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Voltage Profile Enhancement Using DPFC

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Abstract - The DPFC is derived from the unified power flow controller (UPFC) with eliminated common dc link between shunt and series converter. 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 in the DPFC .The DPFC is to use multiple small size single phase series converters instead of large size three phase series converter in the UPFC. The large number of series converters provides the system reliability. As the D-FACTS concept converters are single phase and floating with respect to the ground, there is no high voltage isolation required between the phases. The cost of the DPFC Devices is lower than the UPFC. The DPFC has the same control capability as the UPFC, which includes the adjustment of the line impedance, the transmission angle, and the bus voltage.

Keywords- AC–DC power conversion, UPFC, DPFC, power electronics, sag, swell, power-transmission control.

I. INTRODUCTION

The flexible ac transmission system (FACTS) technology is the application of power electronics in Power transmission systems. The main purpose of this technology is to control and regulate the voltage in the power systems. This is achieved by using converters as a controllable interface between two power system terminals. Basically, the family of FACTS devices based on voltage source converters (VSCs) consists of a series compensator, a shunt compensator, and a shunt/series compensator. The static Compensator (STATCOM) is a shunt connected device that is able to provide reactive power support at a network location far away from the generators. Through this reactive power injection, the STATCOM can regulate the voltage at the connection node. The static synchronous series compensator (SSSC) is a series device which injects a voltage in series with the transmission line.

The injected voltage essentially acts as a synchronous ac-voltage source, which is used to vary the transmission angle and line impedance, thereby independently controlling the active and reactive power flow through the transmission line. The series voltage results in active and reactive power injection or absorption between the series converter and the transmission line. This reactive power is generated internally by the series converter and the active power is supplied by the shunt converter that is back-to-back connected. The shunt converter controls the voltage of the dc capacitor by absorbing or generating active power from the bus; therefore, it acts as a synchronous source in parallel with the system. Similar to the STATCOM, the shunt converter can also provide reactive compensation for the bus [11].

II. UNIFIED POWER FLOW CONTROLLER (UPFC)

The Unified Power Flow Controller (UPFC) is comprised of a STATCOM and a SSSC, coupled via a common DC link to allow bi-directional flow of active power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM. Each converter can independently generate (or) absorb reactive power at its own AC terminal. The two converters are operated from a DC link provided by a DC storage capacitor.

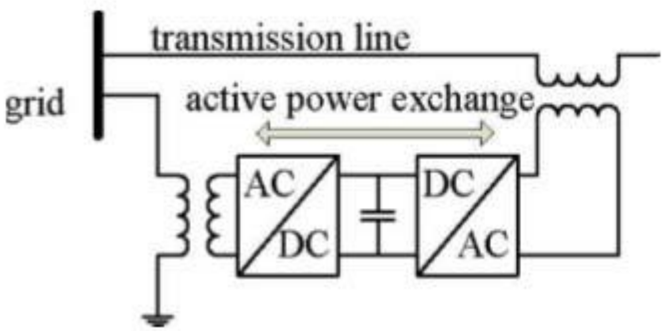

Fig1. Performance of UPFC

The same as the UPFC, the DPFC is able to control all system parameters like line impedance, transmission angle and bus voltage. 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.

III. 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 2.

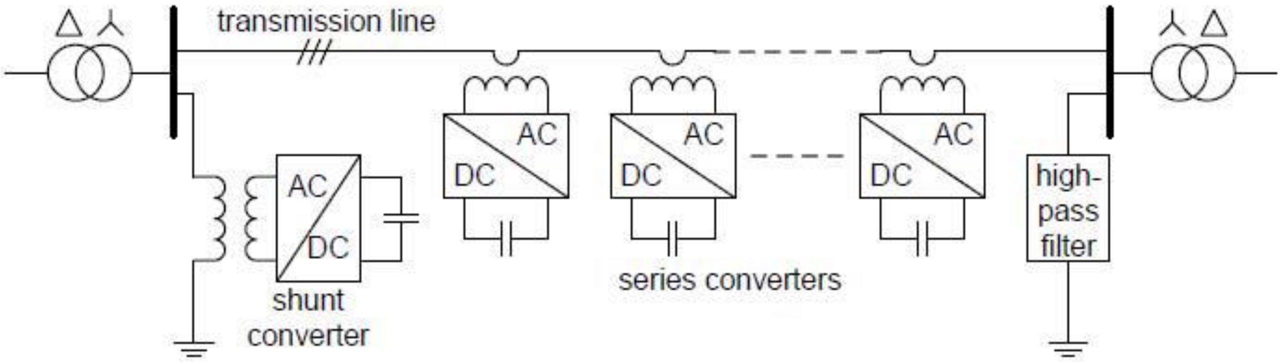

Fig 2.DPFC configuration

Within the DPFC, the transmission line is used as a connection between the DC terminal of shunt converter and the AC terminal of series converters, instead of direct connection 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]. Based on Fourier series, a non-sinusoidal voltage or current can be presented as the sum of sinusoidal components at different frequencies. 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 [1].

$$P = \sum_{i=1}^{\infty} ViIi\ COS\ \varphi i \qquad (1)$$

Where *Vi* and *Ii* are the voltage and current at the *ith* harmonic, respectively, and *φi* is the angle between the voltage and current at the same frequency. Equation (1) expresses the active power at different frequency components are independent. Based on this fact, a shunt converter in DPFC can absorb the active power in one frequency and generates output power in another frequency. Assume a DPFC is placed in a transmission line of a two-bus system, as shown in Fig.1. While the power supply generates the active power, the shunt converter has the capability to absorb power in fundamental frequency of current.

IV. DPFC CONTROL

To control multiple converters, a DPFC consists of three types of controllers: central control, shunt control and series control, as shown in Figure 3. The shunt and series control are localized controllers and are responsible for maintaining their own converters parameters. The central control takes care of the DPFC functions at the power system level. The function of each controller is listed [11]:

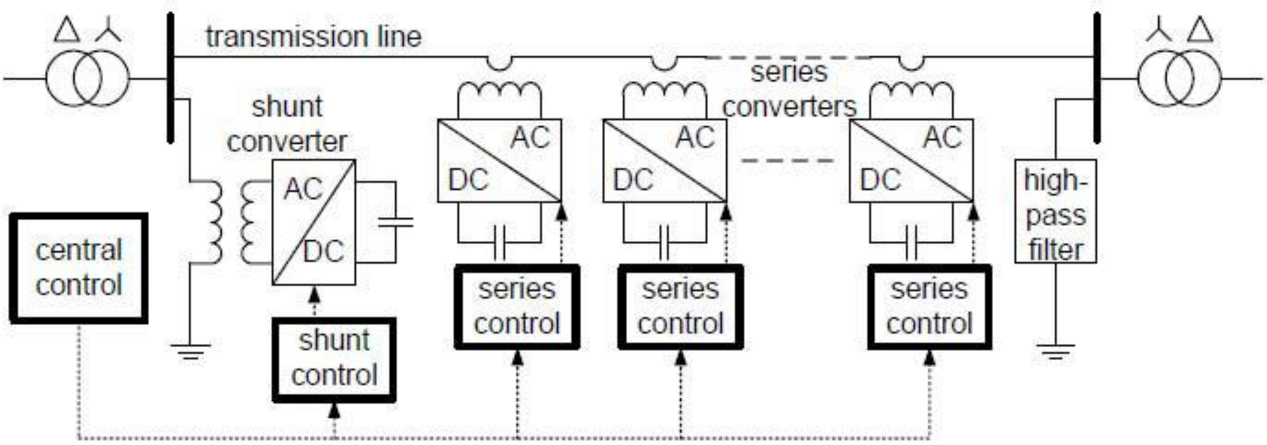

Fig 3. DPFC control block diagram

A. *Central control*

The central control generates the reference signals for both the shunt and series converters of the DPFC. Its control function depends on the specifics of the DPFC application at the power system level, such as power flow control, low frequency power oscillation damping and balancing of asymmetrical components. According to the system requirements, the central control gives corresponding voltage reference signals for the series converters and reactive current signal for the shunt converter. All the reference signals generated by the central control concern the fundamental frequency components

B. *Series control*

Each series converter has its own series control. The controller is used to maintain the capacitor DC voltage of its own converter, by using 3rd harmonic frequency components, in addition to generating series voltage at the fundamental frequency as required by the central control.

C. *Shunt control*

The objective of the shunt control is to inject a constant 3rd harmonic current into the line to supply active power for the series converters. At the same time, it maintains the capacitor DC voltage of the shunt converter at a constant value by absorbing active power from the grid at the fundamental frequency and injecting the required reactive current at the fundamental frequency into the grid.

V. SIMULATION AND RESULT

The whole model of system under study is shown in Fig. 4. The system contains a three-phase source connected to a three phase RLC load through transmission lines. The DPFC is placed in transmission line, which the shunt converter is connected to the transmission line in parallel through a three-phase transformer, and series converters is distributed through the line.

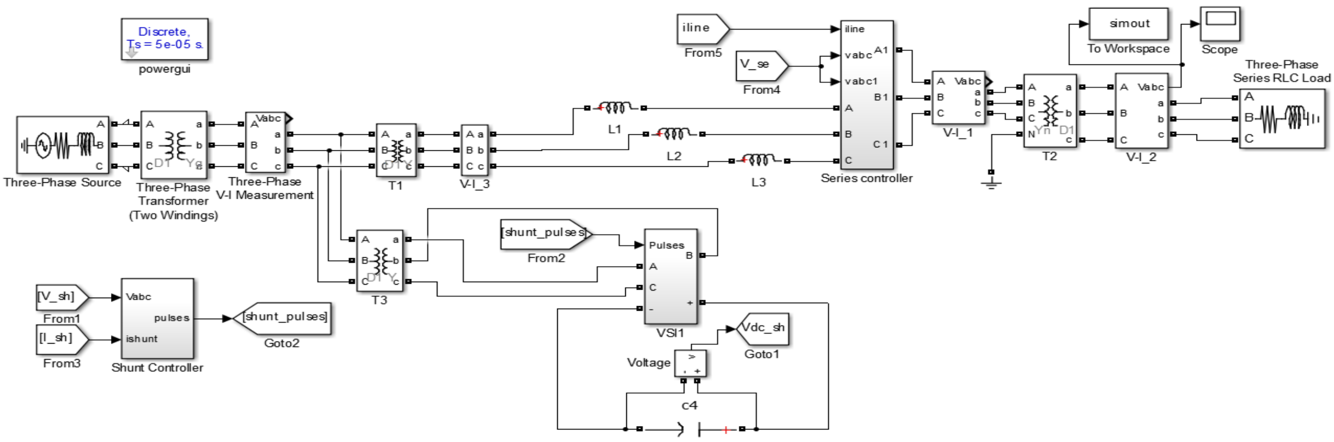

Fig. 4 Simulation of DPFC at Power System

Voltage sag generate in system at 0.3-0.4s, when three phase fault occur. PU value of Voltage is decrease from 10-90% of RMS value

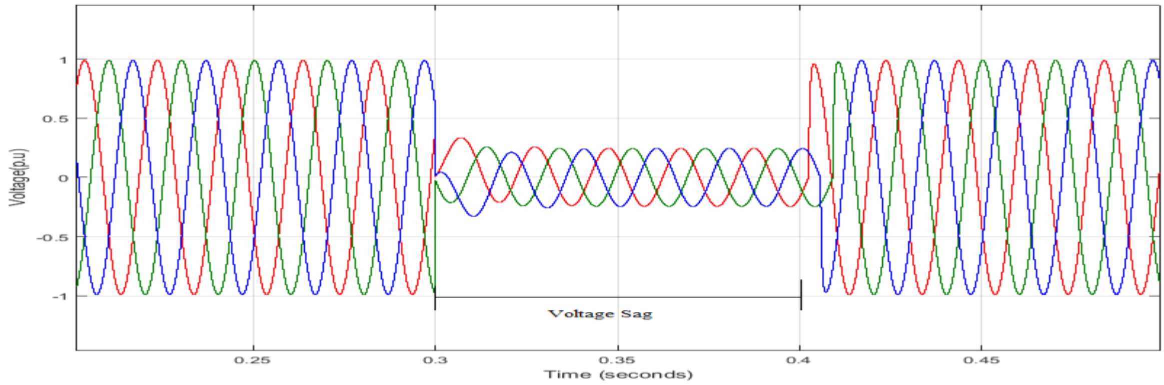

Fig 5 voltage sag at 0.3-0.4s

DPFC connected at power system for a voltage Sag mitigation. When voltage sag is generated due to three phase Fault occur, DPFC take action for voltage control and increase the voltage near to the nominal voltage

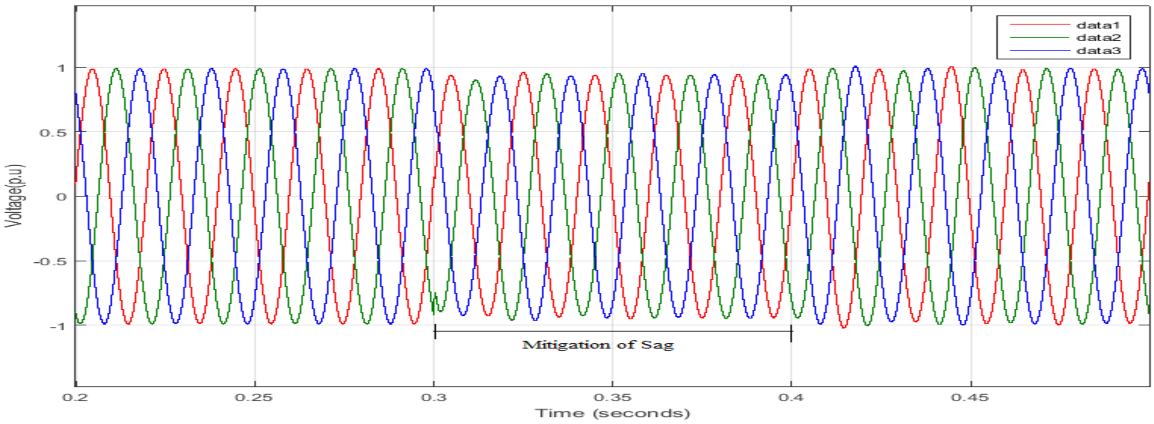

Fig 6 Mitigation of Voltage Sag

Voltage swell generate in system at 0.3-0.4s, when sudden change in load. PU value of Voltage is increase from 110-180% of RMS value

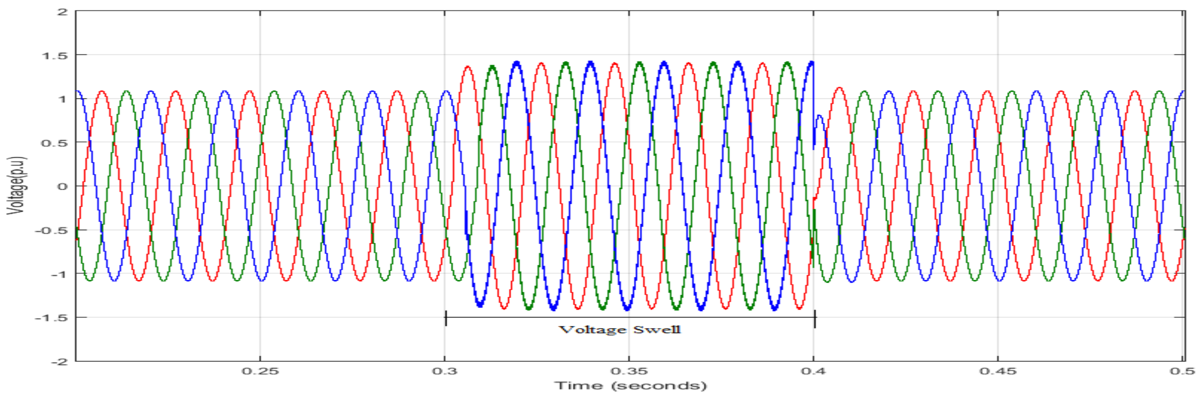

Fig 7 Voltage swell at 0.3-0.4s

DPFC connected at power system for a voltage Swell mitigation. When voltage swell is generated due to sudden change in load, DPFC take action for voltage control and decrease the voltage near to the nominal voltage

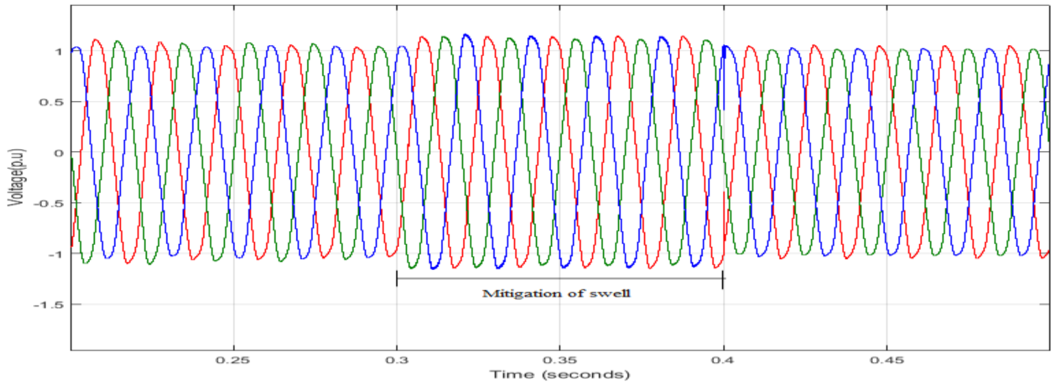

Fig. 8 Mitigation of Voltage swell

VI. ADVANTAGES OF DPFC

The DPFC in comparison with UPFC has some advantages, as follows:

A *High Control Capability*
The DPFC similar to UPFC, can control all parameters of transmission network, such as line impedance, transmission angle, and bus voltage magnitude.

B *High Reliability*
The series converters redundancy increases the DPFC reliability during converters operation. It means, if one of series converters fails, the others can continue 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; single-turn transformers can be used to hang the series converters [1].

VII CONCLUSION

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) 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.

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.

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