

## Setup and performance test of a small-scale vertical axis wind turbine

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The acknowledgement that mankind has a limited amount of resources in energy and a growing demand, joined with the awareness of the environmental impact of an only fuel-based electricity production have led to the expansion and democratization of renewable and green energies. The wind electricity production nowadays exists under various forms, differing one from another by their size, their mechanical structure and their power production.

This master thesis aims at describing the different steps of the installation and accomplishment of the performance testing of a small-scale vertical wind turbine developed by the Swedish company EXAMEC. The company has since a few years ago developed vertically rotating wind turbines for electrical power generation and intends to develop optimized generators as well as control circuits for the units. The cooperation between EXAMEC and The Lund Institute of Technology has for final aim to provide fully operational small-scale wind electricity solutions.



Picture: EXAMEC's vertical wind turbine

The tasks performed during this project cover most of the areas of such a facility, ranging from electrical and mechanical considerations to organization and installation of the setup.

A performance test for a wind power station consists in comparing the wind power received by the turbine to the electrical power produced as an output of the installation. As the final purpose of this study is to come up with a full solution for a grid-connected turbine, the electrical power to be monitored is the one delivered to the grid, downstream of the control units. Furthermore, it is necessary to be able to monitor the wind power over time, which is calculated knowing its speed and density.

The work achieved was first to establish the specifications of this project: what are the requirements for implementing the performance test of a wind turbine? Which equipment is needed? The study of setups already existing and by referring to the standards established by the International Electrotechnical Commission (IEC), the criteria concerning the characteristics of the measuring equipment and the general disposition of the setup could be decided.

The next step consisted in finding suppliers for the measuring equipment and installing the whole setup following the prerogatives determined earlier. The Dutch company EKOPOWER could provide a solution adapted to the requirements of this project. The sensors required for such a performance test are an anemometer and a wind vane, measuring respectively the wind speed and direction, as well as a pressure and a temperature sensor because of the influence of these parameters on the characteristics of the air.

The main structure of the wind turbine was installed on the roof of the mechanical building of LTH. It required an adapted

structure able to support the weight of the equipment and to include safety measures (wires, vertical stabilization) in order to guarantee the safety of the turbine when operating. The turbine is connected to a generator located at the basis of the mast carrying the rotor. The three-phase power generated by the turbine is then sent to an operating room where the control system is installed.

The actions of the different modules constituting the wind turbine setup have to be coordinated and controlled in function of their behavior and the external conditions. This control system consists mainly in three controllers: one main control unit in charge of the supervision of the whole setup ("dControl") and two microcontrollers, in charge of the electrical converters responsible for adjusting the power produced by the wind turbine and making it compatible with the grid. For controlling dControl, the sequence was written in the C++ programming language. It has to give an appropriate response to any kind of situation, depending on the inputs received by dControl.

In the part of the code dedicated to the control sequence of dControl, the structure is divided into two loops: the first one is used for operating in a normal situation. If any error occurs, or the system is required to shutdown, the code switches to the other sequence, dedicated to the shutdown of the system. Having two independent loops grants a good reaction time to the system if anything occurs and more flexibility for handling the response to non-normal situations.

In order to test this sequence before using it with the real setup, a modeling of the facility has been created with the Dymola software. Dymola is a simulation tool used for creating models and simulations of integrated and complex systems for use within automotive,

aerospace, robotics, process and other applications. Hence it was used for simulating the behavior of this wind power system, by reproducing the different modules and components constituting it.

In order to evaluate the properties of the wind turbine when operating in an outdoor environment, a first performance test has been implemented. The purpose of this test is to determine the raw power the turbine can produce and to test the properties of the measuring equipment. In this test, the generator is connected directly to a resistive load, which consists in a set of nine identical heaters, each phase being connected to three of them. The advantage of this setup is that no regulation on the frequencies or on the levels of the voltage and current is required.

As a summary, this paper covers all the following aspects of the design and installation of a small-scale wind power facility:

- The requirements and environment of a performance test for a wind turbine.
- The installation process of the turbine on the roof including the electrical connections.
- The installation and tests of the measurement system
- The design and details of the C++ control sequence ruling over the facility.
- The description of a Dymola model able to simulate the behavior of a wind power setup such as the one presented in this project.
- The design of the cabinets in charge of the electrical part of the setup.

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