Matrix Converter Based Series Compensator For Mitigating Power Quality Disturbances

[1] Dr.K.Umamaheswari, [2]Ramachandran.M, [3]Mariya Chithra Mary.A, [4]Preetha.S
[1] Associate Professor,V.S.B. Engineering College,Karur,Tamilnadu
[2] Assistant Professor, V.S.B. Engineering College,Karur,Tamilnadu
[3] Assistant Professor, Sree Sowdambika College of Engineering,Tamilnadu
[4] Assistant Professor, V.S.B. Engineering College,Karur,Tamilnadu

***Abstract*—** This paper present a new novel compensator, based on a matrix converter without energy storage device to mitigate the current harmonics. By connecting the compensator output terminals to the load side , and the input side of compensator is connected to the supply side. So a matrix converter injects the compensation voltage on the load-side, so it is probable to mitigate the voltage sag/swell harms, resulting in an proficient solution for mitigating voltage related power quality problems. Thus, the future topology can mitigate the voltage fluctuations without energy storage elements and the total harmonic distortion produced by the system also very low. Space-vector modulation (SVM) is used to control the matrix converter. Matlab/Simulink based simulation results are presented to validate the approach.

Keywords- Matrix Converter, series compensator voltage sensitive Load, Matlab/Simulink. Power Quality (PQ).

I. INTRODUCTION

There are several causes for voltage distortion, namely, nonlinear loads, some types of voltage sources and thunderstorms. These problems cause instantaneous and long term effects on electrical equipment. The short term effects are not working, interferences and filth of the performance of devices or equipments. Effects in the long run are, basically, overheating and premature aging of the electrical devices. If the mains voltage is undistorted, but non linear loads are linked to the electrical grid, the current harmonics created will cause voltage distortions in the line impedances, and the voltage at the load terminals will also be distorted. With a distorted voltage, even linear loads absorb distorted current. Passive filters can be used to compensate some of the problems mentioned above, but they have some limitations. Passive filters only filter the frequencies for which they have been earlier tuned, its operation cannot be limited to a certain load, resonances can occur, and the electrical system can start to operate with capacitive power factor. Finally Passive filter cannot control the voltage power quality problem like sag/swell .

Recent developments in series compensator have several advantages over passive ones: compensation is automatic, there is no threat of resonances, unity power factor (or any other desired value) can be achieved permanently and without disturbing the electrical network, they can compensate for phase unbalance, and excellent performance can be achieved. They can also be combined with passive filters (which may be already installed) in hybrid topologies, in order to diminish its rated power.

All the series compensator is controlled by the voltage source converter. But voltage source converter has some draw back present. Due to switching loss, capacitor leakage current, etc., the distribution source must supply not only the active power required by the load but also the additional power required by the VSI to maintain the DC-bus voltage constant. If not these losses are regulated, the DC-bus voltage will drop steadily. Moreover VSC based converter produces more harmonics and switching losses high.

II-MATRIX CONVERTER

In this paper proposes a matrix converter based series compensator instead of a VSC based converter. After the invention of matrix converter in 1976, it has drawn significant attention. A matrix converter can operate as a four quadrature Ac-Ac converter circuit. The output voltage frequency and its amplitude and also the input power factor can be controlled by utilizing the proper modulation method. The main application of the converter is in driving motors where the space and

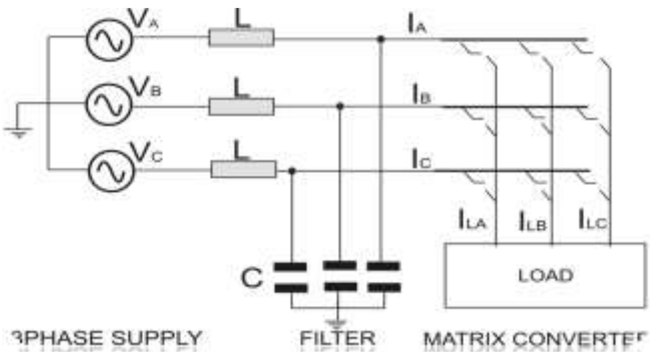

Fig: 1 Basic structure of matrix converter

weight are premium. The main drawbacks of this topology are the need for fully controlled bidirectional switches and complex algorithm to perform commutation. Developing power matrix converter modules and high speed DSP processors have partially solved these problems A series active filter based on matrix converter topology is presented in this paper Although matrix converter was initially introduced as an AC Driver, due to its advantages may be used in voltage compensation applications.

III-PROPOSED SERIES COMPENSATOR

The proposed series compensator is designed using a matrix converter is shown if figure4. L_{abc} are the source impedance, l_{abc} is the smoothing inductor. C_{abc} is the smoothing capacitor .input of matrix converter is connected to the supply voltage and the output voltage is connected injection transformer (T_{abc}).

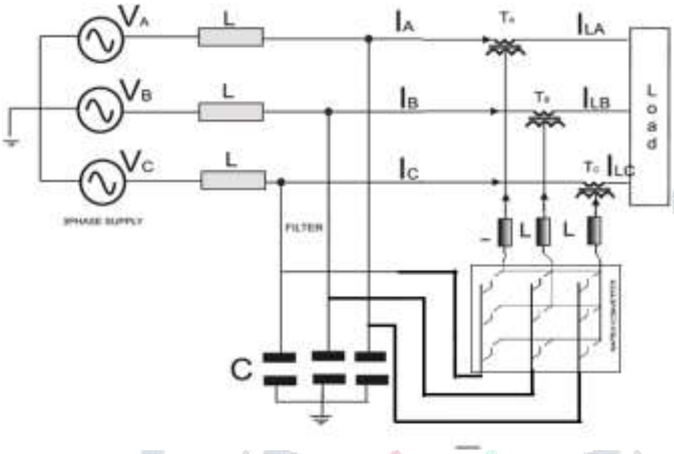

Fig 2: Model of series compensator

Figure 3 shows the schematic diagram of the proposed matrix converter. In the present paper a three-phase to the three-phase matrix converter is utilized to realize a series compensator as shown in Fig.3. Bidirectional switches are implemented by common collector back to back IGBT and diode switch shells.

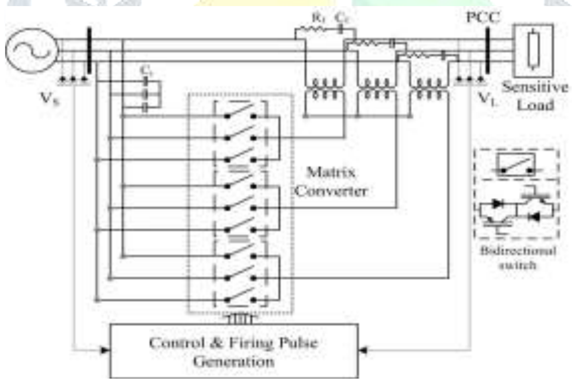

Fig 3. Schematic diagram of series compensator

By eliminating the energy storage unit,DC capacitor and minimizing the size of filters in the series compensator configuration, it is possible to pack all the modules into a small size equipment. The proposed series compensator requires more switching devices but it does not need a large electrolytic capacitor.

IV-CONTROL SYSTEM

The output terminal voltage and input terminal current consider the low frequency transformation function (1) and set a sinusoidal input voltage, as follows:

$$\bar{v}_{abc} = V_i \begin{bmatrix} \cos(\omega_o t + \alpha_o) \\ \cos(\omega_o t + \alpha_o - 2\pi/3 \\ \cos(\omega_o t + \alpha_0 + 2\pi/3 \end{bmatrix} \quad (1)$$

$$\bar{v}_{ABC} = D\bar{v}_{abc} = (aD_i + (a-1)D_2)\bar{v}_{abc} \quad (2)$$

$$= qV_i \begin{bmatrix} \cos(\omega_o t + \alpha_o \\ \cos(\omega_0 t + \alpha_0 - 2\pi/3 \\ \cos(\omega_0 t + \alpha_0 + 2\pi/3 \end{bmatrix}$$

Where ϕ is the output (or load) angle. Using equation (2), the MC output currents can be written as follows:

$$\bar{i}_{abc} = D^T i_{ABC} = qI_0 \left[a \begin{bmatrix} \cos(\omega_i t+\varphi_i \\ \cos(\omega_i+\varphi_0-2\pi/3 \\ \cos(\omega_i t+\varphi_0-2\pi/3 \end{bmatrix} + (1-a) \begin{bmatrix} \cos(\omega_i t+\varphi_0 \\ \cos(\omega_i t+\varphi_0-2\pi/3 \\ \cos(\omega_i t+\varphi_0+2\pi/3 \end{bmatrix} \right] \quad (3)$$

Assume the desired input current to be

$$\bar{i}_{ABC} = I_0 \begin{bmatrix} \cos(\omega_0 t+\alpha_0+\varphi_0 \\ \cos(\omega_0 t+\alpha_0+\varphi_0-2\pi/3 \\ \cos(\omega_0 t+\alpha_i+\varphi_i+2\pi/3 \end{bmatrix} \quad (4)$$

$$m_{ij(t)} = \frac{1}{3}+\frac{2}{3}Q\cos(\omega_i t-2(j-1)\frac{\pi}{3}).\{\cos(\omega_0 t-2(i-i)\frac{\pi}{3})- \frac{1}{6}\cos(3\omega_0 t)+\frac{1}{2\sqrt{3}}\cos(3\omega_i t)\}-\frac{2}{9\sqrt{3}}Q\{\cos(4\omega_i t-2(j-1) -\cos(2\omega_i t-2(j-1)\frac{\pi}{3}\}$$

Where φ_i is the input displacement angle.

$$\bar{i}_{abc} = I_i \begin{bmatrix} \cos(\omega_i t+\alpha_i+\varphi_i \\ \cos(\omega_i t+\alpha_i+\varphi_i-2\pi/3 \\ \cos(\omega_i t+\alpha_i+\varphi_i+2\pi/3 \end{bmatrix} \quad (5)$$

V-REFERENCE VOLTAGE GENERATION

The enhanced Venturini method (EVM) has been used to generate the firing pulses of the matrix converter switches. In this method the ratio of the maximum (RMS) value of the input voltage to the maximum (RMS) values of the output voltage is defined as Q.

$$V_{AF} = nQV_s \quad (6)$$

$$Q = \frac{V_0}{V_i}$$

that is, where V_o and V_i are the maximum (RMS) amplitude of output and input voltages respectively . Considering V_{Af} * to be the amplitude of active filter's reference voltage, the value of Q

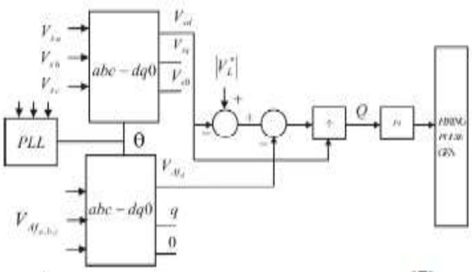

Fig4.reference voltage generation for matrix converter based series compensator.

can be calculated as

$$Q = \frac{V_{AF}^*}{V_s} \quad (7)$$

To find V^{*}_{AF}, the difference between ideal and actual load voltages is calculated, and then divided by the grid voltage as shown in Fig. 4.The block indicated by "EVM firing pulse generator" uses the following equation to calculate the on-time of matrix converter switches

$$m_{ij(t)} = \frac{1}{3} + \frac{2}{3} Q\cos(\omega_i t - 2(j-1)\frac{\pi}{3}).\{\cos(\omega_0 t - 2(i-i)\frac{\pi}{3}) - \frac{1}{6}\cos(3\omega_0 t) + \frac{1}{2\sqrt{3}}\cos(3\omega_i t)\} - \frac{2}{9\sqrt{3}} Q\{\cos(4\omega_i t - 2(j-1) - \cos(2\omega_i t - 2(j-1)\frac{\pi}{3}\} \tag{8}$$

where *i* and *j* are the number of input and output phases(*a* : 1, *b* : 2, *c* : 3), *ωi* and *ωo* are the input and output voltage angular speeds.
Considering *n* as the series transformer voltage ratio

$$V_{AF} = nQV_s \tag{9}$$

The maximum obtainable value of Q is √3⁄2. Hence, the minimum source voltage that active filter can compensate is

$$V_{s(\min)} \geq \frac{1}{1+\frac{\sqrt{3}}{2n}} pu \tag{10}$$

By defining V $_s$ and λ as ideal source voltage and sag depth respectively, $V_s=(1-\lambda)V_s^*$the maximum compensable sag depth can be calculated as

$$\lambda_{\max} = V_s^* - V_{s(\min)} = \frac{\frac{\sqrt{3}}{2}n}{1+\frac{\sqrt{3}}{2}n} \tag{11}$$

So the maximum compensable sag depth is 0.866 p.u. in the presence of transformer. Whereas and without the transformer ($n = 1$) the load voltage will drop if a sag depth larger than0.46 p.u. occurs .Considering the power balance equation for a matrix converter (*Pin* = *Pout*), we have

$$V_s I_i = \frac{1}{n} V_{af} I_{out} \tag{12}$$

where I_{in} and I_{out} are input and output currents of matrix converter, V_{Af} is the injected active filter voltage.

Hence the maximum input current of $\frac{I_i}{I_{out}} = Q$ (13)

$$I_{i(\max)} = n\frac{\sqrt{3}}{2} I_L \tag{14}$$

Considering the load voltage to be constant due to Overcompensation, equation (10) shows that for compensating deepconverter. Replacing V_{Af} from (9) in (13) yields, *out L* $I_{out}= nI_l$ Using the transformer voltage ratio, I_{out} can be written I_i=nQ$I_L$as, where I_L is the load current

Table 1- Simulation parameter

Parameter	Value
V_{Source}	440V
L_s	2mh
L_f	0.5mh
C_f	200µf
R_f	0.1Ω
C_i	2 µf
Matrix converter switching	600 Hz

frequency	
Power System frequency	60 Hz

Table 1 shows the system parameters of the proposed matrix converter based series active filter.

VI-SIMULATION RESULTS

In this work three phase matrix converter based series compensator is used to compensate the voltage sag/swell. The source voltage is 440Vrms, 60Hz. Table 1 shows the proposed system main parameters. It includes source impedance parameters L and C values for passive branches used.The system has been simulated VSC based series active filter and the proposed matrix converter based series compensator separately. In simulation studies, the results are specified before and after applying the matrix converter based compensator. Also the values for Total Harmonic Distortion before compensation and after compensation using, existing series active filter and the proposed matrix converter based series compensator are given..All the simulation is performed by the Matlab Simulink model.

Results and discussion

The voltage sag and swell was intent ally created by using programmable voltage source. Voltage is sag with magnitude of 0.7 p.u between the duration (0.5-1 ms) and swell with the magnitude of 1.15 p.u during the time of (1-1.5 ms) again the voltage sag is created with the magnitude of 0.9 p.u during (1.5 – 2) which is shown in the fig 5 source voltage. The matrix converter is switched according to the voltage sag and swell created in the input voltage. The switching of the matrix converter is controlled by space vector modulation technique.

The voltage injected by the matrix converter is shown in fig 6. the matrix converter inject the voltage to compensate the sag and swell by changing the injected voltage polarity which is clearly sown in fig 6 during the time interval of (1- 1.5 ms).

The load voltage is shown in fig 7.The load voltages contain smooth and pure sine wave form due to the implementation of MDVR.

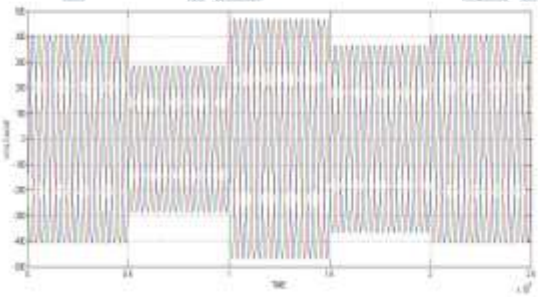

Fig 5 source side voltage

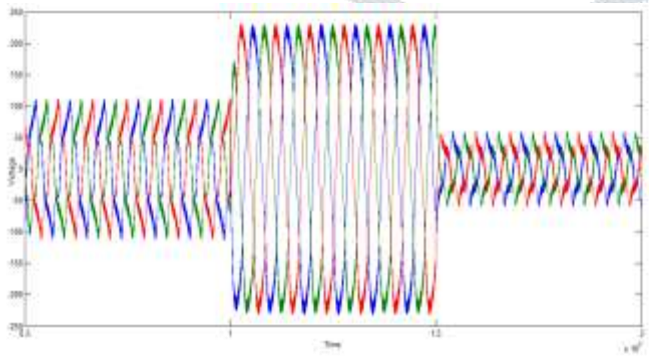

Fig 6 voltage injected by matrix converter

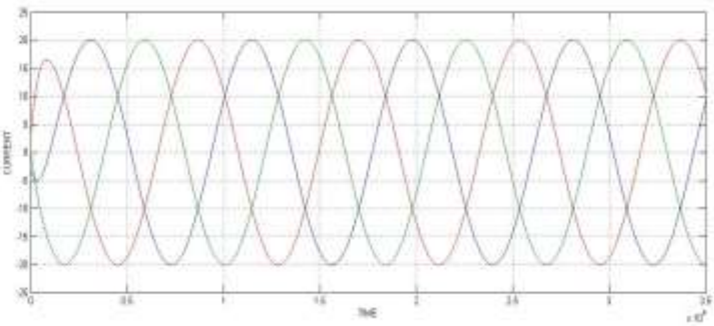

Fig 7 load side voltage

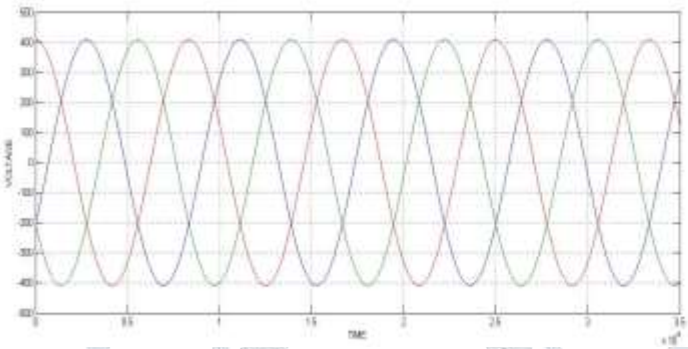

Fig 8 load side current

CONCLUSION

This report was investigated the use of matrix converter based series compensator (MDVR) to mitigate the voltage sag/swell. This report analyzed the matrix converter and conventional voltage source converter based series compensator and found that matrix converter produces less harmonics compared to voltage source converter. MDVR handles both balanced and unbalanced Situations without any difficulties and injects he appropriate voltage component to correct any abnormally in the supply voltage to keep the load voltage balanced and constant at the nominal Value. In the case of voltage sag, which is a condition of a temporary reduction in supply voltage, the MDVR injects an equal positive voltage component in all three phases which are in phase with the supply voltage to correct it. On the other hand, for a voltage swell case, which is a condition of a temporary increase in supply voltage, the MDVR injects an equal negative voltage in all three phases which are antiphase With the supply voltage Based on the simulation results the matrix converter based DVR mitigates the voltage harmonics efficiently with low total harmonic distortion. The matrix converter proved to be efficient for active filtering purposes compared to conventional voltage source converter In this report, performance of a matrix converter based DVR for Mitigating voltage sags/swells is demonstrated with the help of MATLAB.

REFERENCES

1. Ebrahim Babaei, Mohammad Farhadi Kangarlu, and Mehran Sabahi "Mitigation of Voltage Disturbances Using Dynamic Voltage Restorer Based on Direct Converters" IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 25, NO. 4, 2010.
2. K Umamaheswari, V Venkatachalam,"Single phase converters for power factor correction with tight output voltage regulation "International Journal of Emerging Technology and AdvancedEngineering ,VOl.3,issue 2, Pages516-521
3. K Umamaheswari, V Venkatachalam, Optimal PFC corrector of single stage power converter using BC tuned PID controller Journal of Intelligent & Fuzzy Systems 30 (6), 3155-3166
4. V.Venkatachalam, K.Umamaheswari ,Optimal Power Factor Correction Controller for Single Stage Power Converter International Journal of Applied Engineering Research 9 (23), 21473-21499
5. D. Ranjith Perera, and S. S. Choi "Voltage Sag Compensation With Energy Optimized Dynamic Voltage Restorer", IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 18, NO. 3,2003.

6. Chi-Seng Lam,, Man-Chung Wong, and Ying-Duo Han, “Voltage Swell and Overvoltage Compensation With Unidirectional Power Flow Controlled Dynamic Voltage Restorer” IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 23, NO. 4,2008.
7. Hans Nielsen, and Frede Blaabjerg, “Control and Testing of a Dynamic Voltage Restorer (DVR) at Medium Voltage Level” IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 19, NO. 3, 2004.
8. Norbert EDOMAH, “Effects of voltage sags, swell and other disturbances on electrical equipment and their economic implications”, Paper 0018, 20th International Conferenc on Electricity Distribution, Prague, 8-11 June 2009
9. Mehmet Tumay, Ahmet Teke, K. Cağatay Bayındır, M. Uğras Cuma, “Simulation and modeling of a dynamic voltage restorer”
10. N. Mohan, T.M. Undeland, W.P. Robbins, Power Electronics: Converters, Applications and Design, second ed., John Wiley & Sons, Neywork,1995., pp. 471-475.
11. D. M. Vilathgamuwa, A.A.D.R. Perera, S.S. Choi, Voltage sag compensation with energy optimized dynamic voltage restorer, IEEE Trans. Power Deliver.18(3) (2003) 928-936.