p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 12
August 2016

A New Power Flow Control in aTransmission Line UPFC

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ABSTRACT: This paper concentrates on FACT device UPFC which is used for powerflow control in thetransmission side. With the growing demand of electricity, it is not possible to erect new lines to face thesituation. Flexible AC Transmission System (FACTS) makes use of the thyristor controlled devices and optimallyutilizes the existing transmission network. One of such device is Unified Power Flow Controller (UPFC) onwhich the emphasis is given in this present work. Real, reactive power, and voltage balance of the unifiedpower-flow control (UPFC) system is analyzed. A novel coordination controller is proposed for the UPFC.The basic control method is such that the shunt converter controls the transmission line reactive powerflow and the dc-link voltage. The series converter controls the real power flow in the transmission line andthe UPFC bus voltages. Experimental works have been conducted to verify the effectiveness of theUPFC in power flow control in the transmission line. The simulation model was done inMATLAB/SIMULINK platform.

KEYWORDS-FACTS, unified power flow controller (UPFC), coordination controller..

I. INTRODUCTION

The unified power flow controller (UPFC) is one of themost widely used FACTs controllers and its main functionis to control the voltage, phase angle and impedance of thepower system thereby modulating the line reactance andcontrolling the power flow in the transmission line.The basic components of the UPFC are two voltagesource inverters (VSIs) connected by a common dc storagecapacitor which is connected to the power system through acoupling transformers. One (VSIs) is connected in shunt tothe transmission system through a shunt transformer, whilethe other (VSIs) is connected in series to the transmissionline through a series transformer. Three phase systemvoltage of controllable magnitude and phase angle (Vc) areinserted in series with the line to control active and reactivepower flows in the transmission line. So, this inverter willexchangeactive and reactive power with in the line. Theshunt inverter is operated in such a way as to demand thisdc terminal power (positive or negative) from the linekeeping the voltage across the storage capacitor (Vdc)constant.So, the net real power absorbed from the line by theUPFC is equal to the only losses of the inverters and thetransformers.The remaining capacity of the shunt inverter can be usedto exchange reactive power with the line so to provide avoltage regulation at the connection point. The two VSI scan work independently from each other by separating thedc side. So in that case, the shunt inverter is operating as a(STATCOM) that generates or absorbs reactive power toregulate the voltage magnitude at the connection point. Theseries inverter is operating as (SSSC) that generates orabsorbs reactive power to regulate the current flowing inthe transmission line and hence regulate the power flows inthe transmission line. The UPFC has many possibleoperating modes. (1)VAR control mode:-The referenceinput is a simple var request that is maintained by thecontrol system regardless of bus voltage variation. (2)Automatic voltage control mode:-The shunt inverterreactive current is automatically regulated to maintain thetransmission line voltage at the point of connection to areference value with a defined slope characteristics theslope factor defines the per unit voltage error per unit ofinverter reactive current within the current range of the inverter.

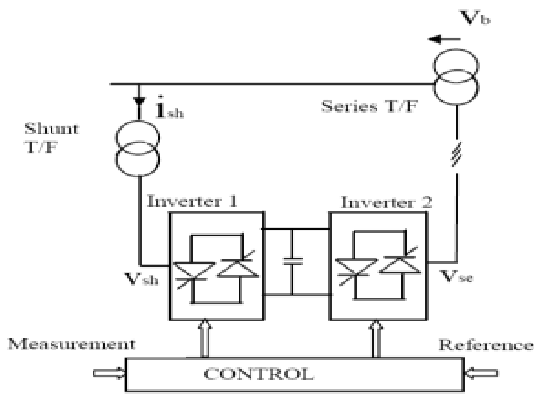

Fig.1 shows the UPFC installed in a transmission line

In Particular, the shunt inverter is operating insuch a way to inject a controllable current into thetransmission line. The fig.1 shows how the (UPFC) isconnected to the transmission line.

II. CONTROL STRATEGY FOR UPFC

A. Shunt Converter Control Strategy

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

B. Series Converter Control Strategy

The series converter of the UPFC provides simultaneouscontrol of real and reactive power flow in the transmissionline. To do so, the series converter injected voltage isdecomposed into two components. One component of theseries injected voltage is in quadrature and the other inphase with the UPFC bus voltage. The quadrature injectedcomponent controls the transmission line real power flow.This strategy is similar to that of a phase shifter. The inphase component controls the transmission line reactivepower flow. This strategy is similar to that of a tap changer.

C. Shunt Converter Control System

Fig.2 shows the de-coupled control system for the shunt converter. The D-axis control system controls the dc link capacitorvoltage and the Q-axis control system controls the UPFCbus voltage /shunt reactive power.The de-coupled control system has been de-signed based onlinear control system techniques and it consists of an outerloop control system that sets the reference for the innercontrol system loop. The inner control system loop tracksthe reference.

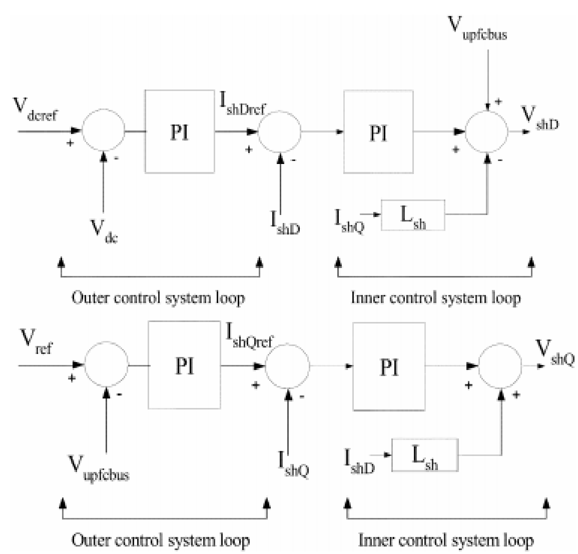

Fig. 2.De-coupled D-Q axis shunt converter control system.

D. Series Converter Control Parameters

1) Transmission line real power flow controller parameters

$$K_p=1 ; K_i=4;$$

p-ISSN: 2348-6848
e-ISSN: 2348-795X
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E. Series Converter Control System

Fig.3 shows the overall series converter control system. Thetransmission line real power flow(P_{line}) is controlled by injecting a component of the series voltage in quadrature with theUPFC bus voltage($V_{se}Q$).The transmission line reactive powerQ_{line})is controlled by modulating the transmission line side busvoltage reference$V_{lineref}$).The transmission line side busvoltage is controlled by injecting a component of the seriesvoltage in-phase with the UPFC bus voltage . The parameters of the PI controllersTransmission line reactive power flow controller parameters:

a) Outer loop controller K_p= -0.1; K_i= -1;
b) Inner loop controller K_p= 0.15; K_i= 25;

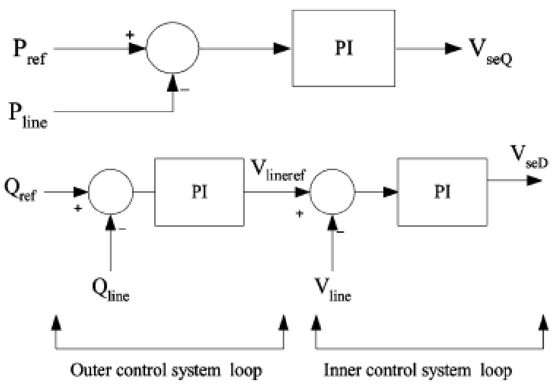

Fig. 3. Series converter real and reactive power flow control system.

F. Real Power Coordination Controller

To understand the design of a real power coordination controller for a UPFC, consider a UPFC connected to atransmission line as shown in Fig.4. The interaction between the series injected voltage and thetransmission line current leads to exchange of realpower between the series converter and thetransmission line.

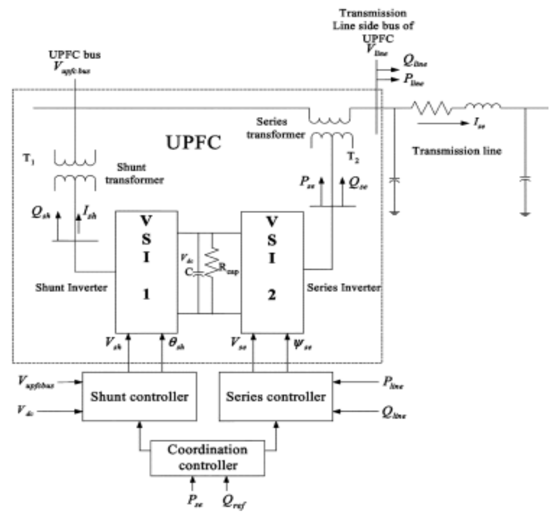

Fig.4. UPFC connected to a transmission line.

The real power demand of the seriesconverter causes the dc link capacitor voltage toei-ther increase or decrease depending on the direction of thereal power flow from the series converter. Thisdecrease/increase in dc link capacitor voltage is sensedby the shunt converter controller that controls the dc linkcapacitor voltage and acts to increase/decrease theshunt converter real power flow to bring the dc linkcapacitor voltage back to its scheduled value.Alternatively, the real power demand of the series converteris recognized by the shunt converter controller only by thedecrease/increase of the dc link capacitor voltage .Thus, the shunt and the series converter operation are in away sep-arated from each other. To provide for propercoordination be-tween the shunt and the series convertercontrol system, a feed-back from the series converter isprovided to the shunt converter control system. Thefeedback signal used is the real power de-mand of the seriesconverter . The real power demand of the seriesconverter is converted into an equivalent D-axis currentfor the shunt converter . By doing so, the shuntconverter responds immediately to a change in its D-axiscurrent and supplies the necessary series converter realpower demand. The equivalent D-axis current is anadditional input to the D-axis shunt converter control systemas shown in Fig.5.

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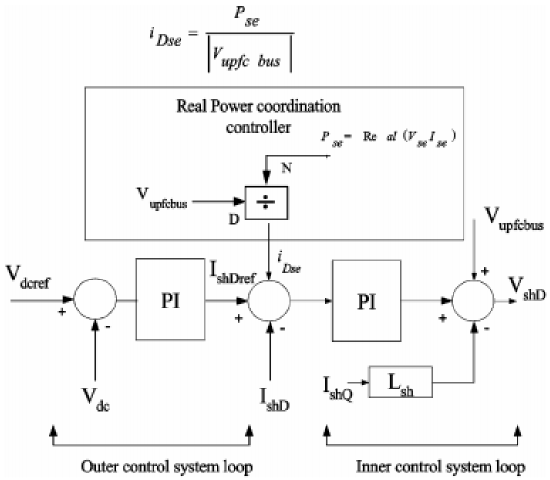


Fig. 5. D-axis shunt converter control system with real power coordinationcontroller

III. SIMULATION RESULTS

An experimental UPFC system has been built to test the power control in transmission line. Recentadvances in high-voltage IGBT technology allow for higher switching frequency with lower loss, and thisallows for practical implementation of PWM control for high-power converters. So in the experiment, both theshunt converter and the series converter have been built as a three-phase PWM converter with IGBT as thepower device. The UPFC device is inserted into a transmission line, and with the help of the UPFC, the powerflow in the transmission line can be controlled effectively while maintaining the UPFC bus voltage constant.The parameters of the whole systems are given below:

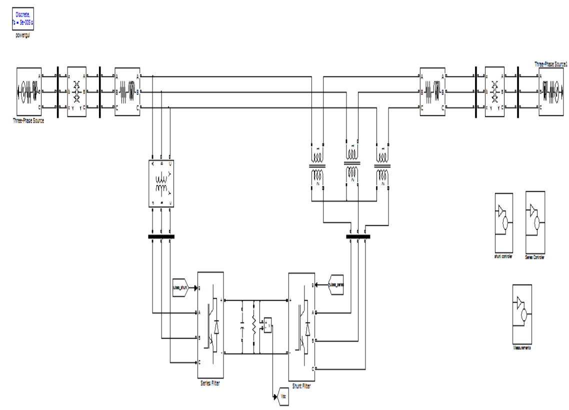


Fig.6 Transmission line without UPFC

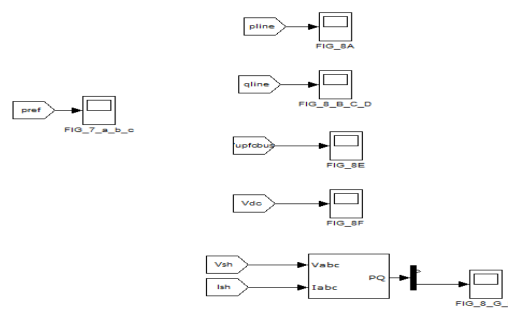
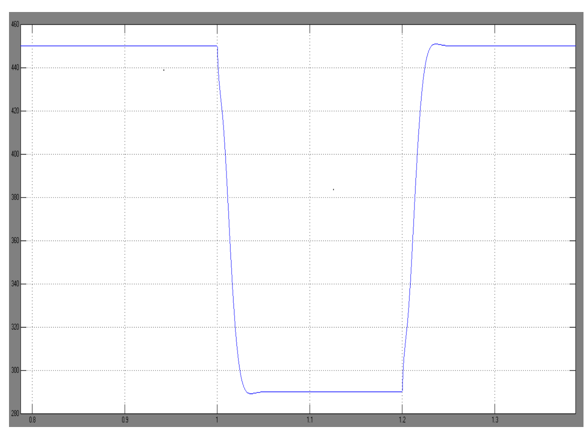


Fig.7 overall measurements of Transmission line without UPFC



Plot-1