International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

An Analysis of Case Study Utilizing Distributed Power Flow Controllers Which Improves and Mitigates Power Quality

Mrs. Naga Sowjanya Palety[1], Dr. Anurag S D Rai[2]

[1]PhD Scholar in Electrical & Electronics Engineering Department, Lakshmi Narain college of Technology, LNCT University, Bhopal, India
[2]Associate Professor and HOD in Department of Electrical Engineering, Lakshmi Narain college of Technology, LNCT University, Bhopal, India

Abstract

Providing high-quality electrical power should be taken into consideration in light of the rising demand for electricity and the rise in non-linear loads in power systems. This research examines power quality concerns related to voltage sag and swell and uses a distributed power flow controller (DPFC) to reduce voltage deviation and enhance power quality. A novel FACTS device, the DPFC shares structural similarities with the unified power flow controller (UPFC). Despite UPFC, DPFC separates the three-phase series converter into many single-phase series dispersed converters via the line and removes the common dc-link between the shunt and series converters. A DPFC located in a single-machine infinite bus power system with two parallel transmission lines is included in the case study. The MATLAB/Simulink environment was used to model the system. The simulation findings that are shown confirm that DPFC may raise power quality.

Index Terms: Distributed Power Flow Controller, Power Quality, Sag and Swell Mitigation, FACTS.

I. Introduction (Heading 1)

Power companies' primary priority over the past ten years has been electrical power quality [1]. The metric that measures how electric power supply and consumption impact electrical equipment performance is known as power quality [2]. Any issue that shows up as a voltage, current, or frequency variation that causes a power outage might be considered a power quality issue from the perspective of the customer [3]. Power quality enhancement is impacted by power electronics advancement, particularly in bespoke power devices and flexible alternating-current transmission systems (FACTS) [4], [5]. Custom power devices, such as dynamic voltage restorers (DVRs), are typically employed to enhance consumer power quality at medium-to-low voltage levels [6]. In electrical grids, voltage sags (voltage drop) and swells (excess voltage) pose the greatest risks to sensitive equipment [1]. These disruptions can be caused by a variety of things, such as a grid short circuit, inrush currents that happen when big machinery is beginning, or grid switching procedures. To reduce disruptions and enhance the quality and dependability of the power system, FACTS devices such synchronous static compensators (STAT-COM) and unified power flow controllers (UPFC) are employed [7], [8].In order to reduce voltage and current waveform deviation and enhance power quality in a matter of seconds, this study uses a distributed power flow controller, which was first presented in [9] as a novel FACTS device. The UPFC structure, which includes a single shunt converter and several tiny independent series converters, provides the basis for the DPFC structure, as seen in Fig. 1 [9]. Line characteristics, such as line impedance, transmission angle, and bus voltage magnitude, may be balanced by the DPFC just as well as by the UPFC [10].The structure of the paper is as follows: The DPFC concept is covered in section II. Section III provides a description of the DPFC control. Section IV is devoted to DPFC's efforts to enhance electricity quality. Section V presents the findings of the simulation.

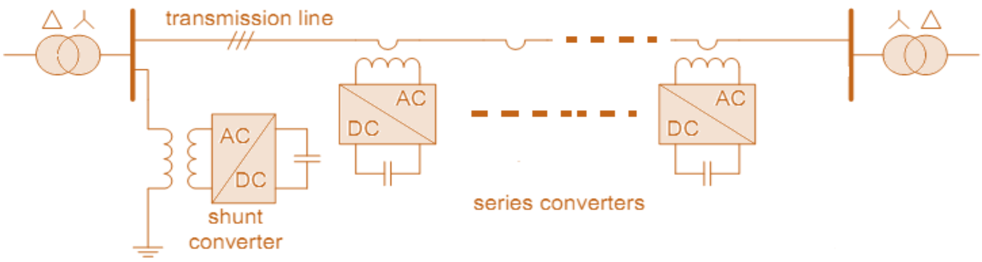

Fig. 1. The DPFC Structure

I. The DPFC Principle

The primary benefit of DPFC over UPFC is the removal of the large DC-link and the use of third-harmonic current for active power exchange [9]. The fundamental ideas of DPFC are described in the next subsections.

A. Disable Power Exchange and DC Link Instead of utilizing a direct connection with a DC-link to interchange power across converters, the DPFC uses a transmission line to connect the DC terminal of a shunt converter to the AC terminal of series converters. The power theory of non-sinusoidal components serves as the foundation for the DPFC power exchange technique [9]. A non-sinusoidal voltage or current can be represented as the sum of sinusoidal components at various frequencies using Fourier series.

The active power is the result of the product of the voltage and current components. The active power equation is as follows since the integral of some components with various frequency is zero.

$$p = \sum_{i=1} V_i I_i \cos \varphi_i$$

where φi is the angle between the voltage and current at the same frequency, and Vi and Ii are the voltage and current at the ith harmonic, respectively. The active power at various frequency components are independent and expressed by equation (1).

Because of this, a DPFC shunt converter may provide output power at one frequency while absorbing active power at another. Suppose, as illustrated in Fig. 1, that a DPFC is installed in a two-bus system's transmission line. The shunt converter may absorb power in the fundamental frequency of current, while the power source produces the active power. At the same time, the Y-Δ transformer traps the third harmonic component. The third harmonic current is injected into the Δ-Y transformer's neutral via the shunt converter's output terminal (Fig. 3). As a result, the transmission line experiences the harmonic current. The DC voltage of series capacitors is regulated by this harmonic current.

The active power exchange between the DPFC's shunt and series converters is shown in Fig. 2. A high-pass filter is necessary to create a closed loop for the harmonic current, and the third harmonic is chosen to swap the active power in the DPFC. The transformer's Δ-winding traps the third-harmonic current. As a result, the high-pass filter at the system's receiving end is not required. In other words, a wire that is linked between the transformer's Δ-winding and ground can be used in place of the high-pass filter when the third harmonic is used. The harmonic current is directed to ground by this wire.

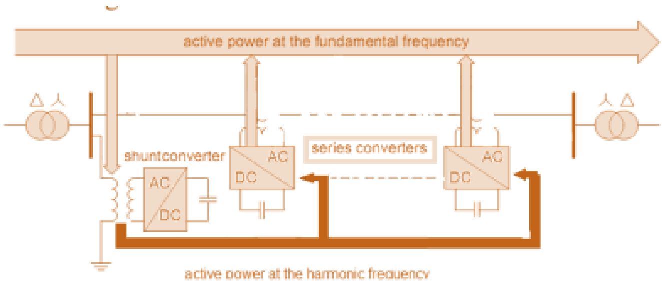

Fig. 2.Active power exchange between DPFC converters

B. The Benefits of DPFC

When compared to UPFC, the DPFC offers the following benefits:

Excellent Control Ability

Like UPFC, DPFC has the ability to regulate every transmission network characteristic, including bus voltage magnitude, transmission angle, and line impedance.

Exceptional Dependability

Redundancy in series converters improves DPFC dependability while the converters are operating [10]. It implies that the other converters in the series can still function even if one fails.

Affordable

Three-phase converters have a higher rating than single-phase series converters. Additionally, the series converters may be hung using single-turn transformers and do not require high voltage isolation in transmission line connection.

II. DPFC MANAGEMENT

Within Figure 3, the DPFC utilizes three control strategies: shunt control, series control, and central controller.

A. Add two line breaks where necessary. Central Authority All shunt and series controllers are managed by this controller, which also supplies them with reference signals. Please add line breaks where needed in the following text.

B. Control in Series Through the line, each single-phase converter is equipped with its individual series control. The controller's inputs consist of the line current, series voltage reference in the dq-frame, and series capacitor voltages. Fig. 4 presents the block diagram of the series converters in the Matlab/Simulink environment.

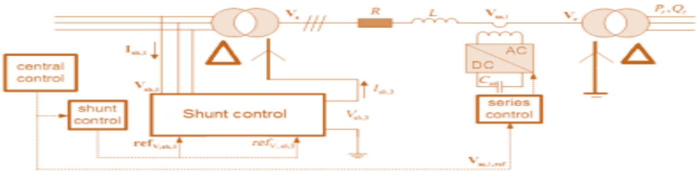

Fig. 3. DPFC control structure

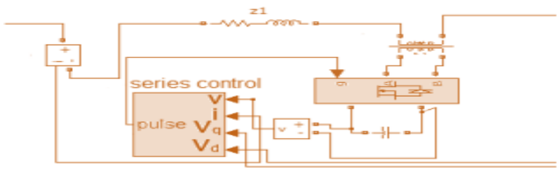

Fig. 4. Block diagram of the series converters in Matlab/Simulink

Equations

A low-pass and a third-pass filter are built into any series controller to produce the fundamental and third harmonic currents, respectively. Frequency and phase information are extracted from networks using two single-phase phase lock loops (PLL) [11]. Fig. 5 displays the block diagram of the series controller in Matlab/Simulink. Switching operations are controlled by the PWM-Generator block.

C. Shunt Management

The shunt converter consists of a three-phase converter that is coupled to a single-phase converter back-to-back. Between this converter and a single-phase one, the three-phase converter regulates the dc voltage of the capacitor and absorbs active power from the grid at a fundamental frequency. Injecting a steady third-harmonic current into lines via the Δ-Y transformer's neutral wire is another function of the shunt converter.

IV. Enhancement of Power Quality:

Fig.5 : displays the entire system model that is being studied. Through parallel transmission lines (Lines 1 and 2) of the same length, the system's three-phase source is connected to a non-linear RLC load. The DPFC is placed within a transmission line. Series converters are then distributed throughout it. A Y-Δ three-phase transformer is connected to the shunt converter, which in turn is connected in parallel to transmission line 2. Appendix TABLE I presents a list of the system parameters. A three-phase fault is considered near the load to accurately represent the dynamic performance. The issue endures for 0. 5 seconds, or 500–1000 milliseconds. An evident voltage sag is observed during the fault, as illustrated in Fig.Please, add a line break before "8. " with two br tags.

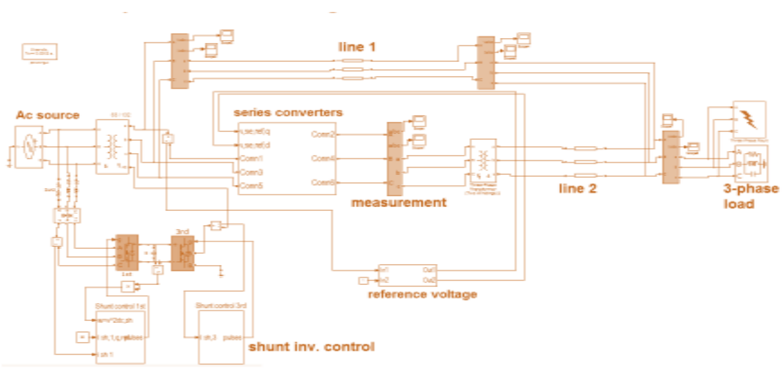

Fig. 7. Simulation model of the DPFC

Fig 5

TABLE I: Simulation System Parameters

Parameters	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
Continue of Table I :	
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

V. EXAMINING SIMULATION RESULTS

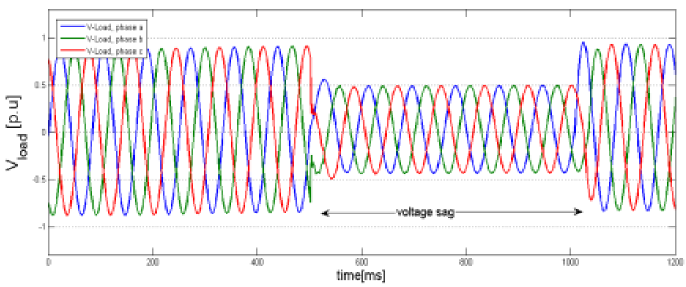

Fig. 8. Three-phase load voltage sag waveform

Fig 6

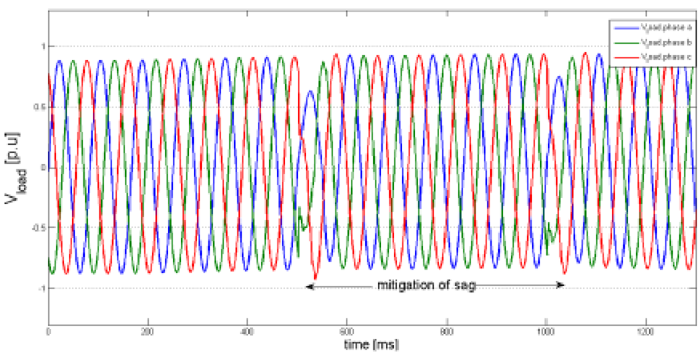

Fig. 9. Mitigation of three-phase load voltage sag with DPFC

Fig 7

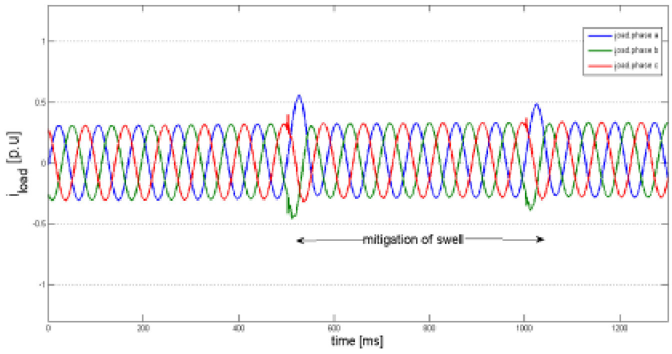

Fig. 11. Mitigation of three-phase load current swell with DPFC

Fig 8

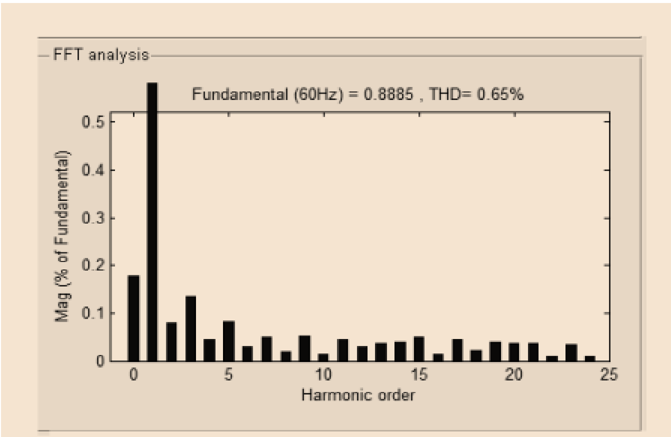

Fig. 13. Total harmonic distortion of load voltage with DPFC

Fig 9

Figure 9: shows the harmonic analysis of the load voltage in the absence of DPFC. After DPFC is implemented in the system, it is evident that the even harmonics are removed, the odd harmonics are reduced to acceptable levels, and the load voltage's total harmonic distortion (THD) is reduced from 45.67 to 0.65 percent meaning that the IEEE standard THD is less than 5 percent.

VI. CONCLUSION

There are a few efficient ways to raise the power transmission system's power quality. This research presents a novel FACTS device dubbed the distributed power flow controller (DPFC) for mitigating voltage sag and swell. The unified power flow controller (UPFC) and the DPFC have a similar structure and control capacity for balancing the line characteristics, such as bus voltage magnitude, transmission angle, and line impedance. In contrast to UPFC, the DPFC has a few benefits, including low cost, great dependability, and strong control capabilities. Three control loops—central controller, series control, and shunt control—are designed and the DPFC is modeled. The system being studied is an infinite-bus single machine system, both with and without DPFC.A three-phase fault is taken into consideration close to the load in order to model the dynamic performance. It is demonstrated that the DPFC performs satisfactorily in terms of power flow control and power quality mitigation.

References

1. 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.
2. P. Pohjanheimo and E. Lakervi, "Steady state modeling of custom power components in power distribution networks," in Proc. IEEE Power Engineering Society Winter Meeting, vol. 4, Jan. 2000, pp. 2949–2954.
3. Zhihui Yuan, Sjoerd W.H de Haan, Braham Frreira and Dalibor Cevoric "A FACTS Device: Distributed Power Flow Controller (DPFC)" IEEE Transaction on Power Electronics, vol.25, no.10, October 2010.
4. Zhihui Yuan, Sjoerd W.H de Haan and Braham Frreira "DPFC control during shunt converter failure" IEEE Transaction on Power Electronics 2009.
5. R. Zhang, M. Cardinal, P. Szczesny and M. Dame. "A grid simulator with control of single-phase power converters in D.Q rotating frame", Power Electronics Specialists Conference, IEEE 2002.
6. J. R. Enslin, "Unified approach to power quality mitigation," in Procedure IEEE Int. Symp. Industrial Electronics (ISIE '98), vol. 1, 1998, pp. 8–20.
7. 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.
8. 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.
9. Alexander Eigels Emanuel, John A. McNeill "Electric Power Quality". Annu. Rev. Energy Environ 1997, pp. 263-303.
10. S. Masoud Barakati, Arash Khoshkbar Sadigh and Ehsan Mokhtarpour, "Voltage Sag and Swell Compensation with DVR Based on Asymmetrical Cascade Multicell Converter" , North American Power Symposium (NAPS), pp.1 – 7, 2011.
11. Song, YH & Johns, A 1999, 'Flexible AC Transmission Systems (FACTS)', IEE Power and Energy Series, London, U.K.: Institution of Electrical Engineers, vol. 30.
12. Sozer, Y & Torrey, DA 2009, 'Modelling and control of utility interactive inverters,' IEEE Trans. Power Electron, vol. 24, no. 11, pp. 2475-2483.
13. Sugeno, M & Kang, GT 1988, 'Structure Identification of Fuzzy Model', Journal of Fuzzy Sets and Systems, vol. 28, no. 1, pp. 15-33.
14. Thanawala, L.Williams, WP & Young, DJ 1979, 'Static Reactive Compensators for Ac Power Transmission - 10 Years Operational Experience with Saturated Reactors', Gec-Journal of Science and Technology.
15. Toliat, HA, Sadeh, J & Ghazi, R 1996, 'Design of augmented fuzzy logic power system stabilizers to enhance power system stability', IEEE Trans. Energy Convers, vol. 11, no. 1, pp. 97-103.
16. Uday Kishan Renduchintala, Chengzong Pang, Satya Veera Pavan, Kumar Maddukuri & Visvakumar Aravinthan 2016, 'Smooth shunt control of a fuzzy based distributed power flow controller to improve power quality, Information and Automation for Sustainability (ICIAfS)', IEEE International Conference on Galle, Sri Lanka.
17. Verma, K. Srividya, A & Deka, BIC 2004, 'Impact of a FACTS controller on reliability of composite power generation and transmission system', Electric Power Systems Research.

18. Vijaya Krishna, B, Venkata Prashanth, B & Anjaneyulu, KSR 2016, 'Designing of multilevel DPFC to improve power quality, Electrical Electronics, and Optimization Techniques', (ICEEOT) International Conference on Chennai India.
19. Wenchao Song, H. Xiaohu Zhou, Zhigang Liang, Subhashish Bhattacharya & Alex Huang, Q 2009, 'Modeling and Control Design of Distributed Power Flow Controller based-on Per-phase control', IEEE Energy Conversion Congress and Exposition, pp. 3262-3267.
20. Yuan, de Haan & Ferreira, JA, 'Control Scheme to Improve DPFC Performance during Series Converter Failures', IEEE PES General Meeting, pp. 1-6.
21. Yuan, Z, de Haan, SWH & Ferreira, B 2007, 'A new facts component: Distributed power flow controller (DPFC)', in Power Electronics and Applications, European Conference, pp.1-4.
22. Zhang M Cardinal, Szczesny, P & Dame, M 2002, 'A grid simulator with control of single-phase power converters in D.Q rotating frame', Power Electronics Specialists Conference, IEEE.
23. Zhang, XP, Rehtanz, C & Pal, B 2006, 'Flexible AC transmission systems modelling and control', Springer.
24. Zhengyu Huang, Yixin, Ni, Shen, CM, Felix F Shousun, Chen Wu & Baolin Zhang 2000, 'Application of Unified Power Flow Conmlla in Interconnected Power Systems-Modelling, Interface. Conml Strategy, and Case Study', IEEE Transactions on Power System, vol. 15, no. 2, pp. 817-824.
25. I Nita R. Patne, Krishna L. Thakre "Factor Affecting Characteristics of Voltage Sag Due to Fault in the Power System" Serbian Journal of Electrical engineering. vol. 5, no.1, May2008, pp. 171-182.