International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 8, No. 2, June 2017, pp. 705~711
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v8i2.pp705-711

Voltage Stability Improvement in Fourteen Bus System during Line Interruption using DPFC

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Article Info

Article history:

Received Jan 5, 2017
Revised Mar 5, 2017
Accepted Mar 19, 2017

Keyword:

Distributed power flow controller
Distributed static series compensator
Multi level Inverter
Static compensator
Total harmonic distortion
Unified power flow controller

ABSTRACT

DPFC is proposed in the present work to improve voltage stability of fourteen bus system during line interruption. The voltage across the load decreases due to the interruption of the line. State space method is used to calculate Line currents and bus voltages. The ability of DPFC to bring voltage, real power and reactive power to normal level is presented in this paper. The simulation results for healthy system, line interrupted system without DPFC and with DPFC are presented. The results of comparative study are presented to show the improvement in power quality. The simulation studies indicate that the power flow with DPFC during line outage is almost equal to the power during healthy condition.

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1. INTRODUCTION

Day by day power demand is increasing. To fulfil increased demand, it is an urgent need to increase power generation and hence increase in power transmission capability. With increasing load demand, hence increase in power generation and transmission, power system becomes more and more complex, as a result, in some cases Transmission Line becomes overloaded (above thermal limit) and in other cases it becomes under loaded though its thermal limit capacity is not reached. It may lead to uncontrolled power flows; and excessive reactive power in the system, thus the full potential of transmission interconnections is not utilized [1].

Unified Power Flow Controller (UPFC) is the most power full FACTS device currently. It can instantaneously control all parameters in a power network, such as line impedance, power angle, and voltage magnitude [2]. The simplified diagram of UPFC is illustrated in Figure 1. However, such solid state power flow controllers are not widely applied because of the following reasons: the high cost due to the high voltage isolation, high power rating and the relative low reliability. The reliability of UPFC depends on the power electronics. A single component failure will cause the whole system shut down [2].

To overcome these disadvantages The Distributed Power Flow Controller (DPFC) recently presented in [3], is a powerful device within the family of FACTS devices, which provides much lower cost and higher reliability than conventional FACTS devices. It is derived from the UPFC and has the same capability of simultaneously adjusting all the parameters of the power system: line impedance, transmission angle, and bus voltage magnitude [4]-[5]. The simplified diagram of DPFC is illustrated in Figure 2.

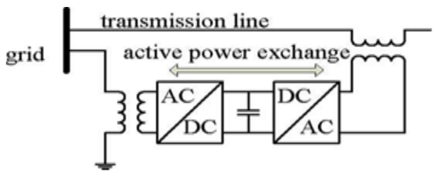

Figure 1. Simplified representation of a UPFC

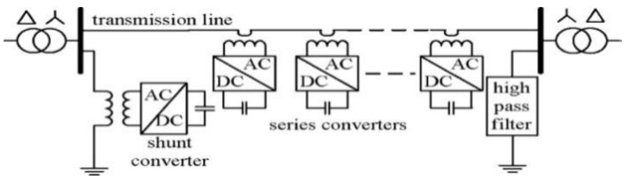

Figure 2. Basic Configuration of DPFC

2. INTRODUCTION TO DPFC

Within the DPFC, there is a common connection between the ac terminals of the converters in different lines, which is the transmission line [6]. Therefore, it is possible to exchange the active power through the ac terminals. The method is based on the power theory of non-sinusoidal components [7]. According to the Fourier analysis, a non-sinusoidal voltage and current can be expressed by the sum of sinusoidal functions in different frequencies with different amplitudes. The active power resulted by 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:

$$P = \sum_{i=1}^{\infty} U_i J_i cos\varphi_i \tag{1}$$

Where U_i and J_i are the voltage and current at the i^{th} harmonic frequency, respectively, and φ_i is the angle between the voltage and current at the same frequency. Equation 1 gives the active powers at different values frequencies. The independency of the active power at different frequencies gives the possibility that a converter without power source can generate active power at one frequency and absorb this power from other frequencies. The 3rd harmonic is selected to exchange the active power in the DPFC, because it is a zero-sequence harmonic and can be naturedly blocked by Y-Δ transformers, which are widely used in power system to change voltage level.

3. DPFC CONTROL

To control the multiple converters, DPFC consists of three types of controllers [8]. They are: central controller, shunt control and series control, as shown in Figure 3.

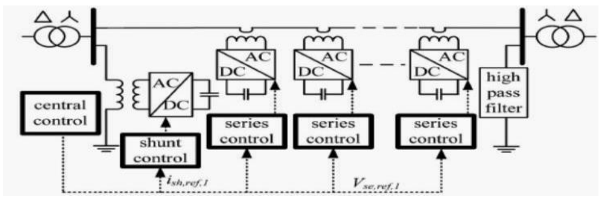

Figure. 3. Block diagram of the control of a DPFC

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 the 3rd harmonic frequency components, and to generate series voltage at the fundamental frequency that is required by the central control. 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 meantime, it maintains the capacitor dc voltage of the shunt converter by absorbing active power from the grid at the fundamental frequency, and injects required reactive current at the fundamental frequency to the grid.

Central control: The central control generates the reference signals for both the shunt and series converters of the DPFC. It is focus on the DPFC applications in the power system level, such as power flow control, low frequency power oscillation damping and balancing unsymmetrical components, etc. According the system requirement, 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 are at the fundamental frequency.

4. ADVANTAGES OF DPFC

The DPFC in comparison with UPFC has some advantages, [9]-[10] 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 [11]. 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. The above literature does not deal with improvement of voltage stability during line interruption.

Power Transfer Capability & Reliability Improvement in a Transmission Line using Distributed Power Flow Controller is given by P. Ramesh, M. Damodara Reddy [12]. Enhancement of Power Quality by an Application FACTS Devices is given by Prashant Kumar [13].

5. SIMULATION RESULTS AND DISCUSSION

Fourteen bus system under normal condition is shown in Figure 3.1. There are five generator busses and nine load busses. Each generator is represented as series combination of voltages source and reactance. Each line is represented as a series combination of R and L. Each load is represented as a combination of R& L in parallel with bus. The voltage at bus fourteen is shown in Figure 3.2. The RMS output voltage at bus fourteen is shown in Figure 3.3 and its value is 4500V. The real and reactive powers at bus fourteen are shown in Figure 3.4 and real power is 0.345MW and reactive power is 0.065VAR. Fourteen bus system with line two open and DPFC in OFF condition is shown in Figure 4.1. The voltage at bus fourteen is shown in Figure 4.2. The voltage decreases from 6000 to 4500 due to increase in the line impedance. RMS voltage at bus fourteen is shown in Figure 4.3 and its value is 3950V. The real and reactive powers at bus fourteen are shown in Figure 4.4 and its value of real power is 0.293MW and reactive power is 0.053MVAR.

Fourteen bus system with line two open and DPFC in ON condition is shown in Figure 5.1. The voltage at bus fourteen is shown in Figure 5.2 and its value is almost equal to the value under healthy condition. The RMS voltage at bus fourteen is shown in Figure 5.3 and its value is 4500V. The real and reactive power at bus fourteen is shown in Figure 5.4. The real power is 0.329MW and reactive power is 0.059MVAR. The comparison of real and reactive power is shown in Table 1.

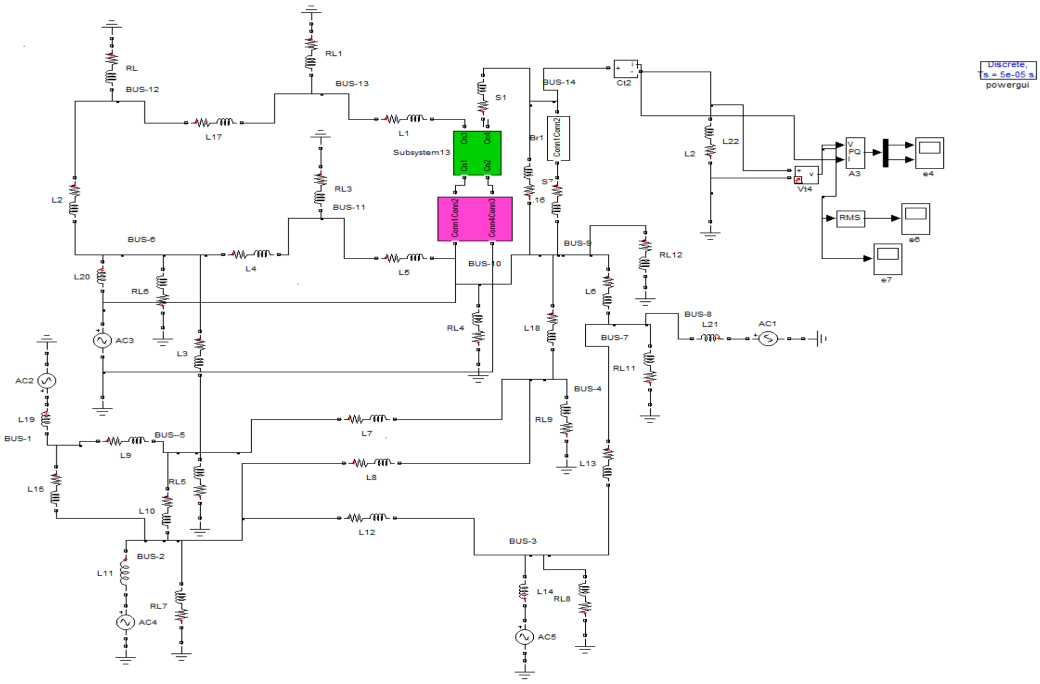

Figure 3.1. 14 Bus system under normal condition

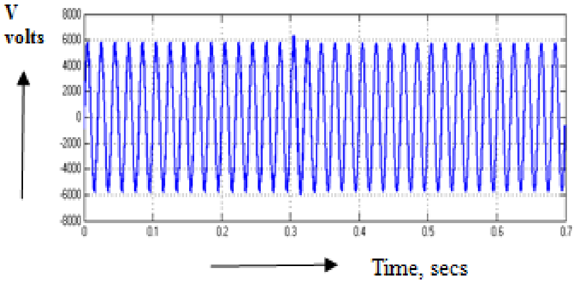

Figure 3.2. Voltage at Bus 14

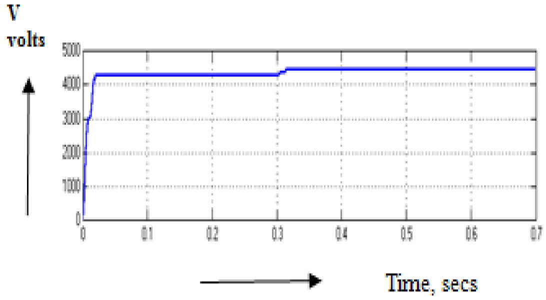

Figure 3.3. RMS output Voltage at Bus 14

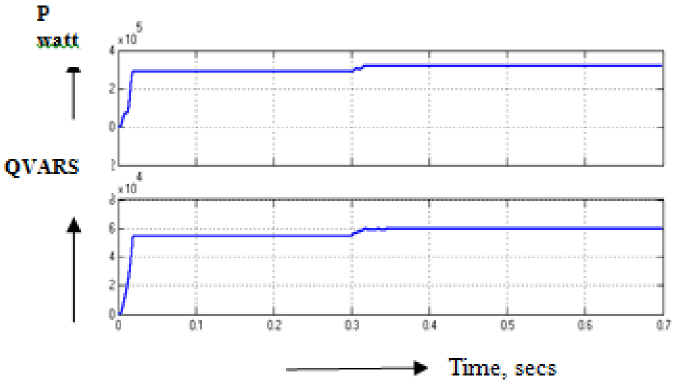

Figure 3.4. Real and Reactive power at Bus 14

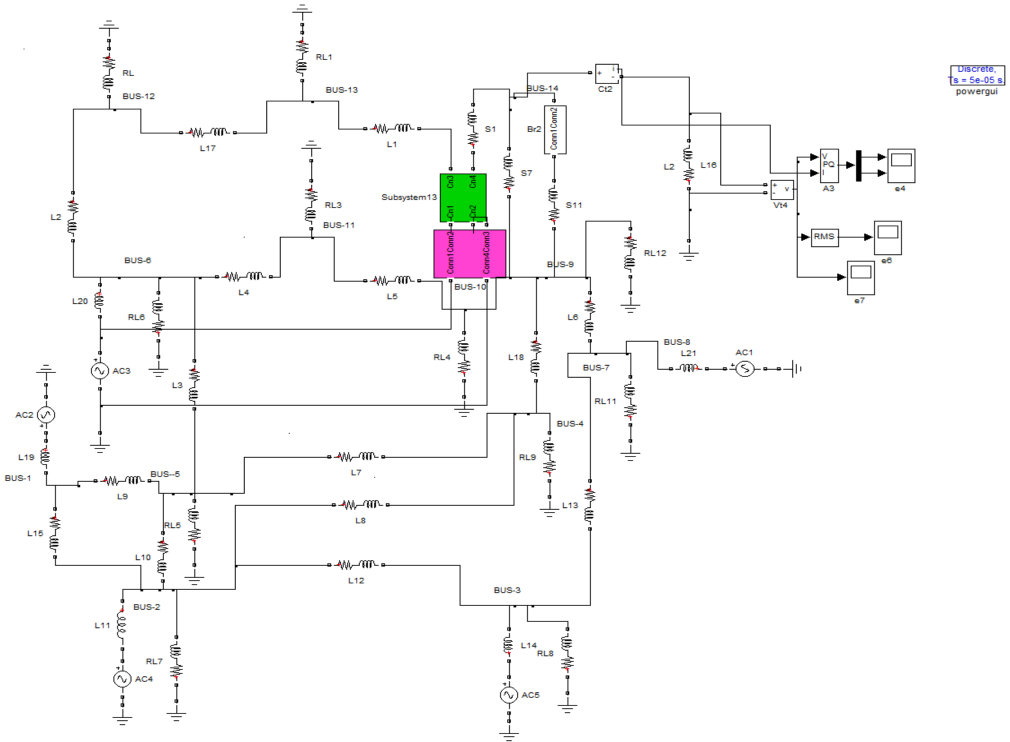

Figure 4.1. 14 Bus system with Line 2 open and DPFC Off condition

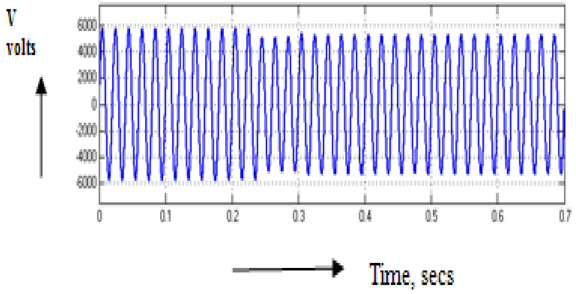

Figure 4.2. Voltage at Bus 14

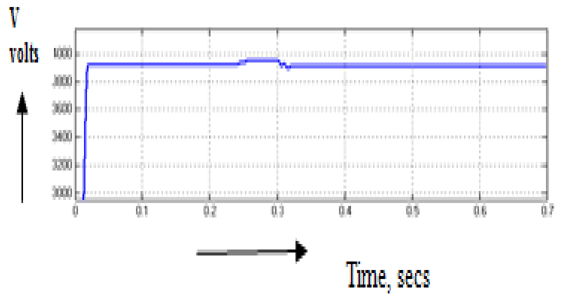

Figure 4.3. RMS output Voltage at Bus 14

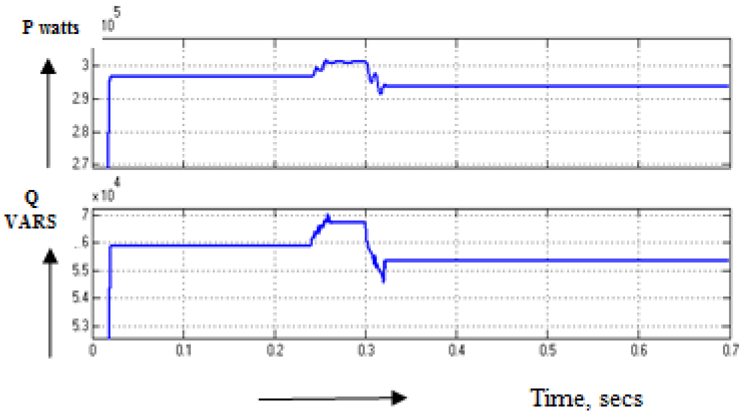

Figure 4.4. Real and Reactive power at Bus 14

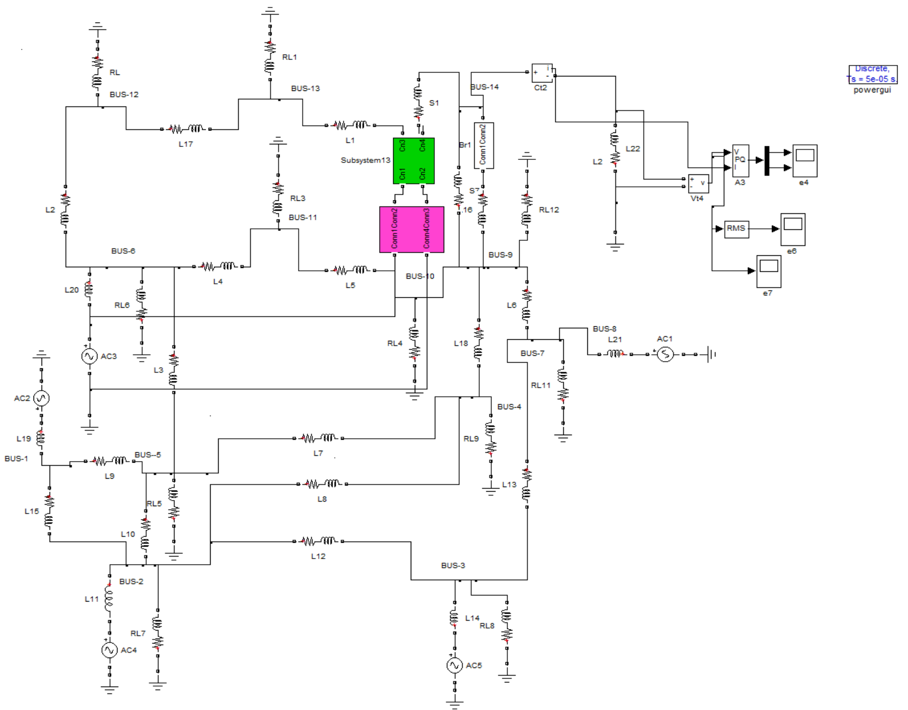

Figure 5.1. 14 Bus system with Line 2 open and DPFC ON condition

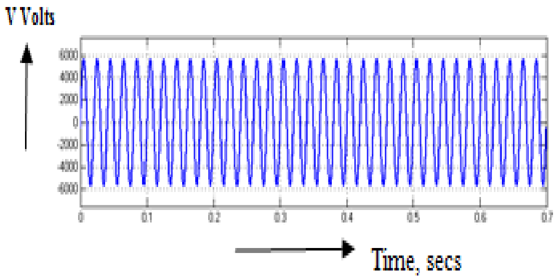

Figure 5.2. Voltage at Bus 14

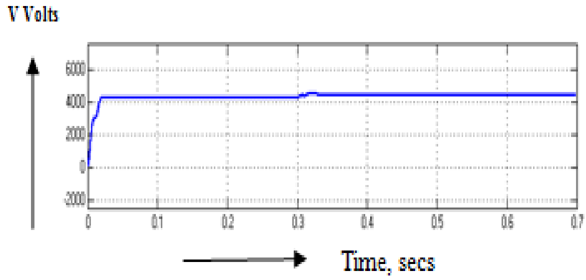

Figure 5.3. Voltage at Bus 14

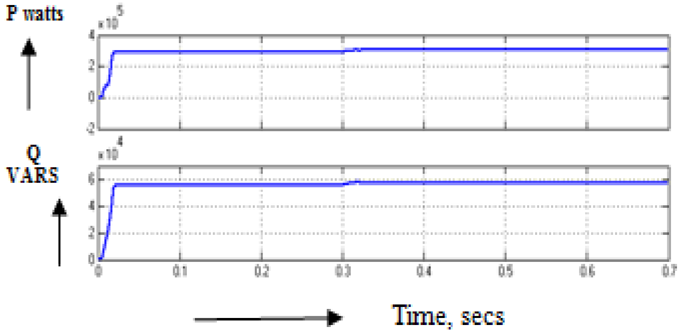

Figure 5.4. Real and Reactive Power at Bus 14

Table 1. Comparision of Real & Reactive Power

14-bus DPFC	Vo	Real power (MW)	Reactive power (MVAR)
Normal condition	4.413kv	0.347	0.065
Line 2 open & DPFC off	3.907kv	0.293	0.053
DPFC ON & Line 2 open	4.013kv	0.329	0.059

From Table -1 Real power under healthy condition is 0.347MW and Real power during contingency is 0.329MW. The reactive power under healthy condition is 0.065MVAR and during contingency is 0.059MVAR.

6. CONCLUSION

Fourteen bus systems with and without DPFC for line interruption are modelled and simulated using Simulink. The introduction of DPFC in uninterrupted line has improved voltage profile apart from enhancing real power transfer. The voltage during line interruption is 0.88 pµ and it improves to 0.91 pµ by including DPFC.The benefits of DPFC are improved voltage stability and power factor. The disadvantage of DPFC is the requirement of multiple series converters and a shunt converter.The scope of the present work is to perform contingency studies on fourteen bus system. The line contingency studies on thirty bus system will be done in near future.

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