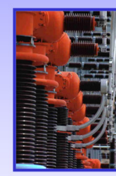
RTDS Technologies Inc.

New Developments at RTDS Technologies



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October 18, 2011

Real time digital simulation for the power industry

RTDS Technologies

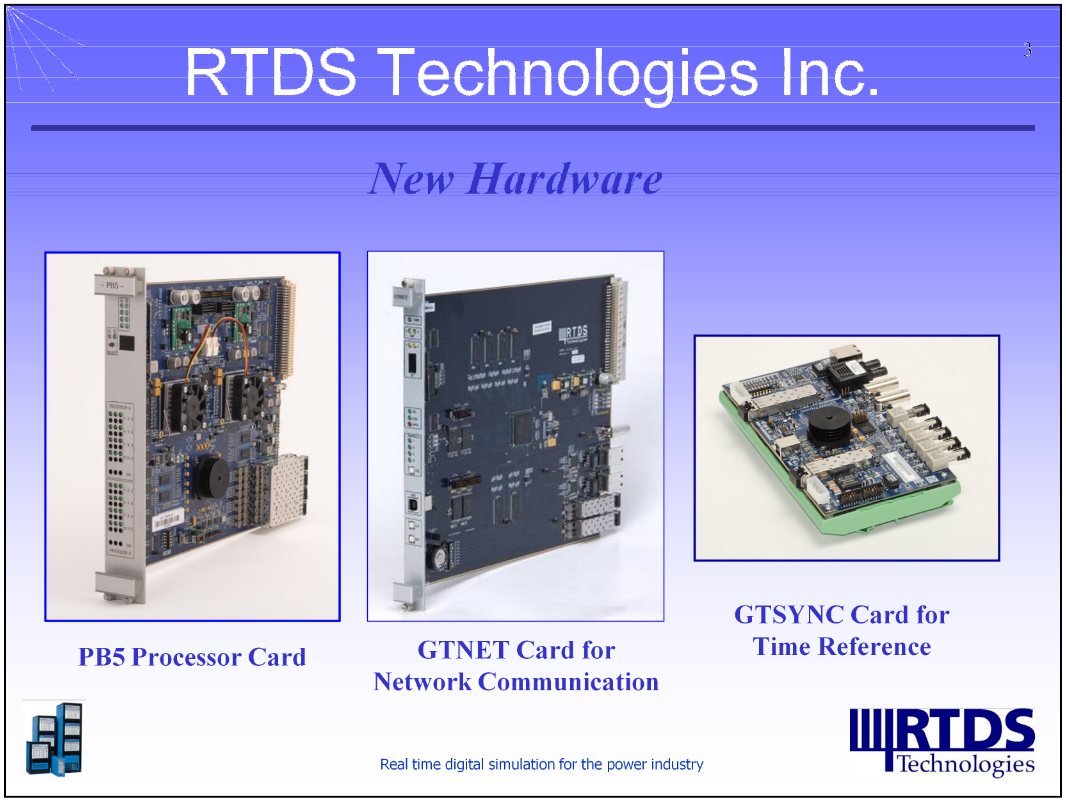
Good afternoon, everyone! I am very glad to have the opportunity to present new developments at RTDS Technologies.

RTDS Technologies Inc.

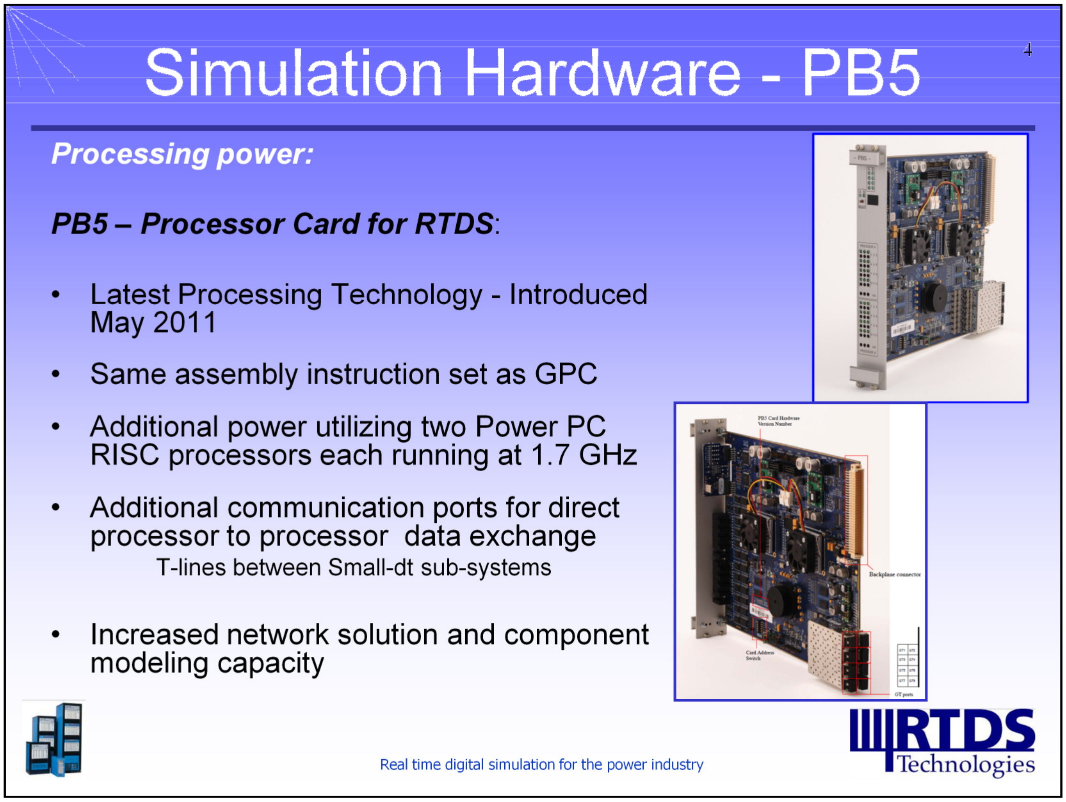
RTDS Technologies – The Company:

- Located in Winnipeg, Manitoba
- Current number of employees is 35
- Company Mandate
  - Continued development of RTDS hardware
  - Continued development of RSCAD software
  - Marketing and sales
  - Training and after sales technical support

RTDS is a Winnipeg company with 35 employees. It is the leader in real time digital simulation for the power industry. At RTDS, we work hard to meet the technological challenges of the industrial by developing new hardware and simulation models.



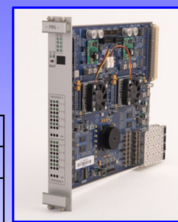
On the hardware side, we have developed the PB5 processor card, GTNET card for network communication and GTSYNC card for time reference.



PB5 is our newest processor card. It has the same assembly instruction set as the GPC card. With its increased computing power and additional communication ports, we can simulate larger networks and more than one small time step sub-systems in a rack.

Simulation Hardware - PB5

Comparison Table: PB5 versus GPC



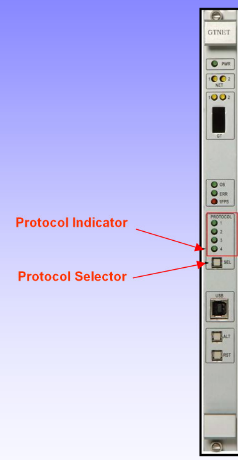
Card Type	*PB5*	GPC
Year of Production	*2011*	2005
Processor type	*Freescale MC7448 RISC*	IBM 750GX RISC
Clock speed	*1.7 GHz*	1.0 GHz
No. of processors per card	2	2
Load units per processor	*12*	10
Network solution (max nodes)	*72x2 = 144 = 48 buses*	66 = 22 buses
No. of I/O fibre ports	2	2
No. of comm. Ports	*6*	2
No. of 12 bit d/a's	*24*	24

Here is comparison with GPC card. The clock speed is 1.7 GHz compared with 1GHz for GPC. The load units per processor is 12 instead of 10. PB5 can handle 2 network solutions each with 72 nodes (or 24 buses), much larger than the 66 nodes for the GPC. It has 6 communication ports which can be used for inter-card communications, such as small dt T-lines.

GTNET Card

GPC Network Communication - GTNET:

- GTNET provides a mechanism to communicate with external devices over the ETHERNET (i.e. the LAN)
  - 100BASE−TXRJ45 Ethernet port, or
  - 100BASE−FX (optical) Ethernet port
- Originally developed for IEC 61850 communication now being adopted by the protection industry
- Additional communication protocols implemented in response to customer requests
- Up to 4 communication protocols can be installed on a single GTNET card
- Only one protocol can be active during a simulation case (user selectable)



Real time digital simulation for the power industry

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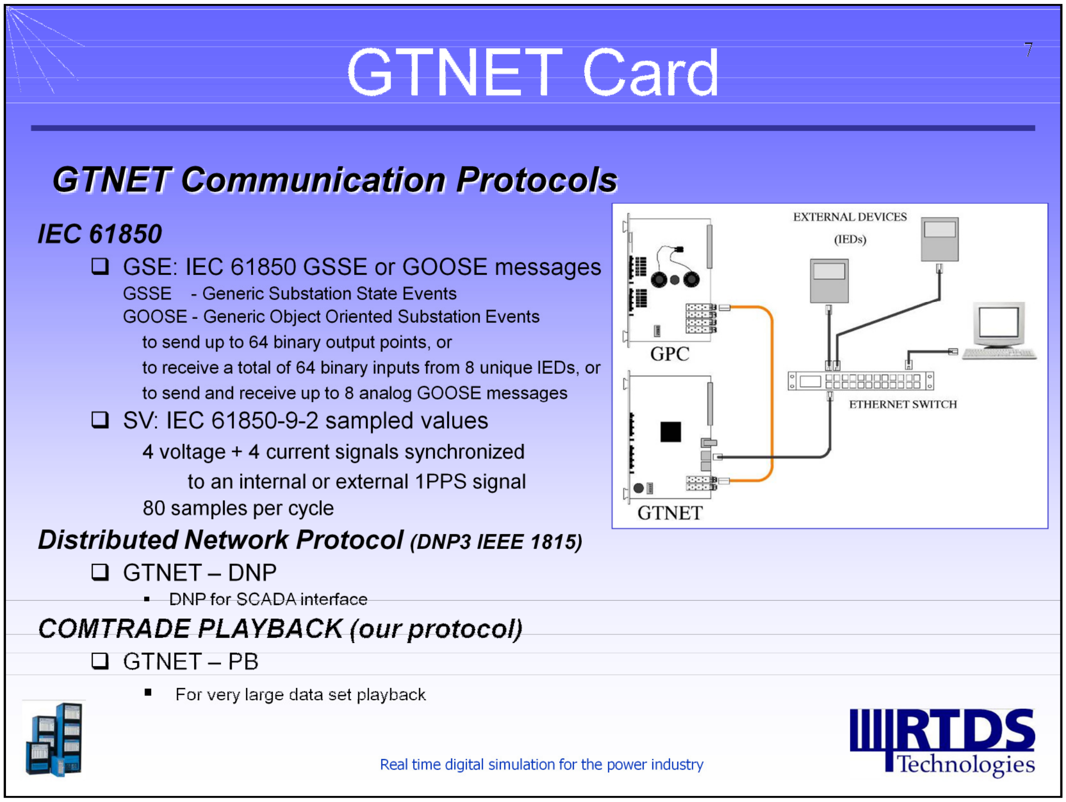
GTNET is a network communication card originally developed for IEC 61850. We have been adding new protocols in response to customer requests. Currently, up to 4 communication protocols can be installed on a single GTNET card. However, only one protocol can be active during a simulation run.

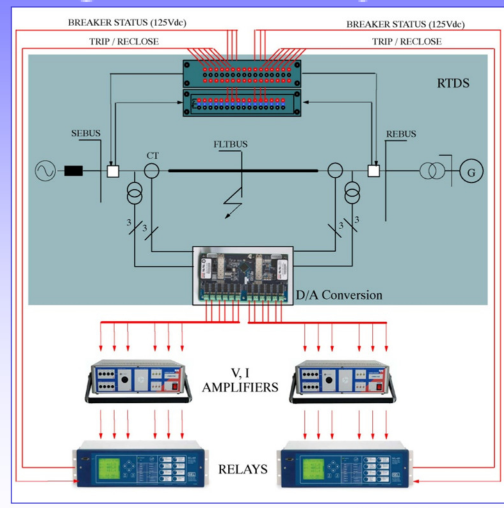


The first two protocols on the GTNET are related to IEC 61850: GTNET-GSE for GSSE or GOOSE messages and SV for sampled values. GTNET-DNP implements the Distributed Network Protocol which can be used for SCADA interface. GTNET-PB is our own protocol. It is used to play back a large set of slow changing data.

GTNET Card

GTNET – Closed Loop Testing of Protection Systems

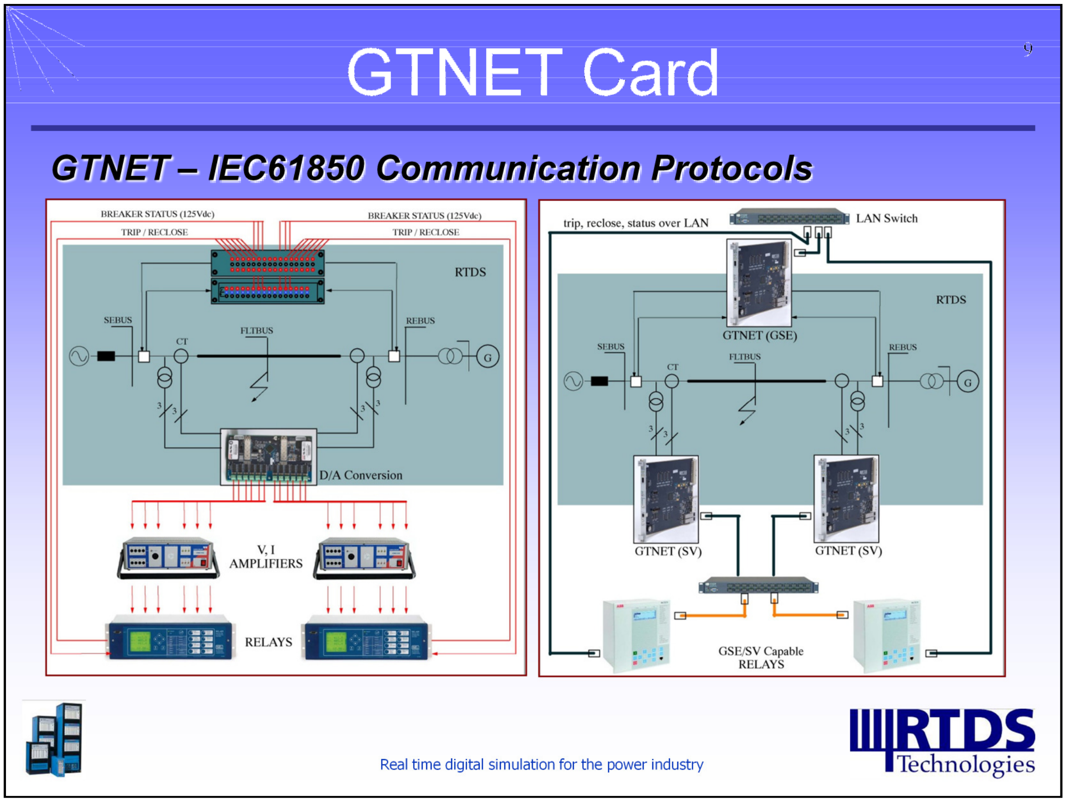
Traditional Closed Loop Relay Test Set-Up



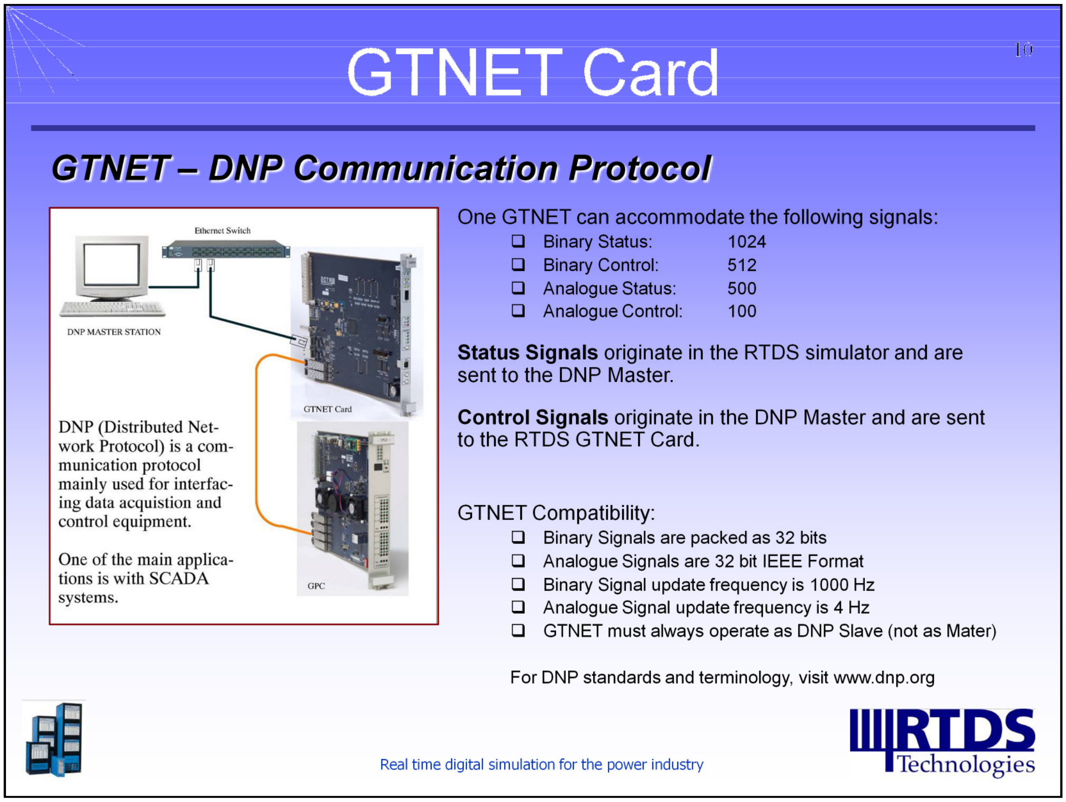
Signal Exchange

- Digital
  - Relay Trip
  - Relay Reclose
  - Circuit Breaker Status
- Analogue
  - Measured Voltage & Current

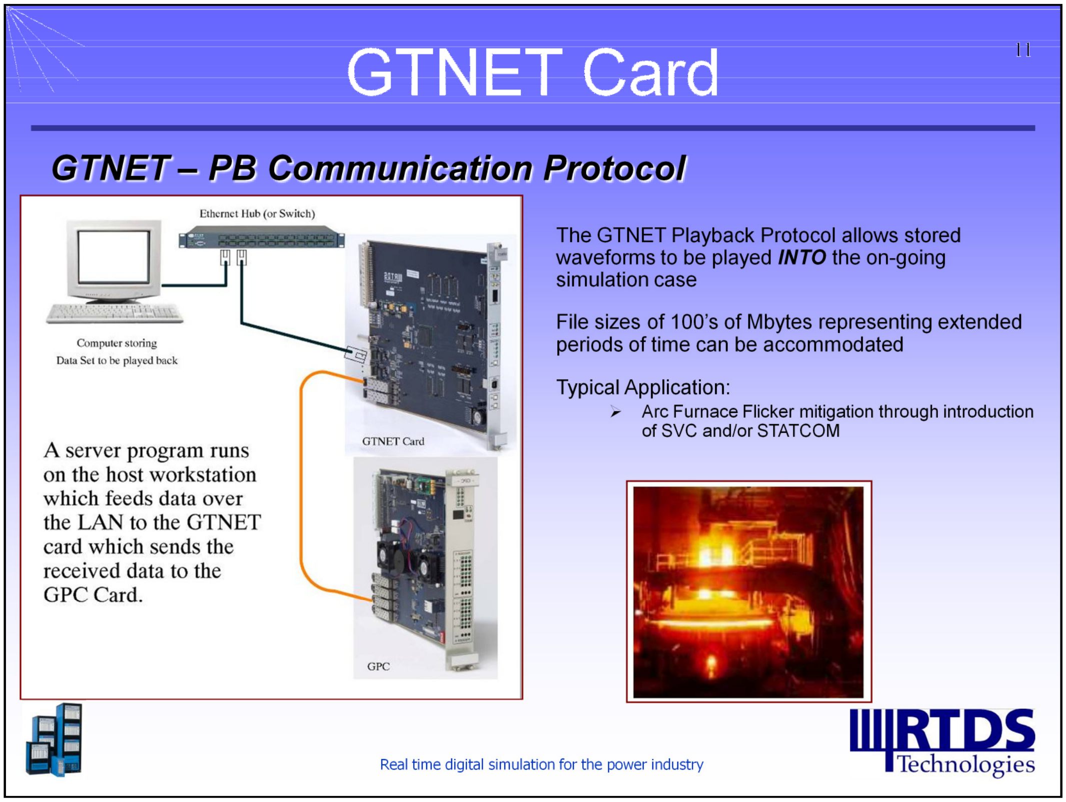
Here is the setup for traditional relay testing: voltage and current signals from power systems simulated on the RTDS are sent out to the relays through D/As and amplifiers, breaker control signals are sent back to the RTDS from the relays, forming a closed loop.



With GTNET, all the signals are sent with through GTNET cards, simplifying wire connections and removing the requirements for voltage and current amplifiers.



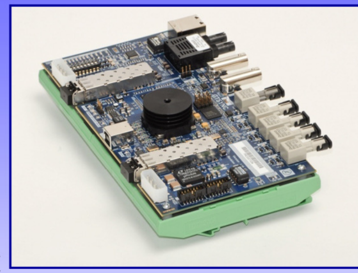
GTNET can send binary and analogue status signals to the DNP master and receive binary and analogue control signals from the DNP master. For DNP protocol, GTNET can only be operated as DNP salve.



The playback protocol can feed data stored on a PC to an running simulation case. A typical application is arc furnace flicker mitigation with SVC or STATCOM.

GTSYNC CARD

GTSYNC:



- GPS external time reference (+/- 1ppm) via
  - 1PPS (in/out via BNC or ST fibre)
  - IEEE 1588 (via RJ45 or ST fibre) with date stamp
  - IRIG-B (future development)
- Adjusts master simulation timestep (Δt) clock
  - RTDS time step clock has an accuracy of +/−100 ppm
  - Δt adjusted in ns range for smooth synchronization
  - Master timestep clock synchronizes the entire simulation to one reference
- Ensures repeatable results with known time reference
  - Does not rely on component tolerances (e.g. oscillator) or ambient conditions (e.g. temperature)

Real time digital simulation for the power industry

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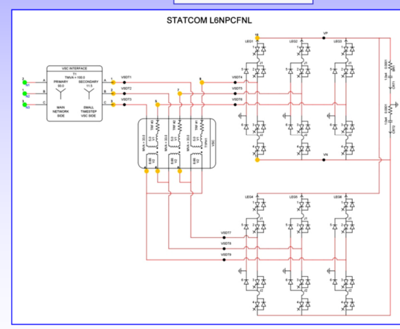
GTSYNC card is designed to provide 1PPS time reference signals to PMUs and other devices. The 1PPS signal is also used to adjust the simulation time step clock on the RTDS to synchronize the entire simulation to the same reference and to produce repeatable results with known time reference.

New Simulation Models

Recently developed models for GPC/PB5 card:

- ➢PMU Wide Area Measurement Model
- ➢Modular Multi-level Converter Model
- ➢Capacitor Commutated Converter Model
- ➢Frequency Dependent PI Section Model
- ➢Embed Electrical Machine Model
- ➢Some Renewable Energy Model



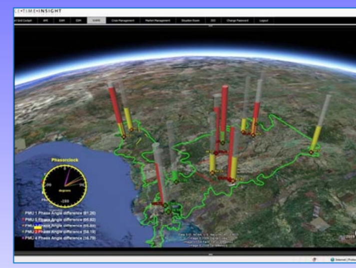
On the software or model side, we have developed the following new models: ….

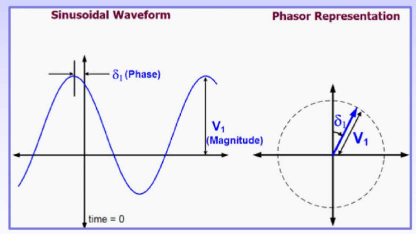
PMU and Synchrophasers

PMU & Synchrophasors:

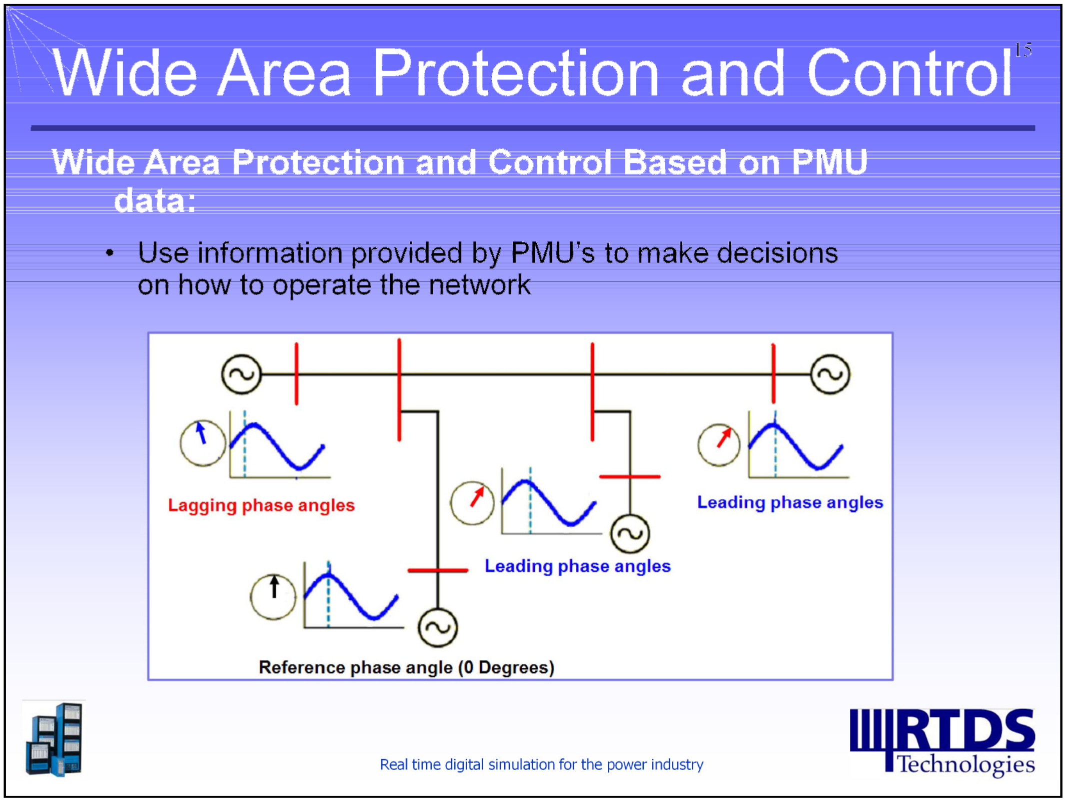
- The concept of using Phasor for AC system analysis was first proposed in 1893 by Charles Proteus Steinmetz
- Measurement defined in IEEE C37.118

  Synchrophasor is defined as magnitude and angle of a cosine function with an absolute time reference
- Phasor measurement units (PMU's) are installed at different points in the network
- PMU's provide information about the voltage and current at point of installation in the form of phasors
- PMU's being deployed for many years for system monitoring

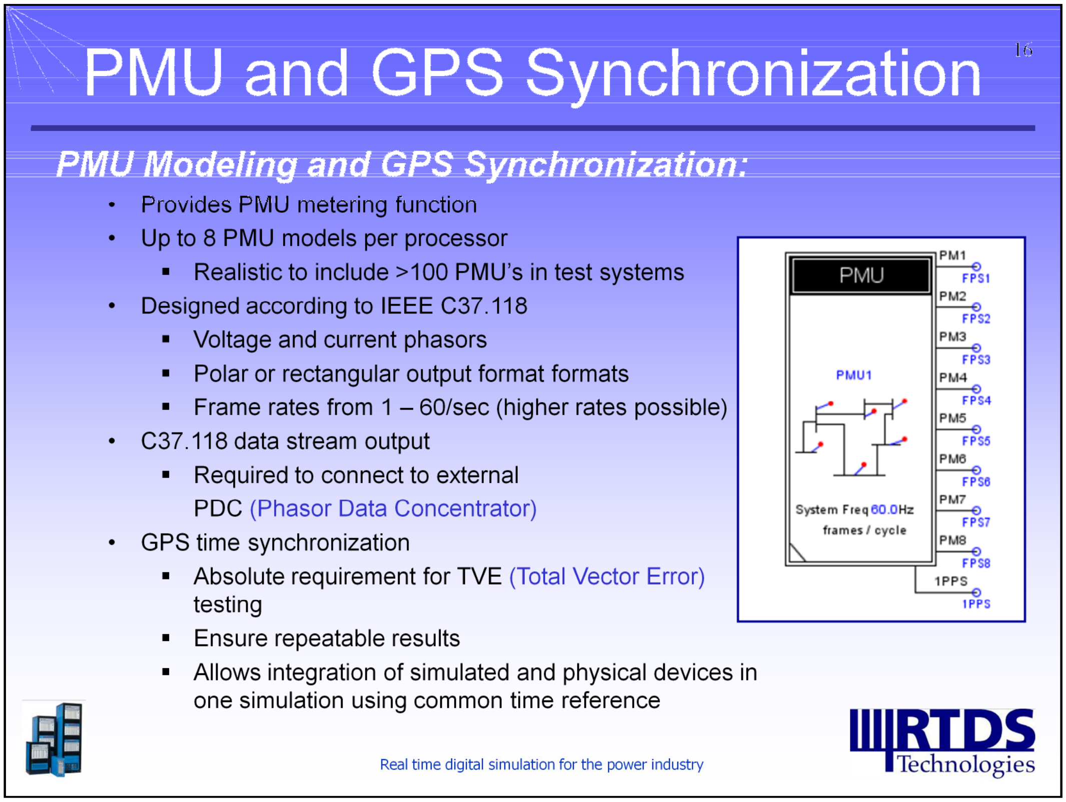




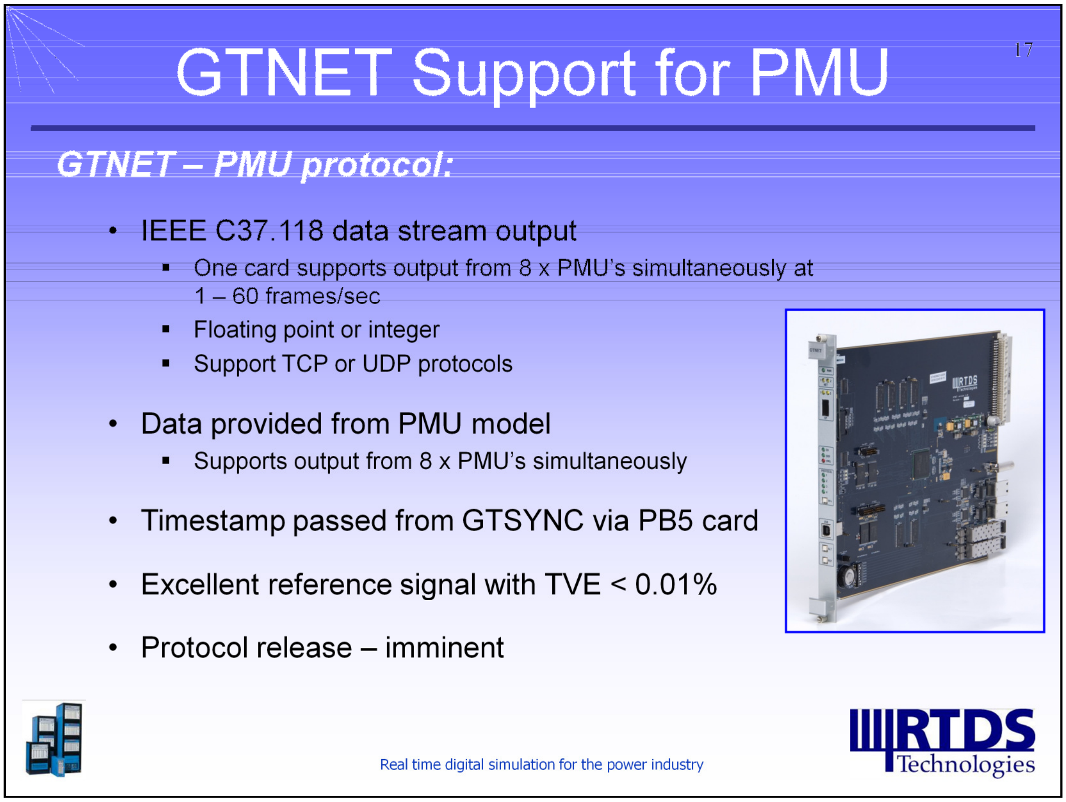
PMUs are phasor measurement units. They provide information about the voltage and current at point of installation in the form of phasors. It has been deployed for many years for system monitoring.



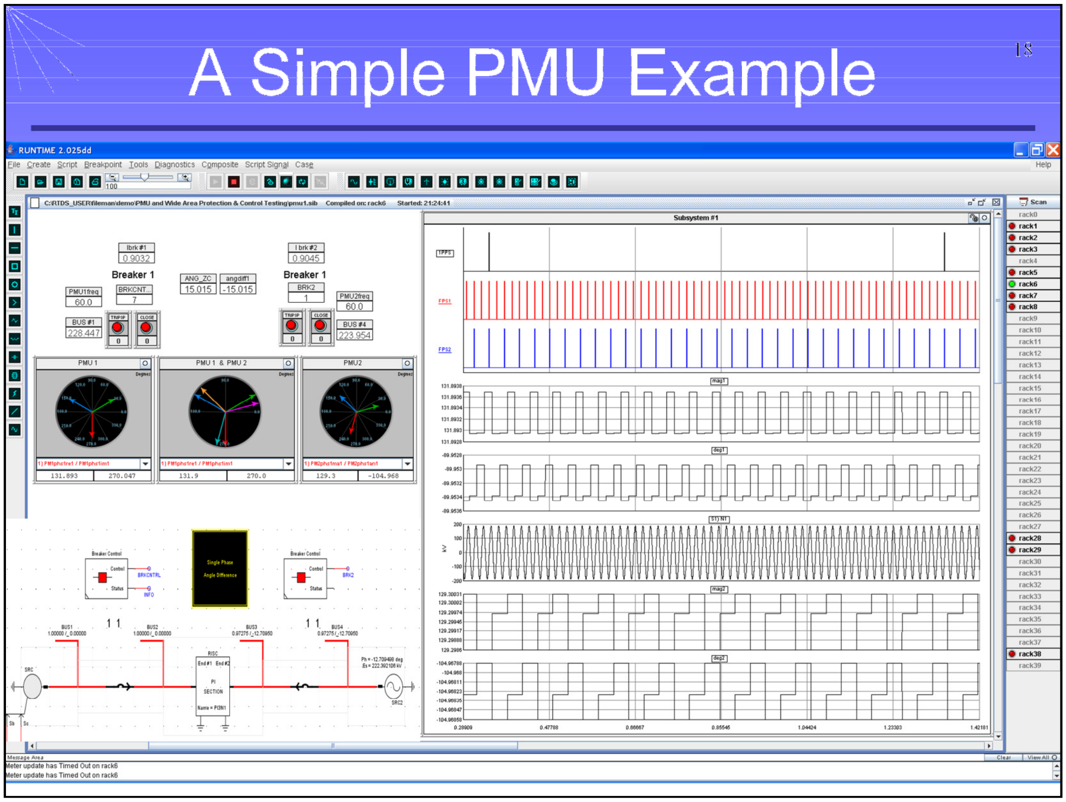
For wide area protection and control, PMUs can be installed at key locations to help operators make decisions.



RTDS PMU model can provide PMU metering function. Up to 8 PMU models can be simulated on a processor which makes it possible to have over 100 PMU's in the test systems.The PMU models are designed according to IEEE standard. The measurements can be synchronized with 1PPS signal allowing simulated and physical devices in one simulation using common time reference.



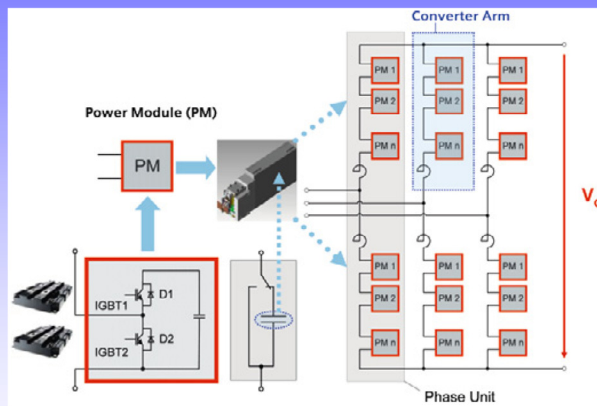
GTNET has been programmed to support PMUs: 1 GTNET card can send out measurements from 8 PMUs. GTSYNC can provide an external 1PPS signal to all the PMUs both simulated and physical.



GTNET has been programmed to support PMUs: 1 GTNET card can send out measurements from 8 PMUs. GTSYNC can provide an external 1PPS signal to all the PMUs both simulated and physical.

New Simulation Models

MMC – Modular Multi-level Converters



M. Davies, M. Dommaschk, J. Dorn, J. Lang, D. Retzmann, D. Soerangr, "HVDC PLUS – Basics and Principle of Operation"
http://www.energy.siemens.com/mx/pool/hq/power-transmission/HVDC/HVDC_Plus_Basics_and_Principle.pdf

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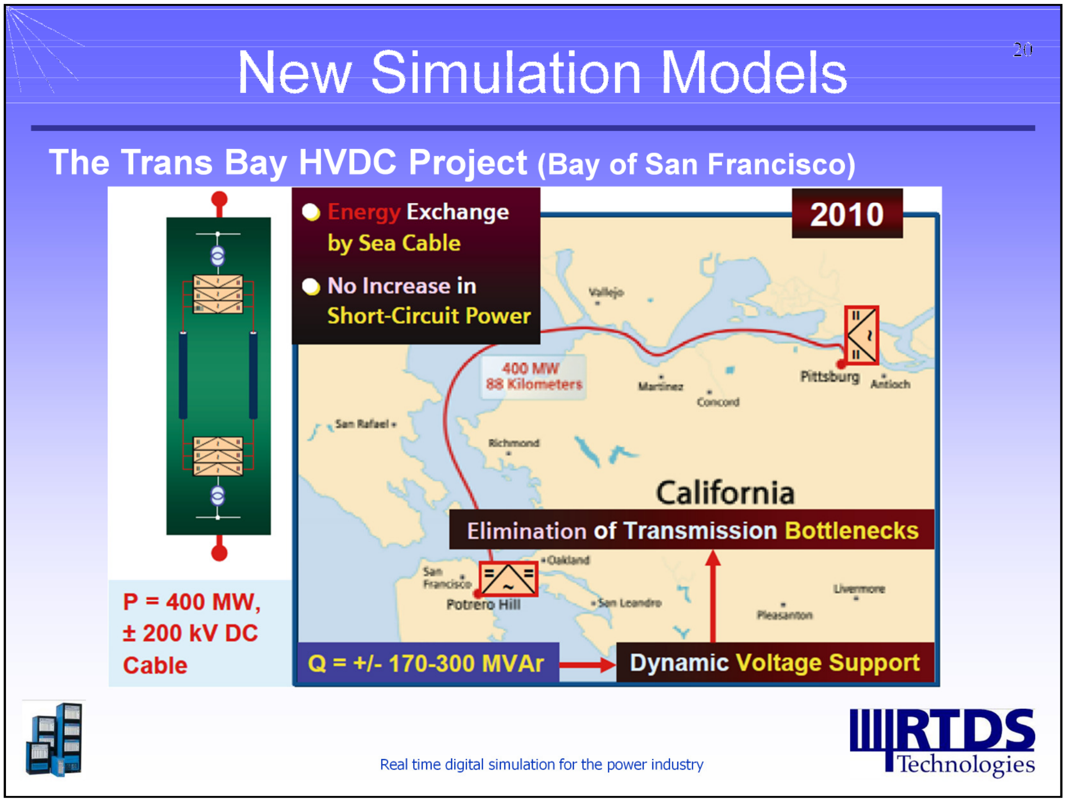
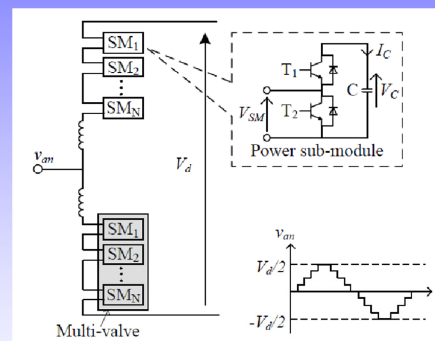
MMC or Modular Multi-level Converters are a hot topic nowadays. A good reference by Siemens is listed here.



The first commericial MMC project was built by Siemens in the Bay of San Francisco. It is rated at +/- 200kV transferring 400MW of power through 88 km of sea cable.

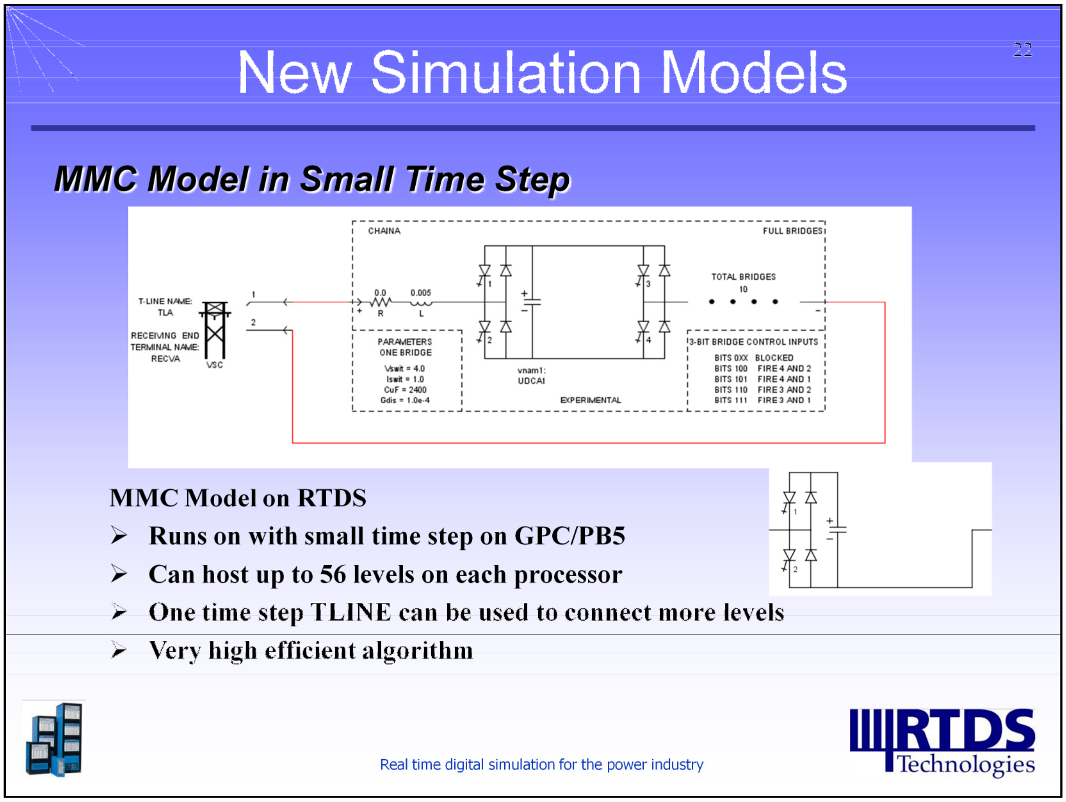
New Simulation Models

Advantages of Modular Multi-level Converter:



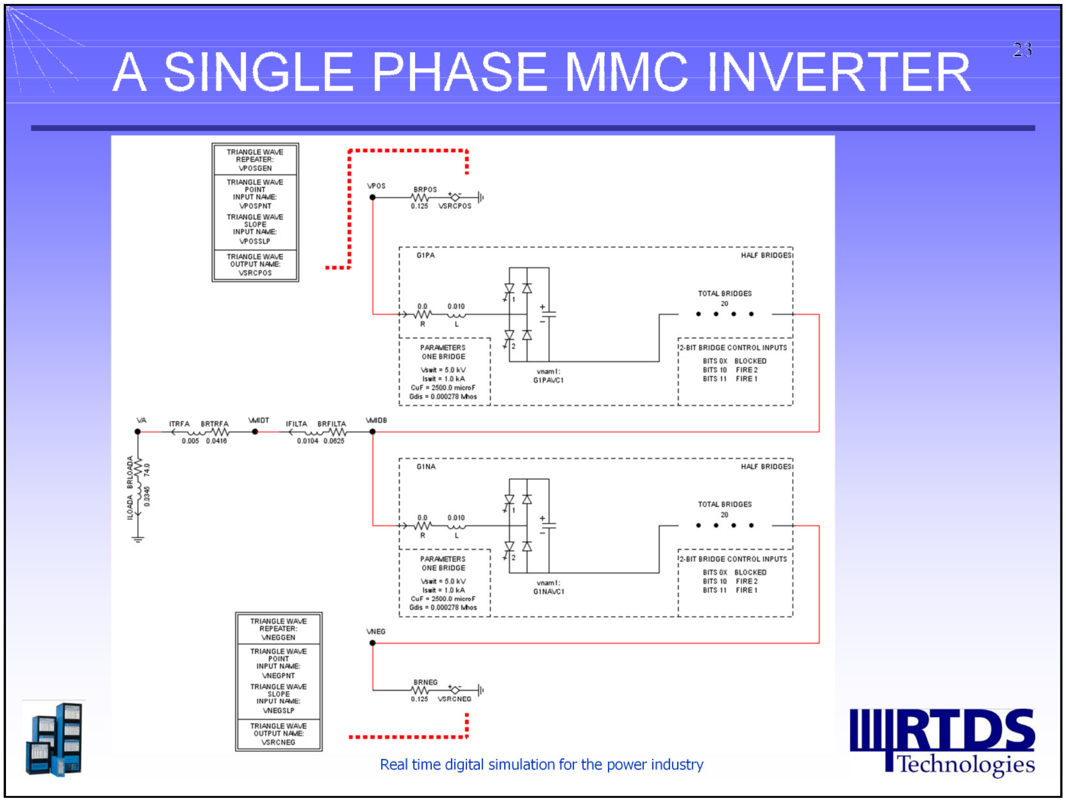
- Redundant, Modular Design:
  - High Reliability
  - Low Maintenance Requirements
- Small Converter AC Voltage Steps
  - Low Generation of Harmonics
  - Low HF Noise
  - No requirements for AC filters
- Low Switching Frequency
  - In normal operation, no more than one level per converter arm switches at any given time
  - Low switching Loss

MMC has redundant, modular design, resulting in high reliability and low maintenance requirements. With larger number of modules in each converter arms, there steps in the AC voltages are very small. Consequently, the harmonic contents are low and no AC filters are required. In normal operation, no more than one level per converter arm switches at any given time, resulting in low switching loss.

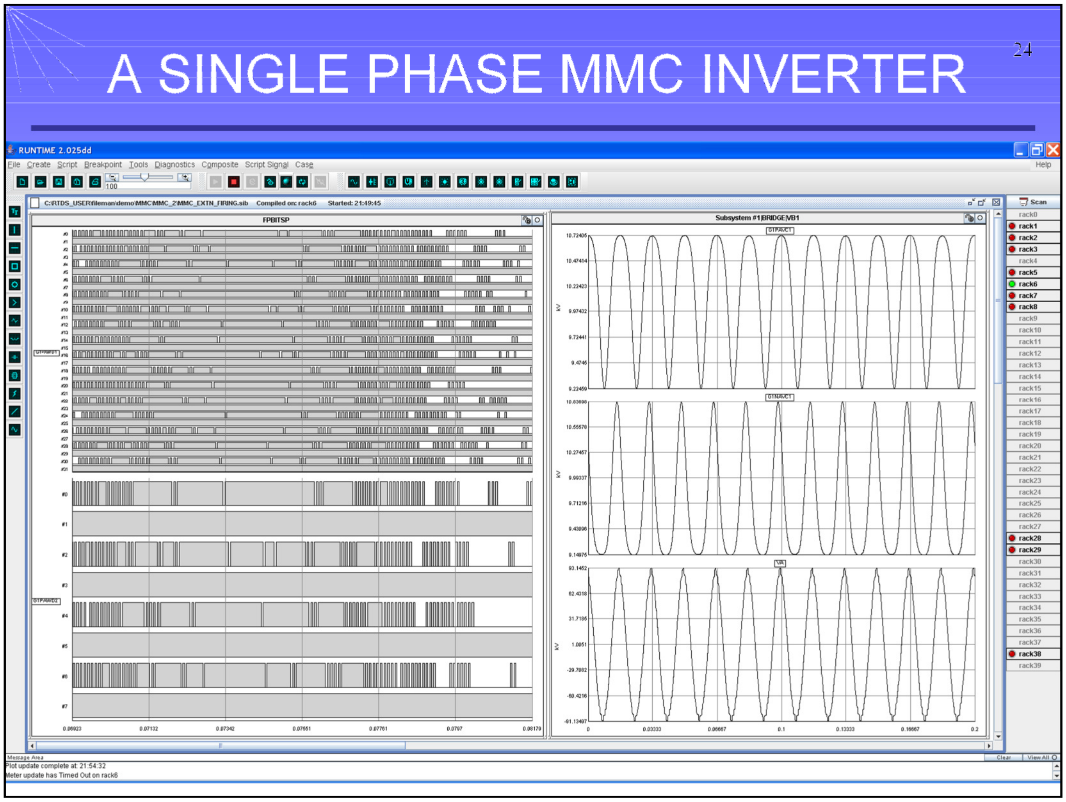


The RTDS small time step MMC model can have up to 56 levels of half or full bridges for each converter arm. One time step T-line can be used to connect more levels.

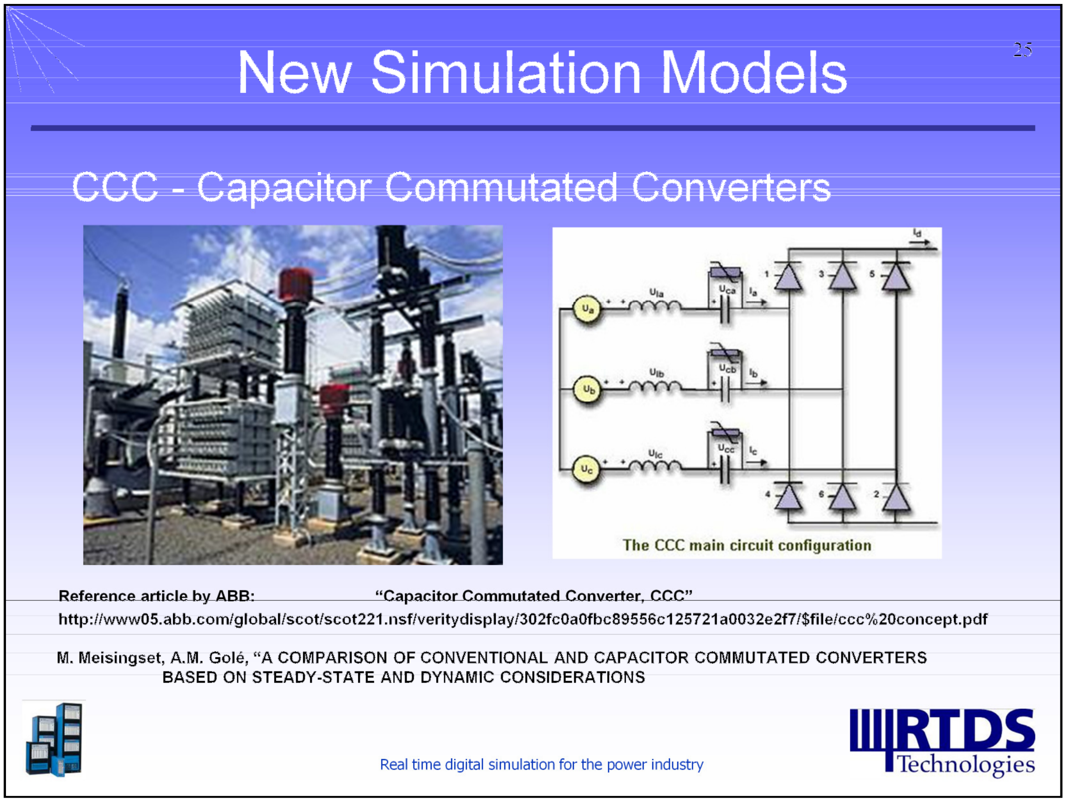
There is also an averaging model which can simulate up to 640 levels.



This is a single phase MMC inverter example. It is a small time step case. VSRCPOS and VSRCNEG provide the DC voltage for the converter. VA is the output AC voltage. There are 20 levels in each of the converter arms.



This is the RunTime screen shot. The plots on the left are firing pulses for the converter. The first plot on the right is the voltage on one of the capacitors in the upper arm. The second plot is the voltage on one of the capacitors in the lower arm. The third plot is the AC output voltage (VA).



CCC or Capacitor Commutated Converters have certain advantages. Commutation capacitors are added between converter transformer and the valves.

New Simulation Models

CCC - Capacitor Commutated Converters

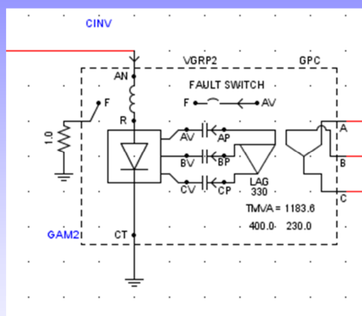
Commutation Capacitors between converter transformer and the valves:

- reduced converter transformer rating
- Higher immunity to commutation failures
- Improved stability of long cable transmissions
- Economical applications in very weak AC systems

The capacitors provide reactive power to the converter, reducing converter transformer rating. The voltages on these capacitors also aid in the commutation process thus resulting in a more robust converter with higher immunity to commutation failures, making it suitable for applications with long cable or weak AC systems.

New Simulation Models

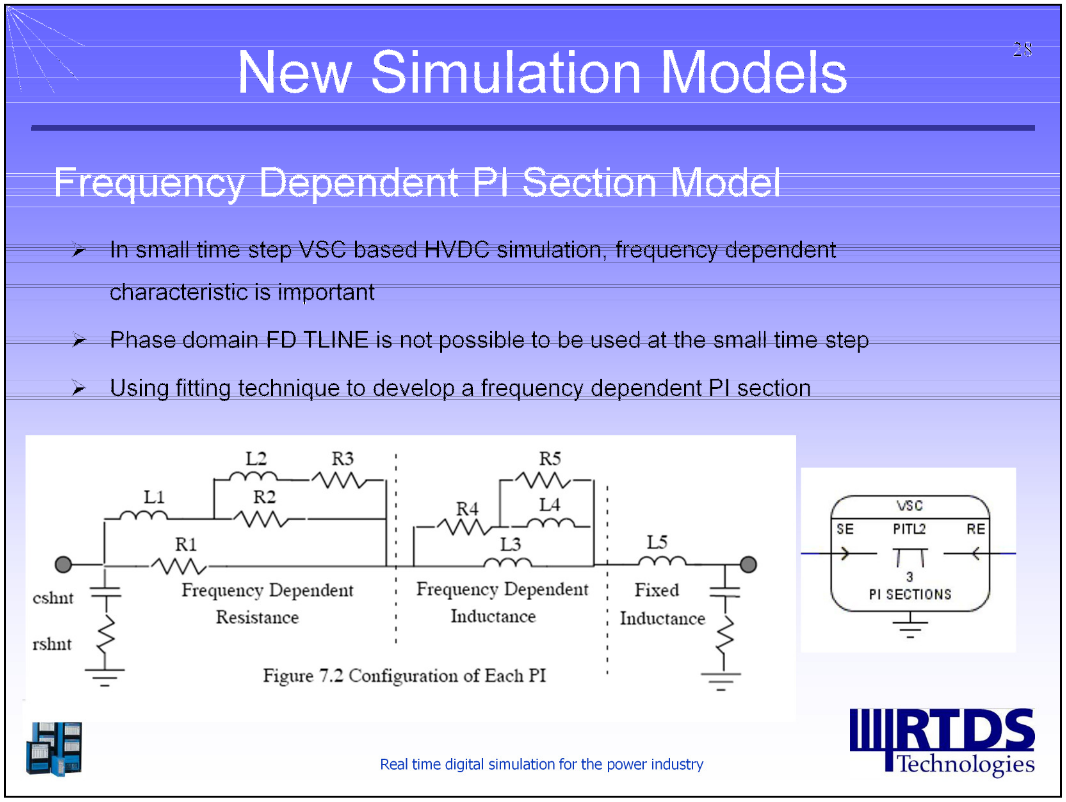
CCC - Capacitor Commutated Converters



CCC Converter Model on RTDS:

- Runs on GPC/PB5
- Arrestor model parallel with capacitor
- With improved firing function
- I/O interface
- Converter transformer included
- Internal fault included
- Resource requested-0.3 GPC card

The RTDS model of CCC runs on GPC/PB5. There are arrestor models parallel with the capacitors. It has all the features of the conventional valve group model, such as ... It takes 1/3 of a GPC card.



In small time step simulation, there is not enough time to implement frequency dependant T-line. A simpler fitted PI section model is implemented instead.

New Simulation Models

Frequency Dependent PI Section Model

- **Fitting the frequency dependent characteristic of resistor-**

$$Z_R(\omega) = \cfrac{R_1}{1 + \cfrac{\frac{R_1}{j\omega L_1}}{1 + \cfrac{\frac{R_2}{j\omega L_1}}{1 + \cfrac{\frac{R_2}{j\omega L_2}}{1 + \frac{R_3}{j\omega L_2}}}}}$$

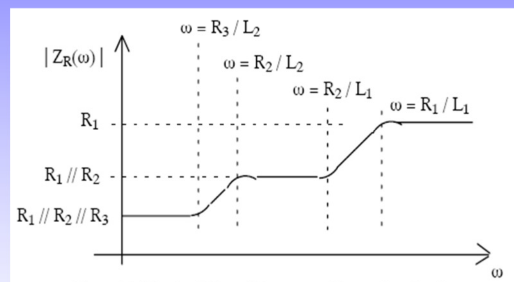
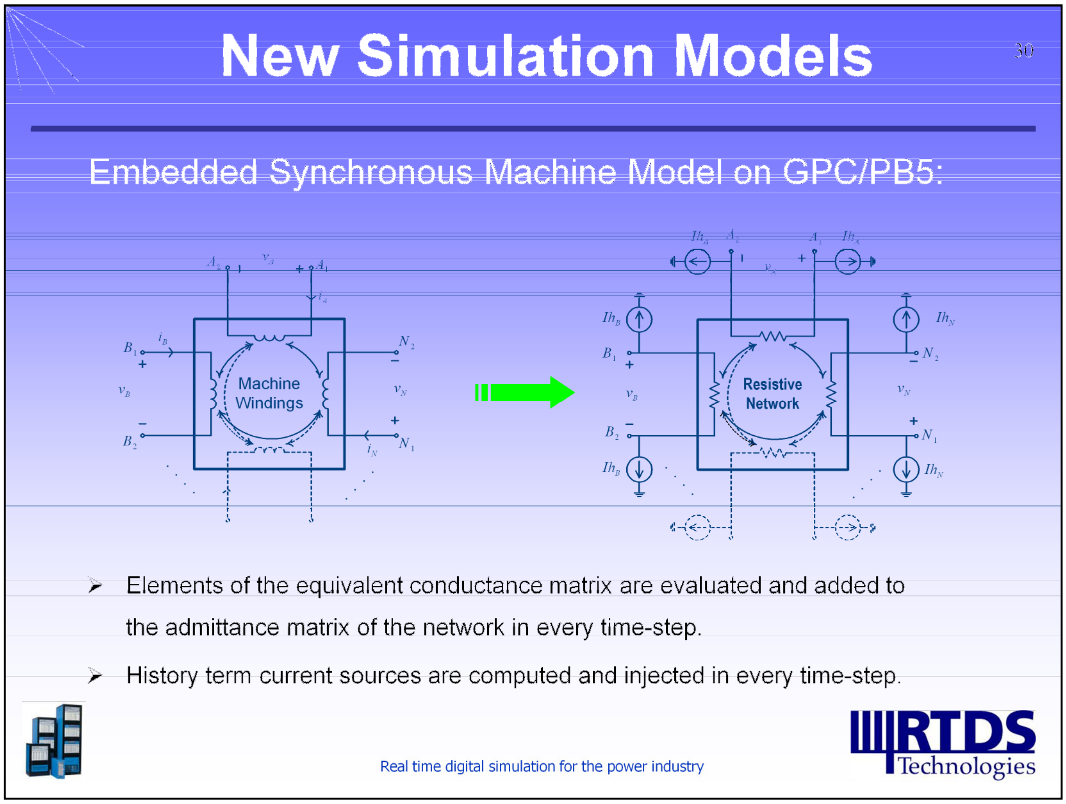


Figure 7.4 Typical Plot of Frequency Dependent Resistance

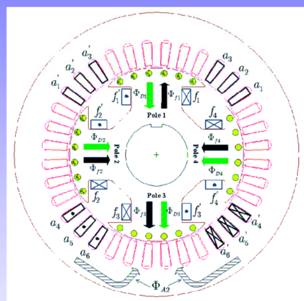
A typical frequency dependent resistance curve is fitted with R1, R2, R3 and L1, L2.

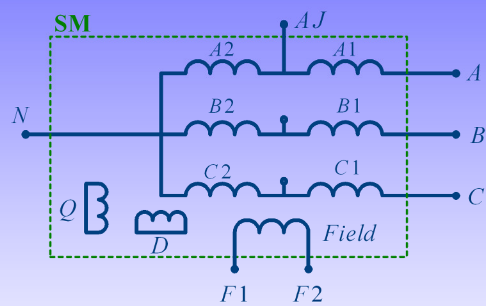


The conductance matrix of a machine is a function of time. To simplify the solutions, an interface approach is taken by most EMTP type simulation programs such as EMTDC and RTDS. An interface introduces an one time step delay between the machine and the rest of the network. The new model eliminate the interface and the conductance matrix is computed and sent to the network solution every time step resulting in a more robust and accurate machine model.

New Simulation Models

Embed Synchronous Machine Model





Validating the Machine Model in Faulted Conditions:

- External faults: -Solid three phase short circuit
  -Terminal-to-neutral short circuit
- Internal Fault: -A solid short circuit between node AJ and the neutral

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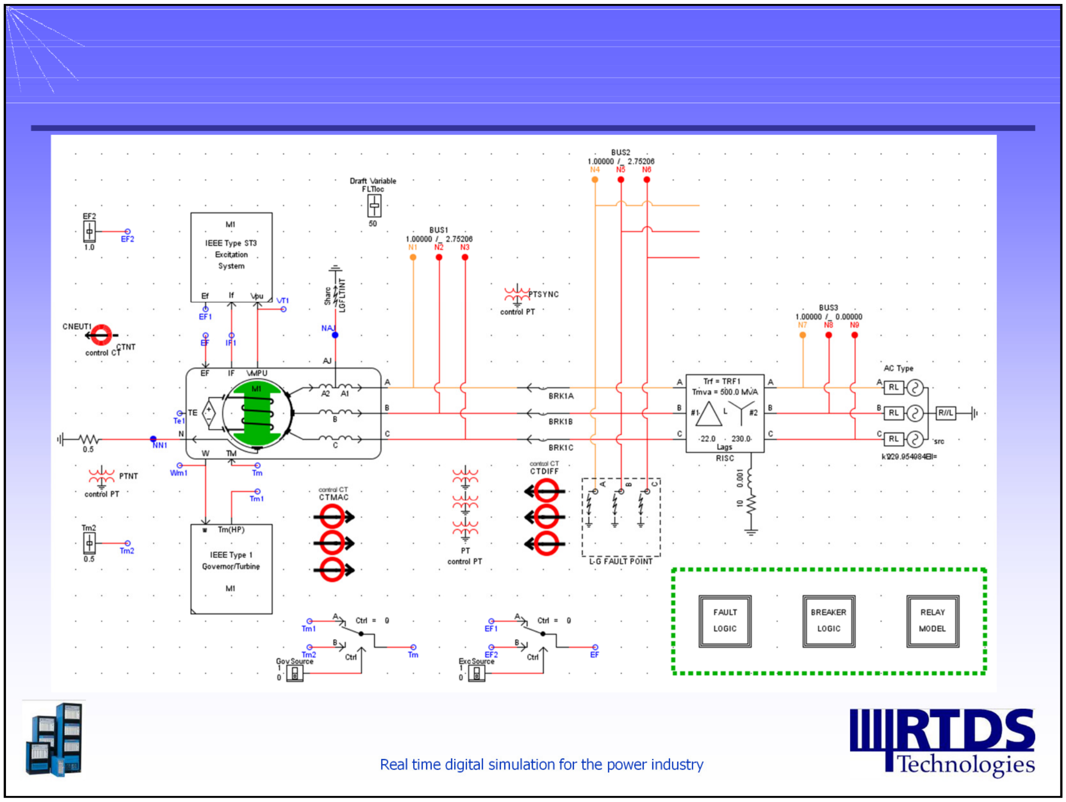
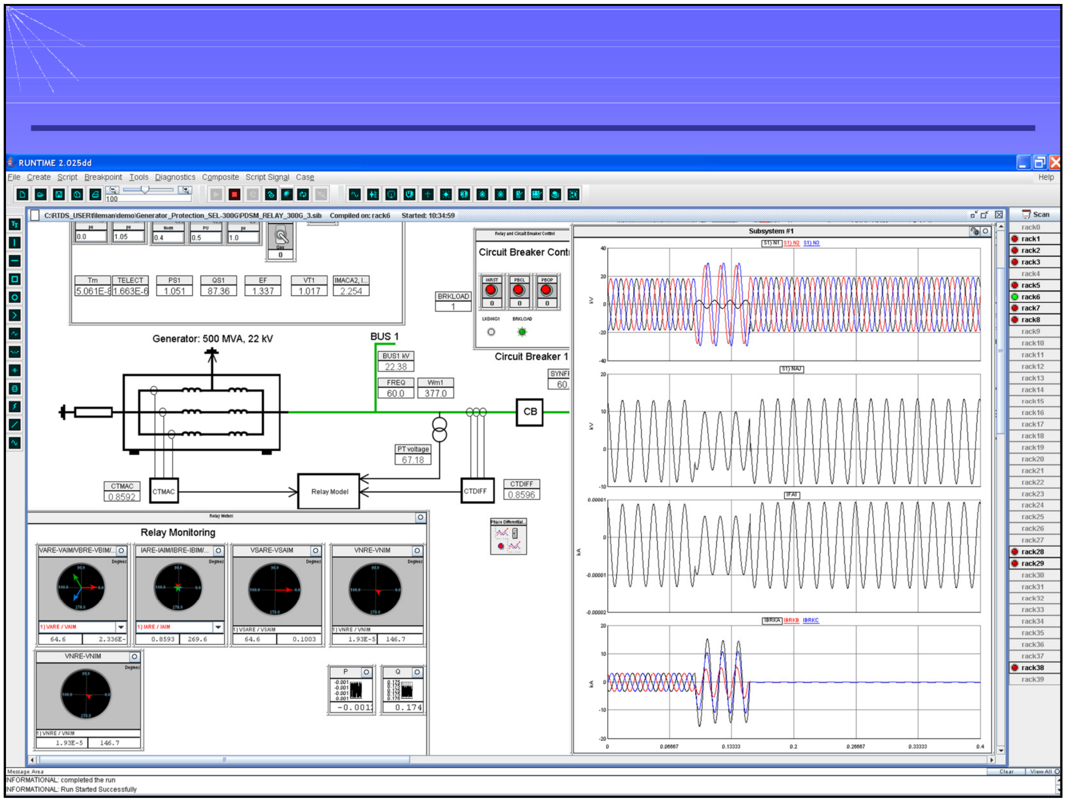
The machine model is suitable for generator protection tests with both external and internal faults.



This is a test case for machine fault. A stator phase A to ground fault is applied. The generator protection relay will open the breakers when the fault is detected.



This is the screen shot. The plots are: bus voltages at the machine terminal, voltage and current at the fault point, currents flowing into the machine.

New Simulation Models

Some Renewable Energy Model

- ***Wind power generation***

  1. **Induction Machine – direct connected**
  2. **Double Fed Induction Machine – soft connected**
  3. **Synchronous/PM Machine - Back-to-back DC connected**

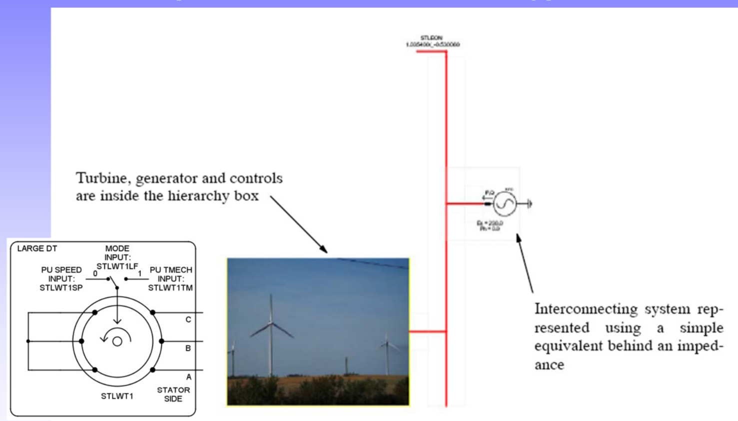
- ***PV (Photovoltaic) generation system***

- ***FC (Fuel Cell) generation system***

There are also new models for renewable energy.

New Simulation Models

Wind power generation simulation:
Variable speed induction machine type



Simulation case for the Wind farm at St. Leon, Manitoba, including Vestas V82 (formerly known as NEC Micon NM82) turbines rated at 1.65 MW

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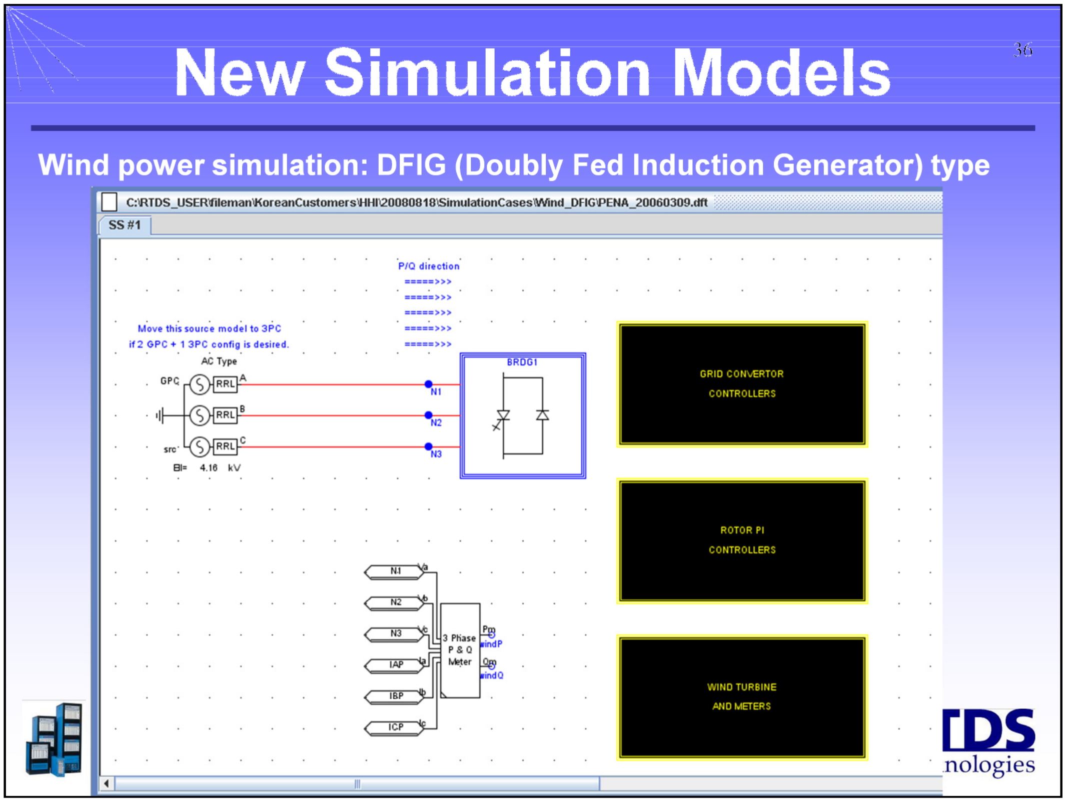
This is a simulation case for the wind farm at St. Leon, Manitoba. It is an induction machine type system rated at 1.65 MW.

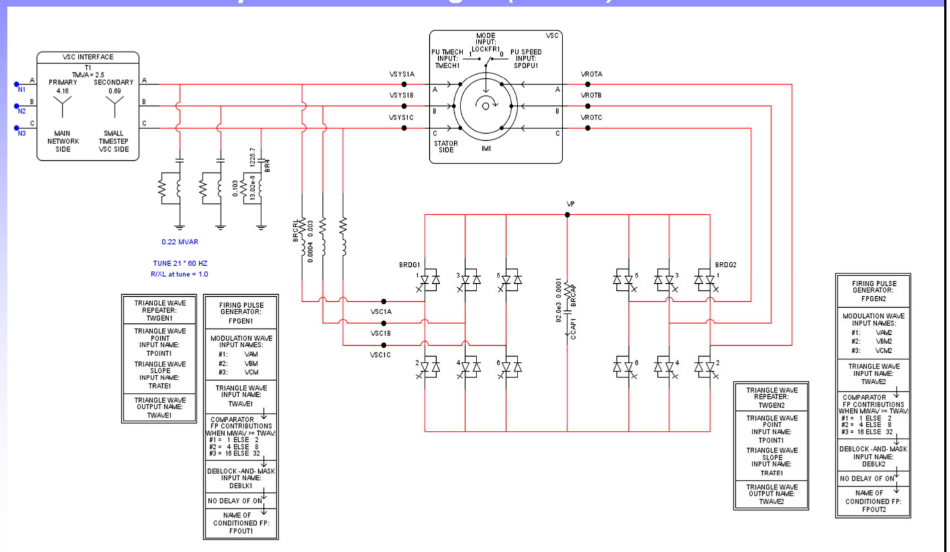


Here we have the doubly fed induction generator connected to a wind turbine.

New Simulation Models

Wind power generation simulation: DFIG type

Small time simulation part – Two bridges (2-level) and IM were modeled:



This is what inside the small time step box: an interface transformer, filters, a DFIG and two 2-level bridges converting AC to DC and then to AC of the power grid side.

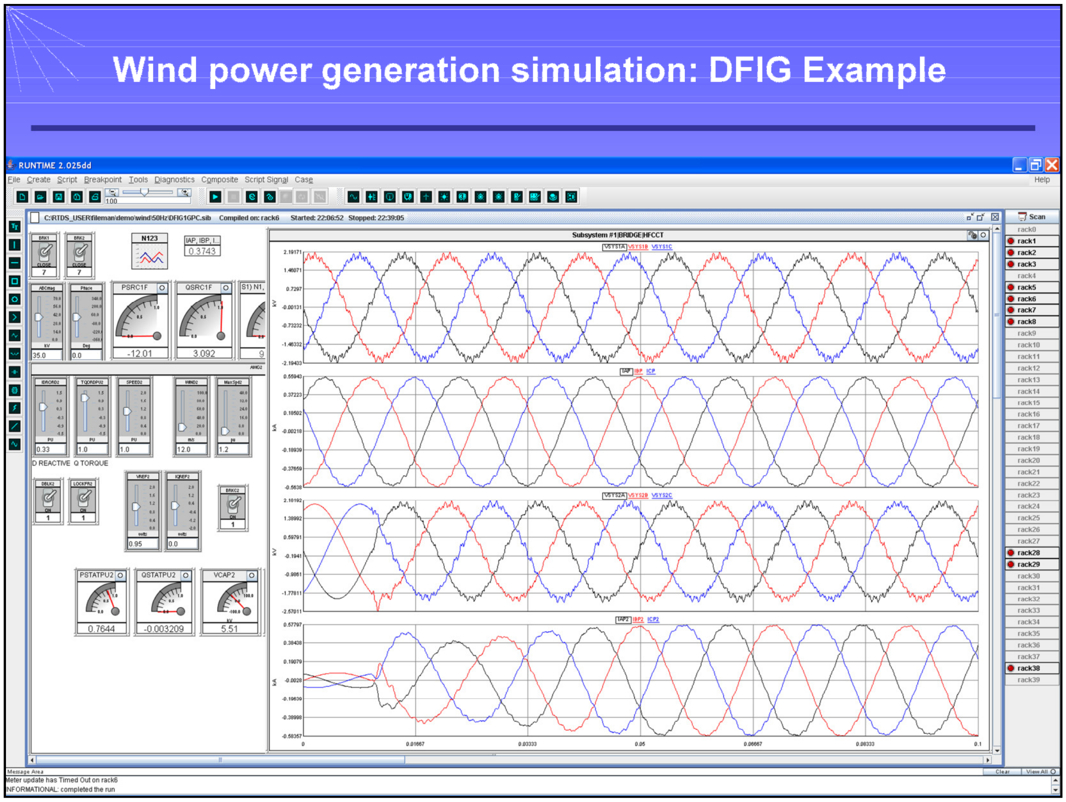
New Simulation Models

Wind power generation simulation: DFIG type

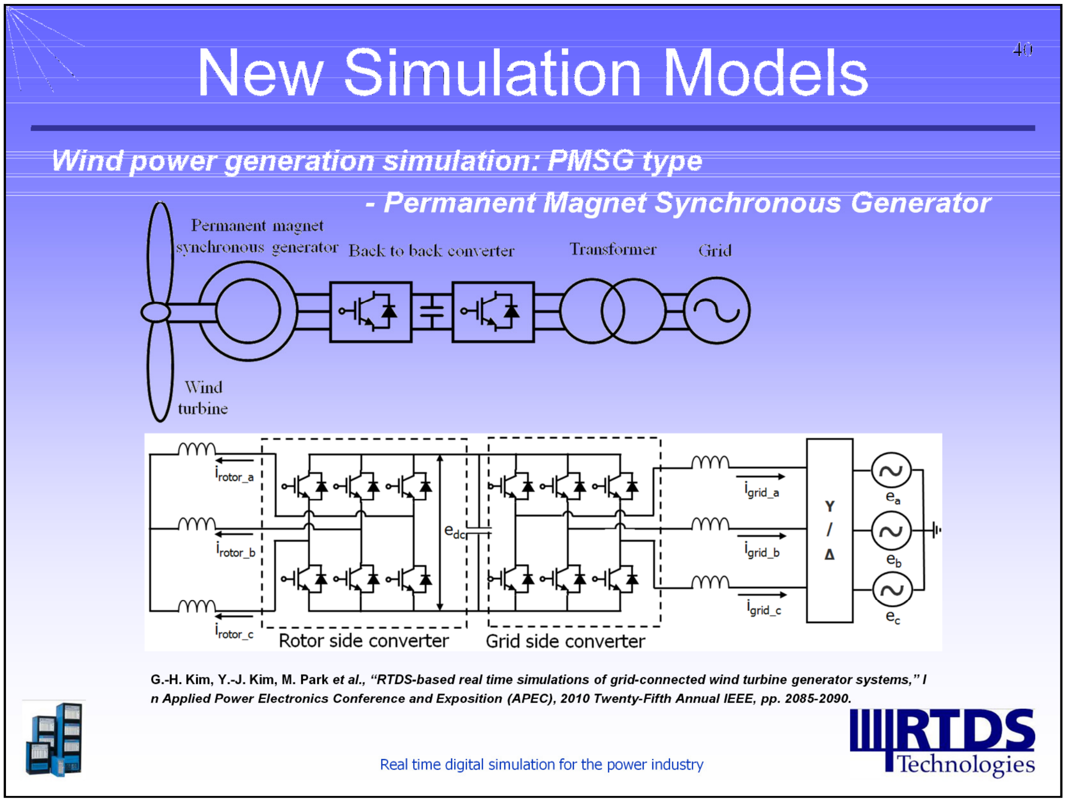
- Based on "*Doubly fed induction generator using back-to-back PWM converters and its application to variable speed wind-energy generation*" by R. Pena et al.
  - Detailed/Realistic parameters were given.

- Control Strategy
  - Grid side bridge: P/Q decoupled control
    - P on d-axis: Controls the bridge cap voltage
    - Q on q-axis: Controls grid side Q flow
  - Rotor side bridge: Vector control
    - Torque order is on Q-axis
    - Basic MPPT (Maximum power point tracking)

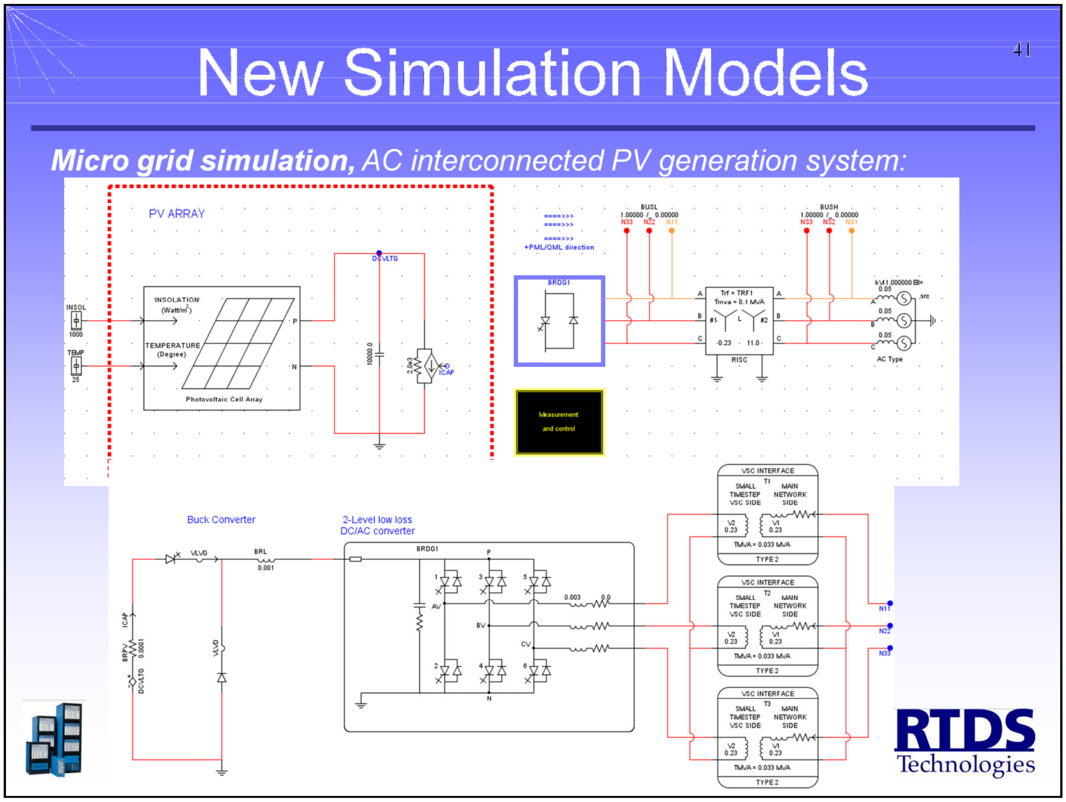
The controllers are based on this paper. P and Q can be controlled separately.



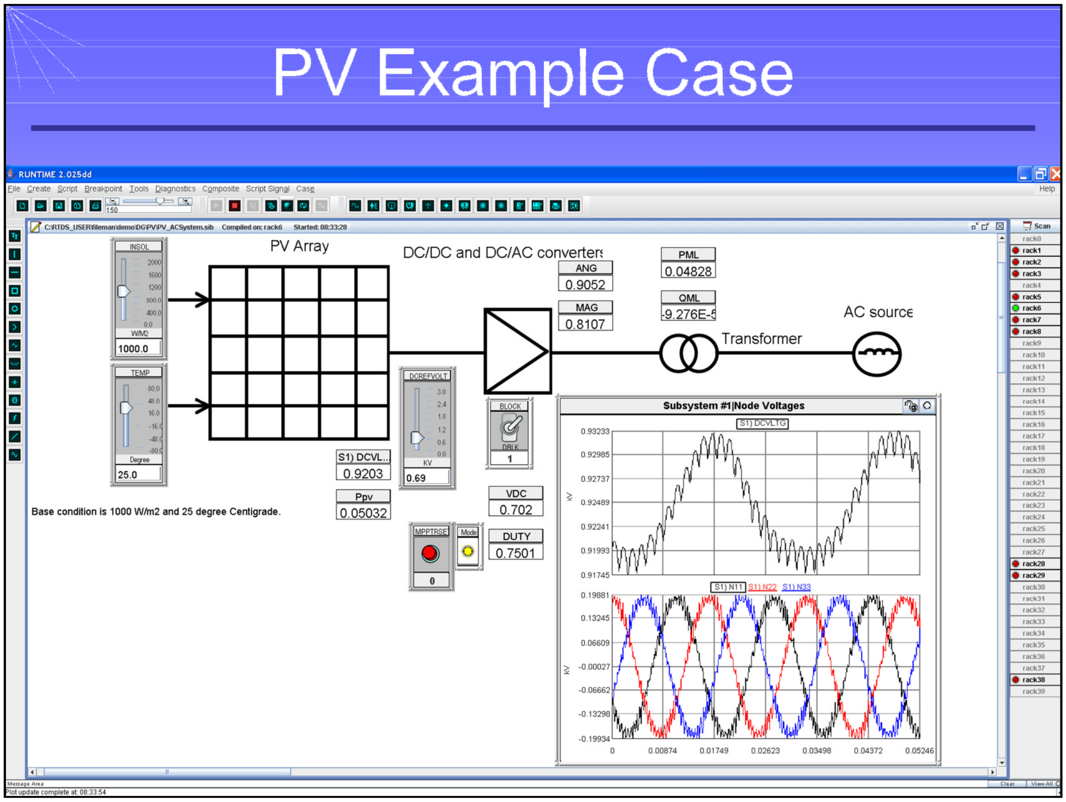
This is the RunTime screen shot. The meters are steady state values. There are actually idential two DFIGs in the system. The first two plots are transformer secondary voltages and primary currents of the first DFIG in steady state. The last two plots are transformer secondary voltages and primary currents of the second DFIG when it is being deblocked.



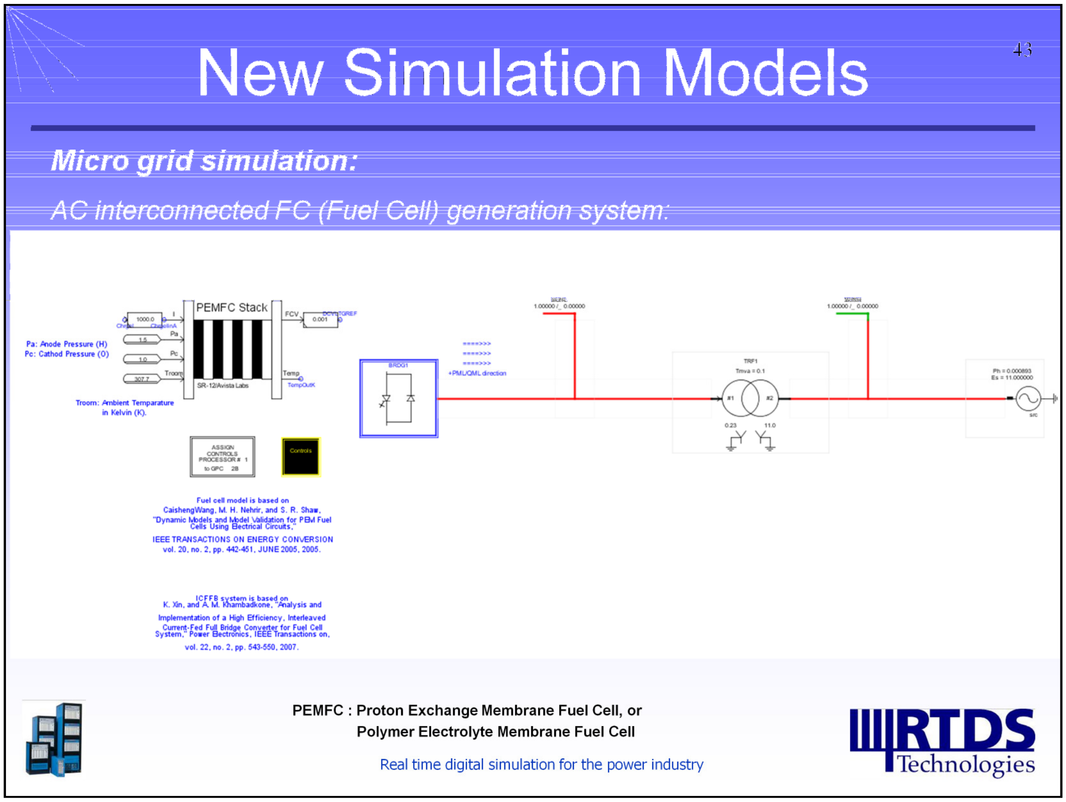
We also have a permanent magnet type of synchronous generator for wind power. A rotor side converter converts AC into DC and a grid side converter then converts the DC to AC connecting to the power grid.



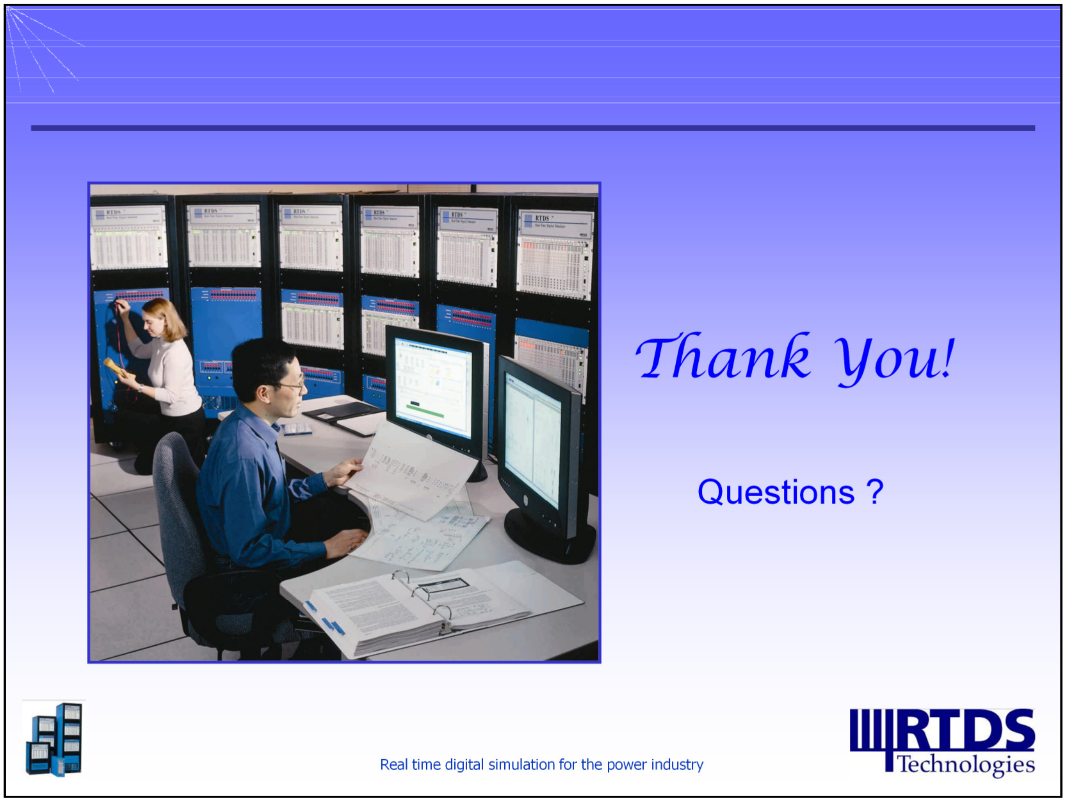
Here is a simulation case with Photovoltaic cells. We have the insolation level and temperature as inputs. The PV cell is connected to a Buck converter and a 2-level DC/AC converter feeding into the power network.



This is the RunTime screen shot. The system is in steady state. The first plot is the capacitor voltage and the second plot is the voltages at BusL.



The last model is a fule cell. The DC voltage is converted into AC by a converter.



Thanks very much for your attention. If you have any questions, please contact me by email.