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Improvement of Power Quality by Using DPFC

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Abstract— Flexible AC transmission system (FACTS) technology is the application of power electronics in transmission system to control and regulate the electric variables in the power system. An UOFC can be converted to DPFC by eliminating the common dc-link between the shunt and series converters and three-phase series converter is divided to several single-phase series distributed converters through the line. DPFC has advantages like improved voltage profile and reduced power loss. 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 experimental results that are studied shows the mitigation of three-phase voltage sag and load current swell of the power quality.

Keywords: Power Quality, DPFC, Voltage Sag, Current Swell

I. Introduction

For power-quality improvement, the development of power electronic devices such as flexible AC transmission system (FACTS) and custom power devices have been introduced as an emerging branch of technology providing the power system with versatile new control capabilities. Advanced control and improved semiconductor switching of FACTS devices have achieved a new era for power-quality mitigation. Conventionally passive L-C filters were used to reduce harmonics and capacitors were employed to improve the power factor of the ac loads. But these passive filters have the demerits of fixed compensation, large size, and resonance.

Currently unified power flow controller (UPFC) is the most powerful device which can simultaneously control all the parameters of the system such as line impedance, transmission angle, bus voltage, etc. UPFC is the combination of static compensator (STATCOM) and static synchronous series compensator (SSSC) coupled via a common DC link. The Distributed Power Flow Controller (DPFC) recently presented in is a power flow device within the FACTS family, which provides much lower cost and higher reliability than the conventional FACTS devices. It is derived from the UPFC and has the same capability of simultaneously adjusting all the parameters of power system like line impedances, transmission angle and bus voltage magnitude.

In this paper, we present a case study that contains a DPFC sited in a single-machine infinite bus power system including two parallel transmission lines, which simulated in MATLAB/Sim link environment.

II. EXISTING SYSTEM

Electrical Power Quality or Power quality is defined as the index which both the delivery and consumption of electric power affect on the performance of electrical apparatus. Power quality means the fitness of electrical power and its stabilized disposition to power consumer device there are several types of power quality problems that a customer may encounter and has been classified according to or depending on how the voltage waveform is being distorted. There are transients, short duration of variations (sags, swells, and interruption), long duration variations (sustained interruptions, under voltages, over voltages), voltage imbalance, waveform distortion (dc offset, harmonics, inter harmonics, notching, and noise), voltage fluctuations and power frequency variations. The FACTS devices, such as unified power flow controller (UPFC) and synchronous static compensator (STAT-COM), are used to improve the power system quality and reliability.

The main reason behind the wide spread of the Unified Power Flow Controller (UPFC) is its ability to pass the real power flow bidirectional, maintaining well regulated DC voltage, work ability in the wide range of operating condition etc. Also it is a device which can control all the parameters such as line impedance, transmission angle, bus voltage etc.

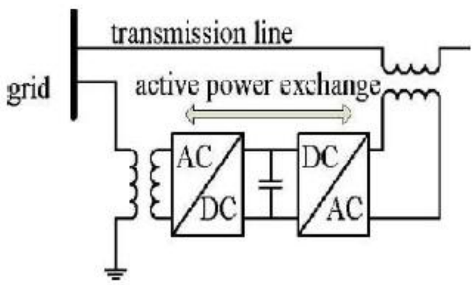

Fig 1: Unified Power Flow Controller

Coupled via a common DC link, UPFC is the combination of static compensator (STATCOM) and static synchronous series compensator (SSSC) allows a bidirectional flow active power between the series output terminal of the SSSC and shunt output terminal of the STATCOM. Despite of the advantages of UPFC, it is not widely applied in practice because of the high cost and redundancy in failure. Inorder to achieve the required reliability for power systems,using a common DC link interconnection, bypass circuit or redundant back ups are needed which leads to increase the cost influencing the whole system.

The Distributed Power Flow Controller (DPFC) a power flow device within the FACTS family provides low cost and higher reliability when compared to conventional FACTS devices.

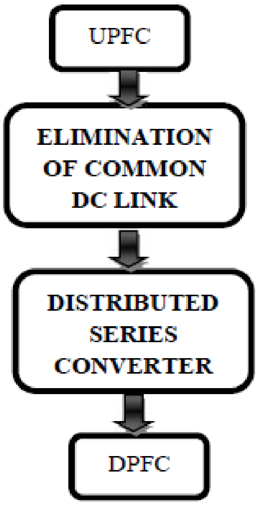

Fig 2. Flowchart from UPFC to DPFC

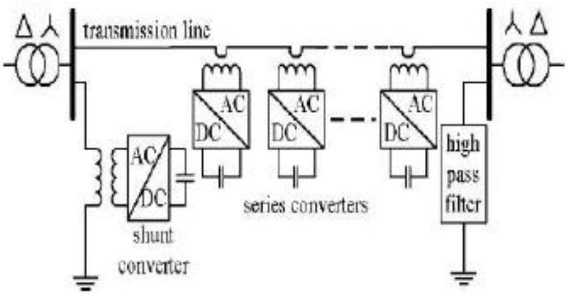

Fig 3: Configuration of DPFC

The main advantage offered by DPFC is eliminating the huge DC-link and instate using 3rdharmonic current to active power exchange.

III. Proposed System

In order to convert UPFC to DPFC, two approaches can be applied to the UPFC so that the reliability can be increased and the cost is reduced. First approach is to eliminate the common DC link and the second approach is distributing the series converter. The DPFC consists of one shunt and several series connected Converters. the series converter employs the DFACTS to use multiple single-phase converters instead of one large rated converter. The shunt converter is similar to STATCOM of UPFC. Each converter within the DPFC is independent and has its own DC capacitor to provide the required DC voltage. DPFC also requires a high-pass filter that is shunt connected at the other side of the transmission line, and two Y–Δ transformers at each side of the line. DPFC have the same control capability as the UPFC, back-to-back connection between the shunt and series converters that allows the exchange of active power between converters with eliminated DC link. In DPFC the independency of the active power at different frequencies gives the possibility that a converter without power source can also generate active power at one frequency and absorb this power from other frequencies. The active power equation is as follows:

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

Where V_i and I_i are the voltage and current at the i^{th} harmonic.

Using a common connection transmission line between the AC terminal of the shunt and series converters it is possible to exchange the active power though the terminals of the converters. In DPFC the shunt converter can absorb the active power from the grid at the fundamental frequency and inject the current back into the grid at a harmonic frequency.

The advantages of DPFC when compared to UPFC can be given as follows:

High Control Capability: The ability to control all parameters of transmission network, such as line impedance, transmission angle, and bus voltage magnitude.

High Reliability: if one of the series converters fails, the others can continue to work.

Low Cost the series converters do not need any high voltage isolation in transmission line Connecting; i.e., single-turn transformers can be used to hang the series converters.

In the proposed implementation we consider three control strategies for the DPFC:

Central Control, Series Control, Shunt Control

Central Control: Manages all the series and shunt controllers and sends reference signals to both of them.

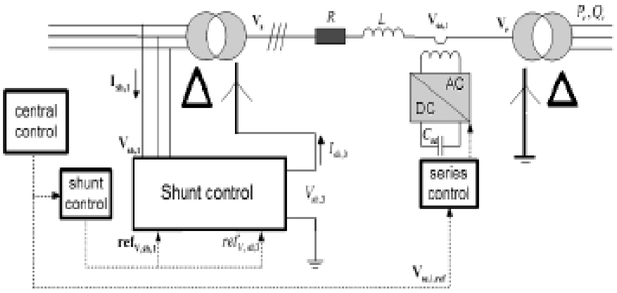

Fig 4:DPFC Control Structure

Series Control: The controller inputs are series capacitor voltages, line current, and series voltage reference in the dqframe.

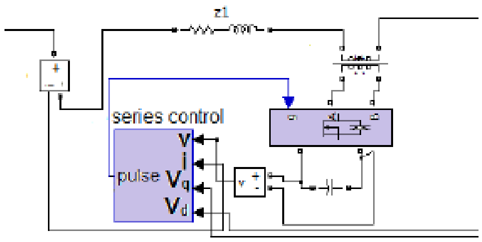

Fig 5: Series Control-Series Converters

Two single-phase phase lock loop (PLL) are used to take frequency and phase information from network.

Shunt Control: The shunt converter includes a three-phase converter connected back-to-back to a single-phase converter. At the fundamental frequency shunt controller controls the dc voltage of capacitor between the converter and single-phase one.

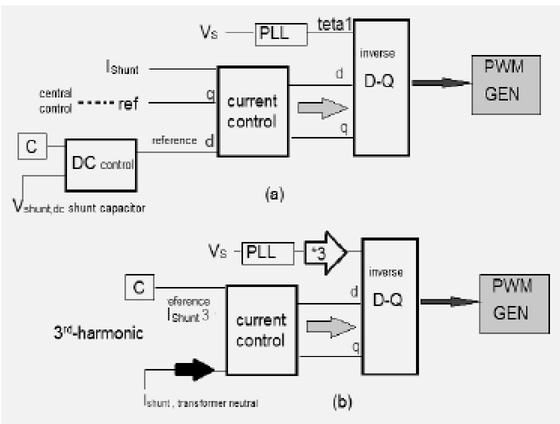

Fig 6: Shunt Control

POWER QUALITY IMPROVEMENT

In the implemented work, the system contains a three-phase source connected to a nonlinear RLC load through parallel transmission lines (Line 1 and Line 2) with the same lengths. From the below given circuit, it is clear that the DPFC is placed in transmission line, which the shunt converter is connected to the transmission line 2 in parallel through a Y-Δ three-phase transformer, and series converters is distributed through this line.

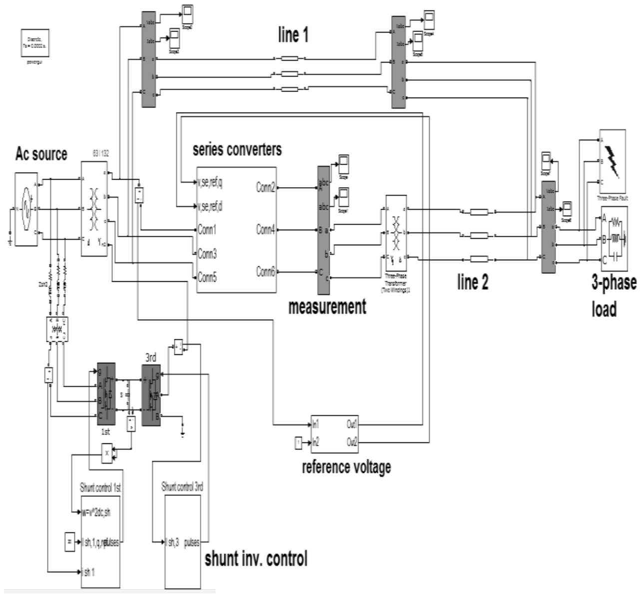

Fig 7: Simulation model of the DPFC

A three-Phase fault is considered near the load, and the time duration of the fault is taken as 0.5 seconds. The voltage sag value is about 0.5 per unit. After adding a DPFC, load voltage sag can be mitigated.

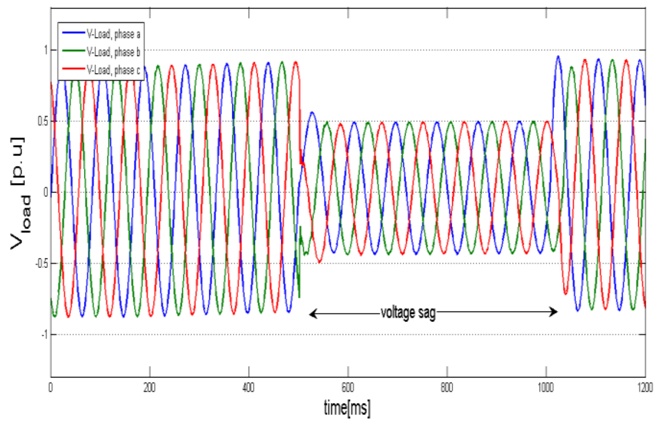

Fig 8: Waveform for three-Phase load voltage sag

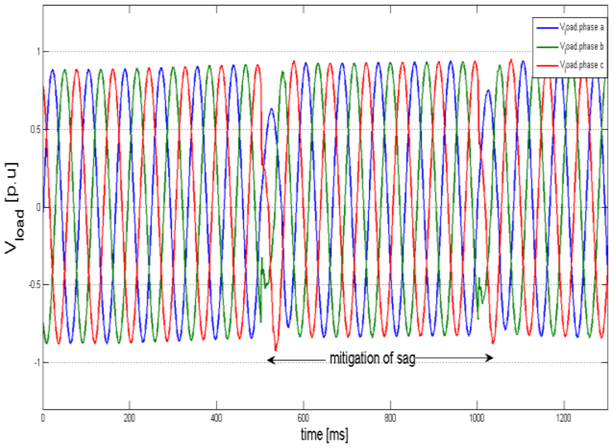

Fig 9: Mitigation of three-phase load voltage sag with DPFC

Also the load current swell is removed effectively after implementation of the DPFC.

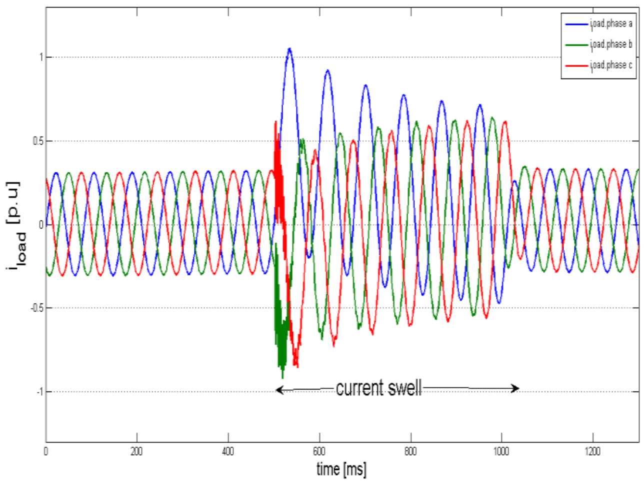

Fig 10 :Waveform for three-phase load current swell

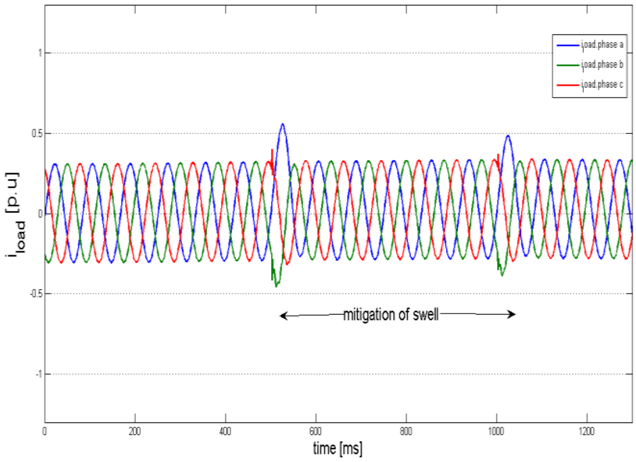

Fig 11: Mitigated Waveform for three-phase load current swell with DPFC

IV. CONCLUSION

The implemented work involves the mitigation of a three-phase voltage sag and load current swell using FACTS device Distributed Power Flow Controller (DPFC). Though UPFC has the ability to control the balance the line parameters line impedance, transmission angle, and bus voltage magnitude, it is less reliable and cost expensive. Hence we have considered DPFC which has high control capability, high reliability and less cost for the study. The system under study is a single machine infinite-bus system, with and without DPFC. From the simulation results, it is shown that the DPFC gives an acceptable performance in power quality mitigation as well as power flow control.

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