A NOVEL POWER QUALITY IMPROVEMENT OF MATRIX CONVERTER BASED UPFC

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ABSTRACT
This paper implements an advanced direct power control technique (DPC) for 3-phase matrix converters function as unified power flow controllers (UPQCs)arrangement. Matrix converters (MCs) convert the direct ac/ac power adaptation without dc energy storage link parameters; accordingly, the Matrix Converter-with UPFC (MC-UPFC) has concentrated cost and volume, minimized capacitor power losses, communally with higher performance and stability. Theoretical analysis of direct power control (DPC) with sliding mode control arrangements are recognized for an MC-UPFC dynamic representation consisting of one of the input filter. As a result ac supply reactive power, can be directly controlled by selecting an appropriate matrix converter switching state guaranteeing good steady-state and dynamic responses, then finally it reduced volume and cost, reduced capacitor power losses, together with higher reliability. As a consequence, line active and reactive powers are combines with ac supply reactive power, can be directly regulated by choosing suitable matrix converter proper working state guaranteeing high-quality steady-state and dynamic response conditions. Experimental outputs of DPC controllers for MC-UPFC demonstrate decoupled active and reactive power regulator with zero steady-state tracking error arrangement, and quick response times. Compared to a Matrix Converter-UPFC by active and reactive power linear modulators with a modified Venturing very high-frequency PWM controller, the experimental consequences of the advanced DPC-MC assurance closer responses without producing overshoot and no steady-state faults, acquiring no cross-coupling in steady-state and dynamic approachment.

Index Terms— Matrix Converter (MC), Direct Power Controlstechnique (DPC), And Unified Power-Flow Controller (UPFC), Power Factor.

I. INTRODUCTION

In past years, electricity market not sufficient by deregulation, by together with increasing investment, social concerns and ecological, has improved the difficulty to damage fossil fuels, and to accomplish new licenses to assemble transmission line arrangements and high-power conveniences. These circumstances created the increase of decentralized electricity production using non-conventional energy resources. Unified power-flow controllers (UPFC) facilitate the process of power transmission systems close to their maximum requirements, by providing power flow during distinct lines. Now a day, UPFCs are one of the attractive and adaptable and powerful flexible ac transmission systems (FACTS) strategies. The UPFC results from the collaboration of a static synchronous series compensator (SSSC) and static synchronous compensator (STATCOM) that uses a common dc link capacitor. The presence of a dc bank capacitor produces auxiliary losses, decreases the converter life time, and enhances its cost, weight, and area. In the past few decades, an escalating attention in new converter methodologies, proficient of working the same functions but with minimized storage necessities, has preferred. These converters are accomplished of developing the required ac/ac conversion possibility by using bidirectional power electronic devices power flow, assurance close to proper sinusoidal input and produced output currents, voltages with irregular magnitude, and flexible power factor. These least energy storage ac/ac converters have the ability to permit independent reactive power regulators on the UPFC series and shunt converter positioned, even though maintaining that the active power transported on the UPFC series association is always absorbed/supplied by the shunt association of STATCOM. Traditional UPFC regulators do not have assurance of robustness. The confidence of the matrix converter produced output voltage on the regulation coefficient was determined; finally that MC-UPFC is capable to modulate the fully collection of power flow. Modern nonlinear arrangements switched to better controlling of PI controller components. Even though, there is room to additional recover from the dynamic response of UPFCs, by nonlinear robust modulators. In the recent years, direct power control methodologies have been selected in many power requiems, owing to their simplicity and good quality performance. In order to propose UPFCs, developing healthy behavior to parameter considerations in variations and to instability, the future DPC-MC control technique, is designed, is associate with sliding mode-control arrangements, accepting the real-time required assortment of adequate matrix vectors to manage input and output required electrical power. Sliding mode technique includes DPC-MC can maintain without zero steady-state faults and good tracking performance, and no overshoots, quick dynamic response conditions, although being easier to execute and acquiring less switching power, when referred to proportional-integral (PI) linear controller arrangements generated from linear reactive and active power circuits of UPFC with a regulated Venturing high-frequency PWM controller. The steady-state and dynamic performance of the implemented DPC-MC P, Q control technique is operated and explained using comprehensive simulation results and experimental developments. Experimental results and MATLAB/Simulation results are achieved by using the nonlinear DPC technique for matrix converter dependent UPFC equipment explain decoupled active series and reactive power control by shunt/series, and zero steady-state error tracking arrangement, and quick operating and switching times, acquiring errorless steady-state and dynamic responses.

II. MODELING OF THE UPFC POWER SYSTEM

2.1 General Architecture

An easiest power transmission network arrangement by the implemented matrix converter-UPFC is accessible in Fig. 1, where V_s andV_r are, the sending-end sinusoidal voltage and receiving-end produced voltages of the G_s andG_r generators associating with load Z_L correspondingly. The matrix converter is associated to transmission line 2, designed as a series resistance with series inductance (R_2 L_2 andL_2), during transformers coupling T_1 andT_2 . Fig.2 represents the reduced three-phase corresponding circuit of the matrix converter UPFC transmission arrangement model. For scheme of modeling, the power considerations and the transformers coupling are all treated as ideal. Moreover, the matrix converter is preferred ideal and performed like as a convenient voltage source, with required magnitudeV_c and phaseρ. In the correspondent circuit, is to maintain required load bus voltage, The DPC-MC controller will pleasure the basic parameters as instability. Preferring a symmetrical and objective three-phase schemeand employing Kirchhoff laws to the three-phase corresponding circuit (Fig. 2), the ac transmission line currents are developedin**dq** coordinates

$$\frac{dI_d}{dt} = \omega I_q \frac{R_2}{L_2} I_d + \frac{1}{L_2}(V_{LD} - V_{Rod}) \ldots (1)$$

$$\frac{dI_Q}{dt} = \omega I_d \frac{R_2}{L_2} I_q + \frac{1}{L_2}(V_{Lq} - V_{Roq}) \ldots (2)$$

The active and reactive power of distribution end the generator are specified in **dq** originates

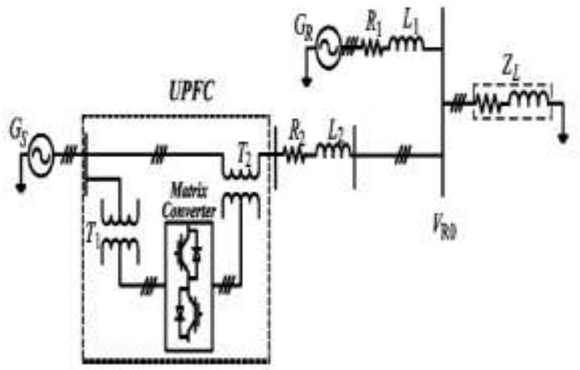
$$\begin{matrix} P \\ Q \end{matrix} = \begin{matrix} V_d & -V_q \\ V_q & V_d \end{matrix} * \begin{matrix} I_d \\ I_q \end{matrix} \ldots(3)$$

ConsideringV_{Rod}andV_{sd} as fixed and a moving rotating required frame modulated to the $sendig\ voltage\ V_s$ source therefore thatV_{sq} =0, active and reactive power P and Q are agreed by (4) and (5), correspondingly,

P=$V_d\ I_d$ …(4)

Q=$-V_d\ I_q$ …(5)

Dependent on the preferred active power and reactive powerP_{ref},Q_{ref} can be premeditated from (4) and (5) for current regulators. Nevertheless, permitting P, Q actual powers are susceptible to faults in the V_d ,V_q standards.



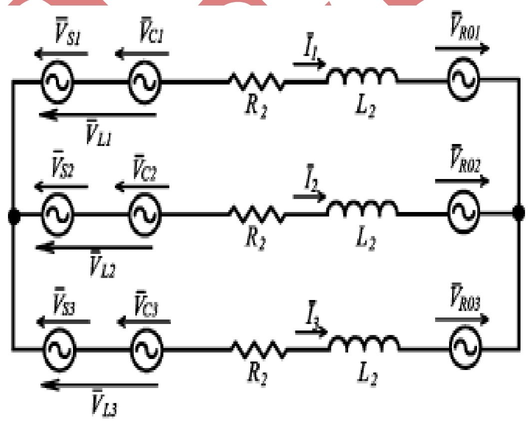


Fig.1.Transmission network with matrix converter UPFC Fig2Three-phase equivalent circuit of the matrix UPFC and transmission line

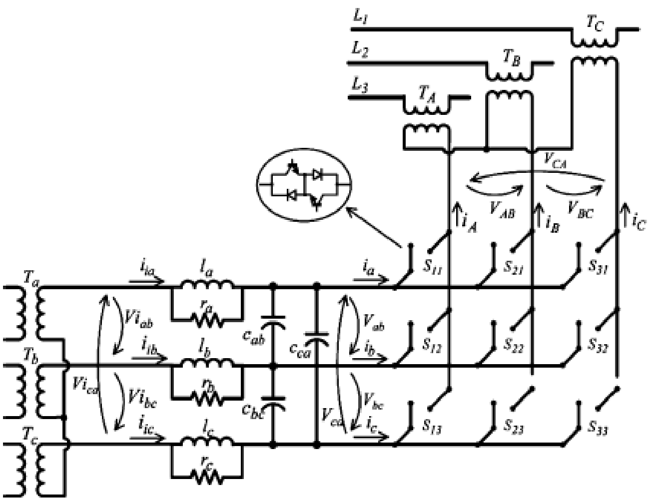


Fig.3Transmission Network with Matrix Converter UPFC

2.2 Matrix Converter Output Voltage and Input Current Vectors

A figure of the UPFC arrangement (Fig. 3) consisting of the three-phase input shunt transformer the three-phase series transformer and also used the three-phase matrix converter, designed by using an array of nine bidirectional IGBT switches S_{kj} with Switched-on and triggered-off ability, accepting the association of each one of three output phases straight to any individual of the three contribution (input) phases. The 3-phase (LC_r) input filter is necessary to reproduce a voltage-source limit to the matrix converter, preferring smooth and flexible input currents.

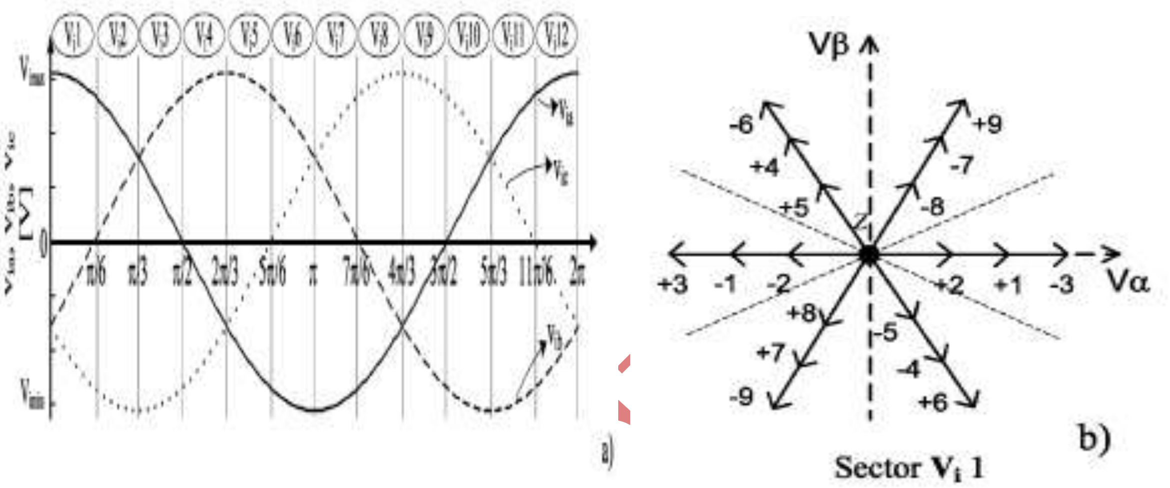


Fig.4.(a) Input voltages and their consequent sector. (b) Produced Output voltage state-space vector waveforms when the input voltages are located at sector V_{i1} . Employing dq originates to the input filter state parameters available in Fig. 3 and desertion the function of the damping resistors, the below equations and calculations are implemented.

$$\frac{dI_D}{dt} = \omega I_q - \frac{1}{2}\frac{1}{L}V_d - \frac{1}{\sqrt[2]{3}L}V_q + \frac{1}{L}V_{id}$$

$$\frac{dIQ}{dt} = -\omega I_d - \frac{1}{2}\frac{1}{L}V_q + \frac{1}{\sqrt[2]{3}L}V_d + \frac{1}{L}V_{iq}$$

$$\frac{dV_d}{dt} = \omega V_q + \frac{1}{2}\frac{1}{C}I_{id} - \frac{1}{\sqrt[2]{3}C}I_{iq} - \frac{1}{2}\frac{1}{C}I_d + \frac{1}{\sqrt[2]{3}C}I_q$$

$$\frac{dV_q}{dt} = -\omega V_d + \frac{1}{2}\frac{1}{C}I_{iq} + \frac{1}{\sqrt[2]{3}C}I_{id} - \frac{1}{2}\frac{1}{C}I_q - \frac{1}{\sqrt[2]{3}C}I_q \;\ldots(6)$$

Where $V_{id}, V_{iq}, I_{id}, I_{iq}$ stand for, input currents and input voltages in **dq** variables correspondingly (at the shunt connected transformer secondary) and V_d, V_q, I_d, I_q represents those are input currents and voltages of matrix converter in **dq** system, respectively.

Considering ideal semiconductors, everyone in matrix converter acts as a bidirectional switch $S_{kij}(k,j \in \{1,2,3\}$ can guess two achievable states: "$S_{kij} = 1$ " if the switch is stopped or "$S_{kij} = 0$" if the switch is release. The nine matrix converter power electronic devices can be denoted as a 3*3 matrix (7)

$$S = \begin{matrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{matrix} \ldots(7)$$

The matrix converter model variable simples $\sum_{j=1}^{3} S_{kij}$.=1

Depended on (7), the association between load and input voltages can be uttered as

$T[V_A \quad V_B \quad V_C]$=S$[V_a \quad V_b \quad V_c]T$…(8)

The source phase currents can be connected to the produced phase currents (9), with the transpose of matrix

$[I_a \quad I_b \quad I_c]T$=S$[I_A \quad I_B \quad I_C]T$…(9)

From the 27 probable switching developments, time-variant vectors can be implemented in (Table I) denoting the matrix develops the voltages and source currents $\propto \beta$ in originates, and drowned in the $\propto \beta$structure [Fig. 4(b)].

The active and reactive power controller DPC-MC will choose one of these 27 vectors at any specified time immediate

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III. DIRECT POWER CONTROL OF MC-UPFC

3.1 Line Active and Reactive Power Sliding Surface

The DPC modulators for line power flow are at this time resulting based on the sliding method control assumption technique. From Fig. 2, in constant state, is required by resource. From (1) and (2), the currents of the transmission-line can be measured by the state values with first-order internal values reliant on the sources and Switching period of impedance$\frac{L2}{R2}$. Consequently, transmission-line has active and reactive powers are generated first-order dynamic responses and have a well-built relative degree of one, because from the control perspective, its first time derivative previously consisting of the control parameters (the strong relative motion commonly designs the number of times the modulate required output variable should be modulated until a control input presents clearly in the dynamics performance). From the sliding method control presumption, robust sliding surface area to modulate the active and Reactive variables with a comparatively strong degree of one can be generate Assuming proportionality to a linear arrangement of the errors of the state variables apparatus. Consequently, define the active power faults and the reactive power problem as the dive rgence between the powers required references$P_{ref}, Q_{ref}$and the actual power delivering P, Q equally

$e_p = P_{ref} - P$..(10)

$e_Q = Q_{ref} - Q$(11)

Then, the healthy sliding circumstances,$S_p\left(e_p, t\right)$and $S_Q\left(e_Q, t\right)$should be relative to these problems, being zero after accomplishment sliding approach

$S_p\left(e_p, t\right) = K_p\left(P_{ref} - P\right) = 0$..(12)

$S_Q\left(e_Q, t\right) = K_Q\left(Q_{ref} - Q\right) = 0$..(13)

The relative gains K_p and K_Q are selected to require suitable operating frequencies.

Group	Name	A	B	C	v_{AB}	v_{BC}	v_{CA}	i_a	i_b	i_c	V_o	δ_o	I_i	μ_i
	1g	a	b	c	v_{ab}	v_{bc}	v_{ca}	i_A	i_B	i_C	v_i	δ_i	$\sqrt{3}i_o$	μ_o
	2g	a	c	b	$-v_{ca}$	$-v_{bc}$	$-v_{ab}$	i_A	i_C	i_B	$-v_i$	$-\delta_i+4\pi/3$	$\sqrt{3}i_o$	$-\mu_o$
I	3g	b	a	c	$-v_{ab}$	$-v_{ca}$	$-v_{bc}$	i_B	i_A	i_C	$-v_i$	δ_i	$\sqrt{3}i_o$	$-\mu_o+2\pi/3$
	4g	b	c	a	v_{bc}	v_{ca}	v_{ab}	i_C	i_A	i_B	v_i	$\delta_i+4\pi/3$	$\sqrt{3}i_o$	$\mu_o+2\pi/3$
	5g	c	a	b	v_{ca}	v_{ab}	v_{bc}	i_B	i_C	i_A	v_i	$\delta_i+2\pi/3$	$\sqrt{3}i_o$	$\mu_o+4\pi/3$
	6g	c	b	a	$-v_{bc}$	$-v_{ab}$	$-v_{ca}$	i_C	i_B	i_A	$-v_i$	$-\delta_i+2\pi/3$	$\sqrt{3}i_o$	$-\mu_o+4\pi/3$
	+1	a	b	b	v_{ab}	0	$-v_{ab}$	i_A	$-i_A$	0	$\sqrt{2/3}v_{ab}$	0	$\sqrt{2}i_A$	$-\pi/6$
	-1	b	a	a	$-v_{ab}$	0	v_{ab}	$-i_A$	i_A	0	$-\sqrt{2/3}v_{ab}$	0	$-\sqrt{2}i_A$	$-\pi/6$
	+2	b	c	c	v_{bc}	0	$-v_{bc}$	0	i_A	$-i_A$	$\sqrt{2/3}v_{bc}$	0	$\sqrt{2}i_A$	$\pi/2$
	-2	c	b	b	$-v_{bc}$	0	v_{bc}	0	$-i_A$	i_A	$-\sqrt{2/3}v_{bc}$	0	$-\sqrt{2}i_A$	$\pi/2$
	+3	c	a	a	v_{ca}	0	$-v_{ca}$	$-i_A$	0	i_A	$\sqrt{2/3}v_{ca}$	0	$\sqrt{2}i_A$	$7\pi/6$
	-3	a	c	c	$-v_{ca}$	0	v_{ca}	i_A	0	$-i_A$	$-\sqrt{2/3}v_{ca}$	0	$-\sqrt{2}i_A$	$7\pi/6$
	+4	b	a	b	$-v_{ab}$	v_{ab}	0	i_B	$-i_B$	0	$\sqrt{2/3}v_{ab}$	$2\pi/3$	$\sqrt{2}i_B$	$-\pi/6$
	-4	a	b	a	v_{ab}	$-v_{ab}$	0	$-i_B$	i_B	0	$-\sqrt{2/3}v_{ab}$	$2\pi/3$	$-\sqrt{2}i_B$	$-\pi/6$
II	+5	c	b	c	$-v_{bc}$	v_{bc}	0	0	i_B	$-i_B$	$\sqrt{2/3}v_{bc}$	$2\pi/3$	$\sqrt{2}i_B$	$\pi/2$
	-5	b	c	b	v_{bc}	$-v_{bc}$	0	0	$-i_B$	i_B	$-\sqrt{2/3}v_{bc}$	$2\pi/3$	$-\sqrt{2}i_B$	$\pi/2$
	+6	a	c	a	$-v_{ca}$	v_{ca}	0	$-i_B$	0	i_B	$\sqrt{2/3}v_{ca}$	$2\pi/3$	$\sqrt{2}i_B$	$7\pi/6$
	-6	c	a	c	v_{ca}	$-v_{ca}$	0	i_B	0	$-i_B$	$-\sqrt{2/3}v_{ca}$	$2\pi/3$	$-\sqrt{2}i_B$	$7\pi/6$
	+7	b	b	a	0	$-v_{ab}$	v_{ab}	i_C	$-i_C$	0	$\sqrt{2/3}v_{ab}$	$4\pi/3$	$\sqrt{2}i_C$	$-\pi/6$
	-7	a	a	b	0	v_{ab}	$-v_{ab}$	$-i_C$	i_C	0	$-\sqrt{2/3}v_{ab}$	$4\pi/3$	$-\sqrt{2}i_C$	$-\pi/6$
	+8	c	c	b	0	$-v_{bc}$	v_{bc}	0	i_C	$-i_C$	$\sqrt{2/3}v_{bc}$	$4\pi/3$	$\sqrt{2}i_C$	$\pi/2$
	-8	b	b	c	0	v_{bc}	$-v_{bc}$	0	$-i_C$	i_C	$-\sqrt{2/3}v_{bc}$	$4\pi/3$	$-\sqrt{2}i_C$	$\pi/2$
	+9	a	a	c	0	$-v_{ca}$	v_{ca}	$-i_C$	0	i_C	$\sqrt{2/3}v_{ca}$	$4\pi/3$	$\sqrt{2}i_C$	$7\pi/6$
	-9	c	c	a	0	v_{ca}	$-v_{ca}$	i_C	0	$-i_C$	$-\sqrt{2/3}v_{ca}$	$4\pi/3$	$-\sqrt{2}i_C$	$7\pi/6$
	Z_a	a	a	a	0	0	0	0	0	0	0	-	0	-
III	Z_b	b	b	b	0	0	0	0	0	0	0	-	0	-
	Z_c	c	c	c	0	0	0	0	0	0	0	-	0	-

Table I .Switching Combinations and Output Oltage/Input Current State-Space Vectors

3.2 Line Active and Reactive Power Direct Witching Laws

The DPC needs a nonlinear law, depended on the e_p and e_Q faults and to choose in genuine time the matrix converter conducting stages (vectors). Because there are no controllers and/or pole zero-aligned methods, high regulating speed is probable. To assurance permanence for active power and reactive power regulators to control the sliding-mode continuous circumstances (14) and (15) should be demonstrated

$S_p(e_p,t)\dot{S}_p(e_p,t) < 0$(14)

$S_Q(e_Q,t)\dot{S}_Q(e_Q,t) < 0$(15)

These surroundings denote that condition$S_p(e_p,t)$>0, then the $S_p(e_p,t)$ value should be minimized; significance that its time derived must be negative$S_p(e_p,t) < 0$. Likewise if, next$S_p(e_p,t) > 0$.

Considering to (12) and (14), the Scenario to decide the matrix vector must be

Condition$S_p(e_p,t) > 0 \rightarrow \dot{S}_p(e_p,t) < 0 \rightarrow P < P_{ref},$

then select a vector sufficient to enhance p.

Condition$S_p(e_p,t) < 0 \rightarrow \dot{S}_p(e_p,t) > 0 \rightarrow P > P_{ref},$

then select a vector sufficient to reduced p.

Condition$S_p(e_p,t) = 0,$ *then select a vector which does not* *specified variable the active power generation..*(16)

The same process should be functional to the reactive power faults.

IV. CONCLUSION

This paper develops a superior non-linear direct power regulators are used to regulate by using the dependent sliding method control strategies, for matrix converters associated to power transmission lines like UPFCs. Accessible MATLAB/simulation and experimental consequences demonstrate that active and reactive power flow can be favorably controlled by the implemented DPC. Results illustrate no steady-state faults, no sensitivity to no-modulated dynamics, no cross-coupling effects and quick reaction times, therefore confirming the probable presentation of the obtainable nonlinear DPC attitude. The generated DPC-MC outputs were checked and verified to PI-linear active power and reactive power regulators with a customized Venturing high-frequency PWM modulator technology. As a result ac supply reactive power, can be directly controlled by selecting an appropriate matrix converter switching state guaranteeing good steady-state and dynamic responses, then finally it reduced volume and cost, reduced capacitor power losses, together with higher reliability. In spite of a correct dynamic reaction process, the PI presentation is substandard when checked to DPC. In addition, the PI regulators are controllers and PWM modulator takes much time to calculate. Generated results demonstrate that DPC is a physically powerful nonlinear manage candidate for line active power and reactive power flow control. It produce transmission-line power managing as well as transport end sufficient reactive power or power factor modulation.

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