

# RTDS Training course of IEPG

DAY 5: RTDS I/O interface with hardware

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## Preamble

The objective of this lab session is to give attendees a picture how to interface RTDS with external devices. The method of interfacing will be explained and demonstrated. **However, for the safety reason, attendees are not required to interface themselves external devices to RTDS.**

At the end of this tutorial, you should be able to:

- a. Have the knowledge about I/O devices
- b. Understand the mechanism of interfacing RTDS to external devices

Before attending this lab session, you should:

- Be familiar with running basic cases in RSCAD (have completed module 2)
- Have the basic knowledge about wind turbine type 4 (have completed module 6)

## 1 Introduction for I/O cards

Digital and analogue signals are exchanged between RTDS real time simulator and external hardware. RTDS provides four I/O cards: GTA0 (Gigabit Transceiver Analogue Output Card); GTAI (Gigabit Transceiver Analogue Input Card); GTDO (Gigabit Transceiver Digital Output Card) and GTDI (Gigabit Transceiver Digital Input Card). Next, the basic introduction about these four cards is first given; and then one example is made to show how to use these cards.

### 1.1 GTA0 card

This card is shown in Figure 1.

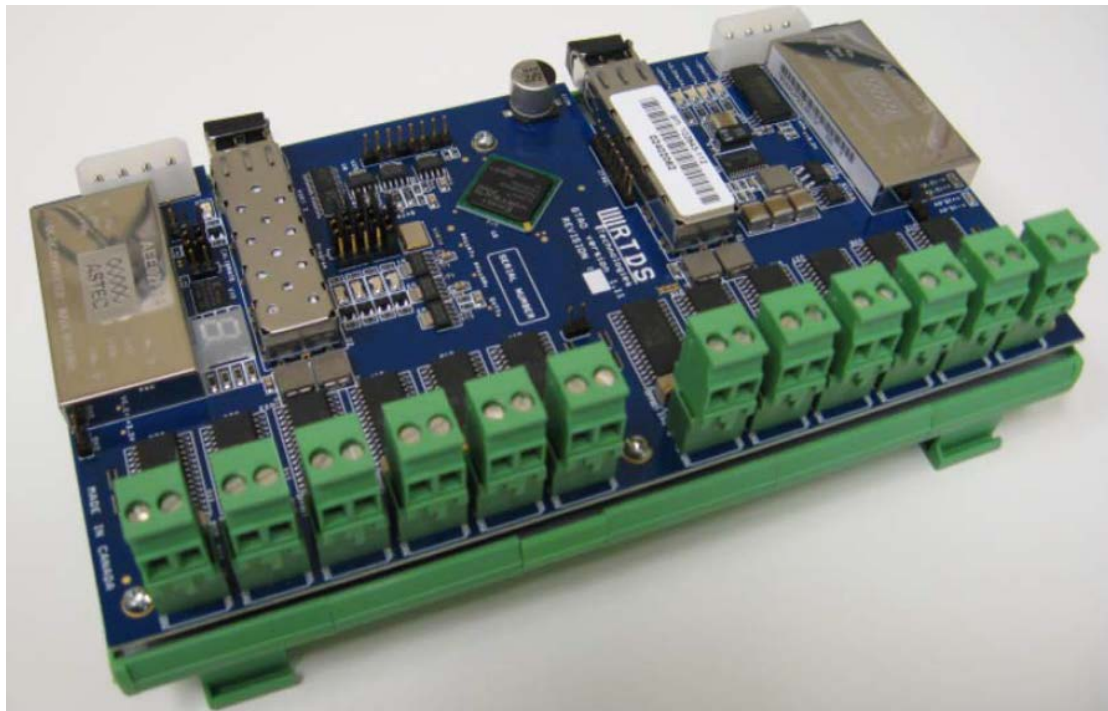


Figure 1 GTA0 card [RTDS manual V5.003.3]

This card is used to interface analogue signals from the RTDS to external devices. The GTA0 card includes twelve 16 bit analogue output channels with an output range of  $\pm 10$  volts. The GTA0 outputs are sampled at a rate of 1 micro-second and the card's output channels are updated synchronously.

Each GTA0 card is connected to an RTDS processor card (GPC or PB5) via a fibre cable, as shown by Figure 2.

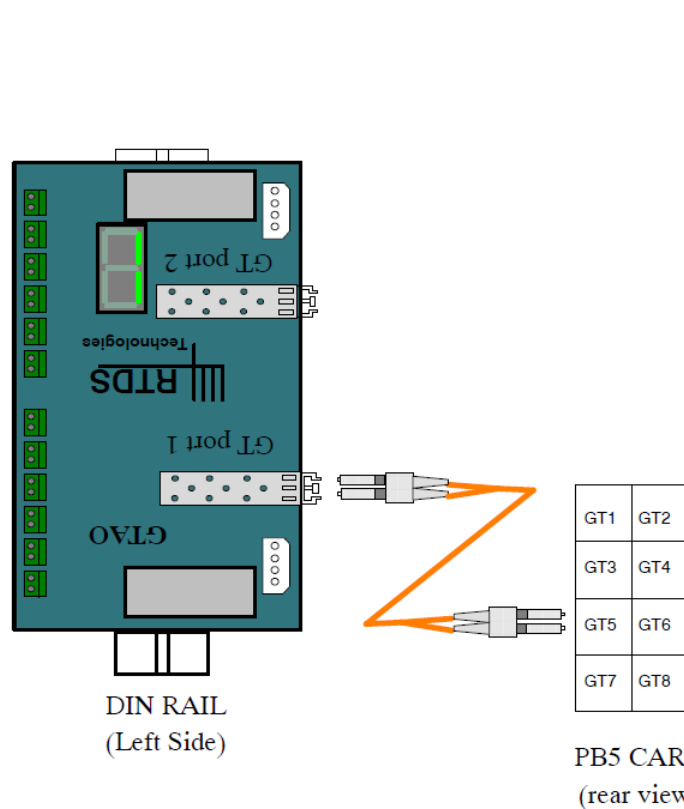


Figure 2 Connection between GTA0 and PB5 processor [RTDS manual V5.003.3]

Theoretically, GTA0 Cards may be connected to any Gigabit Transceiver (GT) port on the PB5 processor. It is recommended, however, to leave GT Port 8 for connection for the network solution processor in the rack.

A single 24 Vdc power supply connection is required to power a GTA0 card. 24 Vdc power plugs, as shown in Figure 3, are available on the both sides of GTA0 card.

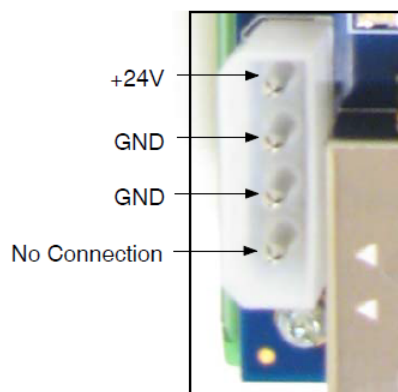


Figure 3 DC power plug [RTDS manual V5.003.3]

## 1.2 GTAI card

This card is shown in Figure 4.

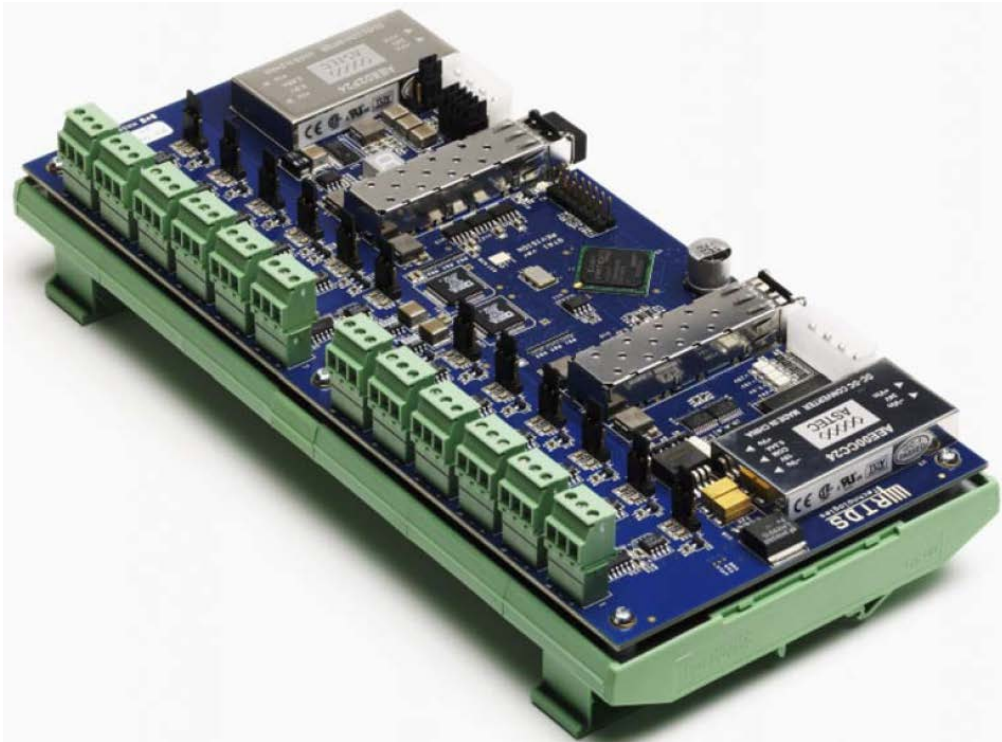


Figure 4 GTAI card [RTDS manual V5.003.3]

The card interfaces analogue signals from an external device to the RTDS simulator. The GTAI card includes 12 analogue input channels with each channel configured as a differential input with an input range of  $\pm 10$  volts. Sixteen bit A/D converters are used on the GTAI card. All 12 analogue channels are sampled synchronously with new samples sent to the processor card every 6.0 micro-seconds.

Data is exchanged between the GTAI card and a GPC/PB5 card using an optical cable connection between the card optical ports and the processors, as shown in Figure 5. The GTAI card can be connected to either GTIO optical port #1 or #2 on the GPC card

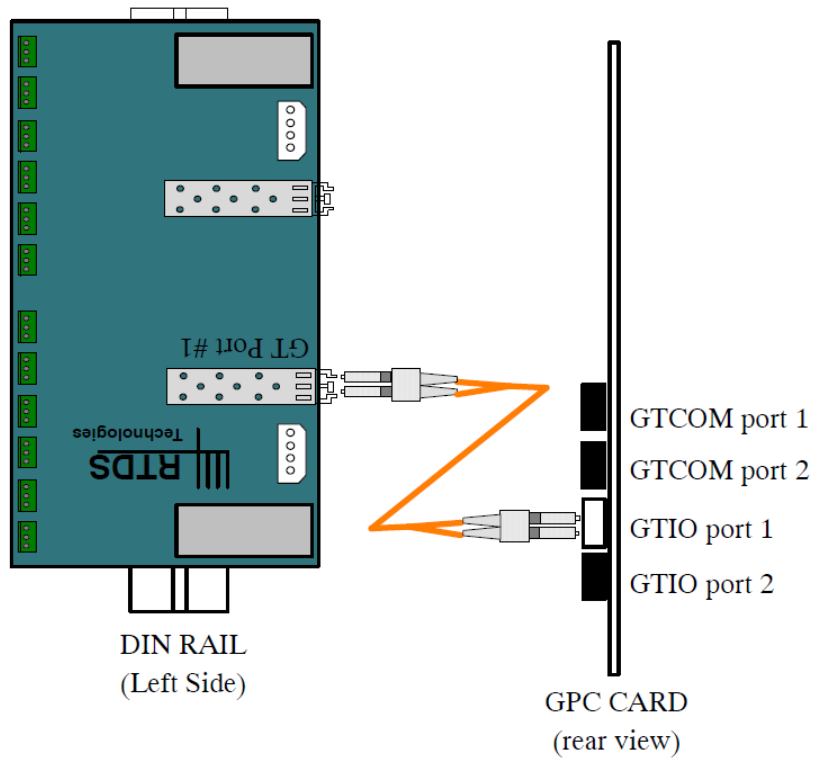


Figure 5 Connection between GTAI and GPC card [RTDS manual V5.003.3]

A single 24 volt power supply signal (as shown in Figure 6) is required to power the card.

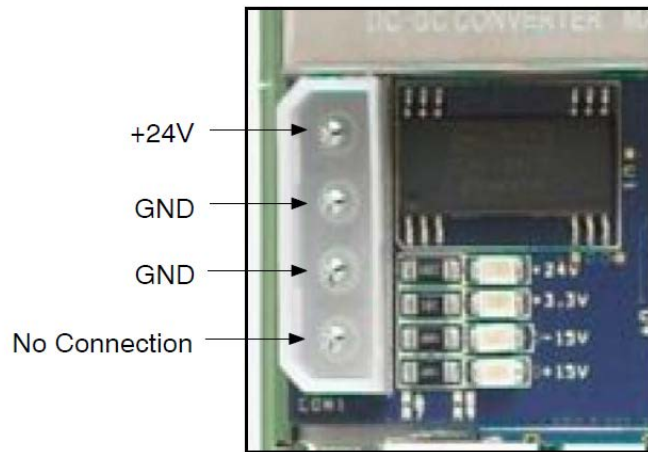


Figure 6 DC power supply [RTDS manual V5.003.3]

### 1.3 GTDO

GTDO card is shown in Figure 7.

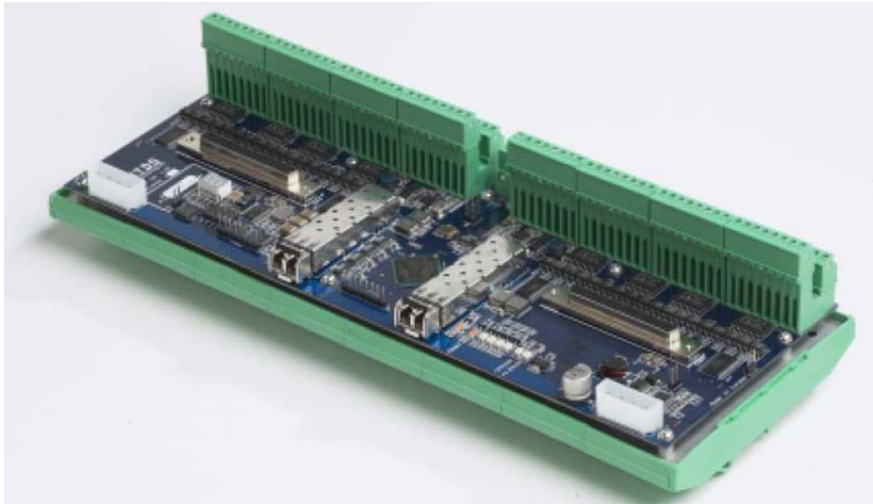


Figure 7 GTDO [RTDS manual V5.003.3]

GTDO card is used to interface digital signals from the RTDS to external equipment. The GTDO card includes 64 optically isolated digital output channels which are arranged into two banks of 32 channels each. Each bank of 32 channels may be operated at a different voltage level in the range of +5V to +24Vdc. The same 24 V external power supply like GTA0 and GTAI is required to supply GTDO card.

The connection between GTDO and the processor card is shown in Figure 8.

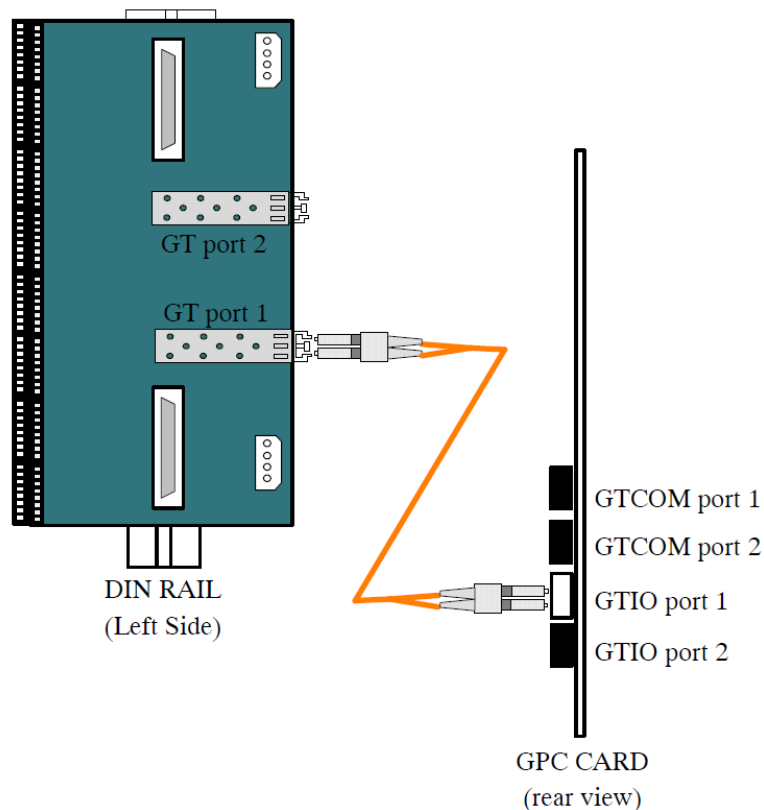


Figure 8 Connection between GTDO and processor card [RTDS manual V5.003.3]

#### 1.4 GTDI card

The GTDI is shown in Figure 9.

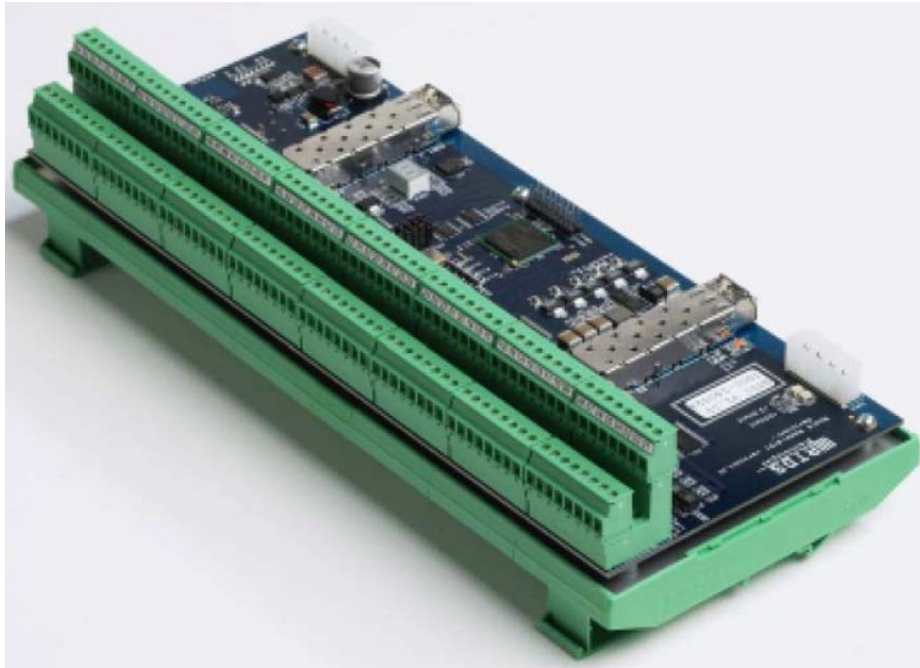


Figure 9 GTDI card [RTDS manual V5.003.3]

GTDI card is used to interface digital signals from an external device to RTDS. This card includes also 64 optically isolated digital input channels. Each GTDI card, like GTDO, is connected to a GPC card via an optical cable, please see Figure 10.

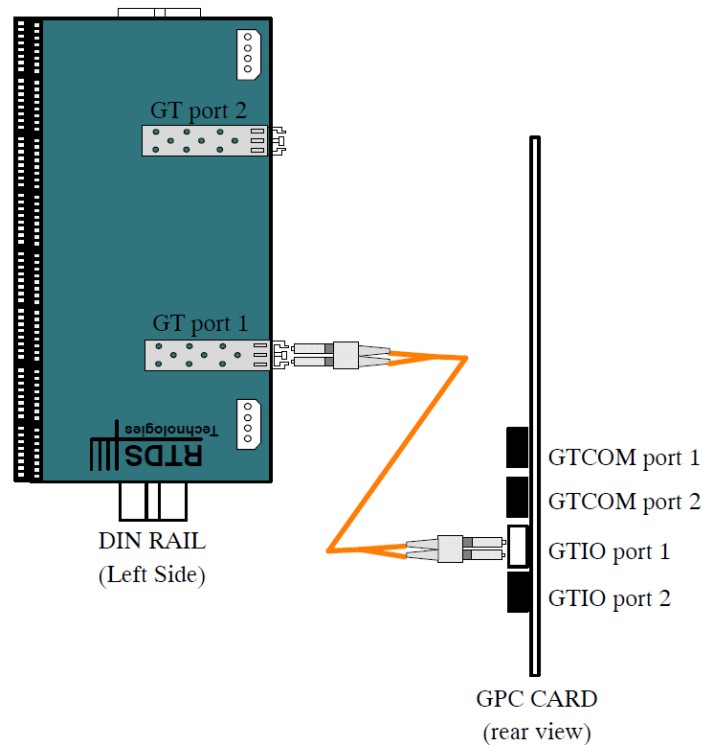


Figure 10 Connection between GTDI and processor card [RTDS manual V5.003.3]

A same single 24 volt power supply signal is required to power the card.

## 1.5 Daisy chain connection between different I/O cards

GT I/O cards can be daisy chained each other. Up to eight GT I/O cards may be connected in a daisy chain to one GT I/O port on a processor card. Each daisy chain connection introduces latency into the communication of data to cards further down the chain. GT I/O cards which communicate time critical signals should be placed at the start of the daisy, preferably connected directly to the processor I/O port.

Each GT I/O card contains an on-board seven segment card number display. The display identifies the GT I/O card number in the chain. The GT I/O card physically connected to the processor card is always considered the start of the chain. The first GT I/O card of its type encountered within the chain is assigned card #1. Thus, for a daisy chain consisting of one GTDI, one GTDO, one GTA0 and one GTAI card, each GT card has a number 1. A daisy chain consisting of two GTDI cards will have the card connected directly to the GPC card displaying #1 and the second card displaying #2.

One example of daisy chain connection of GT I/O cards is shown in Figure 11.

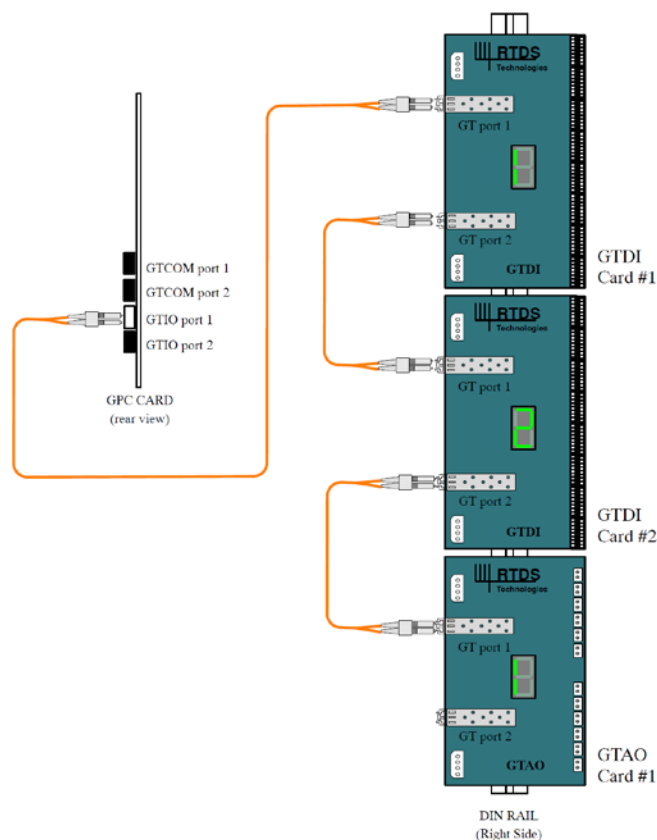


Figure 11 Daisy chain connection [RTDS manual V5.003.3]

**Assignment :** Open manual >> Hardware >> Chapters 6, 7, 8 & 9 for getting more details.



## 2 Demonstration of GT I/O card interfacing

**Info :** This activity will be demonstrated by the lecture. Students need not do this due to the security consideration.

In this part, a demonstration is made to illustrate how to interface RTDS simulator to external devices through GT I/O cards.

### 2.1 Outline of demonstration

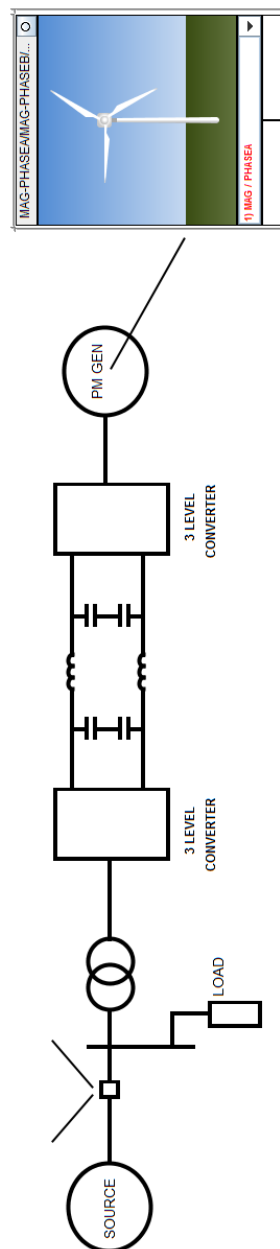


Figure 12 Test system

In this example, a wind turbine type 4 is connected to one external power grid, which is shown in Figure 12. A synchronous generator is used to represent the external grid.

When the frequency reduces after a disturbance, the wind turbine will provide primary frequency regulation. The power system, load, and wind turbine are simulated in RTDS simulator, but the controller for the generator side converter of wind turbine is implemented in a DSP card (TI f28069). Through this example, you will learn how to use GTA0 and GTDI cards in RTDS and how to interface them to an external device (namely DSP).

## 2.2 Primary frequency regulation provided by wind turbine

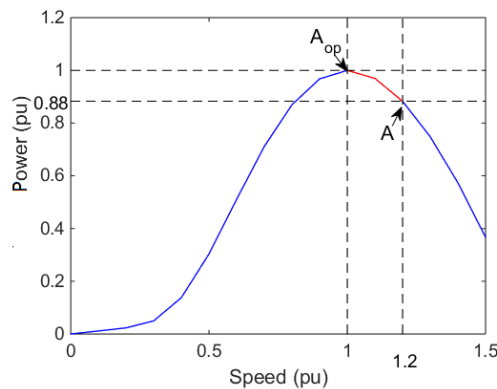


Figure 13: Primary frequency regulation

The adopted frequency regulation algorithm is illustrated in Figure13. For a given wind speed, WT4 operates in the de-loaded mode in order to obtain a certain amount of frequency reserves, indicated by the point A. The point  $A_{op}$  means the maximum power point. At the point A, the wind turbine outputs 1.765 MW active power, and has 0.245 MW reserves (namely a rated power of 2MW). The load is 1.8 MW. The difference between the load and the active power injected by wind turbine is compensated by the external grid. Since the focus is on the frequency support provided by wind turbine, the active power from the main grid is fixed at 0.3MW. After a 0.2 MW sudden increase in load, the frequency reduces. Wind turbine will reduce its speed and increase active power output in order to prevent the frequency dropping.

## 2.3 Connection of GTA0

In order to use GTA0 card, first, two GTA0 components, `rtds_risc_ctl_PROCASN` (Figure 14.a) and `rtds_risc_ctl_GTAOOUT` (Figure 14.b) should be added to the simulation system in RSCAD/Draft.

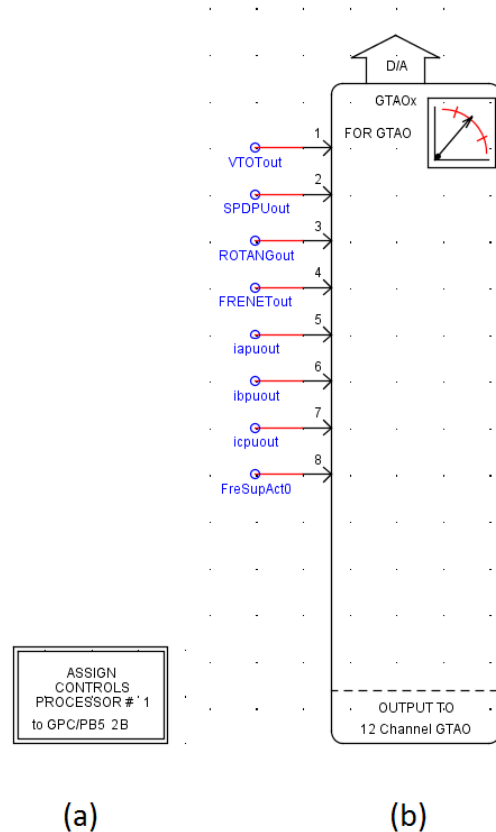


Figure 14 GTA0 components

rtds\_risc\_ctl\_PROCASN locates in the Controls tab. It will decide which processor deals with the communication data sent out by GTA0. rtds\_risc\_ctl\_GTAOOUT locates in the I/O Components hierarchy box under the Controls tab in the Master Library.

In this example, 8 channels of GTA0 are used to output DC voltage of back-to-back converter (VTOTout), rotor speed of wind turbine (SPDPUout), rotor angle of wind turbine (ROTANGout), the frequency of grid (FRENETout), stator current of wind turbine (iapuout, ibpuout, icpuout) and the switch signal of triggering frequency regulation (FreSupAct0).

## 2.4 Connection of GTDI

In this example, two back-to-back three-level converters as shown in Figure 15 connects the wind turbine to the grid. Therefore, 12 PWM pulses for the PMSM side converter should be injected from GTDI to RTDS simulator. The grid side converter is simulated and controlled in RTDS simulator.

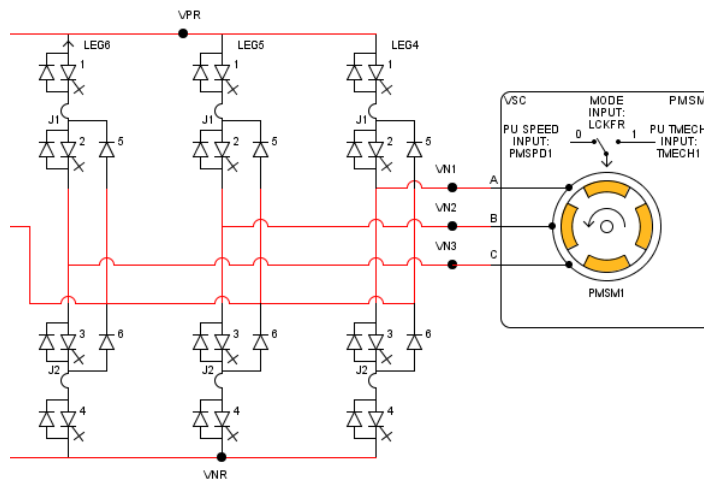


Figure 15 3-level inverter

The first 12 channels of GTDI are connected. Also notice, the negative poles of GTDI should be reliably connected to the ground.

## 2.5 Overall simulation platform

The overall simulation platform is shown in Figure 16. It consists of three parts: real time simulator (RTDS), interface (GTAO & GTDI) and control system (DSP).

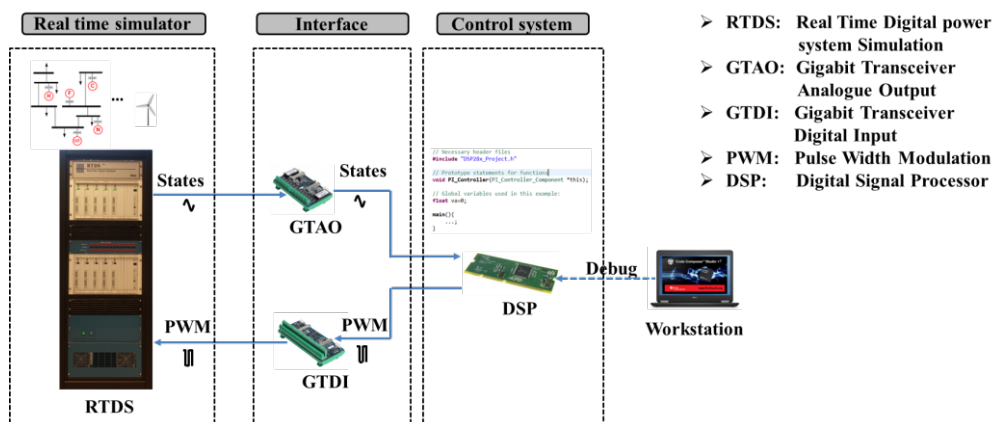


Figure 16: Framework of demonstration platform

The external power system, the wind turbine except its control system on the PMSM side converter are modelled in RSCAD.

GTAO sends the selected 8 systems states measured in RTDS to the control system. Here, a TI DSP f28069 is selected to play the role of control system. The TI DSP calculates the 12 PMW pulses and sends them to GTDI. GTDI brings these PWM signals back to the PMSM sider converter in RTDS.

## 2.6 Test results

The correct starting procedure is: first start DSP and debug the embedded frequency control algorithm. Next, start the RTDS simulation.

The frequencies with and without the frequency regulation of wind turbine are compared in Figure 17. It is seen that without frequency control, the frequency continuously reduces. The frequency control successfully maintains the post disturbance frequency at 50 Hz, as shown by Figure 17 (b).

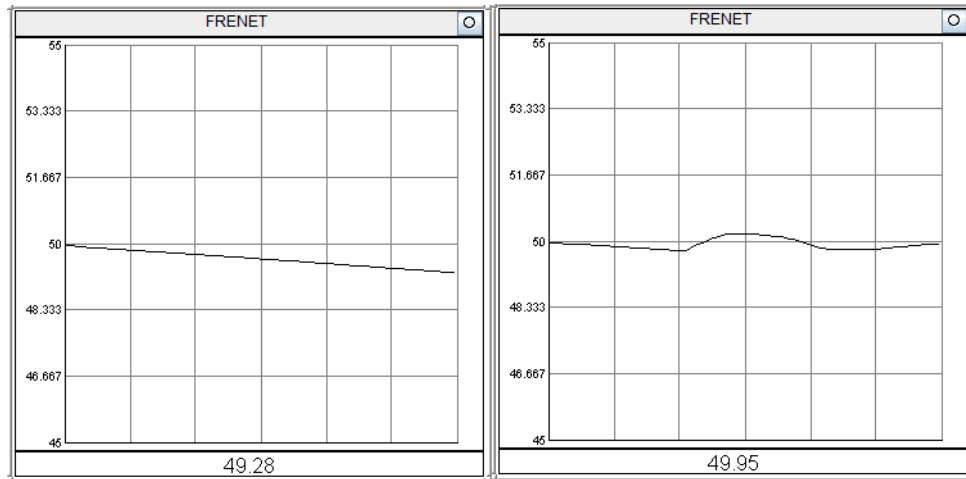


Figure 17 Frequencies : without frequency regulation(a); with frequency regulation(b)

The mechanical power and the speed of wind turbine are shown in Figure 18. It is shown that after the frequency control, the mechanical power increases from 1.765W to 2 MW. Correspondingly, the speed reduces from 1.2 pu to 1 pu.

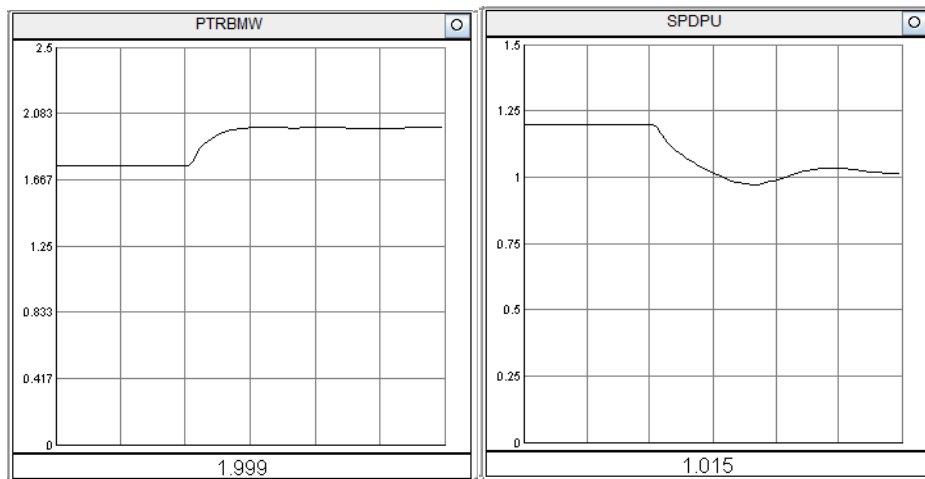


Figure 18 Mechanical power and speed of wind turbine