Simplified wind turbine models for wind energy integration into power systems

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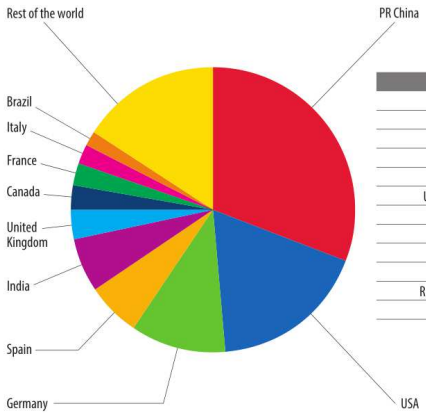
***Abstract** – This paper analyses the boundaries of simplified wind turbine models used to represent the behavior of wind turbines in order to conduct power system stability studies. Based on experimental measurements, the response of recent simplified (also known as generic) wind turbine models that are currently being developed by the International Standard IEC 61400-27 is compared to complex detailed models elaborated by wind turbine manufacturers. This International Standard, whose Technical Committee was convened in October 2009, is focused on defining generic simulation models for both wind turbines (Part 1) and wind farms (Part 2). The results of this work provide an improved understanding of the usability of generic models for conducting power system simulations.*

Introduction

Renewable energy sources (RES) have experienced a rapid development in the last few years. Among the different types of RES, wind energy can be considered as the most promising technology to produce the largest share of renewable electricity needed to meet EU's 2020 targets. In Spain, around 21% of the electric demand has been covered with wind energy during 2013 and 2014, representing the second largest contribution to electricity generation, only exceeded by nuclear power. Similar figures are found in Portugal, where wind energy covered 24% of electricity consumption in 2014 (in line with the value observed in 2013 as well). Even one day in 2014, wind energy reached 89% of instantaneous penetration in Portugal. From a global point of view, 51.477 MW of new wind generating capacity was added in 2014, leading to a total cumulative wind capacity quite close to 370 GW at the end of 2014, Figure 1, [1]. Furthermore, following the moderate scenario suggested by the Global Wind Energy Council, this amount is expected to be doubled in 2020, [2].



Country	MW	% SHARE
PR China*	114,763	31.0
USA	65,879	17.8
Germany	39,165	10.6
Spain	22,987	6.2
India	22,465	6.1
United Kingdom	12,440	3.4
Canada	9,694	2.6
France	9,285	2.5
Italy	8,663	2.3
Brazil**	5,939	1.6
Rest of the world	58,275	15.8
Total TOP 10	**311,279**	**84.2**
World Total	**369,553**	**100**

Figure 1. Total cummulative wind capacity installed in a global basis, [1].

This notable amount of wind capacity installed and must be integrated into the electric power systems in a precise manner in order to enable power systems to operate safely, reliably and cost-efficiently, [3]. For this purpose, grid operators —both Transmission System Operators (TSOs) and Distribution System Operators (DSOs)— need dynamic simulation models of wind turbines and wind farms for conducting power system stability studies [4]–[6]. In this line, wind turbine manufacturers have developed models to estimate the electrical and mechanical behaviour of their generators with the highest level of accuracy, [7], [8]. However, such level of detail is not suitable for stability studies of large power systems due to several reasons. Specifically, the considerable input data required by these complex models, the high computational cost required and the excessive complexity, together with the limited use of the models due to confidentiality issues, are generating some concerns to grid operators [9]. With the aim of providing a solution to these issues, the International Electrotechnical Commission is focused on the development of an international standard, IEC 61400-27, related to the definition of generic —also known as simplified or standard— dynamic models for wind power systems. These generic models are intended to be applicable for transient and dynamic events such as faults, loss of generation or loads and switching of lines. Actually, generic models composed of a publicly available model structure have recently been required in the USA by many utilities [10]–[12].

Approach

Based on the previous introduction, this paper presents a detailed assessment of the response of simplified wind turbine models in comparison with the complex models developed by wind turbine manufacturers under power quality disturbances. Specifically, a simplified wind turbine model for fault ride-through is obtained from a real wind turbine that belongs to the Spanish manufacturer Gamesa. In this line, parting from the detailed (i.e., complex) model of the wind turbine, a simplified model is fitted so that its behavior is simulated for voltage sag studies without increasing the order of the overall system.

Conclusions

The response of simplified wind turbine models is compared with complex wind turbine models developed by manufacturers. Specifically, a real Gamesa wind turbine has been considered in this paper. Therefore, not only simulation activities but also real measurements on field are presented in this paper. In this sense, the results provide an improved understanding of the usability of generic models for conducting RES power system integration studies on large networks.

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References

[1] "Global Wind Statistics 2014". Global Wind Energy Council, GWEC, 2015.

[2] "Global Wind Energy Outlook 2014". Global Wind Energy Council, GWEC, 2015.

[3] Jiménez, F., Gómez-Lázaro, E., Fuentes, J. A., Molina-García, A., & Vigueras-Rodríguez, A. "Validation of a DFIG wind turbine model submitted to two-phase voltage dips following the Spanish grid code". Renewable Energy, 2013, 57, 27-34.

[4] Honrubia-Escribano, A., Gomez-Lazaro, E., Vigueras-Rodriguez, A., Molina-Garcia, A., Fuentes, J. A., & Muljadi, E. (2012, July). "Assessment of DFIG simplified model parameters using field test data". In IEEE Power Electronics and Machines in Wind Applications (PEMWA), 2012 (pp. 1-7).

[5] B. Sørensen, B. Andersen, J. Fortmann, K. Johansen, and P. Pourbeik, "Overview, status and outline of the new IEC 61400 -27 – electrical simulation models for wind power generation," International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Farms, 2011.

[6] J. Fortmann, "Generic aerodynamic model for simulation of variable speed wind turbines," 9th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants, 2010.

[7] Jiménez, F., Vigueras-Rodriguez, A., Gómez-Lázaro, E., Fuentes, J. A., & Molina-Garcia, A. "Validation of a Mechanical Model for Fault Ride-Through: Application to a Gamesa G52 Commercial Wind Turbine". IEEE Transactions on Energy Conversion, 2013, 28(3), 707-715.

[8] Jiménez, F., Gómez-Lázaro, E., Fuentes, J. A., Molina-García, A., & Vigueras-Rodríguez, A. "Validation of a double fed induction generator wind turbine model and wind farm verification following the Spanish grid code". Wind Energy, 2012, 15(4), 645-659.

[9] Fuentes, J. A., Molina, A., Ruz, F., Gómez, E., & Jiménez, F. "Wind turbine modeling: Comparison of advanced tools for transient analysis". In IEEE Power Engineering Society General Meeting, 2007.

[10] M. Behnke, A. Ellis, Y. Kazachkov, T. McCoy, E. Muljadi, W. Price, and J. Sanchez-Gasca, "Development and validation of WECC variable speed wind turbine dynamic models for grid integration studies," AWEA WindPower Conference, 2007.

[11] "WECC wind power plant dynamic modeling guide," WECC Renewable Energy Modeling Task Force, Western Electricity Coordinating Council, 2010.

[12] A. Ellis, Y. Kazachkov, E. Muljadi, P. Pourbeik, and J. Sanchez-Gasca, "Description and technical specifications for generic WTG models –A status report," IEEE/PES Power Systems Conference and Exposition (PSCE), pp. 1–8, 2011