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Power Quality Improvement in Multi Feeders Using MC-DPFC with Fuzzy Controller


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Abstract:

This paper presents a new component within the flexible ac-transmission system (FACTS) family, called multi connected distributed power-flow controller (MC-DPFC) capable of simultaneous compensation for voltage and current in multibus/multifeeder systems. In this configuration, one shunt voltage-source converter (shunt VSC) and two or more series VSCs exist. The system can be applied to adjacent feeders to compensate for supply-voltage and load current imperfections on the main feeder and full compensation of supply voltage Imperfections on the other feeders.The DPFC can be considered as a UPFC with an eliminated common dc link. 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.

The DPFC employs the distributed FACTS (D-FACTS) concept, which is to use multiple small-size single-phase converters instead of the one large-size three-phase series converter in the UPFC. In this proposed system we connected DPFC for multiple bus bars instead of using two custom power devices (CUPS). The large number of series converters provides redundancy, thereby increasing the system reliability. As the D-FACTS converters are single-phase and floating with respect to the ground, there is no high-voltage isolation required between the phases. Accordingly, the cost of the DPFC system is lower than the UPFC. The DPFC has the same control capability as the UPFC, which comprises the adjustment of the line impedance, the transmission angle, and the bus voltage.The operation and analysis of the DPFC with FUZZY control are observed andexperimental results that are carried out on a scaled prototype are also shown.

I. INTRODUCTION:

With increasing applications of nonlinear and electronically switched devices in distribution systems and industries, power-quality (PQ) problems, such as harmonics, flicker, and imbalance have become serious concerns. In addition, lightning strikes on transmission lines, switching of capacitor banks, and various network faults can also cause PQ problems, such as transients, voltage sag/swell, and interruption. On the other hand, an increase of sensitive loads involving digital electronics and complex process controllers requires a pure sinusoidal supply voltage for proper load operation.In order to meet PQ standard limits, it may be necessary to include some sort of compensation. Modern solutions can be found in the form of active rectification or active filtering. A shunt active power filter is suitable for the suppression of negative load influence on the supply network, but if there are supply voltage imperfections, a series active power filter may be needed to provide full compensation.And also we have compensation techniques such as tapping transformers, shunt condensers etc..

In recent years, solutions based on flexible ac transmission systems (FACTS) have appeared. The application of FACTS concepts in distribution systems has resulted in a new generation of compensating devices.Currently, the distributed power-flow controller (DPFC) shown in Fig. is the most powerful FACTS device, which can simultaneously control all the parameters of the system: sag, swell, flickers and bus bar voltages. It is similar to Unified Power Flow Controller (UPFC). The UPFC is the combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC), which are coupled via a common dc link, to allow bidirectional flow of active power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM.

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The unified power quality conditioner (UPQC) compensator seems to be a particularly promising power conditioner device. This apparatus is constituted of a series and a shunt unit, with a common dc section through which power can be exchanged. Its function is to improve the quality levels of the current absorbed at the mains and the load supply voltage. The installation investments are also quite high relative to the power quality level obtained. A solution that has similar performances and advantages, but also makes cost reduction possible, is the proposed MC-DPFC. Advance of UPFC is DPFC. The DPFC is able to control all system parameters. 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.Comparing with the UPFC, the DPFC have two major advantages: 1) low cost because of the low-voltage isolation and the low component rating of the series converter and 2) high reliability because of the redundancy of the series converters.In this paper we modified DPFC as for multi feeders which are in adjacent. So the main advantage is we can use DPFC for two or more power generations without increasing economical and with max pure sinusoidal output.In the last decade, the electrical power quality issue has been the main concern of the power companies [1].

Power quality is defined as the index which both the delivery and consumption of electric power affect on the performance of electrical apparatus [2]. From a customer point of view, a power quality problem can be defined as any problem is manifested on voltage, current, or frequency deviation that results in power failure [3]. The power electronics progressive, especially in flexible alternating-current transmission system (FACTS) and custom power devices, affects power quality improvement [4], [5]. Generally, custom power devices, e.g., dynamic voltage restorer (DVR), are used in medium-to-low voltage levels to improve customer power quality [6]. 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. The FACTS devices, such as unified power flow controller (UPFC) and synchronous static compensator (STATCOM), are used to alleviate thefrom the UPFC structure that is included one shunt converter and several small independent series converters, as shown in Fig. 1 [9].

The DPFC has same capability as UPFC to balance the line parameters, i.e., line impedance, transmission angle, and bus voltage magnitude[10]. The paper is organized as follows: in section II, the DPFC principle is discussed. The DPFC control is described in section III. Section IV is dedicated to power quality improvement by DPFC. Simulation results are presented in sectionV.

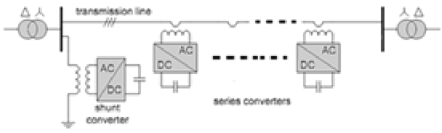

Fig. 1. The DPFCStructure

II. DPFCPRINCIPLE:

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

A.Eliminate DC Link and Power Exchange:

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. 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. Meanwhile, the third harmonic component is trapped in 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. Fig. 2 illustrates how the active power is exchanged 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 current is trapped in Δ-winding of transformer. Hence, no need to use the high-pass filter at the receiving-end of the system. In other words, by using the third-harmonic, the high-pass filter can be replaced with a cable connected between Δ-winding of transformer and ground. This cable routes the harmonic current toground.

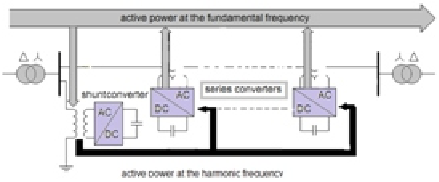

Fig.2.ActivepowerexchangebetweenDPFCconverters

A.The DPFCAdvantages:

The DPFC in comparison with UPFC has some advantages, asfollows:

- High ControlCapability

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

- HighReliability

The series converters redundancy increases the DPFC reliability during converters operation [10]. It means, if one of series converters fails, the others can continue towork.

- LowCost

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 seriesconverters.

III.DPFC CONTROL:

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

A. CentralControl:

This controller manages all the series and shunt controllers and sends reference signals to both ofthem.

B.SeriesControl:

Each single-phase converter has its own series control through the line. The controller inputs are series capacitor voltages, line current, and series voltage reference in the dq- frame. The block diagram of the series converters in Matlab/Simulink environment is demonstrated in Fig.4.

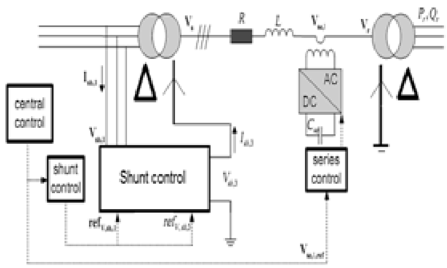

Fig. 3. DPFC controlstructure

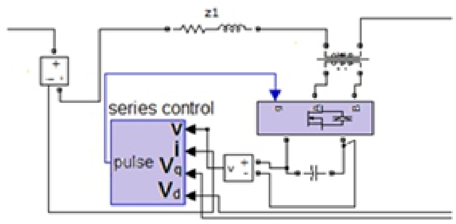

Fig. 4. Block diagram of the series converters in Matlab/Simulink

Any series controller has 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 manages switchingprocesses.

C.ShuntControl:

The shunt converter includes a three-phase converter connected back-to-back to a single-phase converter. The three-phase converter absorbs active power from grid at fundamental frequency and 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 of Δ-Y transformer.

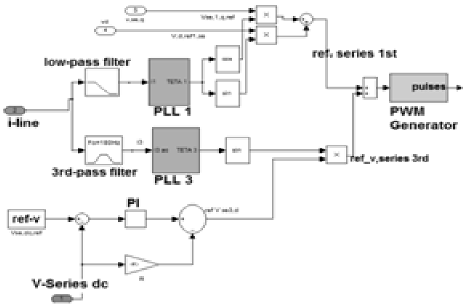

Fig.5.BlockdiagramofseriescontrolstructureinMatlab/Simulink

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.6.

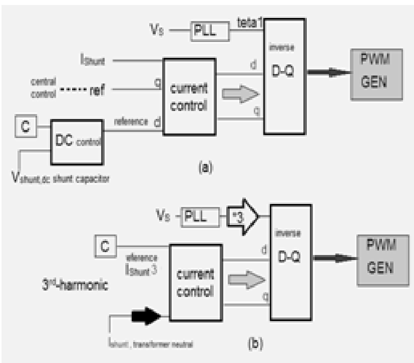

Fig. 6. The shunt control configuration: (a) for fundamental frequency (b) for third-harmonicfrequency

IV. DESIGN OF MC-DPFC USING FUZZY:

The simulation of MC-DPFC and controlling shown in fig7,8. Fuzzy logic is a powerful and versatile tool for representing imprecise, ambiguous and vague information. It also helps to model difficult, even intractable problems. In this paper, all the control algorithms have been validated by MATLAB/simulation study and system performance has been evaluated in detail. The main advantage of FLC resides in the fact that no mathematical modeling is a priori required to design the control law. The fuzzy controller uses a set of control rules that are based essentially on the knowledge of the system behavior and the experience of the control. Fuzzy controllers, like conventional PID controllers, cannot adapt themselves to changes in operation conditions such as varying mechanical parameters. To ensure optimum control performance over a wide range of parameter variations, adaptive fuzzy techniques may be used [13, 14]. In this paper, a new adaptive fuzzy control law is designed.

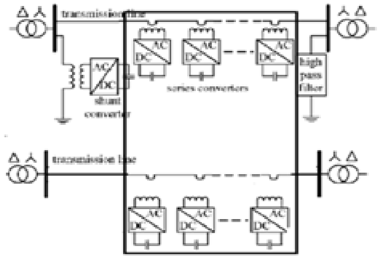

Fig 7: Block diagram of MC-DPFC

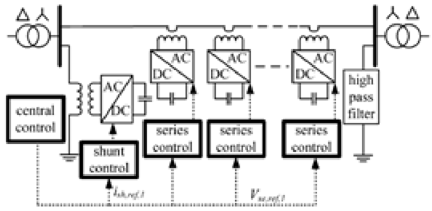

Fig. 8 Shunt and series controller

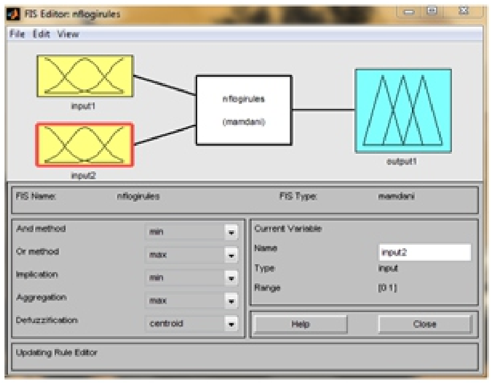

Fig 9. Fuzzy Interface System

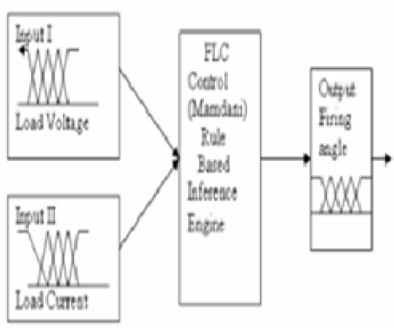

Fig.10 Fuzzy controller

V. SIMULATION RESULTS:

The proposed MC-DPFC and its Fuzzy control schemes have been tested through extensive case study simulations using MATLAB/PSCAD. In this section, simulation results are presented, and the performance of the proposed MC-DPFC system is shown.

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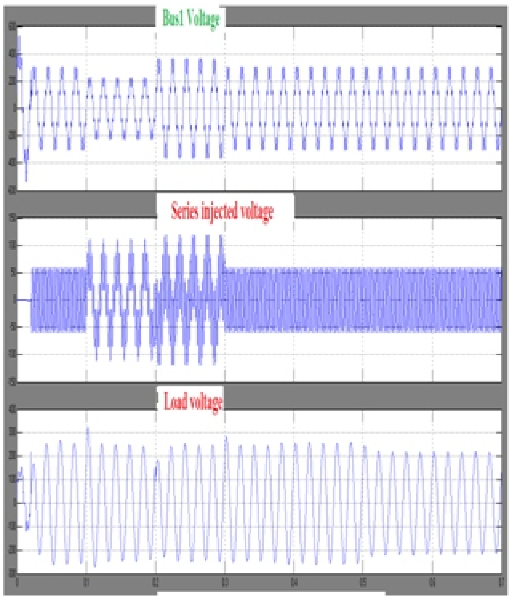

Fig.11 Bus1 voltage, series injected voltage and load voltage at Feeder1

A.Distortion and sag/swell on the Bus voltage:

Let us consider that the power system in Fig. 2 consists of two three-phase three-wire 380(v) (rms, L-L), 50-Hz utilities. The BUS1 voltage ( ) contains the seventh-order harmonic with a value of 22%, and the BUS2 voltage ( ) contains the fifth-order harmonic with a value of 35%. The BUS1 voltage contains 25% sag between 0.1 s < t < 0.2 s and 20% swell between 0.2 s < t < 0.3 s. The BUS2 voltage contains 35% sag between 0.15 s < t < 0.25 s and 30% swell between 0.25 s < t < 0.3 s.

The nonlinear/sensitive load L1 is a three-phase rectifier load which supplies an RC load of 10Ω and 30 μF. Finally, the critical load L2 contains a balance RL load of 10 Ω and 100mH. The MC-DPFC is switched on at t = 0.02 s. The BUS1 voltage, the corresponding compensation voltage injected by VSC1 and finally load L1 voltage are shown in Fig. 8.

In all figures, only the phase a waveform is shown for simplicity.Similarly, the BUS2 voltage, the corresponding compensation voltage injected by VSC3, and finally, the load L2 voltage are shown in Fig. 9. As shown in these figures, distorted voltages of BUS1 and BUS2 are satisfactorily compensated for across the loads L1 and L2 with very good dynamic response.

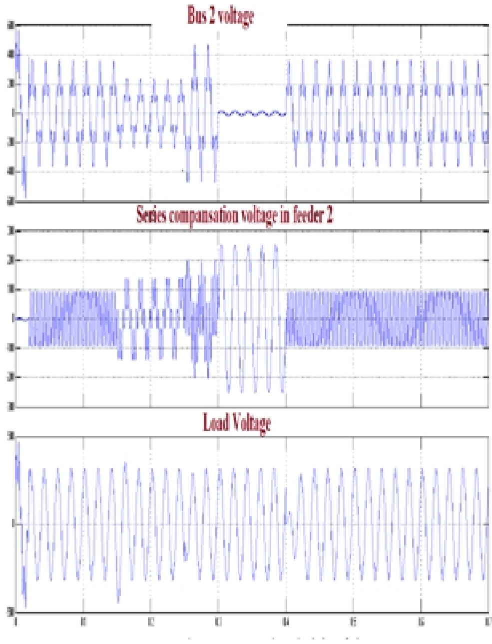

Fig.12 Bus2 voltage, series injected voltage and load voltage at Feeder2

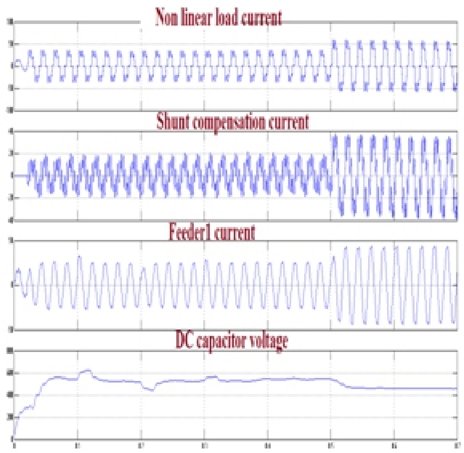

Fig.13 Nonlinear loads, shunt compensation current, feeder1 current and DC capacitor voltage.

The nonlinear load current, its corresponding compensation current injected by VSC2, compensated Feeder1 current, and, finally, the dc-link capacitor voltage are shown in Fig. 10. The distorted nonlinear load current is compensated very well, and the total harmonic distortion (THD) of the feeder current is reduced from 28.5% to less than 5%. Also, the dc voltage regulation loop has functioned properly under all the disturbances, such as sag/swell in both feeders

One of the many solutions is the use of a combined system of shunt and Series converter like multi converter unified power quality conditioner (MC-DPFC) .compensate the supply voltage and the load current or to mitigate any type of voltage and current fluctuations sag, swell and power factor correction in a power distribution network. The control strategies used here are based on PI & ANN controller of the MC-DPFC in detail. The control strategies are modeled using MATLAB/SIMULINK. The simulation results are listed in comparison of different control strategies are shown in figures,10,11,12,13and 14.

V. CONCLUSION:

The present topology illustrates the operation and control of Multi Converter Distributed Power flow controller (MC-DPFC). The system is extended by adding a series VSC in an adjacent feeder. A suitable mathematical have been described which establishes the fact that in both the cases the compensation is done but the response of ANN controller is faster and the THD is minimum for the both the voltage and current in sensitive/critical load. The device is connected between two or more feeders coming from different substations. A non-linear/sensitive load L-1 is supplied by Feeder-1 while a sensitive/critical load L-2 is supplied through Feeder-2. The performance of the MC-DPFC has been evaluated under various disturbance conditions such as voltage sag/swell in either feeder, fault and load change in one of the feeders. In case of voltage sag, the phase angle of the bus voltage in which the shunt VSC (VSC2) is connected plays an important role as it gives the measure of the real power required by the load. The MC-DPFC can mitigate voltage sag in Feeder-1 and in Feeder-2 for long duration.

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