A Comparative Analysis of a Distributed Power Flow Controller to Enhance and Reduce Power Quality.

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Abstract: *Considering the rising demand for electricity and the growing number of non-linear loads in power networks, it is important to provide high-quality electrical power. The power quality problems of voltage sag and swell are examined in this research, and the distributed power flow controller (DPFC) is employed to reduce the voltage deviation and enhance power quality. Similar in form to the unified power flow controller (UPFC), the DPFC is a novel FACTS device. Despite UPFC, the three-phase series converter is split up into several single-phase series dispersed converters via the line, and the common dc-link between the shunt and series converters is removed in DPFC. The case study includes a DPFC that was simulated in a MATLAB/Simulink environment and was situated in a single-machine infinite bus power system with two parallel transmission lines. The simulation results that are displayed verify that DPFC may raise power quality.*

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

I. INTRODUCTION

The electrical power quality issue has been the power companies' top worry for the past ten years. The indicator of electrical equipment supply is known as power quality [1].Any issue that arises from a divergence in voltage, current, or frequency that causes power failure can be classified as a power quality issue from the perspective of the consumer [2]. Power quality improvement is impacted by the advancements in power electronics, particularly the rigid handling of urgent transmission and electric power consumption impact on the FACTS and bespoke power devices [3], [4]. Custom power devices, such as dynamic voltage restorers (DVRs), are often employed to improve consumer power quality at medium to low voltage levels [5]. The two biggest dangers to electrical networks' sensitive equipment are voltage sags, or dips, and swells (over voltage).

Various occurrences, such as a grid short circuit, inrush currents at the startup of big machinery, or grid switching procedures, might cause these disruptions. This study uses a distributed power flow controller, which was first presented in [6] as a novel FACTS device, to reduce voltage and current waveform deviation and enhance power quality in a matter of seconds. The DPFC structure is based on the UPFC structure, which has a single shunt converter and several tiny independent series converters, as seen in Fig. 1.1.The DFACTS idea is used in the series converter, whereas the shunt converter is comparable to the STATCOM [6]. The DPFC can balance the line characteristics, such as the bus voltage magnitude, transmission angle, and line impedance, much like the UPFC can [7].

The DPF Principle is covered in part II of the study, which is structured as follows. Inspection III providing its description for the DPFC control. The enhancement of power quality by DPFC is the focus of Section IV. Inspection V presents the simulation findings.

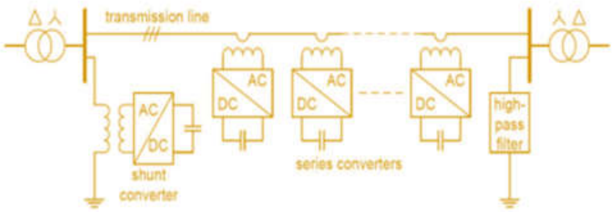

Figure 1. The DPFC Structure

II. DPFC PRINCIPLE OF METHODS AND MATERIAL

The primary benefit of DPFC over UPFC is the removal of the large DClink and the use of third-harmonic current to enable active power exchange [6].The fundamental ideas of DPFC are being described in the next future sub-sections.

A. Get Rid of Power Exchange and DC Link

Instead of employing a direct connection with a DC-link for power exchange between converters, the transmission line is utilized in the DPFC to connect the DC terminals of shunt converters and the AC terminals of series converters. The power theory of non-sinusoidal components serves as the foundation for the DPFC power exchange technique [6].

The sum of sinusoidal components at various frequencies can be used to represent a non-sinusoidal voltage or current based on Fourier series. The active power is the product of the components of voltage and current. The following is the active power equation when the integral of some terms with various frequency is zero:

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

where φ i 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 is expressed independently by equation (1). The active power at various frequencies is isolated from one another, as stated in equation (1) above, and the voltage and current at one frequency have no effect on the active power at other frequencies. Accordingly, the DPFC's shunt converter may inject current back into the grid at a harmonic frequency while absorbing power from the active grid at the fundamental frequency [9].

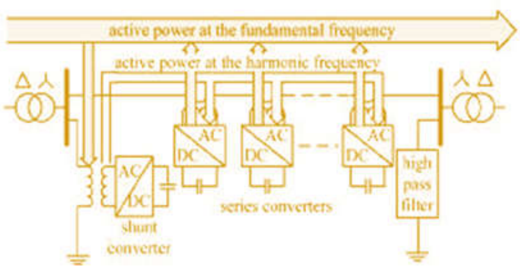

Figure 2. Active power exchange between DPFC converters

As a result, a DPFC shunt converter has the ability to take in active power at one frequency and generate output power at a different frequency. Furthermore, the DPFC series converter has the capability to generate voltage at the harmonic frequency by drawing active power from harmonic components, in accordance with the required amount of active power at the fundamental frequency. Imagine, as depicted in the diagram. One DPFC has been installed in the transmission line of a two-bus system. The shunt converter might consume power at the fundamental frequency of the current, as the power source delivers the active power. The third harmonic in each phase of the three-phase system remains consistent, known as the phenomenon of "zero sequence. " The third harmonic current flows smoothly into the neutral terminal of the ∆Y transformer via the output terminal of the shunt converter. Consequently, the harmonic current flows through the transmission wire. The DC voltage of series capacitors is controlled by the harmonic current. The shunt and series converters in the DPFC transfer active power between them, as demonstrated in the illustration. In order to establish a closed loop for the harmonic current, it is essential to use a high-pass filter, with the third harmonic being selected to effectively exchange active power in the DPFC.

The advantages of employing Dynamic Power Factor Correction (DPFC).

Here are a few advantages of the DPFC compared to the UPFC:

A. Exceptional mastery of control.

Similar to UPFC, DPFC can control all transmission network parameters, such as bus voltage, transmission angle, and line impedance.

B. Unwavering reliability.

Enhancing DPFC reliability is achieved through redundancy in series converters during their operation [7]. If one of the series converters malfunctions, the remaining ones are capable of continuing operation.

C. Affordable pricing.

A three-phase converter possesses a greater capacity compared to a single-phase series converter. In addition, individual transformers can be used to support the series converters, eliminating the need for high voltage isolation in transmission line connections.

DPFC Governance

Figure 3 showcases the three control methods employed by the DPFC: shunt, series, and central controller.

Central Authorities

This controller oversees all shunt and series controllers, while also supplying reference signals to each.

The management of a series.

Each single-phase converter is equipped with its individual series control along the line. The inputs of the controller include the line current, series capacitor voltages, and the series voltage reference in the dq-frame. Figure 4 depicts the block diagram of the series converters within the Matlab/Simulink environment.

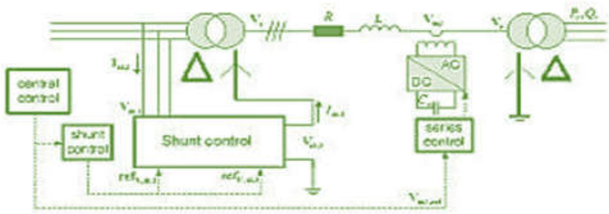

Figure 3. DPFC control structure

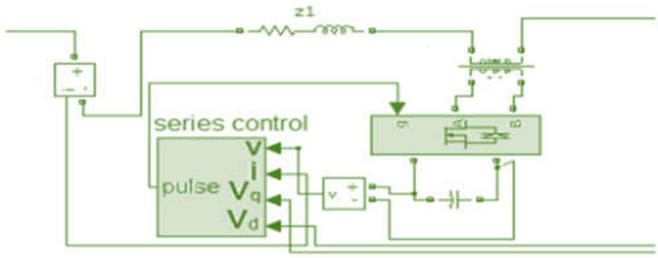

Figure 4. Block diagram of the series converters in Mat lab/Simulink

In order to generate fundamental and third harmonic current, respectively, each series controller contains a lowpass and a third pass filter. To extract frequency and phase information from networks, two single-phase phase lock loops (PLL) are utilized [8].The Matlab/Simulink block design for a series controller is seen in Figure 5. The PWM Generator block controls the switching mechanisms.

Shunt Management

A three-phase converter is paired back-to-back with a single-phase converter to form the shunt converter. The three-phase converter regulates the dc voltage of the capacitor between it and the single-phase one and takes in 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. Every converter has a separate controller that operates at fundamental and third-harmonic frequencies. Fig. 6 shows the block schematic for the shunt control structure.

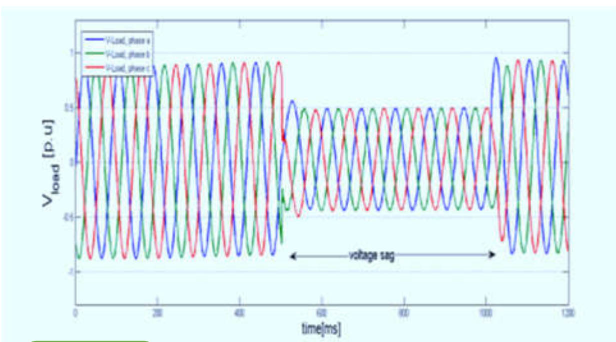

Fig:5 Three-phase load voltage sag waveform.

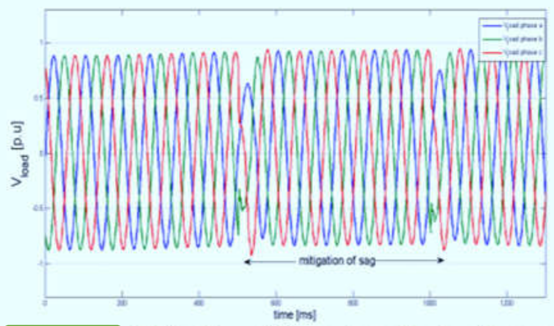

Fig:6 Mitigation of three phase load voltage sag with DPFC

The load current increased by around 1.1 per unit during the failure, as seen in Fig. 7 Following the DPFC's application, the load current swell is successfully eliminated. Fig. 8 shows the present swell mitigation for this instance.

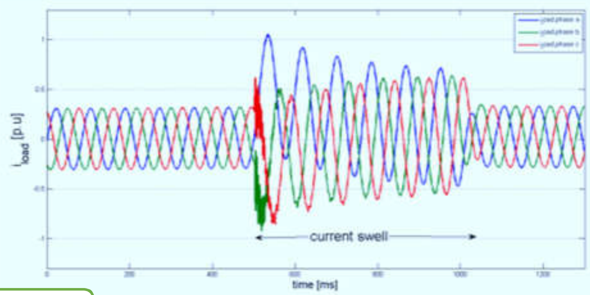

Fig:7 : Three Phase Load Current Swell Waveform Without DPFC

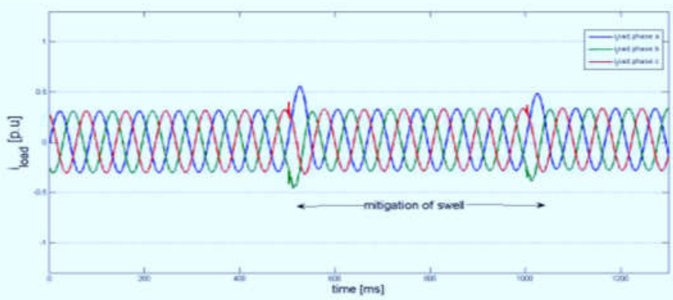

Fig:8 Mitigation of three-phase load current swell with DPFC

IV. Conclusion

Several efficient techniques may be used to enhance the power transmission system's power quality. The distributed power flow controller (DPFC), a novel FACTS device, is introduced in this study to mitigate voltage sag and swell. There are similarities between the DPFC and UPFC structures. It can balance line characteristics including transmission angle, line impedance, and bus voltage magnitude with the same control capabilities. Nonetheless, the DPFC offers a few benefits over the UPFC, including low cost, excellent control capabilities, and high dependability. The central controller, series control, and shunt control are the three control loops that are designed once the DPFC is modeled. The system being examined is an infinite-bus single machine system, both with and without DPFC.It is demonstrated that the DPFC performs satisfactorily in terms of power flow control and power quality mitigation.

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