Nonlinear Control of a Grid Connected Wind Turbine

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Abstract - A non-linear control design for a Doubly Fed Induction Generator (DFIG) that is connected to grid is proposed. The main purpose of this design is to improve power efficiency while ensuring smooth voltage performance. The control approach is realized in the rotor reference frame and is based on Asymptotic non-linear control technique. Two models have been studied the first one represents the doubly-fed induction generator while the second relates to the grid side converter command models. A nonlinear representation of the two cases are developed. Matlab program is applied to simulate and test the proposed control technique. The results are featured to show the effectiveness of the proposed control design.

Keywords - Renewable Energy, Feedback, Asymptotic Tracking.

I. INTRODUCTION

Due to the growing integration of wind energy into power grids, the impact of wind generators on power system able to meet the growing energy demand is of increasing concern. In the latest years, the Doubly Fed Induction Generator (DFIG) became the dominant type of Wind Turbine system used in wind farms. This type of generators has numerous advantages over its counterparts as it provide better results in terms of weight, cost, and size. It also presents greater benefits such as power quality and efficiency[1-4].

Even though the DFIG is considered as a stable symmetric induction machine but there might exist regions of instability due to the natural variation of the wind. The eigenvalue prediction for mapping the boundary of the stability region for DFIG machines was investigated by Banakar in [5]. The analysis shows that the stability region of DFIG machine can be defined by the variation of the d, the q rotor current angle in Id-Idr plane for sensor-less rotor position estimation that based on model reference adaptive system [6]. Though the aforementioned papers [5-8] explain the stability criterion for the DFIG machines, yet the control scheme for stable operation remains unaddressed by the authors. The nonlinear nature of the DFIG model motivated the researchers to develop a nonlinear control designed techniques that ensure a smooth and stable operation for the DFIG. There has been a lot of progress in the nonlinear control designing context in the past years. Most of these control techniques (for example back stepping, regulation, robust and tracking) have been used to control the DFIG [9-21].

Some of the latest researches will be recalled. A nonlinear control strategy to stabilize the DFIG based on back stepping algorithm was proposed in [9]. The proposed controller was successful in tracking the reference rotor speed, stabilizing the stator power. While this control approach provides sufficient results but it still suffers from a lot of constraints with respect to the designing procedure. In [10] a robust nonlinear feedback control approach of a residential Savonu is Vertical Axis Wind Turbine (VAWT) based on Double Fed Induction Generator (DFIG) and connected to a power grid was introduced. The aim of this work was to control the Rotor Side Converter (RSC) using a robust non-linear feedback control scheme, in which, a robust control law based on Lyapunov theory associated with a sliding mode controller is used to handle the issue of parameters uncertainty and to guarantee a global asymptotic stability of the system. The results of this approach were proved to be acceptable. The work was considered incomplete because of the obtained results didn’t show robust a good robustness against the parameters uncertainty. Another example of the nonlinear design technique was investigated in [14].

An input-state feedback linearization controller is proposed in this paper. We designed a system of eight ordinary differential equations and used it to model the wind energy conversion system. The generator has a wound rotor type with back-to-back three-phase power converter bridges between its rotor and the grid; it is modelled using the direct-quadrature rotating reference frame with aligned stator flux. The mathematical model developed in this paper is, in fact, an approximated model which made the result of this controller not an applicable in actual situations. Even though there have been several attempts to design the most powerful nonlinear control technique but it is still a wide open area of research. In this paper, a control technique for a grid-connected doubly fed induction generator (DFIG)-based on wind energy conversion system was presented.

Control strategy for the grid side and rotor side converters placed in the rotor circuit of the DFIG is introduced. The control approach is based on the asymptotic output tracking technique. Simply by applying a feedback with certainly assigned zeros, the system will reproduce an output rotor current that will converge to a specific reference signal.

The paper is structured as follow: section II recalls the definition of asymptotic output tracking control technique. Section III illustrates the modelling considerations of the Doubly Fed Induction Generator and grid side converter command models. The control approach is discussed in section IV. Finally, Section V presents the obtained results while Section VI concludes the paper and formulates further research directions.
Consider the class of SISO nonlinear systems
\[\dot{x} = f(x) + g(x)u, \quad x \in \mathbb{R}^n, u \in \mathbb{R}, y \in \mathbb{R} \]
\[y = h(x)\]  
(1)
where \(x, f(x), g(x)\) represents the state, function of the whole system states and the input function respectively. Assume \(x = 0\) is the equilibrium point (i.e., \(f(0) = 0\)). The system has a well defined relative degree \(r \leq n\) at the origin; namely,
\[L_y \frac{\partial}{\partial y} h(x) = \frac{\partial}{\partial y} h(x) = 0 \quad \text{i.e.} \quad L_y h(x) = \frac{\partial}{\partial y} f(x) \quad \text{for} \quad k < r - 1 \text{ and } L_y \frac{\partial}{\partial y} h(x) \neq 0 \quad \text{in a neighbourhood of } x = 0.

**Asymptotic output tracking**[21]
Since the system has a well defined relative degree one can locally define a mapping \(\Gamma(x)\) that introduce the system in the normal form.
\[
\left(\begin{array}{c}
\zeta \\
\eta
\end{array}\right) = \Gamma(x) - \left(\begin{array}{c}
h(x) \\
L_y^{-1} h(x)
\end{array}\right) \Gamma_2(x) \tag{2}
\]
where \(\Gamma_2(x)\) is such that \(L_y \Gamma_2(x) = 0\) locally puts the system into the normal form; i.e., it gets the form
\[
\begin{align*}
\dot{\zeta} &= \mathcal{A} \zeta + \mathcal{B} (\mathcal{B}(\zeta, \eta) + \alpha(\zeta, \eta) u) \\
\dot{\eta} &= \eta \\
y &= \zeta_1
\end{align*}
\]  
(3)
with
\[
\mathcal{A} = \begin{pmatrix} 0 & L_y^{-1} \\ 0 & 0 \end{pmatrix}, \quad \mathcal{B} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}.
\]
In order to guarantee the exact reproduction of specific reference output function \(y_R(t)\) the input is chosen in the form of
\[
u = -\omega_y \left( -h(\zeta, \eta) + \frac{\partial}{\partial \eta} + \sum_{i=1}^{r-1} c_i \epsilon_i - y R \right) \quad \text{for} \quad 1 \leq i \leq r
\]
and \(c_0, \ldots, c_{r-1}\) are real numbers.

**Remark 1** Imposing the input in the normal form implies
\[
\dot{x} = \dot{y} = 0, \quad c_0 \epsilon^0 \cdot c_{r-1} \epsilon^{r-1} \cdot \cdots \cdot c_0 \epsilon^0 = 0.
\]
The roots of the characteristic equation can be arbitrarily assigned.

## III. MODELLING

This section address the modelling of Doubly Fed Induction Generator (DFIG) and grid side converter command model respectively. These equations will later be used to form the non linear models.

### A. Doubly Fed Induction Generator model

In order to simplify the Doubly Fed Induction Generator (DFIG) model, the following assumption is assumed [21]

1. The flow distribution is sinusoidal.
2. The air-gap is constant.
3. The influences of the heating and the skin effect are not taken into account.
4. The saturation of the magnetic circuit is negligible.

The DFIG modelling with respect to a rotor flux oriented reference frame will be expressed as:

**I. Stator Equations**
\[
\begin{align*}
V_{sd} &= R_s i_{sd} + \frac{d}{dt} \phi_{sd} - \phi_{sq} W_r \\
V_{sq} &= R_s i_{sq} + \frac{d}{dt} \phi_{sq} + \phi_{sd} W_r \\
\phi_{sd} &= L_{si} i_{sd} + M_{is} \quad \text{(4)}
\end{align*}
\]
\[
\begin{align*}
\phi_{sq} &= L_{si} i_{sq} + M_{iq} \quad \text{(5)}
\end{align*}
\]

**II. Rotor Equations**
\[
\begin{align*}
V_{rd} &= R_r i_{rd} + \frac{d}{dt} \phi_{rd} - \phi_{rq} W_r \\
V_{rq} &= R_r i_{rq} + \frac{d}{dt} \phi_{rq} + \phi_{rd} W_r \\
\phi_{rd} &= L_{ri} i_{rd} + M_{ir} \quad \text{(6)}
\end{align*}
\]
\[
\begin{align*}
\phi_{rq} &= L_{ri} i_{rq} + M_{iq} \quad \text{(7)}
\end{align*}
\]
\[
\begin{align*}
\phi_{rd} &= L_{ri} i_{rd} + M_{ir} \quad \text{(8)}
\end{align*}
\]
\[
\begin{align*}
\phi_{rq} &= L_{ri} i_{rq} + M_{iq} \quad \text{(9)}
\quad \text{with}
\end{align*}
\]
\[
\begin{align*}
i_{sd} &= \frac{\phi_{sd} - M_{is} \omega_r}{L_s} \quad \text{(10)}
\end{align*}
\]
\[
\begin{align*}
i_{sq} &= \frac{-M_{is} \omega_r}{L_s} \quad \text{(11)}
\end{align*}
\]
\[
\begin{align*}
i_{rd} &= \frac{\phi_{rd} - M_{ir} \omega_r}{L_s} \quad \text{(12)}
\end{align*}
\]
\[
\begin{align*}
i_{rq} &= \frac{-M_{ir} \omega_r}{L_s} \quad \text{(13)}
\end{align*}
\]
\[
\begin{align*}
W_r &= g_i W_s \quad \text{(14)}
\end{align*}
\]
\[
\begin{align*}
W_r &= g_i W_s \quad \text{(15)}
\end{align*}
\]
\[
\begin{align*}
C_{em} &= p(\phi_{sq} i_{rd} - \phi_{rd} i_{sq}) \quad \text{(16)}
\end{align*}
\]

Where, \(R_s\) and \(R_r\) are, respectively, the stator and rotor phase resistances, \(L_s, L_r, M_{s}\) stator and rotor per phase winding and magnetizing inductances and \(W_s, W_r\) are the stator and rotor speed pair pole number. The direct and quadratic stator and rotor currents are respectively represented as \(i_{sd}, i_{sq}, i_{rd}, i_{rq}\). The voltage of the stator side for both direct and quadratic defined as \(V_{sd}, V_{sq}\) while the voltage of the rotor direct and quadratic represented as \(V_{rd}, V_{rq}\). The stator flux linkage for direct and quadratic frame are given by \(\phi_{sd}, \phi_{sq}\). The \(\phi_{rd}, \phi_{rq}\) referred to the rotor flux for both the direct and quadratic respectively. The Electromagnetic torque is presented by the following equation
\[
J \frac{dW_r}{dt} + f_r W_r - C_{em} - c_r \quad \text{(15)}
\]
\[
C_{em} = p(\phi_{sq} i_{rd} - \phi_{rd} i_{sq}) \quad \text{(16)}
\]
with \(J\) is the moment of inertia, \(c_{em}, c_r\) are the magnetic torque and reluctance torque while \(p\) is the numbers of pairs per pole. The system now will be modelled with respect to the rotor side direct and quadratic \((d, q)_s\) synchronous reference frame.
input in such case are $i_{rd}$ and $i_{rq}$.
First the system expression with respect to $d$ axis frame

$$v_{rd} = R_r i_{rd} + \frac{d}{dt}(L_r i_{rd} + M i_{rq}) - (L_r i_{rq} + M i_{rd}) W_r$$
$$= R_r i_{rd} + \frac{d}{dt}i_{rd}(L_r - \frac{M^2}{L_r}) - L_r i_{rq} W_r - M W_r (-\frac{M i_{rd}}{L_r})$$
$$= R_r i_{rd} + L_r \frac{d}{dt} i_{rd}(1 - \frac{M^2}{L_r L_r}) - L_r i_{rq} W_r - M W_r i_{rq}$$
$$= R_r i_{rd} + L_r \frac{d}{dt} i_{rd} + W_r i_{rq}$$
$$i_{rd}' = \frac{1}{L_r} v_{rd} - \frac{1}{L_r} \frac{d}{dt} i_{rd} + W_r i_{rq}$$
$$i_{rq}' = \frac{1}{L_r} v_{rq} - \frac{1}{L_r} \frac{d}{dt} i_{rd} - W_r i_{rq}$$

with $A = (1 - \frac{M^2}{L_r L_r}), \frac{T}{R_r}$. Now consider $q$ axis frame

$$V_{rq} = R_q i_{rq} + \frac{d}{dt} q_{eq} + \phi_{pq} W_r$$
$$= R_q i_{rq} + L_r \frac{d}{dt} i_{rq} - L_r A W_r i_{rd}$$
$$i_{rq}' = \frac{1}{L_r} v_{rq} - \frac{1}{L_r} \frac{d}{dt} i_{rd} - W_r i_{rq}$$

Finally we obtain the speed from the torque equation as:

$$\dot{W}_r = -\frac{f}{J} W_r + \frac{p}{J} q_{eq} - \frac{p}{J} \phi_{pq} i_{rd}$$

**B: Grid Side Converter command model**
In order to eliminate the harmonics from the converter operation an RL filter is installed[22-23].

$$v_{fd} = R_f i_{fd} + L_f \frac{d}{dt} i_{fd} - W_r L_f i_{fd} - V_{Gd}$$
$$v_{fq} = R_f i_{fd} + L_f \frac{d}{dt} i_{fd} + W_r L_f i_{fd} - V_{Gq}$$
$$i_{fd}' = \frac{1}{L_f} (-R_f i_{fd} + v_{fd} + W_r L_f i_{fd} + V_{Gd})$$
$$i_{fq}' = \frac{1}{L_f} (-R_f i_{fd} + v_{fq} - W_r L_f i_{fd} + V_{Gd})$$

with $V_{Gd}, V_{Gq}$ indicated the input voltage of AC-DC converter in the direct and quadrature frame. The electric network components of voltage and current on the AC side for both the direct and quadrature frame are given by $v_{fj}, i_{fj}, i_{fj}$ and $i_{fj}$ respectively, while the $L_f$ referred to the inductance of the system. The active and reactive power are expressed as:

$$P = V_{Gd} i_{fd} + V_{Gq} i_{fq}$$
$$Q = V_{Gq} i_{fq} - V_{Gd} i_{fd}$$

**Remark 2** Through setting the power factor to be 1 and neglecting the filter losses one can get the following expression $V_{Gd} = V_{fj}, V_{Gq} = V_{fj}, V_{fj} = 0$, leading the active and reactive power to be $P_f = V_{Gd} i_{fd}$ and $Q_f = -V_{Gd} i_{fq}$.

**IV: Control strategy**
In this section, the asymptotic output tracking technique will be applied in the Doubly-Fed Induction Generator and the grid side converter command model. The control will be realized in the rotor reference frame so the $d$ axis regulate the reactive power and the $q$ axis regulate the active power. In general, the system will produce an output that, regardless of the initial state of the system will converge asymptotically to the rotor reference current.

**A: Non linear model of DFIG**
Recalling from the modelling section, the system is introduced in the condensed nonlinear form

$$\dot{x} = f(x) + g_1(x) u_1 + g_2(x) u_2, \hspace{1cm} x \in \mathbb{R}^n, u \in \mathbb{R}^n$$
$$y = h(x)$$

(33)

where $X = [x_1 \ x_2 \ x_3]^T, [i_{rd} \ i_{rq} \ W_r]^T, U = [u_1 \ u_2]^T = [\dot{V}_{rd} \ \dot{V}_{rq}]^T$. The function $f(x), g(x)$ are smooth vector fields and the output function $h(x)$ is a smooth scalar function.

$$f(x) = \begin{pmatrix} -\frac{1}{2} x_1 + x_2 x_3 \\ -\frac{1}{2} x_2 - x_2 x_3 \\ -\frac{1}{2} x_3 - \frac{1}{2} \phi_{pq} x_1 - \frac{1}{2} \phi_{pq} x_2 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$
$$g_1(x) = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}, \hspace{1cm} g_2(x) = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}$$

(34)

(35)

Note that $\Lambda = (1 - \frac{M^2}{L_r L_r}), \frac{T}{R_r}$. Since the purpose of this study is to control the rotor side converter current, the output was chosen as $h(x) = [i_{rd} \ i_{rq}]^T$.

**Remark 3** According to the previous results obtained by isidori, a multi variable nonlinear system in the form of (33) has a relative degree $r_1, \ldots, r_m$ at point $x^0$ if $L_{gj} L_{ij} h_i(x) = 0$ for all $1 \leq j \leq m$, for all $1 \leq i \leq m$, for all $k \leq r_1 - 1$, and for all neighbour of $x^0$.

Following the same definition it can be easily verified that the system relative degree with respect to the outputs $r = 2$.

**1. Control of d-axis motor current**
In order to track rotor current $i_{rd}$ we assume that the system is only affected by $u_1$ and $u_2 = 0$

$$\dot{x} = f(x) + g_1(x)$$
$$y = h_1(x) = i_{rd}$$

(36)

(37)

The system relative degree w.r.t to the output $r = 1$. Now we apply a coordinate transformation and introduce the system in to the normal form.

$$\Gamma(x) = \begin{pmatrix} x_1 & x_1 \\ \eta_1 & x_2 \\ x_2 & \eta_2 \end{pmatrix}$$

(38)
\[
\begin{align*}
\dot{z}_1 &= \frac{-1}{\gamma A} z_1 + \eta_1 n_2 + \frac{1}{\gamma A} u_1 \\
\dot{\eta}_1 &= -\frac{1}{\gamma A} \eta_1 - z_1 n_2 \\
\dot{n}_2 &= p \phi_{td} z_1 - p \phi_{td} n_1 - \frac{L_f}{\gamma} el_\alpha_2 
\end{align*}
\]  
(39)

After applying the proper control law in the form of \( u = T_A (-\frac{1}{\gamma A} x_1 + x_2 x_3 + x_3^2 - c_0 x_1) \) where \( x_3^2 - c_0 x_1 \) represents the rotor current desired value and the chosen zero, we obtain the desired output.

**II. Control of q-axis rotor current**

In this case, the effect of \( n_2 \) is studied

\[
f(x) = \left( \begin{array}{c} -\frac{1}{\gamma A} x_1 + x_2 x_3 \\
-\frac{1}{\gamma A} x_2 - x_2 x_3 \\
-\frac{L_f}{\gamma} x_3 + \frac{p}{L_2} \phi_{rq} x_1 - \frac{p}{L_2} \phi_{rd} x_2 \end{array} \right),
\]

\[
g(x) = \left( \begin{array}{c} 0 \\
0 \\
\frac{1}{\gamma A} x_2 + \frac{1}{\gamma A} n_2 \end{array} \right)
\]

(40)

\[
y = h_2(x) = t_n q.
\]

(41)

The system relative degree \( r_q = 1 \). The coordinate transformation and the normal take the form of

\[
\Gamma(x) = \left( \begin{array}{c} x_1 = x_2 \\
\eta_1 = x_3 \\
n_2 = x_1 \end{array} \right)
\]

(42)

\[
\begin{align*}
\dot{z}_1 &= -\frac{1}{\gamma A} z_1 - \eta_1 n_2 + \frac{1}{\gamma A} u_2 \\
\dot{\eta}_1 &= p \phi_{rd} n_2 - p \phi_{rd} z_1 - \frac{L_f}{\gamma} \eta_1 \\
n_2 &= -\frac{1}{\gamma A} n_2 + x_1 n_2.
\end{align*}
\]

(43)

The input \( u = T_A (-\frac{1}{\gamma A} x_2 - x_1 x_3 + x_3^2 - c_0 x_2) \).

**B. Non linear grid side converter model**

Referring to remark 2 we know that through setting the power factor to unity we get \( V_{Gd} = V_{Gq} = V_f \). In such a case, the system is converted into a single input-single output system in the form:

\[
f(x) = \left( \begin{array}{c} -\frac{R_f}{L_2} x_1 + x_3 x_2 \\
-\frac{R_f}{L_2} x_2 - x_3 x_1 \\
-\frac{L_f}{L_2} x_3 - \frac{p}{L_2} \phi_{rd} x_2 \end{array} \right),
\]

\[
g(x) = \left( \begin{array}{c} \frac{2}{L_2} \eta_1 \\
0 \\
0 \end{array} \right)
\]

(44)

\[
y = x_1
\]

(45)

where, \( x \)-state vector = \([i_{fd} \quad i_{fq} \quad W_T]^T, U = [u_1 \quad u_2]^T \).

\( \) -axis control

In this part, the focus will be in tracking the \( d \)-axis reference filtered current. Since the system obtained a well-defined relative degree \( r = 1 \), then we apply a coordinate transformation in the form \( \Gamma(x) = \left( \begin{array}{c} x_1 \\
x_3 \\
x_2 \end{array} \right) \).

The state space description in the new coordinates

\[
\begin{align*}
\dot{z}_1 &= \alpha(z, \eta) + b(z, \eta) \\
\dot{\eta}_1 &= \frac{L_f}{L_2} \eta_1 - \frac{p}{L_2} \phi_{rd} n_2 \\
n_2 &= -\frac{R_f}{L_2} \eta_1 - \frac{L_f}{L_2} x_1.
\end{align*}
\]

(46)

Through setting the input \( u \) to be \( u = \frac{L_f}{L_2} (-\frac{R_f}{L_2} x_1 + x_3 x_2 + x_3^2 - c_0 x_1) \), one can regulate the rotor current in order to meet a specific active and reactive power.

**V. Simulation and Results**

This section is dedicated for the evaluation of the performance of the proposed technique. Two cases were developed. The first case investigated the performance of controller when it's directly connected to the DFIG, while in the second case the focus was in investigating the behavior of the DFIG when it's connected to the network and under the operating condition of setting power factor to one. The DFIG and grid side models referred to in the third section are used to test the proposed design. Table 1 presents the values of the DFIG parameters used to build the models. The block diagram of figure 1 illustrated the design process of the DFIG model while the block diagram shown in figures 2 illustrated the second case scenario. In order to evaluate the ability of the proposed designed technique for tracking the \( d \)-axis rotor currents reference signal generated at maximum efficiency an input in the form \( u = T_A (-\frac{1}{\gamma A} x_1 + x_2 x_3 + x_3^2 - 1000 x_1) \), \( u = T_A (-\frac{1}{\gamma A} x_2 - x_1 x_3 + x_3^2 - 1200 x_2) \) were applied respectively. Figure 3, illustrac the rotor side reference signal and the generated current signals versus time in seconds in the direct and quadratic frames respectively. It can be noticed from Figure 3, that the proposed control technique succeeded in reproducing a current signal that coincides with the required reference signal in both cases. Figure 5 presents the continuous bus voltage of the DFIG regulated to the standard reference voltage fixed at 1000 V. It is clear that in spite of fluctuation of the wind the voltage remain stationary. In fact the proposed design succeeded in reducing the voltage disturbance in comparison to sliding mode design introduced in [23]. In the second case the the stator of the DFIG was directly connected to the grid while its rotor was connected to it via a cascade (Rectifier, Inverter and Filter). In order to evaluate the grid side model the power factor was set to one (shown in figure 5), thus only the direct rotor current will be produced. The voltage on the output of the inverter will suffer from disturbance signals formed by the original of frequency \( f = 50 \text{Hz} \) and other signals. A passive R-L filter was used to eliminate harmonics. The input in the form \( u = \frac{L_f}{L_2} (-\frac{R_f}{L_2} x_1 + x_3 x_2 + x_3^2 - 900 x_1) \) ensures the reproduction of an output \( i_{rd} \) that will track the required reference signal (shown in Figure 7). Finally, the analysis of this technique has shown that the system hasn’t just succeeded in reproducing an output that will converge asymptotically to the required reference signals but it also minimizes the effect of disturbance.
TABLE I. THE DFIG DATA SHEET

<table>
<thead>
<tr>
<th>Frame / power</th>
<th>7 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency at rated speed</td>
<td>approx. 97...97.5</td>
</tr>
<tr>
<td>Voltage</td>
<td>690V</td>
</tr>
<tr>
<td>Locked rotor voltage</td>
<td>Approx. 1000V</td>
</tr>
<tr>
<td>Operation speed range</td>
<td>1000...2000 rpm</td>
</tr>
<tr>
<td>Power factor</td>
<td>p.f. 0.90 cap ...1.0</td>
</tr>
<tr>
<td>Rotor Resistance</td>
<td>1 KΩ</td>
</tr>
<tr>
<td>Rotor Resistance</td>
<td>0.2 mH</td>
</tr>
<tr>
<td>Stator Resistance</td>
<td>0.5 KΩ</td>
</tr>
<tr>
<td>Stator Resistance</td>
<td>0.001 mH</td>
</tr>
<tr>
<td>Mutual inductance</td>
<td>Msr = 0.078 H</td>
</tr>
<tr>
<td>Number of Poles</td>
<td>4</td>
</tr>
<tr>
<td>Inertia moment</td>
<td>$J = 0.3125 \text{ Nms}^2$</td>
</tr>
</tbody>
</table>

Fig. 1. Simplified Block diagram of the Asymptotic output tracking technique for the DFIG model

Fig. 2. Block diagram of the Asymptotic output tracking for the Grid side model

Fig. 3: Doubly Fed Induction Generator ird rotor current, rotor side reference signal in direct frames.

Fig. 4: Doubly Fed Induction Generator ird rotor current, generated current signals in quadratic frames.
VI. CONCLUSION

The aim of this work is to introduce a non-linear control technique that asymptotically tracks the rotor current of the grid-connected wind turbine based on Double Fed Induction Generator (DFIG). In general, the idea is to produce a certain rotor current in order to meet a specific requirement of active and reactive power production. The modelling of DFIG and the grid side converter command models have been studied. The control of the grid side converter command model was studied under the assumption of the system obtaining a unity power factor. Maximum power point strategy makes it possible to provide totally of the active power produced by the grid with a unity power factor. Two cases have been developed based on the DFIG model and the grid side converter command model. The performance of the DFIG when it’s connected to the proposed design controller was investigated in the first case. In the second case the stator of the DFIG was directly connected to the grid while its rotor was connected to it via a cascade (Rectifier, Inverter and Filter) finally the filter was connected to the suggested controller. The results in both cases showed that the control approach succeeded in reproducing an output signal that coincides with the required reference signal. It was also shown in that the system has a very powerful performance under disturbance such as the wind variation. Finally, further investigation will be carried out regarding practical cases.

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REFERENCES

MARWA HASSAN: NONLINEAR CONTROL OF A GRID CONNECTED WIND TURBINE