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Wind Designer User Guide

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version 1

Contents

1 Disclaimer

WindDesigner was developed as part of project "VENTURAS", founded by Ministero dell'Ambiente. The author would like to thank Ministero dell'Ambiente for its support.

2 Introduction

Wind Generators are based on a energy source (wind) that can vary greatly depending on the time period considered and the location of the generator itself. Also considering a site where wind is strong and frequent, the wind speed can vary greatly throughout the day. Since the generated energy depends on the cube of the wind speed this greatly affect the energy production.

A variable wind speed has also another important consequence. If the wind speed changes components will work in different operative conditions. Different operative conditions means that their efficiency, and therefore the total efficiency of the generator, change with the wind speed.

WindDesigner was therefore developed with the aim of evaluating the global efficiency of a wind generator, according to the variation of wind speed. Two ideas are at the base of this tool. First, given a particular site with an average wind speeds distribution, to evaluate which structure the generator should have to maximize the energy harvested. Second, given a fixed generator composition and an average wind speeds distribution, to evaluate the best control solution to adopt with the aim of maximizing the energy generated.

WindDesigner can therefore help researchers and manufactures to improve the efficiency of wind generators, increasing the energy produced without having an impact on the production costs.

3 How to run the program

The program execution is quite simple:

- Open Matlab;
- Change directory to WindDesigner_open;
- Execute the main file

WindDesignerInterface

That's all. At this point it is possible to perform the desired analysis following the menu-based GUI. Section 4 describes the general structure of the menus, while Sections 5, 6 and 7 describes the analysis performed by each part. Section 8 describes how to add models and profiles to WindDesigner.

4 WindDesigner structure

This Section shows the general organization of the menu-based interface of WindDesigner. The detailed description of each part is reported in the correspondent Sections 5, 6 and 7.

- **Wind Generators Comparison**. Comparison of multiple wind generators.
  - **Define a Wind Generator structure**. Dynamically compose the wind generator component by component. This option can be selected multiple times.
    - **Choose how the generator will be used**. Choose between network connected and isolated generators, right now this choice has no effect.
      - **Network Connected**.
      - **Isolated**.
    - **Choose configuration file**. Select configuration files with components parameters and torque-speed characteristic of the turbine.
    - **Choose gear model**.
    - **Choose generator model**.
    - **Choose rectifier model**.
    - **Choose filter or switching regulator model**.
    - **Choose inverter model**.
    - **Choose output filter model**.
    - **Choose control system model**.
  - **Display Results**. The previously defined wind generators are analyzed.
    - **Wind speed analysis**. Analysis of output power and efficiency at the wind speed variation.
    - **Energy analysis**. Analysis of the energy produced with a specific wind speeds distribution.
      - **Average Analysis**. Select a wind speeds distribution.
    - **Return back**. Return to the previous menu.
  - **Return Back**. Return to the previous menu.
- **Electrical Generator Analysis**. Dedicated analysis of the electric generator.
  - **Generator Analysis with selected torque-speed characteristic**. Analysis of the electric generator with a selected configuration file.

    - **Choose torque-speed characteristic and generator type**. This option can be selected many times comparing different configurations.
        - **Choose configuration file**. Select configuration files with components parameters and torque-speed characteristic of the turbine.
        - **Choose generator model**.
    - **Display results**. The previously selected configurations will be analyzed.
    - **Return back**. Return to the previous menu.
- **3D generator map**. A wind generator will be analyzed without a specific torque-speed characteristic, obtaining a 3-dimensional map of the generator.
    - **Choose generator type and configuration file**. Select the configuration file to obtain the generator parameters. The torque-speed characteristic is not considered. This option can be selected many times.
        - **Choose configuration file**
        - **Choose generator model**
    - **Display results**. Create a 3D map of the generator working area. Minimum and maximum values for torque and speed, as the step to be used in the analysis, must be supplied by the users. WARNING!! If the step is too small and the range of the analysis is too big the computation time will be very high, or in some cases the required memory will be too big.
    - **Return back**. Return to the previous menu.
- **Return Back**. Return to the previous menu.

- **Change System Constants**. Change system constants.
- **Reset Variables**. All variables will be reset. This option is equivalent to close and re-open the program.
- **Quit**. Close WindDesigner.

5 Wind Speed Analysis

This is one of the three main analysis available in this tool. It allows the evaluation of the output power and the efficiency of the generator according to the variation of the wind speed. To perform such analysis some steps must be followed:

- Access to the relative sub-menu selecting the option **Wind Generators Comparison** in the main menu.
- Compose a wind generator structure selecting the option **Define a Wind Generator structure**.
  - Select if the generator must be connected to the electrical grid or not with the option Choose how the generator will be used. Up to now this choice has no effect on the results obtained. This option is present just as a potential future upgrade of the tool.
  - Select the configuration file to be used with the option **Choose configuration file**. The configuration file contain all the parameters required by the various models that describe each generator components and the torque-speed characteristic of the wind turbine, which describes the output mechanical torque and speed for a specific wind speed.
  - Select the components that are part of the generator, this components can include:
    * gear (**Choose gear model**),
    * electrical generator (**Choose generator model**),
    * rectifier (**Choose rectifier model**),
    * a filter or a switching between the rectifier and the inverter (**Choose filter or switching regulator model**),
    * an inverter (**Choose inverter model**),
    * an output filter (**Choose output filter model**),
    * a model for the control system losses (**Choose control system model**).

    This choice of components is provided to grant the maximum flexibility in the analysis. Not all of them are required to build a working wind generator. If a particular component is not necessary the correspondent "No-model" (for example "NoGear") must be selected. A NoGenerator model is provided to obtain the maximum flexibility, however a wind generator without the electrical generator is clearly useless. In every sub-menu a list of components will appear, this list is dynamic and correspond to the list of files present in the relative sud-directory where the models are store. The sub-directories with the component models can be found inside the /CoreFiles sub-directory. Only some models are provided and most of them are very simple. If a more detailed analysis is requested the model must be provided by the users and inserted in the relative folder, as explained in Section 8.
- Compose another wind generator if necessary. The program is totally generic, the number of wind generator structures that can be defined should be only limited by the computation time and the memory required (although the tool was tested with a maximum number of structures equal to 5).
- Analyze the results and compare the wind generators selected choosing the option **Display Results** and then **Wind speed analysis**. A number of graphs will be plotted:
  - one graph with the comparison of the total wind generator output power as a function of the wind speed,
  - one graph with the comparison of the total wind generator efficiency as a function of the wind speed,
  - one graph for each configuration selected showing the efficiency of each component as a function of wind speed.

  Results are also exported to file and can be found in the directory /TableFiles.

6 Average Analysis

The steps to follow for this second analysis are similar to the **Wind speed analysis**. It allows the evaluation of the energy produced by the generator according to the a wind speed profile supplied by the users. To perform such analysis some steps must be followed:

- Access to the relative sub-menu selecting the option **Wind Generators Comparison** in the main menu.
- Compose a wind generator structure selecting the option **Define a Wind Generator structure**.
  - Select if the generator must be connected to the electrical grid or not with the option Choose how the generator will be used. Up to now this choice has no effect on the results obtained. This option is present just as a potential future upgrade of the tool.
  - Select the configuration file to be used with the option **Choose configuration file**. The configuration file contains all the parameters required by the various models that describe each generator components and the torque-speed characteristic of the wind turbine, which describes the output mechanical torque and speed for a specific wind speed.
  - Select the components that are part of the generator, this components can include:
    * gear (**Choose gear model**),
    * electrical generator (**Choose generator model**),
    * rectifier (**Choose rectifier model**),
    * a filter or a switching between the rectifier and the inverter (**Choose filter or switching regulator model**),
    * an inverter (**Choose inverter model**),
    * an output filter (**Choose output filter model**),
    * a model for the control system losses (**Choose control system model**).

    This choice of components is provided to grant the maximum flexibility in the analysis. Not all of them are required to build a working wind generator. If a particular component is not necessary the correspondent "No-model" (like the option "NoGear") must be selected. A NoGenerator model is provided to obtain the maximum flexibility, however a wind generator without the electrical generator is clearly useless. In every sub-menu a list of components will appear, this list is dynamic and correspond to the list of files present in the relative sud-directory where the models are store. The sub-directories with the component models can be found inside the /CoreFiles sub-directory. Only some models are provided and most of them are very simple. If a more detailed analysis is requested the model must be provided by the users and inserted in the relative folder, as explained in Section 8.
- Compose another wind generator if necessary. The program is totally generic, the number of wind generator structures that can be defined should be only limited by the computation time and the memory required (although the tool was tested with a maximum number of structures equal to 5).
- Analyze the results and compare the wind generators selected choosing the option **Display Results** and then **Energy analysis**. A sub-menu will appear which dynamically shows all the wind speed distributions available. Three example of wind distributions are currently available. Users must provide the specific wind distribution required for their analysis following the indications of Section 8. Two graphs will be plotted:
  - one graph showing the wind distribution selected,
  - one graph showing the comparison of the energy produced by every configuration selected.

  Results are also exported to file and can be found in the directory /TableFiles.

7 Dedicated Electrical Generator Analysis

This option provides an analysis dedicated only to the electrical generator. Two possibilities are available.

Analysis of the electrical generator with a specific input torque-speed characteristic.

- Select the option **Electrical Generator Analysis** in the main menu.
- Select **Generator Analysis with selected torque-speed characteristic** in the sub-menu.
- Choose a configuration (**Choose generator type and configuration file**).
  - Select the configuration file to be used with the option **Choose configuration file**. The configuration file contains all the parameters required for the various models that describe each generator components and the torque-speed characteristic of the wind turbine, which describes the output mechanical torque and speed for a specific wind speed.
  - Select the electrical generator (**Choose generator model**).
- Select others configurations. The program is totally generic, the number of generators that can be defined should be only limited by the computation time and the memory required (although the tool was tested with a maximum number of structures equal to 5).
- Show the results by selecting the option **Display results**. Different graphs will appear:
  - one graph showing the comparison of the input power as a function of wind speed,
  - one graph showing the comparison of the torque-speed characteristics selected,
  - one graph showing the comparison of the output power as a function of wind speed,
  - one graph showing the comparison of the generator efficiencies as a function of wind speed,
  - one graph for each solution showing all the losses inside the generator as a function of wind speed,
  - one graph for each solution showing the output voltage,
  - one graph for each solution showing the output current.

Analysis of the electrical generator without a specific input torque-speed characteristic.

- Select the option **Electrical Generator Analysis** in the main menu.
- Select **3D generator map** in the sub-menu.
- Choose a configuration (**Choose generator type and configuration file**).
  - Select the configuration file to be used with the option **Choose configuration file**. The configuration file contains all the parameters required for the various models that describe each generator components and the torque-speed characteristic of the wind turbine, which describes the output mechanical torque and speed for a specific wind speed. However in this particular case the torque-speed profile will not be considered, just the electrical generator parameters will be taken into account.
  - Select the electrical generator (**Choose generator model**).
- Select others configurations. The program is totally generic, the number of generators that can be defined should be only limited by the computation time and the memory required (although the tool was tested with a maximum number of structures equal to 5).
- Show the results by selecting the option **Display results**. The maximum, minimum and step values for both torque and rotation speed must be provided. If a step too small and limits too high are chosen, the required memory and computation time can be too high. Different graphs will appear:
  - one graph for each solution showing a 3-dimensional map of the generator efficiency with any value of torque and speed according to the limits inserted by the users. Different colors identify the input power.

8 How to modify WindDesigner

Since this tool is written in Matlab anyone can easily modify it. There are no general rules to follow to modify the basic program structure. Here are instead reported some general indications on how to add new component models, new configuration files and new wind speed profiles. The program automatically recognize any .m file placed inside the relative folder, so to add a new model, configuration or wind profile it is only necessary to insert the file inside the correspondent folder. The folder and file structure is here reported:

- WindDesigner_open
  - *WindDesignerInterface.m*. Wind Designer interface.
  - **CoreFiles**. Folder containing the main program files
  - **TableFiles**. Folder where the text files are saved.
- CoreFiles
  - *wind_speed_analysis.m*. File describing the wind speed analysis.
  - *average_analysis.m*. File containing the energy analysis.
  - *special_generator_analysis.m*. File containing the first of the two analysis dedicated to the electrical generator.
  - *surface_analysis.m*. File containing the second of the two analysis dedicated to the electrical generator.
  - *constants.m*. File containing the system constant.
  - **ConfigurationFiles**. Folder containing the configuration files.
  - **ControlSystemModels**. Folder containing the models for the control system losses.
  - **ElectricGeneratorModels**. Folder containing the models for the electric generators.
  - **FilterSwitchingModels**. Folder containing the models for the filter or switching regulator placed between the rectifier and the inverter.
  - **GearModels**. Folder containing the models for the gear.
  - **InverterModels**. Folder containing the models for the inverter.
  - **OutputFilterModels**. Folder containing the models for the output filter.
  - **RectifierModels**. Folder containing the models for the rectifier.
  - **WindProfiles**. Folder containing the files with the wind speed distributions.

8.1 Adding new component models

To add a new model for a specific component a new .m file should be created and dropped inside the relative folder. The name of the file should be selected appropriately because it will appear in the selection menu inside WindDesigner. Files should have a structure similar to existing ones.

Generally a model file contains some mathematical equations that link input variables to output variables. The equations can be written at will, using also different name for the variables. It must be reminded however, that if new variable are introduced, then they must be inserted in the configuration file.

The name of input and output variables must remain the same because it is mandatory for correct tool operations. As can be noted from existing models, every variable is not a scalar or a simple vector but it is a multidimensional matrix. This is necessary to the correct operation of the tool and this structure (that means the indexes for each variable) must be preserved. This is mandatory for all input and output variables, that must remain exactly as they are in the existing models. Intermediate variables can (probably, but this is not tested so I cannot guaranty that the model will work) be simple scalars or vectors, avoiding therefore the use of indexes that make the code difficult to read.

8.2 Adding new configuration files

To add a new configuration file a new .m file should be created and dropped inside the **ConfigurationFiles** folder. The name of the file should be selected appropriately because it will appear in the selection menu inside WindDesigner. Files should have a structure similar to existing ones.

A configuration file contains all the parameters used internally by every model. So if a new model is added its internal parameter must be added to all existing configuration files. In the second part the configuration file contains the torque-speed characteristic of the turbine. When a new configuration file is added it is recommended to copy/paste an existing file, modify the components parameters and add new parameters if new models were created. It is better to do not touch the general organization of the variables used to describe the torque-speed characteristic, but to just change the values of the speed, torque and power vectors. The number of points of this vectors (which determines the number of point used in the analysis) are not defined in the configuration files but in the constant files. This choice was made because it is possible to perform multiple analysis with different configuration files, but this analysis must be performed on the same number of points otherwise the program will crash.

8.3 Adding new wind speed profiles

To add a new wind speed profile file a new .m file should be created and dropped inside the **WindProfiles** folder. The name of the file should be selected appropriately because it will appear in the selection menu inside WindDesigner. Files should have a structure similar to existing ones.

Wind profile files contains two vectors, one with the wind speeds and one with the percentage of each wind speed. The total sum of the percentage should be equal to 1000. A third variable is used to store the number of points of this two vectors. The number of points used in the analysis can be changed. Theoretically every wind profile can have a different number of points, however this functionality was not tested thoroughly, so it is advised to keep the number of points for wind speed vectors in each wind profile file equal. Increasing or reducing the number of points means that also the successive statements (from line 32 to 200) must be increase/reduced accordingly. If a new wind profile should be added it is better to copy/paste an existing file, do not change the number of points but just the values of the wind speeds and percentage vectors. The last variable that can be modified is called *WindTimeLenght* and contains the length in hours of the time period considered in the analysis. The three wind profile files are based on a period of time respectively of 1 day, 1 month and 1 year.

9 Known bugs

- If a *wind speed analysis* is performed after an *energy analysis* the program crash. This is due to a difference in the wind speed vectors used in the two analysis. To avoid this problem it is better to execute first a *wind speed analysis* and then a *energy analysis*. Another solution to avoid the problem is to go back to the main menu and *reset variables*.