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Development of Distributed Power Flow Controller for Improved Performance of the Power System Network

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Abstract

This paper presents an advanced component of flexible ac transmission system called Distributed Power Flow Controller. DPFC is derived from the concept of unified power flow controller. The DPFC can be considered like a unified power flow controller with an eliminated common dc link. The large number of series converters provides redundancy, thereby increasing the system reliability. As the D-FACTS converters are single-phase and floating with respect to the ground, there is no high-voltage isolation required between the phases. Accordingly, the cost of the DPFC system is lower than the UPFC. The performance of the distributed power flow controller is verified in Matlab/Simulink.

Keywords: Distributed Power Flow Controller, FACTS Controllers, Power Quality

1. Introduction

Transfer of energy from generating units to the utility customers, the power quality criteria is most important. For solving the power quality problem a new method based on the power electronic based equipment called custom power devices is developed which is one of the flexible alternating current transmission system[1] used in both transmission and distribution control.

The majority of problems in transmission lines are such as voltage dip, overvoltage and interruption. Because of growing power demand and extension of transmission, the distribution is restricted with the environmental constraints and availability of resource. Now a day the power quality improvement is the main criterion from the customer side. Generally, the power quality issues are more concentrated about transmission current, voltage or frequency deviation which also causes the failure of power station[2]. For reducing these power qualities a new concept called unified power flow controller and Static Synchronous Compensator (STATCOM) can be helpful. Now, more concentration is on the new strategy for controlling power known as Distributed Power Flow Controller (DPFC).

In this paper, a new method like distributed power flow controller which is similar to UPFC structure has been developed. The DPFC has a combination of single parallel converter and number of series converters which is used to balance the transmission line parameters, such as bus voltage, line impedance, and transmission angle[3].

2. Description of Proposed Control Strategy

The DPFC is a combination of two converters. One is connected in parallel to line called shunt converter. And STATCOM is one of the most important classifications. Another one is series converter which is connected in series with the transmission line with the help of series injected transformer. The structure of this distributed power flow controller is similar to unified power flow controller[4]. By eliminating this DC link, the converters

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within the FACTS devices are operated independently, thereby increasing their reliability. By elimination of dc link capacitor between the series and shunt converter now the active and reactive powers are exchanged with the help of transmission system.

Figure 1 shows the constructional structure for distributed power flow controller. In this the series converter is separated into three individual converters[5].

The Distributed Power Flow Controller has the following merits as compared to UPFC, such as:

- High capability to control the power. The DPFC can control all transmission parameters such as, impedance, load angle and voltage magnitude[6].
- High efficient.
- Economical.

3. Control Circuit for DPFC

According to Figure 1 the DPFC has three types of control strategies: i.e. central controller, controller for series controller and shunt controller[7,8]. The complete control diagram for distributed power flow controller is shown in Figure 2.

These three controllers are explained as follows:

3.1 Central Controller

Generally, these central controllers have the capability of generating reference signals to the both series and shunt controllers[9].

3.2 Controlling Circuit for Series Converter

The main use of this series controller is to compensate the line voltages with respect to changes due to load and maintain the series capacitor voltage within the limits. Generally, these series controllers have first order low pass and third order band pass filters for injecting natural and 3rd order harmonic currents into the line[11,12]. The closed loop control diagram for series controller is as shown in Figure 3.

3.3 Shunt Controller

The closed loop control diagram for the shunt converter is shown in Figure 4. The main purpose of this shunt converter is for providing active power into the line at frequency of 3rd order. This static converter generally is a three phase converter which is connected with another single phase shunt converter[13].

4. Simulation Result

The Simulation Diagram of DPFC is shown in Figure 5. Results are presented to show the performance of distributed power flow controller.

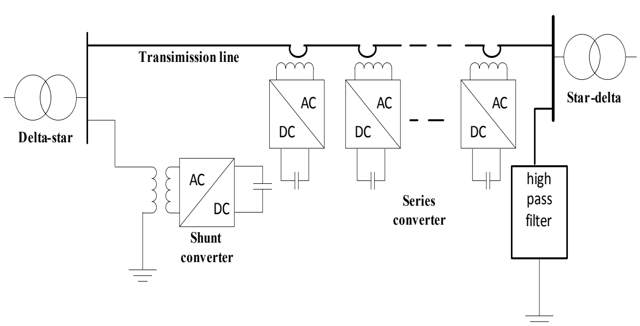

Figure 1. Configuration of DPFC.

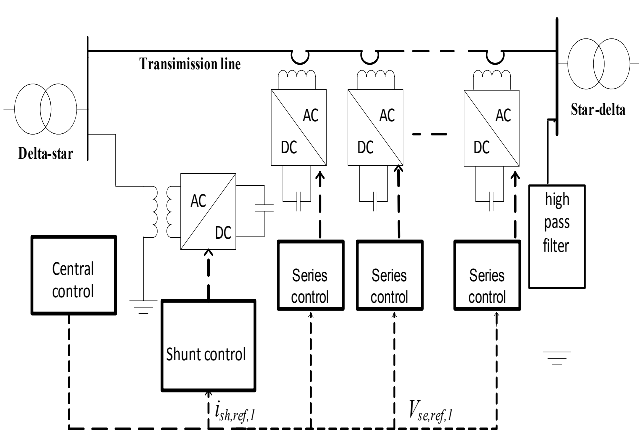

Figure 2. Control diagram of DPFC.

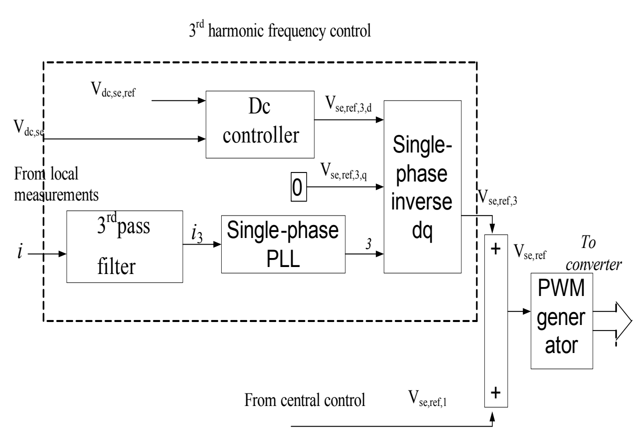

Figure 3. Block diagram for series controller.

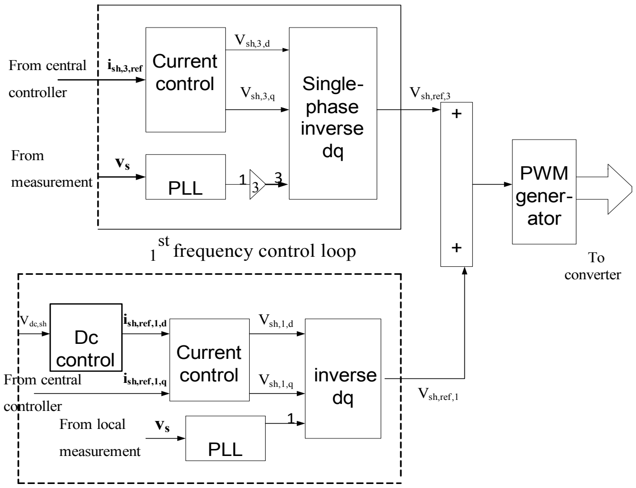

Figure 4. Control diagram for shunt controller.

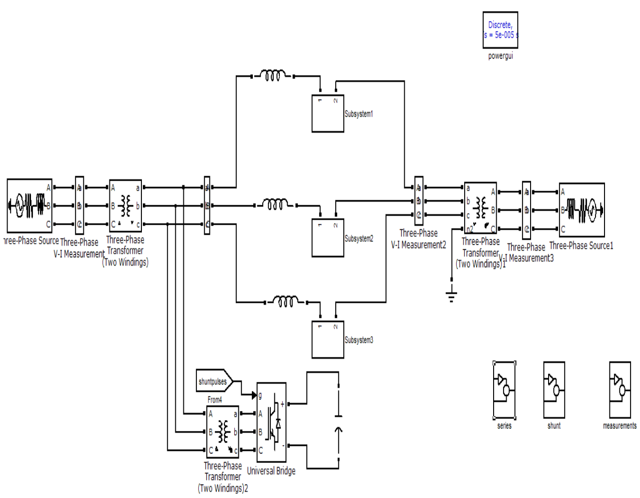

Figure 5. Simulink diagram of DPFC controller.

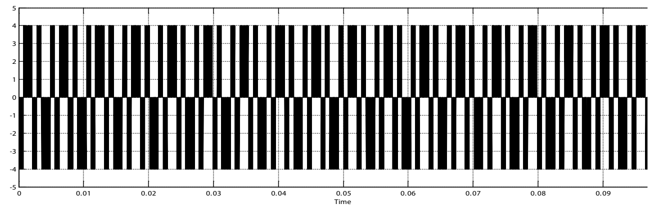

Figure 6. Reference voltage for series converter.

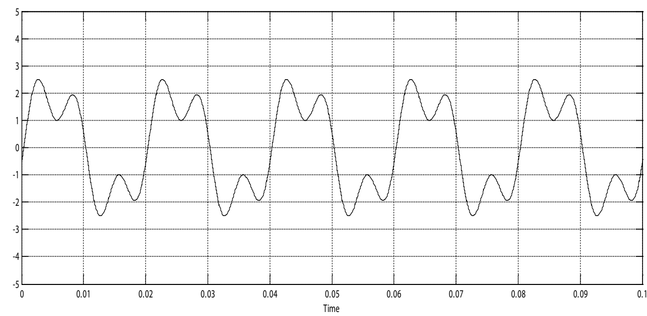

Figure 7. Transmission line current.

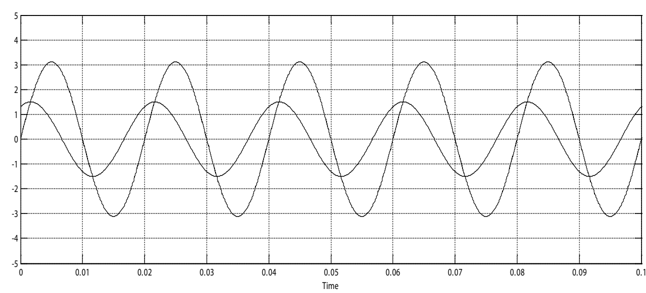

Figure 8. Output transmission voltage and current at delta side of transformer.

The principle of operation of DPFC can be demonstrated by considering the two special cases such as, the behavior of DPFC in steady state and step response.

4.1 Case 1

Performance analysis of DPFC for constant reference voltage of series converter.

The injected voltage from the series converter has two frequency components. The magnitude of the PWM technique waveform represents, the dc capacitor voltage which is used for maintaining the third harmonic component as shown in Figure 6.

The shunt converter injected third harmonic currents evenly distribute to the three phase systems and is superimposed on the fundamental frequency is shown in Figure 7.

Figure 8 shows the simulation result of the transmission system line currents and voltages. In this the line current is filtered by the wye-delta transformer. Then there is no third-harmonic current or voltage disturbance from delta side.

4.2 Case 2

Performance analysis of DPFC for Step change in reference voltage of series converter:

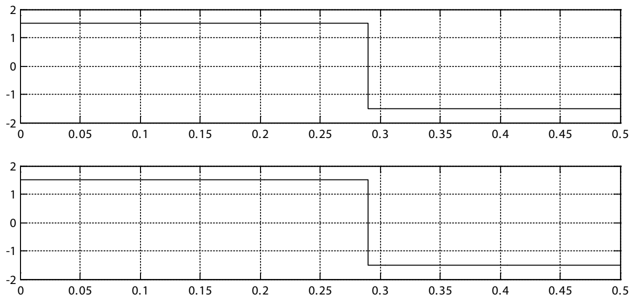

Figure 9. Reference voltage for series converter.

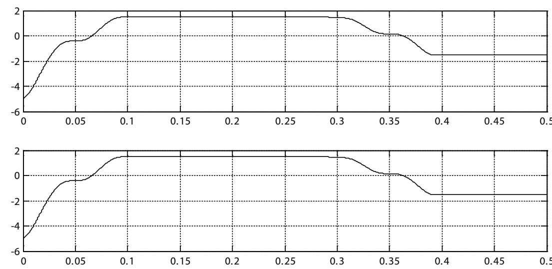

Figure 12. Series converter injected active and reactive power.

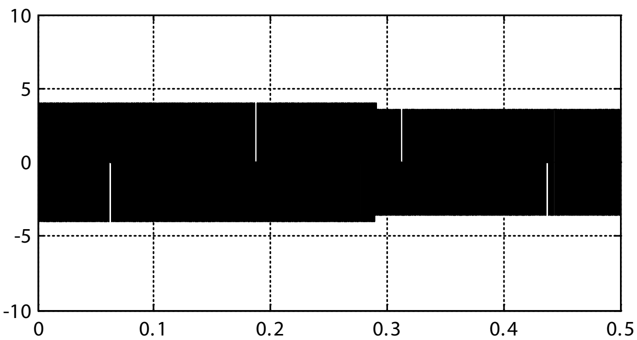

Figure 10. Simulation result for voltage under series converter.

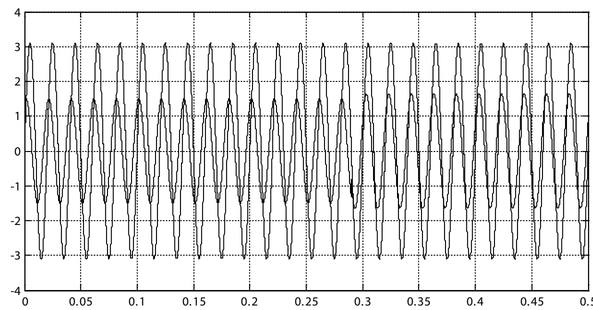

Figure 13. Unit Step response: output transmission voltage and current.

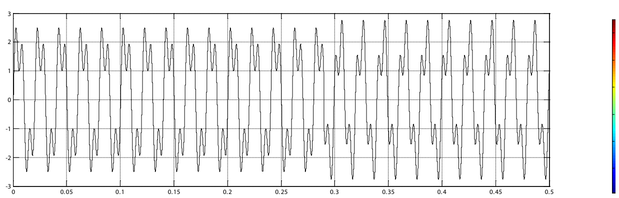

Figure 11. Transmission line current.

In this step change controller, the voltage injected with the series converter voltage vectors i.e direct and quadrature axis components with step change in magnitude at t = 0.28sec as shown in Figure 9.

The series converter injects the voltage under two frequency components such as fundamental and third harmonic components as shown in Figure 10. The simulation waveform shows that it has variations in magnitude during step change.

The shunt converter injected third harmonic currents evenly distribute to the three phase systems and is superimposed on the fundamental frequency is shown in Figure 11.

Figure 12 shows the simulation result for active and reactive powers derived from the series converter and it is varying by controlling the series injected voltage.

The simulation result for the voltage and current waveforms for this transmission line is as shown in Figure 13. In this the line current is filtered by the wye-delta transformer.

5. Conclusion

The performance of Distributed Power Flow Controller (DPFC) is observed in this paper. From the constructional, operational and economical point of view the DPFC plays a key role compared with the Unified Power Flow Controller. In this paper the system is simulated under two cases such as 1. Dynamic response and 2. Consideration of step change in controller voltages. However, with the use of DPFC the reliability of the transmission system is improved. Also in economical point of view the DPFC is much better than the other FACTS controllers, because no high-voltage isolation is requirement at the series-converter.

6. References

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Appendix

Table 1. Specification of the DPFC controller

Symbol	Descriptions	Value (units)
V_s	Nominal Grid S Voltage	220 (V)
V_q	Nominal Grid R Voltage	220 (V)
θ	Transmission angle between grid s & r	1 (θ)
L	Line Inductance	6 mH
$V_{sh\ max}$	Shunt converter maximum ac voltage	50 V
$I_{sh\ max}$	Shunt converter maximum current	9 A
F_{sw}	Switching frequency for the shunt & series converter	6 kHz
$V_{se\ max}$	Maximum ac voltage at line side of series converter	7 V