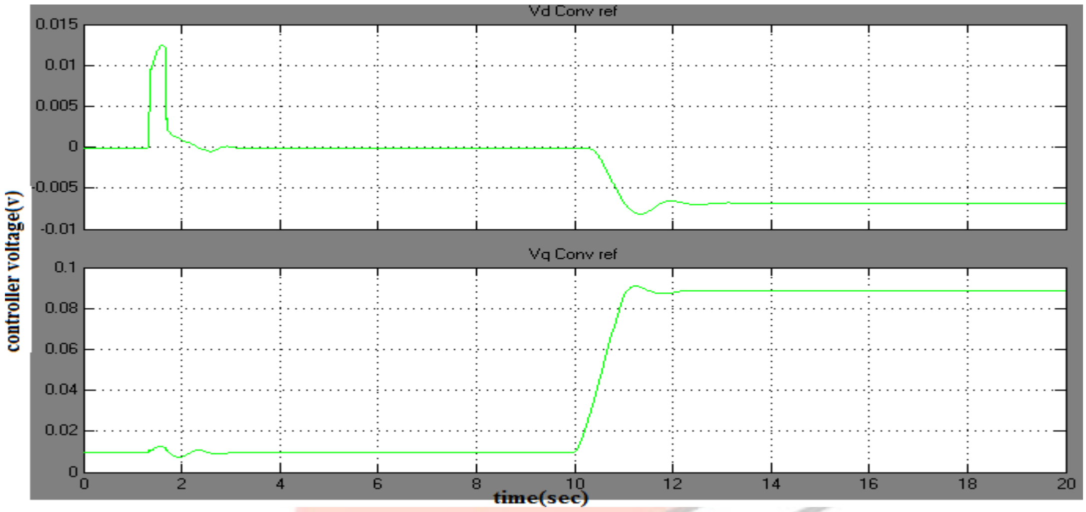
DC link capacitor	2500e-6F
Shunt converter	500KV,100MVA
Series converter	10% injection,100MVA
Reference active and reactive power in UPFC	5.87MW,-0.27MW
Transformers rating	1000MVA,230KV/500KV 800MVA,230KV/500KV



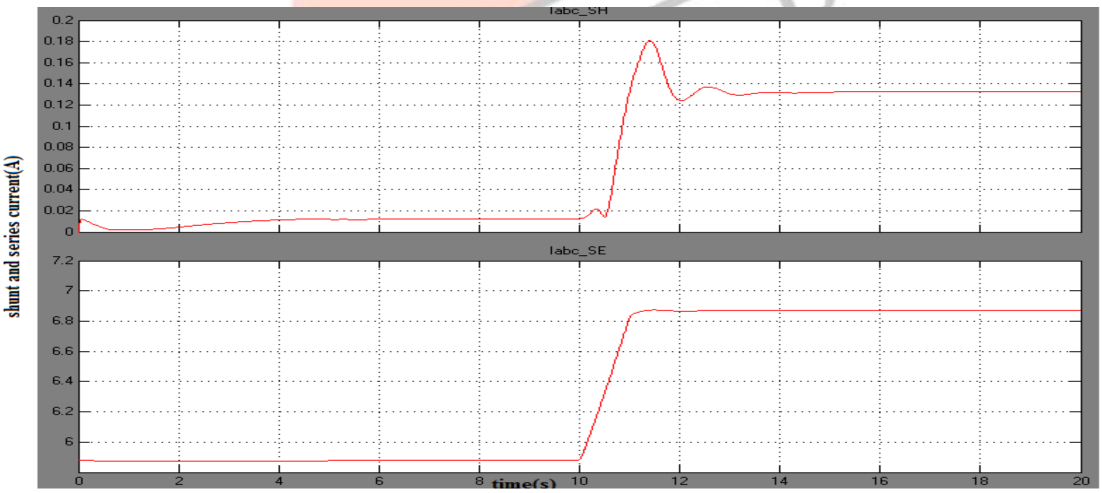
Simulation of UPFC for voltage stability



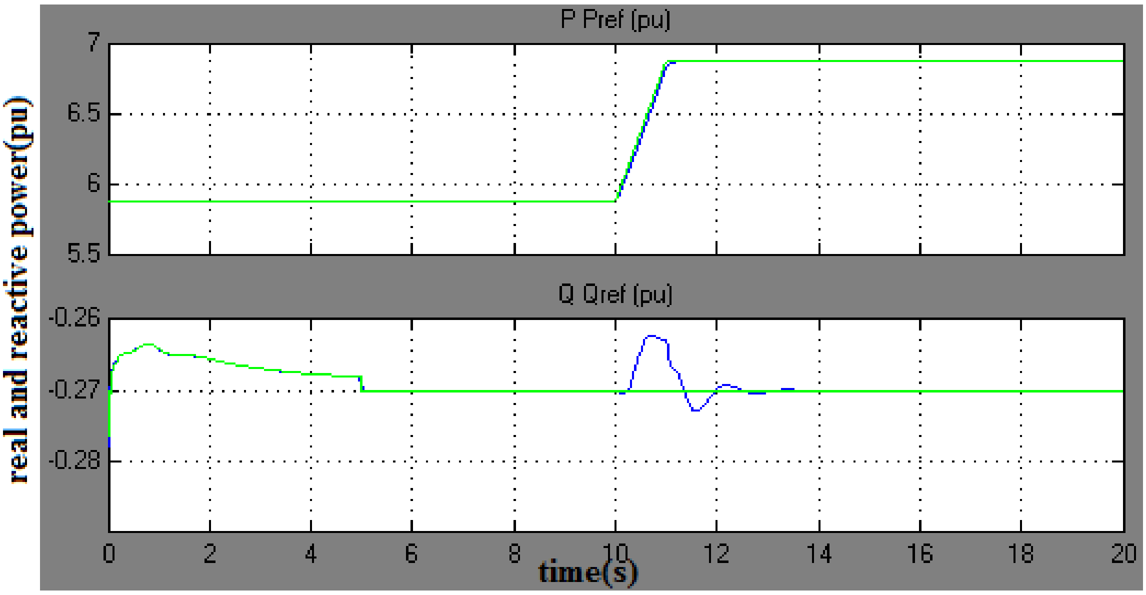
Output of shunt control voltage



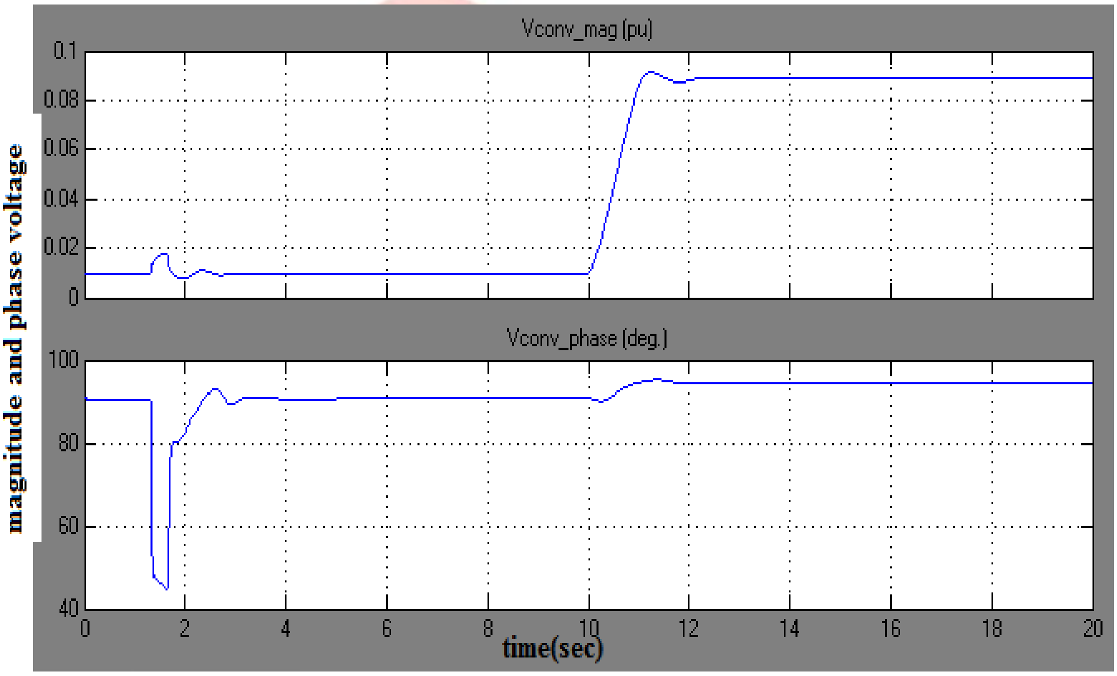
Output of series controller voltage



Output of shunt and series control current



Output of real and reactive power



Output of conventional magnitude voltage and phage angle

	VOLTAGE(pu)	POWER(pu)
WITHOUT CONTROLLER	1.0071	0.32
WITH TCSC CONTROLLER	0.06	11.3
WITH SSSC CONTROLLER	0.08	7.57
WITH UPFC CONTROLLER	0.09	6.87

Comparison of without and with controller voltage and power rating

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