

Adaptive doubly fed induction generator's control driven wind turbine using luenberger observer optimized by genetic algorithm

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ABSTRACT

The calculation of control parameters for a system control method is based on the model of the system with assumed fixed internal parameters. However, these parameters can vary greatly due to several phenomena. This paper presents an adapted control of a doubly fed induction generator machine robust against the rotor resistance variations of the machine used as a generator in wind energy conversion systems. The adaptation is ensured by a system allowing to identify in real time the value of the resistance, the system used is mainly based on a Luenberger observer. The conversion system is divided into two parts, the first mechanical part containing the turbine and the gearbox, the second electrical one consisting of a double fed induction generator, linked on the stator side directly to the grid, and on the rotor, side linked to the grid through two power electronics converters interposed with a direct current (DC) link. The machine-side converter is used to control the active and reactive powers, and the second on the grid side is used to control the DC link voltage. The converters are controlled by the sliding mode strategy, and the validity of the methods is checked by simulation using MATLAB/Simulink.

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NOMENCLATURE

I_{GSC}, I_{RSC} :	are respectively the current at the converter outputs on the grid side, rotor side converter	$\varphi_{rd}, \varphi_{rq}$:	the rotor d and q axis fluxes.
V_{sd}, V_{sq} :	the dq axis stator voltages.	R_s, R_r :	stator and rotor resistances.
I_{sd}, I_{sq} :	the dq axis stator current.	ω_s, ω_r :	the supply and rotor angular frequency.
$\varphi_{sd}, \varphi_{sq}$:	the Stator d and q axis fluxes.	E:	is the DC voltage that comes from the DC link.
V_{rd}, V_{rq} :	the dq axis rotor voltages.	$V_{t1,2,3}$:	are the three-phase system of the source (the grid).
I_{rd}, I_{rq} :	the dq axis rotor current.	$V_{a,b,c}$:	are the single voltages from the converter.
		$I_{t1,2,3}$:	are the line currents coming from the source.

1. INTRODUCTION

In the last decade the world has experienced a significant development in technology, the latter being accompanied by a considerable need for electrical energy. Known as clean energies and given the climate changes that the earth has been experiencing since the 19th century, renewable energies are the most used to produce electrical energy. This justifies the number of works that have been carried out with the aim of improving the quality of the produced energy.

Among these energy sources, we cite wind energy which has been widely used thanks to the advantages it presents. Different structures have been proposed to convert wind energy, there are structures based on an asynchronous machine with a permanent magnet, asynchronous machine, and double fed induction generator [1]. In the present work, the double-feed induction generator structure is used. This doubly fed induction generator (DFIG) generates active power in accordance with the algorithm for maximum power point tracking which is widely developed in [2]-[5]. Due to controlling produced power, different control laws have been developed in [6]-[15], in our case, we will be interested to the adapted control based on sliding mode thanks to the advantages it gives [16]-[20].

The major advantage of the wind turbine lies in its resistance to disturbances that can harm its operation. we quote [21] who were interested to developed a method to diagnose potential electrical faults attacking the DFIG, in [22] the autors focused on the development of a robust algorithm using the sliding mode control to avoid the problem of chattering. To reduce this phenomenon the autors of [23] have combined the sliding mode and the backstepping controller. For an electrical grid in presence of uncertainty the Hassan *et al.* [24] tried to extract the maximum energy and the control of active and reactive power exchanged. The continuous need for energy requires the wind turbine to be put into service for a long time, this causes heating at the level of the rotor windings which results in a variation that reaches up to 70% of the nominal rotor resistance, this influences produced power which produces less than expected. Therefore, a command adaptation is necessary to remedy this problem.

A set of works have been carried out in the literature to identify the DFIG's parameters, we cite [25] who was interested to the rotor and stator inductors identification of DFIG, in Belmokhtar *et al.* [26] gave all the formulas for calculating the stator and rotor resistance. The added value of Boulmane *et al.* [27], results in the estimation of the stator resistance of an induction machine to reduce the error estimation of its rotational speed. Indeed, different techniques have been proposed to estimate an electrical quantity [28], we cite the Kalman filters, the Luenberger observer, and other methods based on the injection of low or high-frequency currents (known as the signal processing method). In this work, an adaptation of the control law based on the sliding mode technique and using a Luenberger observer is established. To have a readjusted rotor resistance estimated value, a readjustment mechanism using the genetic algorithm is developed [29].

This paper is structured as follow. First section is devoted to the studied system modeling with its both parts, mechanical and electrical one. In the same section a control law is drawn up based on the sliding mode and its robustness is tested. Second section is entirely devoted to the presentation of the DFIG adapted control during its parameter's variation, Luenberger observer is used to identify this variation. In the first and second sections a common part is devoted to the presentation of the procedure used for the optimization of the two control approaches using the genetic algorithm. The last section of this paper is devoted to the presentation and analysis of the simulation results using the MATLAB/Simulink environment.

2. RESEARCH METHOD

2.1. Modelling and control

2.1.1. General structure of the studied system

The wind energy conversion systems' basic structure is given in Figure 1. It consists of a DFIG linked directly to the grid from its stator when to the rotor, it is through two power converters (C1 and C2) interposed with a direct current (DC) bus, and a filter modeling the grid line as seen in Figure 1. The converter switches use pulse width modulation of the reference voltages for their control. The reference voltages come from the controller blocks, the first block is used to regulate the power produced at its setpoint, and the second controls the DC link voltage and imposes a unity power factor.

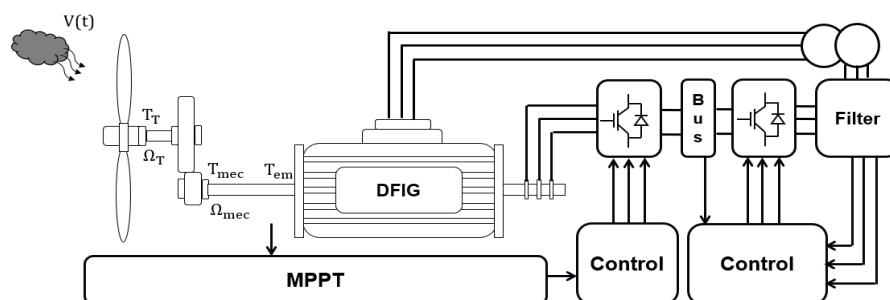


Figure 1. Schematic diagram of wind energy conversion system (WECS) based on DFIG

2.1.2. Wind turbine model

The aerodynamic power applied to the turbine blades is given by (1).

$$P_{aer} = \frac{1}{2} \rho S V^3 \quad (1)$$

Where V is the wind speed, ρ is the air density and S represents the swept area.

According to betz's theory the captured power by turbine P_t is given by:

$$P_T = P_{aer} C_p(\beta, \lambda) \quad (2)$$

with C_p is a specific coefficient to each wind turbine. The turbine torque is defined by:

$$T_T = \frac{P_T}{\Omega_T} \quad (3)$$

the gearbox is a speed adapter from that of the turbine to that of the generator. Its gain is given by:

$$G = \frac{T_T}{T_{mec}} = \frac{\Omega_{mec}}{\Omega_T} \quad (4)$$

Finally applying the fundamental relation of the dynamics, the model is completed by (5).

$$J \frac{d\Omega_{mec}}{dt} = \sum T = T_{mec} - T_{em} - T_{vis} \quad (5)$$

2.1.3. The DFIG model

The double fed induction generator is a very complex non-linear system. To develop a high-performance control of this machine [10], [11], for its different operating regimes, precise mathematical modeling is required. It can be modeled by its state representation or by equation using the Park transformation.

The DFIG model in Park's frame is given by:

$$\begin{cases} V_{sd} = R_s I_{sd} + \frac{d\varphi_{sd}}{dt} - \omega_s \varphi_{sq} \\ V_{sq} = R_s I_{sq} + \frac{d\varphi_{sq}}{dt} + \omega_s \varphi_{sd} \\ V_{rd} = R_r I_{rd} + \frac{d\varphi_{rd}}{dt} - \omega_r \varphi_{rq} \\ V_{rq} = R_r I_{rq} + \frac{d\varphi_{rq}}{dt} + \omega_r \varphi_{rd} \end{cases} \quad (6)$$

$$\begin{cases} P_s = V_{sd} I_{sd} + V_{sq} I_{sq} \\ Q_s = V_{sq} I_{sd} - V_{sd} I_{sq} \end{cases} \quad (7)$$

2.1.4. The DFIG control

To control the DFIG, decoupling is required to facilitate the development of the command, hence the need to use the machine stator flux orientation, the latter is oriented along the axis d while cancelling its component along the axis q, this is justified by the assumption of the choice of a grad of constant voltage and frequency [30], [31]. Taking this hypothesis into account and neglecting the stator resistance (since the DFIG is of great power) the equations given previously become:

$$\begin{cases} V_{sd} = 0 \\ V_{sq} = V_s = \omega_s \varphi_s \\ V_{rd} = R_r I_{rd} + \frac{d\varphi_{rd}}{dt} - \omega_r \varphi_{rq} \\ V_{rq} = R_r I_{rq} + \frac{d\varphi_{rq}}{dt} + \omega_r \varphi_{rd} \end{cases} \quad (8)$$

$$\begin{cases} \varphi_{sd} = \varphi_s = L_s I_{sd} + M I_{rd} \\ 0 = L_s I_{sq} + M I_{rq} \\ \varphi_{rd} = L_r I_{rd} + M I_{sd} \\ \varphi_{rq} = L_r I_{rq} + M I_{sq} \end{cases} \quad (9)$$

$$\begin{cases} I_{sd} = \frac{\varphi_s}{L_s} - \frac{M}{L_s} I_{rd} \\ I_{sq} = -\frac{M}{L_s} I_{rq} \end{cases} \tag{10}$$

$$\begin{cases} P_s = V_{sq} I_{sq} = -\frac{M}{L_s} V_s I_{rq} \\ Q_s = V_{sq} I_{sd} = \frac{V_s \varphi_s}{L_s} - \frac{M V_s}{L_s} I_{rd} \end{cases} \tag{11}$$

$$\begin{cases} V_{rd} = R_r I_{rd} + (L_r - \frac{M^2}{L_s}) \frac{dI_{rd}}{dt} - g \omega_s (L_r - \frac{M^2}{L_s}) I_{rq} \\ V_{rq} = R_r I_{rq} + (L_r - \frac{M^2}{L_s}) \frac{dI_{rq}}{dt} + g \omega_s (L_r - \frac{M^2}{L_s}) I_{rd} + g \frac{M V_s}{L_s} \end{cases} \tag{12}$$

The control of the DFIG is done indirectly through the converter connected to its rotor (C_1). From (11) the control of the active and reactive power of the machine is done through the rotor currents by acting on the rotor voltages, as illustrated in Figure 2.

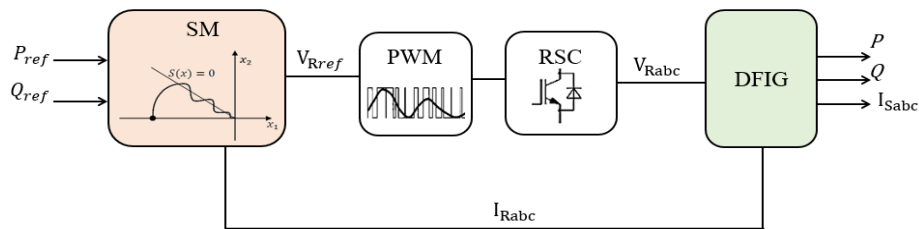


Figure 2. The rotor side converter C1 control

The basic idea of sliding mode control is to force and pull the dynamics (state) of the system to a suitably selected region called the sliding surface, and then to design a control law that will always keep the system in this region [22], [32]. From the (11) we deduce as (13).

$$\begin{cases} I_{rq} = -\frac{L_s}{M V_s} P \\ I_{rd} = -\frac{L_s}{M V_s} Q + \frac{V_s}{\omega_s M} \end{cases} \tag{13}$$

Knowing that the powers must follow their references given by P^{ref} and Q^{ref} we deduce the currents reference.

$$\begin{cases} s(P) = I_{rq}^{ref} - I_{rq} \\ s(Q) = I_{rd}^{ref} - I_{rd} \end{cases} \tag{14}$$

The control vector is given by (15).

$$\begin{cases} V_{rq} = V_{rqeq} + V_{rqcom} \\ V_{rd} = V_{rd eq} + V_{rd com} \end{cases} \tag{15}$$

To calculate this vector, the derivative of the selected sliding surface is used, which gives as (16).

$$\begin{cases} \dot{s}(P) = -\frac{L_s}{M V_s} \dot{P}^{ref} - \frac{1}{\sigma L_r} (V_{rq} - R_r I_{rq} - g \omega_s \sigma L_r I_{rd} - g \frac{M V_s}{L_s}) = -v_1 sgn(s(P)) \\ \dot{s}(Q) = -\frac{L_s}{M V_s} \dot{Q}^{ref} + \frac{V_s}{\omega_s M} - \frac{1}{\sigma L_r} (V_{rd} - R_r I_{rd} + g \omega_s \sigma L_r I_{rq}) = -v_2 sgn(s(Q)) \end{cases} \tag{16}$$

The choice of the sign function for the sliding surface derivative is justified by the attractiveness condition of Lyapunov which requires that the product of the surface and its derivative must be negative or zero. Therefore, the constants v_1 and v_2 must be positive, as a tool to fix their value, the genetic algorithm was used, to have the smallest possible deviation between the power produced and its reference. After developing the (16), the control vector is given by (17).

$$\begin{cases} V_{rq} = -\frac{L_s \sigma L_r}{M V_s} \dot{p}^{ref} + R_r I_{rq} + g w_s L_r \sigma I_{rd} + g \frac{M V_s}{L_s} + L_r \sigma v_1 \operatorname{sgn}(s(P)) \\ V_{rd} = L_r \sigma \left(-\frac{L_s}{M V_s} \dot{Q}^{ref} + \frac{V_s}{M w_s} \right) + R_r I_{rd} - g w_s L_r \sigma I_{rq} + L_r \sigma v_2 \operatorname{sgn}(s(Q)) \end{cases} \quad (17)$$

2.1.5. Parameter’s optimisation using genetic algorithm (GA) for sliding mode technique

As a method for determining the parameters of the sliding mode controller, the GA was used to have a good follow-up of the produced power [33]. In fact, the GA is an optimization and search tool that is based on mechanisms that are like the natural selection found in genetics. The GA theory emulates the natural process where the most skilful individuals in a population are winners and reproduce themselves while the weakest individuals disappear. The method consists of an initial population that is formed by a set of possible solutions for the problem, which are coded as chromosomes. These initial chromosomes are submitted to three genetic operators: selection, crossover, and mutation. Each chromosome represents a possible solution of the problem, and each bit or set of bits, represents a value associated to some variables of the problem. The solutions are classified by a fitness function that plays the role of the environment in the natural process [27], [34].

As mentioned before, the control system must be able to guarantee the two main objectives: closed loop stability of the system and zero regulation of the tracking error. The problem which arises at this level is the determination of the sliding mode adjustment coefficients v_1 and v_2 . The performance of the control system depends essentially on the regulation parameters which are, in our case, the coefficients of the sliding mode regulators v_1 and v_2 that we will determine by genetic algorithm. This will make it possible to have a stable closed loop system and a good reference's values tracking. The constants v_1 and v_2 are fixed using the genetic algorithm. They are chosen in such a way as to minimize (12). Indeed, the fitness function (the input argument of the main GA program) is defined by the error presented by the sliding surface which must be zero. A GA based sliding mode control optimization can be represented as follow Figure 3. The GA properties are given in Table 1. The Parameters’ evolution through the generation is presented in Figure 4. The first simulation results are intended to validate the developed command, the simulation is tested for a 1.5MW turbine with a variable wind profile.

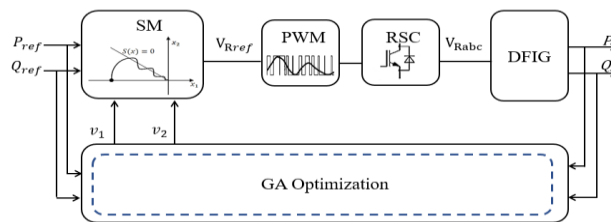


Figure 3. GA based sliding mode optimization

Table 1. Genetic algorithm parameters

Property	Value
Variables to optimize	2
Population size	50
Maximum size of generations	500
Mutation fraction	0.01
Crossover fraction	0.08
Tolerance	$5 \cdot 10^2$

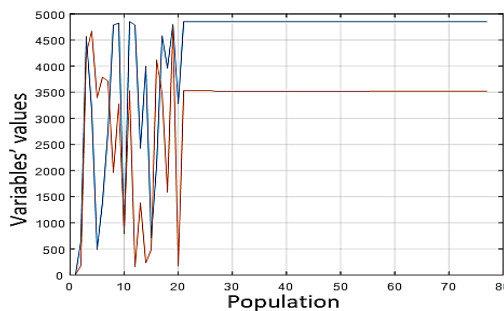


Figure 4. Parameters’ evolution through the generation

Figure 5 illustrates the evolution of the produced active power, which follows the same variations as those of the wind profile. It is clearly remarkable that the produced power faithfully follows its reference in the case of a DFIG with constant internal parameters. On the other hand in Figure 6, with a rotor resistance reaching 50% more than its nominal value, the power produced no longer reaches maximum values [35].

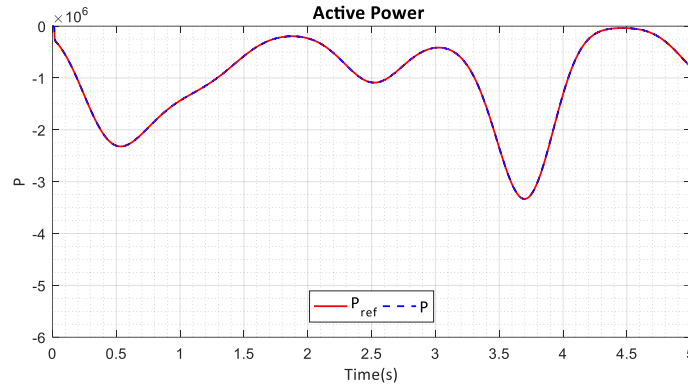


Figure 5. Produced active power with $R_r = R_{rn}$

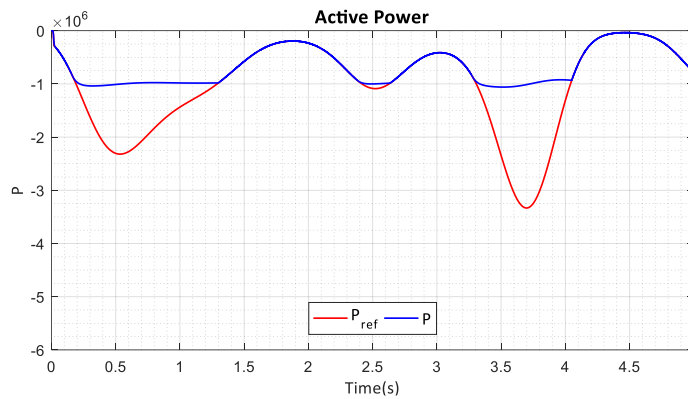


Figure 6. Produced active power with $R_r = 1.5 * R_{rn}$

3. ADAPTED CONTROL USING THE LUENBERGER OBSERVER

The full order Luenberger observer is a deterministic state of observation estimating stator currents and rotor fluxes. In other words, it is an expression of the model of the system in the state representation which makes it possible to reconstruct the evolution of their internal states from measurements of the entry and exit of the real system [36], [37]. The basic structure of the control using the Luenberger observer is shown in Figure 7.

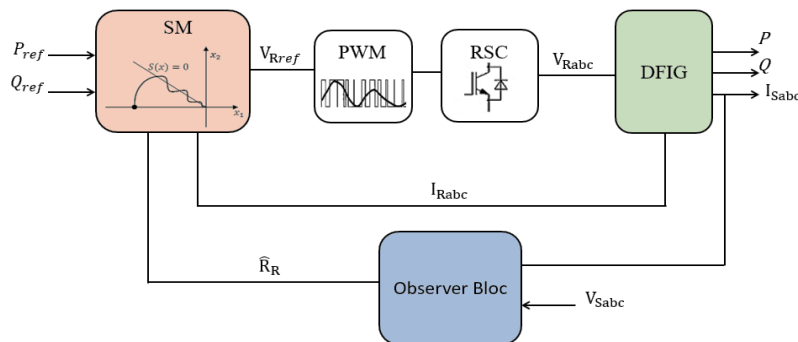


Figure 7. The RSC Adapted control diagram using a Luenberger observer

3.1. Dynamic model of the DFIG in the coordinate (α, β)

To estimate the value of the rotor resistance which changes during the DFIG operation, a state representation of the latter must be made. It can be described by the following state equations in the stationary reference (α, β) :

$$\begin{cases} \dot{[X]} = [A][X] + [B][U] \\ [Y] = [C][X] \end{cases} \quad (18)$$

$$[X] = \begin{bmatrix} I_{S\alpha} \\ I_{S\beta} \\ \phi_{r\alpha} \\ \phi_{r\beta} \end{bmatrix} \quad (19)$$

$$[U] = \begin{bmatrix} V_{S\alpha} \\ V_{S\beta} \end{bmatrix} \quad (20)$$

$$[B] = \begin{bmatrix} \frac{1}{\sigma L_S} & 0 & \beta & 0 \\ 0 & \frac{1}{\sigma L_S} & 0 & \beta \end{bmatrix} \quad (21)$$

$$[Y] = \begin{bmatrix} I_{S\alpha} \\ I_{S\beta} \end{bmatrix} \quad (22)$$

$$[A] = \begin{bmatrix} -\lambda & \omega_S & \frac{\beta}{T_R} & \beta\omega \\ -\omega_S & -\lambda & -\beta\omega & \frac{\beta}{T_R} \\ \frac{M}{T_R} & 0 & \frac{-1}{T_R} & -\omega \\ 0 & \frac{M}{T_R} & \omega & \frac{-1}{T_R} \end{bmatrix} \quad (23)$$

$$[C] = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \quad (24)$$

$$\text{With } \lambda = \frac{1}{\sigma T_R} \quad \beta = \frac{M}{\sigma L_S L_R} T_R = \frac{L_R}{R_R} \quad \sigma = 1 - \frac{M^2}{L_S L_R}$$

According to Kalman a system is observable if the rank of the matrix ψ is equal to n with n being the dimension of the state vector of the system, in this case $n = 4$. The matrix ψ is defined by (25).

$$[\psi] = \begin{bmatrix} C \\ CA \\ CA^2 \\ CA^3 \end{bmatrix} \quad (25)$$

After calculation we find: $\text{rang}[\psi] = 4$. This result confirms the observability of the DFIG.

3.2. Luenberger observer structur

The Luenberger observer structure is illustrated in Figure 8. The Luenberger observer equation is given by (26).

$$\begin{cases} \dot{[\hat{X}]} = [A][\hat{X}] + [B][U] + [L][Y - \hat{Y}] \\ [\hat{Y}] = [C][\hat{X}] \end{cases} \quad (26)$$

The estimated quantities from this observer will be used to reconstruct the value of the rotor resistance, but long before it is necessary to determine the elements of the matrix $[L]$ defined by (27).

$$[L] = \begin{bmatrix} L_1 & -L_2 \\ L_2 & L_1 \\ L_3 & -L_4 \\ L_4 & L_3 \end{bmatrix} \quad (27)$$

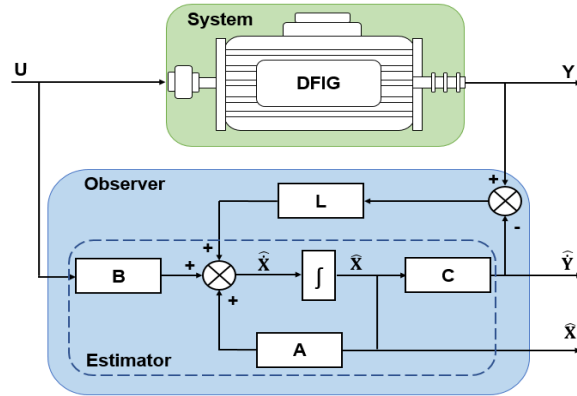


Figure 8. Luenberger observer structure

To do this we define the following matrix:

$$[\hat{A}] = [A] - [L][C] \tag{28}$$

the technique used is that of pole placement, we start by solving the characteristic equations of the full-order observer and the system's one expressed by:

$$\det(SI - \hat{A}) = 0 \tag{29}$$

with I identity matrix. After solving the two equations the gain matrix L is calculated so that the observer poles are proportional to those of the DFIG. After calculation and identification, we find (30).

$$\begin{cases} L_1 = -(k - 1)(\lambda + \frac{1}{T_R}) \\ L_2 = k - 1 \\ L_3 = \frac{k^2 - 1}{\beta} (\lambda - \frac{M\beta}{T_R}) + \frac{k - 1}{\beta} (\lambda + \frac{1}{T_R}) \\ L_4 = -\frac{k - 1}{\beta} \end{cases} \tag{30}$$

3.3. The adaptation mechanism of R_R calculation

Initially, the quantity to be measured must appear in the state matrix of the system and the observer, so the reformulated state matrixes are given by (31), (32).

$$[\hat{A}](\hat{R}_R) = \begin{bmatrix} \frac{-1}{\sigma L_R} \hat{R}_R & \omega_S & \frac{\beta}{L_R} \hat{R}_R & \beta \omega \\ -\omega_S & \frac{-1}{\sigma L_R} \hat{R}_R & -\beta \omega & \frac{\beta}{L_R} \hat{R}_R \\ \frac{M}{L_R} \hat{R}_R & 0 & \frac{-1}{L_R} \hat{R}_R & -\omega \\ 0 & \frac{M}{L_R} \hat{R}_R & \omega & \frac{-1}{L_R} \hat{R}_R \end{bmatrix} \tag{31}$$

$$\Delta A = \begin{bmatrix} \frac{-1}{\sigma L_R} \Delta R_R & 0 & \frac{\beta}{L_R} \Delta R_R & 0 \\ 0 & \frac{-1}{\sigma L_R} \Delta R_R & 0 & \frac{\beta}{L_R} \Delta R_R \\ \frac{M}{L_R} \Delta R_R & 0 & \frac{-1}{L_R} \Delta R_R & 0 \\ 0 & \frac{M}{L_R} \Delta R_R & 0 & \frac{-1}{L_R} \Delta R_R \end{bmatrix} \tag{32}$$

The adaptation mechanism will be deduced by Lyapunov's theory. The stator current estimation error and rotor flux, which is the difference between the observer and the motor model, is given by:

$$\dot{e} = \hat{A}e + \Delta A\hat{X} \tag{33}$$

$$e = X - \hat{X} \tag{34}$$

we consider the following Lyapunov candidate function:

$$v = e^t e + \frac{\Delta R_R^2}{\delta_{R_R}} \tag{35}$$

its derivative is given by:

$$\frac{dv}{dt} = \frac{de^t}{dt} e + e^t \frac{de}{dt} + \frac{2}{\delta_{R_R}} \Delta R_R \frac{d\Delta R_R}{dt} \tag{36}$$

$$\frac{dv}{dt} = (\hat{A}e + \Delta A\hat{X})^t e + e^t (\hat{A}e + \Delta A\hat{X}) - \frac{2}{\delta_{R_R}} \Delta R_R \frac{d\hat{R}_R}{dt} \tag{37}$$

$$\frac{dv}{dt} = [e^t (\hat{A}^t + \hat{A})e] + [(\Delta A\hat{X})^t e + e^t \Delta A\hat{X}] - \left[\frac{2}{\delta_{R_R}} \Delta R_R \frac{d\hat{R}_R}{dt} \right] \tag{38}$$

the development of the second term is given by:

$$(\Delta A\hat{X})^t e + e^t \Delta A\hat{X} = 2e^t \Delta A\hat{X} = 2 * \left[\left(\frac{-1}{\sigma L_R} \Delta R_R \hat{I}_{S\alpha} + \frac{\beta}{L_R} \Delta R_R \hat{\phi}_{R\alpha} \right) e_{I_{S\alpha}} + \left(\frac{-1}{\sigma L_R} \Delta R_R \hat{I}_{S\beta} + \frac{\beta}{L_R} \Delta R_R \hat{\phi}_{R\beta} \right) e_{I_{S\beta}} + \left(\frac{M}{L_R} \Delta R_R \hat{I}_{S\alpha} - \frac{1}{L_R} \Delta R_R \hat{\phi}_{R\alpha} \right) e_{\phi_{R\alpha}} + \left(\frac{M}{L_R} \Delta R_R \hat{I}_{S\beta} - \frac{1}{L_R} \Delta R_R \hat{\phi}_{R\beta} \right) e_{\phi_{R\beta}} \right] \tag{39}$$

The derivative of the Lyapunov candidate function must be negative to check the stability of the system, the first and third terms being negative, it remains to verify the second or else impose it zero, neglecting the error of the rotor flux we find the following (40) and (41):

$$2 * \left[\left(\frac{-1}{\sigma L_R} \hat{I}_{S\alpha} + \frac{\beta}{L_R} \hat{\phi}_{R\alpha} \right) e_{I_{S\alpha}} + \left(\frac{-1}{\sigma L_R} \hat{I}_{S\beta} + \frac{\beta}{L_R} \hat{\phi}_{R\beta} \right) e_{I_{S\beta}} \right] \Delta R_R - \frac{2}{\delta_{R_R}} \Delta R_R \frac{d\hat{R}_R}{dt} = 0 \tag{40}$$

$$\hat{R}_R = \delta_{R_R} \left[\frac{-1}{\sigma L_R} \int (\hat{I}_{S\alpha} e_{I_{S\alpha}} + \hat{I}_{S\beta} e_{I_{S\beta}}) dt + \frac{\beta}{L_R} \int (\hat{\phi}_{R\alpha} e_{I_{S\alpha}} + \hat{\phi}_{R\beta} e_{I_{S\beta}}) dt \right] \tag{41}$$

We pose: $C_1 = \hat{I}_{S\alpha} e_{I_{S\alpha}} + \hat{I}_{S\beta} e_{I_{S\beta}}$ and $C_2 = \hat{\phi}_{R\alpha} e_{I_{S\alpha}} + \hat{\phi}_{R\beta} e_{I_{S\beta}}$

To have a stable system instead of estimating the value of the rotor resistance using an integrator, we opt for the solution of a proportional integrator. Finally, the rotor resistance adaptation mechanism is illustrated in Figure 9.

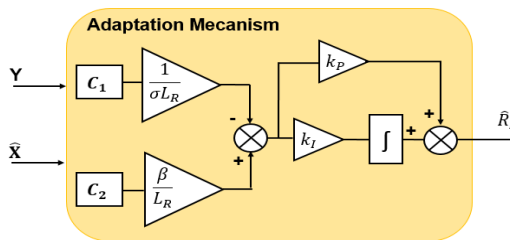


Figure 9. Adaptation mechanism structur

The integrator and the proportional gain of the adaptation mechanism are calculated using the genetic algorithm cited before, to have the value of the rotor resistance estimated as close as possible to the real value. These parameters are adjusted to obtain the optimum performance in terms of dynamics, robustness, and disturbance's rejection. The objective function is therefore chosen to minimize the difference between the rotor resistance mestimated and the reference one. A GA based Adaptation mechanism optimization can be represented as follow Figure 10.

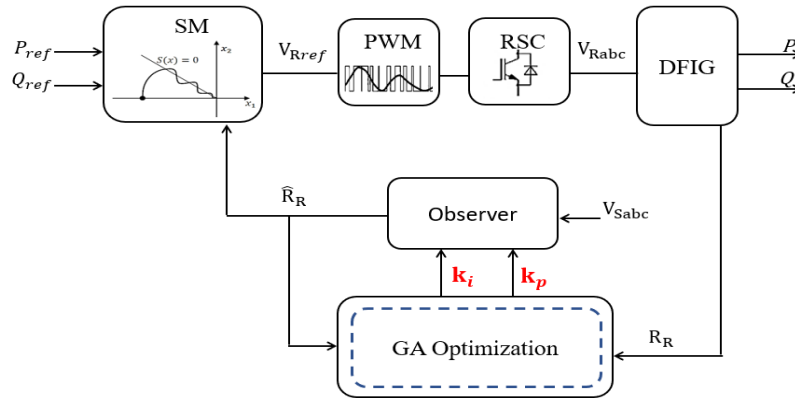


Figure 10. GA-based Luenberger observer optimization

4. SIMULATION RESULTS

Simulations were carried out using MATLAB/Simulink. 1.5 MW wind turbine has been used, its parameters are given in the appendix Table 2. During the simulation, rotor resistance was increased by 50% of its nominal value. Simulation results for 690 V of stator voltage and DC link reference equal to 1200 V are given by these Figures 11-13.

Table 2. Doubly fed induction generator parameters

Parameter	Symbol	Value
Rated power	P_n	300 Kw
Frequency	f	50 Hz
Stator resistor	R_s	8.9 mΩ
Rotor resistor	R_{Rn}	9,13 mΩ
Stator inductor	L_s	12.9 mH
Stator inductor	L_r	12.7 mH
Mutual inductor	M	12.672 mH
Dispersion coefficient	σ	0.0198
Number of pole pairs	P	2

Simulation results compared to the first simulations given in the modelling part, show the monitoring of the reference power even in the presence of the variation of the rotor resistance as shown in Figure 11. In fact, the observer identify the rotor resistance value see Figure 12. In Figure 11 that the DFIG produced power follows its reference from 300 ms using the control adapted by sliding mode. This delay is because of the estimated rotor resistance becomes equal to its reference from the same instant as illustrated in Figure 12. It should be noted that the reactive power also see Figure 13 remains zero equal to its reference from 300 ms. Before this moment active power, reactive power, present a peak for a short time.

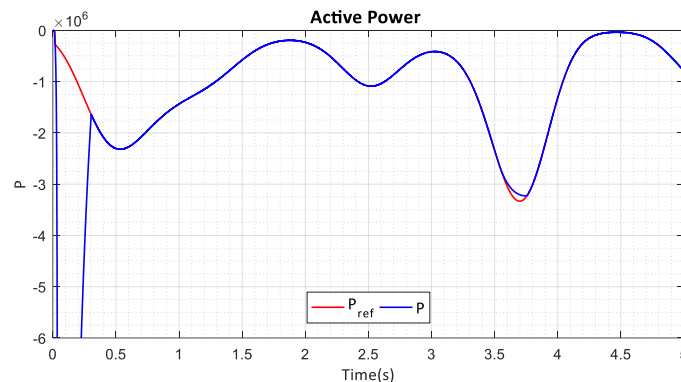


Figure 11. Active power with rotor resistance variation and estimation

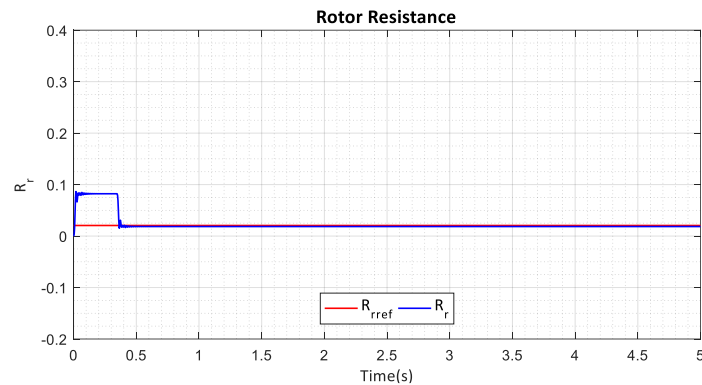


Figure 12. Reactive power with rotor resistance variation and estimation

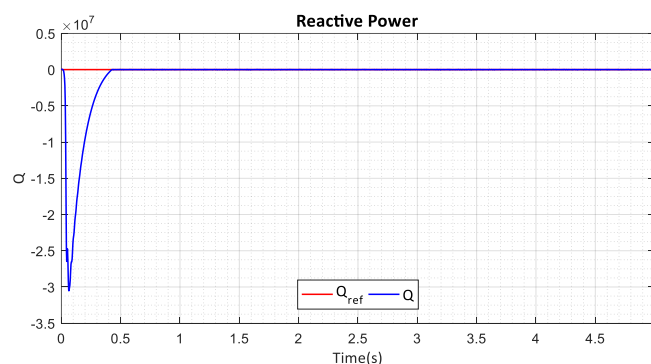


Figure 13. Reactive power with rotor resistance variation and estimation

5. CONCLUSION

In this work, the study, modelling, and control of a wind energy conversion system based on a DFIG were investigated, the evaluation of the dynamic performance of this system controlled by the sliding mode strategy and its sensitivity to the variation of the internal parameters of the DFIG. The control approaches used to control the power exchanged with the grid consist of adapting the DFIG rotation speed to the wind speed by controlling the rotor currents and the electromagnetic torque. We have therefore developed a robust and adaptive control strategy based on the sliding mode and the Luenberger observer with optimization by genetic algorithm. The latter allows to have optimal values of the controller parameters to guarantee the best performances. For normal operation, the internal parameters of the DFIG are assumed to be fixed. From the simulation results we note that the sliding mode control technique, optimised by GA, provides good performance, including fast response and no overshoot. In practice, the internal parameters are always subject to variation due to several physical phenomena. We took as an example the variation of the rotor resistance and found, from the simulation results, that the power output no longer follows its reference for the conventional method. However, the use of the adapted control, proposed in this paper, based on the Luenberger observer presented more satisfactory results. In terms of perspectives, the developed control strategy can be further complemented by the implementation of an observation block taking into consideration all internal parameters including both stator and rotor resistances as well as inductances.

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