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Reactive Power Control for Wind Turbine using Exact Linearization Feedback

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Abstract

The quality of service and the respect of contractual characteristics of the voltage is a major issue of the transmission system operator. In this context, the code requires that the wind turbine system participate in the regulation of the voltage. Any variation in voltage must be compensated by producing or absorbing reactive power.
This article studies the modelling and control strategies of a wind energy conversion system based on a doubly fed induction generator. It presents a linear quadratic regulator with integrator (LQI) and an exact linearization feedback (ELF) controller for a doubly fed induction generator (DFIG). In the ELF technique, the nonlinear model of DFIG is linearized and the reference of active and reactive powers values are calculated by using reactive power management algorithm.
The simulation results show that the decoupling control strategy for DFIG is satisfactory and the predefined operating conditions are respected.

Keywords: Doubly fed induction generator, Wind turbine, Exact linearization feedback, LQI, MPPT.

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List of abbreviations

C_p	Power coefficients
ρ	Air density in (kg/m3)
R	Radius of the blade in (m)
v	Wind speed in (m/sec)
Ω_t	Turbine speed in (rad/sec)
ω_s	Synchronous angular velocity
M	Mutual inductance
V_{sd}, V_{sq}	Stator voltage in the d and q reference
i_{sd}, i_{sq}	Stator current in the d and q reference
ϕ_{sd}, ϕ_{sq}	Stator flux in the d and q reference
Rs, Rr	Stator and rotor resistances
P	Number of the pole pairs
L_s, L_r	Cyclic stator and rotor inductances

1. Introduction

Many countries have established a set of specific requirements for wind energy, among others the connection between wind turbines and the transmission network. This special requirement imposes new constraints on the production of all the parks. It must require the same applicable rules which are applied to conventional power stations connected to the transmission network. Indeed, the Transmission System Operators (GRT) gives a great importance to balancing reactive power [1].

Reactive energy on the transmission network has two consequences: the first one is an increase in the current which causes heating of the links and transformers with greater losses. This consequence can conduce to oversize the transmission network installations. The second consequence consists of the voltage variation during the winter months, when the consumption of reactive energy accentuates the voltage drops.

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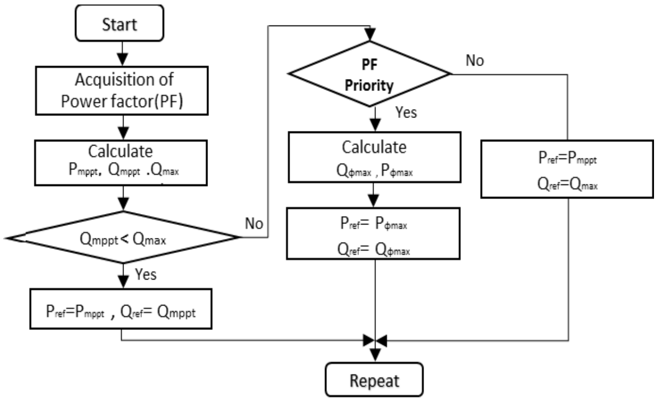

Figure 5. The proposed Reactive Power management

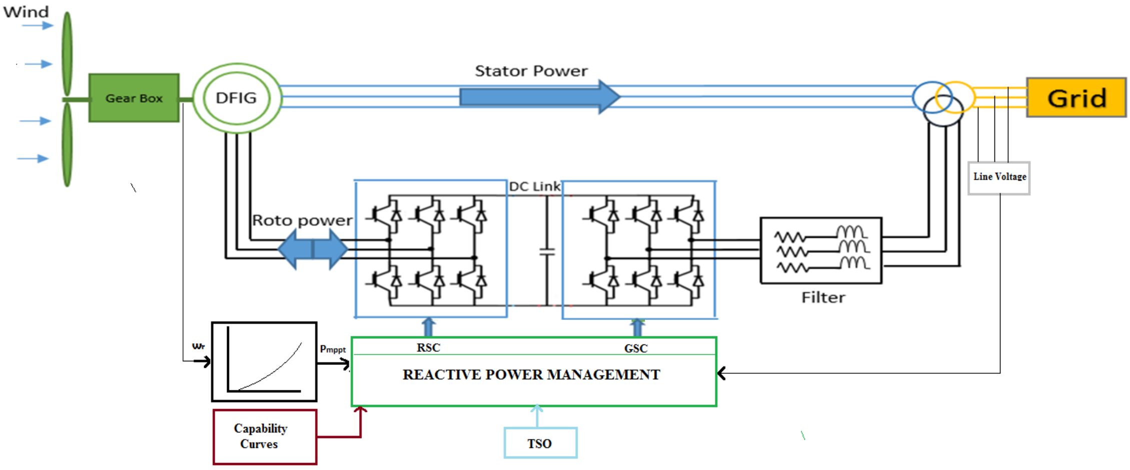

Figure 6. The proposed Diagram of the wind energy conversion system

6. Results and Discussion

All simulations were carried out using SIMULINK environment of MATLAB. The parameters of the Wind turbine and the DFIG are given in the Table1 and Table2.

5.1. Performance Comparison between EFL and LQI Controllers

The EFL controller parameters: P1=1000, P2=1000 and The LQI parameters:

$$K = \begin{bmatrix} 0.3301 & 0.0027 & -31.5933 & -1.3647 \\ 0.0027 & 0.4561 & 1.3647 & -31.5933 \end{bmatrix}$$

The simulations presented are performed with full order DFIG model, the results shown illustrate the performance of the EFL and LQI controllers under different operating zones.

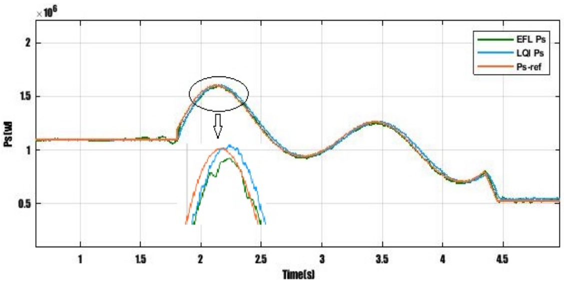

Figure 7a. Active Power

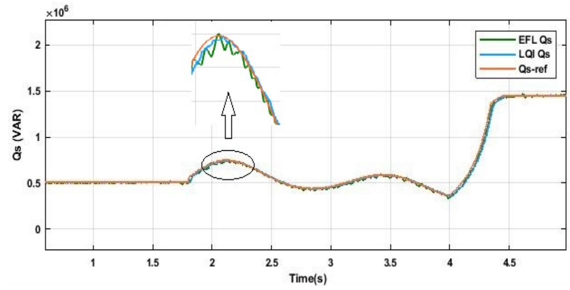

Figure 7b. Reactive Power

5.2. The proposed Reactive Power management

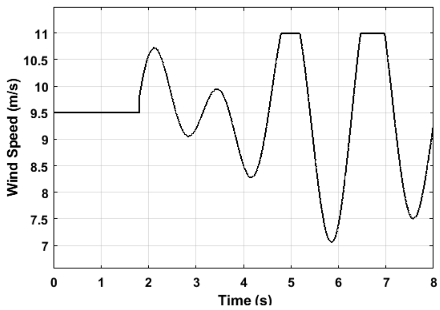

Figure 8a. Wind Speed

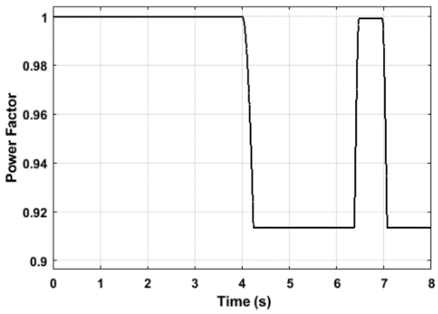

Figure 8b. Power Factor

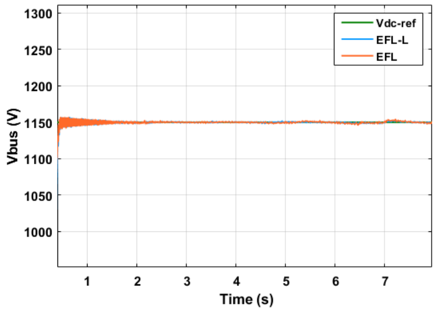

Figure 8c. DC link voltage

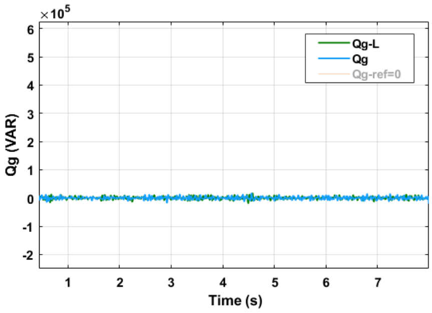

Figure 8d. Grid Reactive power

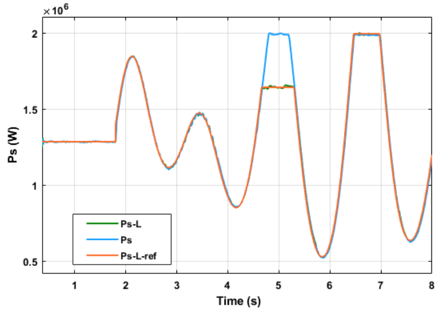

Figure 8e. Active power

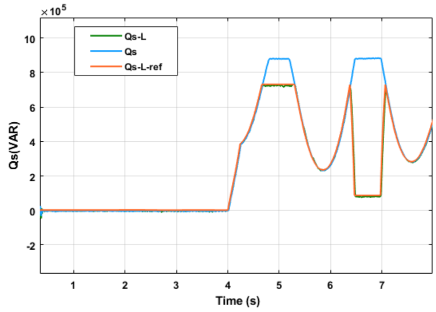

Figure 8f. Reactive power

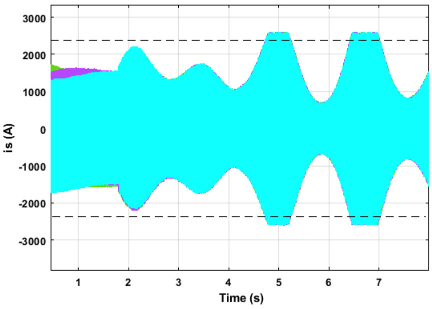

Figure 8g. Stator Current without Power management

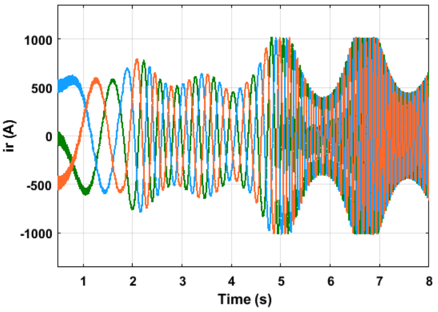

Figure 8i. Rotor Current without Power management

The Figure 8 shows that the strategy of EFL developed to achieve decoupled tracking is checked and the response time is satisfied despite the variation of wind speed and the power factor.
Figure 8g to Figure 8j shows the stator current, rotor current respect constraint limit.

7. Conclusion

In this paper, a model of doubly fed induction generator (DFIG) wind turbine has been developed to control active and reactive power injection on the grid.
It was proven that the exact linearization feedback (ELF) method can transform the DFIG system and the grid side converter (GSC) into a linear canonical form. therefore, Proportional controllers gives good results.
Compared to ELK approach, the linear quadratic regulator with integrator (LQI) applied on the rotor side converter (RSC) has smaller oscillation around the setpoint.
The LQI controller developed in this paper can't be applied on the GSC.

At a second stage, an algorithm aimed at estimating the maximum production capacity of the active and reactive powers in order to generate the reference power is proposed and verified by the simulation results.
The advantage of this algorithm is to improves reactive power compensation and protects the DFIG against maximum temperature limit (rotor current and stator current) and limit isolation (rotor voltage limit).

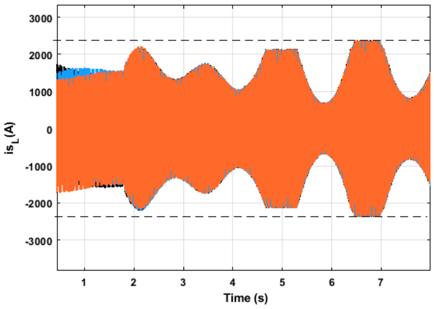

Figure 8h. Stator Current with Power management

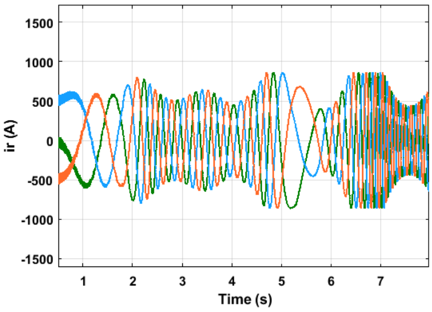

Figure 8j. Rotor Current with Power management

Appendix.

Table 1. Wind Turbine parameters

Parameters	Value	Parameters	Value
Inertia	Ps=2MW	Radius of the turbine	0.087mH
Damping	Ps=2MW	Maximal power coefficient	0.087mH
Gain multiplier	G=20		

Table 2. Double Fed Induction Generator parameters

Parameters	Value	Parameters	Value
Rated Power	Ps=2MW	Stator Inductance	0.087mH
Frequency	50Hz	Rotor Inductance	0.087mH
Number of poles	2	Mutual Inductance	2.5mH
Stator Resistance	2.6mΩ	Rated Stator current	1760Arms
Rotor Resistance	2.9mΩ	Rated Rotor current	1800Arms
Rated Power	Ps=2MW	Stator Inductance	0.087mH

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