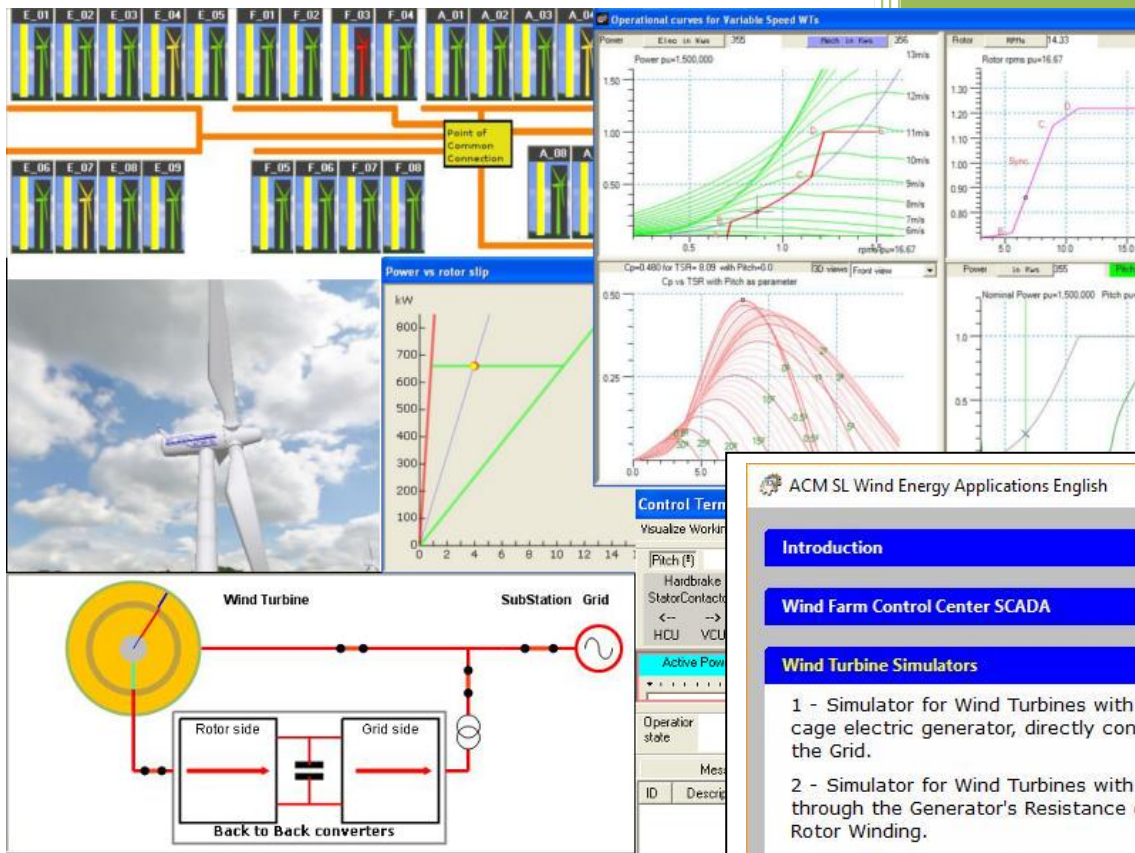




WIND ENERGY Applications v 1-1



ACM SL Wind Energy Applications English

Set of Wind Turb

- Introduction
- Wind Farm Control Center SCADA
- Wind Turbine Simulators
 - 1 - Simulator for Wind Turbines with squirrel cage electric generator, directly connected to the Grid.
 - 2 - Simulator for Wind Turbines with control through the Generator's Resistance of the Rotor Winding.
 - 3 - Simulator for Wind Turbine with Doubly Fed Induction Generator (DFIG)
- Some practical experiments
- Special applications
- Tutorials

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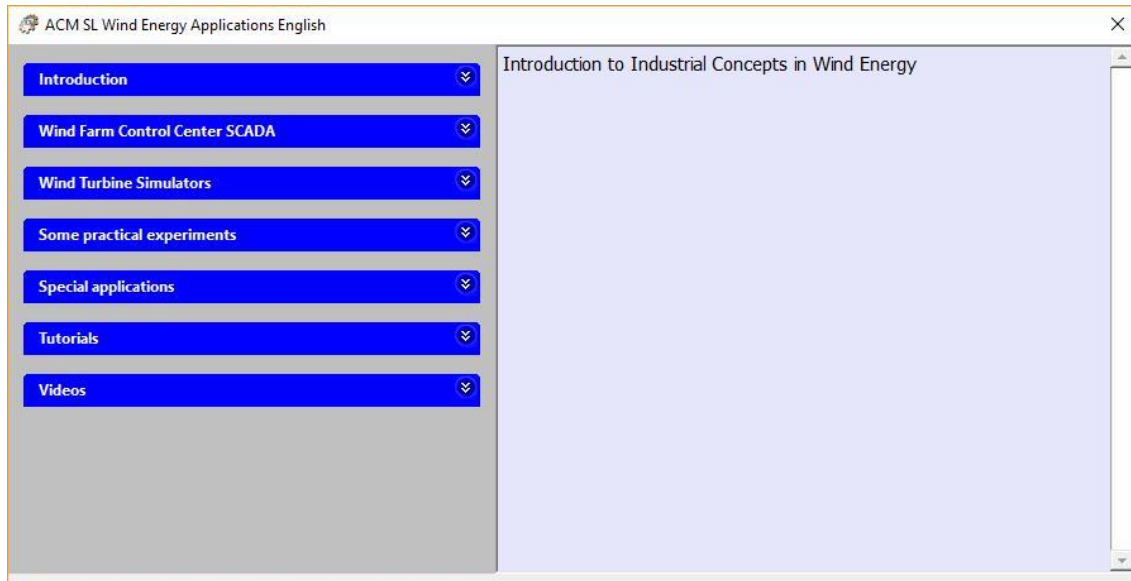
November 2017

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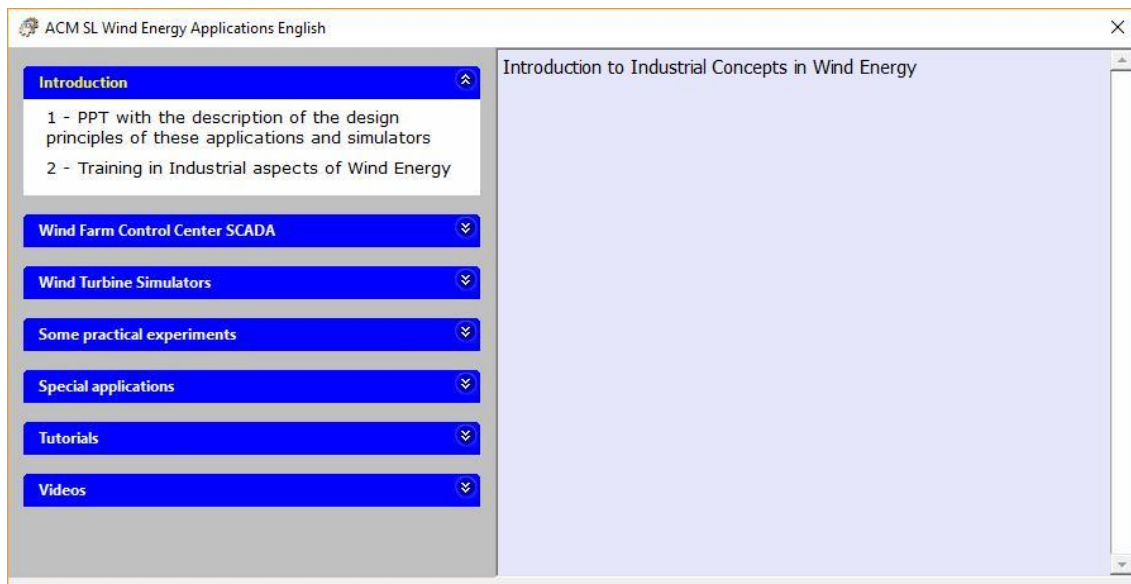
What's new in this version?

In this version we introduce **a simpler-to-use user interface**, grouping applications by sections, and adding **new didactic material**. All the applications, tutorials, suggested experiments, videos, etc. are now accessible through a single Desktop entry labelled “ACM SL Wind Energy Applications”: its execution presents a new [launcher](#), as shown in the next figure.



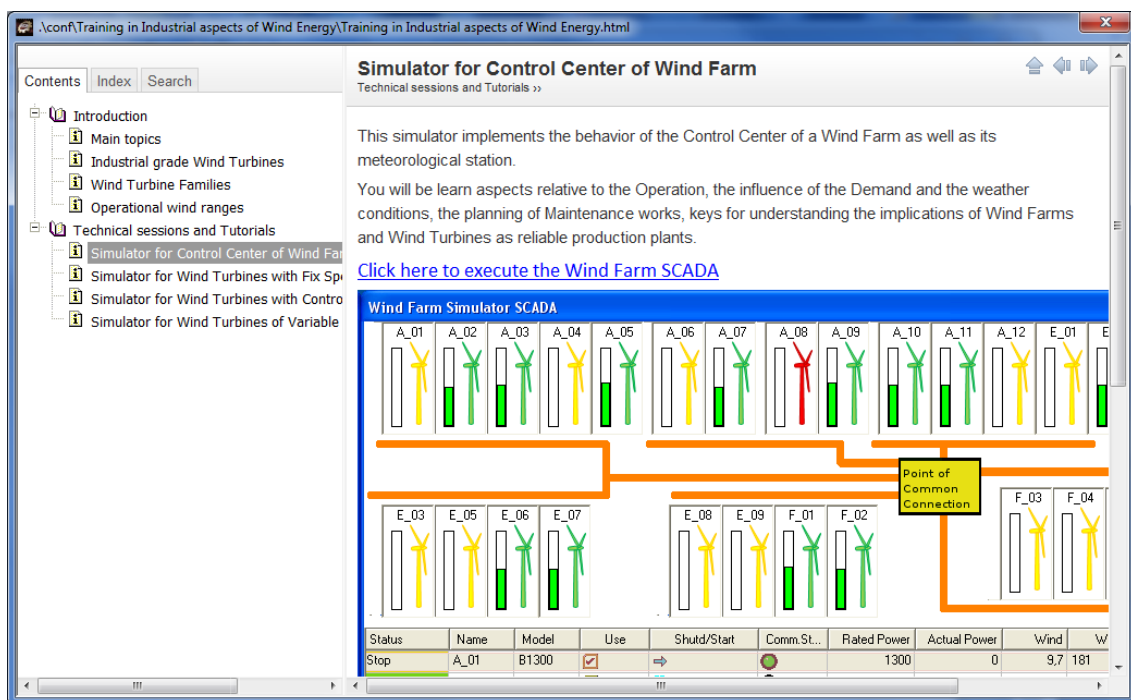
Each entry in the left panel can be expanded to present the access to different options. The order of these sections helps locating specific simulators, applications, etc. Next figures show expanded views of these options.

“Introduction”

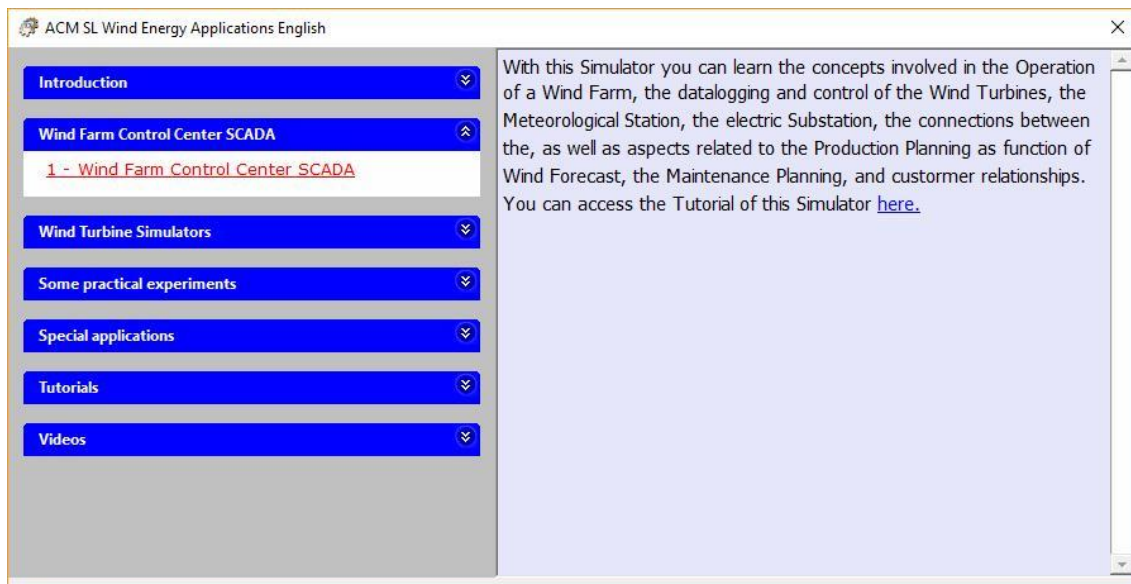


This section contains pointers to:

- a PowerPoint presentation that explains the concepts used to develop this material.
- A web application that continues the introduction above and includes links for the launching of the four simulators, with an easy to follow introduction.

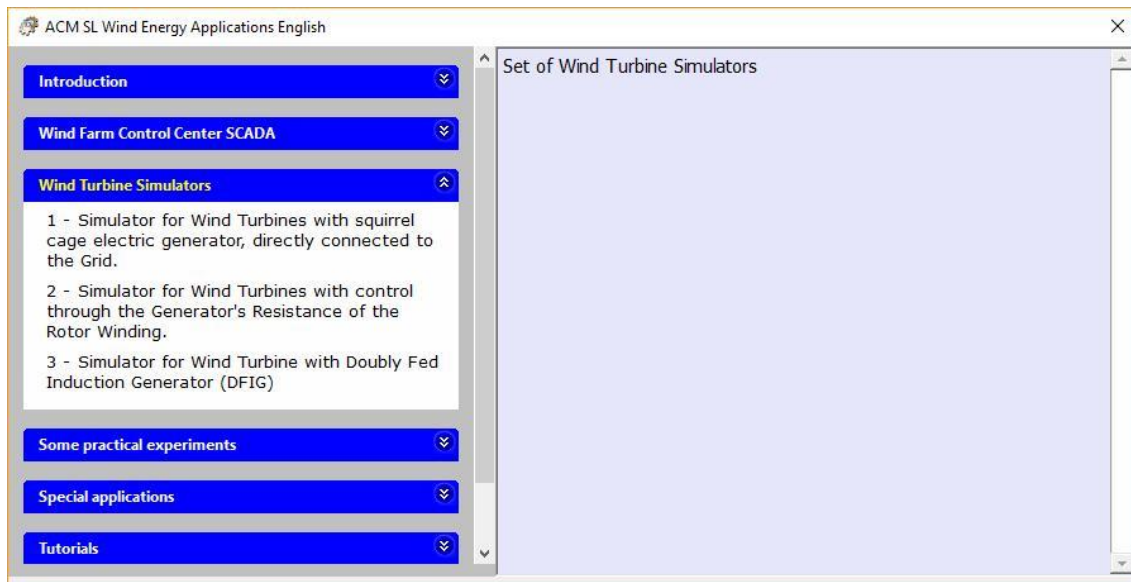


Wind Farm Control Center SCADA



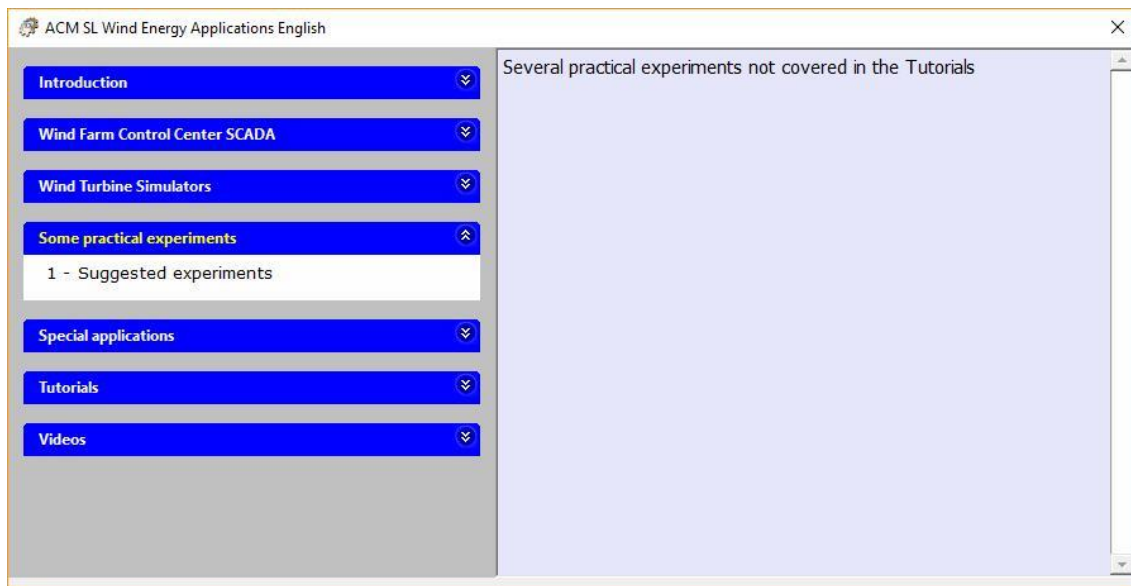
This section contains a single pointer to the launcher of the “*Wind Farm Control Center SCADA Simulator*”. With it, the trainee can learn the concepts required to operate a Wind Farm, together with other aspects (Grid) required to understand the following Wind Turbine Simulators.

Wind Turbine Simulators

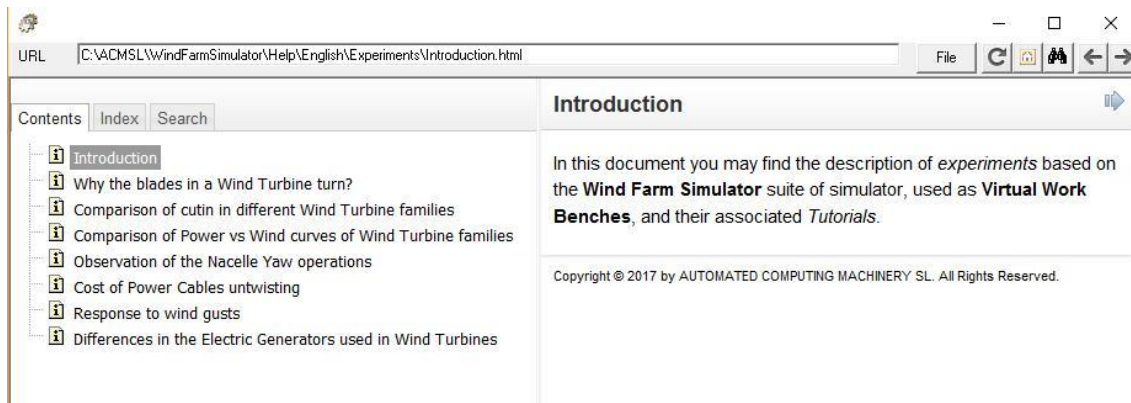


This section contains three pointers for the launcher of the 3 Wind Turbine Simulators. It is recommended to follow the order in which they are presented, as they are designed with as a didactic unit.

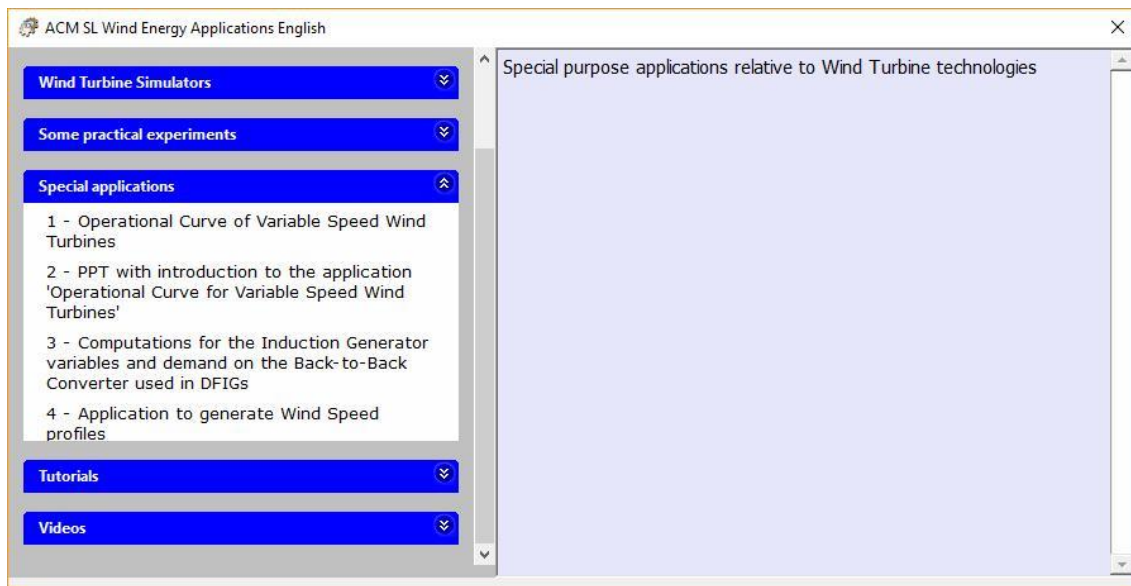
Some practical experiments



Each of the simulators contains 'Training sessions' or classes, specific for each one of them. In this section there is a link to a web application with suggested experiments with cross references to several of them.



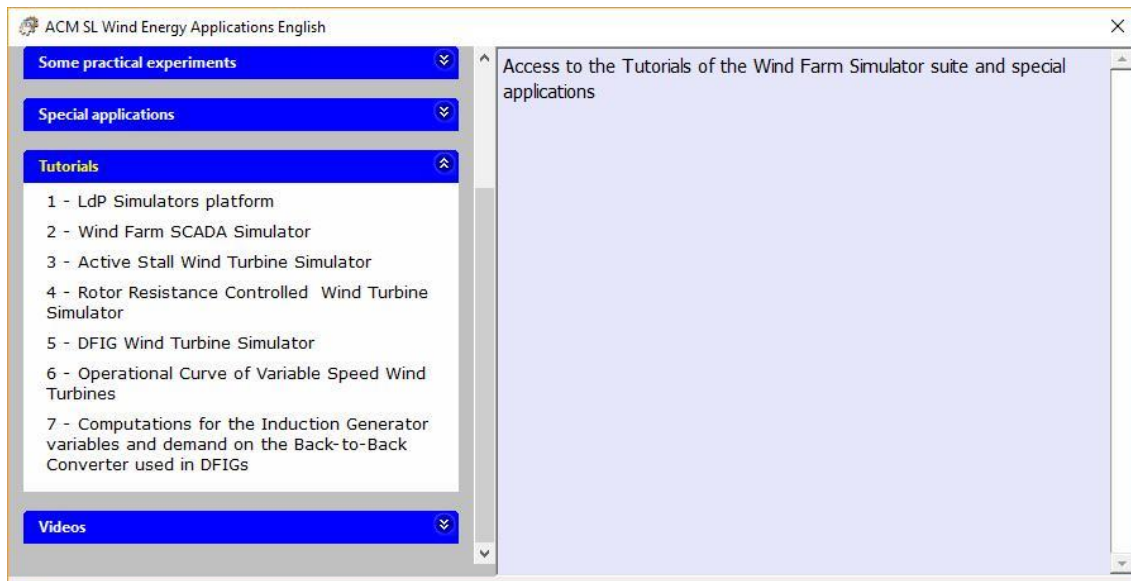
Special applications



Together with the *Real Time Simulators* for the Wind Farm SCADA and the Wind Turbines, we offer two applications, described in detail below, for the study of two key aspects of Wind Turbines: their *Operational Curve for the Drive Train* and the *Back-to-Back converter variables* in *DFIG* Wind Turbines.

There is also another application for the creation of '*Wind profiles*', useful for creating specific *wind gusts profiles*, or wind speed evolutions recorded from actual Wind Farms to observe the reaction in the Simulators.

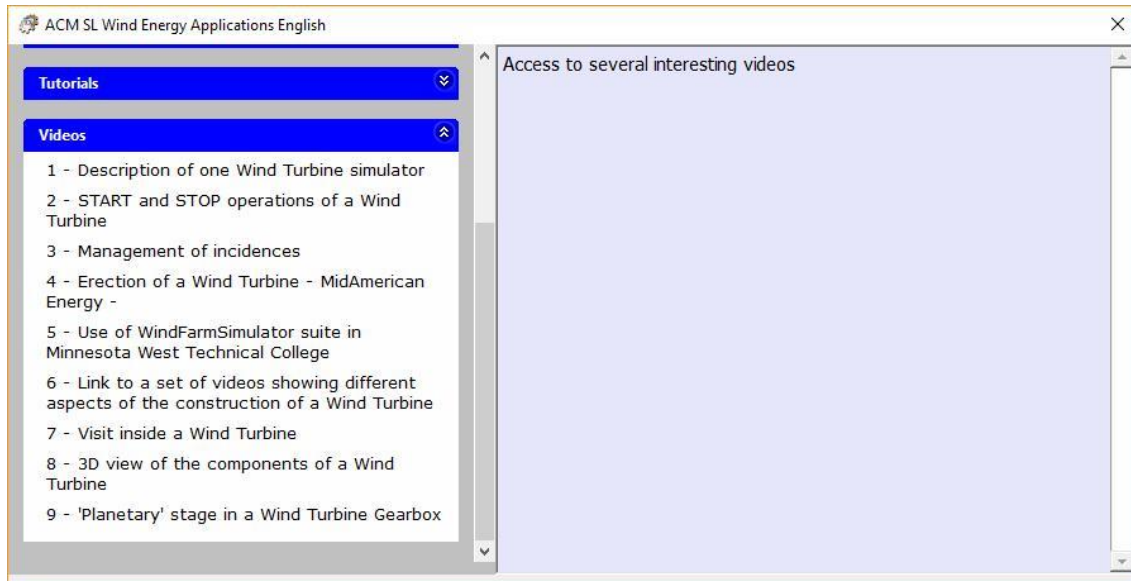
Tutorials



The user can access the tutorial associated with each simulator and application when they are being executed. However, sometimes it is convenient to have a handy way to access these

tutorials outside the simulators and application. This section has pointers with direct access to all the available tutorials.

Videos



This section has pointers to videos, made by ACM SL or freely available in the Web, that we recommend as useful didactic material.

Summary

The “**ACM SL WIND ENERGY APPLICATIONS**” suite is a set of *Real Time Simulators* and *Tutorials*, and additional *specialized applications*, aimed to expose the technologies used in actual Wind Turbines.

The Real Time Simulators for Wind Turbines are specific for each of the families in the installed based. They focus on showing the **behavior** of each of the subsystems in the Wind Turbine, using high performant graphic presentations (synoptics), and of the Wind Turbine as a standalone Production Plant itself.

Another Real Time Simulator is devoted to show the functionalities and concepts in the Control Center of Wind Farms, covering aspects related to the Grid, the customer relationships, the weather forecasts, maintenance, etc.

Two additional applications complement the required knowledge needed to fully understand the working conditions of modern Wind Turbines:

- **Operational Curve for Variable Speed Wind Turbines.**

This program covers the details that are used to decide the operational conditions of the Drive Train of Wind Turbines that can adapt themselves to different wind regimes (aka Variable Speed Wind Turbines). For example, the ‘DFIG Wind Turbines’ or the so called ‘Full Converter Wind Turbines’.

This application can be used for studying the effect of changing the blades length in the reduction of the Nominal Power of a given Wind Turbine, or the best set of parameters for ‘**repowering**’ a Wind Turbine.

- **DFIGB2B.**

Among the Variable Speed Wind Turbines, the family of Wind Turbines that use an Induction Generator coupled with the so called “Back-to-Back converters” (or B2B) constitutes the biggest percentage of Wind Turbines in use today. Their electrical subsystem (Induction Generator + B2B) is known as **DFIG** (for *Doubly Fed Induction Generator*) and is a complex piece of engineering, designed to perform specifically at the working conditions of the Drive Train of variable speed Wind Turbines. As a result, fully understanding its working conditions is a challenging task. This program allows the exploration of all the variables in the Induction Generator under the operational conditions found in DFIG Wind Turbines.

One application of this program is **for computing the actual demand placed to the Back-to-Back converters in DFIG Wind Turbine** under abnormal or extreme situations, such as Drive Train accelerations, or fast wind gusts.

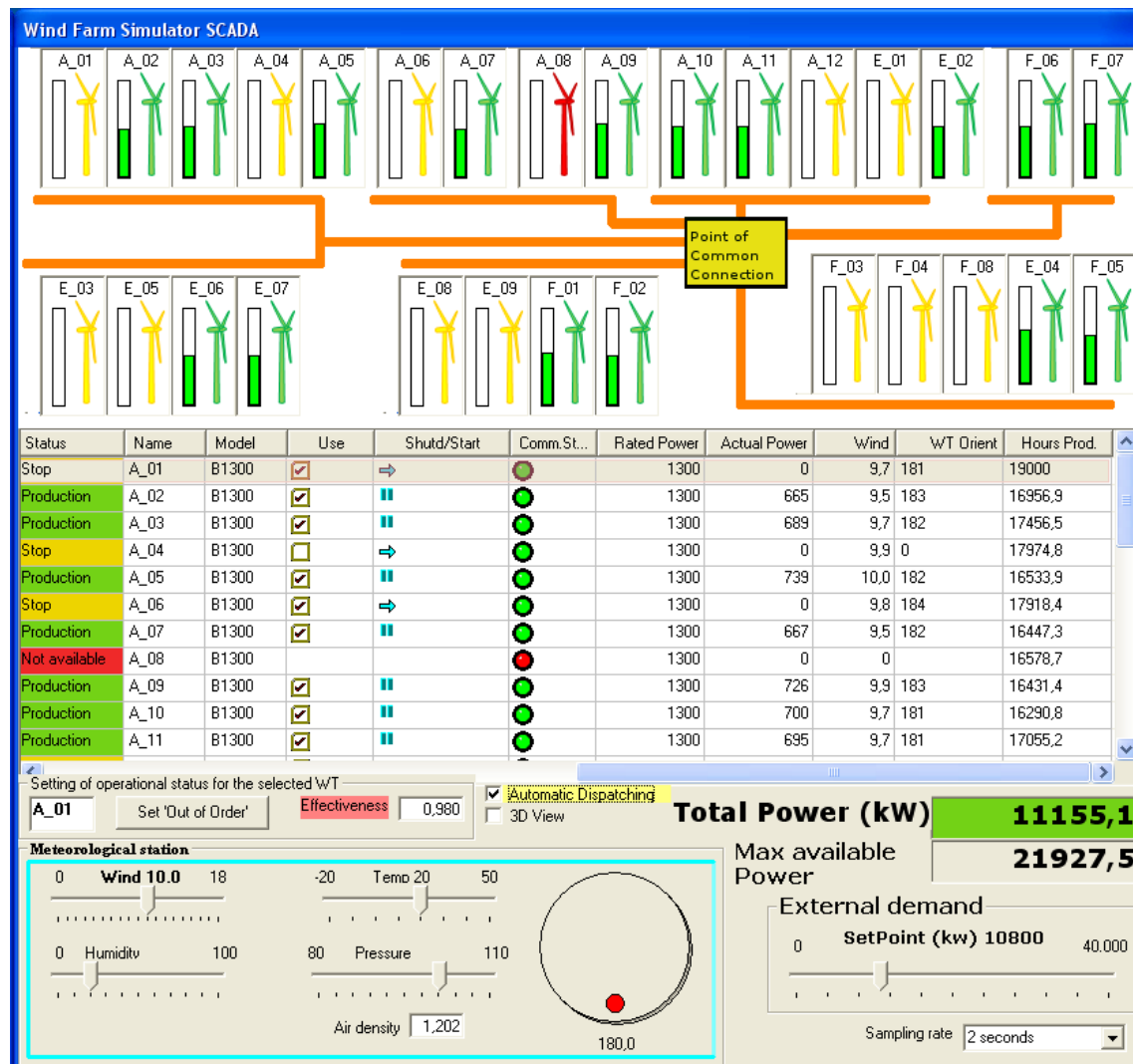
Targets of these simulators and applications

The aim of these applications is to facilitate the understanding of how real industrial grade Wind Turbines work. Historical evolution of Wind Turbine designs has been driven by the challenges of increasing demand on delivered power, adaptation to lower wind regimes, response to wind gusts, support of Grid problems, capabilities for delivering/consuming reactive power, etc., so our simulators show this evolution and facilitate the definition of their actual working conditions and their reactions.

Follows abstracts of the characteristics of them.

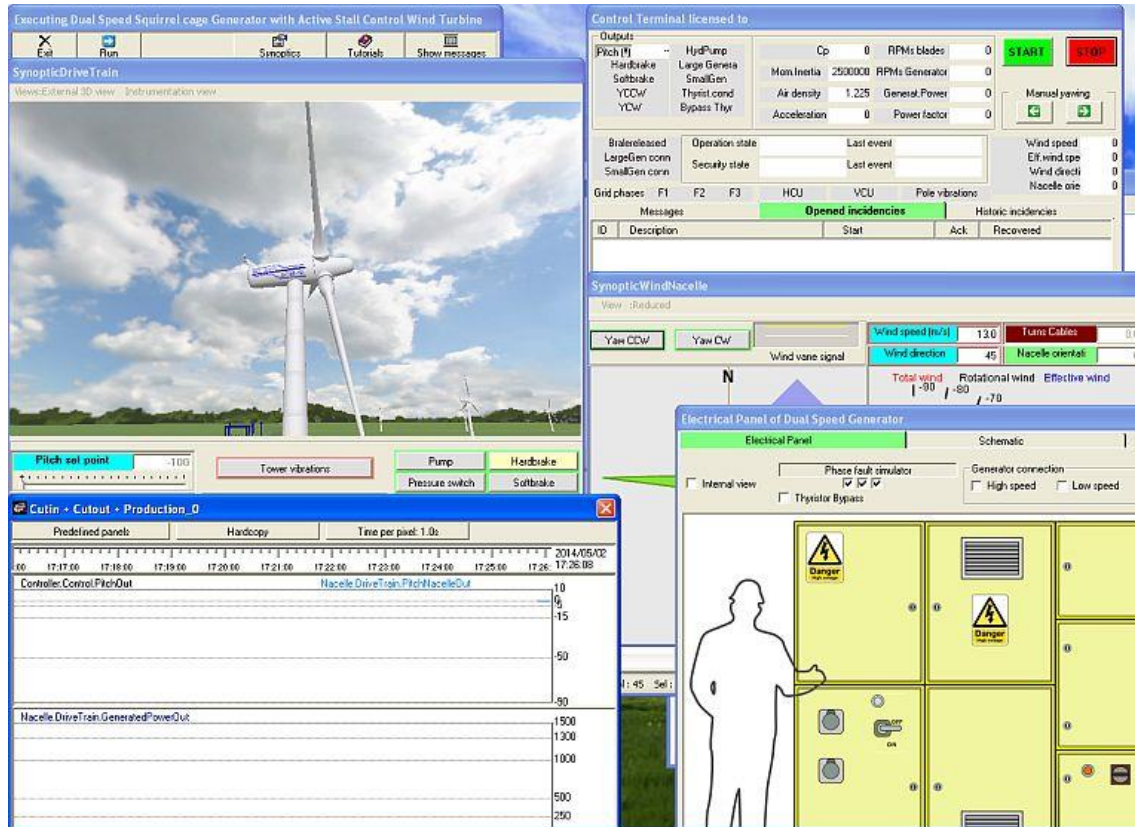
Simulator of the Wind Farm Control Center (SCADA)

Cover the concepts associated with the elements in the Wind Farm (Wind Turbines, Substation, cabling, etc.) as well as those related to the relationships with the Grid, the customers, the weather conditions, the weather forecast, the operation of the Wind Turbines from the SCADA, logistics for the maintenance, etc.



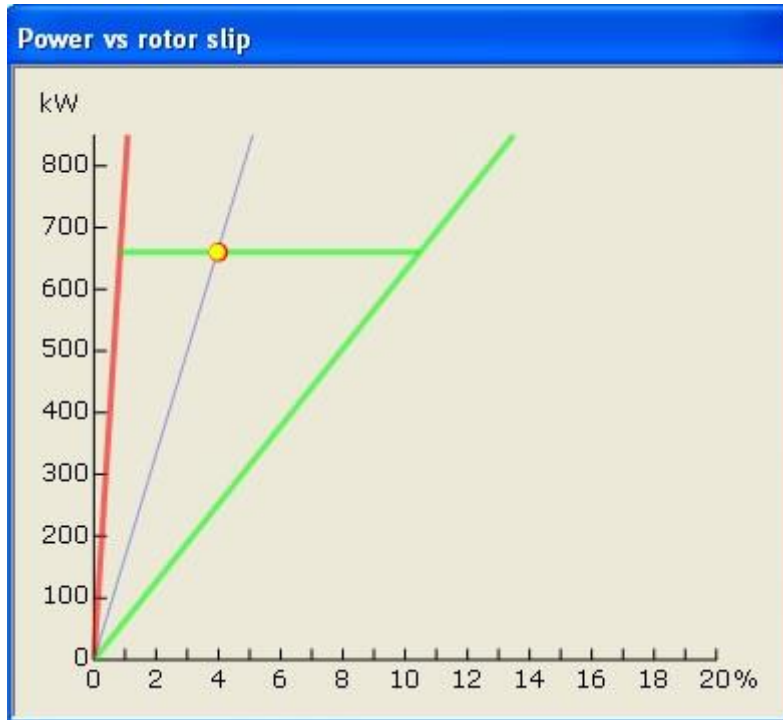
Simulator of Wind Turbines with Squirrel cage generator directly connected to the Grid

This simulator corresponds to the older machines, of which there are many still in operation. The simulated wind turbine includes the model working at two rpms regimes (or two generators), and pitch control by active stalling.



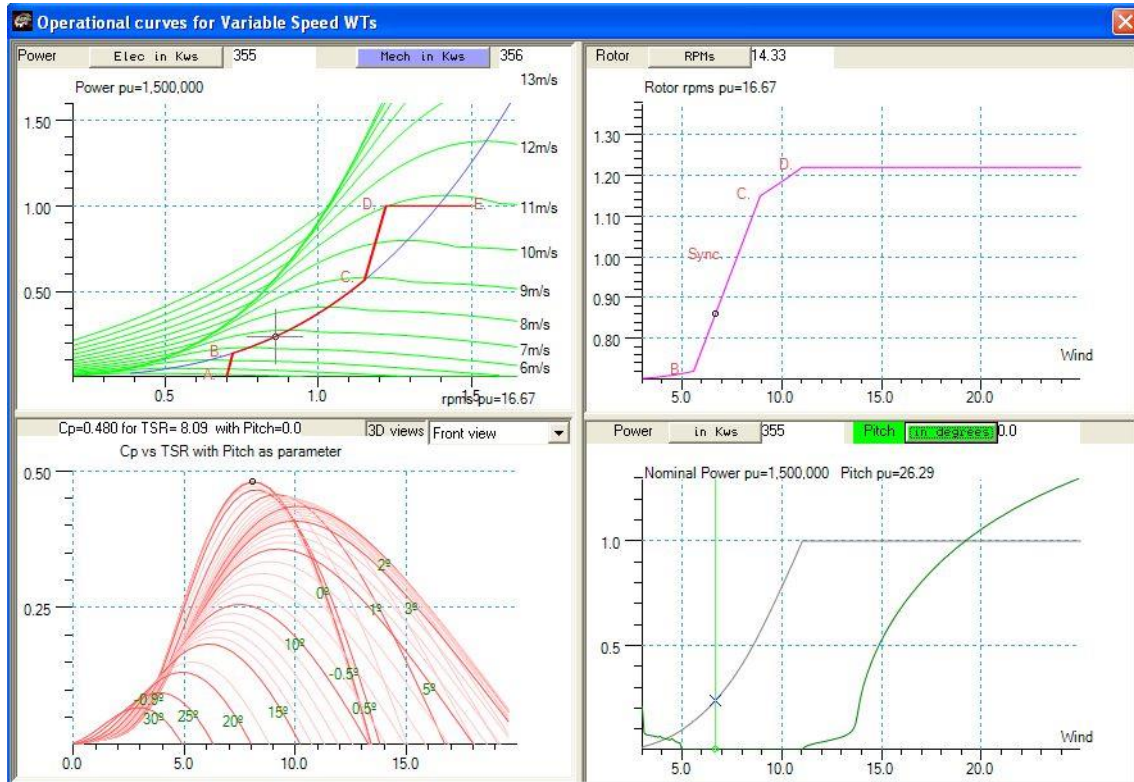
Simulator for Wind Turbines with Control of Drive Train using the Generator Rotor Resistance

This simulator corresponds to the family that uses the modification of the rotor resistance in the generator to cope with *wind gusts*. *Understanding the behavior of this type of Wind Turbines is key to understand the behavior of DFIG Wind Turbines.*



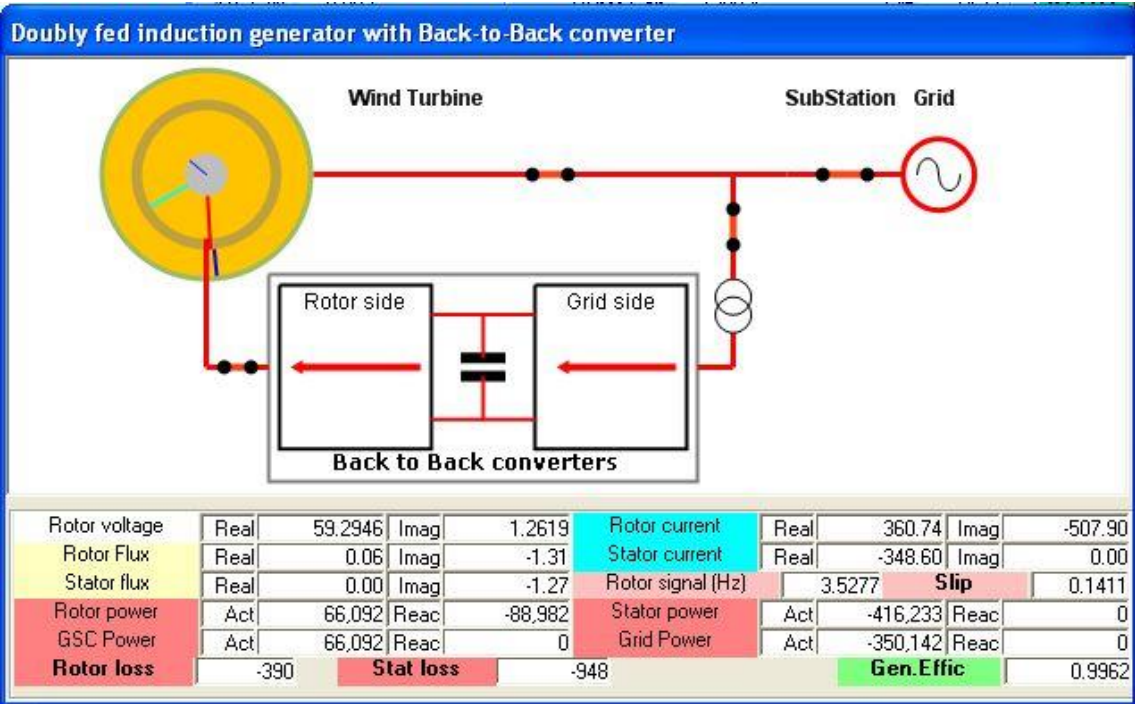
Simulator for Wind Turbines with Full Converter

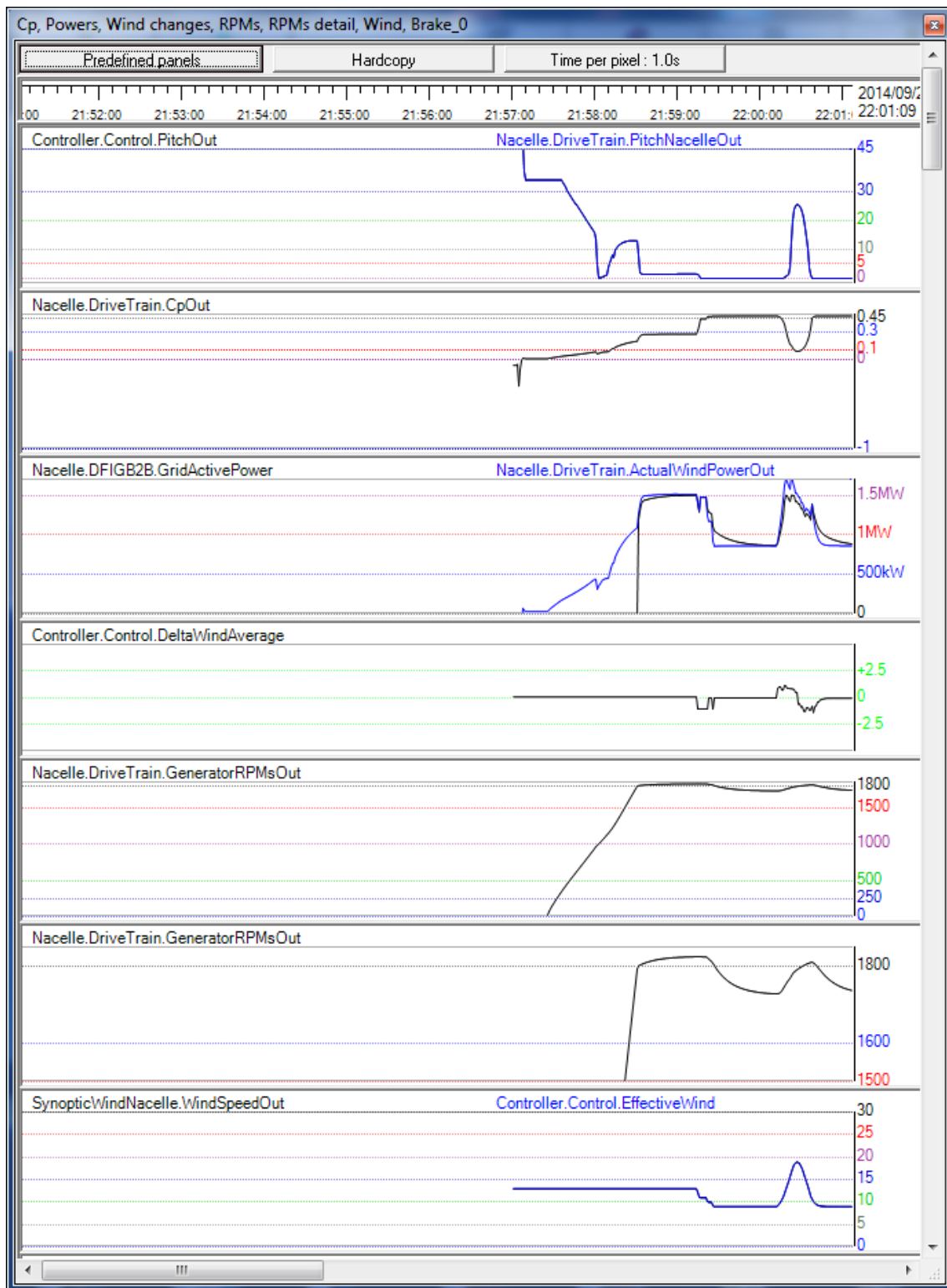
This simulator covers a broad range of converters characterized by the use of a Power Electronics Converter that handles all the power delivered to the Grid. Both with and without gearbox.



Simulator for Wind Turbines with Doubly Fed Induction Generator (DFIG)

This simulator covers the most common nowadays type of Wind Turbine, that uses a wound rotor induction generator connected to Back-to-Back Power Converters for control and delivery of power to the Grid.





Application “Operational Curve for Variable Speed Wind Turbines”

This application implements the computations related to the working operations for the *Drive Train* in a *Variable Speed Wind Turbine*. The required input data corresponds to the description of the airfoil. The user can modify the blade’s length, gearbox ratio, air density, etc. to compute the operational curve. Following the standard description from a [paper from NREL](#).

Modern industrial Wind Turbines are able to work in wide ranges of wind speed, in order to maximize the intake of energy from each possible site they are located.

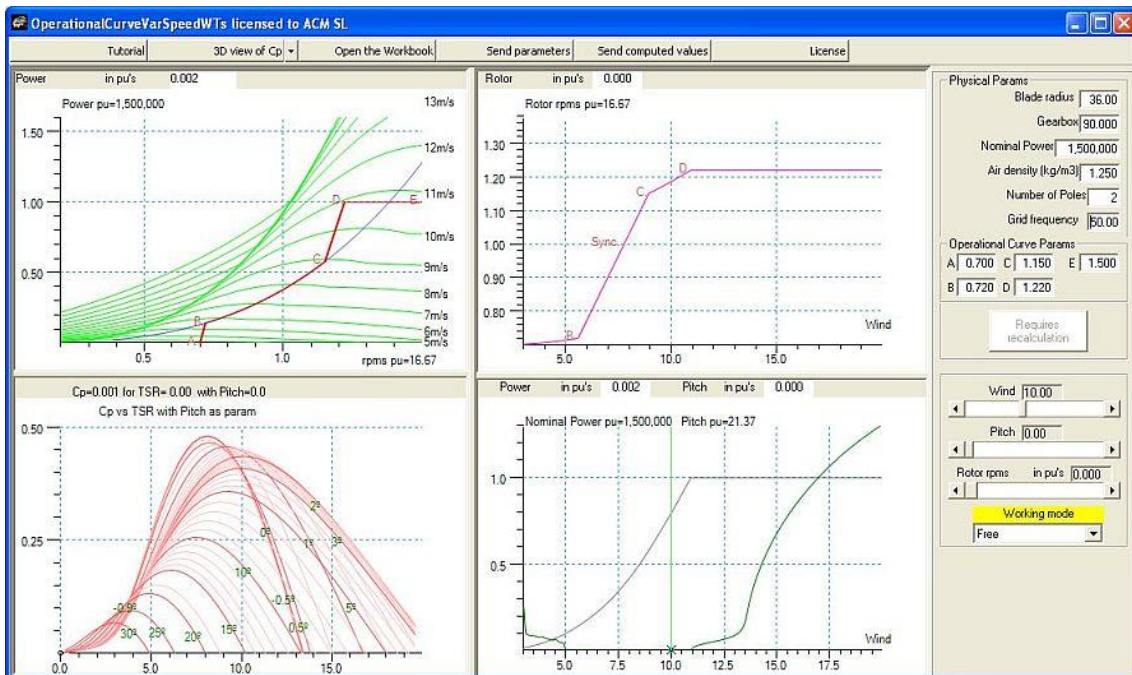
This requirement has several implications, one of them is the need to adjust the pitch angle of the blades according to the working wind speed. This control must take into account the form of the blade, and the wind speed, and must provide as a result the pitch angle of the blades and the “optimal” rotational speed of the drive train.

The behavior of the blades regarding the energy performance is given by complex, non-linear models that use three parameters: the Drive Train rotational speed, the wind speed, and the pitch angle of the blades.

The solution to this control problem is well known in industry (see for example [the NREL report “Advanced Control Design for Wind Turbines” Technical Report NREL/TP-500-42437-March 2008](#)), and ends-up in a Maximum Power Point Tracking (MPPT) curve. But actual construction details of wind turbines, besides the complex behavior of the blades, force to take into account some operational limits in those variables, such as maximum rotational speed of the blades. Therefore, the final “Operational Curve” must follow the theoretical MPPT curve, except in some very specific zones.

One of the consequences of this situation is that is not easy to study the influence of the construction parameters, such as the radius of the blades or gearbox speed ratio or the grid frequency in the actual Operational Curve.

This is the **reason for the development of this program**: to provide the set of tools and views of the implied variables and control mechanisms so it is easy **to see the result of changes in parameters and/or operational variables in a graphic way, in real time**.



DFIGB2B

This application permits the computations of all the electrical and magnetic variables in an induction generator that is connected to a Back-to-Back converter, as in DFIGs Wind Turbines. It is a tool ideal to explore the actual demand on the Back-to-Back converters under normal and extreme working conditions.

The family of industrial wind turbines known as DFIG (Doubly Fed Induction Generators) is by far the most popular nowadays due to excellent price/performance ratio and reliability.

These Wind Turbines are named after the special configuration of the electric generator and associated power electronics control, known as Back-to-Back converter.

Their main property is its ability to supply to the grid under varying rotor speed. DFIG wind turbines has no fixed drive train speed (see our application “Operational Curve for Variable Speed Wind Turbines”) as it tracks the speed of the incoming wind adapting its own rotational speed to the value in which it can get the maximum power out of the wind. It is typical to find that the working range in wind speed goes from 6 m/s to 20 m/s and that the corresponding working range for the drive train rotational speed expand from 9 rpm to 20 rpms.

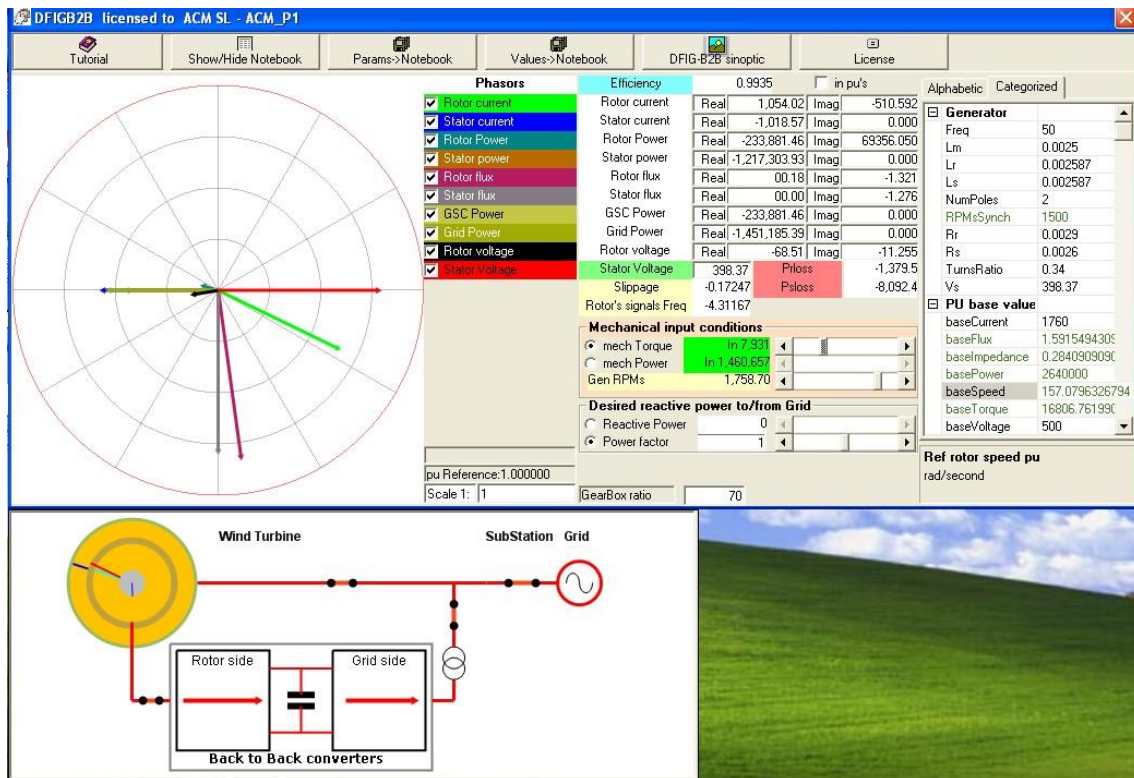
The actual Doubly Fed Induction Generator is in fact a “normal” wounded rotor induction generator. As such it has a “synchronous” rotational speed (related to the frequency of the grid it is connect to) and the number of “poles”. “Standard” working modes are around that synchronous frequency value, so that speed above synchronous implies working as a generator and speed below synchronous implies working as motor.

The “magic” of the DFIG comes from the functionalities of a block of power electronics known as “Back-to-back” (B2B).

This application allows the specification of the real parameters of Induction Generators and to compute all the variables inside it and the requirements placed in the B2B converters.

There is also a synoptic that shows in real time the evolution of the phasors corresponding to the magnetic fluxes in the Induction Generator air-gap simultaneously to the real rotation of the shaft.

Next figure shows the user interface.



Platforms:

Microsoft Windows XP SP3, Windows 7 (32 and 64 bits), Windows 8.1 (64bits), Windows 10.

These applications will not execute in Virtual Machines (Virtual PC, VirtualBox, VMWare, Parallels, etc.)

Multilanguage.

All the *Simulators* have Multilanguage capability built-in: ie., the user interface will adapt automatically to the actual setting of “**Regional settings**” of Windows. The adaptation of this setting maps to versions in the following way:

- Any English derivative maps to English (USA).
- Any Spanish derivative maps to Spanish (Spain).
- Any French derivative maps to French (France).
- Italian.
- German.
- Portuguese.
- **Any other language maps to English(USA)**

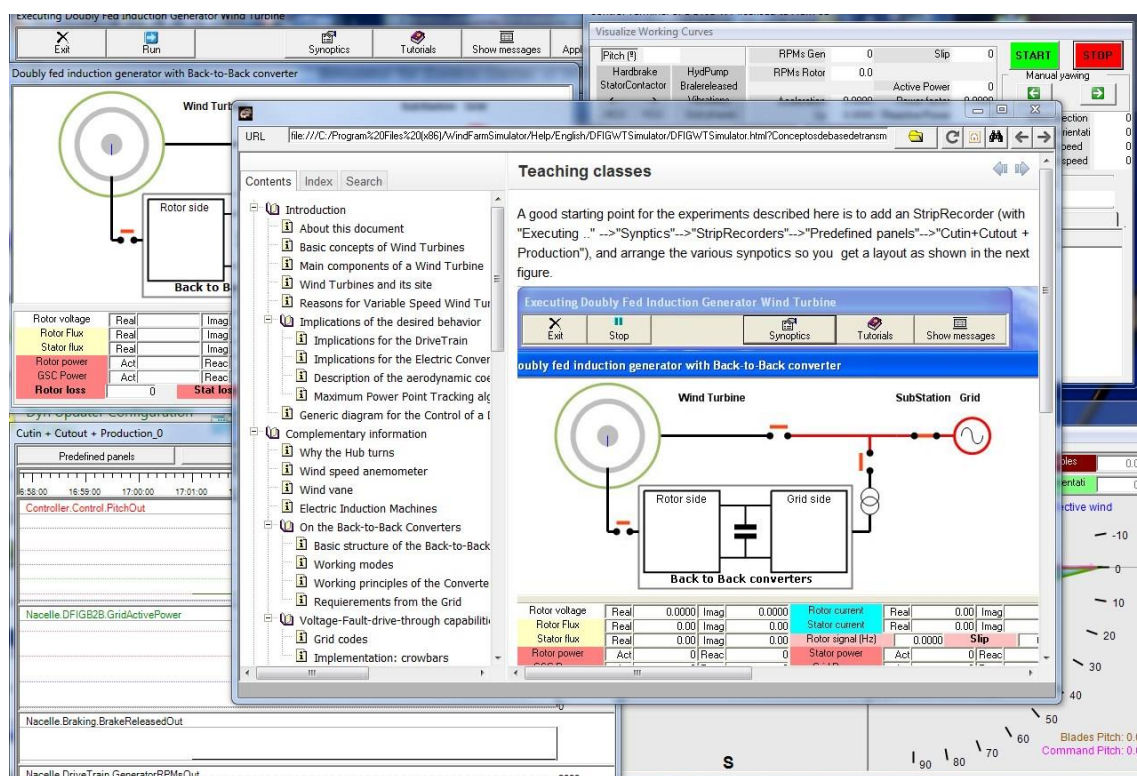
The other applications all available in English and Spanish versions. Any other language maps to English (USA).

User interaction with the Simulators and Tutorials in the WindFarmSimulator.

Each simulator has an associated configuration file. Each configuration file includes one or more (generally at least two) Tutorials, related to the corresponding tutorial.

Each Tutorial includes “Technical Sessions” designed specifically for the corresponding simulator.

Upon invocation of the simulator the program first initializes all the corresponding components, placing them in the screen according to the specifications declared in the configuration file. After that it presents the “default” Tutorial for that simulator. See next figure to see the result for the DFIG simulator.



The purpose is to guide the user through all the possibilities of the simulator and the interactivity with each of its specific Synoptics.

The user may press the “X” control in the Tutorial form and bring it back through the “Tutorials” button in the main “Executing ...” form.