RTDS Training course of IEPG

DAY 4 : Modelling wind turbine type 3 and type 4

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Preamble

Due to the gradually exhausting of fossil energy and considerations on environment protection, wind power as a clean and renewable energy, is being exploited more and more in modern electric power systems. Different types of wind generators are the tools of harvesting wind power. Among them, wind turbines type 3 and type 4 are the ones mainly used.

In this tutorial, we will introduce how to simulate these two wind turbines in RTDS. At the end of this tutorial, you should be able to:

a. Create a simple infinite bus wind power system in RTDS
b. Simulate the basic wind turbine operation conditions

Before attending this lab session, you should:

- Be able to do basic simulations in RSCAD (have completed module 2)
- Have the basic knowledge about wind turbines type 3 and type 4 (cf. the attached RSCAD specification for wind turbines type 3 and type 4)

Attached documents :

- Wind turbine type 3 example. You can find it here : Open RSCAD >> Tutorial >> Samples >> Renewable energy >> WindEnergy >> DIFG
- Specification of wind turbine type 3. You can find it here: Open RSCAD >> Tutorial >> Samples >> Renewable energy >> WindEnergy >> DIFG >> WTG50R3.pdf
- Wind turbine type 4 example. You can find it here: Open RSCAD >> Tutorial >> Samples >> Renewable energy >> WindEnergy >> Permanent Magnet Wind Turbine
- Specification of wind turbine type 4. You can find it here: Open RSCAD >> Tutorial >> Samples >> Renewable energy >> WindEnergy >> Permanent Magnet Wind Turbine >> PMTST550.pdf

Part 1 Wind turbine type 3

The first part will introduce the simulation of wind turbine type 3. Considering the time limit, attendees are not required to build themselves the complete model of wind turbine type 3. What they should do:

1) Understand the main framework of simulation,
2) Regulate the sliders and the switches to see the change in wind turbine operation.

The main simulation blocks are introduces as follows.
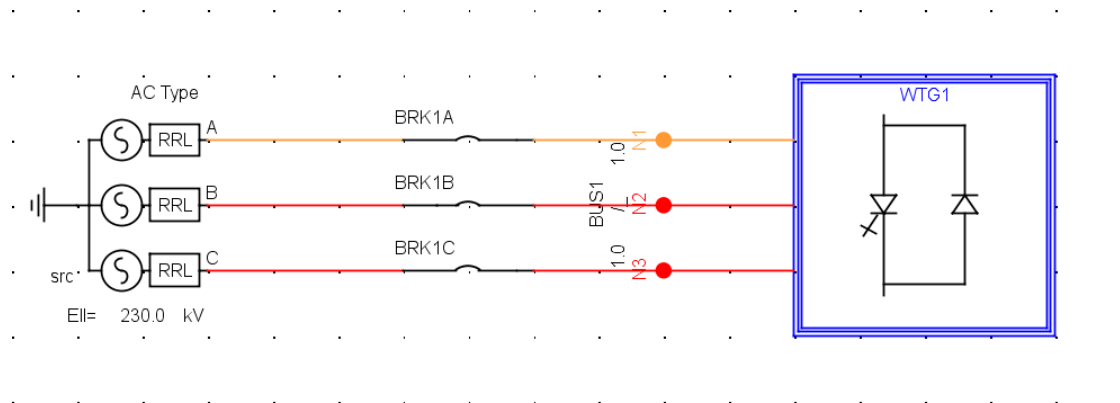
1 Overview of test system

Figure 1 : Test system

In the example, test system includes one AC voltage source and a small time step box where the wind turbine is modelled.
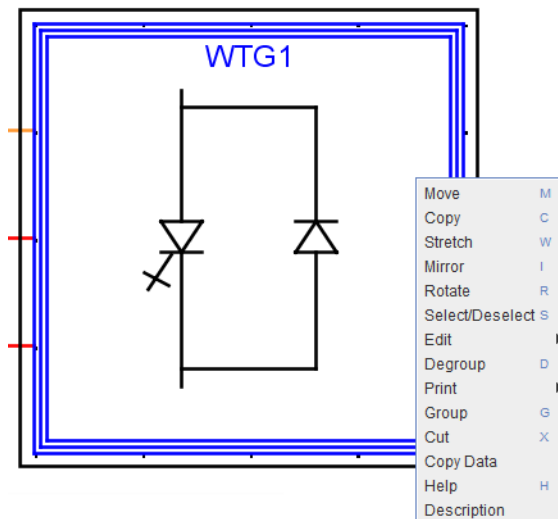
2 Small time step box

Figure 2 Small time step box

Generally, RTDS uses a time step of 50 μs, which is called a large time step. But this time step is too big for power electronics simulation. Therefore, we need a small time step. As a

solution, RTDS provides a small box (cf. Figure 2.) for power electronics, which uses a time step of 1.4 μs ~2.5 μs. The user puts power electronics interfaced components in this block, and put other components outside this block. In this way, RTDS represents enough exactly power electronics behaviours, and at the same time, requires less computation resources. For the further reading, right click on this block and continue to click "help" on the pop-up menu as shown in Figure 2.

Figure 3 Wind turbine system

3

3 Wind turbine system topology

The diagram of wind turbine system is shown in Figure 3. It consists of an induction motor, back-to-back converters, wind turbine transformer, interface transformer, PWM generator and necessary protection devices(crowbar and chopper).

3.1 Induction motor

The induction motor shown in Figure 4 is used to convert wind power to electricity. The motor is rated 2.0 MW and 0.69 kV RMS L−L on the stator.

The stator of this motor is connected to step-up WT transformer and the rotor is connected to the back-to-back converters. For the further reading, right click on this block and continue to click "help" on the pop-up menu as shown in Figure 4.
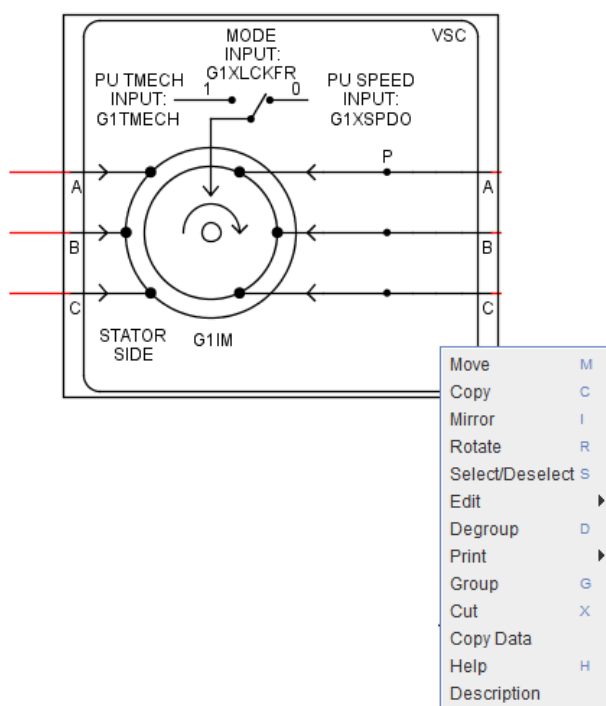

Figure 4 Induction motor

3.2 WT transformer

This transformer shown in Figure 5 connects the outputs of stator and the common coupling point. It increase the stator voltage 0.69 kV to 22 kV so that the wind turbine can be connected to the external transmission line. For the further reading, please go to : manual >> Power System Components >> Chapter 4 Transformer models.
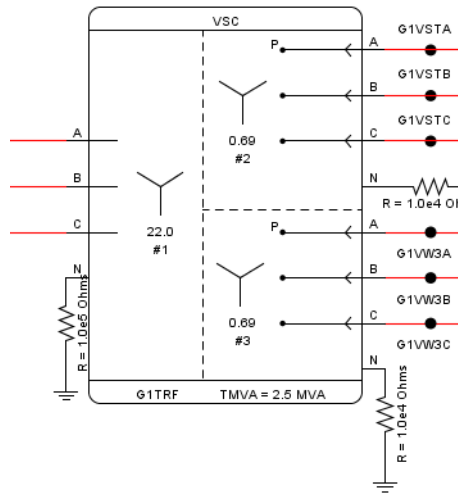
Figure 5 Step up WT transformer

3.3 Back-to-back converters

Two PWM voltage‑fed, current‑regulated converters (cf. Figure 6) are used to connect the rotor to the three windings transformers. To minimize losses, the power rating of the VSC is chosen to be 40% of the machine rating. Vector control in the grid-side VSC allows independently controlling the real and reactive power drawn from the supply. Vector control in the machine-side VSC allows the rotor torque and excitation current to be controlled independently. For the further reading, right click on this block and continue to click "help" on the pop-up menu , like what you do for Induction Motor.
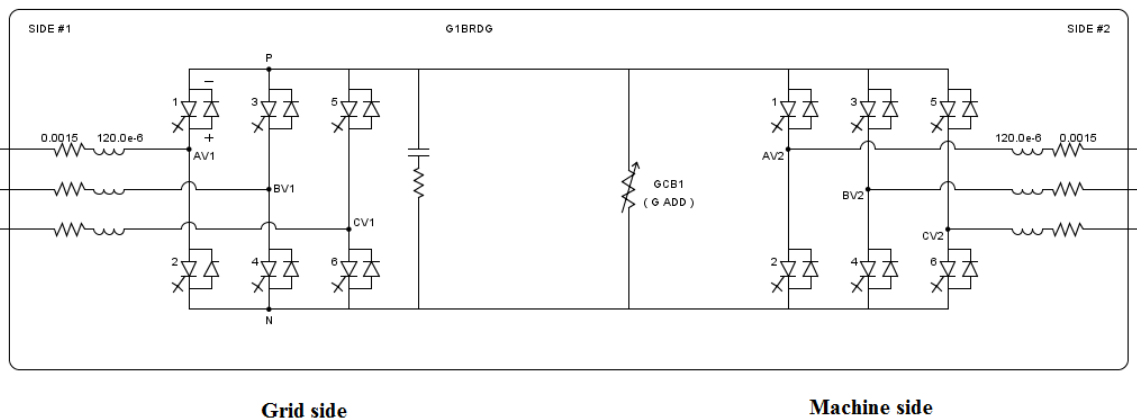

Figure 6 Back-to-back converters

3.4 Interface transformer

As explained before, the power electronics interfaced components are built in the small time step box (1.4 μs ~2.5 μs), but other components are simulated with a standard time step of 50 μs. Therefore, the interface between the large time step and the small time step must be built. RTDS provides the interface transformer to tie the large time step simulation to the small

time step simulation, as shown by Figure 7. For the further reading, right click on this block and continue to click "help" on the pop-up menu.
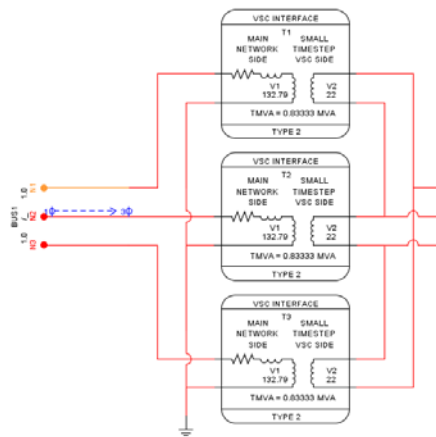

Figure 7 Interfaced transformer

Assignment : Open the parameter dialogue windows of each block in the example and check their main parameters, like rated voltages and powers.

Hint: If you need more information about the blocks in the example, please follow Tutorial >> Samples >> Renewable energy >> WindEnergy >> Permanent Magnet Wind Turbine >> PMTST550.pdf
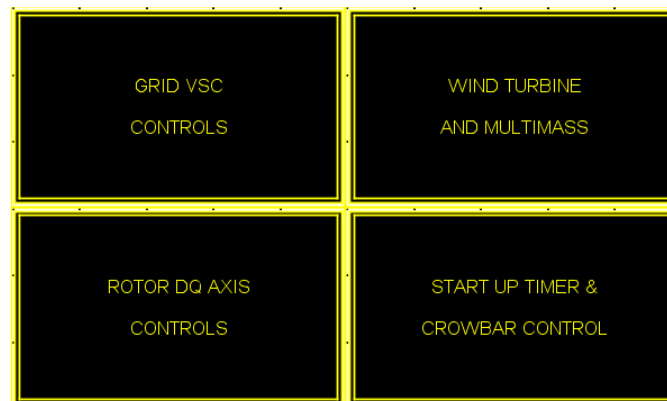
3.5 Wind turbine control systems

Figure 8 control hierarchy boxes

The 4 hierarchy boxes as shown in Figure 8 contain the controls for the grid side VSC, the rotor side VSC, the wind turbine with its controls and the start-up timer and crowbar control in the last box. For the further reading, follow Tutorial >> Samples >> Renewable energy >> WindEnergy >> Permanent Magnet Wind Turbine >> PMTST550.pdf)

Assignment : Open each hierarchy box and check what are inside .

The grid side VSC is responsible to adjust the active power by regulating the d-axis current and adjust the reactive power by regulating the Q-axis current.

The rotor side VSC controls q-axis current to adjust electrical torque and captured wind power. It also adjust d-axis current to zero to change excitation current and minimize the reactive power output.
The wind turbine and multi-mass box regulates the pitch angle of wind turbine following the change of wind speeds. It also provides the protection under large wind speed.

The last hierarchy box, start up timer & crowbar control, is responsible to start the wind turbine and prevent the DC voltage between two converters from reaching a dangerous high voltage.

Assignments :

- Compile and run simulations without any change, observe all meters and figures
- Regulate SLIDERs to see what happen. Find the SLIDERs for regulating wind speed and rotor reactive power (Hint : GIWIND and ROTOR Q).
- Turn on/off SWTICHes to see what happen. Find the SWITCHes for wind turbine controls (Hint : G1LCKFR and G1SGLLMLT).
- Push the fault BUTTON to observe the wind turbine torque, rotor and stator currents, PCC voltages and currents (Hint : Ftrg).

Part II wind turbine type 4

Wind turbine type 4 connects the stator of permanent magnet synchronous machine (PMSM) to the grid through two full-scale back-to-back converters. It is applied more and more due to its large flexibility in operation and control, good capability of providing ancillary service, easy maintenance and so on.

The second part will introduce the simulation of wind turbine type 4. Considering the similarity between wind turbine type 3 and type 4, the focus will be on the different simulation components used by wind turbine type 4. Similar to wind turbine simulations, attendees are not required to build themselves the complete model of wind turbine. They need to understand the main framework of simulation and regulate the sliders and the switches to see the caused change in wind turbine operation.

The main simulation blocks are introduces as follows.

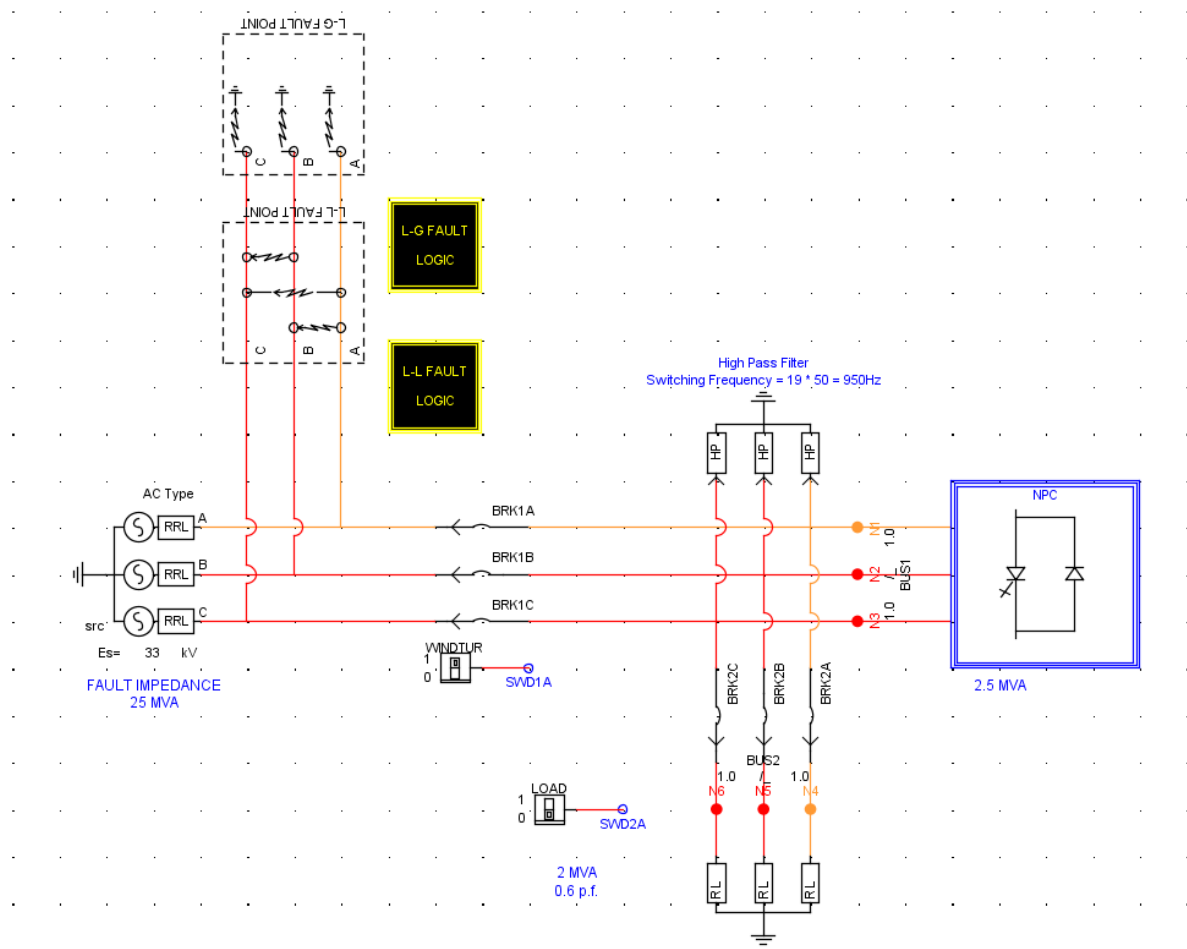## 1 Overview of test system

Figure 9 Test system

The simulation system used for wind turbine type 4 is shown in Figure 9. Except the voltage source and small time step box, there are one load and one filter which eliminates harmonics. The phase-to-phase and phase to ground faults are also considered.
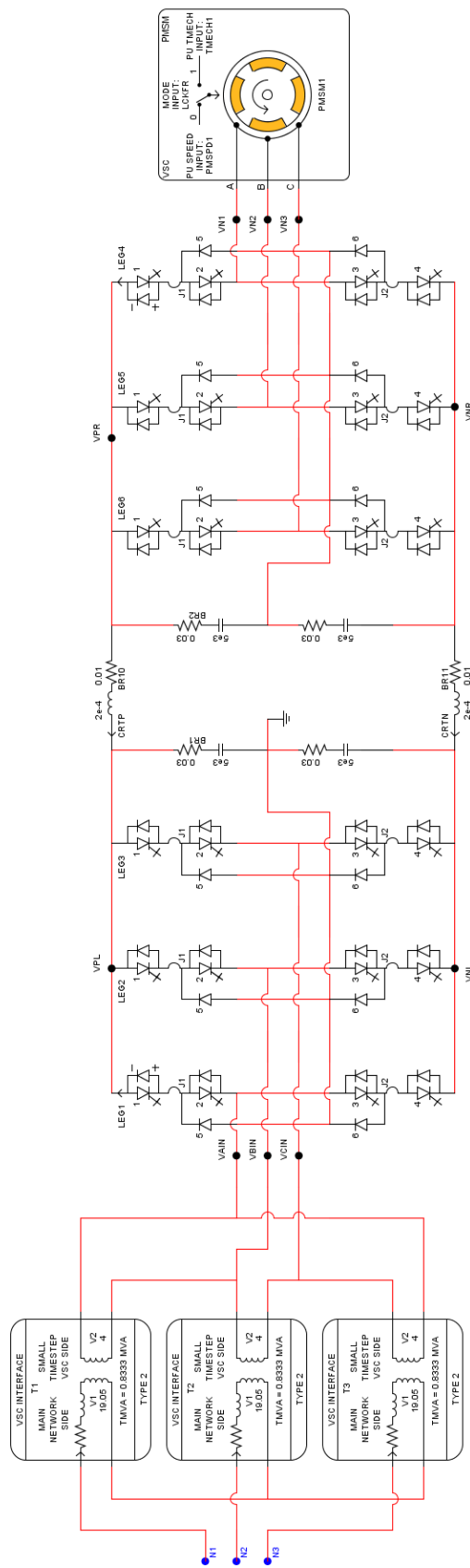
2 Wind turbine system

Figure 10 wind turbine system

The wind turbine system (cf. Figure 10) includes one PMSM, two converters, DC capacitors, interface transformers, and so on. The focus is primarily on control of the grid side converter and the PMSM side converter.
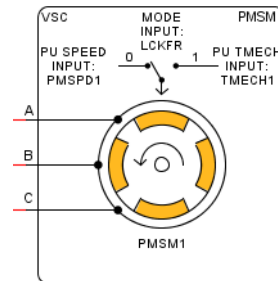
2.1 PMSM

Figure 11 PMSM

The PMSM is modelled as an interior magnet machine, with sinusoidally distributed windings. Damper windings are ignored. The rated power is 2 MW and the rated phase to phase voltage is 4 kVA. For the further reading, right click on this block and continue to click "help" on the pop-up menu.
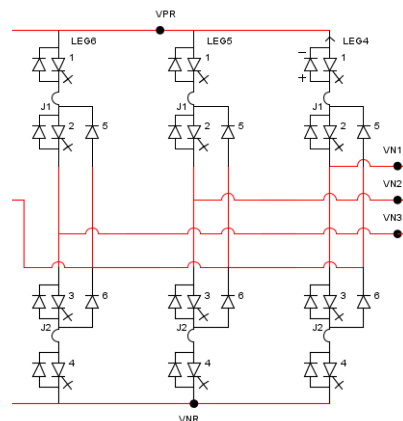
2.2 3 level Neutral−Point−Clamped converter

Figure 12 Three levels converter

In this example, a 3 levels converter is used as the PMSM side rectifier and the grid side inverter. For the further reading, right click on this block and continue to click "help" on the pop-up menu.
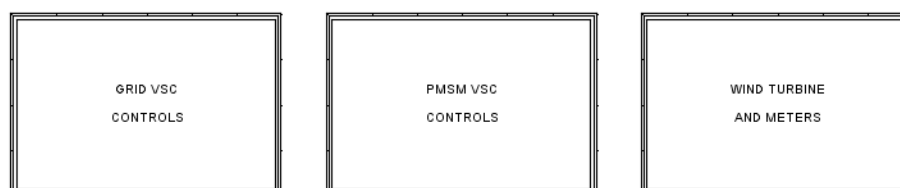
2.3 wind turbine controls

Figure 13 Hierarchy control boxes

3 hierarchy boxes shown in Figure 13 labelled grid VSC controls, PMSM VSC controls and wind turbine and meters, are developed to control wind turbine operation. For the further reading, please follow Tutorial >> Samples >> Renewable energy >> WindEnergy >> Permanent Magnet Wind Turbine >> PMTST550.pdf

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Assignment : Open each hierarchy box and check what are inside .

The grid VSC controls box regulates the d axis current to maintain DC voltage, regulates q axis current to regulate the reactive power output.

The PMSM VSC controls box regulates the d axis current to minimize the reactive power and improve the generator efficiency, regulates q axis current to maximize the captured wind power.

The third one, wind turbine and meters, is responsible to regulates the pitch angle of wind turbine following the change of wind speeds. It also calculates PCC voltage, active power, reactive power, and other states.

Assignments :

- Compile and run simulations without any change, observe all meters and figures.
- Regulate SLIDERs to see what happen. Find the SLIDERs for PCC voltage and DC voltage (Hint : VACREF and VDCR).
- Turn on/off SWITCHes to see what happen. Find the SWITCHes for the load and the wind turbine (Hint : LOAD and WINDTUR).
- Push the fault BUTTON to observe PCC voltage and current, DC voltage, and stator currents (Hint : Ftrg).