Power Quality Improved based on Hysteresis using DPFC

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Abstract: This paper represents a Distributed Power Flow Controller (DPFC) system. The main objective of this paper is to grow a power flow controlling system that offers that same capability as the UPFC, at a reduced cost with increased reliability. The DPFC is derived from the UPFC and DPFC has that same control capability as the UPFC structure, is used to mitigate the voltage sag and voltage swell as a power quality issue. Different UPFC, the common dc-link in Distributed Power Flow Controller, the series converters is eliminated three-phase series converter is divided to many single-phase series distributed converters through line. It's detected the voltage sags and determines the three single-phase reference voltages of DPFC, the hysteresis pulse width modulation method is proposed. Application of Distributed Power Flow Controller in power quality improvement is simulated in Matlab environment which show the effectiveness of the proposed structure.

Keyword: Hysteresis pulse width modulation, power quality, DPFC

I. INTRODUCTION

Present days the power system becomes very complex issues due to the rising load demand of the electricity and the aging of the power system networks. There is a grand need for the power flows manage in the transmission lines with reliability and fast operation [1]. All the flexible ac transmission devices can be used for the control of power flow in the transmission system. Unified Power Flow Controller is one of power flow controller in the flexible ac transmission system family, its can control the both transmission bus voltage, transmission angle and line impedance [2].The Unified Power Flow Controller having both the shunt converter and series converter with a commonly coupled with DC link is used for bidirectional power flow system. The series converter inserting the voltage into the bus causes the reactive and active power injection or absorption between transmission line and the series converter. The devices used in UPFC with current and voltage rating.

The Distributed Power Flow Controller is one of the important device with in FACTS family, which is derived from the UPFC. As compared with the Unified Power Flow Controller, Distributed Power Flow Controller has the same controlling capability to change all the parameters within the transmission bus system. In case of Distributed Power Flow Controller the commonly connected DC link between shunt and series is eliminated and application of DFACTS[3] concept to series converter shown in Fig.(a).The active power swap between the series and shunt converters is at third order harmonic frequency. The D-FACTS theory not only reduces the ratings but also develop the reliability of the system and reducing the cost of high voltage isolation. The paper arranged of follow: section II describes the DPFC operation principle. In Section III, the control strategy of DPFC based on hysteresis pulse width modulation method is proposed. The impact of DPFC in power quality enhancement is investigated in Section IV. Finally, simulation results are analyzed in the last part of this work.

II. DPFC STRUCTURE

The basic issues in DPFC principle are DC-link elimination and using 3rd-harmonic current to active power exchange. In the next subsections, the DPFC basic concept is explained.

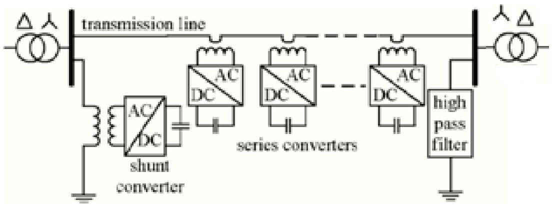

Fig. 1. DPFC structure.

A. *Power Exchange and Eliminate DC-Link*

Within the DPFC, the transmission line is worn as a connection between shunt converter output and AC port of series converters, instead of using DC-link for power exchange between converters. The method of power exchange in DPFC is based on power theory of non-sinusoidal components [9]. Non-sinusoidal voltage and current can be presented as the sum of sinusoidal components at different frequencies. It is the main result of Fourier analysis. The product of voltage and current components provides the active power. Since the integral of some terms with different frequencies are zero, so the active power equation is as follow:

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

where *Vi* and *Ii* are the voltage and current at the *ith* harmonic frequency, respectively, and *φi* is the angle between the voltage and current at the same frequency. Equation. 1 expresses the active powers at different frequencies are independent from each other's. Thus, the converter can absorb the active power in one frequency and generates output power in another frequency. Assume the DPFC is located in transmission line of a two-bus system; therefore, the power supply generates the active power and the shunt converter absorbs it in fundamental frequency of current. Meanwhile, the third harmonic component is trapped in Y-Δ transformer. Output terminal of the shunt converter injects the third harmonic current into the neutral of Δ-Y transformer. Consequently, the harmonic current flows through the transmission line. This harmonic current controls the dc voltage of series capacitors. Fig. 2 illustrates how the active power is exchanged between the shunt and series converters in the DPFC.

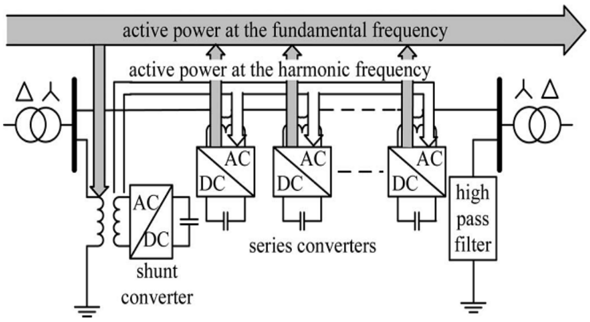

Fig. 2. Active power exchange between DPFC converters.

A. The DPFC Advantages

The DPFC in comparison with UPFC has some advantages, as follows:*1) High control capability*. The DPFC can control all parameters of transmission network: line impedance, transmission angle and bus voltage magnitude. *2) High reliability*. The series converters redundancy increases the DPFC reliability during converters operation [10]. It means, if one of series converters fails, the others can continue to work. *3) Low cost*. The single-phase converters rating, in comparison with three-phase converters is very low. Furthermore, the series converters, in this configuration, no need to any voltage isolation to connect in line. We can use the single turn transformers for series converters hanging. To explore the feasibility of the DPFC, a case study which is to use DPFC to replace UPFC of the Korea electric power corporation (KEPCO) is investigated. To achieve the same control capability as the UPFC, the DPFC construction requires less material [9].

III. DPFC CONTROL BASED ON HYSTERESIS PULSE WIDTH MODULATION METHOD

The DPFC has three control strategies: central controller, series control and shunt control, as shown in Fig. 3.

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. This controller inputs are series capacitor voltages, line current and series voltage reference in dq-frame. Any series controller has one low-pass and one 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 [11]. The simulated diagram of series controller is shown in Fig. 4

C. Shunt Control The shunt converter includes a three-phase converter which is back-to-back connected to a single-phase converter

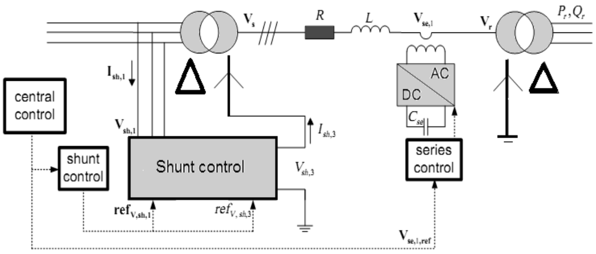

Fig. 3. DPFC control structure.

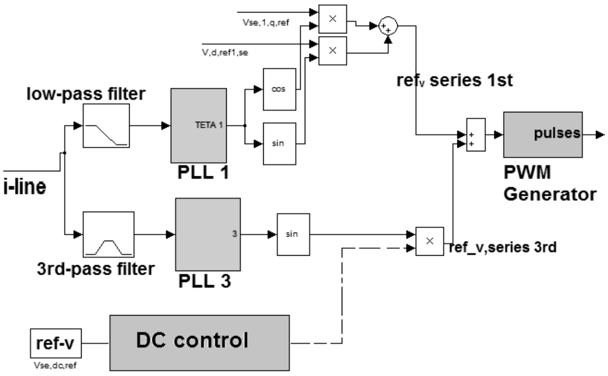

Fig. 4. The series control structure.

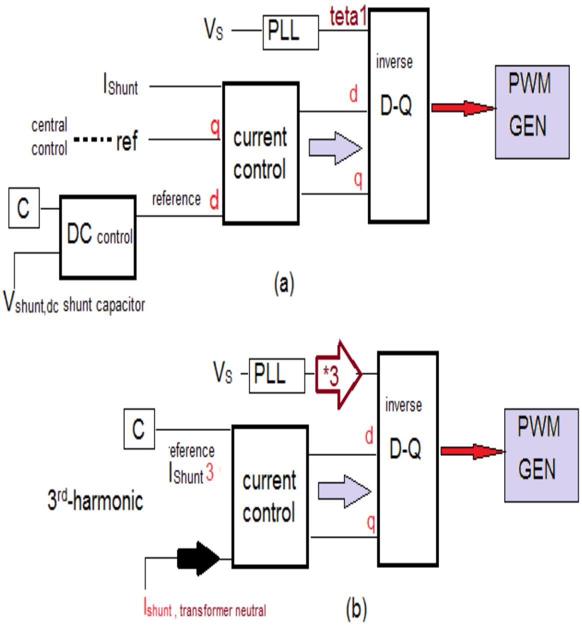

Fig. 5. The shunt control configuration: (a) for fundamental frequency (b) for third-harmonic frequency.

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. The shunt control structure block diagram is shown in Fig. 5.

D. Proposed Detection and Determination Methods

To detect the voltage sags and determine the three single phase reference voltages of DPFC, the Hysteresis Pulse Width Modulation method is introduced as a detection and determination method. The line-to-neutral voltages of grid in the pre-sag state are

$$V_{dpfc,d}^{ref} = V_{grid,d}^{ref} - V_{grid,d} \rightarrow (2)$$

$$V_{dpfc,q}^{ref} = V_{grid,q}^{ref} - V_{grid,q} \rightarrow (3)$$

Where $V_{dpfc,d}^{ref}$ and $V_{dpfc,q}^{ref}$ are the reference dq component of DPFC desired injected voltages in the HPWM, respectively

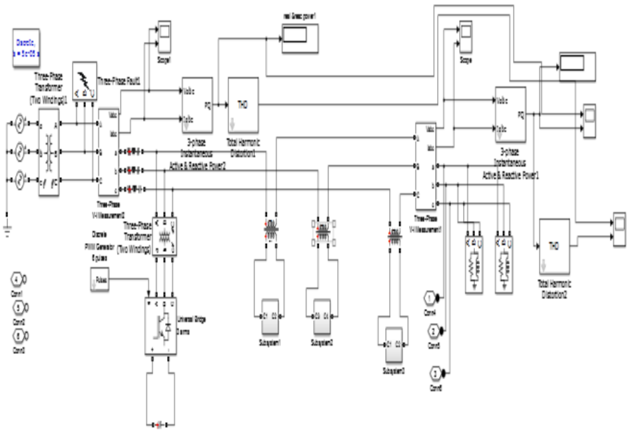

Fig. 6. Simulated model of the DPFC

Convicted from *abc* coordinate system to SRF (*dq0*) as the first step of this method. Then, the dq0 values of actual and reference line-neutral grid voltages are compared which the existence of the difference between them is representation of voltage sag and considered as the *dq0* values of DPFC desired injected voltages.

IV. POWER QUALITY ENHANCEMENT

This modeling has been developed using Matlab/Simulink environment as shown in Fig. 6. The system is simulated with a three-phase source connected to a non-linear load. The simulation parameters are listed in Table 1. The supply is connected to load through the parallel transmission lines including the transmission line 1 and 2. The parallel transmission lines have same length. The DPFC is incorporated in transmission line 2. For analyzing dynamic performance, the inductive and capacitive loads are connected. The fault should be connected near the load to receive transient analysis. The shunt three-phase converter is connected to the transmission line 2 in parallel through a Y-Δ three-phase transformer, and series converters are distributed through this line.

V. SIMULATION RESULTS AND DISCUSSION

The case study, considering sag/swell condition is implemented in single machine infinite bus system and analyzed results are as follows. To analyze voltage dip, a three-phase fault near the system load, as shown in Fig. 6 is created. The time duration for this fault is 0.5 seconds (500-1000 ms). The three-phase fault causes observable voltage sag during this time, as shown in Fig. 7. The voltage sag value is about 0.5 per unit. The DPFC can compensate the load voltage sag effectively. The voltage sag mitigation with DPFC is shown in Fig. 8. After creating three-phase fault, Fig. 9 depicts the load current swell around 1.1 per unit. The fault time duration is 0.5 seconds. In this case, after implementation of the DPFC, the load current magnitude is comparatively come down. The current swell mitigation for this case can be observed from Fig. 10. The load voltage harmonic analysis, using fast fourier transform (FFT) of power GUI window by Simulink, as shown in Fig. 11. It can be seen, after DPFC implementation in system, the odd harmonics are reduced within acceptable limits and total harmonic distortion (THD) of load voltage is minimized.

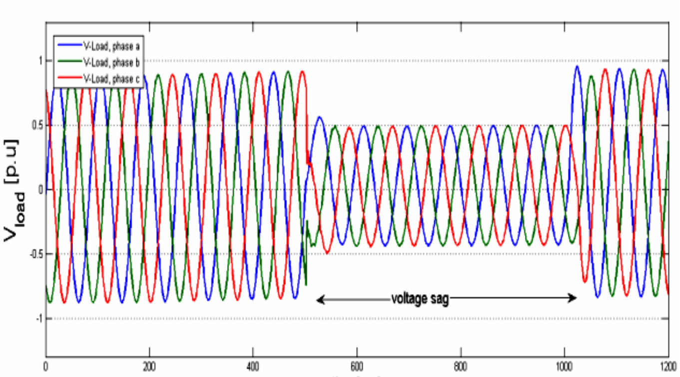

Fig. 7. Three-phase load voltage sag waveform.

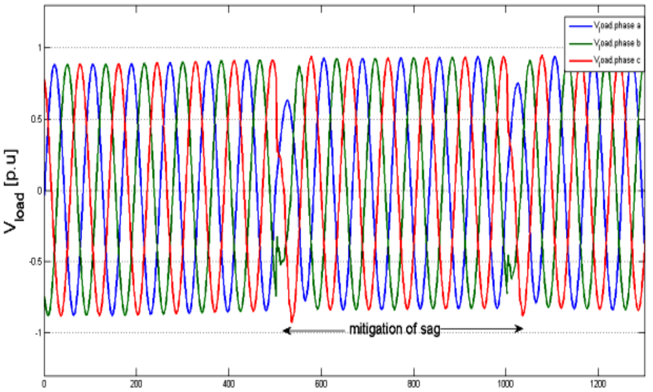

Fig. 8. Mitigation of three-phase load voltage sag with DPFC.

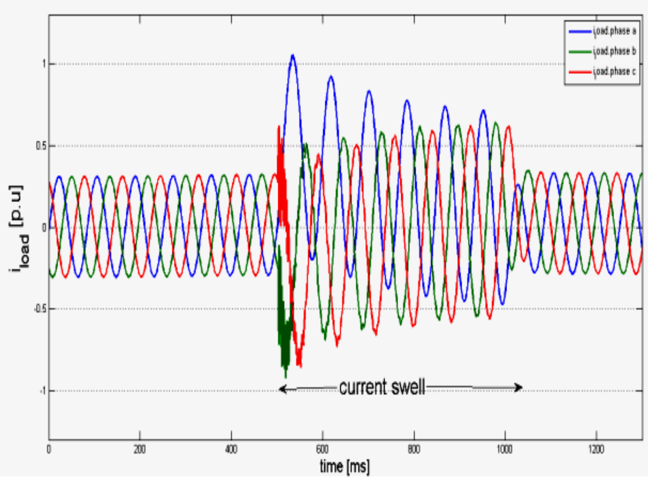

Fig. 9. Three-phase load current swell waveform.

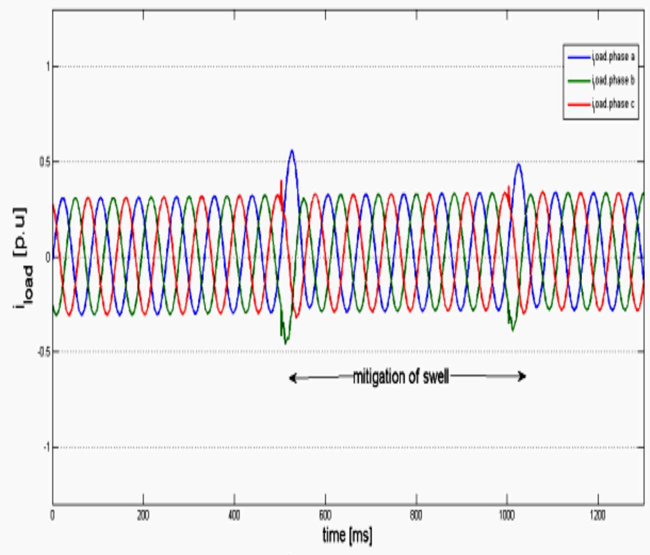

Fig. 10. Mitigation of load current swell with DPFC.

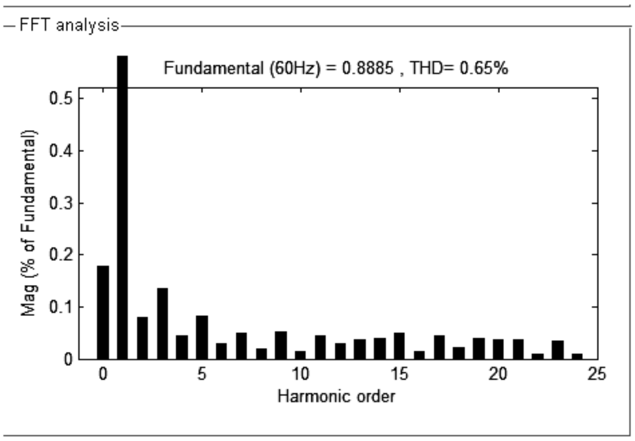

Fig. 11. The load voltage THD.

Table I: The simulation parameter

Parameters	**Values**
Rated Voltage	230kv
Rated Power / Frequency	100mw / 50hz
X /R	3
Short Circuit Capacity	11000 Mw
Transmission Line Parameter	
Resistance	0.012 Pu/Km
Inductance/Capacitance Reactance	0.12/0.12 Pu/Km
Length Of Transmission Line	100 Km

VI. CONCLUSION

The power quality enhancement of the power transmission systems is an vital issue in power industry. In this study, the application of DPFC as a new FACTS device, in the voltage sag and swell mitigation of a system composed of a three-phase source connected to a non-linear load through the parallel transmission lines is simulated in Matlab/Simulink environment. The voltage dip is analyzed by implementing a three-phase fault close to the system load. To detect the voltage sags and determine the three single phase reference voltages of DPFC, the HPWM method is used as a detection and determination method. The obtained simulation results show the effectiveness of DPFC in power quality enhancement, especially in sag and swell mitigation.

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