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Abstract: This research paper presents the performance evaluation of the Direct Power Control (DPC) and Direct Torque Control (DTC) and Doubly – Fed Induction Generator (DFIG) connected to the Grid Systems. Based on the designing procedure and mathematical description of DTC and DPC, the performances of DFIG in grid are analyzed using PSCAD software. In the simulation results, % pulsation of $T_e$, $P_{DFIG}$, $Q_{DFIG}$ and % THD values of $i_s$ and $i_r$ with DFIG controllers are analyzed at network disturbance. And also harmonic analysis of $i_s$ and $V_{GRID}$ are analyzed in the interconnected grid system. With the stepped up speed, $V_s$ is magnified from its rated value. But, controlling of RSC is achieved by rotor current in $dq+$ and $dq-$ frames through $e^{j\omega_l}$ & $e^{j\omega_r}$. So, the pulsation of torque $T_e$ is 2.5% less than resonant controller. In the DTC control technique, during the stepped up of the wind speed, the pulsation rating of DFIG parameters are controlled by controlling of $T_e$. But in DPC, the stator current and voltage, grid voltage and current controls the converters of DFIG.

Keywords: Doubly – Fed Induction Generator, Power Control, Direct Torque Control.

1 Introduction

During the transient period, flux power angle magnitude is increased with respect to sudden rise in stator current. So the differential value of real and reactive powers of DFIG is changed and also controls the Rotor Side Control (RSC) of DFIG. Simultaneously, the magnitude of $dq$ frame of grid current is increased. This incremental current changes the real and reactive powers of grid and it controls the GSC. The exponential value of slip angular frequency value of the Direct Torque Control depends upon $dq+$ frame rotor voltage and current. During the transient period, the short circuit current of stator is increased. Simultaneously, 3 phase rotor current is also increased. This increases the magnitude of $dq+$ frame of rotor current and this current control the error signals which are given to the PI controller of RSC.
The Direct Power Control (DPC) technique, the control techniques are implemented in both rotor and grid side converters. Leakage factor, stator angular frequency, magnitude of reference value of rotor flux and flux power angle control the change in real and reactive powers of DFIG [1 -3]. Rotor Side Control (RSC) and GSC are controlled by actual value of voltage and current of DFIG and grid respectively by DPC technique. Separate control scheme is implemented to control the GSC in DPC, that is, differential value of grid voltage $dV_{GRID}$ and current $di_{GRID}$ effectively control the Grid Side Control (GSC).

2. Characteristics of DFIG with wind speed variations

The behavior of DFIG is analyzed at transient and post-transient conditions and the test system is shown in the Figure 1. The time at end of the 2 Second the three phase short circuit fault is applied across the terminal and the length of the fault is extended up to 0.15 second. During the transient period the speed of the wind turbine connected to the DFIG is oscillated and it is shown in the Figure 1 below.

![Figure 1. DFIG with 3 Phase Short Circuit Fault](image-url)
The performance of DFIG is analyzed with the 40% of rise of speed from its rated value and the test system at the time of 2 s, the speed is stepped up from 1 to 1.4 p.u, as shown in the Figure 2.

Figure 2. Characteristics of DFIG with DTC and DPC at variable wind speed.

In the DTC control technique, during the stepped up of the wind speed, the pulsation rating of DFIG parameters are controlled by controlling of $T_e$. But in DPC, the stator current and voltage, grid voltage and current controls the converters of DFIG. Hence, the magnitude of pulsation values are 0.89%, 1.79%, 5%, 13.04% of $V_s$, $T_e$, $P_{DFIG}$, $Q_{DFIG}$ less than DTC technique respectively.
3. Pulsation of DFIG parameters with the DTC & DPC techniques

The simulation studies of DFIG parameters are carried out at unbalanced load which is connected across the DFIG and the system is similar to as shown in Figure 1 below in the Table 1.

Table 1. Pulsation of DFIG parameters with DTC and DPC techniques

<table>
<thead>
<tr>
<th>DFIG Controllers</th>
<th>$T_e$ Pulsation (%)</th>
<th>$P_{DFIG}$ Pulsation (%)</th>
<th>$Q_{DFIG}$ Pulsation (%)</th>
<th>THD Value of $i_s$ (%)</th>
<th>THD Value of $i_r$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTC</td>
<td>± 6.56</td>
<td>± 4.18</td>
<td>± 7.24</td>
<td>2.85</td>
<td>6.84</td>
</tr>
<tr>
<td>DPC</td>
<td>± 4.82</td>
<td>± 3.26</td>
<td>± 6.56</td>
<td>2.04</td>
<td>5.27</td>
</tr>
</tbody>
</table>

4. Analysis of the result of the DFIG parameters with the DTC & DPC

**DTC:** With the unbalanced condition, pulsation of real and reactive powers and THD value of $i_s$ and $i_r$ are controlled by electromagnetic torque. The oscillation of $T_e$ can be controlled by $dq+$ and $dq-$ frames of rotor current in RSC and this controlling procedure is already discussed in case 1 and 2. But in the resonant controller technique, the rise time and steady state error are reduced by $K_p$ and $K_i$ and overshoot problem is minimized by $C_d$ and $C_q$. Also, the fundamental components of PI and harmonic component of resonant controllers control the RSC. Hence, the pulsation of DFIG parameters and total harmonic distortion of stator and rotor currents are less than resonant controller. With the stepped up speed, $V_s$ is magnified from its rated value. But, controlling of RSC is achieved by rotor current in $dq+$ and $dq-$ frames through $e^{j\theta_l}$ & $e^{j\theta_s}$. So, the pulsation of torque $T_e$ is 2.54% less than resonant controller based on sine and cosine components of $T_e$. With the controlling of electromagnetic torque of DFIG, oscillation of $V_s$, $P_{DFIG}$, $Q_{DFIG}$ are 0.93%, 7.14% and 8% less than resonant controller respectively. At the post-transient period, flux power angle of RSC and grid current in $dq$ frame are within the normal range and the system is maintained at stable region shown in Figure 2 (a-e). In this control technique, grid voltage and current control the GSC. But the hysteresis band only controls the GSC in torque controller. The pulsation magnitudes of $V_s$, $T_e$, $P_{DFIG}$, $Q_{DFIG}$ are 3.15%, 3.92%, 14.29% and 16.67% less than DTC controller respectively.

**DPC:** RSC and GSC are controlled by actual value of voltage and current of DFIG and grid respectively by DPC technique. Separate control scheme is implemented to control the GSC in DPC, that is, differential value of grid voltage $dV_{GRID}$ and current $di_{GRID}$ effectively control the GSC [4 - 5]. By $s$ and $r$, the differential value of real and reactive powers such as $dP_{DFIG}$ and
$dQ_{DFIG}$ are controlling the RSC [6]. But, and are not considered in DTC. Hence pulsation of $T_e$, $P_{DFIG}$, $Q_{DFIG}$, THD of $i_s$, $V_{GRID}$ are less than DTC technique shown in Table 1 above.

5. Conclusion

This paper has presented the torque equation of DTC based on sine and cosine components and mathematical expression of stator power equation of DPC. Also discussed about the designing of DTC and DPC control techniques of DFIG and analyzed its performance in the grid system. From the simulation results, the following points are observed. In the DTC technique, electromagnetic torque $T_e$ only controls the pulsation of DFIG parameters and hysteresis band technique is adopted in GSC. The separate control schemes are implemented in converters of DFIG in DPC control technique. Actual value of real and reactive powers of DFIG and grid controls the RSC and GSC respectively. So the pulsation magnitude of $V_s$, $T_e$, $P_{DFIG}$ and $Q_{DFIG}$ are minimized than DTC. Based on the above discussions, performance of DFIG is improved with the DPC technique than DTC in the grid.

References