International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || REETA-2K16 ǁ PP. 425-433

POWER QUALITY IMPROVEMENT USING DISTRIBUTED POWER FLOW CONTROLLER

K.JANARDHAN [1], Y.N VIJAYAKUMAR [2]
[1]*Assistant professor, Dept of EEE, S.V.C.E.T, Chittoor, A.P, India*
Email: janardhan.215@gmail.com
[2]*Associate professor, Dept of EEE, S.V.C.E.T, Chittoor, A.P, India*
Email:yn.vijayakumar@gmail.com

Abstract: This paper presents a new component within the flexible ac-transmission system (FACTS) family, called distributed power-flow controller (DPFC). The DPFC is derived from the unified power-flow controller (UPFC). The DPFC can be considered as a UPFC with an eliminated common dc link. The active power exchange between the shunt and series converters, which is through the common dc link in the UPFC, is now through the transmission lines at the third-harmonic frequency. The DPFC employs the distributed FACTS (D-FACTS) concept, which is to use multiple small-size single-phase converters instead of the one large-size three-phase series converter in the UPFC. 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 DPFC has the same control capability as the UPFC, which comprises the adjustment of the line impedance, the transmission angle, and the bus voltage. According to growth of electricity demand and the increased number of non-linear loads in power grids, providing a high quality electrical power should be considered. In this project, voltage sag and swell of the power quality issues are studied and distributed power flow controller (DPFC) is used to mitigate the voltage deviation and improve power quality. The DPFC is a new FACTS device, which its structure is similar to unified power flow controller (UPFC). In spite of UPFC, in DPFC the common dc-link between the shunt and series converters is eliminated and three-phase series converter is divided to several single-phase series distributed converters through the line. The case study contains a DPFC sited in a single-machine infinite bus power system including two parallel transmission lines.

I. INTRODUCTION

The growing demand and the aging of networks make it desirable to control the power flow in power-transmission systems fast and reliably. The flexible ac-transmission system (FACTS) that is defined by IEEE as "a power-electronic based system and other static equipment that provide control of one or more ac-transmission system parameters to enhance controllability and increase power-transfer capability", and can be utilized for power-flow control. Currently, the unified power-flow controller (UPFC) is the most powerful FACTS device, which can simultaneously control all the parameters of the system: the line impedance, the transmission angle, and bus voltage. In this paper, a distributed power flow controller, introduced as a new FACTS device, is used to mitigate voltage and current waveform deviation and improve power quality in a matter of seconds. The DPFC structure is derived from the UPFC structure that is included one shunt converter and several small independent series converters shown in fig 1.. The DPFC has same capability as UPFC to balance the line parameters, i.e., line impedance, transmission angle, and bus voltage magnitude.

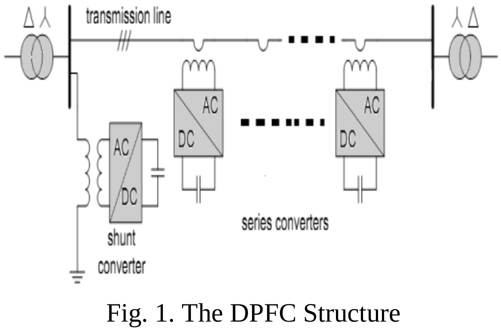

Fig. 1. The DPFC Structure

This paper introduces a new concept, called Distributed Power-Flow Controller (DPFC) that is derived from the UPFC. The same as the UPFC, the DPFC is able to control all system parameters. The DPFC eliminates the common dc link between the shunt and series converters. The active power exchange between the shunt and the series converter is through the transmission line at the third-harmonic frequency. The series converter of the DPFC employs the Distributed FACTS (D-FACTS) concept. Comparing with the UPFC, the DPFC have two major advantages. 1.Low cost because of the low-voltage isolation and the low component rating of the series converter.2.High reliability because of the redundancy of the series converters. In this the DPFC sited in a single-machine infinite bus power system including two parallel transmission lines ,which simulated in MATLAB/Simulink environment.

The paper is organized as follows: in section II, the DPFCprinciple is discussed. The DPFC control is described in section III. Section IV is dedicated to power quality improvement by DPFC. Simulation results are presented in section V

II. DPFC PRINCIPLE

Because of high control capability, the PE-based combined PFCs, specifically UPFC and IPFC are suitable for the future power system. However, the UPFC and IPFC are not widely applied in practice, due to their high cost and the susceptibility to failures. Generally, the reliability can be improved by reducing the number of components; however, this is not possible due to the complex topology of the UPFC and IPFC. To reduce the failure rate of the components by selecting components with higher ratings than necessary or employing redundancy at the component or system levels are also options. Unfortunately, these solutions increase the initial investment necessary, negating any cost- related advantages.

Accordingly, new approaches are needed in order to increase reliability and reduce cost of the UPFC and IPFC at the same time. After studying the failure mode of the combined FACTS devices, it is found that a common DC link between converters reduces the reliability of a device, because a failure in one converter will pervade the whole device though the DC link. By eliminating this DC link, the converters within the FACTS devices are operated independently, thereby increasing their reliability.

The elimination of the common DC link also allows the DSSC concept to be applied to series converters. In that case, the reliability of the new device is further improved due to the redundancy provided by the distributed series converters. In addition, series converter distribution reduces cost because no high-voltage isolation and high power rating components are required at the series part. By applying the two approaches – eliminating the common DC link and distributing the series converter, the UPFC is further developed into a new combined FACTS device: the Distributed Power Flow Controller (DPFC), as shown in Figure 2.

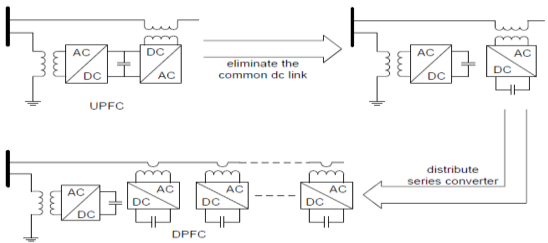

Fig 2: Flowchart from UPFC to DPFC

In this chapter, the principle of the DPFC is presented, followed by a steady-state analysis of the DPFC. During the analysis, the control capability and the influence of the DPFC on the network are investigated. The principle and analysis of another device that emerges from the IPFC, the so-called Distributed Interline Power Flow Controller (DIPFC), is also introduced.

Distributed Power Flow Controller (DPFC)

In this section, DPFC topology and operating principle are introduced.

DPFC Topology

By introducing the two approaches outlined in the previous section (elimination of the common DC link and distribution of the series converter) into the UPFC, the DPFC is achieved. Similar as the UPFC, the DPFC consists of shunt and series connected converters. The shunt converter is similar as a STATCOM, while the series converter employs the DSSC concept, which is to use multiple single-phase converters instead of one three-phase converter. Each converter within the DPFC is independent and has its own DC capacitor to provide the required DC voltage. The configuration of the DPFC is shown in Figure 3.

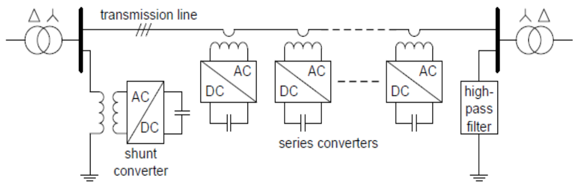

Fig 3: DPFC configuration

As shown, besides the key components - shunt and series converters, a DPFC also requires a high pass filter that is shunt connected to the other side of the transmission line and a Y-_ transformer on each side of the line. The reason for these extra components will be explained later. The unique control capability of the UPFC is given by the back-to-back connection between the shunt and series converters, which allows the active power to freely exchange. To ensure the DPFC has the same control capability as the UPFC, a method that allows active power exchange between converters with an eliminated DC link is required.

DPFC Operating Principle

Active power exchange with eliminated DC link

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

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

where Vi and Ii are the voltage and current at the ith harmonic frequency respectively, and _i is the corresponding angle between the voltage and current. Equation (3.1) shows that the active powers at different frequencies are independent from each other and the voltage or current at one frequency has no influence on the active power at other frequencies.

The independence of the active power at different frequencies gives the possibility that a converter without a power source can generate active power at one frequency and absorb this power from other frequencies. By applying this method to the DPFC, the shunt converter can absorb active power from the grid at the fundamental frequency and inject the power back at a harmonic frequency. This harmonic active power flows through a transmission line equipped with series converters. According to the amount of required active power at the fundamental frequency, the DPFC series converters generate a voltage at the harmonic frequency, thereby absorbing the active power from harmonic components. Neglecting losses, the active power generated at the fundamental frequency is equal to the power absorbed at the harmonic frequency. For a better understanding, Figure 4 indicates how the active power is exchanged between the shunt and the series converters in the DPFC system. The high-pass filter within the DPFC blocks the fundamental frequency components and allows the harmonic components to pass, thereby providing a return path for theharmonic components. The shunt and series converters, the high pass filter and the ground form a closed loop for the harmonic current.

Using third harmonic components

Due to the unique features of 3rd harmonic frequency components in a three-phase sys- tem, the 3rd harmonic is selected for active power exchange in the DPFC. In a three-phase system, the 3rd harmonic in each phase is identical, which means they are 'zero-sequence' components. Because the zero-sequence harmonic can be naturally blocked by Y-_ trans- formers and these are widely incorporated in power systems (as a means of changing voltage), there is no extra filter required to prevent harmonic leakage.

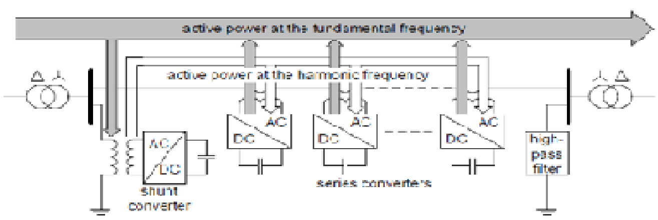

Fig 4: Active power exchange between DPFC converters

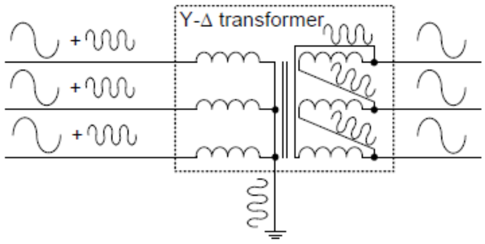

Fig 5: Utilize grounded Y-_ transformer to filter zero-sequence harmonic

Another advantage of using the 3rd harmonic to exchange active power is that the grounding of the Y-_ transformers can be used to route the harmonic current in a meshed network. If the network requires the harmonic current to flow through a specific branch, the neutral point of the Y-_ transformer in that branch, at the side opposite to the shunt converter, will be grounded and vice versa. Figure 5 shows a simple example of routing the harmonic current by using the grounding of the Y-_ transformer. Because the floating neutral point is located on the transformer of the line without the series converter, it is an open-circuit for 3rd harmonic components and therefore no 3rd harmonic current will flow through this line.

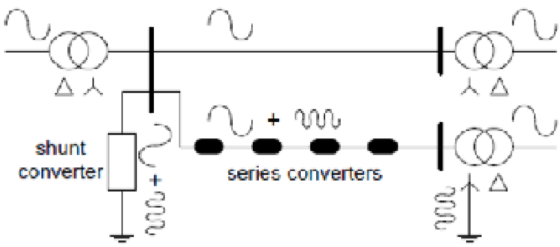

Fig 6: Route the harmonic current by using the grounding of the Y-_ transformer

III. DPFC CONTROL

The DPFC has three control strategies: central controller, series control, and shunt control, as shown in Fig. 7. A. Central Control This controller manages all the series and shunt controllers and sends reference signals to both of them. B. Series Control Each single-phase converter has its own series control through the line. The controller inputs are series capacitor voltages, line current, and series voltage reference in the d-q frame. The block diagram of the series converters in Matlab/Simulink environment is demonstrated in Fig. 8.

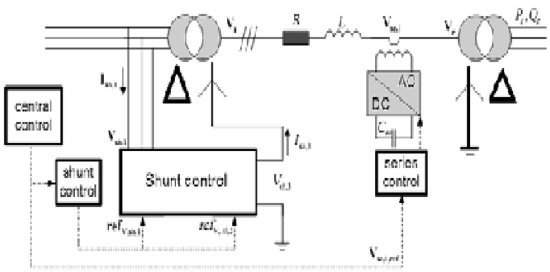

Fig 7 DPFC control structure

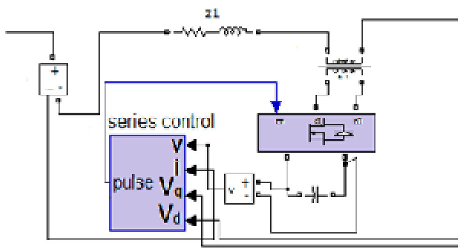

Fig. 8 Block diagram of the series converters in Matlab/Simulink

Series control structure

Any series controller has a low-pass and a 3rd-pass filter to create fundamental and third harmonic current, respectively. Two single-phase phase lock loop (PLL) are used to take frequency and phase information from network. The block diagram of series controller in Matlab/Simulink is shown in Fig. 9. The PWM-Generator block manages switching processes.

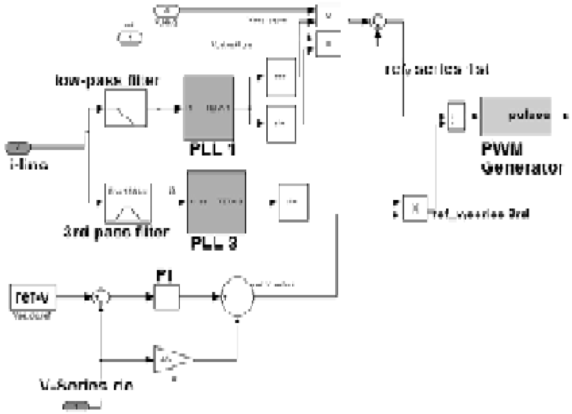

Fig. 9 Block diagram of series control structure in Matlab/Simulink

Shunt Control

The shunt converter includes a three-phase converter connected back-to-back to a single-phase converter. The three-phase converter absorbs active power from grid at fundamental frequency and controls the dc voltage of capacitor between this converter and single-phase one. Other task of the shunt converter is to inject constant third-harmonic current into lines through the neutral cable of Δ-Y transformer.Each converter has its own controller at different frequency operation (fundamental and third-harmonic frequency). The shunt control structure block diagram is shown in Fig. 10.

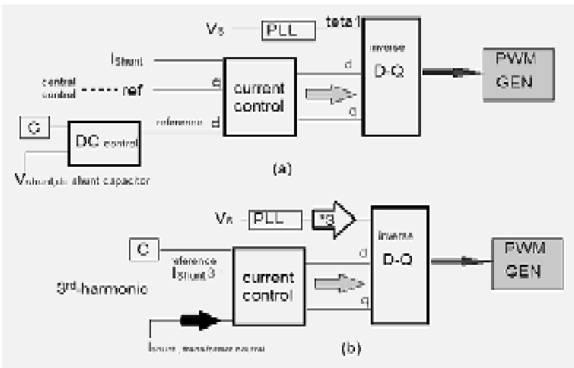

Fig. 10. The shunt control configuration
(a) for fundamental frequency
(b)for third-harmonic frequency

Advantages and Limitation of the DPFC

The DPFC can be considered a UPFC that employs the D-FACTS concept and the concept of exchanging power through the 3rd harmonic. In this way, the DPFC inherits all their advantages:

• **High controllability:** the DPFC can simultaneously control all the parameters of the transmission network: line impedance, transmission angle and bus voltage.

• **High reliability:** the redundancy of the series converter gives high reliability with-out increasing cost. In addition, the shunt and series converters are independent and failure of one will not influence the other converters.

Low cost: there is no phase-to-phase voltage isolation required between the series converters of different phases. The power rating of each converter is also low. Because of the large number of the series converters, they can be manufactured in series production. If the power system is already equipped with the STATCOM, the system can be updated to the DPFC with only low additional costs.

IV. POWER QUALITY IMPROVEMENT

The whole model of system under study is shown in Fig. 11. The system contains a three-phase source connected to a nonlinear RLC load through parallel transmission lines (Line 1 and Line 2) with the same lengths. The DPFC is placed in transmission line, which the shunt converter is connected to the transmission line 2 in parallel through a Y-Δ three-phase transformer, and series converters is distributed through this line.

The system parameters are listed in appendix TABLE I. To simulate the dynamic performance, a three-phase fault is considered near the load. The time duration of the fault is 0.5 seconds (500-1000 millisecond). As shown in Fig. 8, a significant voltage sag is observable during the fault, without any compensation. The voltage sag value is about 0.5 perunit.After adding a DPFC, load voltage sag can be mitigated effectively, as shown in Fig 13.

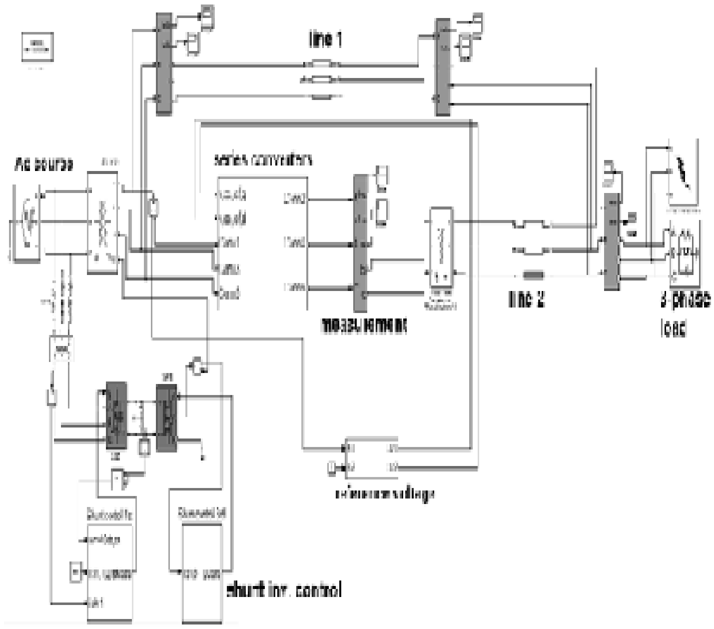

Fig.11 Simulation model of the DPFC

V. SIMULATION RESULTS

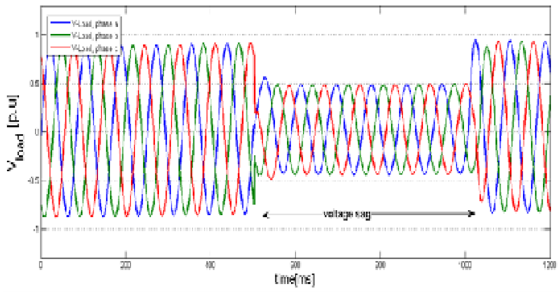

Fig 12 Three-phase load voltage sag waveform without DPFC

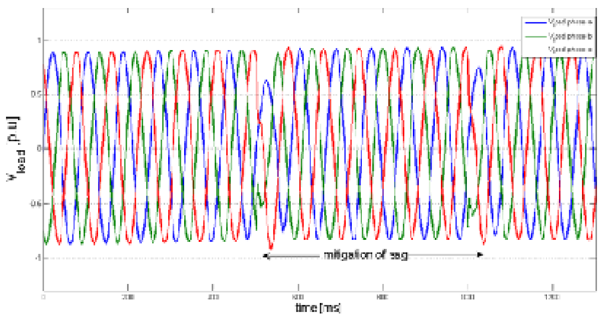

Fig.13 Mitigation of three-phase load voltage sag with DPFC

Fig 14 depicts the load current swell about 1.1 per- unit, during the fault. After implementation of the DPFC, the load current swell is removed effectively. The current swell mitigation for this case can be observed from Fig. 15

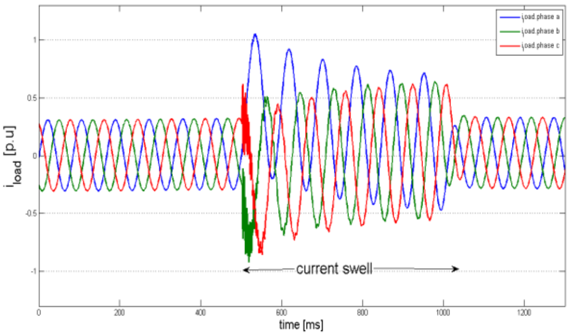

Fig. 14 Three-phase load current swell waveform without DPFC

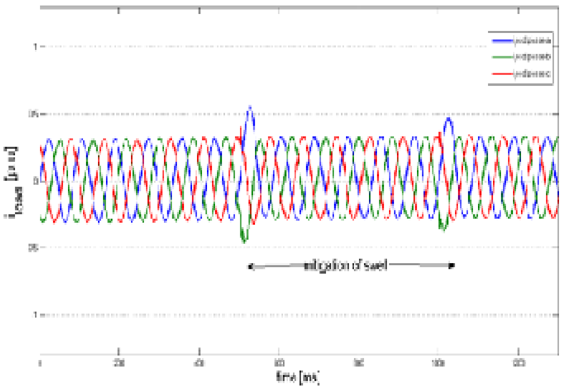

Fig. 15. Mitigation of three-phase load current swell with DPFC

The load voltage harmonic analysis without presence of DPFC is illustrated in Fig. 16. It can be seen, after DPFC implementation in system, the even harmonics is eliminated, the odd harmonics are reduced within acceptable limits, and total harmonic distortion (THD) of load voltage is minimized from 45.67 to 0.65 percentage (Fig. 17), i.e., the standard THD is less than 5 percent in IEEE standards.

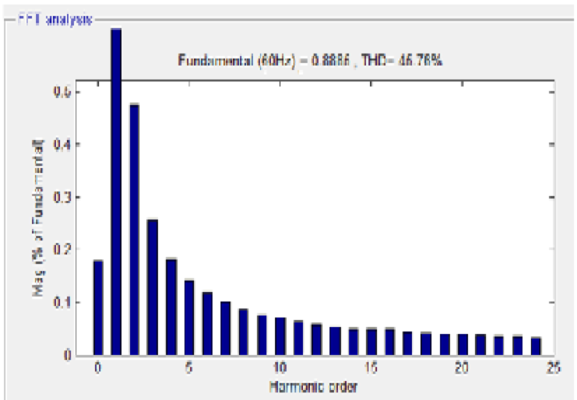

Fig. 16 Total harmonic distortion of load voltage without DPFC

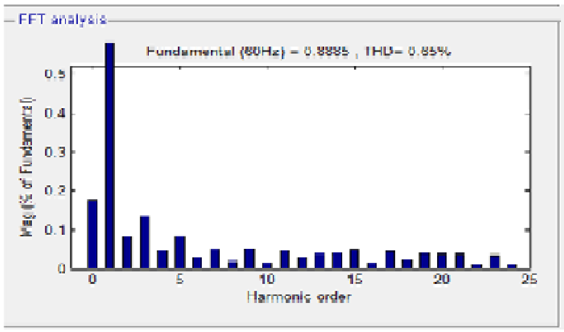

Fig. 17 Total harmonic distortion of load voltage with DPFC

VI. CONCLUSION

This paper has presented a new concept called DPFC. The DPFC emerges from the UPFC and inherits the control capability of the UPFC, which is the simultaneous adjustment of the line impedance, the transmission angle, and the bus-voltage magnitude. The common dc link between the shunt and series converters, which is used for exchanging active power in the UPFC, is eliminated. This power is now transmitted through the transmission line at the third-harmonic frequency. The series converter of the DPFC employs the D-FACTS concept, which uses multiple small single-phase converters instead of one large-size converter. The reliability of the DPFC is greatly increased because of the redundancy of the series converters. The total cost of the DPFC is also much lower than the UPFC, because no high-voltage isolation is required at theseries-converter part and the rating of the components of is low. To improve power quality in the power transmission system, there are some effective methods. In this project, the voltage sag and swell mitigation, using a new FACTS device called distributed power flow controller (DPFC) is presented. The DPFC structure is similar to unified power flow controller (UPFC) and has a same control capability to balance the line parameters, i.e., line impedance, transmission angle, and bus voltage magnitude. However, the DPFC offers some advantages, in comparison with UPFC, such as high control capability, high reliability, and low cost. The DPFC is modeled and three control loops, i.e., central controller, series control, and shunt control are design. The system under study is a single machine infinite-bus system, with and without DPFC. To simulate the dynamic performance, a three-phase fault is considered near the load. It is shown that the DPFC gives an acceptable performance in power quality mitigation and power flow control

APPENDIX

TABLE I. Simulation System Parameter
Parameters with values
Three phase source
- Rated voltage= 230 kV
- Rated power/Frequency =100MW/60HZ
- X/R= 3
- Short circuit capacity= 11000MW

Transmission line
- Resistance= 0.012 pu/km
- Inductance/ Capacitance reactance =0.12/0.12pu/km
- Length of transmission line =100 km

Shunt Converter 3-phase
- Nominal power =60 MVAR
- DC link capacitor =600 μF

Coupling transformer (shunt)
- Nominal power =100 MVA
- Rated voltage =230/15 kV

Series Converters
- Rated voltage =6 kV
- Nominal power= 6 MVAR

Three-phase fault
- Type ABC-G
- Ground resistance =0.01ohm

REFERENCES

[1]. S. Masoud Barakati, Arash Khoshkbar Sadigh and Ehsan Mokhtarpour,"Voltage Sag and Swell Compensation with DVR Based onAsymmetrical Cascade Multicell Converter" , North American PowerSymposium (NAPS), pp.1 – 7, 2011

[2]. Alexander Eigels Emanuel, John A. McNeill "Electric Power Quality".*Annu. Rev. Energy Environ* 1997, pp. 263-303.

[3]. I Nita R. Patne, Krishna L. Thakre "Factor Affecting Characteristics Of Voltage Sag Due to Fault in the Power System" *Serbian Journal OfElectrical engineering.* vol. 5, no.1, May2008, pp. 171-182

[4]. J. R. Enslin, "Unified approach to power quality mitigation," *in Proc.IEEE Int. Symp. Industrial Electronics* (ISIE '98), vol. 1, 1998, pp. 8–20.

[5]. B. Singh, K. Al-Haddad, and A. Chandra, "A review of active filters for power quality improvement," *IEEE Trans. Ind. Electron*. vol. 46, no. 5,pp. 960–971, 1999.

[6]. M. A. Hannan and Azah Mohamed, member IEEE, " PSCAD/EMTDC Simulation of Unified Series-Shunt Compensator for Power Quality Improvement", *IEEE Transactions on Power Delivery*, vol. 20, no. 2, April 2005.

[7]. A. L. Olimpo and E. Acha, "Modeling and analysis of custom power systems by PSCAD/EMTDC," *IEEE Trans. Power Delivery*, vol. 17, no.1, pp. 266–272, Jan. 2002.