

RTDS Training course

Intelligent Electrical Power Grids, TU Delft

Overview of RTDS Hardware and RSCAD

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1. INTRODUCTION

The objective of this lab session is to provide an overview of the Real Time Digital Simulator (RTDS) hardware and the RSCAD software. RTDS simulator is used for real time power system simulation. The simulator is designed to conduct ElectroMagnetic Transient Simulations (EMT). The simulator can work over a frequency range of DC to 3 KHz. The RSCAD software is also designed by RTDS Technologies. It is a power system simulation software designed for interfacing to the RTDS Simulator hardware. The RSCAD software acts as an interface which intends to create a working environment familiar to the power system engineer. It allows the user to perform all of the necessary steps to prepare and run simulations, and to analyse simulation results [1-2].

The manual is further divided in two sections. The first section would give an overview of the RTDS simulation hardware and the second section will explain the RSCAD software.

2. RTDS Hardware

RTDS simulator hardware can simulate complex power systems with a typical time step of 25-50 μ s. The hardware also allows for small time-step in the range of 1-4 μ s [1]. The hardware is composed of modular chassis which contains multicore processor. The first generations of processor cards were called 3PC. The next generation of processor cards are called PB5 cards, which is currently widely used around the world. The newest generation of simulation hardware is called **NovaCor**. RTDS facility in TU Delft has 2 NovaCor cards while others are with PB5 processor cards. Figures 1A,1B,1C show the different RTDS type of installations in TU Delft.

2.1 RTDS Cubicle

RTDS cubicle consists of racks on which the processor cards are mounted together with the input/output cards and power entry connections.



Figure 1A: A typical RTDS hardware setup

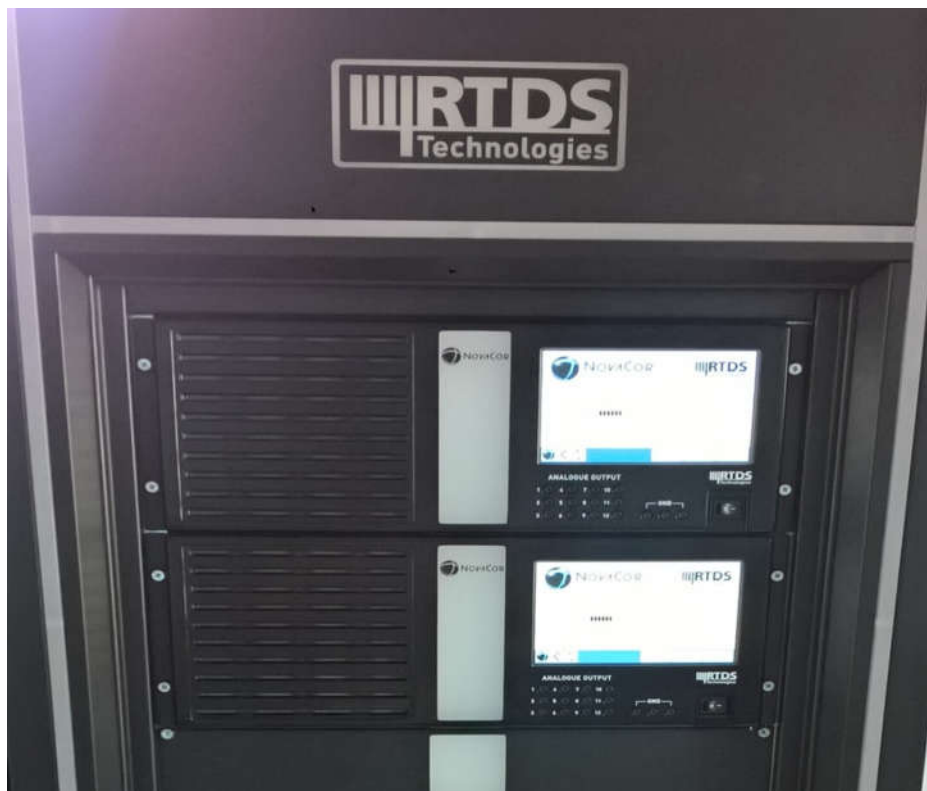


Figure 2B: RTDS hardware setup with the latest NovaCor processor card

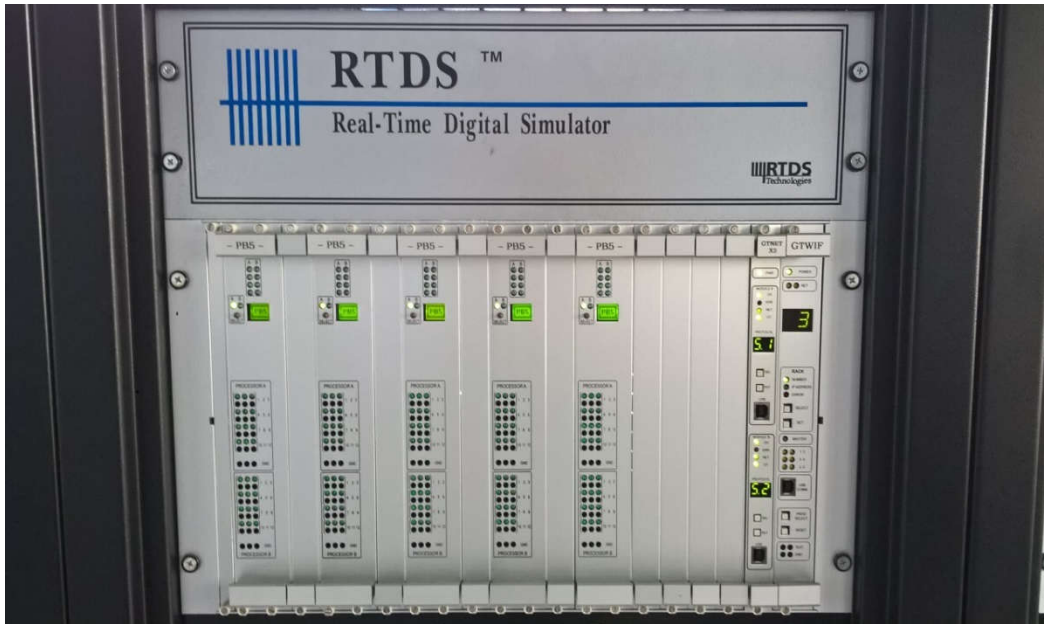


Figure 3C: RTDS hardware setup with the PB5 processor card

2.2 Giga Transceiver Work Station Interface Card (GTWIF)

Each RTDS rack includes a GTWIF card as seen in figure 2. The main functions of the GTWIF card are:

1. It helps in communication between the RTDS rack and the computer workstation running the RSCAD software. Communication is over an ethernet based LAN. RSCAD/RunTime software communicates with the GTWIF card's real-time O/S to send and receive messages associated with plot updates and user initiated events. The GTWIF card is also used for communication of data with the computer workstation in order to load new simulation cases, as well as, to start and stop the simulations.
2. It also helps in synchronization of racks for multi-rack simulation cases. Each time-step, and the communication intervals within the time-step, are synchronized by the GTWIF installed in the first rack allocated for the simulation case. The first rack in the simulation case is designated as the *master rack*.
3. It communicates with other racks participating in a simulation case. It can communicate with up to six other racks while the simulation case is running.



Figure 2: RTDS GTWIF card

2.3 PB5 Processor Card

The RTDS racks used in this training module are equipped with PB5 processor cards. The processor cards as seen in figure 3 are the heart of RTDS as they solve the equations representing the power and control system modelled in the RTDS. Each PB5 card comprises of two Freescale PowerPC MPC7448 processors running at 1.7 GHz. PB5 cards allows for two network solution processors within a single rack, allowing for a total of 144 nodes. The number of nodes per network solution processor can be further increased to 90 via the newly introduced fibre enhanced backplane feature, allowing for a total of 180 nodes within a single rack.

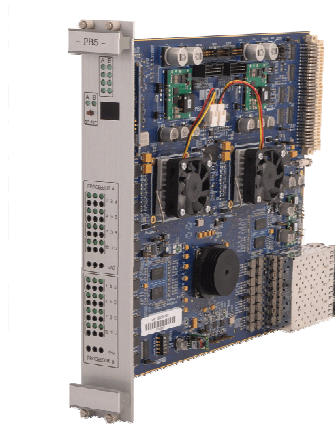


Figure 3: RTDS GTWIF card

2.4 Inter-Rack Communication Card (IRC)

Inter-Rack Communications Card (IRC) provides direct, bi-directional, data communication paths from one rack to at most six others. IRC cards are required for multi-rack RTDS systems which are equipped with WIF cards. RTDS systems equipped with GTWIF cards do not require IRC cards as the IRC function is included as part of the GTWIF. It can provide direct data communication between as many as 60 racks. Figure 4 shows the a typical RTDS IRC

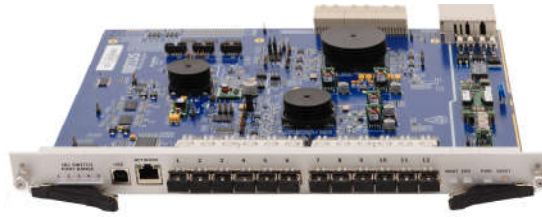


Figure 4: RTDS IRC

2.5 Global Bus Hub (GBH)

A Global Bus Hub is used to control and coordinate the operation of RTDS simulators consisting of 3 or more RTDS racks. It allows for common timestamp of all racks and a maximum of 60 racks can be driven by this one common timestamp. Figure 5 shows what a typical GBH looks like.



Figure 5: RTDS Global Bus Hub

2.5 Gigabit Transceiver Analogue Input and Output Cards (GTAI/ GTAO)

The Gigabit Transceiver Analogue Input and Output cards (figure 6A & 6B) are used to interface analogue signals from RTDS to external devices. The cards include twelve, 16 bit analogue output channels with an output range of +/-10 volts. The cards are oversampled at a rate of 1 micro second and the input/ output channels are updated synchronously.

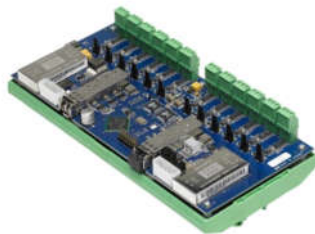


Figure 6A: RTDS GTAI card



Figure 6B: RTDS GTAO card

2.6 Gigabit Transceiver Digital Input and Output Cards (GTDI/ GTDO)

The Gigabit Transceiver Analogue Input and Output cards (figure 7A & 7B) are used to interface digital signals from RTDS to external devices. The cards include 64 optically isolated digital output channels arranged in two slots of 32 channels each. The channels may be operated at different voltage level in the range of +5V to +24Vdc. The GTDO card includes a digital output time-stamp (DOTS) function. Similarly, GTDI card includes digital input time-stamp (DITS) function. These functions allow the output/ input signals to change at any instant within a simulation time-step. One of the application of the DOTS function is to provide current zero pulses to an external HVDC controller.



Figure 7A: RTDS GTDI card



Figure 7B: RTDS GTDO card

2.7 Gigabit Transceiver Network Interface Card (2nd Gen.) (GTNETx2)

GTNETx2 is the 2nd generation Network Interface Card (figure 8) of the RTDS. The card is used to interface the RTDS to external equipment over a LAN connection using the various standard network protocols. The various protocols supported are:

GSE/Goose	IEC 61850
SV	IEC 61850-9-2
PMU	IEEE C37.118
DNP3	Distributed Network Protocol (SCADA)
PB	Playback of very large data
SKT	Communication over TCP/UDP sockets

Each GTNETx2 card is capable of running two network protocols simultaneously. The two processors are known as Module A and Module B.



Figure 8: GTNETx2 card

2.8 Gigabit Transceiver Synchronization Card (GTSYNC)

The GTSYNC card (figure 9) is used for internal synchronization of the simulations in absence of external sources. During simulations, the phase of signals computed within the RTDS generally drifts relative to the phase of signals of external equipment. Hence, synchronization to a high precision time reference is required to maintain accuracy of the simulations. The clock used to generate the RTDS simulation time-step has an accuracy of ± 100 ppm. The GTSYNC card is used to ensure that the RTDS time-step clock remains locked to the time-reference signal provided as an input to the GTSYNC.

GTSYNC card of RTDS uses IEEE 1588 PTP, 1 PPS or IRIG-B unmodulated signals as the synchronization source.

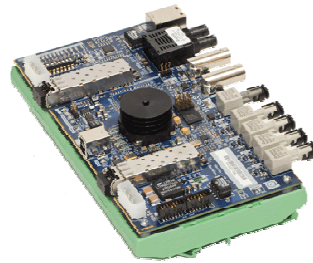


Figure 9: RTDS GTNETx2 card

3. RTDS SOFTWARE

RTDS has its own software support system called RSCAD. RSCAD is used for modelling any power system, compiling it to see if it fits all RTDS requirements and finally executing it in the RTDS hardware. RSCAD is organized into a hierarchy containing three separate levels: high level graphical user interface, mid-level compiler and communications and the low level WIF multi-tasking operating system. The RTDS user is exposed only to the high level software with the lower levels being automatically accessed through higher level software.

RSCAD Configuration Files

RSCAD configuration files are very important as they contain all the information regarding the hardware configuration of RTDS. It contains information about the IP addresses of different rack ports and the GTAO, GTDO, GTDI cards. RSCAD provides a tool to edit the hardware configuration known as the config file editor. If the config file is wrongly configured, RTDS will not simulate any case. Config file editor can be accessed under the Tool menu. The config file editor screenshot in Fig. 10 shows the different configuration parameters of the different racks. Rack 3 (highlighted in red) configuration also shows that the GTAI, GTAO, GTDI and GTNETx2 are connected to Rack 3 along with a PMU.

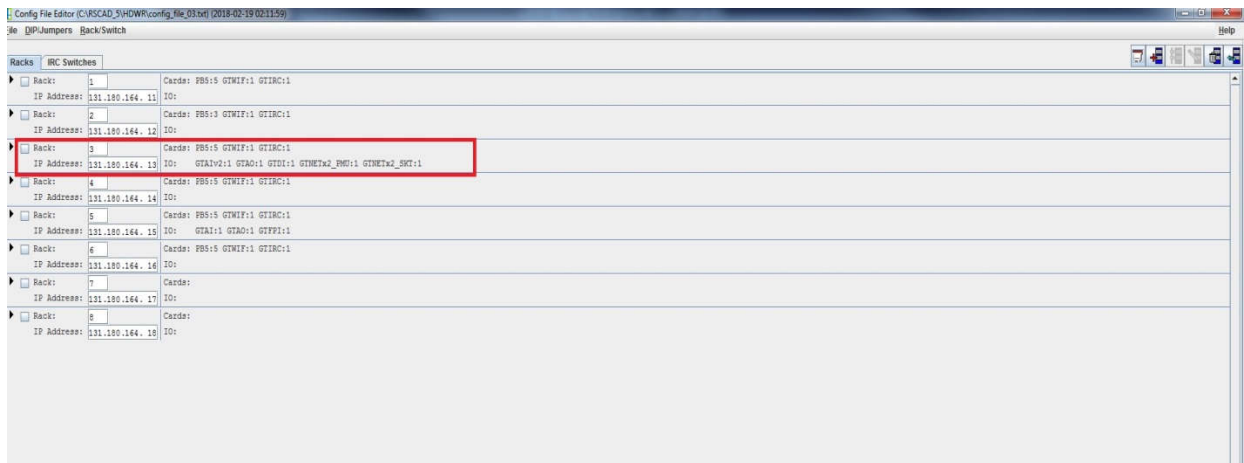


Figure 10: Config File Editor

RSCAD Graphical User Interface

The high level RTDS software comprises the RSCAD family of tools. RSCAD is a software package developed to provide a fully graphical interface to the RTDS. Prior to the development of RSCAD, another software suite: PSCAD served as the graphical user interface to the RTDS hardware.

RSCAD/FileManager (Fileman) as seen in the screenshot in figure 11 represents the entry point to the RSCAD interface software. Fileman is used for project and case management and facilitates information exchange between RTDS users. All other RSCAD programs are launched from the Fileman module. Different RSCAD modules can be seen in figure 12.

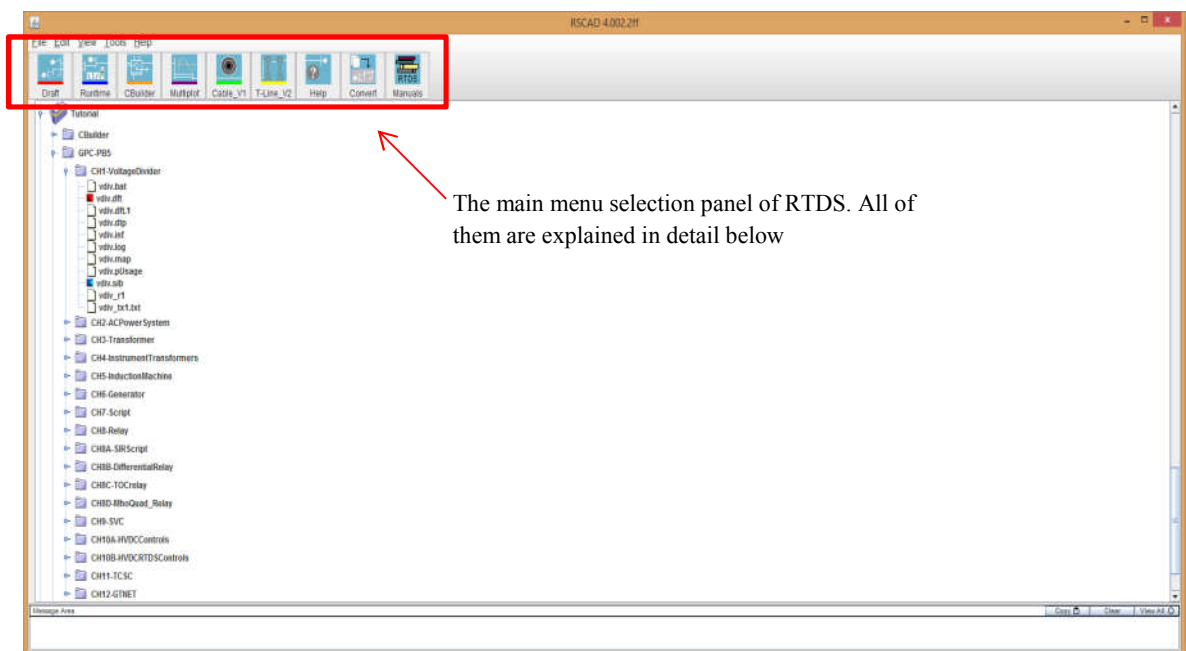


Figure 11: RSCAD FILEMAN

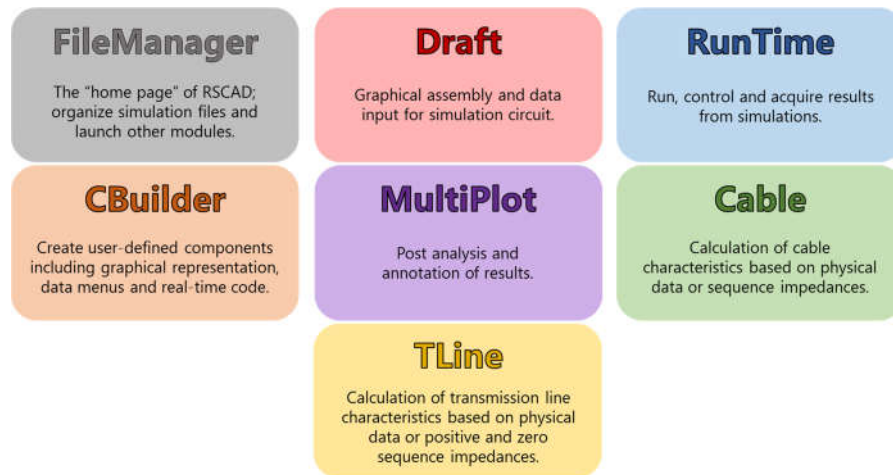


Figure 12: Different RSCAD Modules [2]

In RSCAD fileman, a circuit is first designed in the draft file and saved. Compiling of the draft file is done to check if it meets all design requirements of RSCAD modelling. Any warning/error is indicated by the software at this stage so that it can be rectified. A draft file cannot be executed on the RTDS hardware unless successfully compiled in the RSCAD software.

RSCAD/Draft is used for circuit assembly and parameter entry. The Draft screen is divided into two sections: the library section and the circuit assembly section. Individual component icons are selected from the library and placed in the circuit assembly section. Interconnection of individual component icons and parameter entry follows through a series of menus.

RSCAD/T-Line and **RSCAD/Cable** are used to define the properties of overhead transmission lines and underground cables respectively. Data is generally entered in terms of physical geometry and configuration. Line and Cable constants and equations are solved, resulting in ready to use data for the RSCAD/Draft program. Draft cross-references line and cable output files by name. The parameter input menus for TLINE and Cable in RSCAD can be seen in figure 13 and 14.

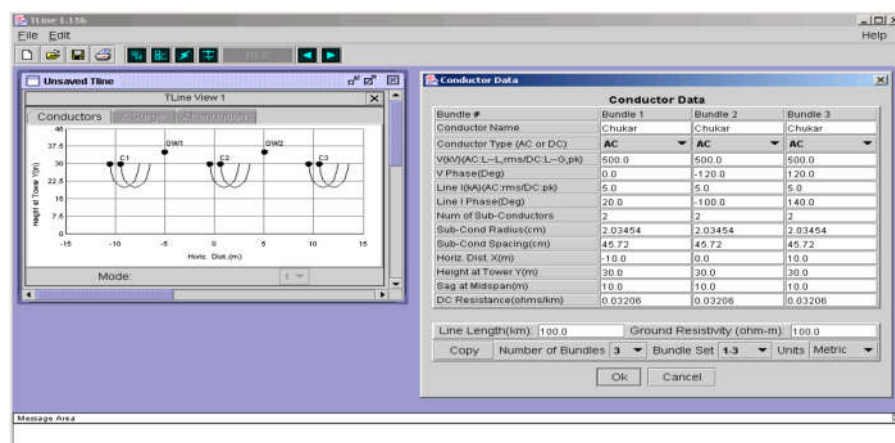


Figure 13: TLINE parameter input menu

Cable Data

		Cable 1	Cable 2	Cable 3
General	LL Last Layer	Insulator 3	Insulator 3	Insulator 3
	LC Ground Last Metallic Layer	No	No	No
	Xi X-Coordinate(m)	0.0	10.0	20.0
	Yi Y-Coordinate (-ve in ground)(m)	-1.0	-1.0	-1.0
Conductor	r1 Inner Radius(mm)	0.0	0.0	0.0
	r2 Outer Radius(mm)	22.0	22.0	22.0
	pc Resistivity(Q-m)	1.68E-8	1.68E-8	1.68E-8
	μc Relative Permeability	1.0	1.0	1.0
Insulator 1	r3 Outer Radius(mm)	39.5	39.5	39.5
	ε1 Relative Permittivity	4.1	4.1	4.1
Sheath	μ1 Relative Permeability	1.0	1.0	1.0
	r4 Outer Radius(mm)	44.0	44.0	44.0
Insulator 2	ps Resistivity(Q-m)	2.2E-7	2.2E-7	2.2E-7
	μs Relative Permeability	1.0	1.0	1.0
Armour	r5 Outer Radius(mm)	47.5	47.5	47.5
	ε2 Relative Permittivity	2.3	2.3	2.3
Insulator 3	μ2 Relative Permeability	1.0	1.0	1.0
	r6 Outer Radius(mm)	58.3	58.3	58.3
Insulator 3	pa Resistivity(Q-m)	1.8E-7	1.8E-7	1.8E-7
	μa Relative Permeability	400.0	400.0	400.0
Insulator 3	r6 Outer Radius(mm)	63.5	63.5	63.5
	ε3 Relative Permittivity	1.0	1.0	1.0
Insulator 3	μ3 Relative Permeability	1.0	1.0	1.0
	μ3 Relative Permeability	1.0	1.0	1.0

Cable Length(km) 2.0 Ground Resistivity(Q-m) 0.25 Ground Permeability 1.0

Copy Number of Cables 1 Cable Set 1-3 Units Metric

Ok Cancel

Figure 14: Cable model parameter input menu

RSCAD/RunTime is used to control the simulation case(s) being performed on the RTDS hardware. Simulation control, including start / stop commands, sequence initiation, set point adjustment, fault application, breaker operation, etc. are performed through the RunTime Operator's Console. Additionally, on line metering and data acquisition / disturbance recording functions are available in RunTime. The different Draft module and the circuit construction modes can be seen in figure 15,16 & 17.

RSCAD/MultiPlot is used for post processing and analysis of results captured and stored during a simulation study. Report ready plots can be generated by MultiPlot.

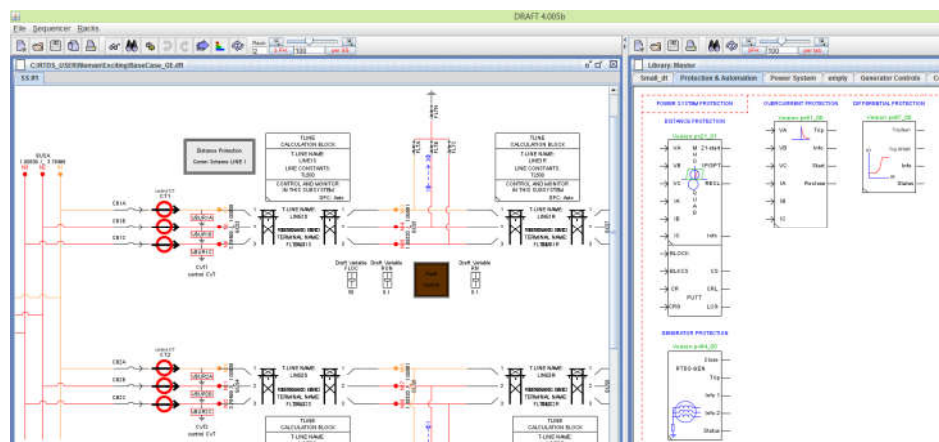


Figure 15: RSCAD Module: DRAFT

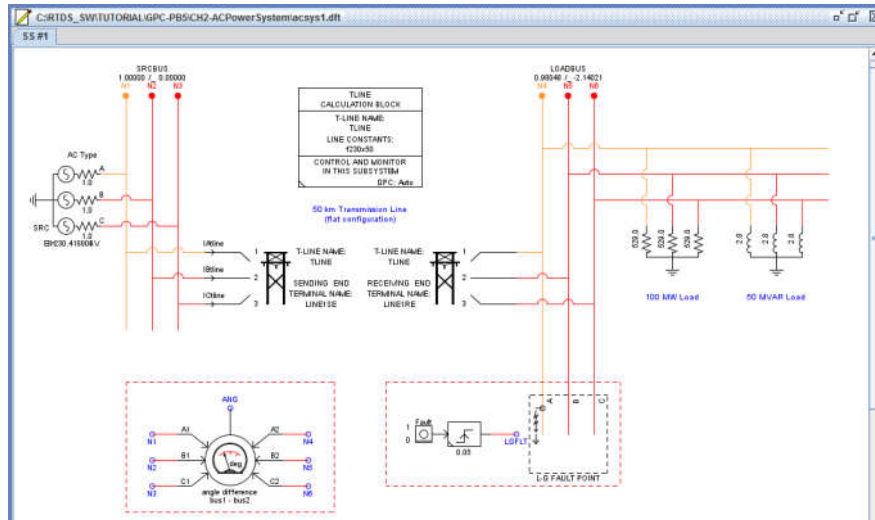


Figure 16: Circuit Construction in Draft (Three Phase drawing mode)

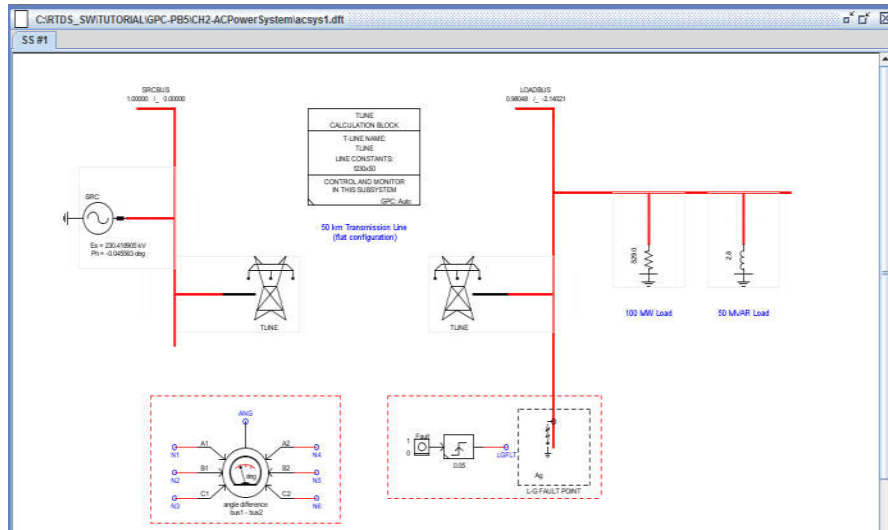


Figure 17: RSCAD Module: DRAFT (single line drawing mode)

RTDS Component Builder (C Builder)

RSCAD software also has the flexibility to model new components. The C Builder option of the software allows RTDS users to create and develop their own component models. C builder gives option to develop models for both Power System and Control System. C Builder provides an interface for drawing and creating various components. It also provides the structure to define the parameters and input/output signals, which will configure the new component model. A compiler converts the user written C code for the new component model into an executable code which is then integrated into the RTDS software library. The C Builder module can be seen in figure18.

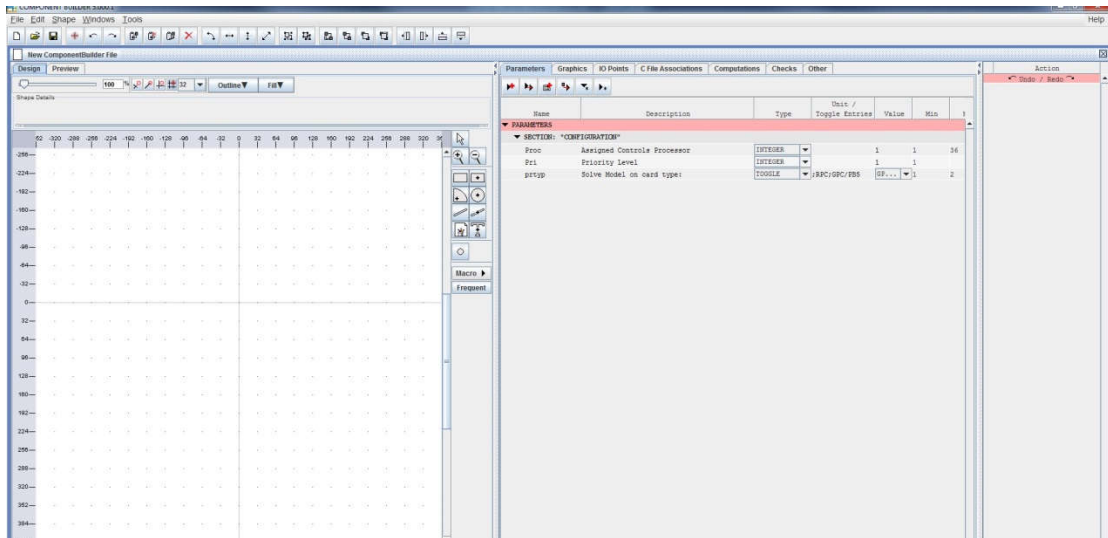


Figure 18: RSCAD C Builder module start screen.

RTDS Compiler / Linker & Operating System

RTDS mid-level software is divided into two separate parts, the operating system and the compiler.

The RTDS operating system performs many functions. Part of the O/S runs on the host computer workstation while part runs on the workstation interface cards. The major function of the WIF based portion of the O/S is to handle I/O requests which are usually initiated by the user. Diagnostic tests performed by the system administrator are also handled through the operating system level of software residing on the WIF. Finally, cross-rack communication errors, if they occur, will be detected by the WIF based operating system software which will in turn cause the simulation to be stopped and the appropriate LED indicators to be illuminated.

The executable code required for each new simulation case is generated through a specially developed set of software programs collectively termed the RTDS compiler. The compiler takes as input the power system data entered by the user through RSCAD/DRAFT along with a hardware configuration file (RSCAD\HDWR\config_file) which defines the hardware making up the user's RTDS installation. As output, the compiler produces all of the parallel processing code required by the digital signal processors, as well as memory allocation and data communication transfer schedules.

In order to generate the executable code, the compiler accesses the lowest level of RTDS software, the component library. The library contains code modules for all available power and control system component models. The code modules generally consist of low level machine language code for the individual component models and

also for the overall system solution. Based on the user defined circuit, processor allocation and required library access will be performed by the RTDS compiler in a manner transparent to the user. Processor assignment can be either automatic (i.e. decided by the compiler) or can be manually specified by the user during the RSCAD/DRAFT session. The final product of the compiling process is a file (or set of files) containing DSP code which is transferred to the RTDS over the ethernet using the RSCAD/RunTime Start Command.

The compiler also produces a **.MAP** file. The .MAP file is a user readable file which provides information on processor allocation (i.e. : cross reference listing for component/ processor match-up), input / output channel allocation, analogue output channel scaling and system initial conditions. The .MAP file is particularly useful and important when physical connections are to be made between the RTDS and external equipment.

RSCAD has various component libraries which can be used for designing of the different circuits. There are three main component libraries:

1. Power System Component Library
2. Control System Component Library
3. Small Time Step Component Library

The different libraries as seen in figure 19,20,21 have various component heads. The component heads are the major component categories with respect to that library type. Under these component libraries there are various models related to that component head. The user can choose the model best suited for the simulation case.

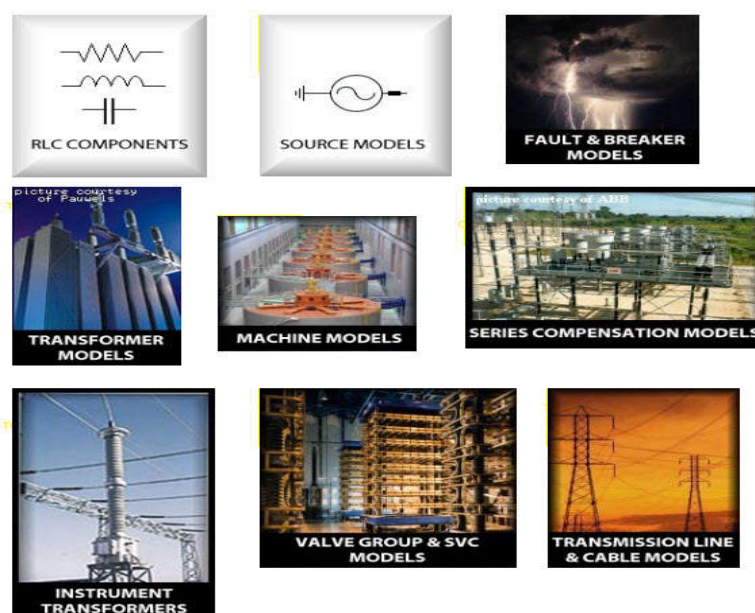


Figure 19: Power System Component Library

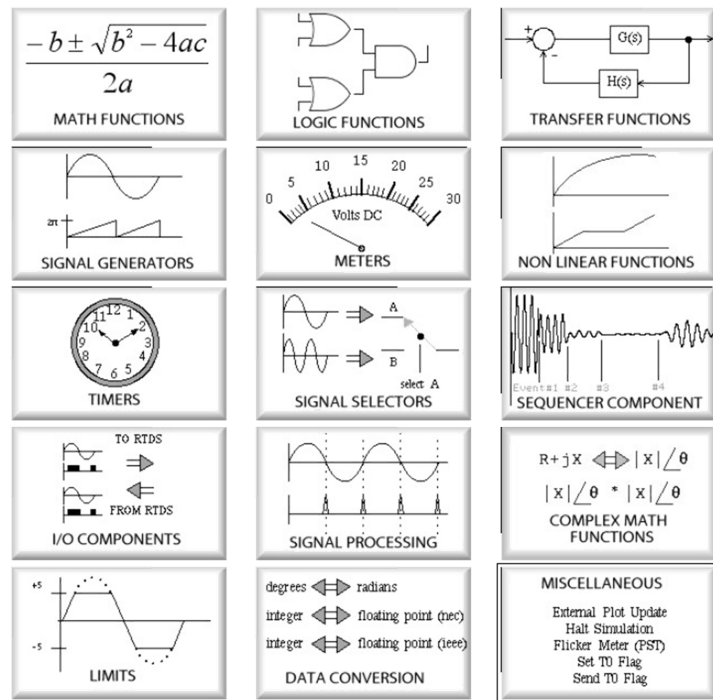


Figure 20: Control System Component Library

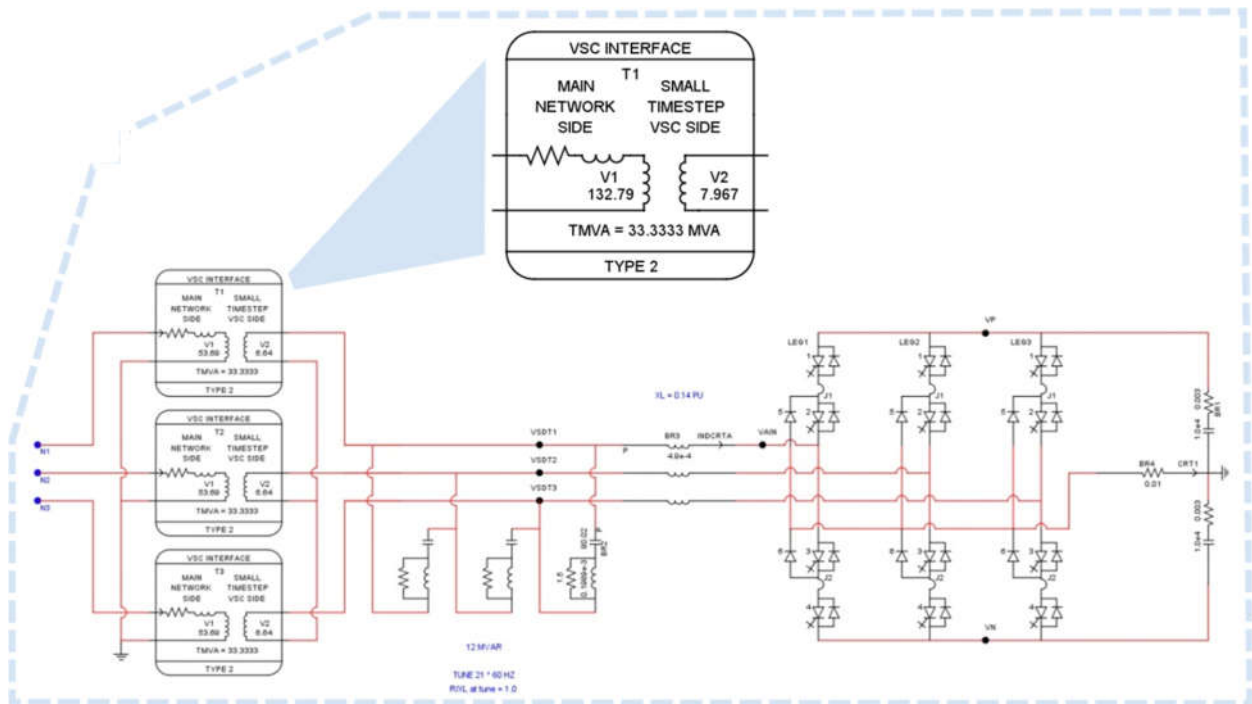


Figure 21: Small Time-step Subnetwork Interface

REFERENCES

- [1] www.rtds.com
- [2] 'RTDS hardware manual', RTDS Technologies, January 2009.