Power Quality Improvement in Integrated Renewable Energy System Using Intelligent Control System

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Abstract

This project discusses the use of an AC-AC matrix converter, as an alternative to AC-DC-AC converter system, an interface power converter between a variable load and a wind energy system. A new approach is proposed to solve the commutation problems associated with the switches so it improve the power quality compared to conventional system and it reduces the cost because there is no energy storage element between the line-side and load-side converters. Total harmonic distortion of the power converter is minimized by using filters it improves the power quality. It can be achieve high efficiency without large energy storages. The effectiveness of the proposed method is verified by develop simulation model in MATLAB-Simulink environment.

1. Introduction

In the recent years, awareness about global warming and the harmful effect of carbon emission is significantly increased among the people and researchers as well. So that clean and substantial energy sources like Wind, Sea, Sun, Biomass etc. comes into higher demand. Among all these, Wind energy has experienced the highest growth in last 10 years. This is just because wind energy is a pollution free resource which has inexhaustible potential and also delivering the competitive cost advantage over others. The wind energy can be harnessed by a wind energy conversion system (WECS), composed of a wind turbine, an electric generator, a power electronic converter and the corresponding control system.

Now a days variable speed operations became more attractive because of the development of power electronics and falling cost of component and technology as well. By running the wind turbine generator in variable speed, variable frequency mode, and the maximum power could be extracted at low and medium wind speeds. Among all kinds of wind energy conversion systems (WECSs), a variable speed wind turbine (WT) equipped with a multi pole permanent magnet synchronous generator (PMSG) is found to very attractive and suitable for the application in large wind farms. With gearless construction of such PMSG, advantages like low maintenance, reduced losses and costs, high efficiency and good controllability could be derived.

Wind speed used by wind turbine for generation of electricity is called productive wind speed. Since wind power is directly proportional to cube of wind's speed therefore as wind speed falls the amount of energy produced also decreases rapidly and vice-versa. Productive wind speed range between 4m/sec to 35m/sec WECS is composed of three parts: aeronautical, mechanical and electrical. In this the electrical part is again divided into: wind generators, power electronics converters (PEC) and utility grid or loads. The main advantage of a matrix converter is to obtained variable frequency output from fixed frequency input supply. Matrix converter is based on the concept of "fictitious dc link" used in controlling the conventional matrix converter. However, there is no energy storage element between the line-side and load-side converters.

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Matrix converter offers four control levels that can be used to control the input displacement angle and output voltage magnitude, frequency and phase angle. When compared with the AC-DC-AC converter system, the bold feature of MC is elimination of the DC-link reactive elements. A controlled rectifier rectifies the output voltage of permanent magnet synchronous generator and rectified output is given to the inverter. As there is no DC link element between the converter and the inverter, the converter produces the constant DC voltage irrespective of wind velocities. The constant DC voltage from the converter is given to the input of inverter to obtain an AC output voltage of constant amplitude with constant frequency. There by constant output voltage with constant frequency is obtained from the proposed Wind Energy Conversion Scheme. To investigate the input/output condition of develop wind energy system for different loads.

2. Conventional Matrix Converter Topology

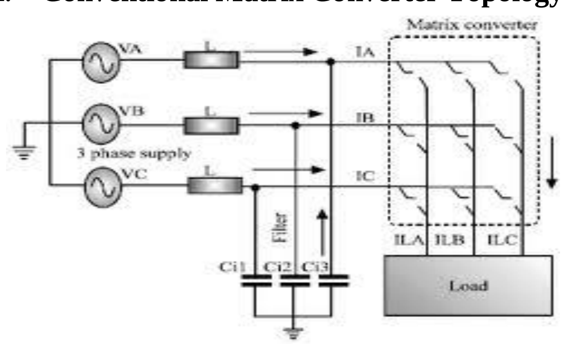

Fig: 1. Three Phase Matrix Converter

Fig: 1. shows the schematic diagram of a conventional matrix converter. The conventional matrix converter topology is composed of an array of nine bi-directional switches connecting each phase of the input to each phase of the output. By properly operating the switches in the matrix converter, one can achieve control on the output voltage magnitude, frequency and phase angle, as well as control on the input displacement angle. Matrix converter is a bi-directional power flow device with the capability of producing high quality input and output waveforms.

3. Proposed Matrix Converter

Figure shows the schematic diagram of the improved matrix converter topology. The improved matrix converter is based on the concept of "fictitious dc link" used in controlling the conventional matrix converter. However, there is no energy storage element between the line-side and load-side converters.

The improved matrix converter topology has the following advantages with respect to the conventional matrix converter topology:

- The commutation problems associated with the switches have been solved.
- All the switches at the line-side turn on and turn off at zero current.
- Reduce the total harmonic distortion by using series and shunt filter.

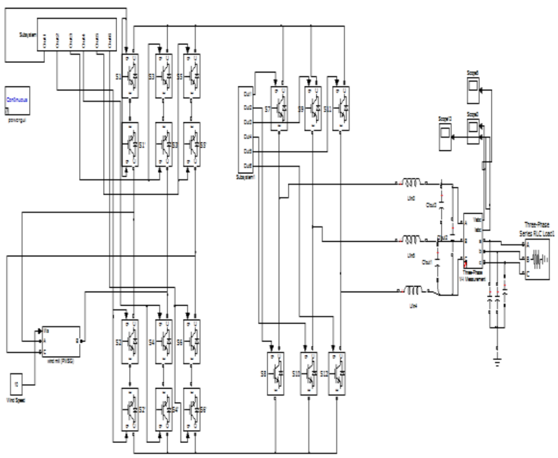

Fig: 2. Proposed Matrix Converter

As shown in Figure 2, matrix converter offers four control levels that can be used to control the input displacement angle and output voltage magnitude, frequency and phase angle.

4. Simulation and Result

A controlled rectifier rectifies the output voltage of permanent magnet synchronous generator and rectified output is given to the inverter. Then the inverter produce the AC output voltage it's given to difference load.

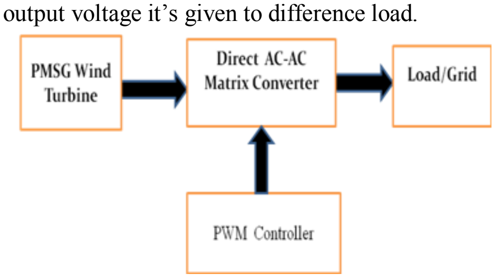

Fig: 3. Over all Block Diagram

To implement proposed wind energy conversion system (WECS) using MATLAB/ SIMULINK. To investigate the input/output condition of develop wind energy system with direct matrix converter for different loads.

A. Simulink Model for PMSG

A special model of the machine is required to determine the steady state and transient behavior of the PMSG. The model of the PMSG can be obtained by means of 2-phase machines in direct and quadrature axes.

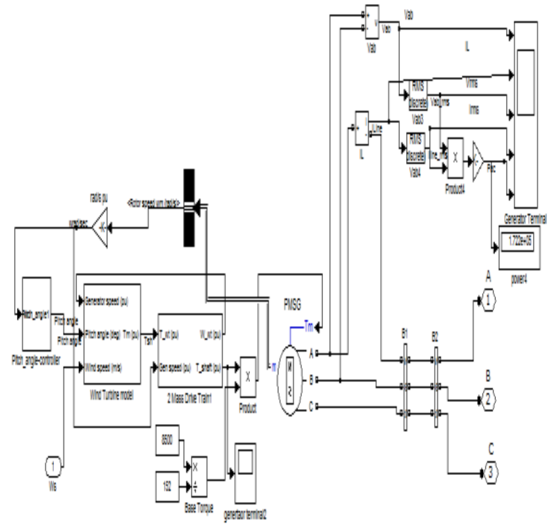

Fig: 4. PMSG Model

The rotor speed of the PMSG is depends on the wind speed. If the wind speed is 10m/s so the rotor speed is 19 rad/sec for various loads. The rotor speed and torque, Vline, Iline, Vab-rms, Iline-rms, Pac of the PMSG is shown in Fig 5, 6 and 7.

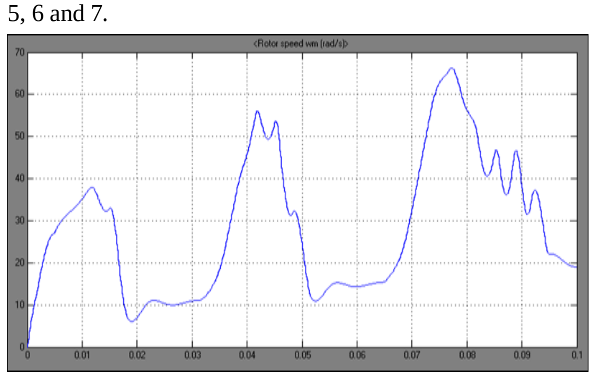

Fig: 5. Rotor Speed of Wind Turbine Generator

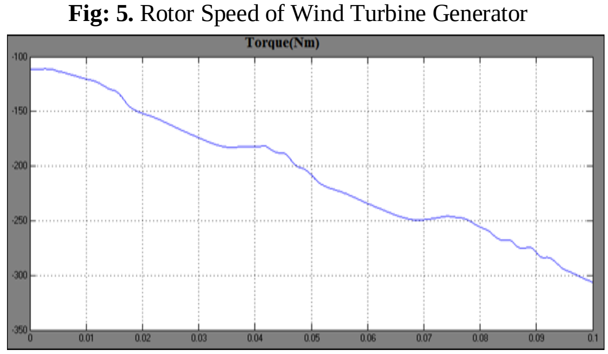

Fig: 6. Torque of Wind Turbine Generator

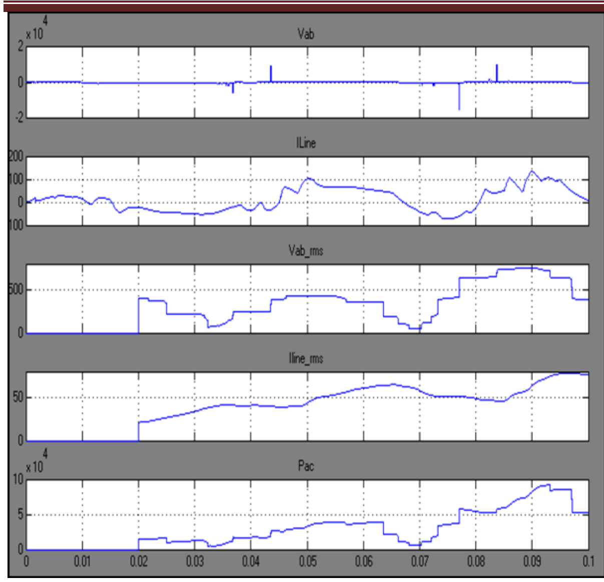

Fig: 7. PMSG Parameters

B. Simulink Model for Direct Matrix Converter for Various Loads

In the matrix converter model the IGBT is connected back to back with diodes and a single bidirectional switch six switches are connected in input side and its output is given to the inverter without DC link and its output is given to various load. The loads are connected in the output side of inverter.

1. R load

A controlled rectifier rectifies the output voltage of permanent magnet synchronous generator and rectified output is given to the inverter. Then the inverter produce the AC output voltage it's given to R load. Fig 4.6 shows the direct matrix converter model for R load.

Direct AC-AC matrix converter output voltage, current and total harmonic distortion values are analyzed with filter and without filter for R load. Fig 4.7, 4.8 & 4.9 shows the Output voltage, Output current and THD values of DMC for R load.

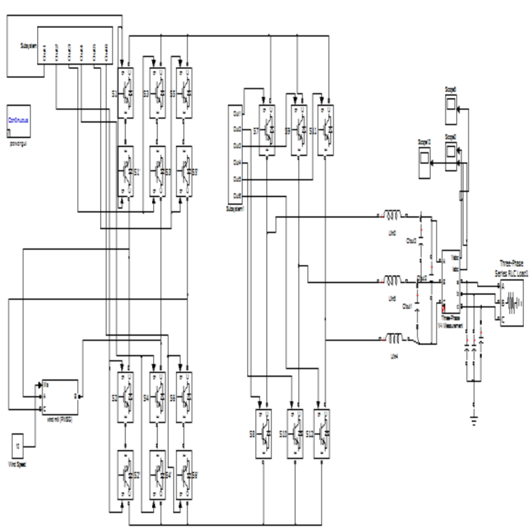

Fig: 8. Direct Matrix Converter Model for R Load

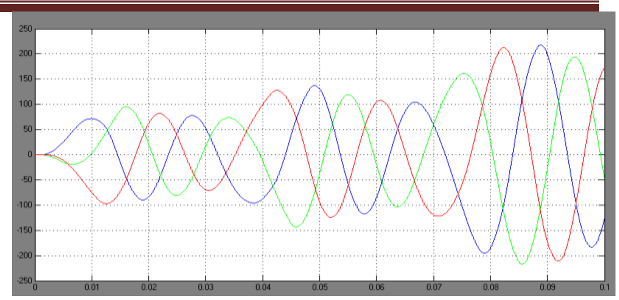

Fig: 9. Output voltage of DMC for R Load

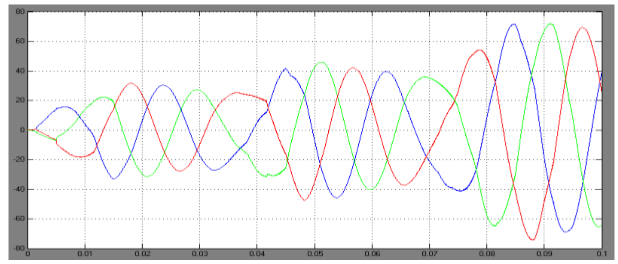

Fig: 10. Output current of DMC for R load

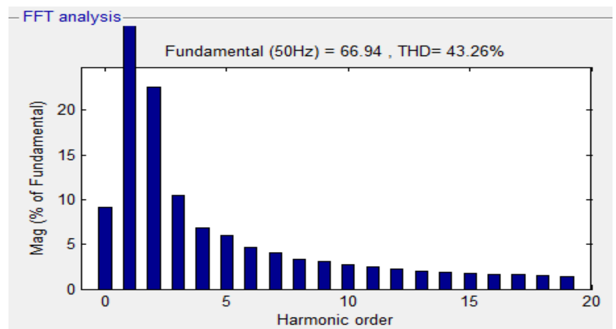

Fig: 11. THD Values for Output Voltage of DMC with R Load

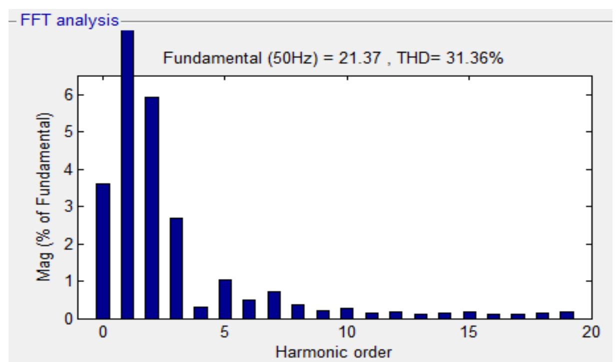

Fig: 12. THD Values for Output Current of DMC with R Load

The THD value of the proposed matrix converter is analyzed and compared with conventional matrix converter for R,RL and RLC load. It is observed that he harmonics is less when compared with conventional method. In conventional matrix the THD value is more than 90%, where as in proposed matrix converter, the THD value is reduced to 31.36% (fig 4.10).

2. RL Load

A controlled rectifier rectifies the output voltage of permanent magnet synchronous generator and rectified output is given to the inverter. The output of the inverter is connected to RL load. Fig 4.11 shows the direct matrix converter model for RL load.

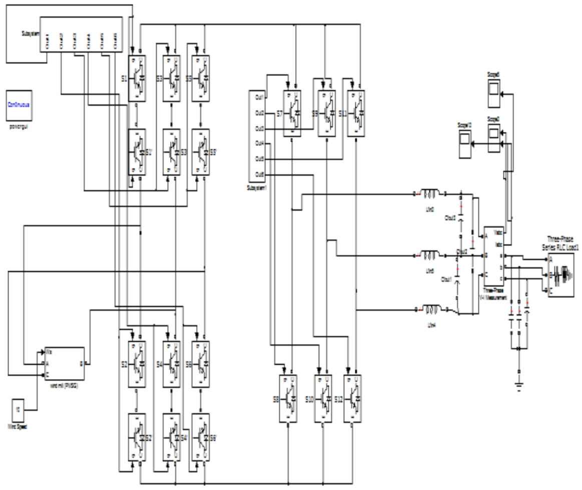

Fig: 13. Direct Matrix Converter Model for RL Load

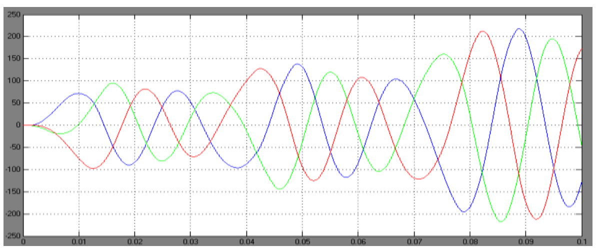

Fig: 14. Output Voltage of DMC for RL Load

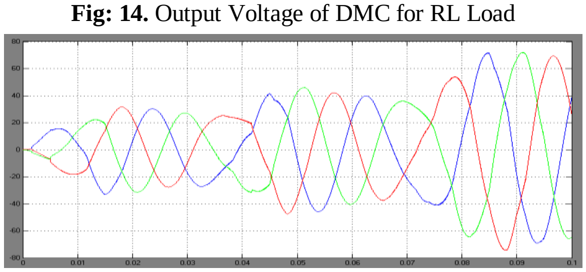

Fig: 15. Output Current of DMC for RL Load

The output of the PMSG is connected to load through matrix converter. The voltage, current and THD values are measured with and without filter circuits. Fig 4.12 and 4.13 shows the Output voltage and output current of DMC for RL load.

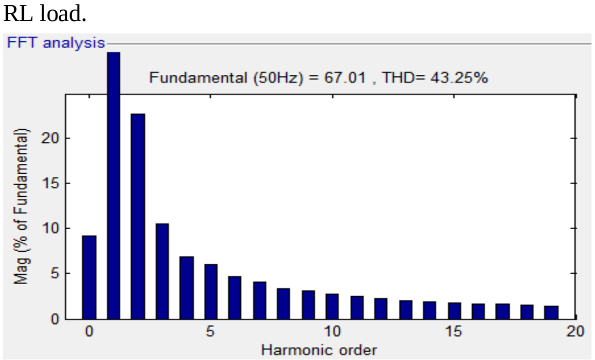

Fig: 16. THD Values for Output Voltage of DMC with RL Load

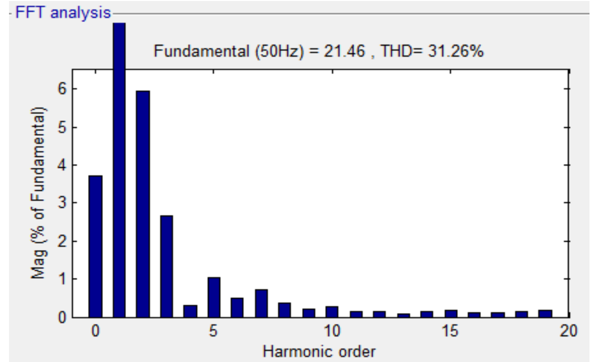

Fig: 17. THD Values for Output Current of DMC with RL Load

It is found that the THD value with filter circuit is 31.40% and without filter circuit is 72.98% which is higher than the proposed model. In the proposed PMSG-matrix converter, model, the THD value is reduced and hence it improves the output voltage and current, this shows the improved in the power quality.

3. RLC Load

In fig 4.16 shows a controlled rectifier rectifies the output voltage of permanent magnet synchronous generator and rectified output is given to the inverter. The output of the inverter given to RLC load. The THD value is measured for matrix converter for RLC load and the harmonics are less when compared to conventional method by using filters.

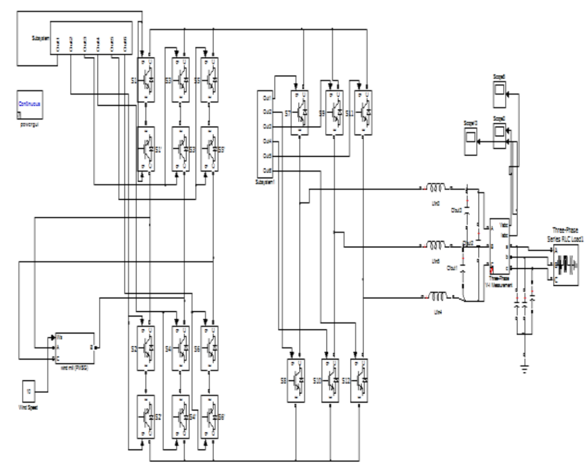

Fig: 18. Direct Matrix Converter Model for RLC Load

Fig 4.16 shows the direct matrix converter model for RLC load.

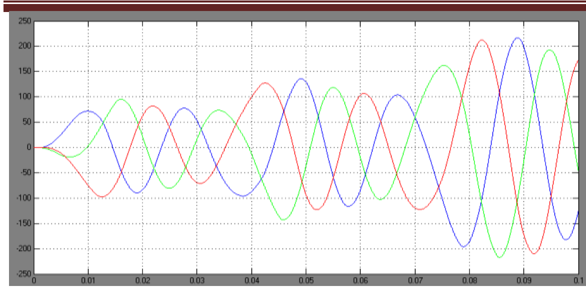

Fig: 19. Output Voltage of DMC for RLC Load

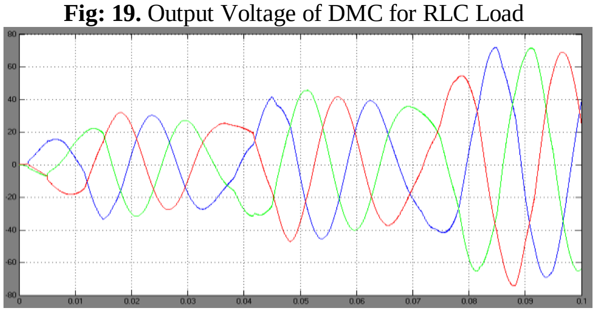

Fig: 20. Output Current of DMC for RLC Load

The output voltage and current with RLC load in shown in fig 4.17 and 4.18.The THD analysis for RLC load is given in fig 4.19 & 4.20.

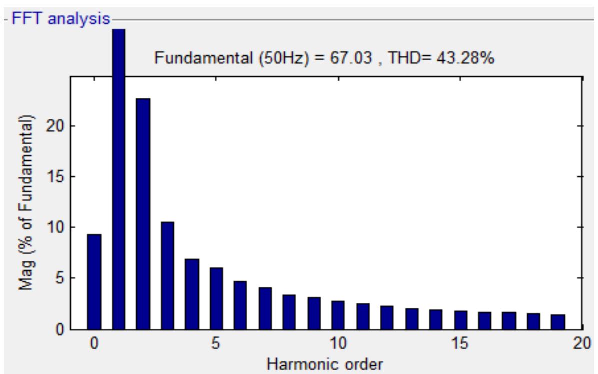

Fig: 21. THD Values for Output Voltage of DMC with RLC Load

If the wind speed is 10 m/sec, the generator output is connected to the matrix converter. The converter output parameters like voltage, current, harmonics are given better results than the conventional converter, which shows the improvement in the power quality. The THD value of the voltage and current is 43.28% and 31.26% which is lesser than the existing system.

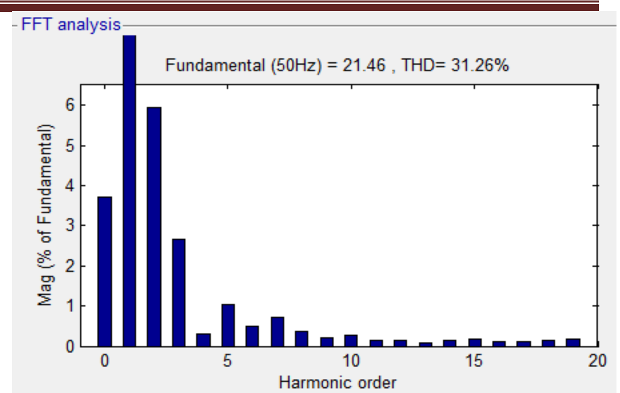

Fig: 22. THD Values for Output Current of DMC with RLC Load

Table: 1. THD for Direct Matrix Converter

The for Direct Matrix Converter						
	With Filter			Without Filter		
	R load	RL load	RLC load	R load	RL load	RLC load
V_o	43.26	43.25	43.28	131.20	1355.63	1192.4
I_o	31.36	31.40	31.26	131.20	72.98	73.74

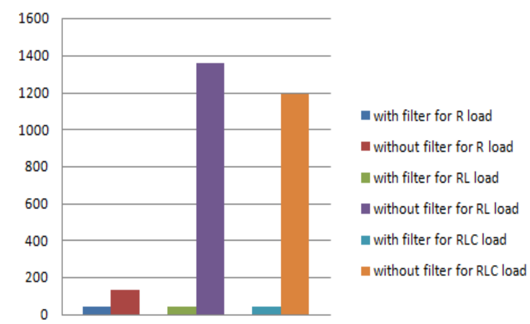

Fig: 23. Output Voltage of DMC for Various Loads

The PMSG rectified output is given to the inverter which is connected to the RLC load. The Fig 4.21 shows the graphical representation of direct matrix converter output voltage with and without filter for various loads like R, RL and RLC.

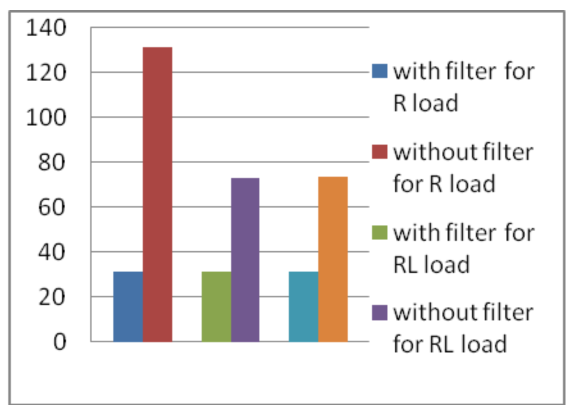

Fig: 24. Output Current of DMC for Various Load

The bar chart shown in figure 4.21 and 4.22 clearly explains the output voltage and current of proposed PMSG connected Matrix converter is improved and the harmonics in the circuit is considerably reduced. This proved that quality of the power in the integrated renewable energy system is improved. The output current of direct matrix converter with filter and without filter for various loads like R, RL and RLC are tested. The inductor and capacitors is connected to output arm of each matrix converter, and then it connects to the load. The shunt capacitor is connected in parallel for each phase to reduce the harmonics in output of matrix converter.

4. Conclusion

The wind turbine driven synchronous generator is modeled using Matlab/ Simulink tool and is also analyzed. A controlled rectifier rectifies the output voltage of permanent magnet synchronous generator and rectified output is given to the inverter. As there is no DC link element between the converter and the inverter, the converter produces the constant DC voltage irrespective of wind velocities. Direct matrix converter increases the output voltage level and it solves the commutation problem. Total harmonic distortion of the power converter is minimized by using filters and compared with conventional system. Direct matrix converter is connected to various load and its THD values are analyzed successfully.

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