Benefits of virtual inertia for power system

Anssi Mäkinen, SGEM deliverable 5.1.19

1. Introduction

In this study, the impact of wind turbine virtual inertia to the power system operation is evaluated. The aim of the paper is to present realistic PSCAD simulation model for wind turbine virtual inertia studies. The virtual inertia means that in case of frequency drop in the network, the wind turbine uses the energy stored in the rotational mass of its turbine to produce increased amount of electrical power to the grid. The aim is to restrain the decrease of the network voltage frequency. In the simulations, the network model uses parameters found from the Hailuoto, Finland. [1] The network model consists of constant power loads, diesel generator and wind turbine connected to the main grid. The virtual inertia is investigated by isolating the loads, wind turbine and diesel generator from the grid. During grid connected mode of operation, the automatic voltage regulator (AVR) of diesel generator is in reactive power mode and the engine is in active power control mode. However, during the islanding, the diesel generator AVR is switched to voltage control mode and the engine starts to be in speed control mode in order to maintain the frequency of the islanded grid voltage between boundaries. The aim of the full-power converter wind turbine after islanding is to react to the decrease in frequency by increasing the active power output. In this study, three different cases are studied. In the first case, the full-power converter wind turbine does not have the feature of virtual inertia. In the second case, the virtual inertia feature is added to the control of wind turbine. In the last case, same power level induction generator wind turbine is used. The induction generator wind turbine is known to have contribution to the power system inertia. The full-power converter wind turbine used in this study is represented in [2]. The induction generator wind turbine and power system model are same as in [1]. The islanding occurs after opening of Viinikantie circuit breaker. [1]

2. Simulation results

The active and reactive powers measured from the Viinikantie circuit breaker are shown in Fig. 1. The opening of the circuit breaker occurs at 10s. Before islanding the active power deficit in the island zone is 320kW and the inductive load in the island zone is taken care by feeding 150kVAr reactive power from the main grid.

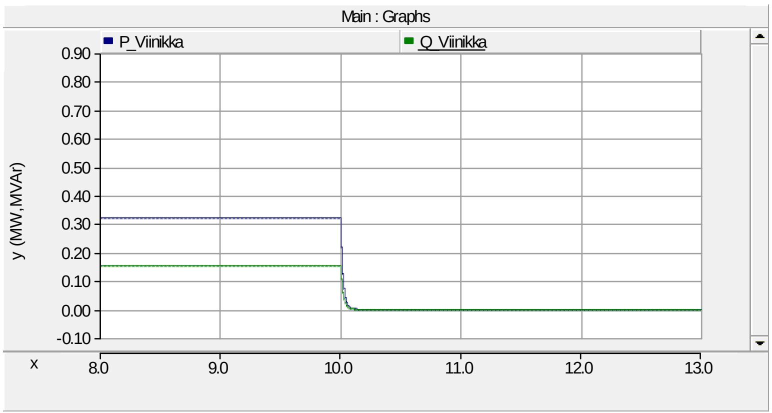

Fig. 1. Active and reactive power of the Viinikka circuit breaker.

When the wind turbine does not have the virtual inertia mode of operation, the wind turbine currents measured from the 690kV side of the wind turbine transformer do not change as shown in Fig. 2a. The voltages measured from the same point are shown in Fig. 2b. The voltage envelope has clearly low frequency oscillations. The wind turbine currents with virtual inertia are shown in Fig. 3a. The currents after islanding are increased 430A (RMS value) to the 560A (RMS value) for a time 0.5s. The wind turbine voltages, Fig. 3b, show less oscillating response. The currents of induction generator wind turbine are shown in Fig. 4a and the voltages in Fig. 4b. It can be seen that the envelope of both measures changes very smoothly. The maximum current of the wind turbine after islanding is 630A (RMS value).

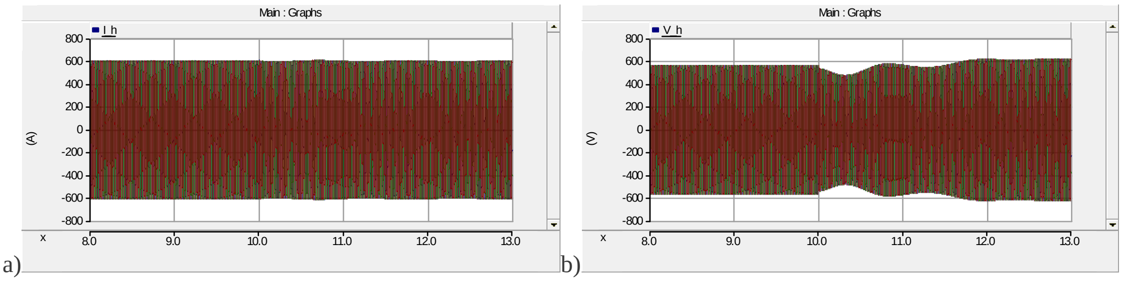

Fig. 2. Wind turbine without virtual inertia: a) currents, b) voltages.

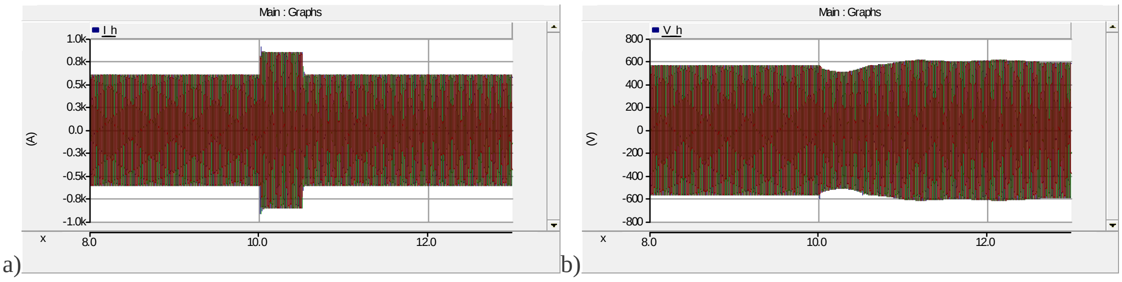

Fig. 3. Wind turbine with virtual inertia: a) currents, b) voltages.

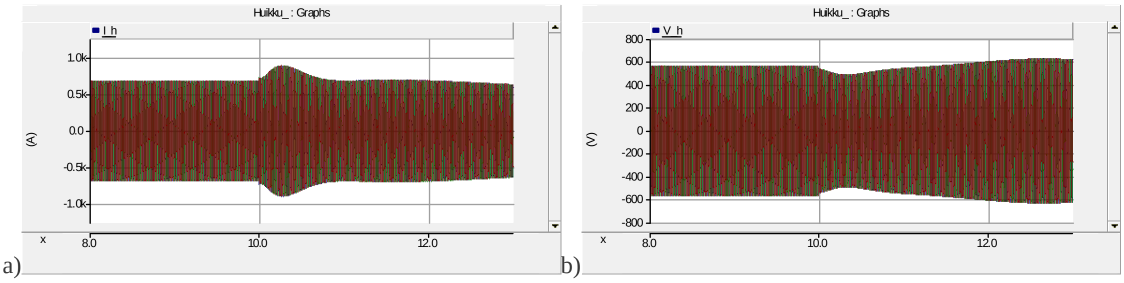

Fig. 4. Wind turbine with induction generator: a) currents, b) voltages.

The active power, reactive power, line to line voltages and network frequency when wind turbine does not have virtual inertia operation are shown in Fig. 5a. Corresponding measures when virtual inertia is added to the wind turbine control system are shown in Fig. 5b. It can be seen that the without virtual inertia the active power is decreased after islanding which is not desirable in the viewpoint of the frequency control in the islanded zone. However, if the wind turbine has the virtual inertia feature, the active power is increased. It can be seen that the lowest value of the frequency in the islanded zone is 48.8Hz if the virtual inertia is used. Without virtual inertia feature the corresponding value is 47.7Hz.

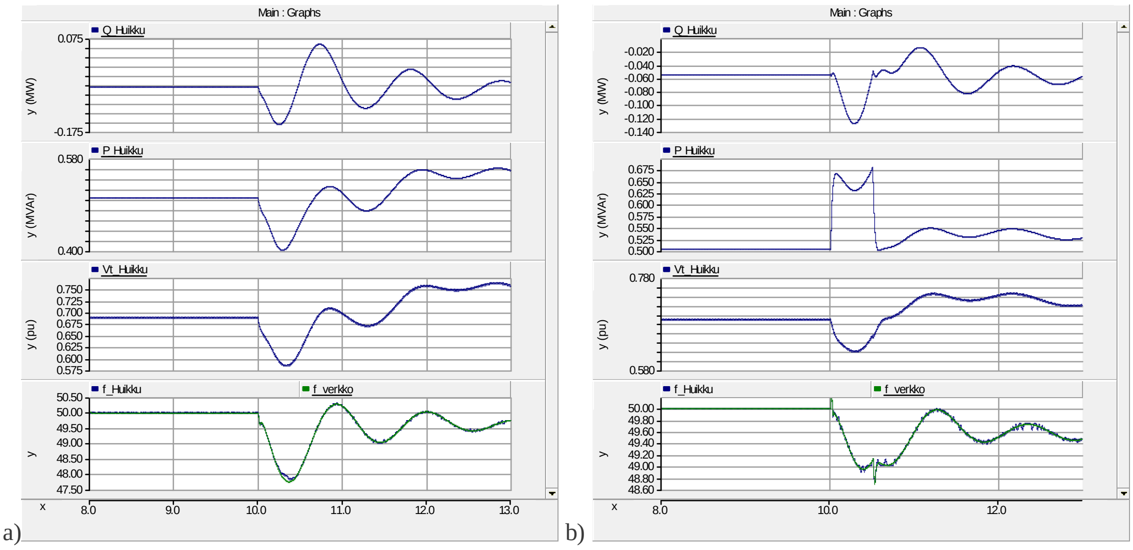

Fig. 5. Active power, reactive power, wind turbine line to line voltage and frequency of the islanded zone: a) wind turbine without virtual inertia, b) wind turbine with virtual inertia.

If the induction generator wind turbine is used the same measures as in Fig. 5. are shown in Fig. 6. In addition, the rotational speed of the generator in p.u. is illustrated. The active power of the wind turbine increases after islanding like in virtual inertia case. However, the natural response of the induction generator wind turbine to the frequency change is to oppose the change of wind turbine speed. The oscillations in active power, reactive power, network voltages and frequency have lower frequency than in the case of full power converter wind turbine. The lowest value for frequency is 48.7 Hz.

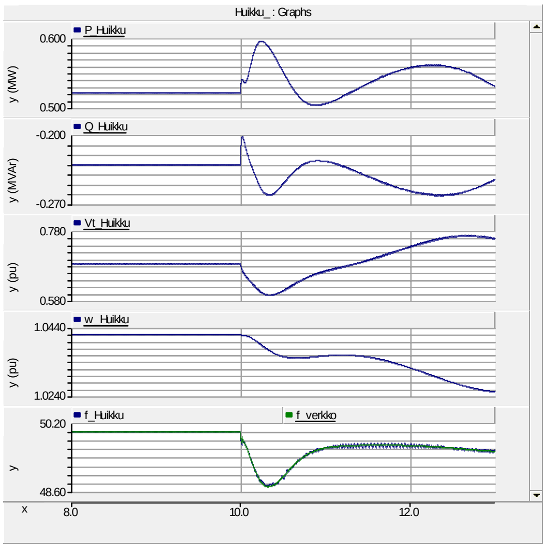

Fig. 6. Active power, reactive power, wind turbine line to line voltage, rotational speed of the wind turbine and the frequency of the islanded zone when induction generator wind turbine is used.

3. Conclusion

The aim of this study was to introduce the simulation model constructed in PSCAD for wind turbine virtual inertia studies. The network model used in the study contains parameters measured from Finnish network in the area of Hailuoto. The simulation results show that the virtual inertia can contribute to the frequency of the islanded area in a similar way as the wind turbine with induction generator. The importance of virtual inertia feature is increasing as the number of wind turbines installed in the electricity grid increases. Thus, further studies relating to the topic is needed.

References

1. H. Laaksonen, Hailuoto PSCAD simulations, SGEM internal research report, 2FP – WP 5 and 6 (Task 5.1 and 6.13.2), 28.3.2012, p. 51.
2. A. S. Mäkinen, H. Tuusa, Impact of strength of fault current path on the operation of decoupled double synchronous reference frame – phase locked loop, International conference on Renewable Energies and Power Quality, March 2013, Bilbao, Spain, 6p.