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

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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.

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 inverter 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.

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.

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.

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.
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.

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

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: 14. Output Voltage of DMC for RL Load

Fig: 15. Output Current of DMC for 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: 16. THD Values for Output Voltage of DMC with RLC Load

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

Fig: 18. Direct Matrix Converter Model for RLC Load

Fig 4.16 shows the direct matrix converter model for RLC load.
The output voltage and current with RLC load is shown in fig 4.17 and 4.18. The THD analysis for RLC load is given in fig 4.19 & 4.20.

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.

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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.

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The THD values for Output current of DMC with RLC load are given in Table 1.

Table 1. THD for Direct Matrix Converter

<table>
<thead>
<tr>
<th>Load Type</th>
<th>With Filter</th>
<th>Without Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>R load</td>
<td>43.26</td>
<td>131.20</td>
</tr>
<tr>
<td>RL load</td>
<td>43.25</td>
<td>1355.63</td>
</tr>
<tr>
<td>RLC load</td>
<td>43.28</td>
<td>1192.40</td>
</tr>
<tr>
<td>R load</td>
<td>31.36</td>
<td>72.98</td>
</tr>
<tr>
<td>RL load</td>
<td>31.40</td>
<td>73.74</td>
</tr>
<tr>
<td>RLC load</td>
<td>31.26</td>
<td></td>
</tr>
</tbody>
</table>

The bar chart shown in figure 4.21 and 4.22 clearly explains the output voltage and current of proposed PMSG.
4. Conclusion

References


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.