DPC Method for Three-Phase Matrix Converters Operating as Unified Power Flow Controllers (UPFCs)

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Abstract:

Power control, broadly speaking, is the intelligent selection of transmitter power output in a communication system to achieve good performance within the system. In this paper, a matrix converter- based UPFC is proposed, using a direct power control approach (DPC-MC) based on an MC-UPFC dynamic model. In order to design UPFCs, presenting robust behavior to parameter variations and to disturbances, the proposed DPC-MC control method, is based on sliding mode-control techniques, allowing the real-time selection of adequate matrix vectors to control input and output electrical power. By selecting an appropriate matrix converter switching state, line active and reactive power, together with ac supply reactive power, can be directly controlled, and guaranteeing good steady-state and dynamic responses.

The line active and reactive power linear controllers based on a modified Venturini highfrequency PWM modulator compared with direct power controller (DPC) by using MC-UPFC; guarantee faster responses without overshoot, presenting no cross-coupling in dynamic and steady- state responses and no steady state error. Experimental results of direct power controllers for MC based UPFC shows decoupled active and reactive power control and fast response times.

Keywords:

DPC, UPFC, MC, reactive power, Power control.

Introduction:

In the last few years, electricity market deregulation, together with growing economic, environmental, and social concerns, has increased the difficulty to burn fossil fuels, and to obtain new licenses to build transmission lines (rights-of-way) and high-power facilities.

This situation started the growth of decentralized electricity generation (using renewable energy resources). UPFC enable the operation of power transmission networks near their maximum ratings, by enforcing power flow through well-defined lines. These days, UPFCs are one of the most versatile and powerful FACTS devices. The UPFC results from the combination of a STATCOM and a SSSC that shares a common dc capacitor link. The existence of a dc capacitor bank originates additional losses, decreases the converter lifetime, and increases its weight, cost, and volume.

In the last few decades, an increasing interest in new converter types, capable of performing the same functions but with reduced storage needs, has arisen. These converters are capable of performing the same ac/ac conversion, allowing bidirectional power flow, guaranteeing near sinusoidal input and output currents, voltages with variable amplitude, and adjustable power factor. These minimum energy storage ac/ac converters have the capability to allow independent reactive control on the UPFC shunt and series converter sides, while guaranteeing that the active power exchanged on the UPFC series connection is always supplied/absorbed by the shunt connection.

Conventional UPFC controllers do not guarantee robustness. In, the dependence of the matrix converter output voltage on the modulation coefficient was analyzed, concluding that Matrix Converter -UPFC is able to control the full range of power flow. Recent nonlinear approaches enabled better tuning of PI controller parameters. Still, there is room to further improve the dynamic response of UPFCs, using nonlinear robust controllers.

EXISTING SYSTEM LIMITATIONS:

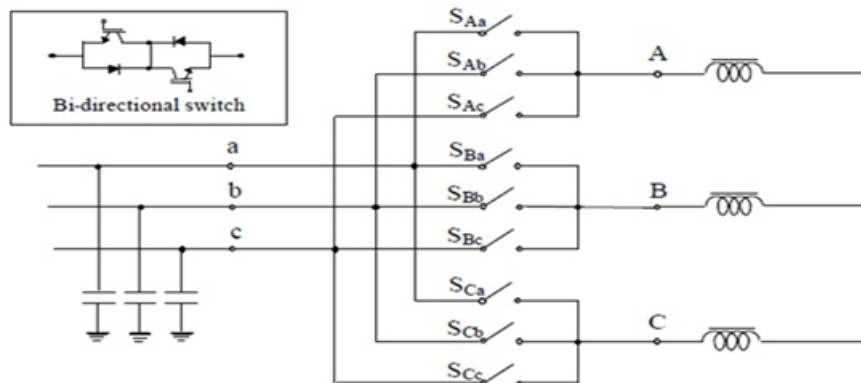Conventional UPFC controllers do not guarantee robustness.

The existence of a dc capacitor bank originates additional losses, decreases the converter lifetime, and increases its weight, cost, and volume. Minimum Storage Capability and Conventional UPFC controllers do not guarantee robustness.

PROPOSED SYSTEM MERITS:

Unified power-flow controllers (UPFC) enable the operation of power transmission networks near their maximum ratings, by enforcing power flow through well-defined lines.MC-based UPFC (MC-UPFC) has reduced volume and cost, reduced capacitor power losses, together with higher reliability. As a result, line active and reactive power, together with ac supply reactive power, can be directly controlled by selecting an appropriate matrix converter switching state guaranteeing good steady-state and dynamic responses.

APPLICATIONS:

• Many Power Applications,
• It's controlled the input and Output Electrical Powers (ex. Transformers.)
• Transmission line Power Control as well as Power Factor Control.

MATRIX CONVERTER:

The matrix converter has several advantages over traditional rectifier-inverter type power Frequency converters. It provides sinusoidal input and output waveforms, with minimal higher Order harmonics and no sub harmonics; it has inherent bi-directional energy flow capability; the Input power factor can be fully controlled. Last but not least, it has minimal energy storage Requirements, which allows to get rid of bulky and lifetime- limited energy-storing capacitors. But the matrix converter has also some disadvantages.

First of all it has a maximum input output Voltage transfer ratio limited to 87 % for sinusoidal input and output waveforms. It requires more semiconductor devices than a conventional AC-AC indirect power frequency Converter, since no monolithic bi-directional switches exist and consequently discrete unidirectional devices, variously arranged, have to be used for each bi-directional switch. Finally, it is particularly sensitive to the disturbances of the input voltage system.The comments and remarks made in this chapter are somewhere supported by simulation Results.

Circuit scheme of a three phase to three phase matrix converter. a, b, c are at the input terminals. A, B, C are at the output terminals.

UNIFIED POWER FLOW CONTROLLER:

Gyugyi proposed the UPFC concept in 1991. The UPFC was devised for the real time control and dynamic compensation of ac transmission systems, providing multifunctional flexibility required to solve many of the problems facing the delivery industry. Within the framework of traditional power transmission concepts, the UPFC is able to control, simultaneously or selectively.

All the parameters affecting power flow in the transmission line (i.e., voltage, impedance and phase angle), and this unique capability is signed by the adjective "unified" in its name. Alternatively, it can independently control both the real and reactive power flows in the line.

The UPFC is a combination of a static compensator and static series compensation. It acts as a shunt compensating and a phase shifting device simultaneously.
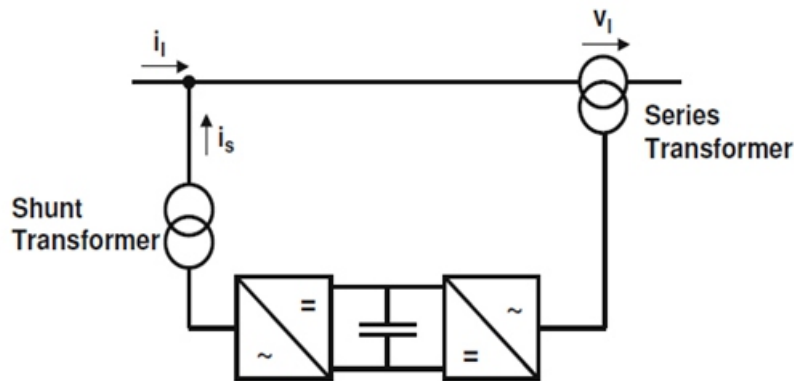
Principle configuration of an UPFC

The UPFC consists of a shunt and a series transformer, which are connected via two voltage source converters with a common DC-capacitor. The DC-circuit allows the active power exchange between shunt and series transformer to control the phase shift of the series voltage.

OPERATING PRINCIPLE OF UPFC:

The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer.
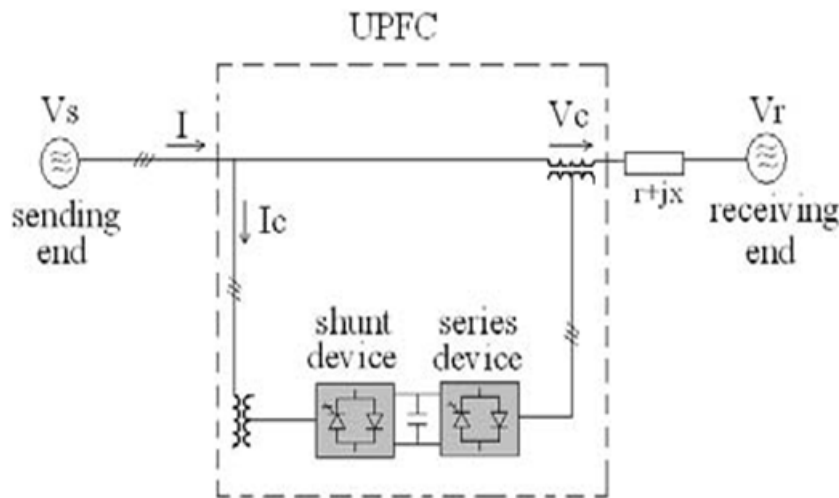
Basic schematic diagram of UPFC

A basic UPFC functional scheme is shown in above Figure. The series inverter is controlled to inject a symmetrical three phase voltage system (Vse), of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this inverter will exchange active and reactive power with the line.

MODELING OF MC UPFC
General Architecture:
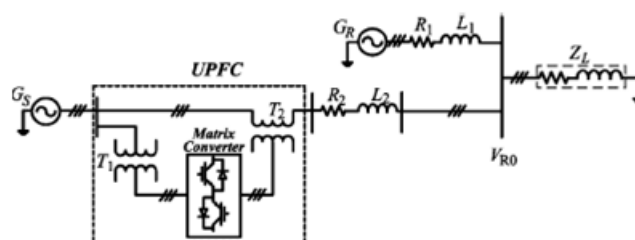
Transmission network with matrix converter UPFC.

A simplified power transmission network using the proposed matrix converter UPFC is presented in the above figure, where VS and VR are, respectively, the sending-end and receiving-end sinusoidal voltages of the GS and GR generators feeding load ZL. The matrix converter is connected to transmission line 2, represented as a series inductance with series resistance (L2 and R2), through coupling transformers T1and T2.

Below figure shows the simplified three-phase equivalent circuit of the matrix UPFC transmission system model. For system modeling, the power sources and the coupling transformers are all considered ideal. Also, the matrix converter is considered ideal and represented as a controllable voltage source, with amplitude VC and phase. In the equivalent circuit, VRo is the load bus voltage. The DPC-MC controller will treat the simplified elements as disturbances.
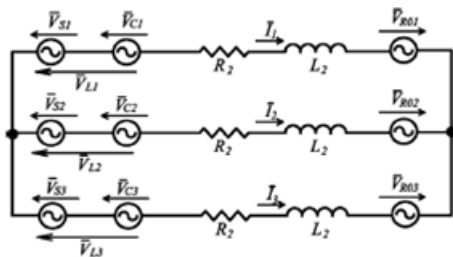
Three-phase equivalent circuit of the matrix UPFC and transmission line.

Considering a symmetrical and balanced three-phase system and applying Kirchhoff laws to the three-phase equivalent circuit as shown in Fig5.2, the ac line currents are obtained in dq coordinates.

$$\frac{dI_d}{dt} = \omega I_q - \frac{R_2}{L_2}I_d + \frac{1}{L_2}(V_{Ld} - V_{R0d}) \tag{1}$$

$$\frac{dI_q}{dt} = -\omega I_d - \frac{R_2}{L_2}I_q + \frac{1}{L_2}(V_{Lq} - V_{R0q}) \tag{2}$$

The active and reactive power of sending end generator [19] are given in coordinates by

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} V_d & V_q \\ V_q & -V_d \end{bmatrix}\begin{bmatrix} I_d \\ I_q \end{bmatrix} \tag{3}$$

Assuming VRod and Vsd = Vd as constants and a rotating reference frame synchronized to the Vs source so that Vsq= 0, active and reactive power P and Q are given by (4) and (5), respectively

$$P = V_d I_d \tag{4}$$

$$P = -V_d I_q \tag{5}$$

Based on the desired active and reactive power (Pref, Qref), reference currents (Idref, Iqref) can be calculated from (4) and (5) for current controllers. However, allowing P,Q actual powers are sensitive to errors in the Vd, Vq values.

IMPLEMENTATION OF THE DPC-MC AS UPFC:
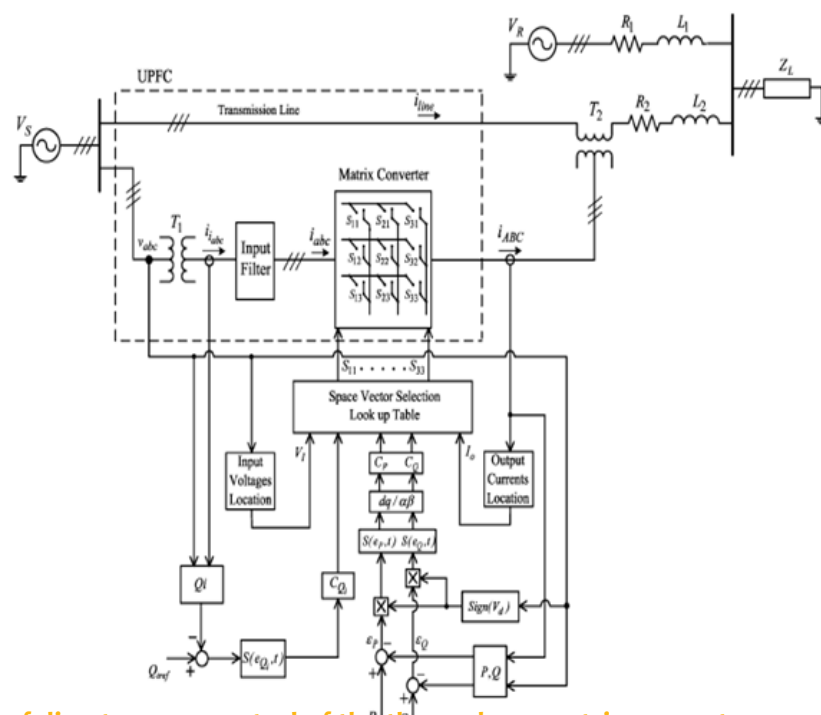
**Control scheme of direct power control of the three-phase matrix converter operating as a UPFC.**

As shown in the above Fig, the control of the instantaneous active and reactive powers requires the measurement of Gs voltages and output currents necessary to calculate $S\alpha(e_p, t)$ and $S\beta(e_Q, t)$ and sliding surfaces. The output currents measurement is also used to determine the location of the input currents component. The control of the MC input reactive power requires the input currents measurement to calculate $S_{Qi}(e_{Qi}, t)$.

Results:

Fig. Results 1 - (a) and (b) shows, respectively, the simulation results for the active and reactive power step response (Δ Pref = +0.4 p.u. and Δ Qref =+ 0.2 p.u.) and shunt reactive power, considering initial reference values: Pref = 0.4 p.u., Qref = 0.2 p.u., and Qref = -0.07 p.u. Both results clearly show that there is no cross-coupling between active and reactive power.
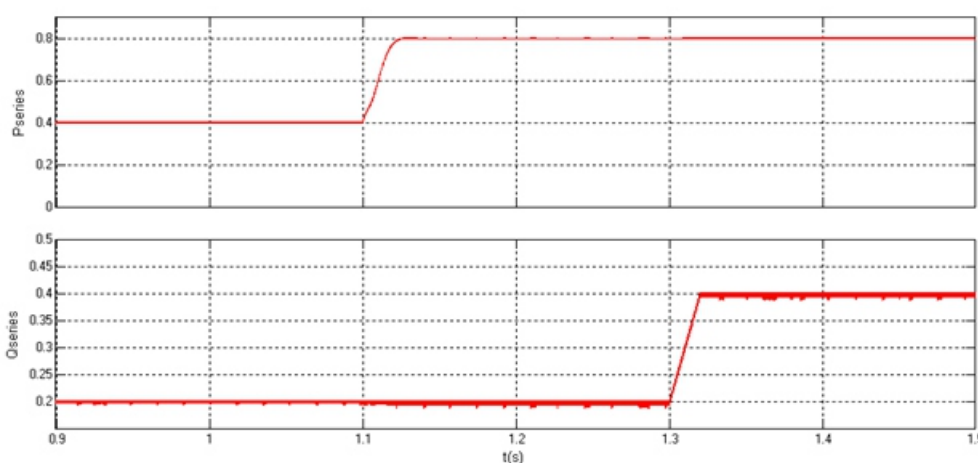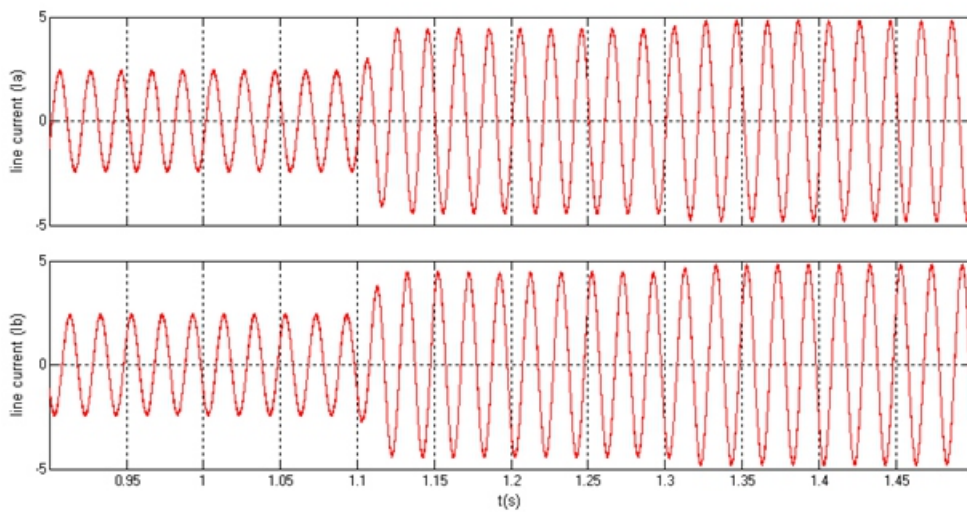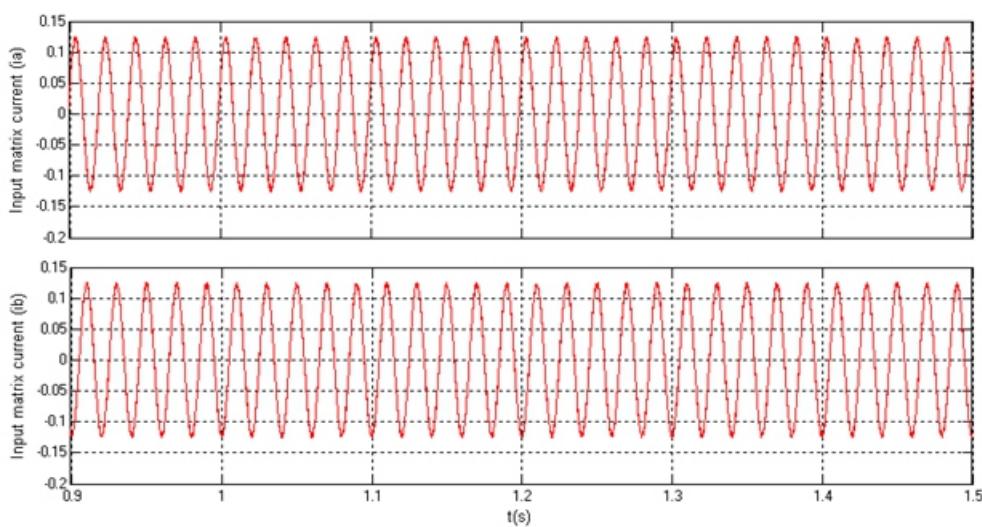

(a)
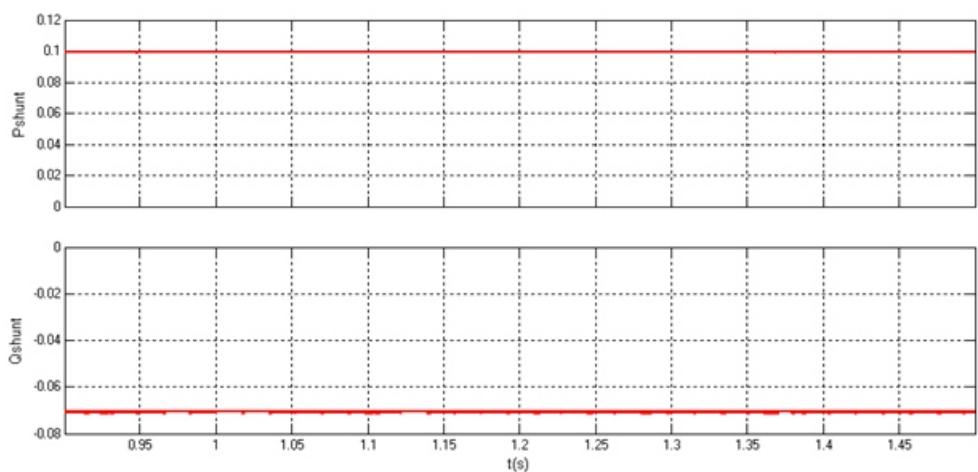
(b)

Fig Result 1: Power Response for P and Q step (Pref = +0.4 and Qref=+0.2)
(a) Active and reactive series power response
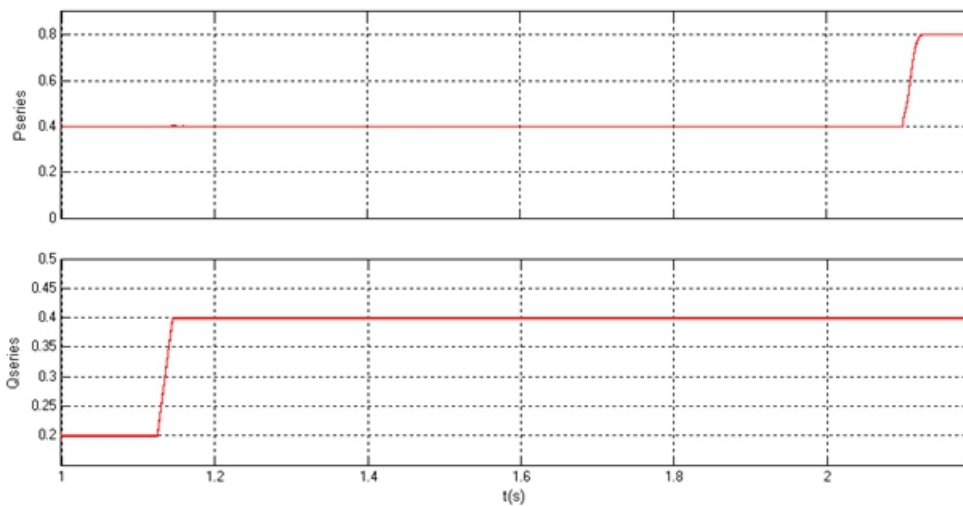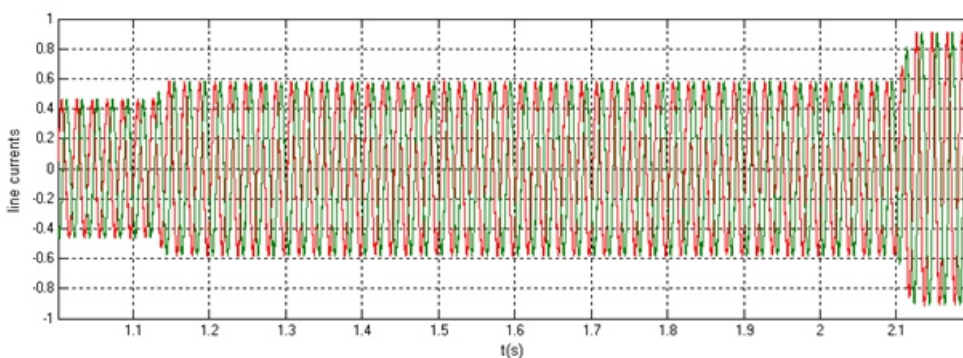**(b) Reactive shunt power**

(a)

b)

Fig Result-2: (a) Line currents (IA, iB)
(b) Input matrix converter currents (ib, ic) p.u.
DPC simulation results presented in Fig.(a) and (b), showing the claimed DPC faster dynamic response to step active and reactive power reference change.
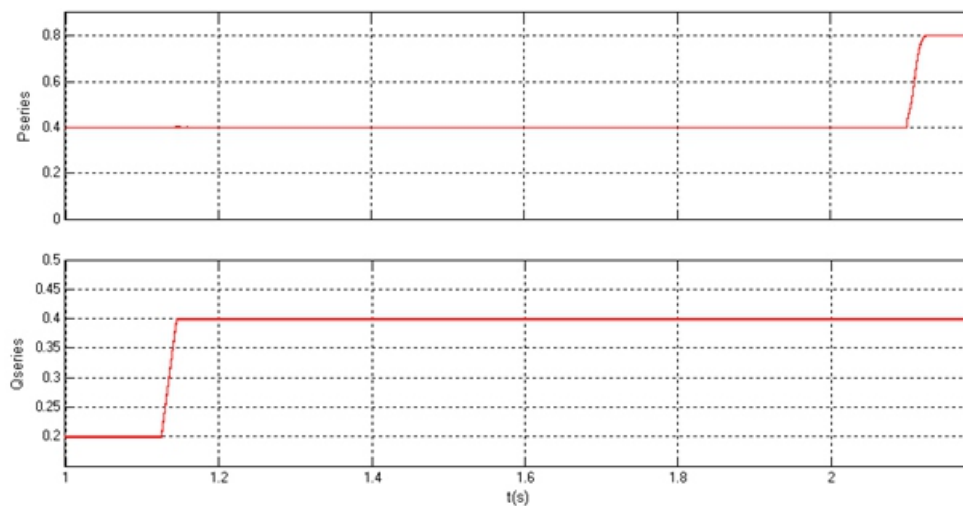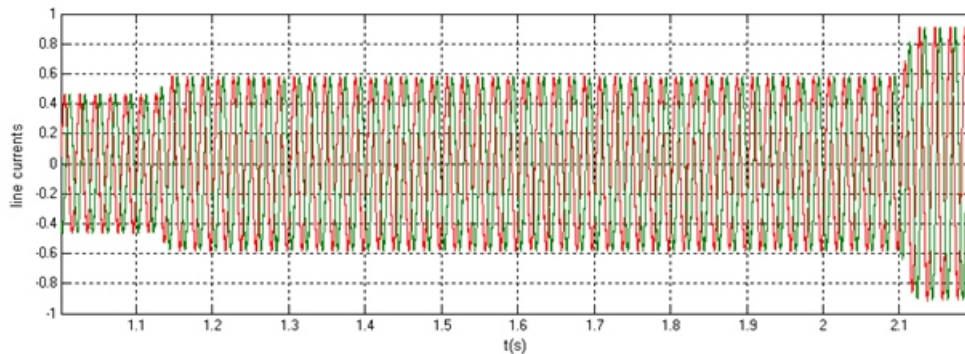
(a)

(b)

Fig Result 3- : Power Response for a P and Q step (Pref = +0.4 and Qref=+0.2)
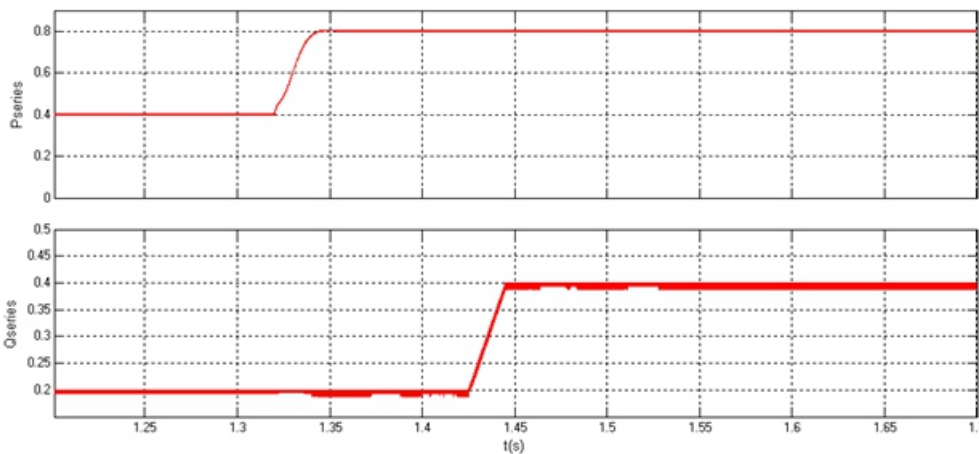**(a) Active and reactive Power Response**
(b) Line currents

(a)

(b)

Fig Result-4: Power Response for a P and Q step (Pref = +0.4 and Qref=+0.2)
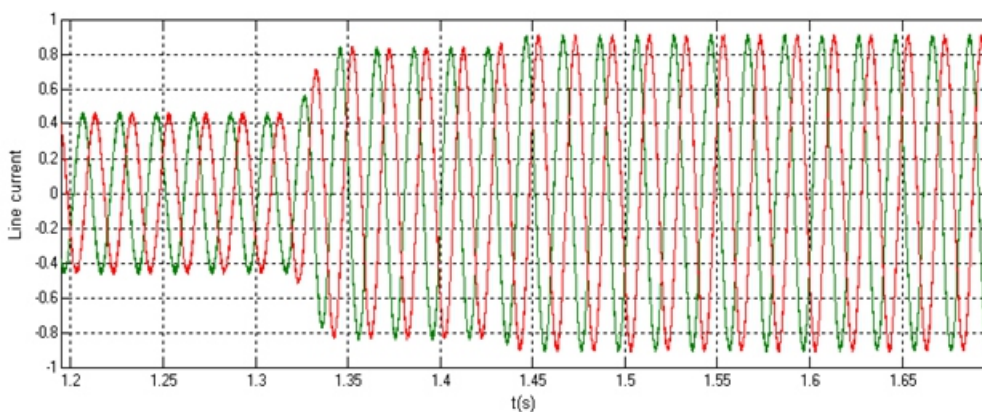**(a) Active and reactive Series power response**
(b) Line currents under linear controller

DPC controller ability to operate at lower switching frequencies, the DPC gains were lowered and the input filter parameters were changed accordingly (r=25Ω, l=5.9 mH C=12.6µF) to lower the switching frequency to nearly 1.4 kHz. The results (Fig.6.6) also show fast response without cross coupling between active and reactive power. This confirms the DPC-MC robustness to input filter parameter variation, the ability to operate at low switching frequencies, and insensitivity to switching nonlinearity.

(a)

(b)

Fig Result 5: Power Response for P and Q step (Pref = +0.4 and Qref=+0.2)
(a) Active and reactive power response
(b) Line currents under Non linear Controller

CONCLUSION:

This project includes advanced nonlinear direct power controllers, for matrix converters connected to power transmission lines as UPFCs. Presented simulation and experimental results show that active and reactive power flow can be advantageously controlled by using the proposed DPC. Results show no steady-state errors, no cross-coupling, insensitivity to non modeled dynamics and fast response times, thus confirming the expected performance of the presented nonlinear DPC methodology.

Despite showing a suitable dynamic response, the PI performance is inferior when compared to DPC. Furthermore, the PI controllers and modulator take longer times to compute. Obtained results show that DPC is a strong nonlinear control candidate for line active and reactive power flow.

REFERENCES:

[1] N. Hingorani and L. Gyugyi, Understanding FACTS—Concepts and Technology of Flexible AC Transmission Systems. Piscataway, NJ: IEEE Press/Wiley, 2000.

[2] L. Gyugyi, "Unified power flow control concept for flexible AC transmission systems," Proc. Inst. Elect. Eng. C, vol. 139, no. 4, Jul. 1992.

[3] L. Gyugyi, C. Schauder, S. Williams, T. Rietman, D. Torgerson, and A. Edris, "The unified power flow controller: A new approach to power transmission control," IEEE Trans. Power Del., vol. 10, no. 2, pp. 1085–1097, Apr. 1995.

[4] C. Schauder, L. Gyugyi, M. Lund, D. Hamai, T. Rietman, D. Torgerson, and A. Edris, "Operation of the unified power flow controller (UPFC) under practical constraints," IEEE Trans. Power Del., vol. 13, no. 2, pp. 630–639, Apr. 1998.

[5] T. Ma, "P-Q decoupled control schemes using fuzzy neural networks for the unified power flow controller," in Electr. Power Energy Syst.. New York: Elsevier, Dec. 2007, vol. 29, pp. 748–748.

[6] L. Liu, P. Zhu, Y. Kang, and J. Chen, "Power-flow control performance analysis of a unified power-flow controller in a novel control scheme," IEEE Trans. Power Del., vol. 22, no. 3, pp. 1613–1619, Jul. 2007.

[7] F. Gao and M. Iravani, "Dynamic model of a space vector modulated matrix converter," IEEE Trans. Power Del., vol. 22, no. 3, pp. 1696–1750, Jul. 2007.

[8] B. Geethalakshmi and P. Dananjayan, "Investigation of performance of UPFC without DC link capacitor," in Elect. Power Energy Res.. New York: Elsevier, 2008, pp. 284–294, 736-746.

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