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POWER QUALITY ENHANCEMENT BY USING SAG-SWLL SIMULATION SYSTEMS

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ABSTRACT

Distributed Power Flow Controller is a new device within the family of FACTS. The DPFC has the same control capability as the UPFC, but with much lower cost and higher reliability. This paper addresses one of the applications of the DPFC namely compensation of unbalanced currents in transmission systems. Since the series converters of the DPFC are single phase, the DPFC can compensate both active and reactive, zero and negative sequence unbalanced currents. To compensate the unbalance, two additional current controllers are supplemented to control the zero and negative sequence current respectively.

Keywords: **FACTS, DPFC, modeling , Unbalanced currents, Zero sequence**

I. INTRODUCTION

There is a great demand of power flow control in power systems of the future and combined FACTS devices are the most suitable devices [1-3]. However, due to the cost and the reliability issues given above, there are many hurdles to the widespread application of combined FACTS devices. The new concept is Distributed Power Flow Controller (DPFC). It is a combined FACTS device, which has taken a UPFC as its starting point. The DPFC has the same control capability as the UPFC; independent adjustment of the line impedance, the transmission angle and the bus voltage. The components in the series converters. Also, the reliability of the DPFC is improved because of the redundancy provided by the multiple series converters [4-5]. The elimination of the common DC link also allows the DSSC concept to be applied to series converters. In that case, the reliability of the new device is further improved due to the redundancy provided by the distributed series converters [6]. By applying the two approaches eliminating the common DC link and distributing the series converter, the UPFC is further developed into a new combined FACTS device: the Distributed Power Flow Controller (DPFC), as shown in fig 1

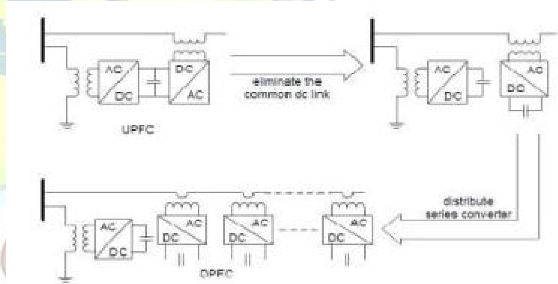

Fig 1. Flow chart from UPFC to DPFC

II. DISTRIBUTED POWER FLOW CONTROLLER (DPFC)

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

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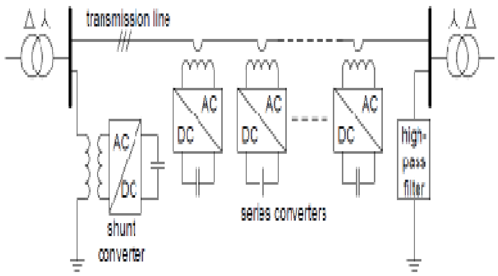

As shown, besides the key components – shunt and series converters, a DPFC also requires a high pass filter that is shunt connected to the other side of the transmission line and a star-delta transformer on each side of the line. The unique control capability of the UPFC is given by the back-to-back connection between the shunt and series converters, which allows the active power to freely exchange. To ensure the DPFC has the same control capability as the UPFC, a method that allows active power exchange between converters with an eliminated DC link is required.

III. DPFC OPERATING PRINCIPLE

A)ACTIVE POWER EXCHANGE WITH ELIMINATED DC LINK

Within the DPFC, the transmission line presents a common connection between the AC ports of the shunt and the series converters. Therefore, it is possible to exchange active power through the AC ports. The method is based on power theory of non sinusoidal components. According to the Fourier analysis, non-sinusoidal voltage and current can be expressed as the sum of sinusoidal functions in different frequencies with different amplitudes. The active power resulting from this non-sinusoidal voltage and current is defined as the mean value of the product of voltage and current. Since the integrals of all the cross product of terms with different frequencies are zero, the active power can be expressed by:

Where Vi and Ii are the voltage and current at the ith harmonic frequency respectively, and is the corresponding angle between the voltage and current. Equation shows that the active powers at different frequencies are independent from each other and the voltage or current at one frequency has no influence on the active power at other frequencies. The independence of the active power at different frequencies gives the possibility that a converter without a power source can generate active power at one frequency and absorb this power from other frequencies.

By applying this method to the DPFC, the shunt converter can absorb active power from the grid at the fundamental frequency and inject the power back at a harmonic frequency. This harmonic active power flows through a transmission line equipped with series converters. According to the amount of required active power at the fundamental frequency, the DPFC series converters generate a voltage at the harmonic frequency, thereby absorbing the active power from harmonic components. Neglecting losses, the active power generated at the fundamental frequency is equal to the power absorbed at the harmonic frequency.

For a better understanding, Figure 3 indicates how the active power is exchanged between the shunt and the series converters in the DPFC system. The high-pass filter within the DPFC blocks the fundamental frequency components and allows the harmonic components to pass, thereby providing a return path for the harmonic components. The shunt and series converters, the high pass filter and the ground form a closed loop for the harmonic current.

B) USING THIRD HARMONIC COMPONENTS

Due to the unique features of 3rd harmonic frequency components in a three-phase system, the 3rd harmonic is selected for active power exchange in the DPFC.

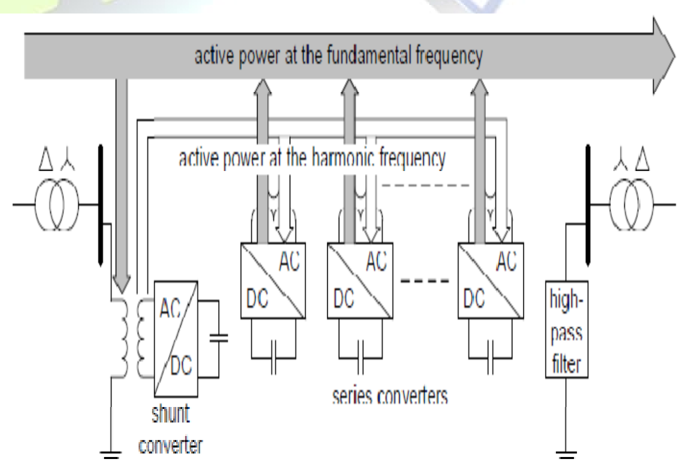

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Fig.3 Active power exchange between DPFC converters

In a three-phase system, the 3rd harmonic in each phase is identical, which means they are 'zero sequence' components. Because the zero-sequence harmonic can be naturally blocked by star-delta transformers and these are widely incorporated in power systems (as a means of changing voltage), there is no extra filter required to prevent harmonic leakage. As introduced above, a high-pass filter is required to make a closed loop for the harmonic current and the cut-off frequency of this filter is approximately the fundamental frequency. Because the voltage isolation is high and the harmonic frequency is close to the cut-off frequency, the filter will be costly. By using the zero-sequence harmonic, the costly filter can be replaced by a cable thatconnects the neutral point of the star delta transformer on the right side in Fig 3 with the ground. Because the delta winding appears open circuit to the 3rd harmonic current, all harmonic current will flow through the Y-winding and concentrate to the grounding cable as shown in Fig 4. Therefore, the large high-pass filter is eliminated.

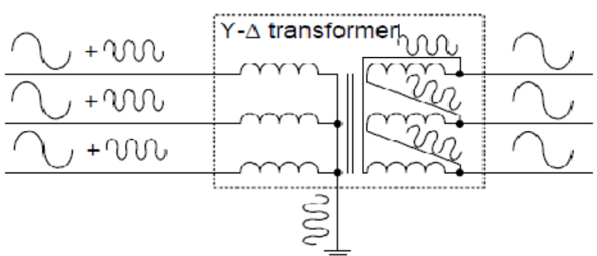

Fig. 4 Utilize grounded star-delta transformer to filter zero sequence harmonic

Another advantage of using the 3rd harmonic to exchange active power is that the grounding of the star-delta transformers can be used to route the harmonic current in a meshed network. If the network requires the harmonic current to flow through a specific branch, the neutral point of the star-delta transformer in that branch, at the side opposite to the shunt converter, will be grounded and vice versa. Fig 5 shows a simple example of routing the harmonic current by using the grounding of the star-delta transformer. Because the floating neutral point is located on the transformer of the line without the series converter, it is an open-circuit for 3rd harmonic components and therefore no 3rd harmonic current
will flow through this line.

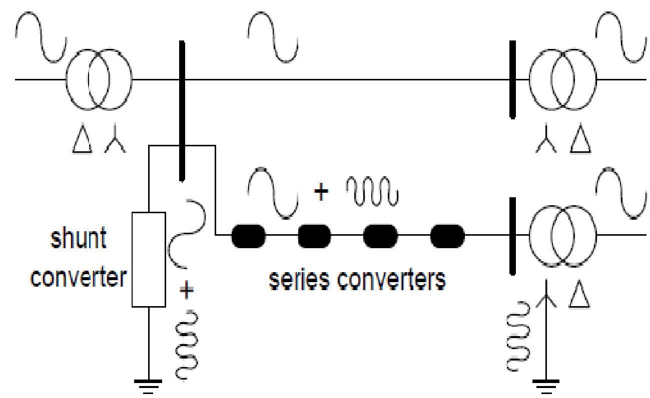

Fig.5 Route the harmonic current by using the grounding of the star-delta Transformer

The harmonic at the frequencies like 3rd, 6th, 9th... are all zero-sequence and all can be used to exchange active power in the DPFC. However, the 3rd harmonic is selected, because it is the lowest frequency among all zero-sequence harmonics. The relationship between the exchanged active power at the ith harmonic frequency and the voltages generated by the converters is expressed by the well known the power flow equation and given as:

Where Xi is the line impedance at ith frequency |VSh | and |Vse | the voltage magnitudes of the ith harmonic of the shunt and series converters, and (_sh,i – _se,i) is the angle difference between the two voltages. As shown, the impedance of the line limits the active power exchange capacity. To exchange the same amount of active power, the line with high impedance requires higher voltages. Because the transmission line impedance is mostly inductive and proportional to frequency, high transmission frequencies will cause high impedance and result in high voltage within converters. Consequently, the zero-sequence harmonic with the lowest frequency
the 3rd harmonic has been selected.

IV. ADVANTAGES AND LIMITATION OF THE DPFC

The DPFC can be considered a UPFC that employs the D-FACTS concept and the concept of exchanging power through the 3rd harmonic. In this way, the DPFC inherits all their advantages:

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High controllability:
The DPFC can simultaneously control all the parameters of the transmission network: line impedance, transmission angle and bus voltage. High reliability:

The redundancy of the series converter gives high reliability without increasing cost. In addition, the shunt and series converters are independent and failure of one will not influence the other converters. Low cost:

There is no phase-to-phase voltage isolation required between the series converters of different phases. The power rating of each converter is also low. Because of the large number of the series converters, they can be manufactured in series production. If the power system is already equipped with the STATCOM, the system can be updated to the DPFC with only low additional costs. However, there is a drawback to using the DPFC.
Extra currents:

Because the exchange of power between the converters takes place through the same transmission line as the main power, extra currents at the 3rd harmonic frequency are introduced. These currents reduce the capacity of the transmission line and result in extra losses within the line and the two star-delta transformers. However, because this extra current is at the 3rd harmonic frequency, the increase in the RMS value of the line current is not large and through the design process can be limited to less than 5% of the nominal current.

V.SIMULATION AND RESULTS OF DPFC

A) Modeling Of DPFC Shunt Converter:

The modeling of this converter is done by using MATLAB software and the modeling diagram is shown in the fig 6 Simulation circuit for the modeling of Shunt converter.

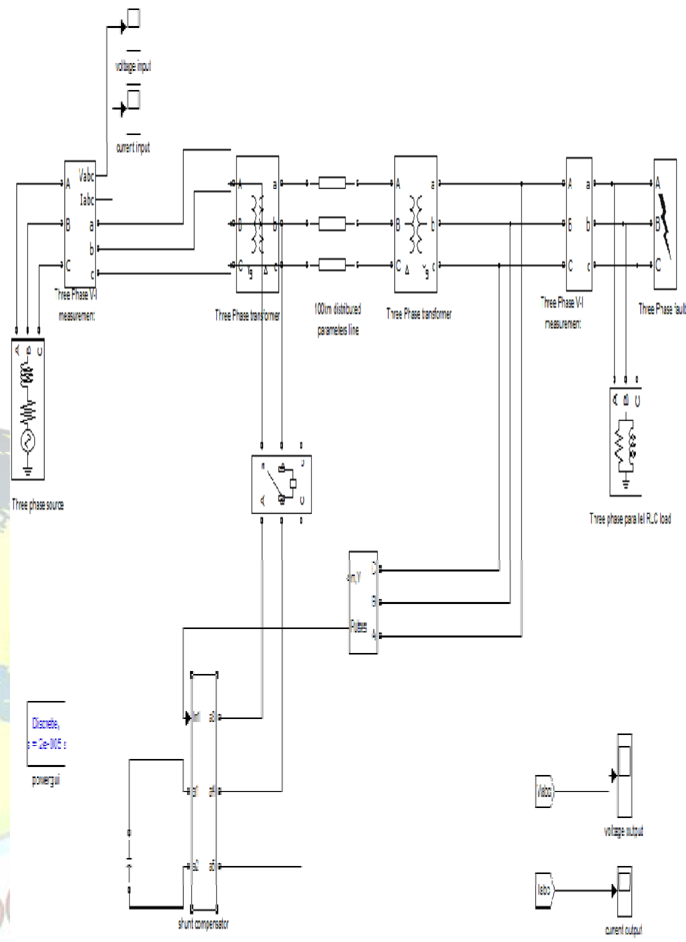

Fig 6. Simulation circuit for the modeling of Shunt converter

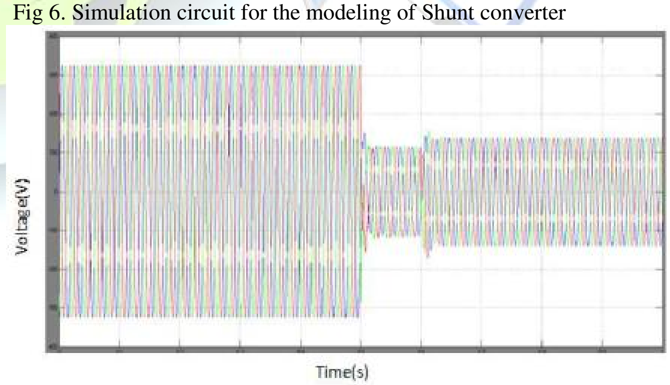

Fig 7. Shunt converter Input voltage

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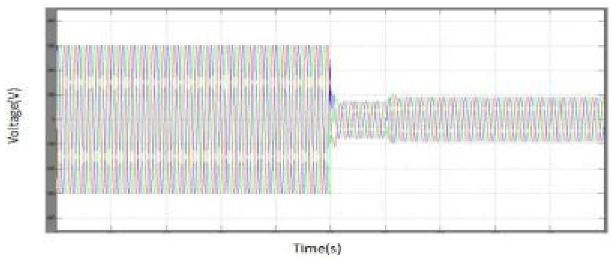

Fig 8. Shunt converter Output voltage

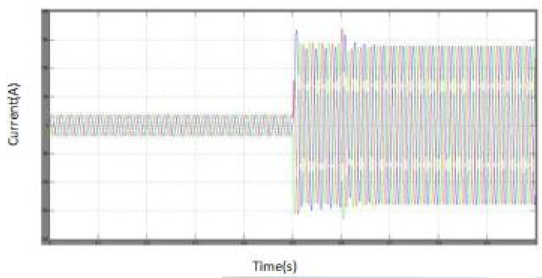

Fig 9. Shunt converter Input current

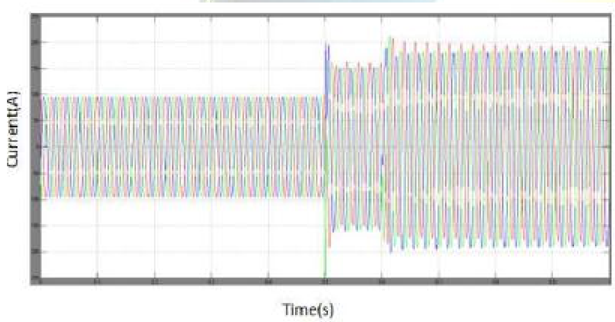

Fig 10. Shunt converter output current

When fault is applied between 0.5 to 2 second, current is increased to 150 A, thereby voltage reduced to 8 times the normal value. When the shunt compensator is connected at 0.6 second, current is increased and thereby simultaneously the voltage value is reduced. Analysis of shunt converter shown in table 1. In order to compensate the voltage, a series compensator is used.

Table 1 Analysis Of Shunt Converter

Supply current(A)	100 A
Fault Occurring period(Sec)	0.5- 2 S
Current during fault period(A)	150 A
Compensated current	200 A

B)Modelling of DPFC Series Converter

The modeling of this converter is done by using MATLAB software and the modeling diagram is shown in the figure 8 Simulation circuit for the modeling of Series converter.

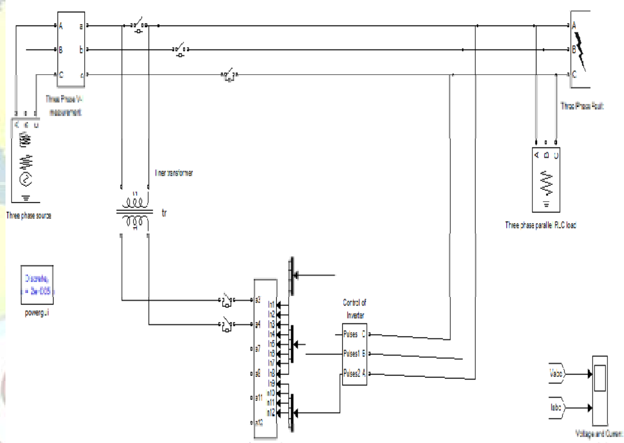

Fig. 11 Simulation circuit for the modeling of Series converter

When fault is applied between 0.5 to 2 second, voltage is reduced to 180v, thereby current increased to 8 times the normal value. When the series compensator is connected at 0.6 second, voltage is increased and thereby simultaneously the current value is reduced. Analysis of series converter shown in table 2. In order to compensate the current, a shunt compensator is used.

VI. CONCLUSION

This paper investigates the capability of the DPFC to balance a network. It is found that the DPFC can compensate both negative and zero sequence components, consequently the DPFC is more powerful than other FACTS device for compensation of

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unbalanced currents. Additional controllers are supplemented to existing DPFC controller, and their principle is to monitor the negative and zero sequences of the current through the transmission line, and to force them to be zero by applying an opposing voltage. As a side effect, the DPFC generates non-zero sequence 3rd current during the unbalance situation, which can not be blocked by the Y-K transformer. However the magnitude of the nonzero sequence 3rd current is much smaller than the nominal current at the fundamental frequency, less than 4% typically.

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