European Pattern Recognition - Renewable Energy Impact

Work Package 7: Inertia Support

SCOPE AND REQUIREMENT DETERMINATION

CONTENTS

1 INTRODUCTION

The previous report has been revealed the literature review for the inertial support mechanisms for wind energy conversion systems. The objective of this report is the scope and requirement determination for the WP7. Current Permanent Magnet Synchronous Generator (PMSG) Wind Turbines will also be explained. The outputs of this study will also be defined at the end of this report.

2 SCOPE

The scope of this study is evaluating the potential of the wind farm, BARES, for the inertial support. In order to evaluate the capacity and the potential of the wind farm for inertial support, the wind farm should be modelled on the simulation environment. Then the real measurements from wind farm can be utilized and the frequency deviations can be investigated.

The inputs of this study will be the wind farm properties and the real measurements taken from field. These data will be utilized to reach a conclusion which includes the capacity of such inertial support and its economical results.

3 CURRENT PMSG WIND TURBINES

The main control diagram of the PMSG wind turbine is given below. In the figure, the aerodynamic model represents the wind turbine structure which captures power from the air. The mechanical model represents the generator and wind turbine connection via gearbox.

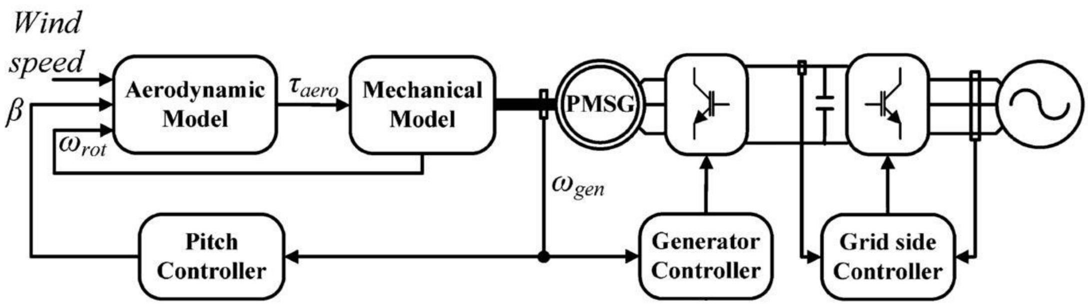

Figure 1:Main Control Diagram of the PMSG Wind Turbine[1]

The aerodynamic power captured from wind depends on the wind speed, pitch angle and the rotational speed. The term power coefficient, C_p is the aerodynamic efficiency of the operating point of the wind turbine. Therefore, the responsibility of pitch controller and generator side controller is to maintain the maximum efficiency.

$$Pt = 0.5\ Cp(\lambda, \beta)A\rho\upsilon 3 \qquad (1)$$

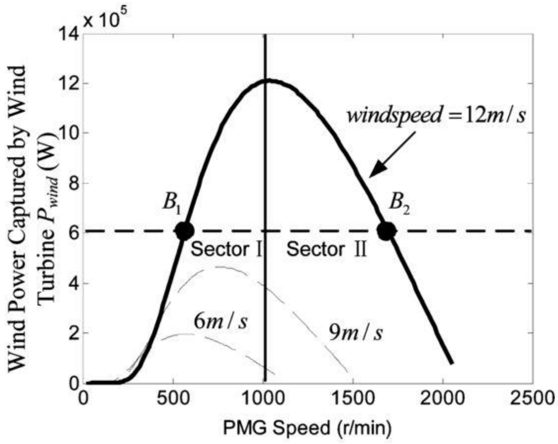

Figure 2: Wind power–speed characteristics for a 1.5-MW system[2]

Permanent magnet coupled to wind turbine shaft is connected to grid with the Back-to-Back(BTB) Converter structure. This structure gives operator freedom of control. Therefore, by making use of BTB converter, the operator can define active and reactive power set points independently. BTB converter is composed of two different structure. The first one is the generator or machine side controller (MSC) which is connected to machine side. The other one is connected to grid side and hence it is called grid side converter (GSC).

The responsibilities are shared between these converters. MSC is responsible for speed reference and the active power reference meanwhile the GSC is responsible for the reactive power reference (also the power factor) and the DC voltage reference. As seen the figure below, the generator speed is dictated by controlling the q-axis current. This generator speed should be the maximum power point which is generally taken from look up table.

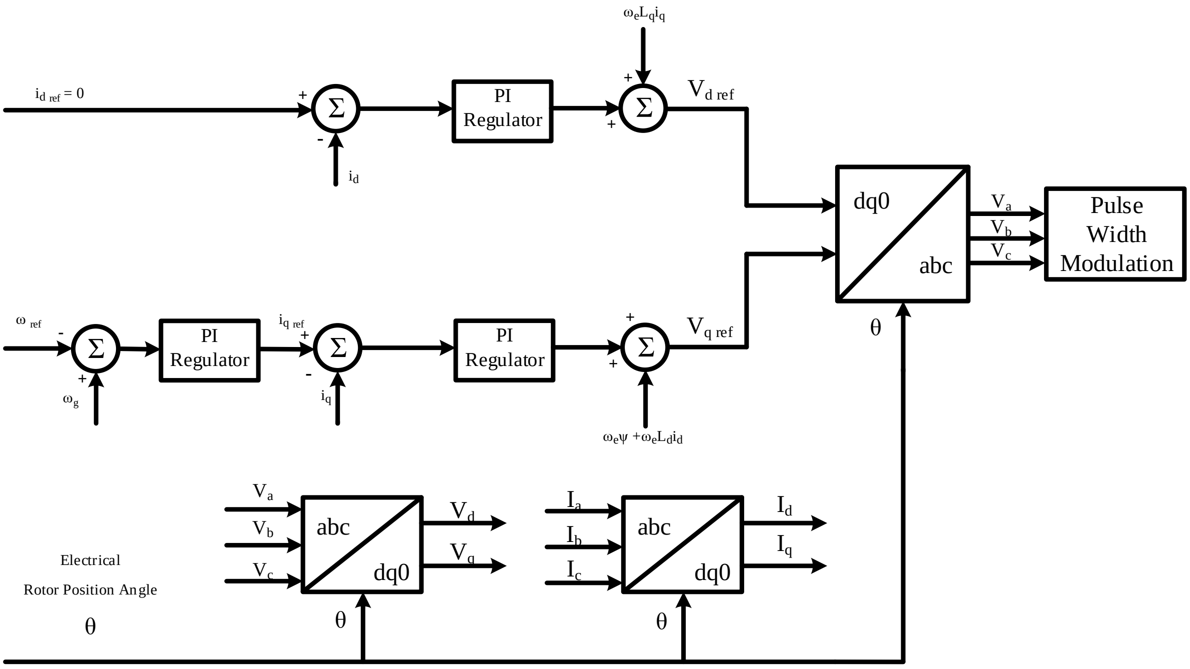

Figure 3: Machine Side Controller Diagram [3]

Grid Side Controller is responsible for maintaining constant DC voltage and the reactive power amount. Reactive power amount can be set by controlling the q-axis current. For normal operation, wind turbines and also other renewable sources are desired to operate at unity power factor. This is achieved by setting zero current for the q-axis. Note that for the LVRT capabilities, this set point would change time to time. GSC is also responsible for maintaining the constant voltage in the DC link. The diagram for GSC is given for a wind turbine which is connected to grid with L filter.

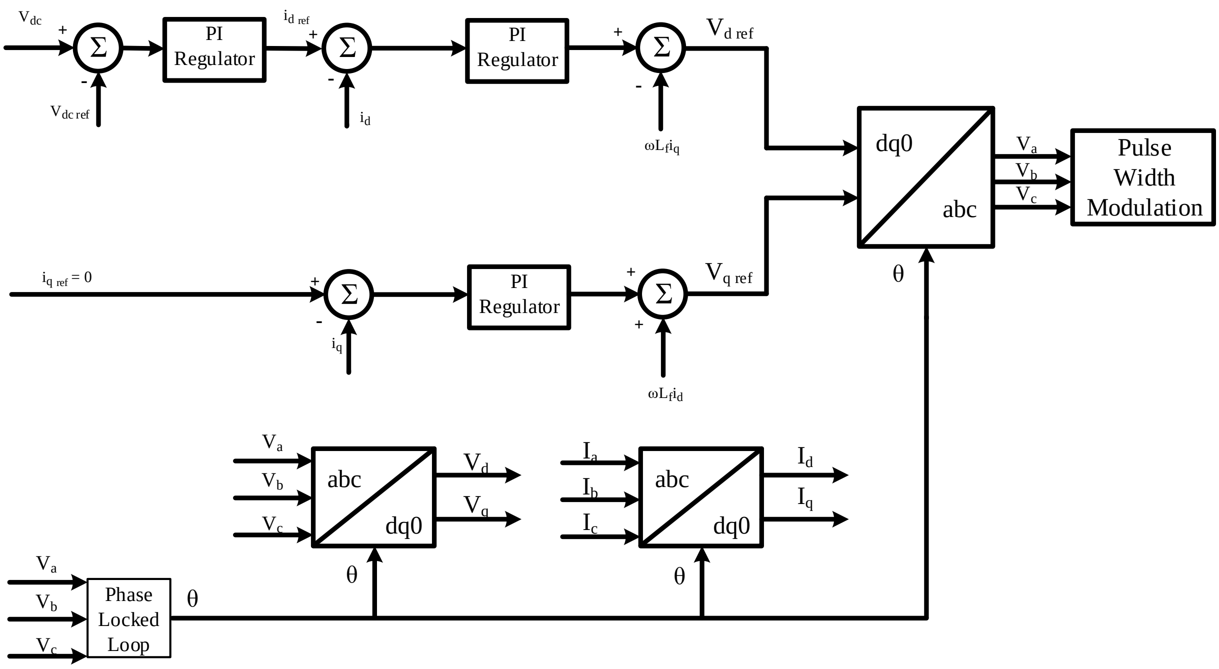

Figure 4: Grid Side Controller Diagram[3]

4 REQUIREMENTS

4.1 REQUIREMENTS FOR AERODYNAMIC MODEL

Parameter	Unit
Wind Turbine Power	MW
Wind Turbine Blade Diameter	m
Wind Turbine Blade Inertia or Mass	$kg.m^2/kg$

4.2 REQUIREMENTS FOR MECHANICAL MODEL

Parameter	Unit
Gear Ratio	-
Gearbox Inertia	$kg.m^2/kg$
Gearbox Efficiency	%

4.3 REQUIREMENTS FOR PMSG

Parameter	Unit
Generator Rating	MVA
Active Power	MW
Generator Inertia	$kg.m^2/kg$
Generator Voltage Rating	V
Generator Flux	V.s
d-q axis Leakage Inductances	H
Stator Resistance	Ω

4.4 REQUIREMENTS FOR BACK-TO-BACK CONVERTER

Parameter	Unit
Detailed Control Diagram	-
PI Compensator Constants	-
DC Link Voltage	V
DC Link Capacitance	C
IGBT Model	-

4.5 REQUIREMENTS FOR FILTER

Parameter	**Unit**
Filter Type	L or LCL Filter
Inductance/s	H
Capacitance (if any)	C

4.6 REQUIREMENTS FOR FREQUENCY MEASUREMENTS

Due to the fact that this study is related to the inertial support, frequency measurement resolution should be high. Therefore, frequency measurements per seconds should be up to 50 measurements per second. However, the existing measurement devices might not provide such resolution. Therefore, the maximum number of frequency measurement should be provided in order to obtain accurate results for this study. The frequency measurements should be obtained from 100 ms data window.

5 OUTPUTS

The requested data will be used for the modelling of the wind farm in BARES. After the modelling, the frequency measurements will be utilized for the possible frequency disturbances. By using these frequency disturbances, the differences between existing and modified conditions will be observed. At the end of this study following outputs will be presented.

Outputs	**Unit**
Improvement in Frequency Nadir	% and Hz
Improvement in RoCoF	% and Hz/s
Cost	kWh

It should be noted that all these outputs will be dependent on the active power increase of the Wind Turbine, support duration and the grid generation profile. Therefore, a set of outputs is supposed to be created at the end of this study.

Moreover, the inertial support will distort the Maximum Power Point Tracking algorithm. Therefore, it is expected to cause some energy lost in the generation. This is why an economic cost will also be presented.

6 CONCLUSION

In this report, scope and requirement determination for WP7 is presented. Which inputs and outputs will be included in the study is clearly stated. As it is stated in the previous section, the main results will be improvement in frequency nadir, improvement in the rate of change of frequency and the economic cost for such modification will be presented for each study case. These study cases can be high or low wind speed or power generation profiles.

One other issue is related to the accuracy of the outputs. In other words, the difference between simulation environment and the real life is also important. The outputs will have high accuracy if all required parameters are presented. Any missing parameters will be refilled with parameters of similar wind turbines in the literature. However, such substitution will result in inaccuracy or errors in the outputs.

7 REFERENCES

[1] J. Licari, J. Ekanayake, and I. Moore, “Inertia response from full-power converter-based permanent magnet wind generators,” *J. Mod. Power Syst. Clean Energy*, vol. 1, no. 1, pp. 26–33, 2013.

[2] X. Yuan, F. Wang, D. Boroyevich, R. Burgos, and Y. Li, “DC-link voltage control of a full power converter for wind generator operating in weak-grid systems,” *IEEE Trans. Power Electron.*, vol. 24, no. 9, pp. 2178–2192, 2009.

[3] T. Orłowska-Kowalska, F. Blaabjerg, and J. Rodríguez, *Advanced and intelligent control in power electronics and drives*. 2014.