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IMPROVERMENT OF POWER QUALITY BY USING DISTRIBUTED POWER FLOW CONTROLLER

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ABSTRACT—The Distributed Power Flow Controller (DPFC) is a new device within the FACTS devices. In DPFC there is two types of converters that are connected in shunt and series to grids. DPFC is same as UPFC except the common DC link which is connected between shunt and series converters. Due to elimination of DC link the active power exchange between series and shunt unit take place through transmission line by utilizing 3rd harmonic component of voltage and current. In addition DPFC has a lower cost due to the small rating of the series converters and a higher reliability due to the redundancy than UPFC. In this paper, the compensation of power quality problem such as voltage sag has been analyzed by using DPFC. This paper represents a new category of the Flexible AC Transmission System (FACTS) called as Distributed Power- Flow Controller (DPFC). Due to increase in electricity demand and the increased number of non-linear loads in power grids, providing a high quality electrical power should be taken into consideration. The study of DPFC contains double side feeder (supply) and transmission line, which is simulated in MATLAB/Simulink. The presented simulation results validate the DPFC ability to compensate the voltage variations.

Keywords: DPFC, voltage sag, voltage swell.

INTRODUCTION

At present the conditions that are seen in industrial devices most of equipments are basically consists of electronic devices such as programmable logic controllers and electronic drives. These power electronic devices are largely affected by disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics in the entire problems associated with voltage sag is considered as more dangerous disturbances to the industrial equipments than other disturbances [13]. Especially, short duration power disturbances, such as voltage dips, swells and short interruptions. The most common form of power quality disruption is the voltage sag, which accounts 70% of all power disturbances. Several voltage sags can result in total equipment shutdown having the same effect as outage sag of normally below 20% of nominal voltage will result equipment shutdown and the voltage sags that occurs during the operation of the equipment will cause a reduction in the life span and efficiency of these devices [14]. The problem of poor power quality like voltage sag for sensitive loads can be compensated by using DPFC. With the application of DPFC, the power system can be operated without voltage sag by flexibly changing the distribution configuration after the occurrence of a fault. DPFC is the combination of series and shunt converters with PI controller for the power quality improvement in the distribution system. Here linear load are considered, only when different voltage variation conditions are measured with these loads to analyze the operation of DPFC to improve the power quality in distribution system. A new control strategy has been developed for achieving maximum benefits by eliminating or mitigating voltage sag and power quality problem when abnormal condition occur in the distribution system, for this purpose the DPFC is proposed to improve the power quality and to reduce the sag and swell problem in the system. The DC link capacitor of UPFC is eliminated .The features of power flow converters to compensate voltage variations by utilizing the third harmonic components which for maximum utilization of distribution voltage, via star delta transformer.

Power quality means the fitness of electrical power and its stabilized disposition to power consumer device. PQ problem is defined as any problem that has been seen in voltage, current or a frequency deviation that leads to the failure or

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malfunctioning of consumer equipment. Power quality is not a single term of measurement it has several types which includes Capacitor switching, lightning surge (Transient), Interruptions; Sags/Swells (Disturbance), Harmonics, Flicker, Voltage regulation, Reliability, Power factor (Steady-state). There are several types of power quality problems that a customer may encounter and may classified according or depending on how the voltage waveform is being distorted[15]. There are transients, short duration of variations (sags, swells, and interruption), long duration variations (sustained interruptions, under voltages, over voltages), voltage Reducing the Voltage Sag and Swell Problem in Distribution System Using DPFC.

Voltage Sags: Voltage sag is defined as the reduction of RMS voltage between 0.1 p.u. and 0.9 p.u. and lasting between 0.5 cycles to 1 minute. Voltage sag are mostly caused by system fault and last for duration ranging from 3 cycles to 30 cycles depending on the fault clearing time.

Voltage Swells: voltage swells is defined as a rise in RMS voltage which is between 1.1 p.u and 1.8p.u for period stuck between 0.5 cycles to 1 minute. A voltage swell is characterized by its magnitude (RMS) and duration.

Solutions of Power Quality problems:
Power quality problem can be overcome by switching devices such as FACTS devices by varying the impedance angle and line impedances, power angle etc.

DISTRIBUTED POWER FLOW CONTROLLER

In comparison with UPFC, the main advantage offered by DPFC is eliminating the huge DC-link and instate using 3rdharmonic current to active power exchange [9]. In the following subsections, the DPFC basic concepts are explained.

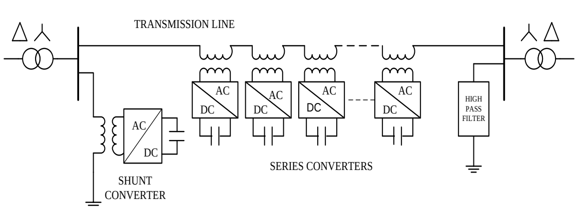

FIG. (!) CONFIGURATION OF DPFC

A. Eliminate DC Link and Power Exchange

Within the DPFC, the transmission line is used as a connection between the DC side of shunt converter and the AC side 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. The active power at different frequency components is independent [12]. Due to this, 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 system, as shown in fig. (1).

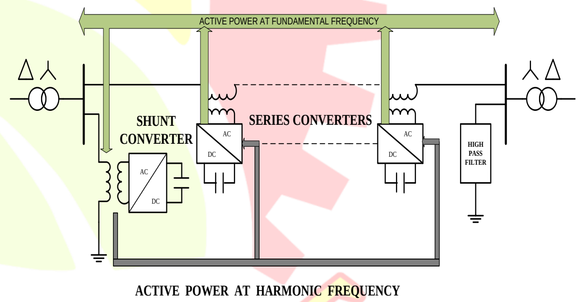

Fig. (2) Active power exchange between series and shunt unit of DPFC

The power supply generates the active power and the shunt converter has capable to absorb power in fundamental frequency of current from transmission line. The third harmonic component can be utilized by Y-Δ transformer. Output terminal of the shunt converter injects the third harmonic current into the neutral of Δ-Y transformer (Fig. 3). Consequently, the harmonic current flows through the transmission line. This harmonic current controls the DC voltage of series capacitors under the control of series and central controller.

Fig. (2) Shows how the active power is exchange action occurs in between the shunt and series converters in the DPFC. *The third harmonic is selected to exchange the active power in the DPFC and a high-pass filter is required to make a closed loop for the harmonic current*. The third-harmonic

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current is collected in Δ-winding of transformer. Hence, no need to use the high-pass filter at the receiving-end of the system. By using the third-harmonic, the high-pass filter can be replaced with a cable connected between Δ-winding of transformer and ground.

Advantages of DPFC

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

• *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 [14].

• *High Reliability*

Whenever fault occurs in on series unit it will not affect the working of other series converters hence due to this reason DPFC is more reliable than UPFC.

• *Low Cost*

The single-phase series converters rating are lower than one three-phase converter. Because it does not require capacitor with high rating that's why cost of system will be less. Thereafter, the series converters do not need any high voltage isolation in from transmission line; single-turn transformers can be used to hang the series converters.

II. DPFC CONTROL

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

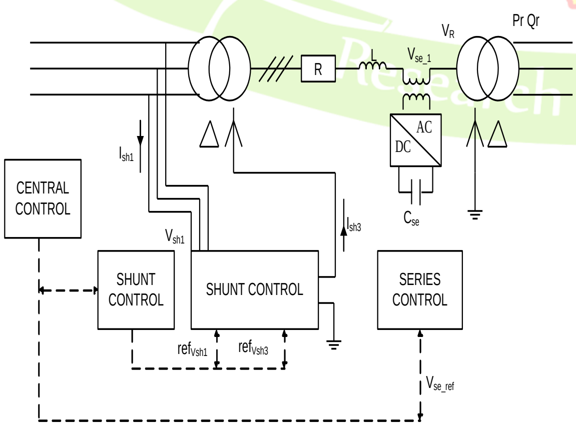

Fig.(3) DPFC control structure

Central Control

This controller controls all the series and shunt controllers and sends reference signals to both types of controllers [12].

B. Series Control

Each single-phase converter has its own series control through the line. Input of the controllers are series capacitor voltages, line current, and series voltage reference voltages, line current, and series voltage reference in the dq frame. Reference signals are generated by central control. The block diagram of the series converters in Matlab/Simulink environment is demonstrated in Fig. (4).

Any series controller consists of a low-pass and a 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 block diagram of series controller in Matlab/Simulink is shown in Fig. (5). The PWM-Generator block controls all switching processes.

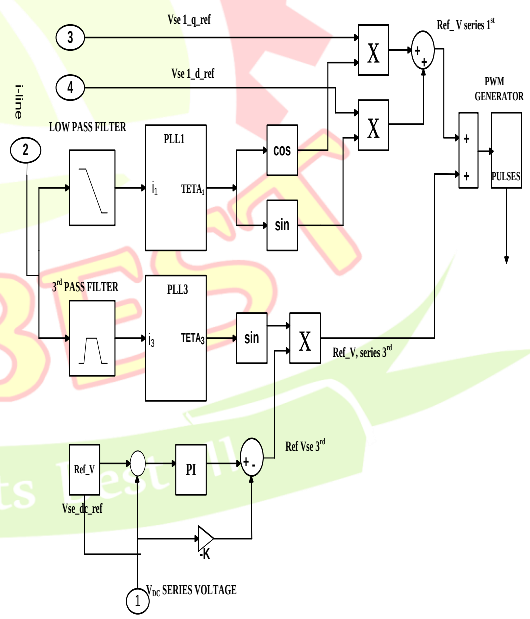

Fig.(4) Series control

Shunt Control

The shunt converter includes a three-phase converter connected back-to-back to a single-phase converter. The three-phase AC/DC converter absorbs active power from grid at fundamental frequency and

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controls the dc voltage of capacitor between this converter and single-phase one. Other task of the shunt converter is to inject constant third-harmonic current into lines through the neutral cable which is connected to the neutral of Δ-Y transformer.

Each converter has its own controller at different frequency operation (fundamental and third-harmonic frequency). The shunt control structure block diagram is shown in Fig. (5).

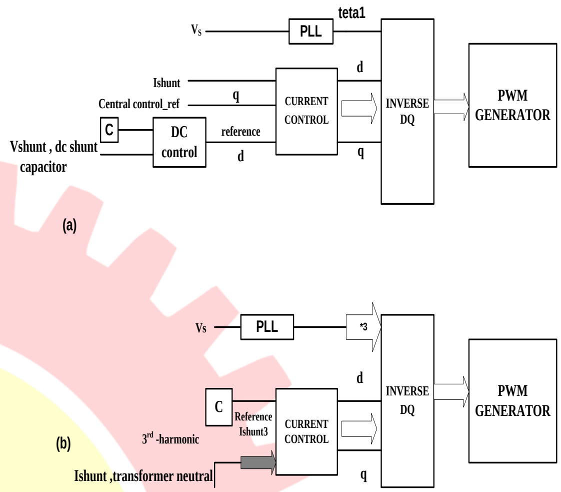

Fig.(5) Shunt control (a) For fundamental (b)For Third harmonic component

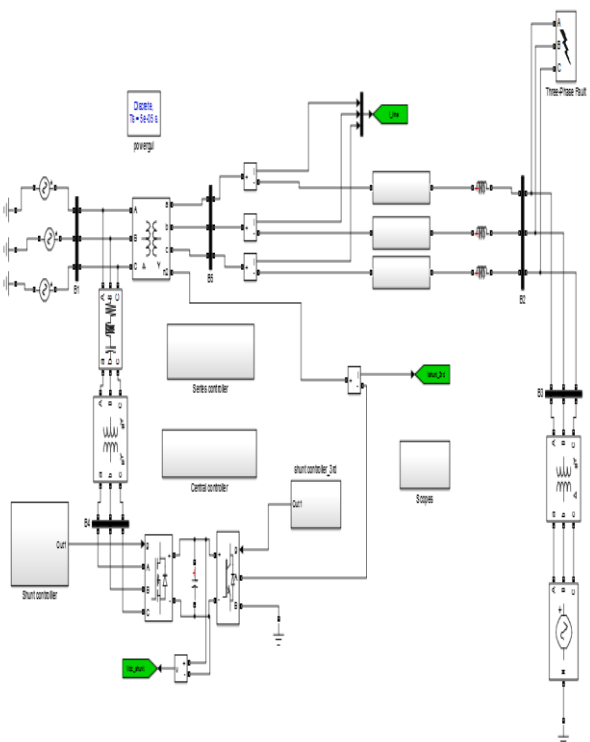

Fig.(6) Simulink model of DPFC under study

POWER QUALITY IMPROVEMENT (SIMULATION RESULT)

The model of system under study is shown in fig (7) the system contains a three-phase source connected to a nonlinear RL load through transmission line with the same. 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.

The system parameters are listed in TABLE I .To simulate the dynamic performance, a single-phase fault is considered near the bus (2). The time duration of the fault is .28 seconds (16.66-300 milliseconds). As shown in Fig. (7) a significant voltage sag is observable during the fault, without any compensation. The voltage sag value is about 6.4 per unit after adding a DPFC; load voltage sag can be mitigated effectively, as shown in Fig. (8)

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TABLE1

Symbol	Discription	Value	Unit
Vs	Nominal voltage of Sending end	220	V
Vr	Nominal voltage of receiving end	220	V
L	Line inductance	6	mH
Vsh ,max	Shunt converter maximum ac voltage	45	V
Vshdc	Shunt converter dc source supply	20	V
Vse max	Series converter maximum ac voltage	6	V
Ise max	Maximum ac side current of series converter	14.8	A

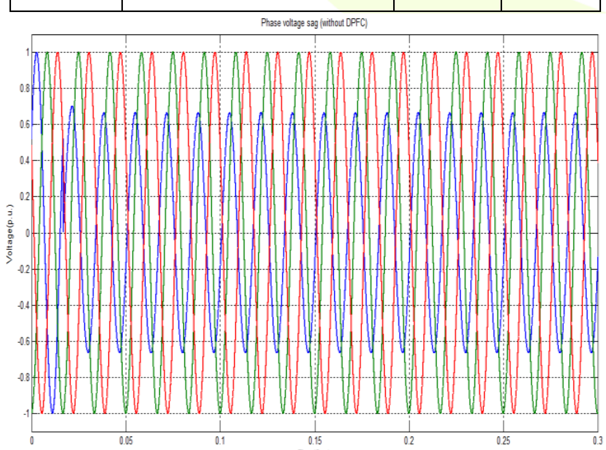

Fig.(8) Bus voltage (Without DPFC) sag 36%

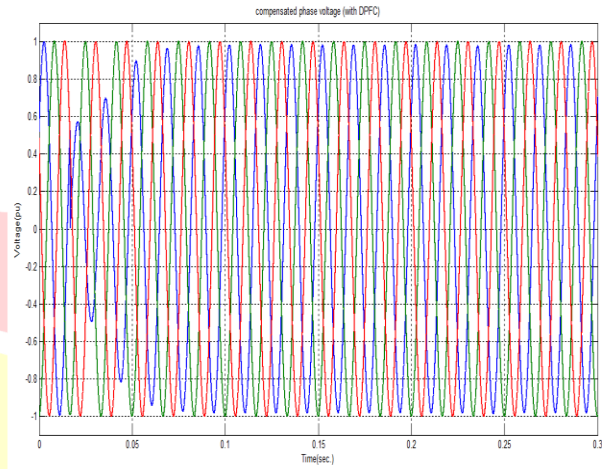

Fig.(7) Compensated bus voltage(with DPFC)

CONCLUSIONS

DPFC is originated from UPFC in which the common dc link between the series and shunt unit is use for power exchange is replaced by transmission line and third harmonic component. Due to elimination of common dc link the cost of higher rating capacitor is decreased and rating of distributed converters is also less due to this the overall cost effective solution of power quality problem can be achieved by using DPFC. D FACTS concept is employed in series converter which uses multiple single phase converters instead of single three phase converter. From sag analysis it is clear that DPFC can be used for shallow as well as deep sag by certain modification shunt and series parameters. In future hopefully it can be use to compensate voltage unbalance to due to interruption.

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