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Effects of Grid Frequency Drop on the Dynamic Performance of Full Converter Wind Turbine Generator

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Abstract. Recently, wind turbine generators connected to the grid is increased significantly. It has reached about 540 GW worldwide installation in the mid of 2018. One of the popular wind turbine types is Full Converter Wind Turbine Generator (FCWTG). It has a capability in extracting more energy compared to fixed speed type and also could contribute some amount of reactive power when the grid is required. Although frequency deviation rarely occurs in a grid side, it might be important to investigate the effects to FCWTG as FCWTG is very sensitive to a grid fault. In this paper, a deviation of frequency at the grid side is applied to investigate the dynamic performance of FCWTG during the rise and down frequency at the grid side. The system under study is carried out using Matlab/Simulink and the simulation results show that the grid frequency drop of 47.5 Hz has been started to cause the unstable dynamic performance of FCWTG. The worse scenario of grid frequency drop of 45 Hz could even lead the FCWTG to get damage.

1 Introduction

Wind turbine generator becomes a popular alternative energy source to generate electric power. It has been installed widely all around the world and already reaches about 540 GW in the mid of 2018 [1]. One of modern wind turbine type that contributes to the wind turbine market niche is Full Converter Wind Turbine Generator (FCWTG) or so-called

Type-4 WTG. It could extract more wind energy compared to Fixed Speed Wind Turbine Type [2]. Moreover, with a full-size converter that equipped with the turbine, it could contribute to supply reactive power to the grid [3].

Among its advantages over other wind turbine types, however, it is very sensitive with grid faults. Many papers have discussed FCWTG dynamic responses during voltage sag [4]-[6] and flicker [7], no attention is given to investigate the effects of grid frequency drop on the dynamic performance of FCWTG.

Although frequency drop might scarcely occur, in fact, some cases that even lead to brown and blackout are due to the frequency deviation. For example, a case of East Ontario Canada in 1972, caused islanding electrical grid due to frequency variation between 58.7 Hz-62.6 Hz [8]. New York City the USA, had also experienced the islanding electrical grid in 1977 due to frequency drop until less than 47.5 Hz [9] and the new case in Europe was cascading outage in 2006 [10]. Tabel 1 shows the major frequency deviation cases from 1970s-2000s.

Table 1. Major Frequency Deviation Cases from 1970s-2000s

No	Places	Frequency Deviation	Causes	Year
1	East Ontario, Canada [8]	58.7 Hz-62.6 Hz	Islanding Electrical Grid	1972
2	Italy [8]	NA	Cascading Transmission Line	1994
3	Malaysia [8]	49.1 Hz	Cascading Fault	1996
4	Brazil [8]	55.25 Hz-58.0 Hz	Cascading Fault	1996
5	New York City, USA [9]	< 47.5 Hz	Islanding Electrical Grid	1977
6	West and South Coast of England [10]	47.3 Hz	Islanding Electrical Grid	1981
7	France [10]	49.6 Hz	Cascading Fault	1985
8	Perth, Australia [10]	<3.5 Hz/s	Cascading Outage	1994
9	Europe [11]	NA	Cascading Outage	2006
10	Italy [12]	47.0 Hz	Lack of Generation	2003

2 Research Methodology

Typical FCWTG is described in Figure 1, where it consists of two converters to allow voltage adaptation during wind speed variation. A dc link capacitor is placed between the two converters to maintain the permissible voltage level in order to smooth out the energy transfer to the grid.

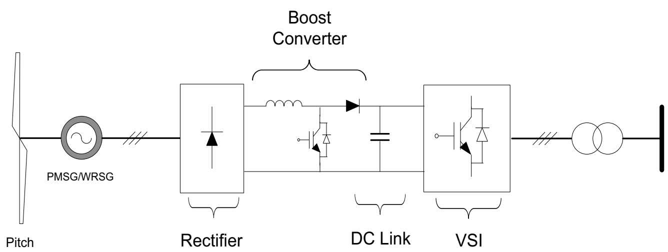

Figure 1. A typical type of FCWTG

In this paper, five of 2 MW FCWTG are connected to the grid via 30 Km distribution line s shown in Figure 2. All systems under study are simulated and carried out using Matlab/Simulink.

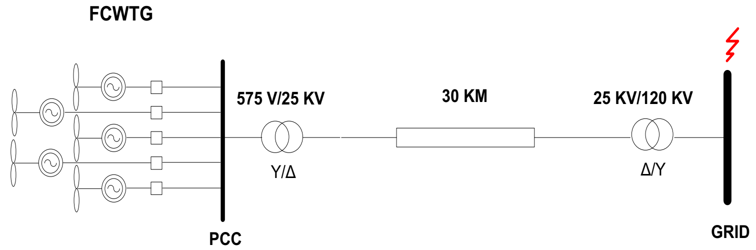

Figure 2. System under study

The parameters used in the system under study including the FCWTG are provided in Table 1 and 2.

Table 2. FCWTG parameters

Parameters	FCWECS
Rated Power	5 x 1.5 MW
R_s (p.u.)	0.006
H(s) (p.u.)	0.62
V_{dc} (V)	1100

Table 3. System under study parameters

Parameters	Distribution line
R_1 (ohms/km)	0.1153
R_0 (ohms/km)	0.413
L_1 (H/km)	1.05e-3
L_0 (H/km)	3.32e-3
C_1 (F/km)	11.33e-9
C_0 (F/km)	5.01e-9

All the system were modeled and simulated using Matlab/Simulink doftware package and the simulation results will be elaborated and the following section.

3 Simulation Results and Discussion

In this paper, four levels of frequency deviation are applied to the grid side. The lowest deviation is 55 Hz and the most worse is 45 Hz. Frequency drop of 47.5 Hz is also applied to resemble the case of New York City case in 1977 [9], to see its impact on the dynamic performance of FCWTG.

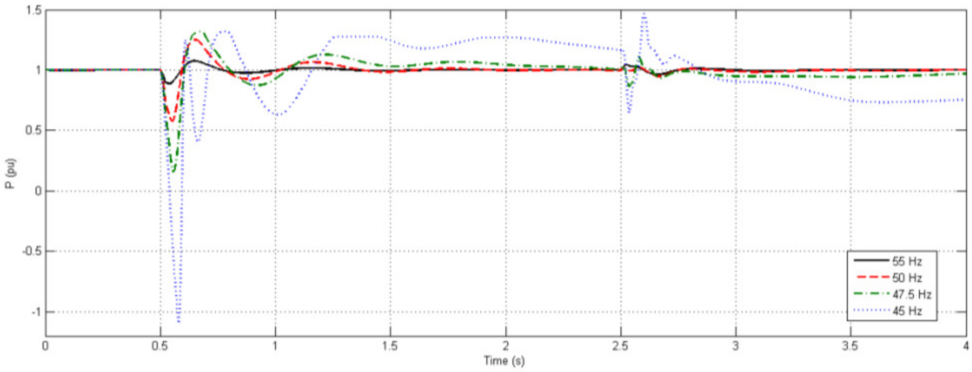

Figure 3. Power output responses with various frequency drops

Figure 3 shows the dynamic impacts of grid frequency drops on FCWTG. Output power has a quite significant drop up to 0.5 pu during grid frequency drop at 0.5s. However, with a proper controller of FCWTG particularly for the self-healing system, the generated power is forced back to stable but giving a small and short fluctuate response when the fault is cleared out. The worse scenario has occurred on grid frequency drop at 45 Hz, the generated power goes significantly down and might damage the generator. The self-healing system of FCWG is also malfunctioned in this fault level.

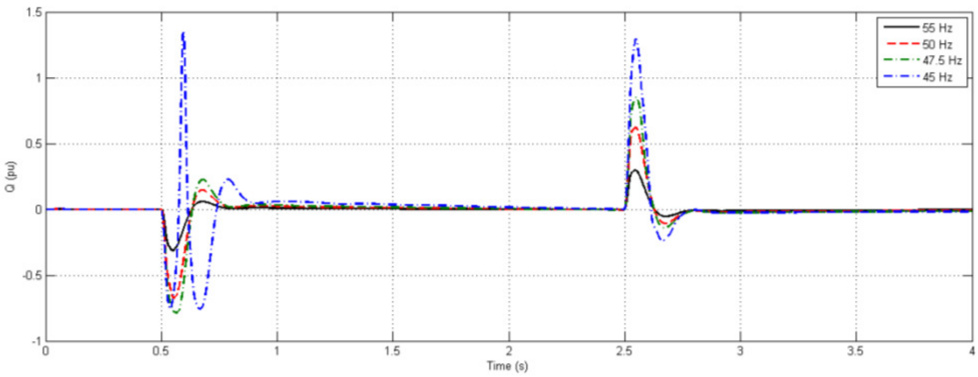

Figure 4. Reactive power output responses with various frequency drops

Figure 4 depicts the reactive power spark response during faults start and end for all grid frequency drops, however, the worse condition is for grid frequency drop at the level 45%.

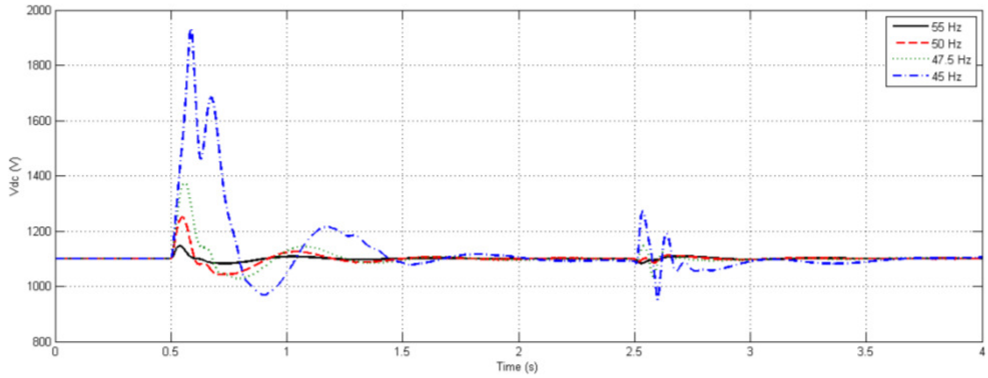

Figure 5. Vdc link voltage of FCWTG during various drops of the grid frequency

Figure 5 shows the DC link response during various grid frequency drops. The voltage rise for the grid frequency drops of 47.5 Hz has violated the safety margin of 120% maximum overshoot of allowable DC link voltage. This might lead to the converter protection blocks the converters of FCWTG.

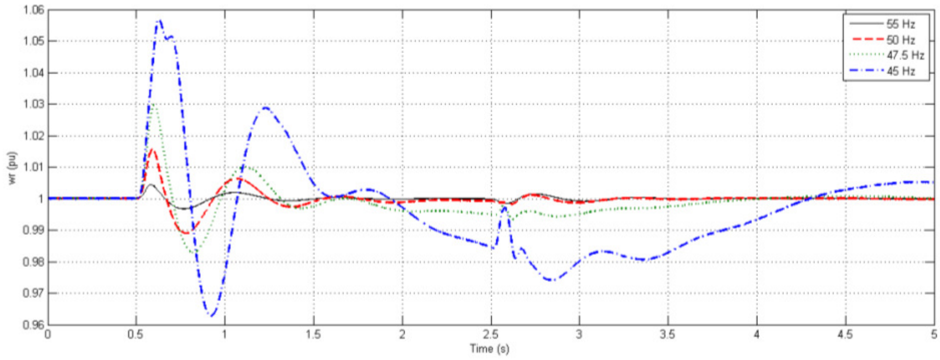

Figure 6. Generator speed of FCWTG during various drops of the grid frequency

Figure 6 exhibits generator speed responses during various grid frequency drop. It clearly demonstrated that the larger level of grid frequency drop the larger oscillation occur which means the generator is under an unstable condition that might damage the generator.

4 Conclusion

This paper investigates the effects of various grid frequency drops on the dynamic performance of FCWTG. The overall systems are simulated and carried out using Matlab/Simulink. In the range of grid frequency drop about 55 Hz to 50 Hz, the self-healing mechanism could maintain the dynamic responses are still within safety margin. However, from 47.5 Hz drop, the dynamic response of FCWTG is started to be unstable and in the worse condition, it might lead to the damage of FCWTG.

References

1. http://www.wwindea.org/2017-statistics/ (accessed: 01 March 2018)
2. J. M. Carrasco *et al.*, “Power-Electronic Systems for the Grid Integration of Renewable Energy Sources : A Survey,” *Ieee Trans. Ind. Electron.*, vol. 53, no. 4, pp. 1002–1016, 2006.
3. B. Bechir, B. Faouzy, and M. Gasmi, “Wind Energy Conversion System with Full-Scale Power Converter and Squirrel Cage Induction Generator", *International Journal of Physical Sciences* Vol. 7(46), pp. 6093-6104, 9 December 2012.
4. A. M. S. Yunus, A. Abu-Siada, and M. A. S. Masoum, “Effects of SMES on dynamic behaviors of type D-Wind Turbine Generator-Grid connected during short circuit,” *IEEE Power Energy Soc. Gen. Meet.*, pp. 11–16, 2011.
5. A. M. S. Yunus, A. Abu-Siada, and M. A. S. Masoum, "Effect of SMES unit on the performance of type- 4 wind turbine generator during voltage sag," in *IET Conference on Renewable Power Generation (RPG 2011)*, 2011, pp. 6–9.
6. Shiddiq Yunus, A. M., Siada, A. A., and Masoum, M. A. S, "Effect of STATCOM the low-voltage-ride-through capability of type-D wind turbine generator", in 2011 *IEEE PES Innovative Smart Grid Technologies, ISGT Asia 2011 Conference: Smarter Grid for Sustainable and Affordable Energy Future 6167072*
7. Shiddiq Yunus, A. M., Alharbi, Y. M., Siada, A.A., and Masoum, M. A. S., “Investigation of near flicker source impact on the dynamic performance of FCWECS”, *2013 Australasian Universities Power Engineering Conference, AUPEC 2013 6725397*
8. N. Janssens, P. Baratella, D. Bickers, D. Bones, A. Cooke, E. Gaglioti, E. Grebe, R. Hartman, M. Houry, T. Inoue, J. Jardim, K. Karoui, P. Kundur, M. O‟Malley, F. Thoden, R. Schulz, D. Tong, P. Scarpellini and F. Casamatta,, 1998, “Analysis and Modeling Needs of power Systems under Major Frequency Disturbances”, *IEEE /CIGRE Task Force 38.02.14 Rep*.
9. B. Weedy, B. Corny, N. Jenkins, J. Ekanayake and G. Strbac, 2012, “Electric Power System”, 5th ed. *John Wiley & Sons Ltd*, p. 152.
10. M. Altin, 2012, "Dynamic Frequency Response of Wind Power Plants", Ph.D., Aalborg University, Denmark.
11. C. Li, S. Yuanzhang and X. Chen, 2007, “Analysis of the Blackout in Europe in November 4, 2006”, *Power Engineering Conference, 2007. IPEC 2007. International, Singapore*, pp. 939-944.
12. S. Crosi and C. Sabelli, 2004, "General Blackout in Italy Sunday, September 28, 2003, h. 03:28:00", *IEEE, Power Engineering Society General Meeting*, pp. 1691-1702.