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Power Quality Improvement Using Matrix Converter Based UPQC with PI & Fuzzy Controller

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***ABSTRACT*_This is a approach of unified power quality conditioner which is made up of a matrix converter without energy storage devices to mitigate the current harmonics, voltage sags and swell. By connecting the matrix converter output terminals to the load side through series transformer and the input side of matrix converter is connected to the supply side with step up transformer. So a matrix converter injects the compensation voltage on the load-side, so it is possible to mitigate the voltage sag/swell problems, resulting in an efficient solution for mitigating voltage and current related power quality problems. Thus, this topology can mitigate the voltage fluctuations and current harmonics without energy storage elements and the total harmonic distortion produced by the system also very low. It also reduced volume and cost, reduced capacitor power losses, together with higher reliability.**

Keywords—***Power quality (PQ), MATLAB, unified power quality conditioner (UPQC), Matrix converter***

I. INTRODUCTION

Application of electronically switched and nonlinear devices in distribution systems and industries causes power-quality (PQ) problems, such as harmonics, sag, swell. In order to eliminate these power quality problems some sort of compensation can be included. Modern solutions can be found in the form of active power compensation using active filters. In recent years the solutions for these problems have appeared in the form of custom power devices.

In distribution systems the application of FACTS concepts has resulted in a new generation of compensating devices so by extending the UPFC concept at distribution level a new device named unified power quality conditioner (UPQC) is developed. It consists of combined series and shunt converters to simultaneous compensate the imperfections in voltage and current in a supply feeder. Unlike UPFC which controls power flow in a single line the aim of UPQC is to control power flow in multi lines. UPQC consists of both DSTATCOM and DVR that combines a shunt connected DSTATCOM can balance the source currents and eliminate the harmonics in them in the presence of unbalanced nonlinear loads. By injecting reactive current of desired magnitude, the power factor or displacement factor on the source side can be controlled. Instead of controlling the power factor, it is possible to control the load bus voltage magnitude (within limits determined by the source impedance).A series connected DVR can balance the voltages at the load bus in addition to isolation of the harmonics from the source side.

Thus the provision of both DSTATCOM and DVR enables the UPQC to control the power quality of the source current and the load bus voltage. In addition, if the DVR and DSTATCOM are connected on the DC side, the shunt connected DSTATCOM regulates the dc bus voltage, while the DVR supplies the required energy to the load in case of the transient disturbances in source voltage. But the existence of dc capacitor link causes additional losses, such as reduced converter lifetime, and increase in weight, cost and volume. So we are going for UPQC based on matrix converter which eliminates dc capacitor link and provides effective power quality control.

II. PROPOSEDUPQC

A. Description

The UPQC based on matrix converter contains a matrix converter design connected between two feeders by shunt and series transformers. The feeder 1 with load L1 is connected to the matrix converter design by the shunt transformer and the feeder2 with load L2 by the series transformer. The load L1 is a nonlinear/sensitive load with non-sinusoidal current and harmonics needs a pure sinusoidal voltage for proper operation.

Similarly sensitive/critical load L2 needs a purely sinusoidal voltage and should be protected against distortion, sag/swell, and interruption fully. These types of loads are commonly used in production industries and critical service providers, such as medical centres, airports, or broadcasting centres where interruption in voltage can result in severe economic losses or human damages.

The objectives of shunt converters are

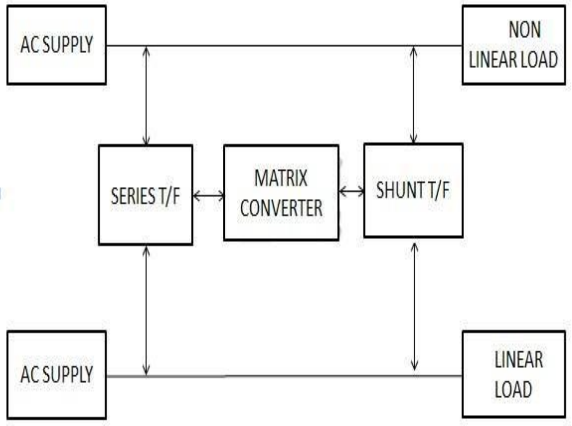


Fig.1.Block diagram of MC-UPQC

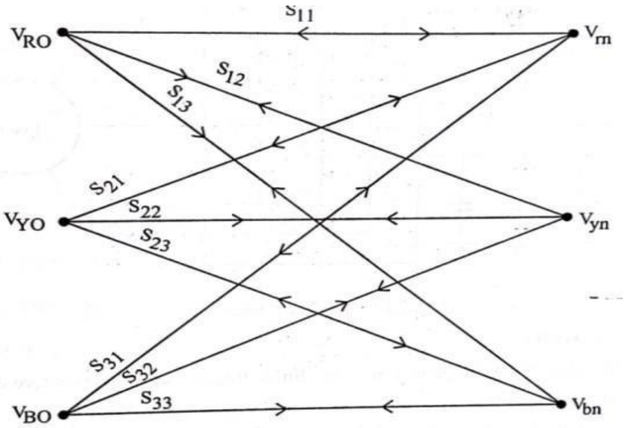
1. Injecting negative and zero sequence componentsrequired by the load to compensate source current.
2. Elimination of current harmonics
3. Injecting the required reactive current (at fundamental frequency) for controlling power factor
4. DC bus voltage regulation

The objectives of series converters are

matrix converter consists of 9 switches that are bidirectional. The bidirectional witches are arranged in3*3 matrix form.

The bidirectional switches are also arranged that any of the 3 input phases could be connected to any output phase through the switching matrix symbol.

Fig.2.Switching matrix



1. Injecting negative and zero sequence voltage to compensate for voltage at load bus.2. Elimination of voltage harmonics
3. Injecting the required real and reactive components (at fundamental frequency) depending on the power factor on the source side to regulate the magnitude of load voltage.
4. Controlling power factor at input side of UPQCwhere source is connected.

Above mentioned Compensation of active and reactive power, controlling of power factor can be done by controlling the switches of matrix converters using various types of switching techniques.

B. Matrix converter

Matrix converter is a converter which converts AC to AC by using the bidirectional fully controlled switches. The Matrix converter arranges

Semiconductor switches into a matrix configuration and control them to convert an Input ac voltage directly into the desired ac voltage; the matrix converter is a 3phase to 3 phase matrix converter. The Shows the circuit scheme of a three phase to three phase matrix converter. The matrix converter can theoretically assume 512(2^9) different switching states combination but in 3 phase to 3 phase matrix converter only 27 are permitted as switching combinations.

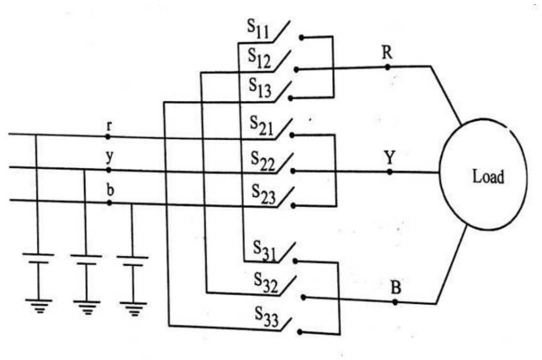


Fig.3.Structure of three phase matrix converter

The matrix converter used in the UPQC due to the following advantages.

1. Provides AC to AC conversion, thus eliminating need of reactive energy storage elements.
2. Power flow in a Matrix converter is bidirectional.
3. Its input power factor can be controlled fully.

C. Space vector modulation control for matrix converterThe space vector modulation technique is used mainly in speed control drives and power converters; its main aim is to provide reference voltage generated by various inverter configurations. The SVM technique applied to matrix converter uses zero and synchronous configurations, the main advantage of SVM is that it can be digitally implemented and provide maximum voltage transfer ratio and power factor control. It requires 6 input phases to reduce losses and harmonic distortions. The aim of the SVM control algorithm is to generate the desired output line-to- line vector and the input line current vector phase angle which set the input power factor. The input line-to-neutral voltage vector is defined, by the following expression

$$e_i=1/3v_i\, e_{-j \prod/6} \qquad (1)$$

The power balance establishes that for a given output power and input voltage vector, which is impressed by the AC mains supply, there are infinite possible solutions for the input current vector. On the contrary, if we define the phase angle of by a suitable modulation of the converter, the power balance equation provides the complete determination of the input current vector.

In order explain the basic modulation algorithm reference will be made to fig 4d and fig 4b wherev_0 and i_i are both lying in sector 1

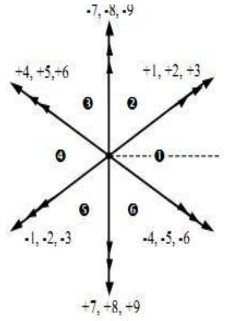


Fig.4a.output voltage space zero vectors for active and zero Configuration

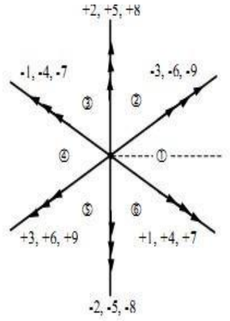


fig.4b.input active and current space Vectors for active and zero

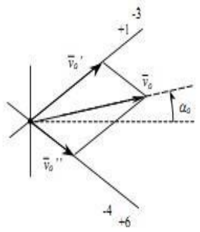


Fig.4c.svm of reference voltage vector

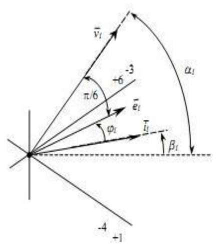


fig.4d.svm of output reference input current phase angle

Table 1: combination of output voltage and input current vector for matrix converter configuration

i_i \ V_0	❶	❷	❸	❹	❺	❻
①	-3 +1 +6 -4	+9 -7 -3 +1	-6 +4 +9 -7	+3 -1 -6 +4	-9 +7 +3 -1	+6 -4 -9 +7
②	+2 -3 -5 +6	-8 +9 +2 -3	+5 -6 -8 +9	-2 +3 +5 -6	+8 -5 -2 +3	-5 +6 +8 -9
③	-1 +2 +4 -5	+7 -8 -1 +2	-4 +5 +7 -8	+1 -2 -4 +5	-7 +8 +1 -2	+4 -5 -7 +8
④	+3 -1 -6 +4	-9 +7 +3 -1	+6 -4 -9 +7	-3 +1 +6 -4	+9 -7 -3 +1	-6 +4 +9 -7
⑤	-2 +3 +5 -6	+8 -5 -2 +3	-5 +6 +8 -9	+2 -3 -5 +6	-8 +5 +2 -3	+5 -6 -8 +9
⑥	+1 -2 -4 +5	-7 +8 +1 -2	+4 -5 -7 +8	-1 +2 +4 -5	+7 -8 -1 +2	-4 +5 +7 -8
	I II III IV	I II III IV	I II III IV	I II III IV	I II III IV	I II III IV

Among the six possible matrix converter switches configurations (±1, ±2, ±3), the one that allow the modulation of the input current direction, also, have to be chosen. It is verified that this constraint allows the elimination of two Using the same procedure, it is

configuration

$(i_i^{l\,lll} d^{lll} + i_i^{lV} d^{lV}).\ j\ i_1 e^{j\beta} = 0$ (5)

reconfigurations and $K_v=1,2,3\ldots, 6$ represents the output voltage sector $v^l, v^{ll}, v^{lll}, v^{lv}$ are the output voltage vectors associated, respectively, with the switches configurations l,ll,lll and lv given in Table I. In above $\tilde{a}_0$ and $_\beta$ are the output voltage and input current phase angle referred to the bisecting line of the corresponding sector. . Solving equations above and with respect to the on-time ratios, after some formulae manipulations, leads to the following relationships$d_l = 2/\sqrt{3}\ v_0/v_i \cos(\tilde{a}_0 - \prod/3) \cos(_{\beta i} - \prod/3) \,/\, \cos\Phi_i(6)d_{ll} = 2/\sqrt{3}\ v_0/v_i \cos(\tilde{a}_0 - \prod/3) \cos(_{\beta i} + \prod/3) \,/\, \cos\Phi_i$(7) $d_{lll} = 2/\sqrt{3}\ v_0/v_i \cos(\tilde{a}_0 + \prod/3) \cos(_{\beta i} - \prod/3) \,/\, \cos\Phi_i$(8) $d_{lv} = 2/\sqrt{3}\ v_0/v_i \cos(\tilde{a}_0 + \prod/3) \cos(_{\beta i} + \prod/3) \,/\, \cos\Phi_i$(9)

Equations above have a general validity. For any combination of the output voltage sector and the input current sector Table I provide the four switches configurations to be used within the cycle possible to determine the four switches configurations correspondent to any possible combination of output voltage and input current sectors, which are quoted in Table I.

Now, it is possible to write in a general form the basic equations of the SVM algorithm which satisfy, at the same time, the requirements for the reference output voltage vector and the input displacement angle.

$V_{lO} = V_{l0} d_l + V_{l\ 0} d_{ll}$

$= 2/\sqrt{3}\ V_0 \cos(\tilde{a}_0 - \prod/3)\ e^{j[(K_v-1)]\prod/3+\prod/6]}$ (2)

$V_{l\ O} = V_{lllO} d_{lll} + V_{lv} d_{lv}$

$= 2/\sqrt{3}\ V_0 \cos(\tilde{a}_0 + \prod/3)\ e^{j[(K_v-1)]\prod/3-\prod/6]}$ (3)

$(i_{li} d_l + i_{ll\ i} d_{ll}).j\ i_1 e^{j\ \beta} = 0$ (4)

where $d^l, d^{ll}, d^{lll}, d^{lv}$ the on-time ratio i.e $d^l = t^l/t_c$ the fourThis equation leads to the following relation

$V_0 \le v_i \sqrt{3}/2\ |\cos\Phi_i|$ (13)

Where V_0 and v_i represent the constant values of the period and equations give the correspondent on-time ratios.

In equations d^l to d^{lv} the following angle limits apply:-

$\prod/6 < \tilde{a}_0 < +\prod/6,\ -\prod/6 < _{\beta i} < +\prod/6$ (10)

For the feasibility of the control algorithm, the sum of the four on-time ratios must be lower than or equal to unity:

$d^l + d^{ll} + d^{lll} + d^{lv} \le 1$ (11)

A zero configuration is applied to complete the sampling period. If equations d^l to d^{lv} substitute in above equation, after some formulae manipulations, the following equation can be obtained:

$V_0 \le v_i \sqrt{3}/2\ |\cos\Phi_i| \,/\, \cos\tilde{a}_0 \cos{}_{\beta i}$(12)

This is a significant equation. What is on the right hand side of the equation is, at any Instant, the theoretical maximum limit for the output voltage vector magnitude, which depends On the instantaneous input voltage vector magnitude, the output voltage and input current vectors phase angle and the reference displacement angle of the input current vector. The equation is very useful in order to define the performance limits of the matrix converter when not- ideal input voltage conditions exist on the AC mains supply or when a dynamic control of the output voltage vector is required, as for high-performance AC drives.

output and input voltage vector magnitude. When reference input power factor is set at unity, V_0 equation gives the well-known theoretical maximum voltage transfer ratio of matrix converters under the constraint of sinusoidal input and output waveforms.Equations d^{l} to d^{lv} show that the implementation of the SVM algorithm requires, at any cycle period, the knowledge of the input line-to- line voltage vector Therefore, two line-to-Line input voltages have to be measured. For balanced and sinusoidal supply voltages this Requirements are not necessary since the synchronization with the input voltages can be achieved by detecting the zero crossing of an input voltage.

III. SIMULATION RESULTS

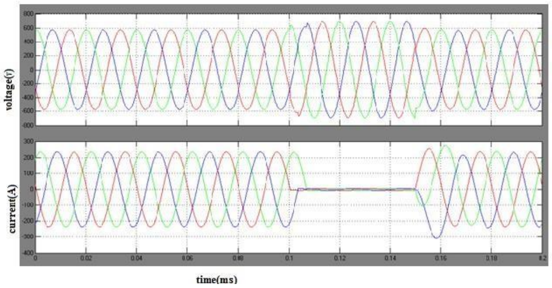


Fig.1.Uncompensated voltage and currentwaveforms The above fig 1shows the voltage and current affected by the line to ground fault in distribution feeder without MC-UPQC causing sag /swell disturbance.

Feeder1 with non-linear load

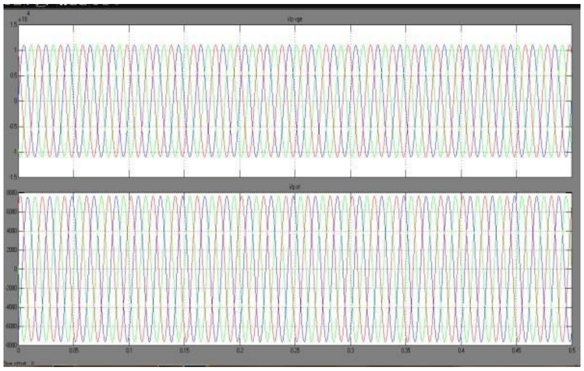


Fig.2a.Compensated source voltage and current waveforms

V. CONCLUSION

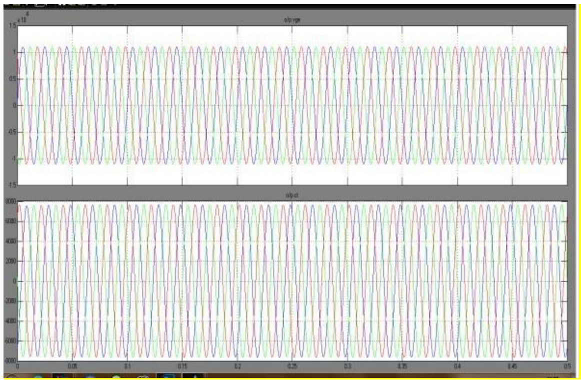


Fig.2b.Compensated load voltage and current waveforms

The above fig 2aand 2b shows the compensated voltage current waveforms in the feeder 1with non-linear load by MC-UPQC

For feeder 2 with linear load

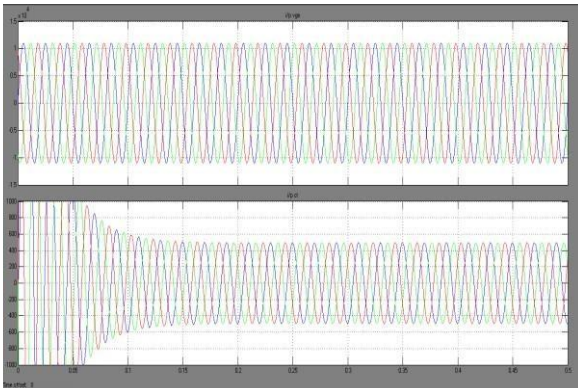


Fig.3a.Compensated source voltage and current waveform

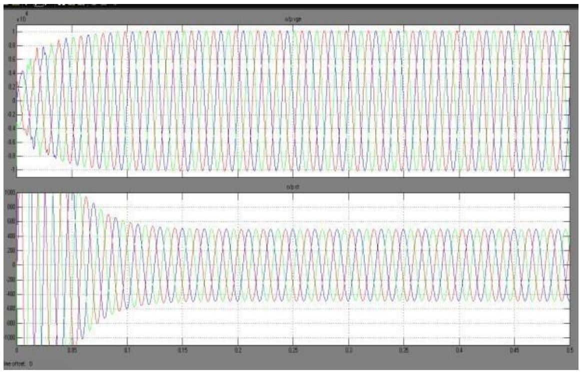


Fig.3b.Compensated load voltage and current waveform

The above fig3a and 3b shows the compensated voltage and current waveform in feeder 2 with linear load by MC-UPQC

Thus the proposed UPQC based on matrix converter can compensate the voltage and current in a two feeder system with linear and nonlinear load against sag/swell disturbances. Its performance is evaluated using MATLAB simulation where the result shows improvement in power quality of the distribution system.

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