Power Quality Conditioners for Matrix Converter Using Shunt and Series Active Filters

**Shubra Goel[1], Devender Tiwari[2] ,
Mohit Kumar Pandey[3] and Saurabh Bajpai[4]**

*[1,2,3,4] Faculty, Department of Electrical & Electronics Engineering
[1,2]Vidya College of Engineering,Meerut, India.
[3]Acme College of Engineering,Ghaziabad,India.
[4]Vira College of Engineering.Bijnor,India
Email:[1]ershubra@gmail.com ,[2]tiwaridevender@gmail.com,
[3]mohitkumar_pandey@yahoo.co.in ,[4]saurabhbajpai897@gmail.com4*

Abstract

Power quality is defined as set of limits or conditions that allows electrical devices to function in their planned manner without loss of performance. Without proper power load may malfunction, fail permanently or not operate well. Ideally. Harmonic currents have been present in the electricity supply system for many years. By minimizing the total harmonic distortion the harmonic pollution in the power system will be reduced and power quality will be increased. Matrix converter injects significant and non standard frequency components into power systems. The active filter technology is used to minimize the inductance value. To improve harmonics problem series and shunt active filter is used with matrix converter. A shunt active filter senses the load current and injects a current into the system to compensate current harmonics. A series active filter is used to eliminate voltage harmonics produced by the matrix converter. The series converter deals with the input voltage distortions. The proposed approach has been tested and validated on the matrix converter using simulink. The datasheet parameters are included in these models to bring it more close to actual circuit model. Simulated results confirm that the active power filters using series and shunt filter can maintain high performance for matrix converter.

Keywords: Matrix Converter, series active filter, shunt active filter, passive filter, power quality, Total Harmonic Distortion(THD), Switching error.

Introduction

Ideally voltage is fed by utility as sinusoidal having voltage and frequency given by international standards and the disturbance in power quality can be produced by inverters and converters. The beginnings of the Matrix Converter date back to the late 1970s.[2] Nowadays, the name "Matrix Converter" is used to label any power topology that can be organized into sub blocks placed in a matrix shape. The matrix converter is the 3 phase to 3 phase and is just one of the possible direct A.C-A.C converter topology .The matrix converter has several advantages over traditional rectifier-inverter type power frequency converters. The Matrix Converter requires a bi-directional switch capable of blocking voltage and conducting current in both directions.[1] Unfortunately there are no such devices currently available, so discrete devices need to be used to construct suitable switch cells and therefore discrete unidirectional devices are arranged. It has inherent bidirectional energy flow capability and the input power factor can be fully controlled. The Matrix Converter is a single stage converter which has an array of mxn bidirectional power switches to connect, directly, an m-phase voltage source to an n-phase load.[4] The Matrix Converter of 3x3 switches, shown in figure 1, has the highest practical interest because it connects a three-phase voltage source with a three-phase load. Defining the switching function of a single switch as
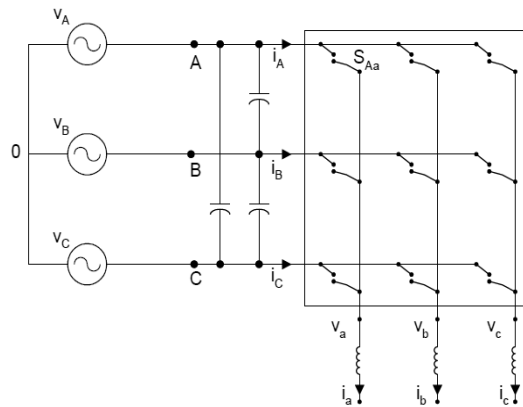
$S_{kj} = \quad$ 1 Switch S_{kj} closed k=A,B,C

$\qquad$ 0 Switch S_{kj} open j =a,b,c $\hfill (1)$

Where A, B, C are input phase and a,b,c are output phases.
The constraints discussed above can be expressed by
$S_{Aj} + S_{Bj} + S_{Cj} = 1$ j= a ,b ,c $\hfill (2)$

With these restrictions, the 3x3 Matrix converters has 27 possible switching states

Fig.1: Simplified circuit of a 3x3 Matrix Converter.

Normally, the Matrix Converter is fed by a voltage source and for this reason; the input terminals should not be short-circuited. On the other hand, the load has typically

an inductive nature and for this reason an output phase must never be opened. With respect to an A.C. drive application of the matrix converter, overvoltages can originate externally as voltage surge existing on to the A.C. mains or internally as a consequence of switching commutation error.[5] The clamp circuit is operative for all nine bi-directional switches. The advantage of protection scheme is simple, small hardware requirement and safe in all operating conditions. But the disadvantage is that it increases the number of semiconductor devices required and also the amount of reactive component needed.

The disadvantage of matrix converter is that it has maximum input output voltage transfer ratio limited to 87% for sinusoidal input and output waveforms. It requires more semi- conductor devices than a conventional A.C-A.C. indirect frequency converter.

"Harmonics" means a component with a frequency that is an integer multiple (where n is the order of harmonic) of the fundamental frequency; the first harmonic is the fundamental frequency (50 or 60 Hz). The second harmonic is the component with frequency two times the fundamental (100 0r 120 Hz) and so on. Harmonic distortion can be considered as a sort of pollution of the electric system which causes problems if the sum of the harmonic currents exceeds certain limits. So to convert nominal frequency to variable frequency power electronics circuitry (non-linear loads) is needed, which distorts the voltage and current waveforms. Therefore, the main source of harmonics in the power systems is the non linear loads. [1-3]The total harmonic distortion (THD), of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. THD is a measurement of the sum value of the waveform that is distorted. The THD is a very useful quantity for many applications. However, it has the limitation that, it is not a good indicator of voltage stress within a capacitor because that is related to the peak value of voltage waveform.

$$THD = \frac{\sqrt{\left(V_2^2 + V_3^2 + \ldots\ldots + V_N^2\right)}}{V_1}$$

The advantage of Active filters over passive filter are:

Inductors can be avoided. Passive filters without inductors cannot obtain a high Q (low damping), but with them are often large and expensive (at low frequencies), may have significant internal resistance, and may pick up surrounding electromagnetic signals.

The shape of the response, the Q (Quality factor), and the tuned frequency can often be set easily by varying resistors, in some filters one parameter can be adjusted without affecting the others. Variable inductances for low frequency filters are not practical.

The amplifier powering the filter can be used to buffer the filter from the electronic components it drives or is fed from, variations in which could otherwise significantly affect the shape of the frequency response.

**Table 1:** Effect of Voltage and Current on Harmonics

Classification of Criterion	Type of Effect	Comments
Period	Very short-term Effects	These effects are associated with a failure, malfunction or inoperative state of equipment exposed to high harmonics, such as control and instrumentation equipment, electronic equipment, IT equipment, etc.
	Long-term effects	Mainly of thermal nature. The thermal effect (Causing accelerated ageing of insulation) is a function of many variables, of which the most important are the values and orders of harmonics.
Physical Nature Of The Distorted Quantity	Current effects	Related to the instantaneous or time-averaged current value (overheating of electric machines, capacitor fuses blowing, increased losses in transmission lines, unwanted operation of relays, etc.). Harmonics in power supply systems are the main cause of temperature rise in the equipment and shortening of in-service time.
	Voltage effects	Related with the peak, average or RMS value of distorted voltage.

General Compensation Technique of Matrix Converter

General Structure. A matrix converter is very simple in structure and has powerful controllability. The converter consists of nine modular H-bridge capacitor clamped switch cells that are connected from each input phase to each output phase. The terminal AC voltages of the Converter is synthesized from the modulation techniques of Space Vector Modulation. The space vector modulation approach is a well-known technique for control of three phase converters. The switching pulses for the power devices in each bridge are obtained from the modulation techniques. Multilevel switching can be used to synthesize the voltage waveforms at both the input and output of the converter. The switch cells can be connected in series with branch of the matrix to increase the voltage rating of the converter.

Passive Filter Compensation. The principal method of reducing the harmonics generated by the static converter is provided by the input filter using reactive storage elements as shown in Figure 2. So many configurations are proposed for the matrix converter input filter. As far as the matrix converter is concerned, a high displacement angle of the input line current due to the input filter capacitance component might be compensated by the matrix converter, setting as reference for the input current a lagging displacement angle. But in this way the maximum voltage transfer ratio for the converter will be significantly reduced. Therefore, even for the matrix converter, the upper limit of the input filter capacitance is set by the minimum acceptable AC main power factor. Similarly the control of the impedance interaction between the input filter and the voltage converter is necessary. In general, an optimized design of

the matrix converter input filter is a quite difficult task, since it relies on a system approach.
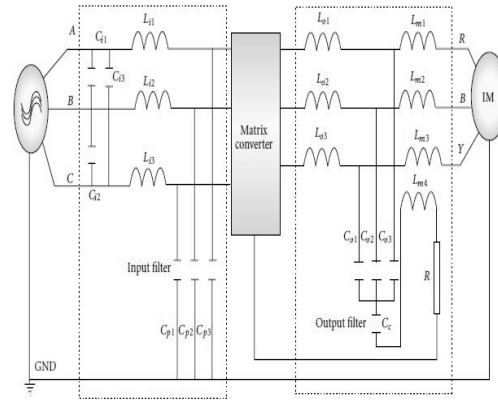
Fig.2: Existing technique of power quality improvement for the matrix converter.

The Proposed Compensation Scheme for Matrix Converter

The proposed technique includes two parts: the first part compensates matrix converter's input power quality problems and the second part compensates matrix converter's output power quality problems. The matrix converter is considered as two types of load, that is, Current-Source Type of Harmonic Sources, Voltage-Source Type of Harmonic Sources. The enhanced control system is proposed to further eliminate harmonics with higher accuracy.

1. Current-Source Type of Harmonic Sources in Matrix Converter.

Power electronic converters are a common and typical source of harmonic currents. The distortion of the current waveform, that is, the generation of harmonics, results from the switching operation. Because the harmonic current contents and characteristics are less dependent upon the AC side, this type of harmonic source behaves like a current source. Therefore, they are called current-source type of harmonic source (or harmonic current source) and represented as a current source. A shunt active filter is to be placed in parallel with a load (matrix converter) to detect the harmonic current of the load and to inject a harmonic current with the same amplitude of that of the load into the AC system. In order not to lose generality, the harmonic current source is represented as Norton's equivalent circuit.

2. Voltage-Source Type of Harmonic Sources in Matrix Converter.

Another type of common harmonic source is matrix converter output, which produces harmonic voltage and current waveforms. Although the current is highly distorted, its harmonic amplitude is greatly affected by the impedance of the AC side. Therefore, the matrix converter output behaves like a voltage source harmonic. The harmonic voltage source is represented as Thevenin's equivalent circuit, as shown in Figure 6.

A pure voltage-source type of harmonic source is a special case of Thevenin's equivalent with $Z_L \rightarrow 0$.

Simulations Results
### Simulation results when Harmonics present in supply
The results show that the THD can be reduced with the help of series and shunt active filters. The comparison of THD is done between matrix converter without filter and with filter both when harmonics is induced in the supply or when switching error occurs.

System Parameters: The system parameters considered for the study and comparison of THD of matrix converter in different cases are

- Case(A): Matrix converter without the use of series and shunt filters i.e in ideal condition.

Table 2: Parameters for Case (A)

|	System Parameters	Value
1	AC voltage source	100 (peak)
2	Frequency	60 Hz
3	Resistance	2 ohm
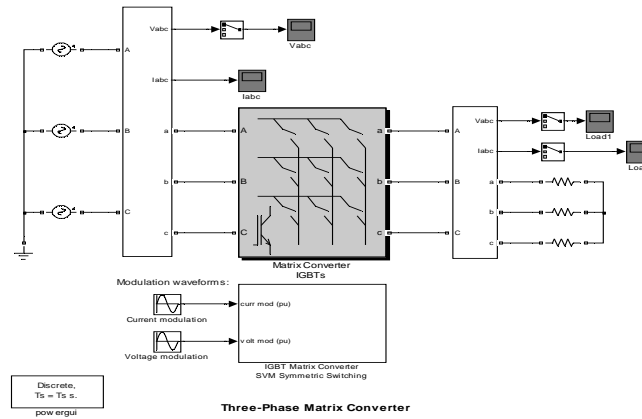
Fig.3: Three Phase Matrix Converter without Filter

- Case(B):Matrix converter with use of series and shunt active filters and if harmonics is not induced in it.

Table 3: Parameters for Case (B)

	System Parameters	Value
1	AC voltage source	100 (peak)
2	Harmonics induced	100
3	Frequency	60 Hz
4	Resistance	2 ohm
5	Inductance	1e-4 henry
6	Capacitance	1e-6 Farad
7	Linear transformer- windings 1	[1 0.002 .08] [V R L]
8	Linear transformer- windings 2	[1 0.002 .08] [V R L]
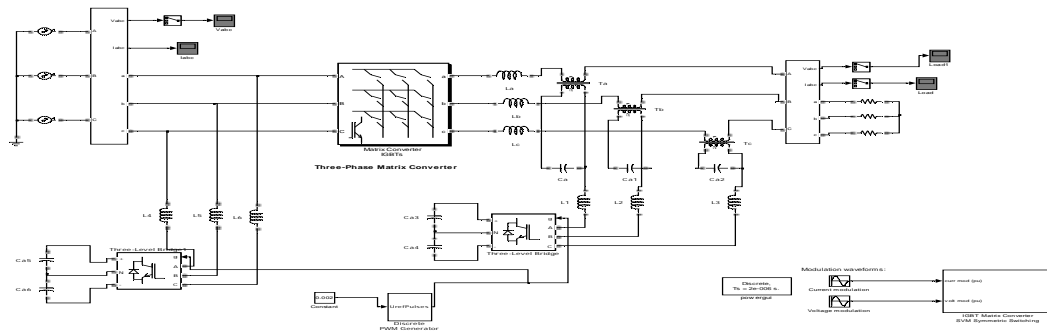
Fig.4: Series and shunt active filter used with matrix converter
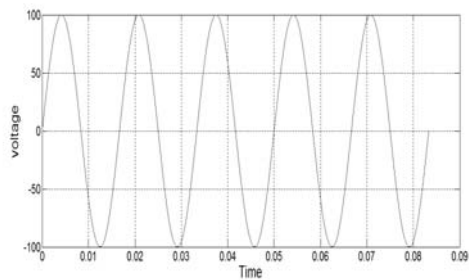
Fig.5: Source Voltage for Case (A)
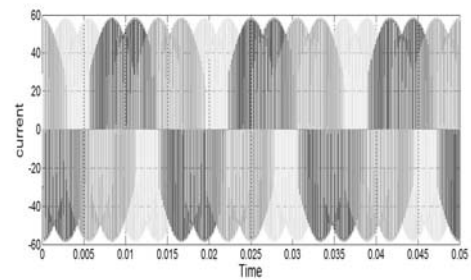
Fig.6: Source Current for Case (A)
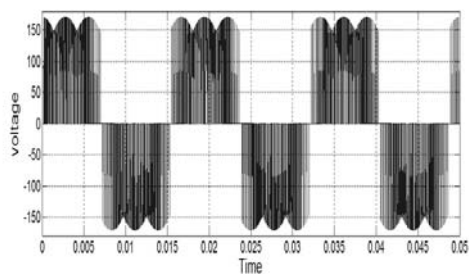
Fig.7: Output Voltage for Case (A)
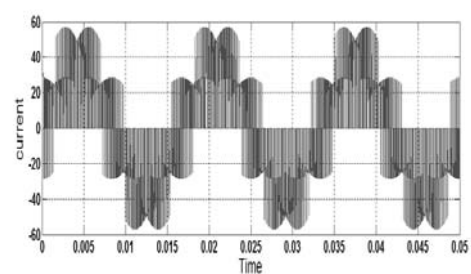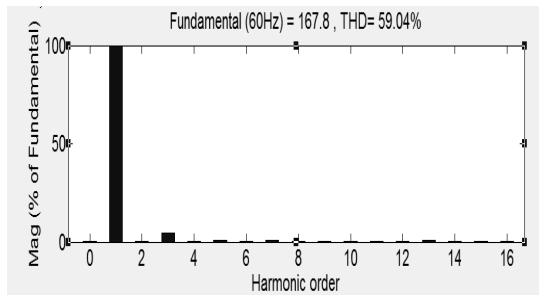

Fig.8 Output Current for Case (A)

Fundamental (60Hz) = 146.6 , THD= 60.68%

Fundamental (60Hz) = 42.33 , THD= 60.59%
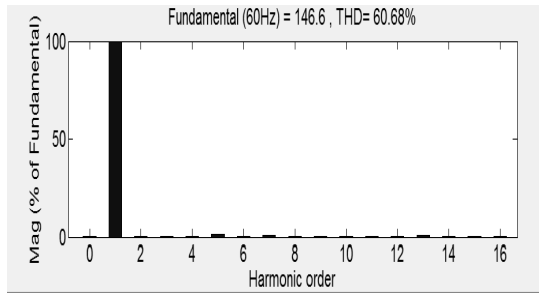
Fig.9: Voltage THD without Filter Case (A)
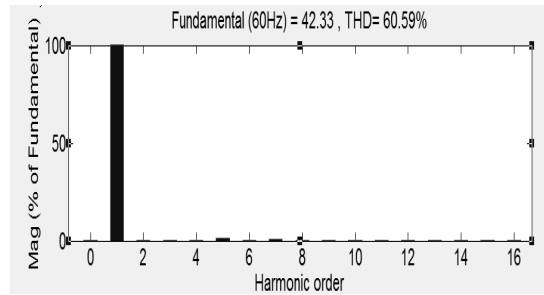
Fig.10: Current THD for case (A)

If 1/3*100 harmonic is induced in the supply.

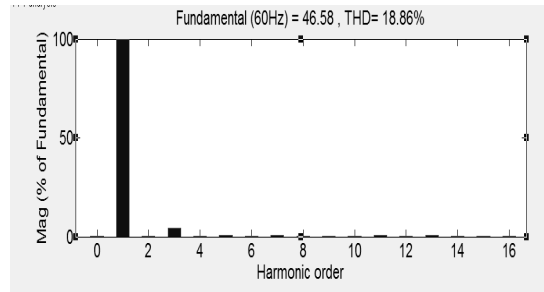Fundamental (60Hz) = 167.8 , THD= 59.04%

Fundamental (60Hz) = 49.59 , THD= 57.27%

Fig.11: Voltage THD without Filter Case (B)
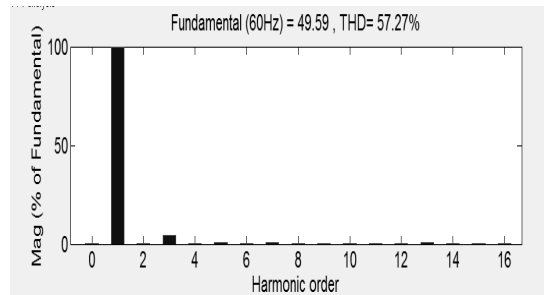
Fig.12: Current THD for case (B)

Fundamental (60Hz) = 157.7 , THD= 19.46%

Fundamental (60Hz) = 46.58 , THD= 18.86%
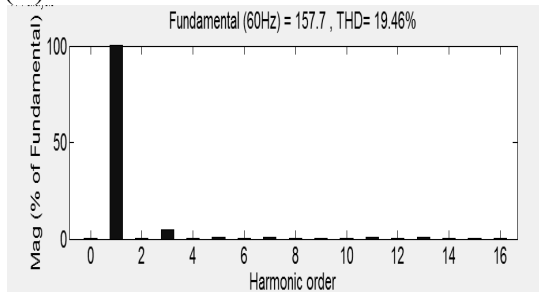
Fig.13: Voltage THD without Filter Case (B)

Fig.14: Current THD for case (B)

The result proves that with the help of series and shunt active filters the THD is reduced comparing with that without a filter.

Simulation Result when Harmonics present in supply:

TABLE 4: THD Analysis Due to 1. Harmonics Present In Supply

| S. No	Case	Harmonics	%THD Without filter (voltage)	%THD With filter (voltage)	%THD Without filter (current)	%THD With filter (current)
1	I	0	60.68	19.62	60.59	19.59
2	II	1/3*100	59.04	19.46	57.27	18.86
3	III	150/3* 100	67.85	37.49	58.58	33.03
4	IV	170/5* 100	67.34	36.93	58.16	32.57

2. *Harmonics Induced Due to Error in Switching:*
System Parameters: The system parameters considered for the study and comparison of THD of matrix converter in case of switching error:
CASE(C): Matrix converter without the use of series and shunt filters i.e in ideal condition.

TABLE 5: Parameters for (c)

	System Parameters	Value
1	AC voltage source	100 (peak)
2	Frequency	60 Hz
3	Resistance	2 ohm
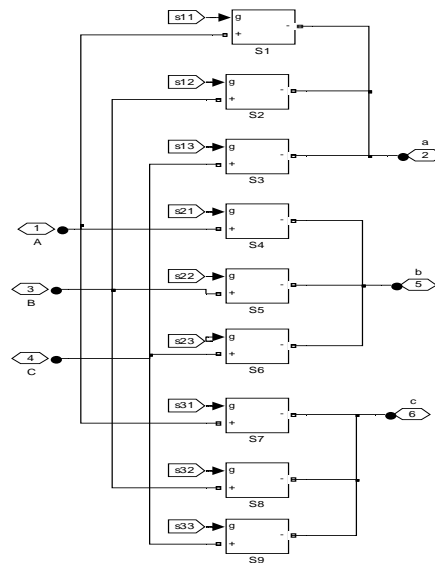
Fig 15: Switching Of Matrix Converter In Ideal Condition

Case(D): Matrix converter without the use of series and shunt filters and if error is induced in switching.

TABLE 6: Parameters for Case (D)

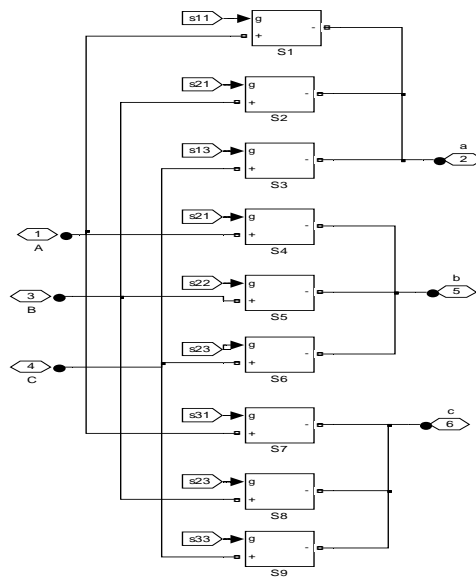|	System Parameters	Value
1	AC voltage source	100 (peak)
2	Switching error	S12 to S21 and S32 to S23
3	Frequency	60 Hz
4	Resistance	2 ohm

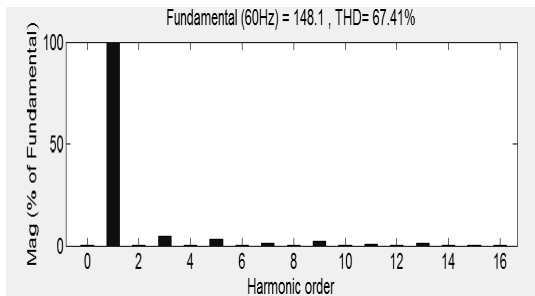Fig.16: Switching of Matrix Converter with switching error
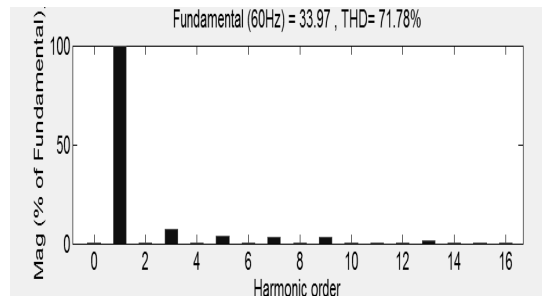
Fig.17:Voltage THD without Filter Case (D)
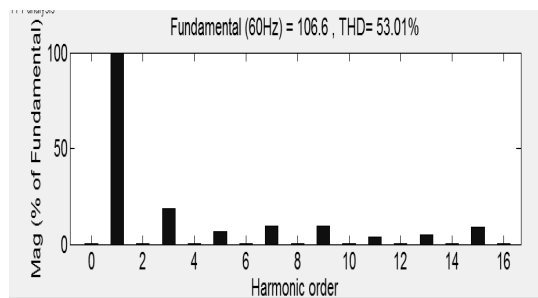
Fig.18: Current THD for case (D)
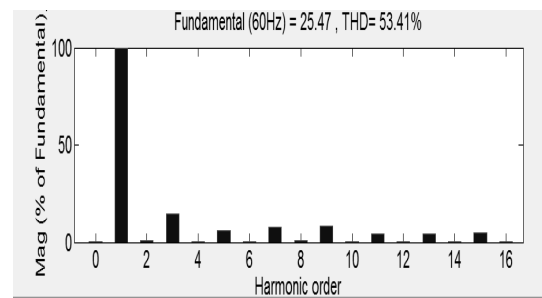
Fig.19:Voltage THD without Filter Case (D)

Fig.20:Current THD for case (D)

Harmonics Induced Due to Error in Switching:

Table 7: THD Due To Switching Error

S. No	Case	Switching Error	%THD Without filter (voltage)	%THD With filter (voltage)	%THD Without filter (current)	%THD With filter (current)
1	I	0	60.68	19.62	60.59	19.59
2	II	S12-S21, S32-S23	67.41	53.01	71.78	53.41
3	III	S13-S31, S23-S32	76.82	53.49	72.73	54.41
4	IV	S13-S33, S23-S33, S32-S33	60.54	26.50	53.98	21.28

Conclusion

The proposed Matrix Converter with series and shunt active filter techniques was simulated using Matlab/ Simulink model blocks. The result proves that with the help of series and shunt active filters the THD is reduced comparing with that without a filter. It also has the minimum THD level when harmonics or error in switching is present and hence the reduced losses on the drives. It can be implemented by DSP technique for future work.

Refrences

[1] P.Jeno Paul, Jacob Raglend and T. Ruban Dev Prakash, "Matrix converter disturbances compensating shunt and series active filters." International Journal of Signal System Control Engineering and Applications, 2010.

[2] P. Jeno Paul "shunt active and series active filters-based power quality conditioner for matrix converter" Advances In Power Electronics, 6 May 2011.

[3]   P. Jeno Paul "power quality improvement using series active filter for matrix converter Controlled load" International Journal Of Signal System Control Engineering And Applications,2010.

[4]   P.Jeno paul, I. Jacob Raglend, T.Ruban Deva Prakash "power Quality Improvement for Matrix Converter Using Shunt Active Filter" International Journal Of Computer Applications (0975 – 8887) Volume 11– No.2. December, 2010.

[5]   Murat Kale, Engin O Zdemir "harmonic and reactive power compensation with shunt active power filter under non-ideal mains voltage" Electric Power System Research,11 August 2003.

[6]   D. Casadei, G.Serra and A.Tani, "a general approach for the analysis of input power quality in matrix converters" IEEE Transactions On Power Electronics, .13, No5, Pp.882.891.Sep.1998.

[7]   A. Alesina, M.Venturni,Jan 1989. Analysis and design of optimum amplitudenine switch direct ac-ac converters,*IEEE Transactions on Power Electronics*,Vol:4 Issue:1;pp.101-112.

[8]   J.M.D .Murphy, F.G Turnbull, 1988 power electronics control of ac motors,Pergamon Press.

[9]   L. Gyugyi, B.R Pelly1988.static power frequency changers theory, performance and applications, ISBN 0-08-022683-3.

[10] L.Gyugyi, B.R Pelly, 1976.static power frequency changers theory, performance and applications, ISBN 0-471-6780007-7, *John Wiley and Sons,USA*.