Comparative Study between Two Types of Wind Chains

Aïcha Wahabi, Abdelhadi El Moudden, Fatima Ezzahra Bounifli, Kaoutar Senhaji Rhazi

National School of Electricity and Mechanic, Post box. 8118, University Hassan II Ain Chock - Casablanca - Morocco

ABSTRACT: We will begin this discussion with a description of a wind conversion chain of average power to make an optimal choice of a system with a reduced cost. A device MPPT ‘Maximum Power Point Tracking’ is to be introduced in order to achieve maximum energy efficiency. In order to minimize the cost of the conversion chain and increase efficiency, we will compare the performance of two asynchronous generators for the same input parameters. This will allow us to evaluate the two structures.


I. INTRODUCTION

In recent years, wind systems have received increased attention and have been widely used as a suitable power source. Asynchronous generators are increasingly used in wind power generation systems, their advantages are its simple construction (brushless), robustness and low maintenance cost [1]. Wind systems can be used in standalone mode or connected to the network. Today, we can identify two types of wind turbines connected to electric network: fixed speed wind turbines, it consists of an asynchronous machine with squirrel cage. The second type is a variable speed wind turbine with asynchronous generator dual supply (DFIG) or a synchronous machine with permanent magnet (SMPM). The latter (SMPM or DFIG), which have large adjustment capabilities, are mainly used to increase the power extracted from the wind. Current wind turbines are very sophisticated machines, taking advantage of the aerodynamic improvements to the structure, materials technology and electrical control, they are able to produce several megawatts of electrical power. We note that with the development of power electronics, asynchronous machines are doubly fed increasingly used for electricity generation high power.

II. DESCRIPTION OF A SYSTEM OF WIND ENERGY CONVERSION.

The chain includes, the wind turbine, speed multiplier, converters and the asynchronous machine whose stator circuit is connected directly, or via a transformer, to the mains. If the asynchronous generator is a (DFIG), a second circuit disposed on the rotor is also connected to the network but by way of power converters.

The Wind chain does not only depend on the asynchronous machine, but also the way in which the two parts of "back-to-back" converter is controlled. The power converter machine side is called "Rotor Side Converter" (RSC) and the network side power converter is called "Grid Side Converter" (GSC). The machine side power converter controls the active power and reactive power produced by the machine. As for the network-side converter, it controls the DC bus voltage and line-side power factor [1],[2].
III. MODELLING OF THE ASYNCHRONOUS GENERATOR:

A. The modeling of asynchronous squirrel cage machine:
For the 3-phase stator, this writing is summarized by the following condensed matrix [5], [6], [7], [8]:

\[ V_{sabc} = [R_s] * [i_{sabc}] + \frac{d}{dt} [\phi_{sabc}] \] (1)

With: \( V_{sabc} \): three-phase stator voltage of the asynchronous machine.
\( [R_s] \): Resistance of stator phase.
\( [i_{sabc}] \): Three-phase stator current of the asynchronous machine.
\( [\phi_{sabc}] \): Feed-phase stator of the synchronous machine.

And:

\[ V_{rabc} = [R_r] * [i_{rabc}] + \frac{d}{dt} [\phi_{rabc}] \] (2)

With: \( V_{rabc} \): three-phase rotor voltage of the asynchronous machine.
\( [R_r] \): Resistance of rotor phase.
\( [i_{rabc}] \): Three-phase rotor current of the asynchronous machine.
\( [\phi_{rabc}] \): Feed-phase rotor of the synchronous machine.

B. The doubly fed induction generator (DFIG)
For the 3 phases of stator, we have the same condensed matrix (1):

\[ V_{sabc} = [R_s] * [i_{sabc}] + \frac{d}{dt} [\phi_{sabc}] \]

And For the 3 phases of rotor, we have:

\[ V_{rabc} = [R_r] * [i_{rabc}] + \frac{d}{dt} [\phi_{rabc}] \] (≠0) (3)

After the Three phase two-phase transformation (Park), we get the following components along the axis d and q axis, for the stator voltages:

\[ v_{ds} = R_s i_{ds} + \frac{d}{dt} \phi_{ds} - \omega \phi_{qs} \] (4)
\[ v_{qs} = R_s i_{qs} + \frac{d}{dt} \phi_{qs} + \omega \phi_{ds} \] (5)

And for the rotor voltages:

\[ v_{dr} = R_r i_{dr} + \frac{d}{dt} \phi_{dr} - \omega \phi_{qr} \] (6)
\[ v_{qs} = R_r i_{qr} + \frac{d}{dt} \phi_{qr} + \omega \phi_{dr} \] (7)

To adequately control the production of electricity, we will achieve independent control of active and reactive powers \( P_s \) and \( Q_s \) stator [2], [3], [4], [5], [6]. The reference (dq) is oriented so that
\( \phi_{ds} = \phi_s \) and \( \phi_{qs} = 0 \) (8)

Assuming that the stator flux \( \phi_s \) is constant (constant electric network) and ignoring the stator resistance we obtained for \( P_s \) (stator active power), \( Q_s \) (stator reactive power) and \( C_{em} \) (electromagnetic torque):

\[
P_s = -\frac{V_s}{L_s} \phi_{qs} \quad (9)
\]
\[
Q_s = -\frac{V_s}{L_s} \bar{I}_{dr} + \frac{V_s}{L_{ds}} \quad (10)
\]
\[
C_{em} = -p \frac{M}{L_s} \phi_{ds} I_{qr}, \quad (p: \text{Number of pairs of poles}) \quad (11)
\]

\[
\begin{align*}
\phi_{ds} &= L_s I_{ds} + M I_{dr} \\
\phi_{qs} &= L_s I_{qs} + M I_{qr} \\
\phi_{dr} &= L_r I_{dr} + M I_{ds} \\
\phi_{dr} &= L_r I_{qr} + M I_{qs}
\end{align*}
\]

Also: \( L_s = L_s - M_s \); \( L_r = L_r + M_r \)

Ls and Lr are cyclical inductance of a stator phase and rotor phase.

IV. SIMULATION OF A WIND CHAIN DRIVEN BY A SQUIRREL CAGE GENERATOR

A. Block diagram of the simulation

Fig. 2. Block diagram of the wind turbine and Fig. 3. Block diagram of the wind chain the squirrel cage generator driven by a squirrel cage generator

B. Simulation parameters

<table>
<thead>
<tr>
<th>Asynchronous generator</th>
<th>( S_n=1.5e4 ) VA ( U_n=575V ) f=50Hz</th>
<th>Number of pairs of poles</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor Inductance</td>
<td>0.179 H</td>
<td>Stator Resistance</td>
<td>0.0048 ( \Omega )</td>
</tr>
<tr>
<td>Rotor Résistance</td>
<td>0.0044( \Omega )</td>
<td>Stator Inductance</td>
<td>0.1248 ( \Omega )</td>
</tr>
<tr>
<td>Mutual inductance</td>
<td>6.77 H</td>
<td>Stator Inductance</td>
<td>0.1248 ( \Omega )</td>
</tr>
<tr>
<td>Balanced three-phase Load</td>
<td>575V - 4kW - 4kVAR</td>
<td>Transformer</td>
<td>[25e3V, 575V]</td>
</tr>
<tr>
<td>Wind speed</td>
<td>12m/s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Characteristics of the 1st wind chain.
C. Results of the simulation

Fig. 4. Active power, final value Pf ≈ 1100W

Fig. 5. Reactive power, final value Qf ≈ -600VAR

Fig. 6. Rotation speed (trum/mn) Nf ≈ 3017 trum/mn

Fig. 7. Effective value of the stator voltage (V) Ufs = 804V

V. SIMULATION OF A WIND CHAIN DRIVEN BY A DOUBLY-FED INDUCTION GENERATOR

A. Block diagram of the simulation

Fig. 8. Block diagram of a Wind Turbine driven by a Doubly-Fed Induction Generator
B. Simulation parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator</td>
<td>1.5e^4 VA</td>
</tr>
<tr>
<td>Sn(VA), Vn(Vrms), fn(Hz)]</td>
<td>575 V, 50Hz</td>
</tr>
<tr>
<td>Wind speed</td>
<td>12 m/s</td>
</tr>
<tr>
<td>Rotor Résistance</td>
<td>0.0044 Ω</td>
</tr>
<tr>
<td>Number of pairs of poles</td>
<td>3</td>
</tr>
<tr>
<td>Rotor Inductance</td>
<td>0.179 H</td>
</tr>
<tr>
<td>Stator Résistance</td>
<td>0.0048 Ω</td>
</tr>
<tr>
<td>Mutual inductance</td>
<td>6.77 H</td>
</tr>
<tr>
<td>Stator Inductance</td>
<td>0.1248 H</td>
</tr>
<tr>
<td>Balanced three-phase Load</td>
<td>575V, 4kW, -4kVAR</td>
</tr>
<tr>
<td>Transformer</td>
<td>[25e3V, 575V]</td>
</tr>
</tbody>
</table>

Table 2 Characteristics of the wind chain

C. Results of the simulation

- Fig. 9. Active power (W), Pf ≈ 1400W
- Fig. 10. Reactive power (VAR), Qf ≈ 0 VAR
- Fig. 11. Rotation speed, Nf ≈ 2800 tr/min
- Fig. 12. Effective value of the stator voltage, Ufs=813V
VI. COMMENTS AND DISCUSSIONS

In this paragraph, we will try to compare simulation results of two conversion channels wind power driven by a synchronous generator whose components are identical (see Table 1 and Table 2), but the generators drive them are different, the former is a squirrel cage generator and the second is an asynchronous generator with dual power. These two electric generators practically have the same parameters: same power, same rated voltage and the same frequency and almost identical internal parameters. All this in order to make a good comparison of the performance of each wind turbine chain.

We see all sides that the two channels are working properly: they provide both to the load (here a load R-C), a relatively large electric power. We note that the two chains pass through a transitional period lasting almost 3 seconds (150 times the signal period).

The steady has allowed us to make a good comparison of two wind turbines channels, for this, we grouped in Table 3, the measured values steady following main variables: P (active power), Q (reactive power), N: rotational speed and Us (the effective value of the stator voltage).

<table>
<thead>
<tr>
<th>Chain</th>
<th>P: Active power</th>
<th>Q: Reactive power</th>
<th>N: Rotation speed</th>
<th>Us: Effective value of stator voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Chain (With an squirrel cage machine)</td>
<td>Pf = 1100 W</td>
<td>Qf = - 600 VAR</td>
<td>Nf = 3017 trum/mn</td>
<td>Usf=804V</td>
</tr>
<tr>
<td>2nd Chain (With a doubly-fed asynchronous generator)</td>
<td>Pf = 1400 W</td>
<td>Qf = 0 VAR</td>
<td>Nf = 2800 trum/mn</td>
<td>Usf = 813V</td>
</tr>
</tbody>
</table>

Table 3. Final values of the variables measured for both wind chains

We can say that for:
- Active power: The active power supplied to the load (R-C) is more important for the second chain.
- Reactive power: The Difference between two of the output chain is obvious. The 2nd Chain with a doubly-fed asynchronous generator have a reactive power at the output which is almost zero.
- Rotational speed: this variable Is Almost Identical, but we note that in the 2nd chain it is not very stable.
- The stator voltage: Same It is Almost a footnote what is more Slightly High for the second chain.

VII. CONCLUSION

We can conclude from this study, that for both chains all variables are stable during continuous operation, which shows that the system works properly.

We note, for this power range, that the second channel works best, in fact, the active power delivered to the load is more important, that because the rotor to bi-fuel machines restores active power load: Pr (power supplied by the rotor) = g * Ps(Ps active power in the stator, g is the slip).

Regarding reactive power which is zero for the second string, we can say that the load capacitors offset the reactive energy involved in the wind power system something that does not happen with the first string. We can conclude from this study, that for both chains, all variables are stable during continuous operation, which shows that the system works properly.

We note, for this power range, that the second chain works best, in fact, the active power delivered to the load is more important, that because the rotor of doubly-fed asynchronous generator restores active power load: Pr (power supplied by the rotor) = g * Ps(Ps active power in the stator, g is the slip).

Regarding reactive power which is zero for the second string, we can say that the capacitors of load offset the reactive energy involved in the wind system, this does not happen with the chain driven by a squirrel cage machine.
REFERENCES


AUTHORS' BIOGRAPHY

Pr. WAHABI Aicha
I am an assistant professor at the School of Technology (EST) in Casablanca, Morocco in 1991. Between 2012 and 2015, I was part of the Computer Systems Laboratory and renewable energy (Liser) - analysis and control power systems Team (CACEE). I wish to inform you that I am preparing my doctoral thesis in the field of renewable energy including wind power at the National School of Electricity and Mechanics (ENSEM). I obtained the graduate degree in 2000 at the National School of Electricity and Mechanics (ENSEM) Casablanca, Morocco. I am an electromechanical engineer from the National School of Mineral Industry (ENIM) in Rabat, Morocco (1990). I have published articles in Morocco, and in international scientific journals of wind energy in the years 2013, 2014 and 2015.

Pr. Dr. EL MOUDDEN Abdelhadi
Doctor of Science from The National Polytechnic Institute of Toulouse (INPT) in 1993 - FRANCE. He is now a professor in the National School of Electricity and Mechanics (ENSEM), University Hassan II Ain Chock, Casablanca, Morocco. Between 2006 and 2015, he has been a member of Laboratory Computing, Systems and Renewable Energies (LISER) - Team Analysis and Command of Electrical Energy Systems (ACSEE). His research interests include Dynamic Simulations of Electric Machinery, Simulation and Optimization of Renewable Energy Systems. He has presented and published many articles in scientific journals and conferences.

BOUNIFLI Fatima-Ezzahra

Pr.SENHAJI RHAZIKaoutar
I am a professor at the superior school of technology (EST) in Casablanca, Morocco.

Copyright to IJARSET www.ijarset.com 2846