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Designing and Control of Converters used in DPFC for Mitigation of Voltage Sag and Swell In Transmission Line

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Abstract – This paper presents a new control scheme for the improvement of a system by Distributed Power Flow Controller (DPFC) based stabilizer from distributed flexible ac-transmission system (D-FACTS) family. The DPFC is derived from the UPFC by eliminating common DC link and inherits the same control capability of the UPFC. DPFC independently controls the active and reactive power flow in transmission line by adjusting the line impedance, the bus-voltage magnitude and the transmission angle. On basis of control objects, the DPFC control can be distinguished as the control at device level and at system level. The aim at device level is to maintain the capacitor DC voltage of each converter. It also ensures that the DPFC generates the series voltages and shunt reactive current at the fundamental frequency, required by the system operator.

Keywords: *FACTS, D-FACTS, UPFC, DPFC, power quality, converters, steady state analysis.*

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I. INTRODUCTION

The power demand is growing dramatically but the extension of transmission line and generation is restricted due the rigid environmental constraints and limited availability of resources. The FACTS technology increases controllability and optimize the utilization of existing power system capacities using high speed and reliable power electronic devices [1]. A distributed FACTS (D-FACTS) device has been recently introduced in the FACTS family and gaining importance because of several merits over conventional FACTS devices. The D-FACTS devices exhibit much lower cost and higher reliability than the conventional FACTS devices mainly UPFC. A Distributed Power Flow Controller (DPFC) has been derived from UPFC and has same capability of simultaneously adjusting all the parameters of power system such as impedance of line, transmission angle and magnitude of bus voltage [2]. The prime advantage of DPFC is the elimination of common DC link between shunt and series converters and uses transmission line to exchange active power between converters at 3rd harmonic frequencies. Instead of one large 3 phase converter, it employs multiple single phase converters as series compensator, thus the rating of components reduces and also provides a high reliability because of its redundancy [3]

II. DPFC PRINCIPLE

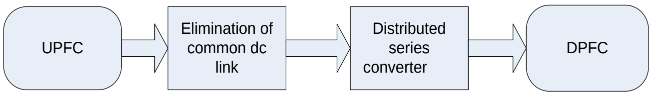

Fig. 1 DPFC Block Diagram

Figure 1 shows block diagram representation of DPFC. It contains one shunt and several series converters. The shunt converter resembles a STATCOM while the series converter employs the D-FACTS concept, which uses multiple single-phase converters instead of one large converter. Each series converter is an SSSC converter [4]. Each converter within the DPFC is independent and has its own dc capacitor to provide the necessary dc voltage. The basic configuration of DPFC is shown in Fig. 2. DPFC also requires a high-pass filter that is shunt connected at the other side of the transmission line, and two Y–Δ transformers at both side of the line. The high-pass filter within the DPFC blocks the fundamental frequency components and passes the harmonic components, thus provides a return path for the harmonic components. A close loop is formed for harmonic current by the ground, shunt and series converters, high-pass filter [2]. The unique control capability of UPFC is given by the back-to-back connection between the shunt and series converters, which allows the exchange of active power freely. For ensure of that the DPFC have the similar control capability as the UPFC, a method that allows the exchange of active power between converters with eliminated dc link is rudiment [2].

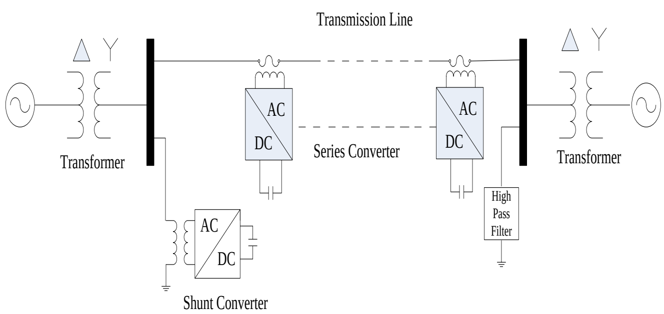

Fig. 2 Configuration of DPFC

The third harmonic is selected for its unique characteristics to exchange the active power in the DPFC [1]. The mean value of the product of voltage and current is the active power resulting from this non- sinusoidal voltage and current which can be expressed by

$$P = \sum_{i=1}^{\infty} V_i I_i \cos \phi_i$$

Where V_i and I_i are the voltage and current at the *i*th harmonic frequency and ϕ_i is the corresponding angle between the voltage and current. From this equation it is clear that the active power at different frequencies is isolated from each other and the voltage or current in one frequency has no influence in the other active power at different frequency [5]. Thus a converter without a power source can generate active power at one frequency and absorb this power from other frequency [6].

Shunt Converter

Based in this method, the shunt converter of DPFC can absorb active power from the grid at the fundamental frequency and inject the current back into the grid at a harmonic frequency and this harmonic current will flow through the transmission line. The shunt converter consists of a three-phase converter that is back-to-back connected to a single-phase converter [7]. Similar as a STATCOM, the three-phase converter is connected to the low-voltage side of the Y-△ transformer to absorb active power from the grid. The single-phase converter is connected between the ground and the neutral point of the Y-△ transformer to inject 3rd harmonic current.

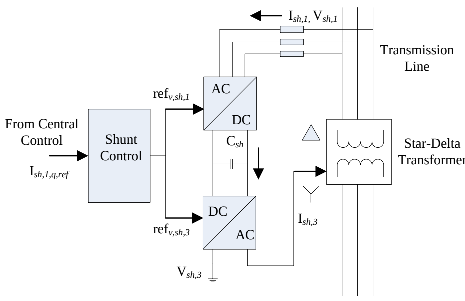

Fig. 3 Simplified diagram of Shunt Converter

The overall shunt converter model is created by connecting the AC and DC sides of the shunt converter model. The input signals for the model are reference voltage signals and current, at both frequencies, while the outputs are the fundamental and 3rd harmonic frequency voltages, generated by the shunt converter. Due to no 3rd harmonic component at the △ side of the transformer, the converter at the left side contains only the components at the fundamental frequency, namely the voltage $Vs_{h,1}$ and the current $I_{sh,1}$. The voltage $V_{sh,3}$ and current $I_{sh,3}$ at the 3rd harmonic frequency are single-phase components.

Distributed Series Converter

The idea of the D-FACTS to use a large number of controllers with low rating instead of one large rated controller. A single phase converter is the small controller attached to the transmission lines by a single phase transformer. For avoiding the high cost of isolation, the converters are hanged on the line. The single-turn transformer uses the transmission line as the secondary winding and inserts controllable impedance into the line directly [8]. The DPFC series converters generate a voltage at the harmonic frequency, according to the amount of required active power at the fundamental frequency, thereby absorbing the active power from harmonic components.

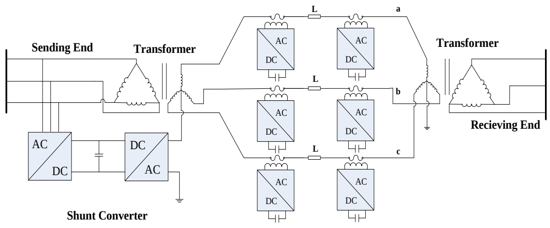

Fig. 4 DPFC Connections in Three Phase

The DPFC series converters are identical, as are their models. The series converter is PWM control single-phase converter. The AC side and the DC side voltages of the series converter are V_{se} and $V_{se,DC}$ respectively and $ref_{V,se}$ is the modulation amplitude of the reference AC signal in pu, which is generated by the series control.

DPFC Control

DPFC consists of three types of controllers; they are central controller, shunt control, and series control. The central control takes account of the DPFC functions at the power-system level. The shunt and series control are local controllers maintains their own converter's parameters.

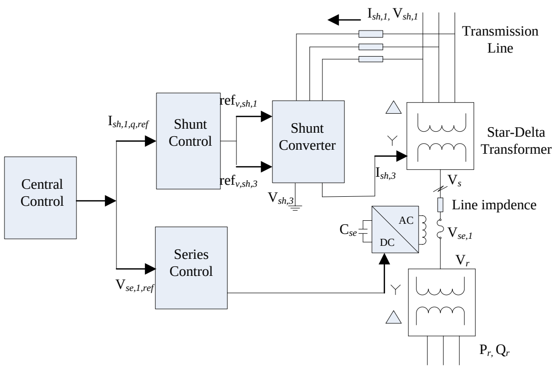

Fig. 5 DPFC Control Structure

Central Control

The reference signals for both the shunt and series converters of the DPFC are generated by the central controller. The focus is on the DPFC tasks at the power-system level i,e low-frequency power oscillation damping, power-flow control and balancing of asymmetrical components [2]. Based on the system requirement, the central control generates corresponding voltage-reference signals for the series converters and reactive current signal for the shunt converter. At the fundamental frequency, all reference signals generated by the central control.

Series Control

Series converters have individual series control. The function of controller is to maintain the capacitor dc voltage of its own converter by using the third-harmonic frequency components and to generate series voltage at the fundamental frequency that is prescribed by the central control. The major control loop with the DPFC series converter control is the third-harmonic frequency control. For the dc-voltage control the principle of the vector control is used here. For the single-phase park transformation, the third-harmonic current through the line is selected as the rotation reference frame, because it is easy to be captured by the phase-locked loop (PLL) in the series converter [4]. The line current contains two frequency components, so a third high-pass filter is needed to reduce the fundamental current. The d-component of the third harmonic voltage is the parameter that is used to control the dc voltage. The reference signal is generated by the dc-voltage control loop. For the minimization of the reactive power that is caused by the third harmonic, series converter is controlled as a resistance at the third-harmonic frequency. During the operation, the q-component of the third-harmonic voltage is kept zero. There will be voltage ripple at the dc side of each converter. The frequency of the current that flows through the converter determines the frequency of the ripple. As the current contains the fundamental and third harmonic frequency components, 100-, 200-, and 300-Hz frequency component will be present in the dc-capacitor voltage [5]. Two possible ways are there to reduce this ripple. First is to increase the turn ratio of the single-phase transformer of the series converter to reduce the magnitude of the current that flows into the converter. Another way is to use the dc capacitor with a larger capacitance.

Shunt Control

A constant third harmonic current is injected into the line by the shunt control to provide active power for the series converters. The bus voltage at the fundamental frequency is locked with the third-harmonic current. For capturing the bus-voltage frequency, a PLL is used and the output phase signal of the PLL is multiplied by three to create a virtual rotation reference frame for the third-harmonic component. The aim of shunt converter's fundamental frequency control is to inject a controllable reactive current to grid and to keep the capacitor dc voltage at a constant level [5]. Two cascaded controllers are used for controlling fundamental frequency components. The inner control loop is current control, which is to modulate the shunt current at the fundamental frequency. The d-component is generated by the dc control and the q-component of the reference signal of the shunt converter is obtained from the central controller.

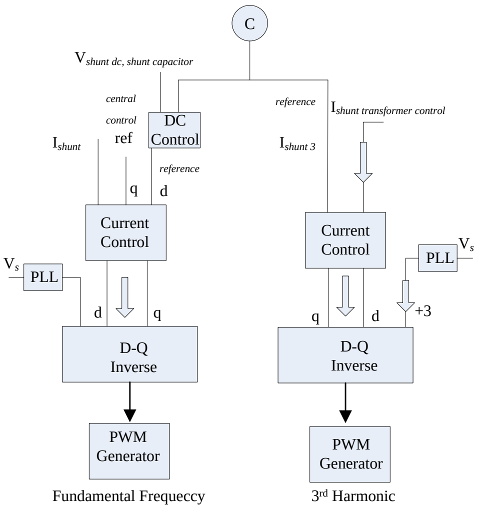

Fig. 6 Control scheme of the shunt converter: (a) for the fundamental frequency components; (b) for the 3rd harmonic frequency components

III SOLUTION METHODOLOGY

To simulate the effect of the DPFC on distributed system is processed using MATLAB, one shunt converter and two single phase series converters are built and tested. The test data specifications of the DPFC in MATLAB are listed below [2].

TABLE 1

Parameters	**Value**
Sending end voltage (Vs)	200 V
Receiving end voltage (Vr)	200 V
Series converter voltage (Vse)	120 V
Shunt converter voltage (Vsh)	120 V
Line resistance (r)	0.3864 Ω/km
Line inductance (L)	4.1264 mH/km
Source resistance (rs)	0.8929 Ω
Source inductance (Ls)	16.58 mH
Series capacitor (Cse)	1 μF
Shunt capacitor (Csh)	1 μF

IV RESULTS

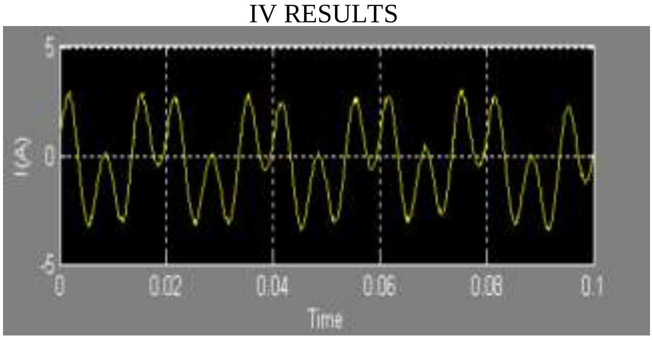

Fig. 7 DPFC operation in steady-state: line current

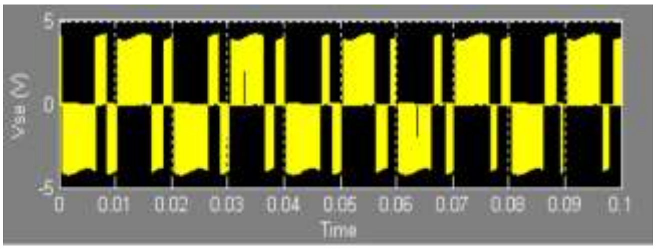

Fig. 8 DPFC operation in steady-state: series converter voltage

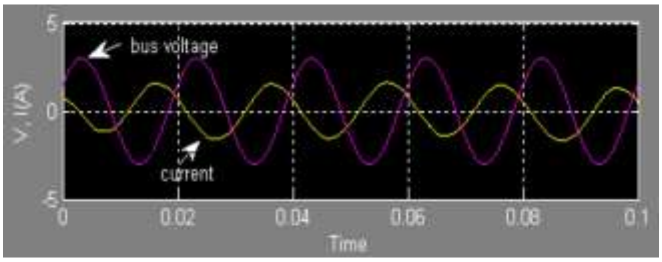

Fig. 9 DPFC operation in steady-state: bus voltage and current at the Δ side of the transformer

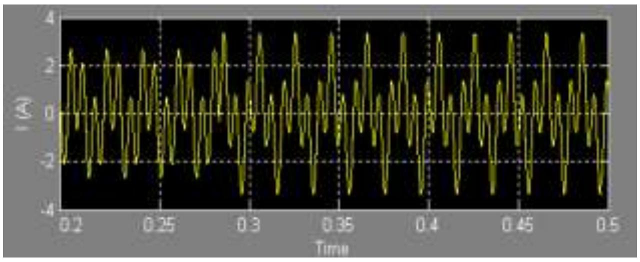

Fig. 10 Step response of the DPFC: line current

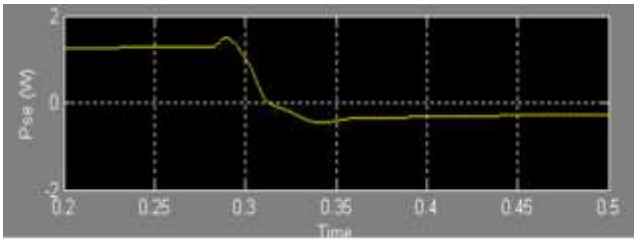

Fig. 11 Step response of the DPFC: active power injected by the series converter at the fundamental frequency

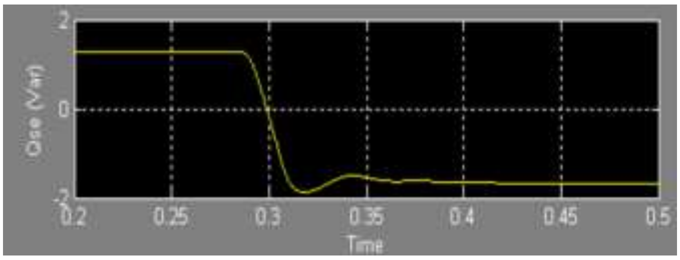

Fig. 12 Step response of the DPFC: reactive power injected by the series converter at the fundamental frequency

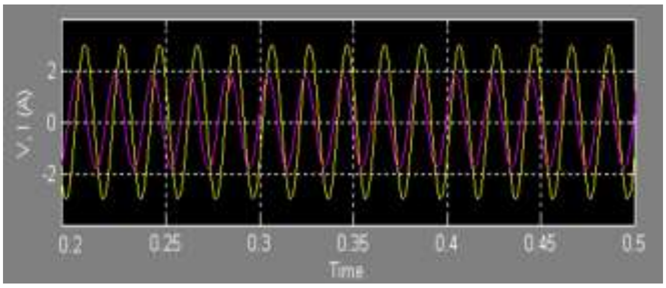

Fig. 13 Step response of the DPFC: bus voltage and current at the Δ side of the transformer

Under steady-state conditions the series converter is controlled to inject a fundamental voltage of 2V. The line current, voltage injected by the series converter and the voltage and current at the Δ-side of the transformer are shown in Fig. 7 to 9. The constant third harmonic current injected by the shunt converter evenly disperses to the three phases and is superimposed on the fundamental current as shown in Fig. 7. It is observed from Fig. 8. that the voltage injected by series converter is a pulse width modulated (PWM) waveform containing two frequency components. The amplitude of the waveform represents the dc-capacitor voltage at the line side of the transformer.

The step response results are shown in Fig. 10.to 13. A step change of the fundamental reference voltage of the series converter is made as shown in Fig. 12. It consists of both active and reactive variations. The dc voltage of the series converter is stabilized before and after the step change. The line current through the line is shown in Fig. 7. It is observed that the change in the voltage injected by the series converter changes the current flowing through the line. The active and reactive powers injected or absorbed by the series converter are shown in Fig. 12. It is observed from Fig. 13. that the Δ-side of the network contains no 3rd harmonic component.

CONCLUSION

The above discussion reflects various work and philosophies are covered in the area of DPFC. It provides widespread, versatile control for power systems. The high control capability of DPFC, it can also be used to improve the power quality and system stability, such as voltage sag restoration, low-frequency power oscillation damping or balancing asymmetry. AS the shunt and series converters works independently, the failure at one place will not influence the other converters. Distributed FACTS devices may offer a new approach to meeting this critical need.

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REFERENCES

[1] N. G. Hingorani and L. Gyugyi, "Understanding FACTS : Concepts and Technology of Flexible AC Transmission Systems" *New York: IEEE Press*, 2000

[2] Zhihui Yuan, Student Member, IEEE, Sjoerd W. H. de Haan, Member, IEEE, Jan Braham Ferreira, Fellow, IEEE, and Dalibor Cvoric, Student Member, IEEE "A FACTS Device: Distributed Power-Flow Controller

ISSN: 2321-8169
162 – 166

(DPFC)” *IEEE Transactions on Power Electronics, vol. 25, no. 10, October 2010*.

[3] Akhib Khan Bahamani, G.V. Siva Krishna Rao, A.A. Powly Thomas and Dr V.C. Veera Reddy, “Modelling and Digital Simulation of DPFC System using Matlab Simulink” *International Journal of Emerging Trends in Electrical and Electronics (IJETEE – ISSN: 2320-9569) vol. 6, issue. 1,* Aug-2013

[4] Shanker N., B. Sampath Kumar, “Voltages sag and swell mitigation using DPFC for Multibus system”, *International Journal of Engineering Research & Technology (IJERT), Vol. 2 issue 10, October* – 2013

[5] P. Ramesh, M. Damodara Reddy, “Modeling and Analysis of Distributed Power- Flow Controller (DPFC)”, *International Journal of Engineering Research and Applications, Vol. 2, Issue 2,Mar-Apr 2012,* pp.609-615.

[6] T Santosh Tej, M. Ramu, Ch. Das Prakash, K. Venkateswara Rao, “Compensation of Unbalanced Three Phase Currents in a Transmission Line using Distributed Power Flow Controller”, *International Journal of Engineering Research and Applications (IJERA) Vol. 1, Issue 2, pp.183-189*.

[7] K. Ravichandrudu, P. Raghava Rani, P. Yohanbabu, G. V. P. Anjaneyulu, “Comparison of Simulation Results of D-FACTS & UPFC used for Power Quality Improvement”, *International Journal of Scientific and Research Publications, Volume 3, Issue 9, September 2013*.

[8] K. M. Rogers, Student Member, IEEE, and T. J. Overbye, Fellow, IEEE,” Some Applications of Distributed Flexible AC Transmission System (D-FACTS) Devices in Power Systems”.

[9] Panigrahi C. K., Mohanty P. K., Soren N., Akhilesh A. Nimje, “Enhancing Power Quality and Reliability in Deregulated Environment” *International Journal of Electrical Engineering and Technology (IJEET), Vol 2, No. 2, May – July (2011), pp 1-11.* ISSN 0976 – 6553.

[10] Akhilesh A. Nimje, C. K. Panigrahi, A. K. Mohanty, “Enhanced Power Transfer Capability by using SSSC”, *Journal of Mechanical Engineering and Research, Vol. 3 (2), pp 48 - 56, February 2011*.