ADVANCES in NATURAL and APPLIED SCIENCES

ISSN: 1995-0772
EISSN: 1998-1090
2016November10(16):pages 30-36

Published BY**AENSI Publication**
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Open Access Journal

Hysteresis Controlled Distributed Power Flow Controller to Regulate Voltage of a Ten Bus System

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Received 23 August 2016; Accepted 1 November 2016; Published 20 November 2016

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ABSTRACT

DPFC is a popular FACTS device which is used to improve power quality in the power system. This paper shows the conception and simulation of ten bus radial system with DPFC. The aim of this work is to regulate receiving end voltage in ten bus radial system. This paper deals with modeling and tuning of ten bus system with closed loop hysteresis controlled DPFC. Line impedance is obtained using the line parameters available in the hand book and investigations are performed. The main objective of the work to reduce THD, steady state error, settling time etc. using hysteresis controller, The THD is reduced from 5.75% to 2.73%, Steady state error is also reduced 9.3v to 6.2v.when compared with PID the hysteresis controller show reduction in the peak value of current, peak time, settling time and THD content. At finally the paper conclude Hysteresis controller is observed to show better characteristics than PID controlled system.

KEYWORDS: DPFC Voltage regulation Hysteresis controller

INTRODUCTION

The growing demand and aging of networks make it desirable to control the power flow in power transmission system fast and reliability. Flexible AC transmission system (FACTS) is the better application of power electronics in transmission system. The main purpose of this technology is to control and regulate the electric variables in the power system and hence therefore increases the power transfer capability and can be utilized for power flow control. Unified power flow controller (UPFC) is the most powerful device which controls all the parameters like line impedance, the transmission angle, bus voltage etc., of the system.

The main purpose of the UPFC are certainly to pass the real power flow bi directionally, maintaining regulated DC voltage, work widely range of operating condition etc. Simplified diagram of UPFC as shown in Fig.1. UPFC is the combination of static compensator (STATCOM) and static synchronous series compensator (SSSC) coupled via a common DC link to allow bidirectional flow active power between the output terminals of the series connected SSSC and shunt connected output terminal of the STATCOM.

The two shunt and series converters operated from a DC link provided by a DC storage capacitor. The UPFC is not applied widely in practice due to its high cost and the redundancy to failure. Since all components of the UPFC handle high voltages and high current, the total cost of the system is also very high. Due to the common DC link interconnection a failure that made at any one converter will affect the whole system. To

ToCite ThisArticle: S. Vadivel and. Baskaran., Hysteresis Controlled Distributed Power Flow Controller to Regulate Voltage of a Ten Bus System. **Advances in Natural and Applied Sciences**. 10(16);Pages: 30-36

achieve the required reliability for power systems, bypass circuit or redundant back ups are needed which leads to increase the cost.

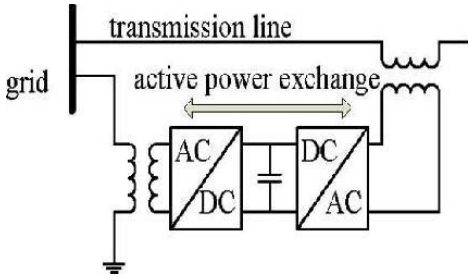

Fig. 1: Simplified diagram of a UPFC

The same as the UPFC, The Distributed Power Flow Controller (DPFC) presently used power flow device within the FACTS, which provides very lower cost and higher reliability than the FACTS devices. It is derived from the UPFC and has the same ability of simultaneous adjustment of all the parameters of power system like line impedances, transmission angle, bus voltage magnitude etc. Generally a power devices like dynamic voltage restorer (DVR) is used in medium to low voltage levels to improve power quality [7]. Most serious threats for sensitive equipment in electrical grids are voltage sags (voltage dip) and swells (over voltage) [5].

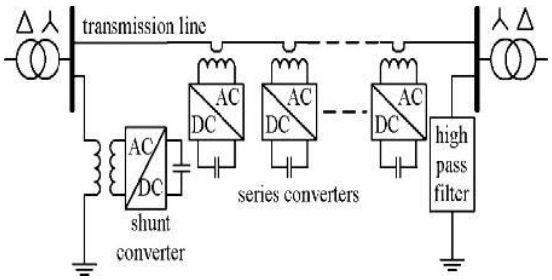

Fig. 2: DPFC structure

These disturbances causes due to some any event like short circuit in the grid, inrush currents involved with the starting time of large machines, or switching operations in the grid. In this paper a distributed power flow controller (DPFC) a new FACTS device is used to mitigate voltage and current waveform deviation and improve power quality in few seconds. The DPFC Structure is derived from the UPFC structure that is included with one shunt converter and many small independent series converters, as shown in Fig.2 [6][4]. The shunt converter is similar to the STATCOM while the series converter employs the D-FACTS concept. The DPFC has same capability of UPFC to balance the line parameters like line impedance, transmission angle, and bus voltage magnitude etc., [4].The concept of DPFC is introduced by Zhihui Yuan in 2010 with specific control range. Modeling of DPFC was also explained by Ahmad Jamshidi and S. Masoud Barakati in 2012 along with working principle and its advantages.

DPFC Principle:

The Unified Power Flow Controller (UPFC) is modeled from SSSC and STATCOM. Both are coupled by DC storage capacitor via a common DC link. When compared with UPFC, the advantage of DPFC is eliminating the huge DC-link and instead of using 3rd-harmonic current to achieve active power exchanges (Fig 3) [2]. Theoretically the third, sixth, and ninth harmonic frequency can be used to exchange active power in the DPFC, which are normally zero sequence frequencies only. The capacity of a transmission line to deliver power also depends on its impedance. The transmission line impedance is inductive and proportional to the frequency, so the high transmission frequencies will cause high impedance. Because of this the third harmonics frequency is selected which is lowest zero sequence harmonic frequency. In the following subtopics; the DPFC basic concepts are explained.

DC Link Elimination and Power Exchange:

In the DPFC, instead of common DC link, the transmission line is used as a connection between the terminal of series converters and DC terminal of shunt converter, for power exchange between shunt and series converters [2] [6]. The theory of non-sinusoidal apparatus is used to exchange power in DPFC. A non-sinusoidal voltage or current is presented as the sum of sinusoidal components at various frequencies based on Fourier series. The product of current and voltage components gives the active power. Since the integral of some terms with different frequencies are zero, the active power equation is given as:

$$P = \sum_{n=1}^{\infty} V_n I_n \, Cos\phi_n$$

Where Vn and In are the voltage and current at the nth harmonic, respectively, and ϕn is the angle between the voltage and current at the same frequency. Equation (1) expresses the active power at different frequency components. From the above equation (1), the current and voltage in a frequency has no influence on the active power at other frequencies. The active power at different frequencies is sequestered from each other. So the concept of shunt converter in DPFC can absorb active power from the grid at the fundamental frequency and inject the current back into the grid at a harmonic frequency. The shunt converter in DPFC can absorb the active power in a frequency and generate output power in another frequency and also conferring to the amount of active power requested at the fundamental frequency, the DPFC series converter produce the voltage at the harmonic frequency there by riveting the active power from harmonic components.

The series converters of the DPFC are single-phase, it gives the opportunity to DPFC for controlling current in each phase independently, which suggests that both negative and zero sequence unbalanced current can be remunerated. Additional controllers are enhanced to the present DPFC controller. The control principle is to monitor the negative and zero sequences current through the transmission line and to force them to zero. The above literature does not deal with the comparison of closed loop controlled DPFC system using PID and Hysteresis controllers. The objective of this paper is to study the improvement in dynamic response using Hysteresis controller.

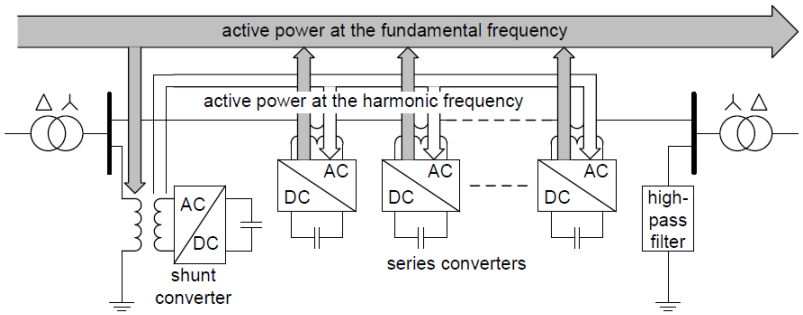

Fig. 3: Active Power Exchange

KVL in primary of DVR

$$V_i = iR + L\frac{di}{dt}$$

$$V_0 = IZ$$

Real power is calculated with the formula

$$P = V_S V_R \frac{Sin\,\partial}{X}$$

Reactive power is calculated with the formula

$$Q = V_R \frac{V_S - V_R}{X}$$

Block diagram of existing system is shown in fig3.Block diagram of proposed system is shown in fig4.

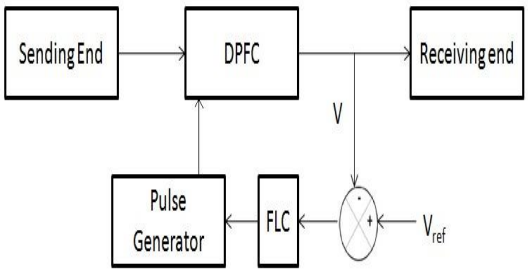

Fig. 4: Block Diagram of Proposed System

3. Simulation Results:

3.1 Ten bus system with DPFC and with PID controller:

Ten bus system with DPFC and with PID controller is shown in figure 5.The output voltage is shown in figure 6 and the value is 4500V.

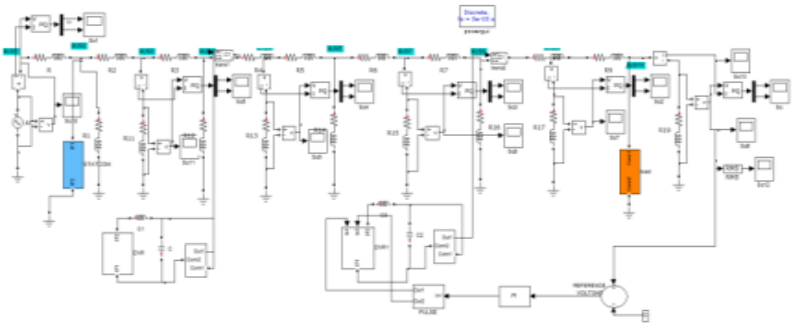

Fig. 5: Ten bus system with PID controller

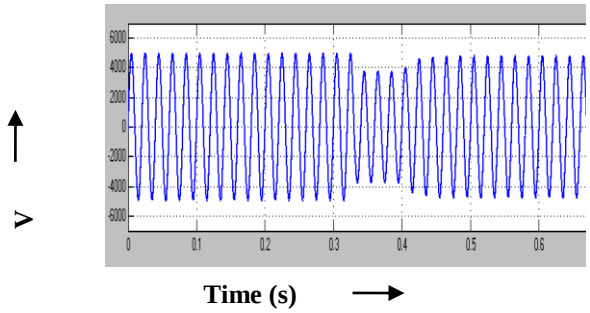

Fig. 6: Receiving end voltage

The output current is shown in figure 7. The Real and Reactive powers are shown in figure 8. The current THD is shown figure 9. The THD content is 5.75 %

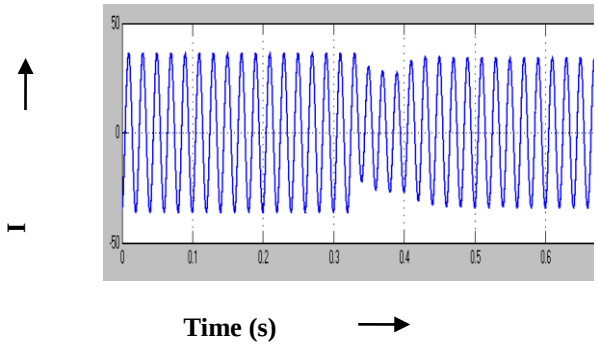

Fig. 7: Receiving end Current

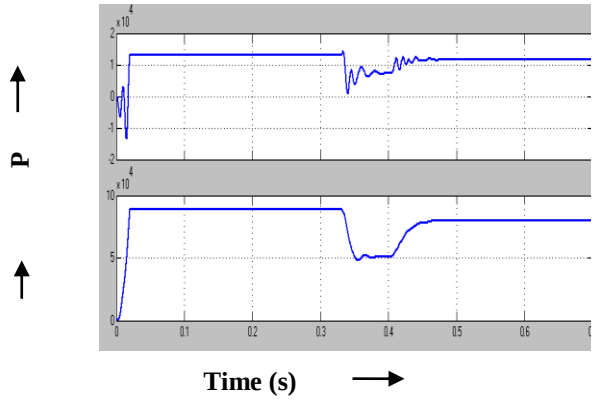

Fig. 8: Real and Reactive powers

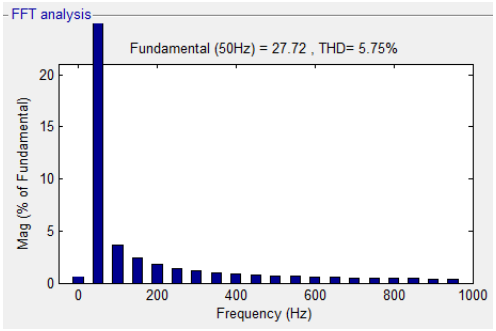

Fig. 9: Current THD

3.2 Ten bus system with DPFC and with hysteresis controller:

Ten bus systems with DPFC and with hysteresis controller is shown in figure 10 .The receiving end voltage is shown in figure 11. The receiving end current is shown in figure 12.

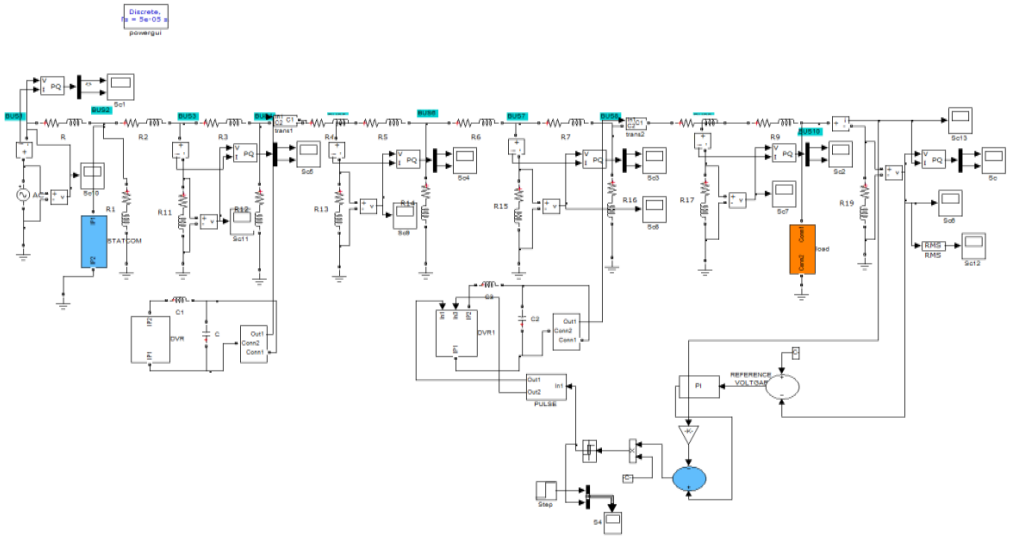

Fig. 10: Ten Bus System with hysteresis Controller

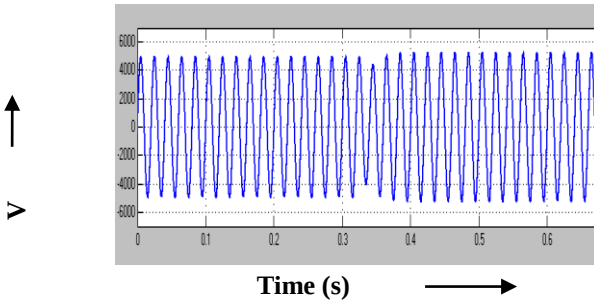

Fig. 11: Output voltage

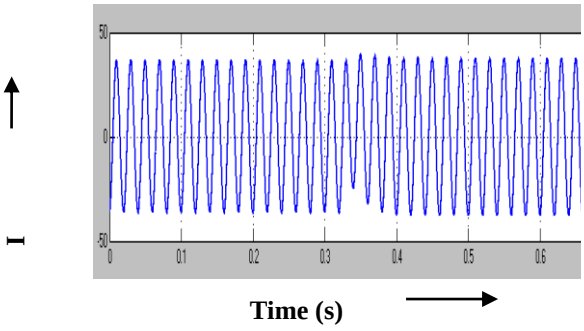

Fig. 12: Output Current

The Real and Reactive Powers are shown in figure 13. The current THD is shown in figure 14 and THD is 2.5

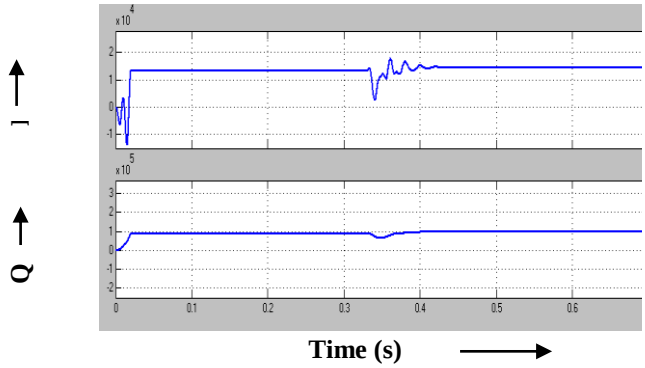

Fig. 13: Real and Reactive Powers

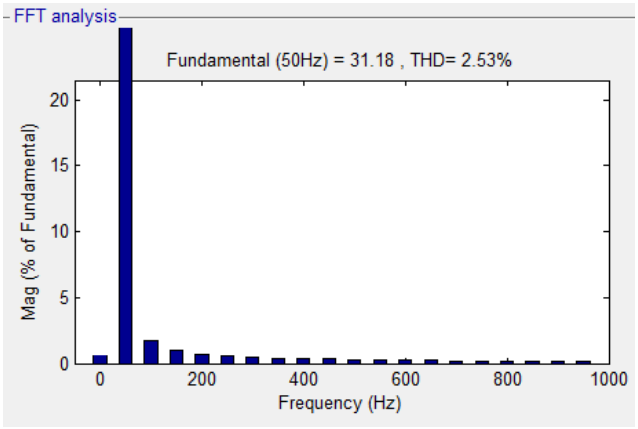

Fig. 14: Current THD

The comparison of time domain parameter is shown in Table-1. The settling time is reduced to 0.41 Sec using hysteresis controller. The steady state error is reduced from 9.3V to 6.2V using hysteresis controller comparison of THD is shown in Table-2. The THD with hysteresis controller is as low as 2.53%.

Table 1: Time domain parameters

Controllers	Rise time (s)	Peak time (s)	Settling time (s)	Steady state error (E_{ss})
PID controller	0.32	0.35	0.45	9.3
Hysteresis	0.31	0.34	0.42	6.2

Table 2: THD

DPFC	Output Current THD
With PID controller	5.75%
With hysteresis controller	2.53%

Conclusion:

Ten bus System with PID and with hysteresis control for DPFC is modeled and simulated using Simulink. The simulation results indicate that the time domain response with hysteresis control is superior to PID controlled system. The settling time is found to be as low as 0.42 Seconds. The steady state error is 6.2V the advantage of proposed system are reduced settling time and steady state error.

The scope of the present work is comparison between PID and Hysteresis controllers. The comparison of hysteresis with FLC and ANN will be done in future.

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