Power Quality Improvement by Designing the LCL Filters for the Matrix Converter in a DFIG System

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Abstract— This paper proposes a new DFIG system using Matrix Converter with indirect space-vector modulation scheme, which can effectively interconnect the wind power system with the power grid. Indirect space-vector modulation considers the MC as a rectifier and inverter connected via a DC link with no energy storage. This paper also proposes the LCL filter design to eliminate the harmonics; those are produced by the converter. The results are simulated by MATLAB/SIMULINK software. All the results are analysed by the FFT analysis.

Keywords—LCL filter, doubly fed induction generator (DFIG), matrix converter (MC), indirect space-vector modulation (ISVM).

I. INTRODUCTION

Doubly fed induction generator (DFIG) is very efficient one in wind power generation when wind speed is widely varying. The power grid is directly connected to stator terminals and to rotor through matrix converter (MC). DFIG is generating the constant frequency power to the grid without reference to wind speed variation, and control the power factor at the connection point [1-3].

Matrix converter is a new technology in DFIG to connect the rotor output with the power grid and converting the low frequency (s*f) AC power to the

50Hz (f) commercial power. Back to back converter technology is replaced by this new technology because back to back converter has high switching loss and bulky structure because it has 3-step power conversion such as AC-DC-AC. this weak point is improved by matrix converter, which can directly convert the AC power from one frequency to another [4].

LCL filters are designed for MC both sides (i.e. rotor side and grid side) because MC works in both directions. When the wind speed is low then the rotor receives power from grid and when the wind speed is high then the rotor will supply power to the grid. So we designed Y-connected LCL filter for grid side and delta-connected filter for rotor side [1].

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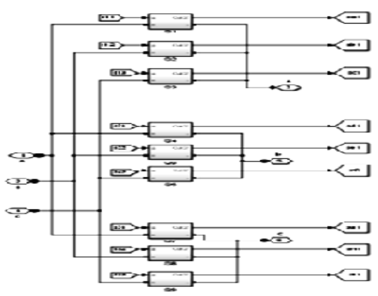
II. MATRIX CONVERTER

Matrix converter is designed with nine bidirectional solid-state switches. These switches are gated ON or OFF simultaneously to get desired results. Bidirectional power transfer can possible with matrix converter as well as power factor correction for the input current [6], [9-12].



Matrix converter is controlled by indirect space-vector modulation scheme. This scheme is a form of pulse width modulation that is based on two-phase representation of three-phase quantities some advantages of this scheme than other PWM techniques are [7]:

1. A wide linear modulation range [8].

2. It has improved Total Harmonic Distortion (THD) characteristics as much of the disturbance is centered on the switching frequency.

3. The switching frequency is much greater than the input supply fundamental frequency and thus it is possible to

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remove the high frequency switching components using a low pass filter.

4. It has improved Total Harmonic Distortion (THD) characteristics as much of the disturbance is centered on the switching frequency.

5. It is easily implemented in digital applications.

For these reasons, ISVM is adopted for use in this paper [13-15].

III. LCL FILTER DESIGN

LCL filter which we designed is two types one is star connected LCL filter which is connected between grid and converter another one is delta connected LCL filter which is connected between rotor and converter [1], [16].

Fig. 2 presents the schematic diagram of the star connected LCL filer. Where U_O & U_S are the terminal voltage of MC and grid voltage respectively, L_1 & L_2 are the converter side and grid side inductors respectively, R_1 & R_2 are the equivalent resistances of L_1 & L_2 respectively, C_3 is the capacitance, R_3 is the damping resistor in series with C_3. The transfer function between input voltage U_O and output current I_2 is:

$$H(s) = \frac{(R_3C_3s+1)}{(L_1L_2C_3s^3 + (L_1+L_2)\,R3C3s2+\;)\,(L_1+L_2)\,s)} \quad \text{……... (1)}$$

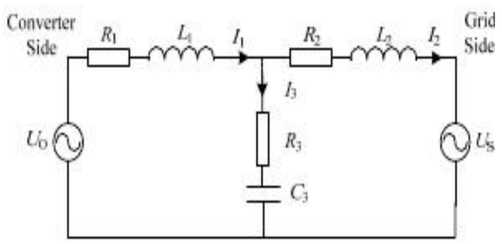

Fig.2. LCL filter equivalent circuit diagram

While for an L filter, the transfer function becomes:

$$H(s) = \frac{1}{sL} \quad \text{…..... (2)}$$

As we are observing above equations LCL filter having a third order transfer function so it gets higher harmonics attenuation at high frequency than the L filter with a first order transfer function

TABLE-I Y-CONNECTED FILTER PARAMETERS

L_{1g}	L_{2g}	R_g	C_g
1.0e-3H	0.73e-3H	0.68Ω	100µF

By taking current ripple, power factor and resonance into consideration we were designed the above parameters [1].

IV. MATRIX CONVERTER WITH FILTERS

There are nine bi-directional switches are there in Fig. 1.

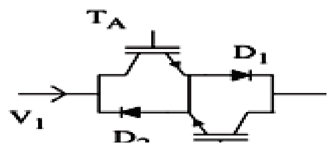

Fig.3. Bi-directional switch

In this session we connected the MC with LC, LCL and without filter to analyse the result with FFT window.

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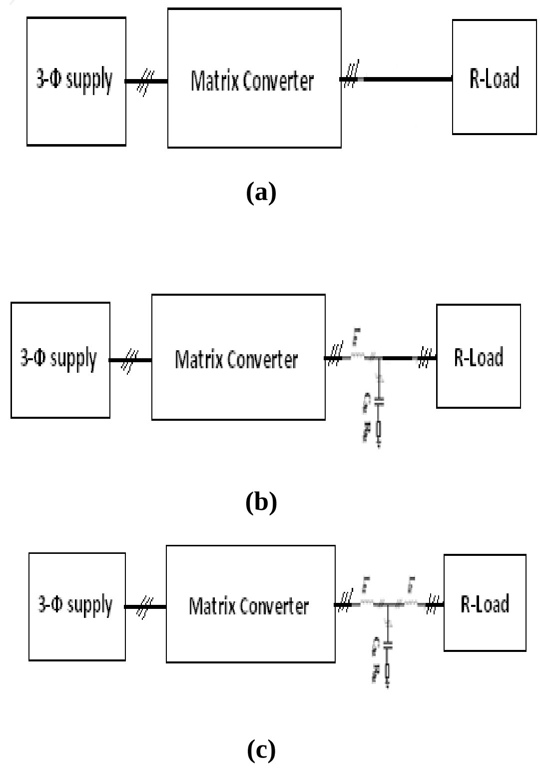

Fig.4. Matrix Converter with (a) No filter (b) LC filter (c) LCL filter

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A. Simulation Results of MC with No filter

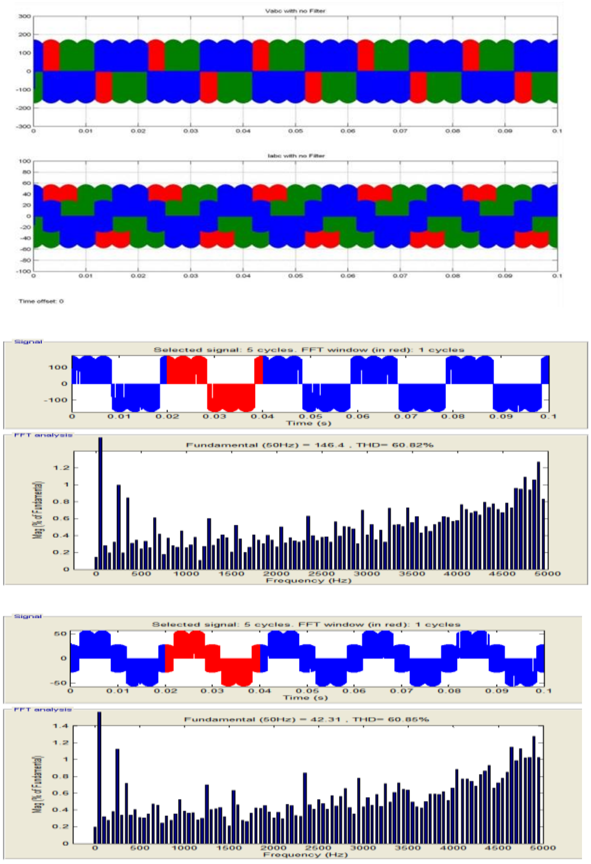
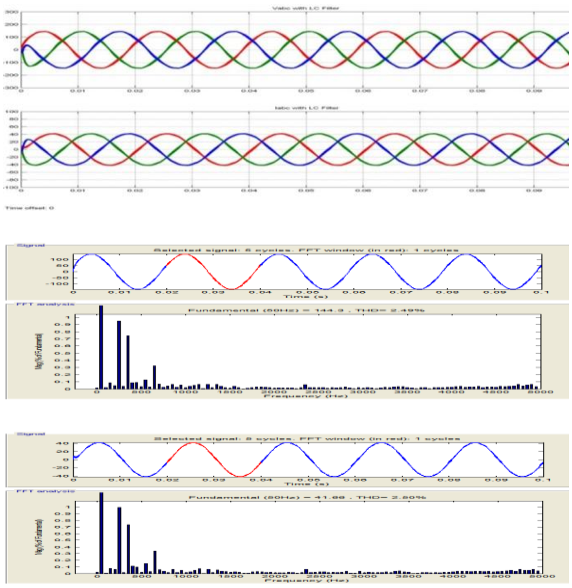


Fig.5. MC output V's, I's & FFT windows

B. Simulation Results of MC with LC filter



C. Simulation Results of MC with LCL filter

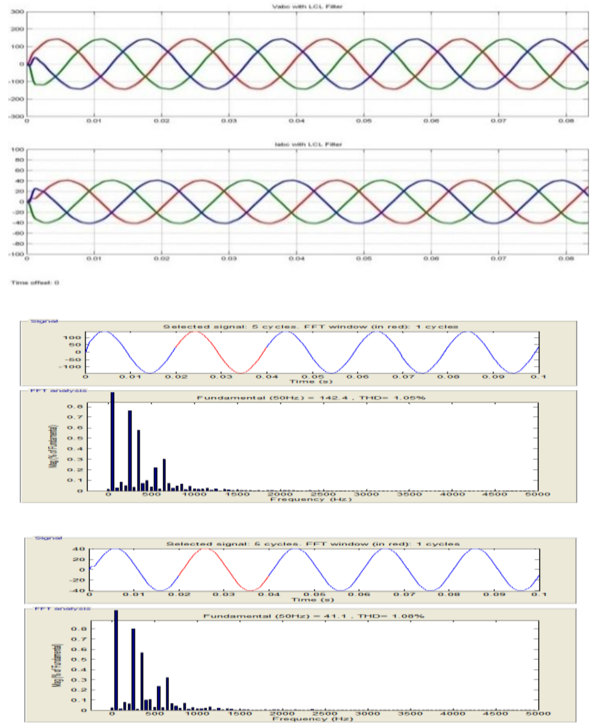


Fig.7. MC output V's, I's & FFT windows

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If we observe above waveforms we can identify that the total harmonic distortion (THD) is very good when we are using LCL filters. Without filters the output waveforms are combined with harmonics but when we use LC filter the output waveforms are giving pure sine wave but the sine wave combined with some harmonics. When we use LCL filter we can observe that result is very good than MC with without filter and MC with LC filter.

V. MATRIX CONVERTER IN DFIG SYSTEM

The DFIG is an induction machine with a wound rotor where the rotor and stator are both connected to electrical sources, hence the term 'doubly-fed'.

Fig.8. shows the overall configuration of DFIG system. In this system stator terminals are directly connected to the grid and the rotor terminals are connected to grid through Matrix converter. LCL filters are designed both sides of the matrix converter. Matrix converter converts fixed frequency and fixed voltage into variable frequency and variable voltage.

For example if the grid side frequency is fundamental frequency, f then the rotor side frequency is s*f. so we have to control the matrix converter by using suitable switching strategies. We are controlling the voltage at grid side and current at rotor side of the MC.

Here we are connecting six 1.5MW wind turbines in series so the total power generating by DFIG is 9MW (6*1.5MW). Whenever the wind speed is high then the power generating by the DFIG system is 9MW, which is generated by both stator side and rotor side. If the wind speed is low then the rotor will take power from grid so in this situation the total power is generated by DFIG system is 0.5pu.

So DFIG is very efficient in variable speed wind turbine stations. Modern wind farms, with a nominal turbine power up to several MWs, are a typical case of DFIG application.

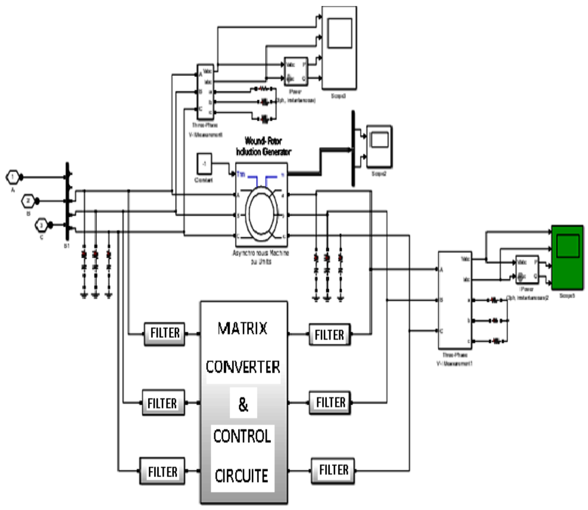
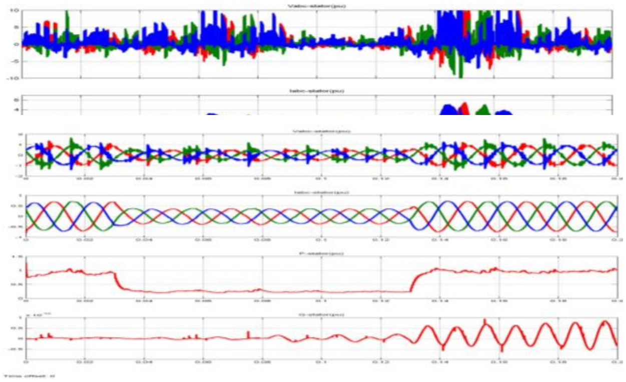
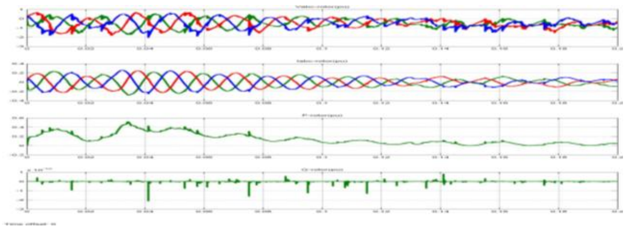


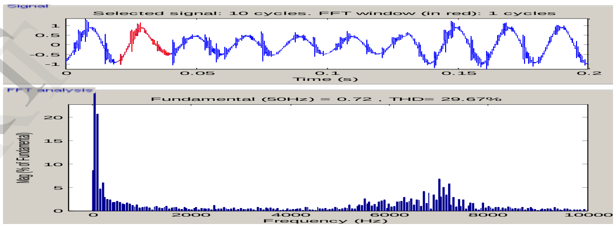
Fig.8. MATLAB/SIMULINK Circuit of DFIG System

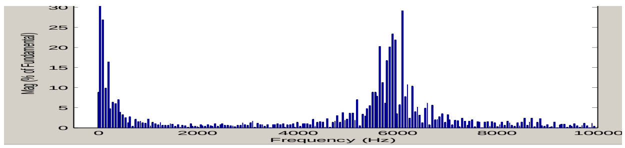
VI. SIMULATION AND ANALYSIS

A. MC without Filter in DFIG System









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C. MC with LCL Filters in DFIG System

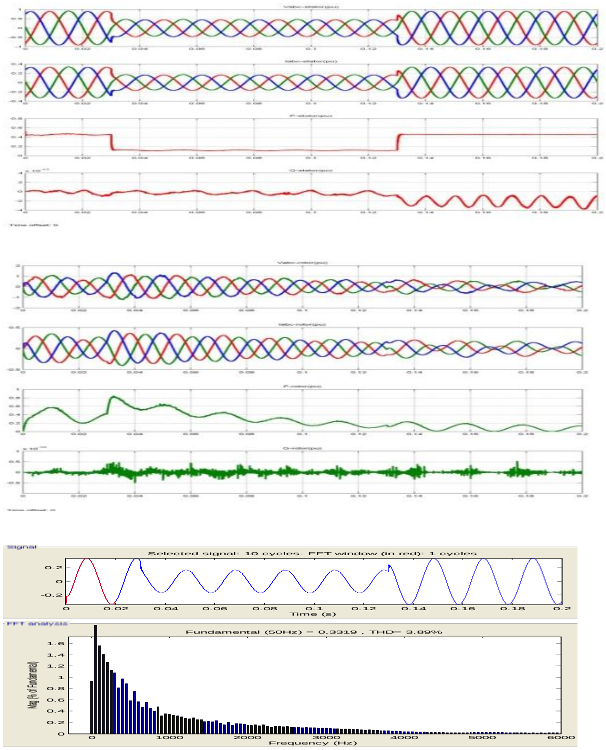

Fig.11.DFIG Stator & Rotor V, I, P,Q & FFT window

VII. CONCLUSION

By analysing the waveforms with FFT analysis THD values are given in Table-2 &3. THD after filtering the voltage is 1.05% on MC and 3.89% on MC in DFIG System respectively, which verify the effectiveness of the LCL filter than other filters. So by attnuating the harmonics produced by Matrix converter efficiancy of the system will be increase and also increase the power quality.

TABLE-2 THD of MC with Different Filters

	Matrix Converter		
	No Filter	LC	LCL
THD%	60.82%	2.49%	1.05%

TABLE-3 THD of MC in DFIG System with Different Filters

	MC in DFIG System		
	No Filter	LC	LCL
THD%	126.59%	29.67%	3.89%

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