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Impact of Distributed Power Flow Controller (DPFC) in power system

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Abstract - *Modern power utilities have to respond to a number of challenges such as growth of electricity demand specially in non-linear loads in power grids. So, there is a great demand to control the power flow in the lines. Power Flow Controlling Devices (PFCDs) are required for such purposes because power flow over the lines mainly depends on the impedance of the line. Nowadays the trend is to replace mechanical PFCDs with Power Electronics PFCDs. Among all Power Electronics PFCDs, Unified Power Flow Controller (UPFC) is the most versatile one. But it is not applied widely in utility grids due to its high and low reliability. A new PFCD called Distributed Power Flow Controller (DPFC) that offers the same controlling capability as that of UPFC with reduced cost and increased reliability have been highlighted in this paper. DPFC can be thought of as emerged from UPFC with some modifications in it. The DPFC eliminates the common DC link within the UPFC to enable the independent operation of shunt and series converters. The D-FACTS concept is employed in the design of series converters. High rating three phase series converters are being replaced by multiple low rating single phase converters which greatly reduces cost thereby increasing reliability and stability. The active power exchange takes place through transmission line at third harmonic frequency which in UPFC was done through common DC link.*

Key Words: **DPFC, UPFC, PWM, Shunt controller, Series controller, D-FACTS, PFCDs**

1. INTRODUCTION

Electricity is one of the most important forms of energy which is used in almost every sphere of life, be it residential, commercial, industrial, etc. The electrical power system serves to deliver electrical energy to consumers. An electrical power system deals with electricity generation, transmission, distribution and consumption. The power station generates electrical energy and transports to customers via the transmission and distribution network. The rate of the transported electrical energy within the lines of the power system is referred to as 'Power Flow'. The term power flow means the active and reactive power that flows in the transmission line. In modern power system, its operation has changed due to growing consumption, development of new technology, the behavior of the electricity market and the development of renewable energies. In addition to existing changes, new devices like electrical machines, distributed generation and smart grid concepts are making the system even more complex. So, there is great demand for secured, controlled, stable, economic and quality power. PFCDs are used to fulfill the given objectives. Among all FACTS devices UPFC is the most versatile device due to its ability to pass real power flow bidirectionally, maintaining well-regulated DC voltage, working ability in the wide range of operating condition, etc. But due its high cost, it is not widely used. In this paper, the use of a new PFCD called Distributed Power Flow Controller (DPFC) is highlighted that has the same controlling capability as that of UPFC with reduced cost and increased reliability. DPFC has been modeled using d-q fame on the basis of which its basic control is developed. The basic control ensures that the converter injects voltage according to the command from central control. DPFC consists of a shunt converter and a number of series converters. The shunt converter injects constant current at third harmonic frequency while the series converter injects voltage of controllable magnitude and phase at fundamental frequency thereby controlling the flow of active and reactive power through the transmission line.

2. DPFC

2.1 Configuration

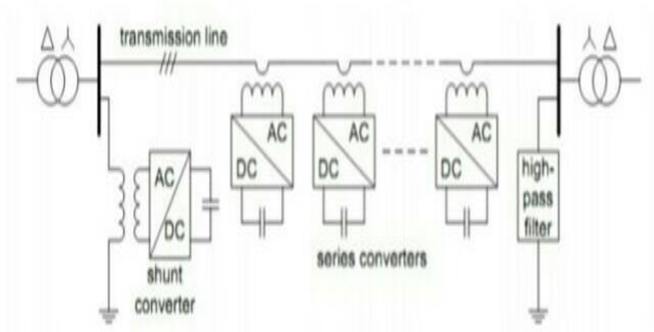

Fig-1: DPFC configuration

DPFC consists of a shunt converter and a number of series converters. Shunt converter is similar to a STATCOM, while the series converter uses the DSSC concept, multi-phase converters is used instead of a three-phase inverter. Each converter within the DPFC is independent and has its own DC capacitor to provide the required DC voltage. In addition to the key components of the series and shunt - converting a DPFC also requires a high pass filter which is connected in shunt across the transmission line and a transformer Y-Δ on each side of line so that harmonics get reduced and output is distortionless. The unique ability to control the UPFC is given by the connection back to back between the shunt and series converters, allowing the active power to share freely. To ensure DPFC has the same control capability as the UPFC, a method that allows the exchange of active power between converters with DC link removed is required.

2.2 Operating principle

Active power exchange between DPFC converters takes place through transmission line. The transmission line has a common connection between the ports of AC shunt and series converters. Therefore, it is possible to exchange active power through AC ports. The method is based on the theory of non-sinusoidal power components. According to Fourier analysis, non-sinusoidal voltage and current can be expressed as the sum of sinusoidal functions of frequencies with amplitudes. The active power resulting from this non sinusoidal voltage or current is defined as the mean value of the product of the voltage and current. From the integrals of all the cross product terms with frequencies are zero, the active power can be expressed by:

$$P = \sum_{i=1}^{\infty} V_i \, I_i \cos \emptyset_i \tag{1}$$

where Vi and Ii are the voltage and current at ith harmonic frequency respectively, and φi is the corresponding angle between the voltage and current. Equation (1) shows that active frequencies powers are independent of each other and the voltage or current at a frequency has no influence on the active power at other frequencies According to the required amount of active power at the fundamental frequency, DPFC series converters generate a voltage at the harmonic frequency, thereby absorbing the active power from harmonic components. Neglecting losses, the active power at the fundamental frequency is equal to the absorbed power at the harmonic frequency.

2.3 Control

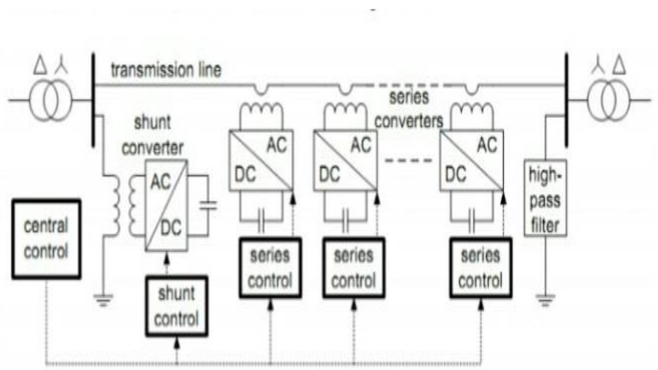

Fig-2: DPFC control

(A) Central control: The central control generates the reference signals for both the shunt and series converters of the DPFC. According to the system requirements, the central control gives corresponding voltage reference signals for the series converters and reactive current signal for the shunt converter. All the reference signals generated by the central control concern the fundamental frequency components.

(B) Series control: Each series converter has its own series control. The controller is used to maintain the capacitor DC voltage of its own converter, by using 3rd harmonic frequency components, in addition to generating series voltage at the fundamental frequency as required by the central control.

(C) Shunt control: The objective of the shunt control is to inject a constant 3rd harmonic current into the line to supply active power for the series converters.

3. SOFTWARE IMPLEMENTATION

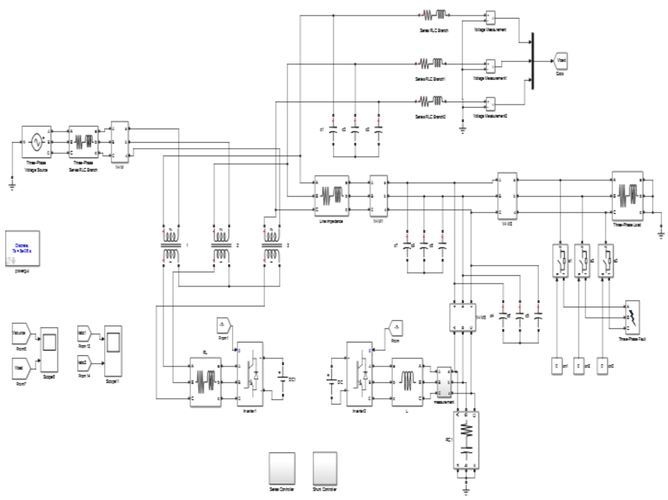

Fig-3: Simulink block diagram of DPFC

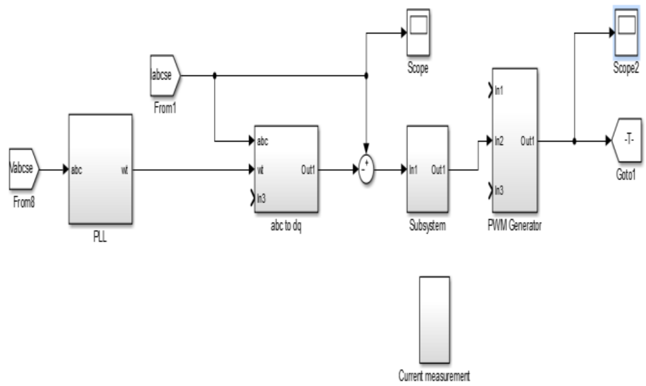

Fig-4: Simulink block diagram of shunt controller

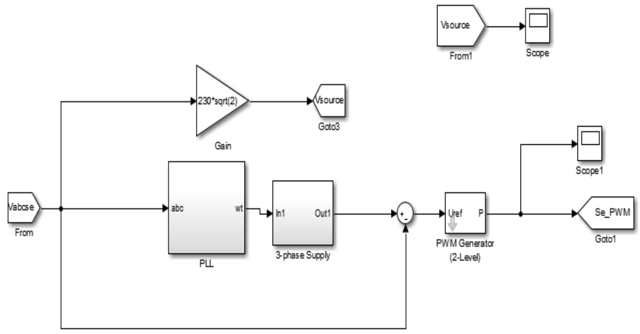

Fig-5: Simulink block diagram of series controller

Figure 3 shows the Simulink block diagram of the main system (DPFC) consisting of a three phase voltage source, series controller, shunt controller, a three phase load with an extra three phase fault system connected to transmission line to check the performance of DPFC in event of fault.

Figure 4 shows the Simulink block diagram of shunt controller. It consists of PLL (Phase Locked Loop), abc to dq0 transformation block and PWM (Pulse Width Modulation) generator. PLL will continously match the phase of the output signal with the input signal. 3 phase Park's transformation is used here to covert abc coordinate system to dq0 reference frame to make calculations easier. PWM generator will generate output in the form of pulses. By varing the time period of the pulse, we can control the current flowing through a device. It basically deals with current control.

Figure 5 shows the Simulink block diagram of series controller. It also consisits of PLL and PWM generator. Same work is performed by them here also. It basically deals with voltage control.

4.PARAMETERS RATING

Table-1 Parameters rating

Three phase AC voltage source

Positive sequence amplitude Amplitude Vrms ph-ph (V), phase (degree), Frequency (Hz)	400, 0, 50
Per unit values (Amplitude values)	1, 0.5,1,1.5,1
Time values (sec)	0, 0.2, 0.5, 0.7, 0.8
Branch type	RL (R = 0.01Ω, L = $4e^{-3}$H

Controllers

Series controller	Shunt controller
Inverter Snubber resistance Rs = 100Ω Snubber capacitance Cs = ∞ Ron = $1e^{-3}$Ω	Inverter Snubber resistance Rs = $1e^{5}$Ω Snubber capacitance Cs = ∞ Ron = $1e^{-3}$Ω
Branch type RL R = 100Ω L = $1000e^{-3}$H	Branch type RC R = 5Ω C = $25e^{-6}$H
DC voltage source V = 800√2V	DC voltage source V = 800√2V

Three phase load

Branch type	RL
Resistance	R = 100Ω
Inductance	L = $20e^{-3}$H

5. RESULTS

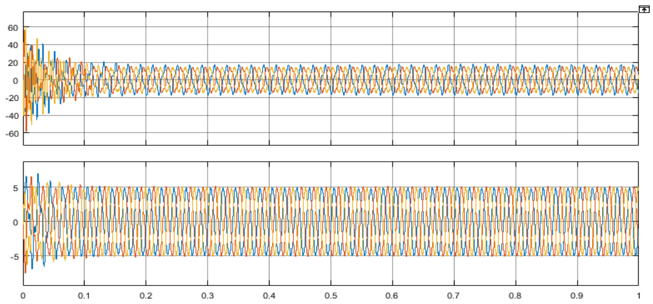

Fig-6: Main current output (a) source (b) load

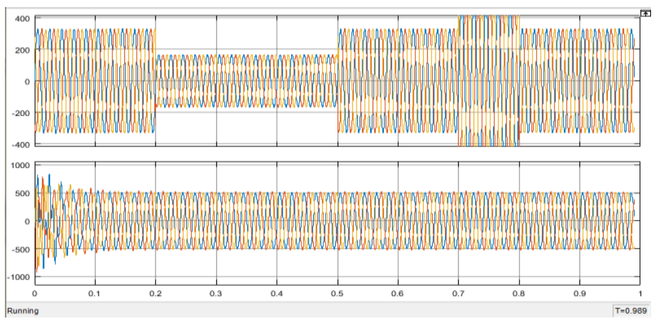

Fig-7: Main volatge output (a) source (b) load

Result analysis

Figure 6 shows the main current v/s time graph. The source current is unbalanced and fluctuating in nature with harmonics present in it. But due to shunt controller of DPFC, the load current is seen balanced and constant in nature with smooth waveform as harmonics have been reduced.

Figure 7 shows the main voltage v/s time graph. The source voltage is highly unbalanced and uncontrolled with voltage sags and swells. But due to series controller of DPFC, the load voltage is seen balanced and controlled. Initially, the voltage magnitude is high for fraction of seconds because at starting, more voltage is required for more reactive power consumption.

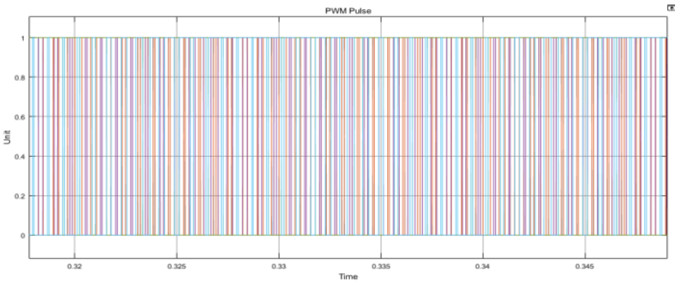

Fig-8: Shunt controller PWM output

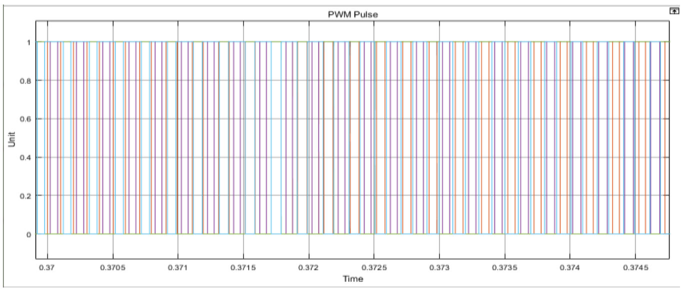

Fig-9: Series controller PWM output

Result analysis

Figure 8 shows the shunt controller PWM waveform. It is a graph between current (Y-axis) and time (X-axis). PWM waveform is generated by PWM generator in the form of pulses.

Figure 9 shows the series controller PWM waveform. It is a graph between voltage (Y-axis) and time (X-axis).

CONCLUSION

DPFC can be seen as an advanced or modified version of UPFC. It also inherits the control capability of the UPFC, which is the simultaneous adjustment of the line impedance, transmission angle and the magnitude of the bus voltage. The common DC link between the series and shunt converters, used to exchange active power in the UPFC is removed. The series converter of DPFC uses the concept D-FACTS, which uses multiple small single phase converters instead of a large inverter. DPFC reliability is greatly increased due to the redundancy of the series converters. The total cost of DPFC is also much lower than the UPFC, because no high voltage isolation is required and the rating of the components is quite low. It is proved that the shunt and series converters can exchange the DPFC active power at the third harmonic frequency and the series converters are able to inject controllable active and reactive power at the fundamental frequency. The simulation model of DPFC has been designed by using MATLAB/SIMULINK. DPFC gives the finest performance characteristics with improved power quality, increased system reliability as well as stability and reduced cost. The active and reactive power flows through the line are controlled successfully with improved power quality and voltage sag and swell mitigation.

REFERENCES

[1] Y.H. Song and A. Johns, "Flexible ac Transmission Systems (FACTS)" (IEE Power and Energy Series), vol. 30. London, U.K.: Institution of Electrical Engineers, 1999.

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

[3] L.Gyugyi, C.D. Schauder, S. L.Williams, T. R. Rietman,D. R. Torgerson, and A. Edris, "The unified power flow controller: Anewapproach to power transmission control," IEEE Trans. Power Del., vol. 10, no. 2, pp. 1085–1097, Apr. 1995.

[4] Zhihui Yuan, Sjoerd W. H. de Haan, Jan Braham Ferreira and Dalibor Cvoric, "A FACTS Device: Distributed Power-Flow Controller (DPFC)", IEEE Transactions on Power Electronics, vol. 25, no.10, October 2010.

[5] Sarimalla Pedakotaiah and Santosh A, "Simulation of Distributed Power-Flow Controller (Dpfc)", International Journal of Engineering and Science ISBN: 2319-6483, ISSN: 22784721, vol. 2, Issue 1 (January 2013), PP 25-32.

BIOGRAPHIES

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