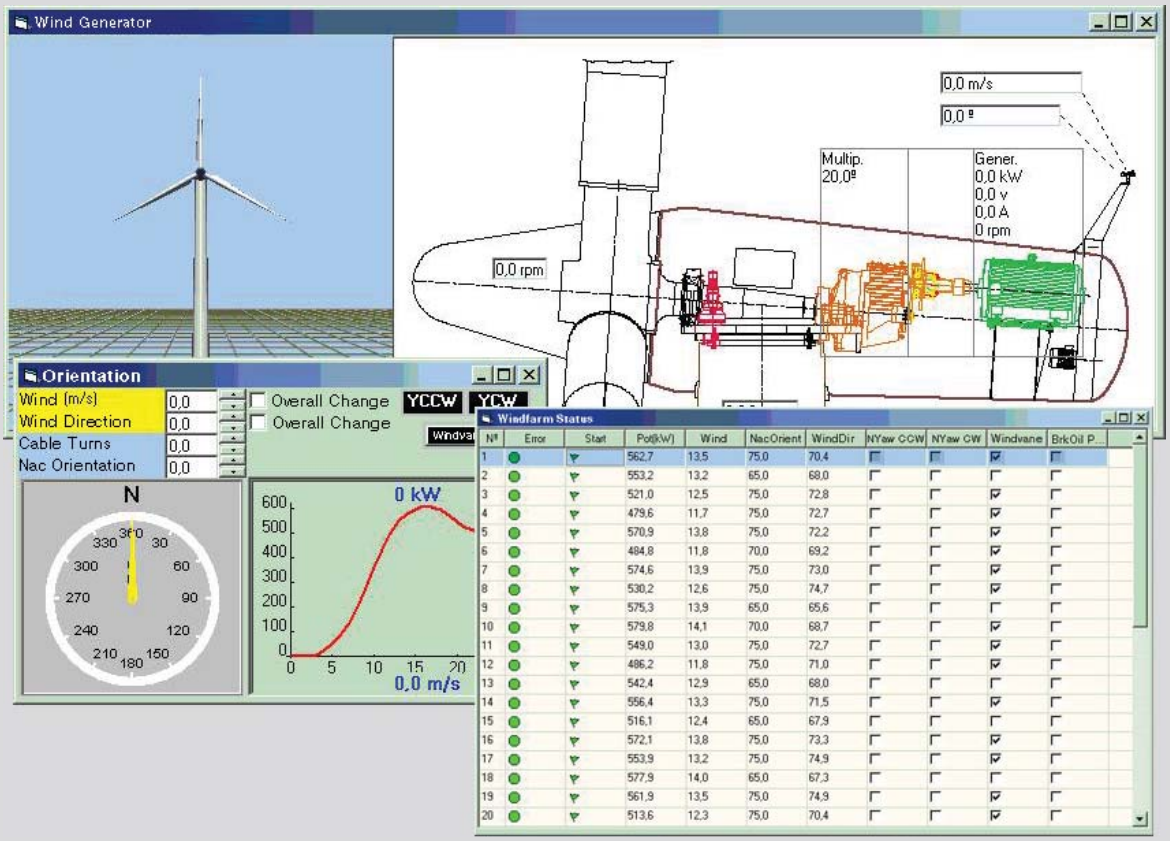
Alternative & Renewable Energy
Training Systems

WIND FARM SIMULATION SOFTWARE



GENERAL DESCRIPTION

A Wind Farm is a set of Wind Turbines, located near each other, sharing a common point of connection to the electrical distribution grid called a Common Connection Point. Generally, a Wind Farm has a SCADA (Supervisory Control and Data Acquisition) system used to control individual wind turbines and monitor the entire wind farm. For example, the wind farm operator may use the SCADA control system to implement operational policies of the owner. This SCADA system is also used to monitor the operational aspects of the Wind Farm and give technicians a view of how the systems are behaving.

From an operational standpoint, a Wind Farm Control Center is an installation where the set of wind turbines can be controlled, monitored, and maintained. The Wind Farm Simulation Software simulates the behavior of every aspect of the wind turbines in a wind farm. A simulated SCADA system and a user friendly HMI (Human Machine Interface) create an ideal Operator and Technician Training System. The wind turbines in

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GENERAL DESCRIPTION (cont.)

this software program are modeled after the popular Bonus 1300 KW wind turbine, a variable pitch, stall regulated, dual fixed speed wind turbine with a squirrel cage asynchronous generator. Additional versions of the Wind Farm Simulator are planned for doubly-fed induction generators.

The Wind Farm Simulation Software is a software-only solution: no special hardware is required, only a PC with adequate performance capabilities. The HMI is designed to be user-friendly and intuitive. It presents every parameter as well as the values of the signals, both internal to the wind turbine and published to the SCADA system. Each wind turbine in the wind farm has its own dedicated simulator, enabling users to change individual parameters independently of the other turbines and observe the resulting behavior of each wind turbine. Access to each signal and parameter is designed to easily change the different scenarios that the user may want to create and observe.

Controlling and monitoring of the wind turbines is done through communication lines that tie each wind turbine to a central SCADA system where the operator of the Wind Farm can monitor the status and production of each system, shut each system down, give permission for startup, etc. The SCADA system also collects data from the wind turbines and stores it for further analysis. All these functionalities are also exercised in the Wind Farm Simulator.

The Wind Farm Simulator solves the problem of how to train personnel who must understand the behavior of the sub-systems of the wind turbine as well as the wind farm as a whole. Wind farm operators need their technicians to understand hundreds of operating parameters and to be able to react to a plethora of nominal and faulty operating conditions. A technician or operator is able to reproduce with the Wind Farm Simulator situations such as: vibration sensor activated, motor superheated, asymmetry of currents, upper voltage exceeded, lower voltage exceed, (Security) UPS failure, hydraulic brake pump subsystem starting too often or pumping for too long, excessive brake time, gear bearing superheated, thyristors superheated, bypass contactor welded, bypass contactor not working, excessive angle error in the pitch angle of any of the three blades, pitch oil error, yaw position error, error in the RPM reader, brake lining too thin, gear oil pressure too low, untwisting cables error, etc.

Nothing but a wind power generation system simulator, operating under an unlimited number of conditions, can impart the type of advanced training required. A simulator is able to create the meteorological as well as electrical, and mechanical operational scenarios that could not be produced on-demand with a real wind turbine.

In spite of having access to real systems to train their technical personnel for installing, commissioning and servicing their wind turbines, a simulator is seen as a necessary tool for advanced learning by the wind energy industry.

The Wind Farm Simulator addresses these requirements using two elements within the software: a) elaborated software models of the behavior of each subsystem in the wind turbine; b) graphic user interfaces that facilitate the setting and visualizing of conditions for these subsystems.

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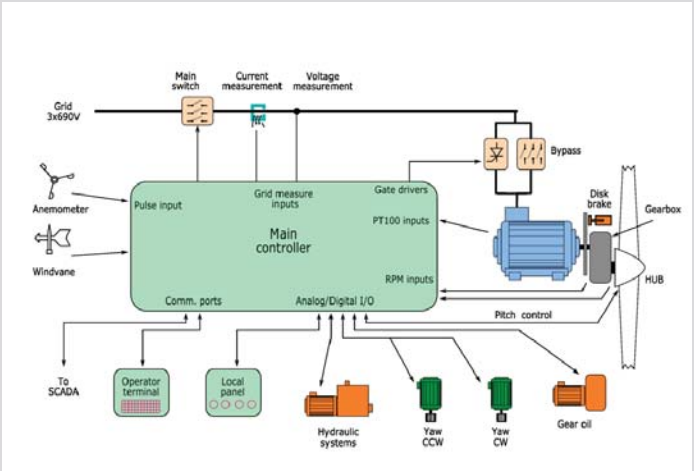
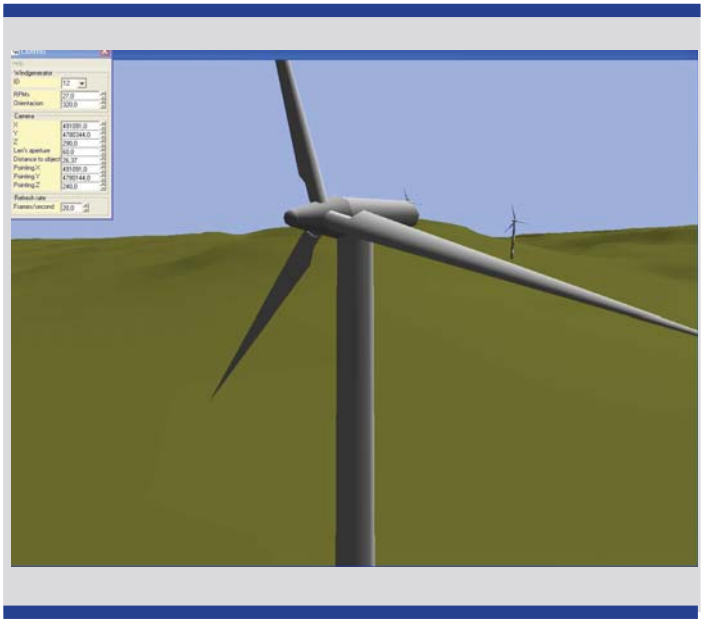
SOFTWARE DESCRIPTION

WInd Turbine Block Diagram



The connection of the generator to the grid while in production is direct. For the “cut-in” operation, the WT uses a set of thyristors for the connection of the generator to the grid during a short, controlled, period of time. The figure above shows the internal structure of a typical WT.

Structure of Simulator



The Wind Farm Simulator (WFS) is organized so that there is a simulator for the Controller of each WT in the Wind Farm. There is also a set of simulators for each subsystem of a WT: hydraulic, mechanical, and electrical.

A single HMI is composed of a number of forms or panels through which users can select the WT they want to monitor and control, accessing its operational parameters and conditions. Users can also access all the internal signals of each subsystem of the selected WT.

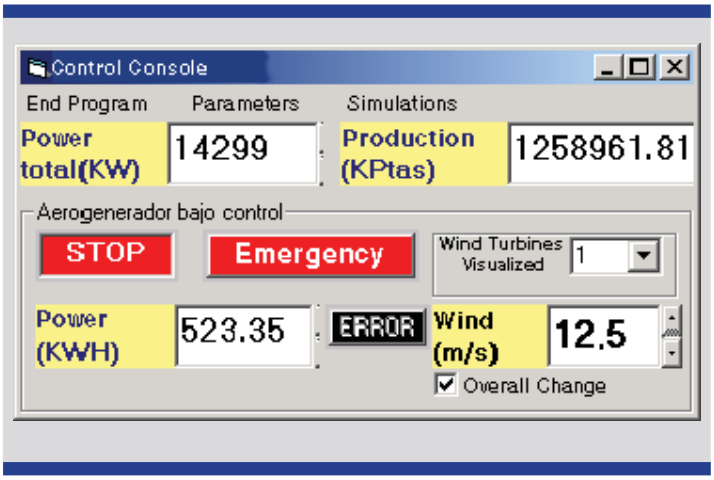
The simulation software also enables users to modify the external conditions (wind speed, wind direction, electrical grid conditions, temperatures, etc.) in which the selected WT is operating.

A specific panel for the simulation of the SCADA of the Wind Farm allows users to see data from all of the WTs simultaneously.

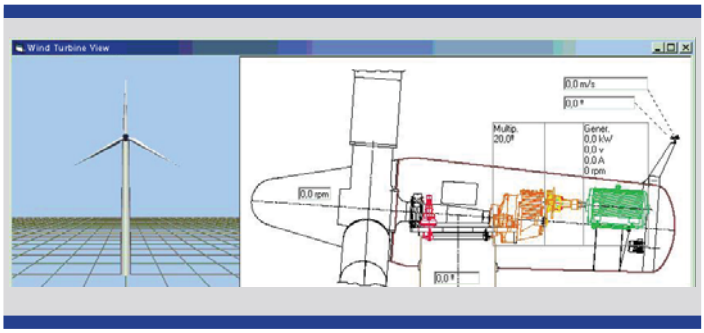
Initial Start-up

The program is designed so that you need a minimum of forms visible to begin the actual simulation of the whole wind farm. However, upon initial program execution, all the forms that constitute the HMI will be visible. The user can change the position of any of these forms, and in some cases, also the size. Upon exiting the software, the program will remember the positions and sizes for the next program launch. Forms are listed below.

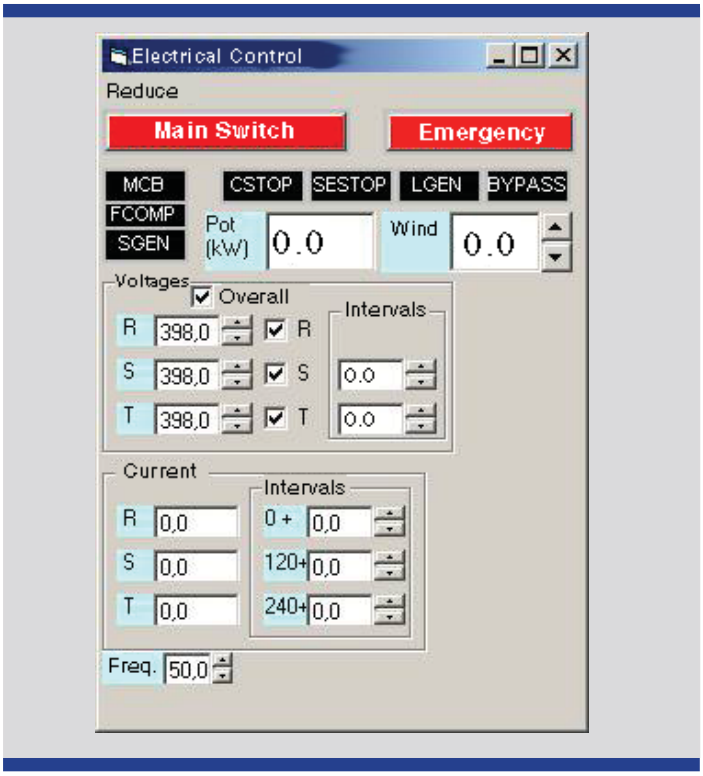
Control Console



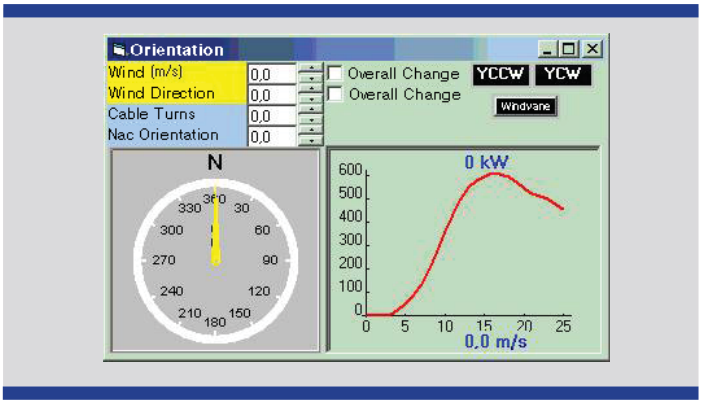
Wind Turbine (WT) View



Electrical Panel

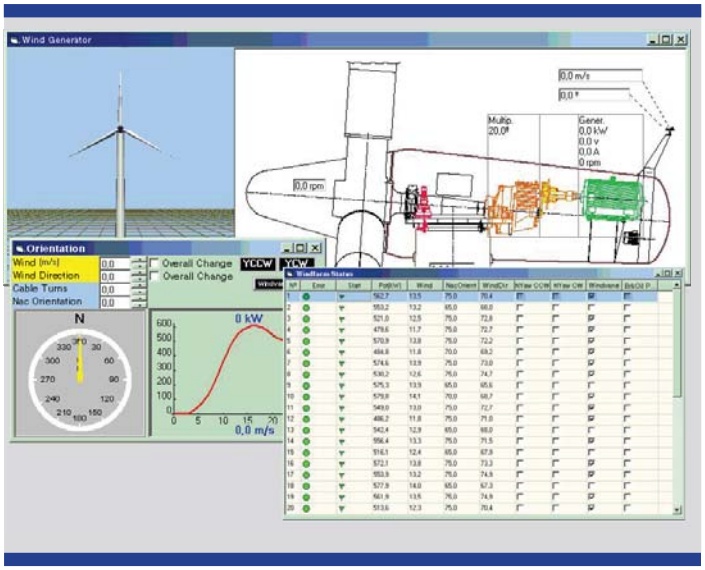


Wind and Nacelle

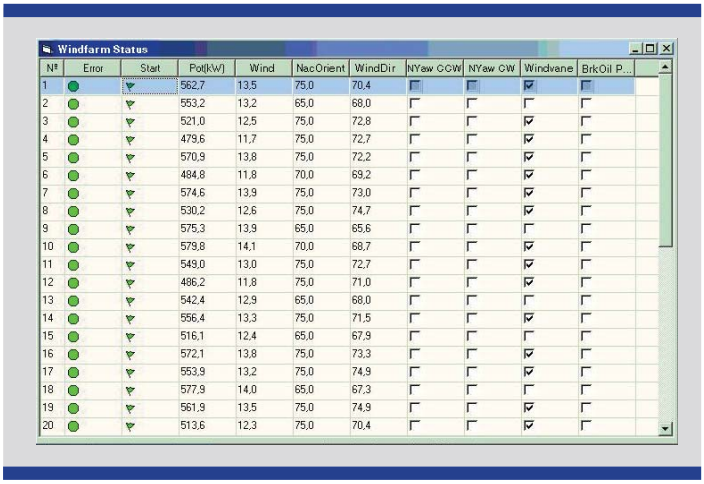


SIMULATORS USED IN PROGRAM

Controller's Simulator



SCADA



Nº	Error	Start	Pot[kW]	Wind	NacOrient	WindDir	NYaw CCW	NYaw CW	Windvane	BrkOil P...
1			562,7	13,5	75,0	70,4				
2			553,2	13,2	65,0	68,0				
3			521,0	12,5	75,0	72,8				
4			479,6	11,7	75,0	72,7				
5			570,9	13,8	75,0	72,2				
6			484,8	11,8	70,0	69,2				
7			574,6	13,9	75,0	73,0				
8			530,2	12,6	75,0	74,7				
9			575,3	13,9	65,0	65,6				
10			579,8	14,1	70,0	68,7				
11			549,0	13,0	75,0	72,7				
12			486,2	11,8	75,0	71,0				
13			542,4	12,9	65,0	68,0				
14			556,4	13,3	75,0	71,5				
15			516,1	12,4	65,0	67,9				
16			572,1	13,8	75,0	73,3				
17			553,9	13,2	75,0	74,9				
18			577,9	14,0	65,0	67,3				
19			561,9	13,5	75,0	74,9				
20			513,6	12,3	75,0	70,4				

The Wind Farm Simulator is a complex program that mimics the actual design of a real WT. Additionally, the goal of the software's design is to present users with an HMI that allows them to easily produce various situations that will help them thoroughly understand the behavior of a Wind Turbine and a Wind Farm.

One key element is the Controller. The WFS includes

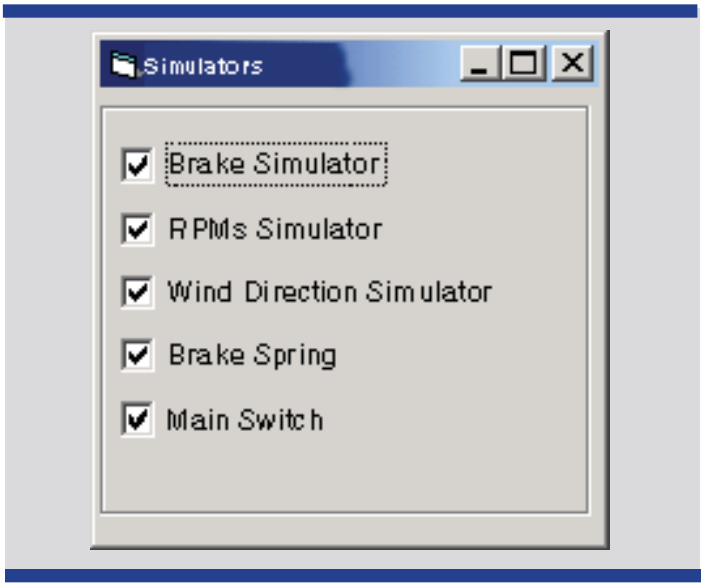
one Controller simulator for each WT in the Wind Farm. This simulator is a key element in the WFS program.

Each Controller's Simulator, for instance, controls all the signals for a single WT, receiving as inputs the signals generated by the other simulators and/or the inputs modified by the user through the HMI. Each Controller's Simulator produces changes in the output signals that are presented to the user and that are also used by the remaining simulators of the other subsystems in the WT so that they react accordingly.

In general terms, the Controller's Simulator is responsible for:

- Starting the WT and connecting it with the grid in production.
- Orientation of the nacelle facing the wind.
- Management of the brake's hydraulic system.
- Monitoring the critical signals to guarantee safe operation, both for the WT itself and for the personnel. This includes commanding safe stopping operations and reporting alarms and error messages to the SCADA and to the operator.

Simulators for Subsystems in the Nacelle



These simulators generate the signals that correspond to the revolutions of mechanical, hydraulic, or electric elements.

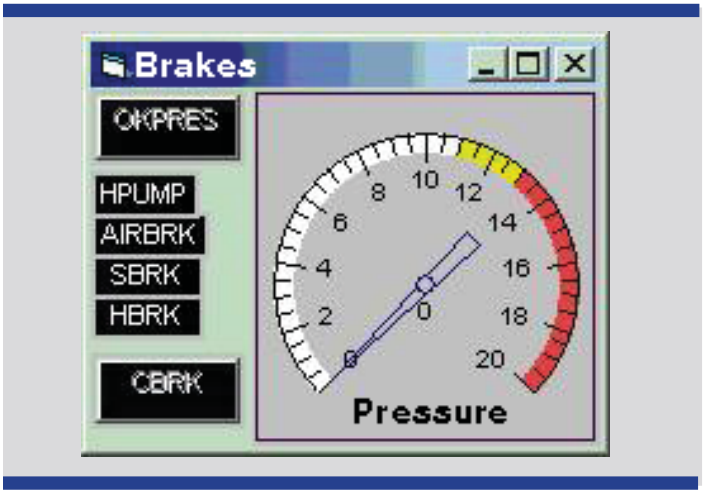
For example, when the brakes are released, the energy from the wind turns the blade's rotor. The revolution speed must be generated in order to simulate the entire mechanical rotating ensemble: blades, hub, rotor, gearbox, brake disc, and generator. The Controller's Simulator monitors this revolution and acts accordingly if it does not meet predefined conditions.

Subsystem simulators include the Brakes Simulator, RPMs Simulator, Wind Direction Simulator, Brake Spring Simulator, and Main Switch Simulator. These simulators are detailed below.

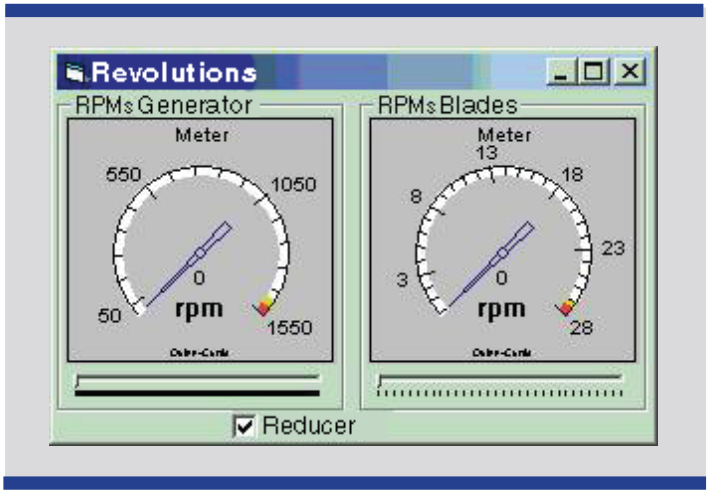
The brake subsystem relies on a hydraulic subsystem that controls how a disc brake is stopped or released. This subsystem simulator includes the following components:

- An oil tank
- A pump that sends oil from the oil tank into an accumulator.
- An accumulator where the oil is kept under pressure.
- A pressure switch that senses the pressure limit in the accumulator.
- A spring cylinder with plunger.
- A pad to stop the disc brake; connected to the plunger.
- Control valves that, when opened, drain the oil from the plunger circuit to the oil tank. The three control valves in this WT are:
  - Normal drain speed, controlled by the SBRK signal.
  - High drain speed, controlled by the HBRK signal.
  - Activation of the blade's air tip, controlled by the AIRBRK signal.
- A sensor for detecting that the disc brake and pad are effectively separated (CBRK signal).

▸ *Brakes Simulator*



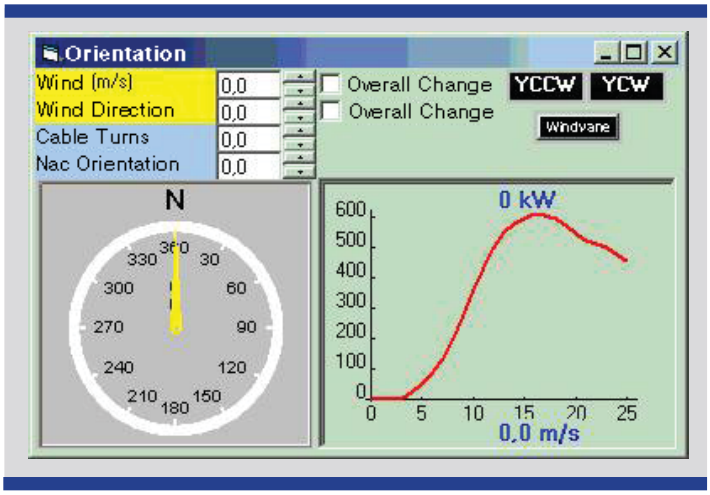
RPMs Simulator



This Simulator takes into account the inertia of the mechanical elements that rotate with the wind: blades, hub, rotor, rotor bearing, gearbox, brakes, generator, as well as the effects of each of the braking signals.

The acceleration or deceleration of the blade rotation depends on the wind speed, aerodynamics, the state of the blade tips (signal AIRBRK), and the position of the disc brakes (SBRK and HBRK signals).

Wind Direction Simulator

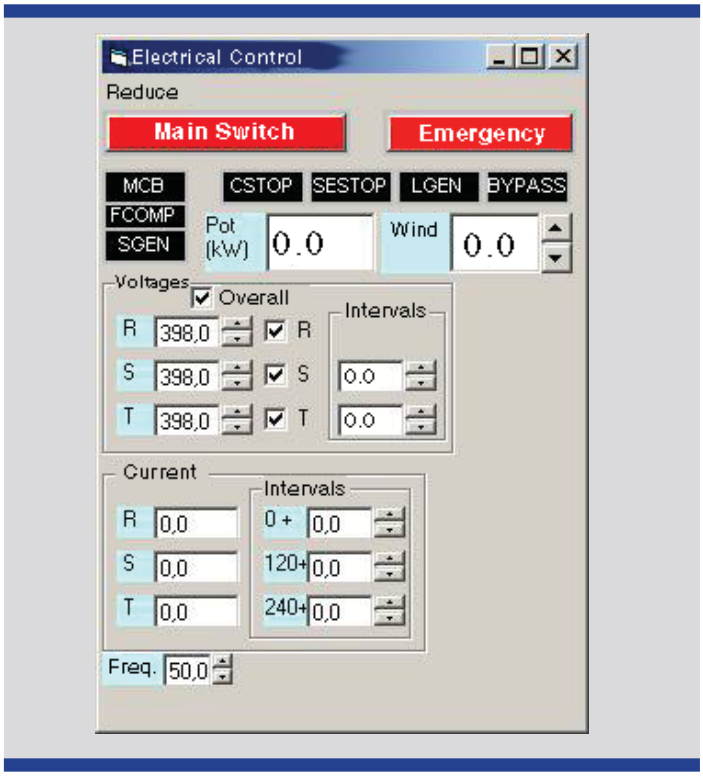


The Controller's Simulator reflects changes in the nacelle orientation signal after the user activates the YCCW (turn counterclockwise) or YCW (turn clockwise).

Brake Spring Simulator

This simulator replicates a spring forcing the pad against the disc brake. Users can disable this simulator to observe how the Controller's Simulator detects a problem with the braking system.

Main Switch Simulator



Typically, electrical emergencies are solved in real-time. Therefore, the WFS safety mechanism does not rely on the WT's Controller for these solutions.

Rather, emergencies are solved through relay logic or specific hardware. The Main Switch simulator sets the Main Switch to the OFF state whenever the EESTOP (Emergency Stop) is ON or the Electric Control Panel Emergency button is pressed.

Reflecting Lab-Volt's commitment to high quality standards in product, design, development, production, installation, and service, our manufacturing and distribution facility has received the ISO 9001 certification.

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