Wind power drive laboratory test setup

The purpose of the work was to build a test setup which could be utilized in studies related to operation of variable speed wind turbine. The study continues the work related to DC distribution network [1] by modifying the laboratory test platform to be suitable for wind turbine studies. The DC distribution network consists of rectifier, DC-link and load inverter. Thus, additional converter for controlling the generator, DC motor to emulate the wind turbine torque and high level control system should be constructed to make the laboratory test setup adequate to wind turbine with full power converter studies.

The circuit diagram of the laboratory test setup for wind turbine that uses permanent magnet synchronous generator (PMSG) and full power converter is shown in Fig. 1. The electric drive uses KONE MX18 PMSG and the three level three wire rectifier, which is used to control the operation of the PMSG. The generator side converter, like grid side converter and load side converter, is sized to 10kW. The converters are interconnected using DC-buss which voltage level is 750 V. The Siemens DC-motor is used to emulate the behavior of the wind turbine rotor by producing mechanical torque to the rotor shaft of the PMSG. The torque of the dc-motor is controlled using ABB DCS500B thyristor rectifier. The reference signal for the torque is gained from the high level control system of the wind turbine which is constructed using dSPACE real-time simulator. The nominal power of the rectifier is 58kW. The gearbox couples the PMSG and the DC-motor with the gear ratio of 1:4.

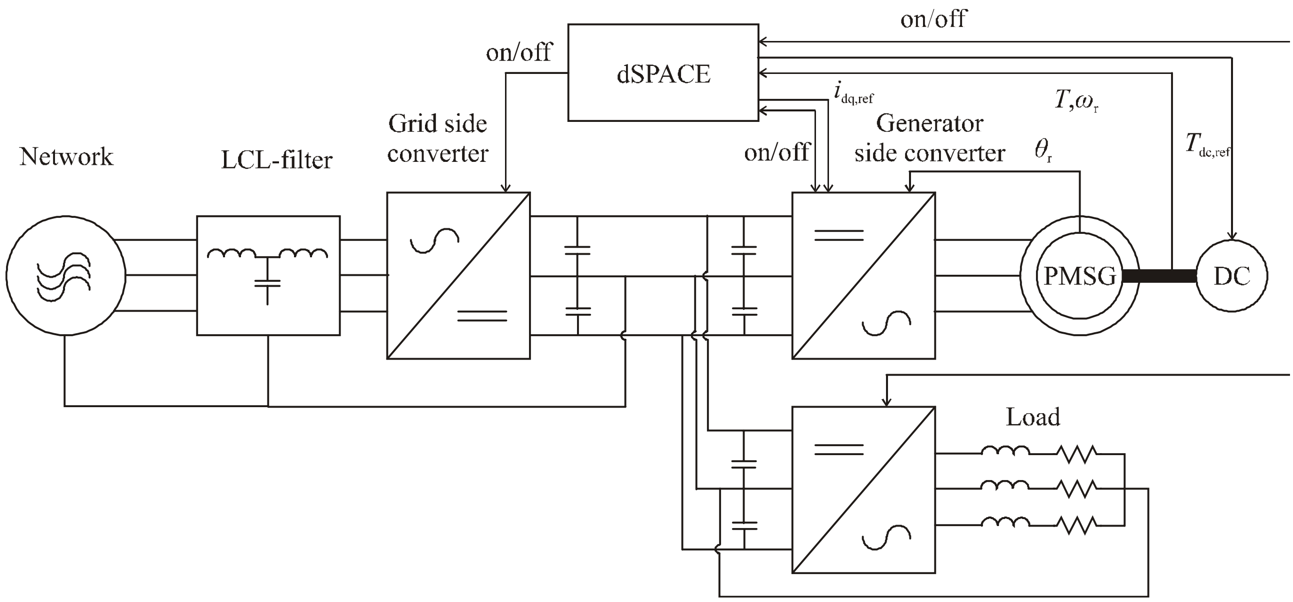

Fig. 1. The circuit diagram of the PMSG prototype.

Control system

The generator side converter controls the speed of the PMSG. The dSPACE is responsible of the outer control loop, i.e., the speed control loop, and the output of the loop is the reference for stator current d- and q -components in a rotor reference frame. In normal operation mode, the d-axis current reference is set to zero. The current control system is implemented using Freescale MPC563 microcontroller. The microcontroller is located on the controller card in addition with the logic circuits for modulation signals, couplings for current and voltage measurements and current limiters. The connection between the controller card and the PC is done using series bus.

The grid side converter controls the dc-link voltage to a constant value thereby assuring that the generated active power is fed to the network. The control system is oriented to the synchronous reference frame which rotates with the network voltage. The network voltage angle is extracted using phase locked loop (PLL). [2] The control systems are implemented using MPC563 microcontroller. The GSC is connected to the network through LCL-filter.

Third converter connected to the dc-link is the load side converter (LSC) which feeds passive load. The three level four wire load side converter generates output voltages that have constant frequency and amplitude. The dSPACE can be used to activate and de-activate all the converters.

The hardware arrangement is shown in Fig. 2. The signals between the dSPACE connector panel and the converters are isolated using Wiedmuller WAS5 VVC HF voltage signal isolators.

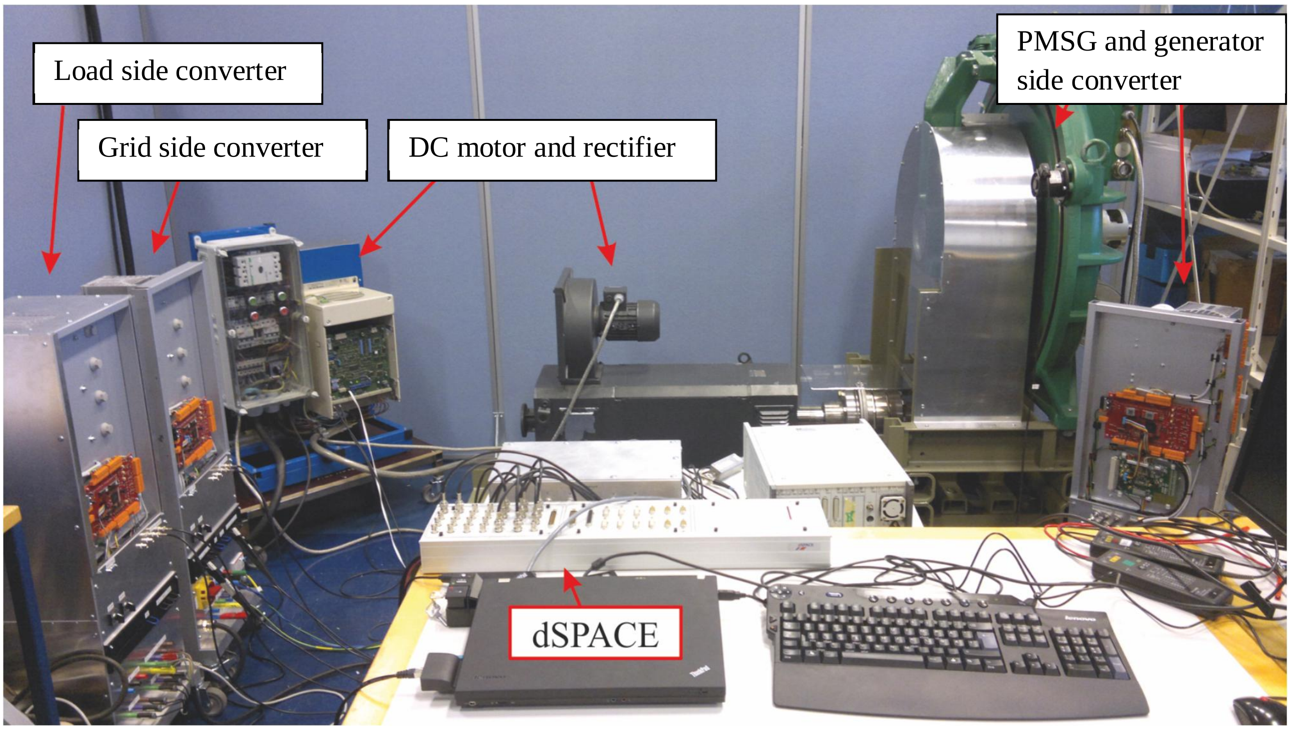

Fig. 2. The hardware arrangement of the laboratory test setup.

Response to load change in the DC-link

The operation of the laboratory system was tested under operation where the load in the DC-link changed suddenly. The positive directions of the active powers are illustrated in Fig. 3. The load change were realized by activating the load side converter to operation at time 0,4s. The connected load is greater than the generated PMSG active power.

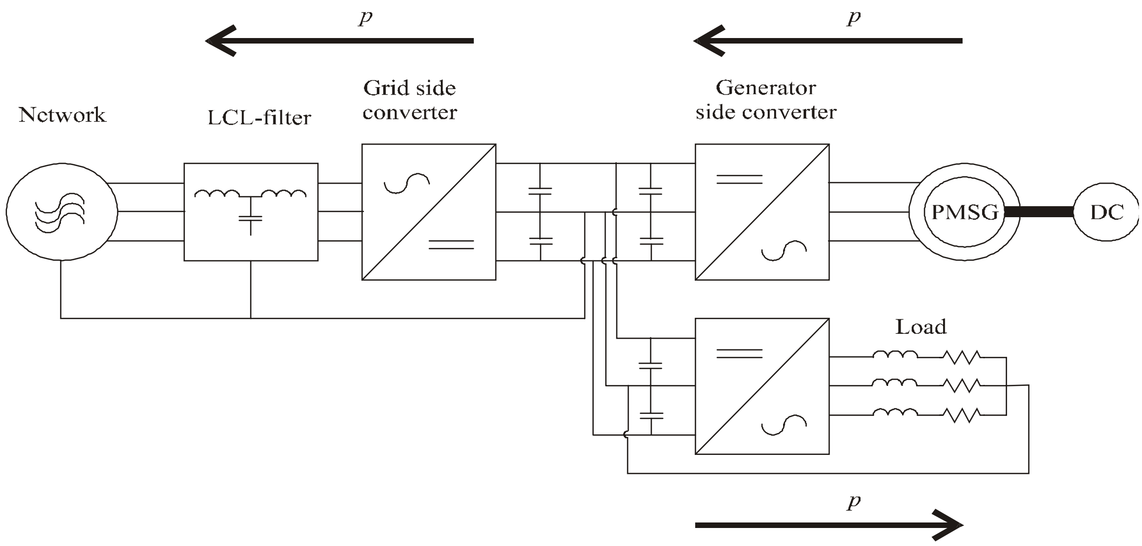

Fig. 3. Laboratory setup in test case and positive active power directions.

The AC side active and reactive power of the PMSG are illustrated in Figs. 4a and 4b. Due to the fact that the active power of the PMSG wind turbine is dependent on the wind conditions the output powers do not change as a result of the load change. The average active power of the PMSG is 9kW.

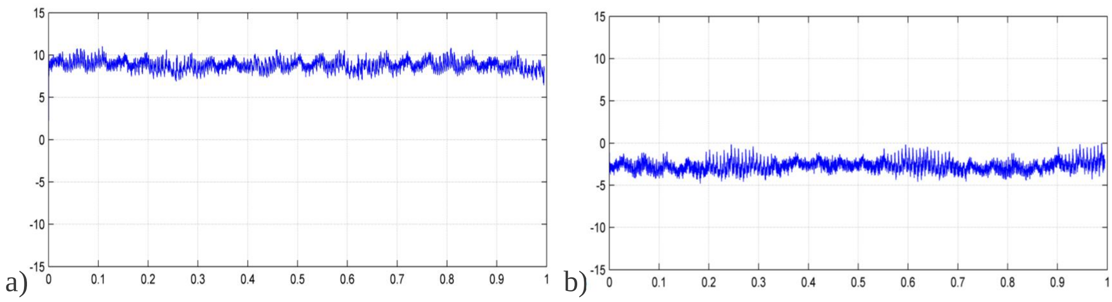

Fig. 4. a) Active power of the PMSG, b) reactive power of the PMSG.

The AC side active and reactive powers of the load side converter are shown in Figs. 5a and 5b. The step change in the active power occurs at time 0,4s as a result of the load side converter activation. The output of the active power is slightly over 10kW. The AC side active and reactive powers of the grid side converter are shown in Figs 6a and 6b. It can be seen that the direction of the active power output changes because the load is greater than the generated power of the PMSG. The output power direction change happens because the DC-link voltage controller keeps the power balance in the DC-link.

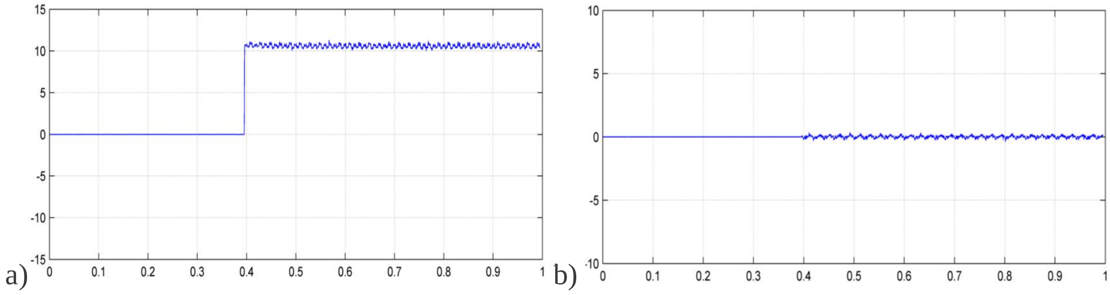

Fig. 5. Load side converter: a) active power, b) reactive power.

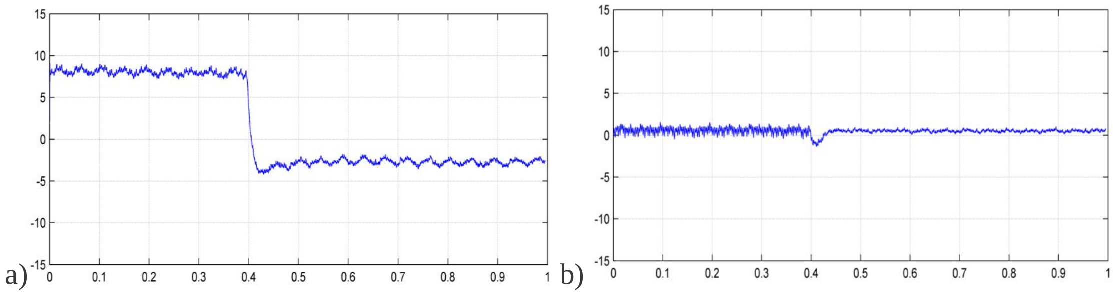

Fig. 6. Grid side converter: a) active power, b) reactive power.

The DC-link voltage is shown in the Fig. 7. When the load changes in the DC-link the DC voltage drops. However, the DC-link voltage controller reacts to the voltage drop and returns the DC-link voltage back to reference value by altering the output power of the grid side converter.

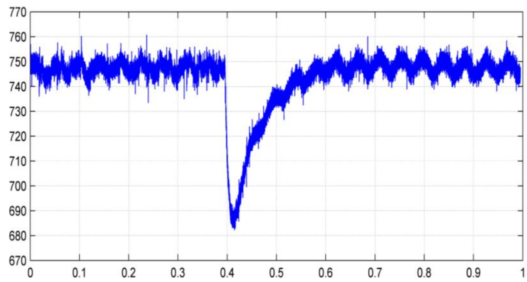

Fig. 7. DC-link voltage.

Conclusion

The laboratory test setup for variable speed wind turbine was constructed and its performance was tested under sudden load change conditions. The test environment consists of grid side converter, load side converter, generator side converter, permanent magnet synchronous generator, DC motor and rectifier for the DC-motor. The high level control system is constructed using the real time simulator dSPACE.

Based on the test results the laboratory setup seems to work properly. However, the parameters of the current and DC-link voltage controllers are not optimized yet. For example, the response time of the DC-link voltage to the load change is rather slow. Further work contains the controller parameter tuning and the construction of the network emulator which uses the Real-Time Digital Simulator (RTDS).

References

[1] O. Pokkinen, Tasasähkönjakelun tutkimiseen soveltuva testilaitteisto, Kandidaatin työ, Tampere, 2010, Tampereen teknillinen yliopisto. 28 s.

[2] M. Jussila, Comparison of space-vector-modulated direct and indirect matrix converters in low-power applications, Doctoral Thesis, Tampere University of Technology, Finland, 2007.