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Implementation of Wind Turbine Using Matlab/Simulink and Labview

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Abstract- This paper deals with the implementation of wind turbine driven by Doubly Fed Induction Generator (DFIG) using Matlab/Simulink and Labview. Here, Matlab/simulink readily deals with the Second Order Sliding Mode (SOSM) controller with DFIG wind turbine. SOSM control is used in order to obtain finite reaching time. Maximum power can be obtained by directly tracking the torque obtained. By SOSM controller, Maximum power extraction can be done with reduced mechanical stresses. In conventional methods due to failure in accuracies optimal power extraction is not done. This can be overcome by using SOSM control which will allow tracking DFIG torque directly for extracting maximum power. Turbine tip speed ratio is considered in doing so. The stator of the machine is directly connected to the power grid while the rotor is controlled by an inverter. Labview here is used for graphical representation of the desired output. Labview programs are integrated with DFIG wind turbine in order to acquire, analyze and displaying the data. In this paper, implementation of a DFIG based wind turbine is done and it is integrated with Labview. The results obtained here readily implies where the maximum power is extracted.

NOMENCLATURE

WT	Wind turbine
DFIG	Doubly fed induction generator
SOSM	Second-order sliding mode
MPPT	Maximum power point tracking
V	Wind speed (m/s)
P	Air density (kg/m3)
R	Rotor radius (m)
Pa	Aerodynamic power (W)
Ta	Aerodynamic torque (N・m)
Λ	Tip speed ratio
Cp (*λ*)	Power coefficient
Ωmr	WT rotor speed (rad/s)
Ωmg	Generator speed (rad/s)
Tg	Generator electromagnetic torque (N・m)
Jt	Turbine total inertia (kg・m2)
Kt	Turbine total external damping
d, *q*	Synchronous reference frame index
s, (*r*)	Stator (rotor) index
V (*I*)	Voltage (current)
P (*Q*)	Active (reactive) power
Tem	Electromagnetic torque
Θr	Rotor position

I. Introduction

Wind energy is renewable and natural. wind turbines are similar to hydraulic turbines. Wind turbine is used to convert wind energy into electricity supply systems. The wind turbine to the supply system is possible to the low, medium, high as well as to the extra high voltage system. While most of the turbines are connected to the medium voltage system of the grid .The three main components for energy conversion in wind turbine are rotor, generator, gear box. The rotor converts the fluctuating wind energy into mechanical energy and is thus the driving component in the conversion system. The generator and possibly an electronic inverter absorb the mechanical power while converting it into electrical energy, fed into a supply grid. The gear box is not necessary for multi pole, slow running generators. The main components for the grid connection of the wind turbine are the transformer and the substation with the circuit breaker and the electricity meter inside it. Because of the high losses in low voltage lines, each of the turbines has its own transformer from the voltage level of the wind turbine to the medium voltage line.

DFIG is usually an induction machine connected to the grid. If the motor is driven slightly faster than the synchronous speed it with generate power and add that to the grid. The main advantage is that it is inherently in phase with the grid, which is also the excitation. The main objective of this paper is maximum power extraction. Here tip speed ratio is considered and it is maintained constant in order to obtain maximum power extraction.

II. GLOBAL WIND TURBINE SCHEME

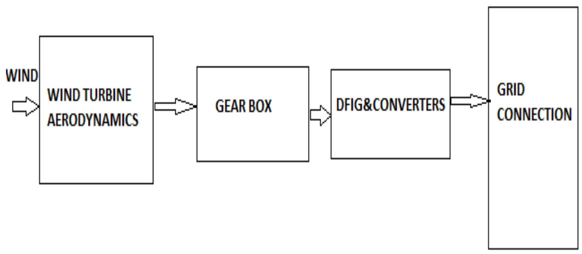

Fig. 1. WT global scheme

A. Turbine model

The turbine modeling is done from [4]. In this case, the aerodynamic power *Pa* captured by the WT is given by

(1)

Where,

(2)

Where, R is the blade radius of the wind turbine, air density and tip speed ratio. The power coefficient is generally given by the fraction of power extracted from the power in the wind by a practical wind turbine. Power coefficient readily varies with the wind speed. It is the function of tip speed ratio and blade pitch angle. At one specific value of tip speed ratio, the turbine is most effective. By varying the rotor speed tip speed ratio is maintained optimum in order to capture maximum power. The rotor power (aerodynamic power) is also defined by

(3)

According to [4], the following simplified model is adopted for the turbine (drive train) for control purposes:

(4)

A. Generator Model

DFIG machines works both as a generator and also as a motor. They operates in both synchronous and sub synchronous speeds. They operates with two modes in synchronous and two modes in sub synchronous modes. Two power converter bridges are connected by means of a dc link. They can accommodate the bi-directional power flow of the rotor in a DFIG[5]. DC link voltage is maintained constant in the grid side converter. While the rotor isde converter controls the flux, active and the reactive powers.

Three legs one for each phase are present in the converter bridge. They contains two transistors. Decoupled active and reactive power is obtained by injecting rotor frequency currents into the rotor circuit. Slip changes with the change in the wind speed. The frequency of the rotor current also varies. Active and the set point values are compared. Slip value is less thean 1. The mechanical torque is transmittd to Dc bus capacitor to rise the DC voltage in super synchronous speed operation. While DC voltage is reduced in sub synchronous operation. Balancing the power which are injected into the DC link capacitor are done in grid side converter. Constant link voltage is maintained using converte which is connected to the grid side. Here, while turning on the lower transistor current is decreased and while turning on the upper transistor cuurent is increased. In DFIG four quardrant active and reactive power operations are done. They operates at 30% speed variation.

III. VARIABLE-SPEED WIND ENERGY CONVERSION SYSTEMS

Since it is possible to track the changes in wind speed by adapting shaft speed, and thus, maintaining optimal power generation currently, variable-speed wind energy conversion systems (VS-WECS) are continuously increasing their market share. The more VS-WECS are investigated, the more it becomes obvious that their behavior is significantly affected by the control strategy used. Typically, the VS-WECS use aerodynamic controls in combination with power electronics to regulate torque, speed, and power. The aerodynamic control systems, usually variable-pitch blades or trailing-edge devices, are expensive and complex, especially when the turbines are larger. This situation provides an incentive to consider alternative control approaches. To achieve power efficiency maximization, the turbine tip-speed ratio should be maintained at its optimum value despite wind variations. Nevertheless, control is not always aimed at capturing as much energy as possible. In fact, in above-rated wind speed, the captured power needs to be limited. Although there are both mechanical and electrical constraints, the more severe ones are commonly on the generator and the converter. Hence, regulation of the power produced by the generator (i.e., the output power) is usually the prime objective and this is the main objective of this paper.

IV. CONTROL OF DFIG-BASED WT

A. Rotor side converter control

The rotor side converter control begins with the stator and rotor current transformation to the d–q reference frame followed by both currents being transformed to the stator flux-oriented frame. Since the objective is to capture the maximum energy available in the wind, the active power reference is always made equal to the available wind turbine power. The reactive power reference value was derived from the active power reference and the desired value of the power factor. The control uses the principle that in the stator flux-oriented frame, the rotor current variations will reflect in stator current variations and hence, by controlling the rotor current, the stator active and reactive powers can be controlled. A reference current was derived from the error between the active power reference and the actual active power by tuning a PI controller. Similarly, a reference current was obtained from the error between the reactive power reference and the actual reactive power. Then, both reference currents were transformed to their natural reference frame that is the rotor frame. These rotor current references, after a dq-to-abc transformation, were used for implementing the hysteresis modulation on the rotor side three-phase converter.

B. *Grid side converter control*

The grid side converter control begins with transforming the grid voltages to the stationary reference frame to obtain the voltage vector angle as given. As seen before, the dc link voltage can be controlled by control of the direct axis current *i*x in the voltage vector-oriented reference frame. Thus, a reference current *i*x, ref was derived from the dc link voltage error of the converter bridge by tuning a second PI controller. The current ref was forced to zero so as to make the displacement equal to zero. The reference currents in the grid voltage vector-oriented frame were then transformed to their natural frame of reference— the stationary frame. An inverse transformation was used to obtain the reference currents as phase currents. With the reference currents for rotor side and grid side converters, hysteresis modulation may then be implemented for both converters.

V. SIMULATION RESULTS

The proposed controllers designed are assessed through simulations, which aim to demonstrate their chattering-free performance and their robust tracking features in the presence of unknown disturbances and uncertainties. Furthermore, for a better appreciation of the WECS SOSM controller assets, their performance has been tuned. The effects of disturbances and uncertainties have been considered by incorporating in the dynamics equations of the system. The maximum level assumed for each one of them was determined by the highest effect. An interface has been developed in MATLAB Simulink enabling users to implement advanced turbine controls in Simulink. Hence, an electrical model (DFIG, grid, control system, etc.) designed in the Simulink environment is simulated while making use of the complete nonlinear aerodynamic WT motion equations. Very good tracking performances are achieved in terms of DFIG rotor current and WT torque with respect to wind fluctuations. The proposed SOMS control strategy does not induce increased mechanical stress as there are no strong torque variations. Indeed and as expected, the aerodynamic torque remains smooth.

To assess the effectiveness of the proposed advanced control strategy, it has been compared to more traditional techniques with the same control objectives. The first one is that using the active power as reference

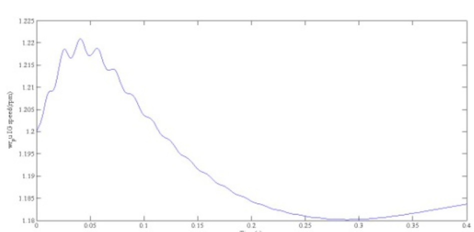

Fig. 5 wind speed profile

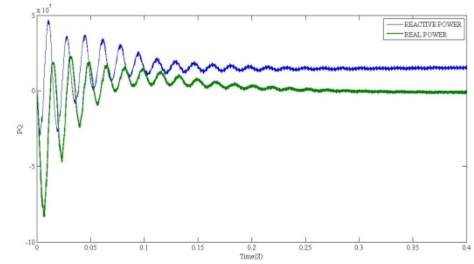

Fig. 6 Real and reactive power

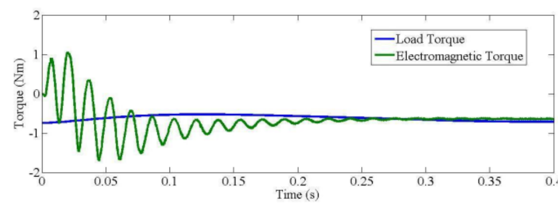

Fig. 7 Torque: reference (blue) and real (green)

This approach supposes that the active power is equal to the DFIG electromagnetic power. This approximation drives a difference between the desired torque given and the generated torque .The second assessed approach is the real and reactive power.

In this case, bad tracking performances are also achieved. Indeed, the control reference is quite inaccurate due to some adopted simplifications (e.g., a constant stator flux). In terms of power extraction and maximization, Figure shows the effectiveness of the proposed SOSM control with respect to approach. This is mainly due to an inaccurate determination of *k*opt. Indeed, there is no accurate way to determine *k*, especially since blade aerodynamics can change significantly over time. This fact is, therefore, an extra justification of the proposed control strategy. If it is assumed that *k* can be accurately determined via simulations or experiments, shows that approaches bad torque tracking can be balanced by the adjustment of *k*opt. This delicate task, which requires a number of simulation tests, remains less efficient.

VI. HARDWARE IMPLEMENTATION

REQUIREMENTS

- PC compatible computer
- Microsoft Windows 3.1x or Windows 95 and new versions of the Windows
- PIC16F73
- MAX232
- Oscillator
- Transformer
- Filter

When a current flows through the coil, the resulting magnetic field attracts an armature that is mechanically linked to a moving contact. The movement either makes or breaks a connection with a fixed contact. When the current to the coil is switched off, the armature is returned by a force approximately half as long as the magnetic force to its relaxed position. Usually this is a spring, but gravity is also used commonly in individual motor starters. Most relays are manufactured to operate quickly. In a low voltage application, this is to reduce noise. In a high voltage or high current application, this is to reduce arcing. If the coil is energized with DC, a diode is frequently installed across the coil, to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a spike of voltage and might cause damage to circuit components. If the coil is designed to be energized with AC, a small copper ring can be crimped to the end of the solenoid. This "shading ring" creates a small out-of-phase current, which increases the minimum pull on the armature during the AC cycle. Then the position steps starts to rotate from initial condition 0 represents the very small amount of power and then it readily forms where the maximum power is obtained. When it readily reaches the stage, they just start to degrade itself.

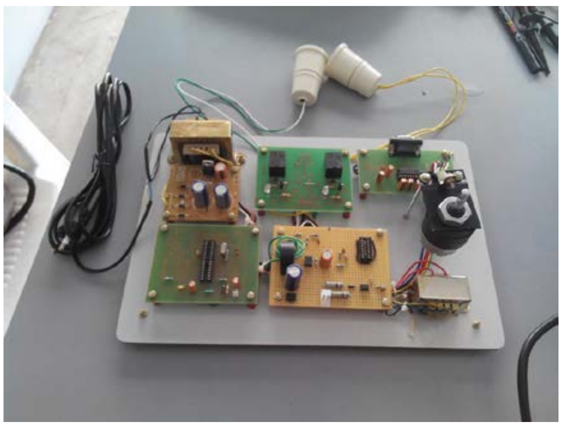

Fig. 8 Hardware implementation of wind turbine

Position step here readily gives the prototype mechanism of clutch and turbine. When the voltage and current are induced in the system, the power gradually gets to increase. When it attains a maximum stage, the power gets readily reduced and thus stops with the two angles. Here maximum power is obtained at 588W at position 6. When the maximum power is attained here, they readily oscillates between step5 and power step 6. This gives the maximum power extraction of a proposed system

Position step	Voltage (V)	Current(A)	Power(W)
1	280	0.1	28.0
2	280	1.5	420
3	277	2.0	516
4	280	2.1	529
5	280	2.1	529
6	280	2.2	588

Table 1 variation in the power obtained

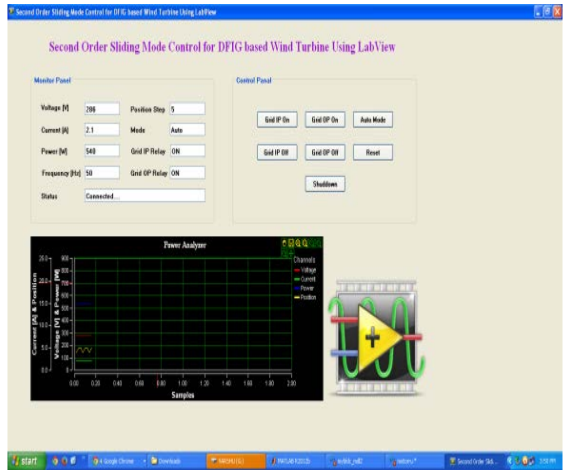

Fig. 9 Result analyser

VII. CONCLUSION

This project presents hardware results of power extracted using second order sliding mode control of a DFIG based wind turbine and it is integrated with LABVIEW using GUI. This prototype readily implies the reduction in the mechanical stresses by applying second order sliding mode control. And the results are obtained under steady state condition. The main features are a chattering-free behavior, a finite reaching time, and robustness with respect to external disturbances (grid) and unmodeled dynamics.

The proposed SOSM control the system according to references given by an maximum power. In this case, the current and voltage is directly tracked, therefore leading to maximum power extraction. The obtained results clearly show the SOSM approach effectiveness in terms of power extraction maximization compared to more traditional techniques. Moreover, it has been confirmed that there is no mechanical extra stress induced on the turbine drive train as there are no strong torque variations.

REFERENCES

[1] F. Valenciaga and P. F. Puleston, “High-order sliding control for a wind energy conversion system based on a permanent magnet synchronous generator,” IEEE Trans. Energy Convers., vol. 23, no. 3, pp. 860–867, Sep. 2008.

[2] I. MunteanuS. Bacha, A. I. Bratcu, J. Guiraud, and D. Roye, “Energyreliability optimization of wind energy conversion systems by sliding mode control,” IEEE Trans. Energy Convers., vol. 23, no. 3, pp. 975– 985, Sep. 2008.

[3] M. Liserre, R. Cardenas, M. Molinas, and J. Rodriguez, “Overview of multi-MW wind turbines and wind parks,” IEEE Trans. Ind. Electron., vol. 58, no. 4, pp. 1081–1095, Apr. 2011.

[4] R. Pena, R. Cardenas, J. Proboste, G. Asher, and J. Clare, “Sensorless control of doubly-fed induction generators using a rotor-current-based MRAS observer,” IEEE Trans. Ind. Electron., vol. 55, no. 1, pp. 330–339, Jan. 2008

[5] R. Fadaeinedjad, M. Moallem, and G. Moschopoulos, “Simulation of a wind turbine with doubly fed induction generator by FAST and Simulink,” IEEE Trans. Energy Convers., vol. 23, no. 2, pp. 690–700, Jun. 2008.

[6] A. Manjock "Design codes FAST and ADAMSR_ for load calculations of onshore wind turbines," Germanischer Lloyd WindEnergie GmbH, Hamburg, Germany, Rep. 72042, May 26, 2005.

[7] F. Poitiers, T. Bouaouiche, and M. Machmoum, "Advanced control of a doubly-fed induction generator for wind energy conversion," Elect. Power Syst. Res., vol. 79, no. 7, pp. 1085–1096, Jul. 2009.

[8] R. Cardenas and R. Pena, "Sensorless vector control of induction machines for variable-speed wind energy applications," IEEE Trans. Energy Convers., vol. 19, no. 1, pp. 196–205, Mar. 2004.

[9] T. Neumann, C. Feltes, I. Erlich, "Development of an Experimental Rig for Doubly-Fed Induction Generator based Wind Turbine". Modern Electric Power Systems 2010, Wroclaw, Poland.

[10] National Instruments, "LabVIEW User Manual" E2003. Available: www.ni.com/pdf/manuals/320999e.pdf

[11] S. Heier, "Grid Integration of Wind Energy Conversion Systems", Kassel University, John Wiley & Sons, Germany, 2006, p. (35 – 38).

[12] R. Cárdenas, R. Peña, Member, "Sensorless Vector Control of Induction Machines for Variable-Speed Wind Energy Applications", IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 19, NO. 1, MARCH 2004.

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