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Power Quality Improvement and Mitigation Case Study Using Distributed Power Flow Controller

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ABSTRACT

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 paper, 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, which simulated in MATLAB/Simulink environment. The presented simulation results validate the DPFC ability to improve the power quality.

Keywords : FACTS, Power Quality, Sag and Swell Mitigation, Distributed Power Flow Controller

I. INTRODUCTION

In the last decade, the electrical power quality issue has been the main concern of the power companies . Power quality is defined as the index which both the delivery of electrical apparatus [1].From a customer point of view, power quality problem can be defined as any problem is manifested on voltage, current, or frequency deviation that results in power failure [2]. The power electronics progressive, especially inflexible alternating current transmission and consumption of electric power affect on the performance system (FACTS) and custom power devices, affects power quality improvement [3], [4].Generally, custom power devices, e.g., dynamic voltage restorer (DVR),are used inmediumtolow voltage levels to improve customer power quality [5]. Most serious threats for sensitive equipment in electrical grids are voltage sags (voltage dip)and swells (over voltage) [1]These disturbances occur due to some events, e.g., short-circuit in the grid, inrush currents involved with the starting of large machines, or switching operations in the grid In this paper, a distributed power flow controller, introduced in [6]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 theUPFC structure that is included one shunt converter andseveral small independent series converters, as shown inFig.1.1The shunt converter is similar to the STATCOM whilethe series converter employs the DFACTS concept[6]TheDPFC has same capability as UPFC to balance the lineparameters, i.e., line impedance, transmission angle, and busvoltage magnitude [7].The paper is organized as follows: in section II, the DPFCprinciple isdiscussed. The DPFC control is described inspection III. Section IV is dedicated to power quality improvement by DPFC. Simulation results are presented insection V.

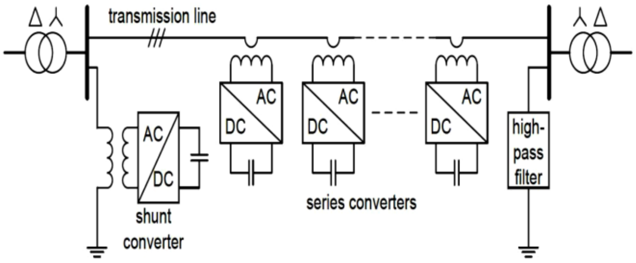

Figure 1. The DPFC Structure

II. METHODS AND MATERIAL

1. DPFC Principle

In comparison with UPFC, the main advantage offere d byDPFC is eliminating the huge DClink and instate using 3rdharmonic current to active power exchang e [6]. In thefollowing subsections, the DPFC bas ic concepts are explained.

A. Eliminate DC Link and Power Exchange

Within the DPFC, the transmission line is used a s aconnection between the DC terminal of shunt conv erter andthe AC terminal of series converters, inst ed of directconnection using DClink for power e xchange betweenconverters. The method of power exch ange in DPFC is basedon power theory of nonsinusoidal components [6]. Based onFourier series, a nonsinusoi dal voltage or current can bepresented as the sum o f sinusoidal components at differentfrequencies. The p roduct of voltage and current componentsprovides the active power. Since the integral of some termswith di fferent frequencies are zero, so the active powereq uation is as follow:

$$P= \sum_{i=1}^{\infty} V_i I_i \cos \varphi_i \ldots\ldots\ldots\ldots \quad (1)$$

Where Vi and Ii are the voltage and current at the ith harmonic,respectively, and φi is the angle between the voltage andcurrent at the same frequency. Equation (1) expresses theactive power at different frequency components is independent. The above equation (1) describes that the active power atdifferent frequencies is isolated from each other and thevoltage and current in one frequency has no influence on theactive power at other frequencies. so by this concept the shuntconverter in DPFC can absorb power from active the grid atthe fundamental frequency and inject the current back into thegrid at a harmonic frequency[9]. Based on this fact, a shuntconverter in DPFC can absorb the active power in onefrequency and generates output power in another frequency,and also according to the amount of active power required atthe fundamental frequency, the DPFC series convertergenerate the voltage at the harmonic frequency there byabsorbing the active power from harmonic components.Assume a DPFC is placed in a transmission line of a two-bus system, as shown in Fig.1. While the power supply generatesthe active power, the shunt converter has the capability toabsorb power in fundamental frequency of current. In thethree phase system, the third harmonic in each phase isidentical which is referred to as “zero sequence”. The zerosequence harmonic can be naturally blocked by Y-Δ transformer.

So the third harmonic component is trapped in Y-Δ transformer [6]. Output terminal of the shunt converter injectsthe third harmonic current into the neutral of ΔYtransformer. Consequently, the harmonic current flowsthrough the transmission line. This harmonic current controlsthe DC voltage of series capacitors. Fig. 2 illustrates how theactive power is exchanged between the shunt and seriesconverters in the DPFC. The thirdharmonic is selected toexchange the active power in the DPFC and a highpass filteris required to make a closed loop for the harmonic current.

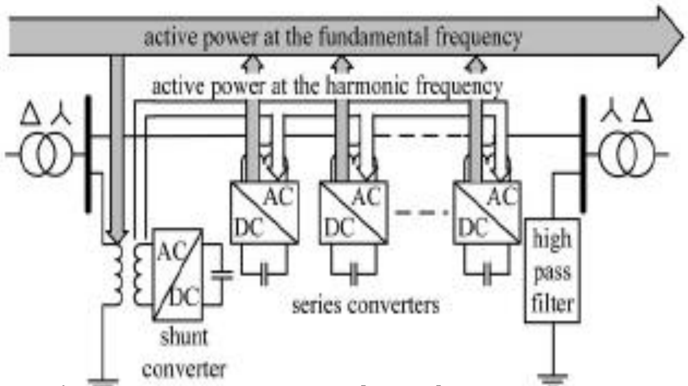

Figure 2. Active power exchange between DPFC convertes

B. The DPFC Advantages

The DPFC in comparison with UPFC has som eadvantages, as follows:

a) High Control Capability

The DPFC similar to UPFC, can control all parameters of transmission network, such as line impedance, trans mission angle, and bus voltage magnitude.

b) High Reliability

The series converters redundancy increases the DPF Creliability during converters operation [7]. It mens, if one ofseries converters fails, the others cancontinue to work.

c) Low Cost

The single-phase series converters rating are lower than one three-phase converter. Furthermore, the series converters do not need any high voltage isolation in transmission line connecting; singleurn transformers can be used to hang the series converters. Reference [6] reported a case study to explore the feasibility of the DPFC, where a UPFS is replaced with a DPFC in the Korea electric power corporation [KEPCO]. To achieve the same UPFC control capability, the DPFC construction requires less material [6].

2. DPFC Control

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

A. Central Control

This controller manages all the series and shunt controll ersand 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 seris capacitor voltages, line current, and series voltage reference in the dqframe. The block diagram of the series converters in Matlab/Simulink environment is demonstrated in Fig. 4.

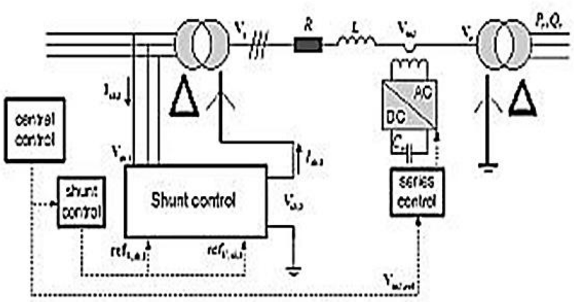

Figure 3. DPFC Control Structure

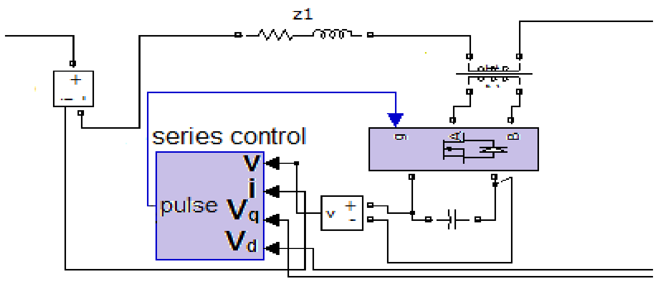

Figure 4. Block diagram of the series converters in Matlab/Simulink

Any series controller has a lowpass and a 3rdpass filter tocreate fundamental and third harmonic current, respectively.Two singlephase phase lock loop (PLL) are used to takefrequency and phase information from network[8].Theblock diagram of series controller in Matlab/ Simulink isshown in Fig. 5. The PWMGenerator block manages switching processes.

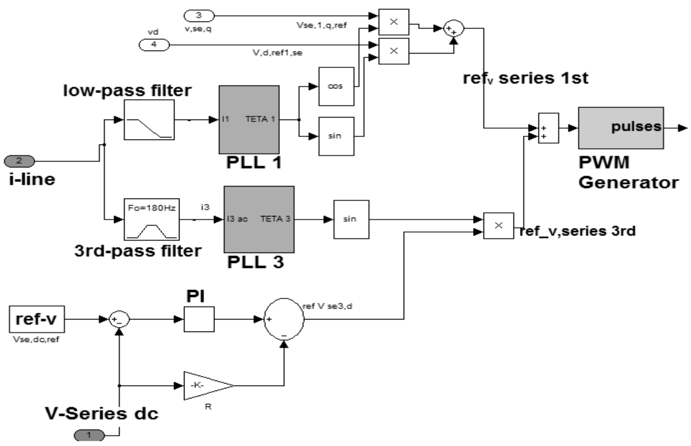

Figure 5. Block diagram of series control structure in Matlab/Simulink

C. Shunt Control

The shunt converter includes a threephase converterconnected backtoback to a singlephase converter. Thethreephase converter absorbs active power from grid atfundamental frequency and controls the dc voltage ofcapacitor between this converter and singlephase one. Othertask of the shunt converter is to inject constant thirdharmoniccurrent into lines through the neutral cable of Δ-Ytransformer.Each converter has its own controller at different frequencyoperation (fundamental and thirdharmonic frequency). Theshunt control structure blockdiagram is shon in Fig. 6.

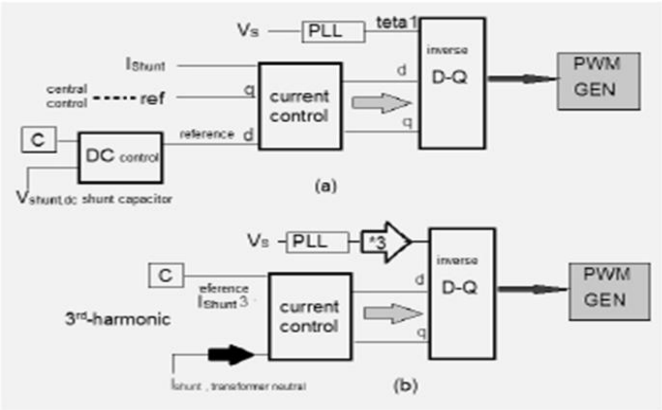

Figure 6. The shunt control configuration: (a) for fundam ental frequency (b) for third-harmonic frequency

III. RESULTS AND DISCUSSION

Power Quality Improvement

The system is in under study. The system contains a three-phase source connected to a nonlinear RLC load through parallel transmission lines with the same lengths. The DPFC is placed in transmission line, which the shunt converter is connected to the transmission line in parallel through a Y-Δ three-phase transformer, and series converters is distributed through this line. 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) [9][1]. As shown in Fig. 7, significant voltage sag is observable during the fault, without any compensation. The voltage sag value is about 0.5 per unit. After adding a DPFC, load voltage sag can be mitigated effectively, as shown in Fig. 8. [1][2]

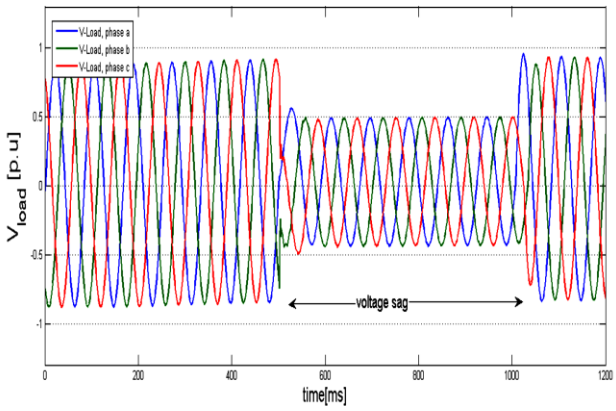

Figure 7. Three-phase load voltage sag waveform

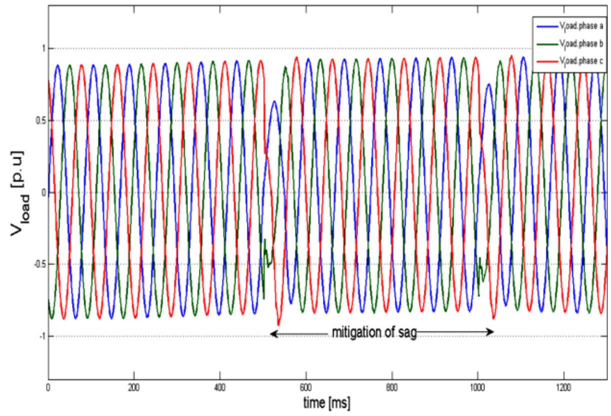

Figure 8: Mitigation of three phase load voltage sag with DPFC

Fig. 9 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. 10 [1].

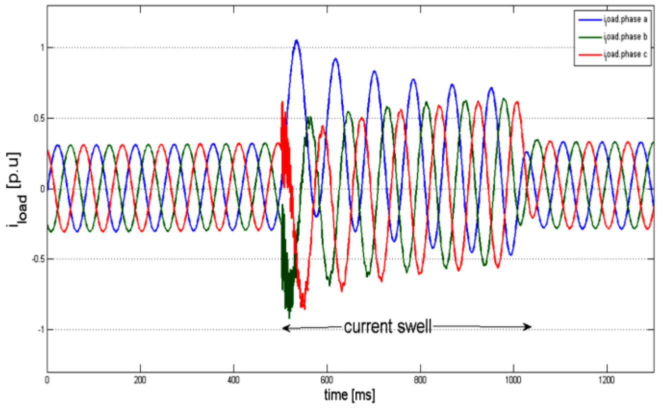

Figure 9 : Three Phase Load Current Swell Waveform Without DPFC

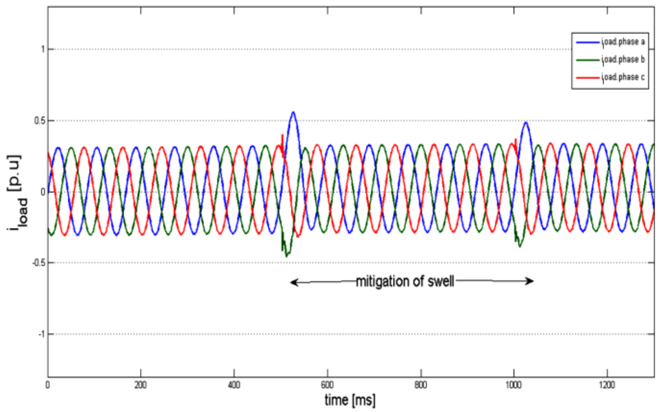

Figure 10 : Mitigation of three-phase load current swell with DPFC

To improve power quality in the power transmission system, there are some effective methods. In this paper, 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). It has a same control capability to balance the line parameters like transmission angle, line impedance and bus voltage magnitude. However, the DPFC has some advantages, as compare to UPFC, such as high reliability, high control capability and low cost. The DPFC is modelled 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. It is shown that the DPFC gives an acceptable performance in power quality mitigation and power flow control.

Table 1: Simulation system parameter

Parameter	Values
Three Phase Source	
Rated Voltage	220KV
Rated Power/ Frequency	100 MW/60Hz
X/R	3
Short Circuit Capacity	11000MW
Transmission Line	
Resistance	0.012 Pu/Km
Length of Transmission Line	100km
Shunt Converter 3-phase	
Nominal Power	60 MVAR
DC Link Capacitor	600 μF
Coupling Transformer (shunt)	
Nominal Power	100 MVA
Rated Voltage	220/15 KV
Series Converter	
Nominal Power	6 KVAR
Rated Voltage	6 KV
Three –phase Fault	
Type	ABC-G
Ground Resistance	0.01Ω

IV. CONCLUSION

The proposed payment system combines the Iris recognition with the visual cryptography by which customer data privacy can be obtained and prevents theft through phishing attack [8]. This method provides best for legitimate user identification. This method can also be implemented in computers using external iris recognition devices.

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