

YOUR  
POWER  
GRID  
YOUR  
CONDITIONS  
IN REAL  
TIME

# KNOWLEDGE

Being the first of its kind, the RTDS® Simulator is the world's benchmark for performing real time simulations. Since worst-case power system conditions are rare and dangerous to induce in the real world, the RTDS Simulator is used to provide them in a controlled and safe environment. Your overall system performance can be optimized through closed-loop testing under the most realistic test conditions possible. Enjoy improved productivity and reliability, all while simulating network conditions in real time.



# IS POWER

## History

RTDS Technologies Inc. was established and incorporated in Manitoba, Canada in February, 1994. We are privately owned and operated and primarily engaged in manufacturing, marketing, servicing and continuing development of the Real Time Digital Simulator (RTDS®). Research on the fundamental RTDS Simulator technology began in the mid 1980s at the Manitoba HVDC Research Centre.

With a lot of dedication, long hours and creative thinking, we developed a real time simulator based on digital technology. The first commercial application of the simulator went live in 1993. The transition from research project to commercial product was overseen by former employees of the Manitoba HVDC Research Centre who were key to the simulator's development and who subsequently founded RTDS Technologies Inc.

# Leadership

As the pioneers of real time digital simulation, RTDS Technologies is the industry leader. Our simulator is more widely used than any other in the world. Over the last 17 years, we have grown to over 200 customers in over 30 countries. Our customers reside on every continent except Antarctica and we work with the biggest names in the industry. Our close relationships and clear understanding of our customer's unique requirements enables us to focus on their individual needs and incorporate requests into further product development.

# Knowledge

Knowledge is power and RTDS Technologies provides the knowledge needed for reliable and efficient operation of power systems and power system equipment. We have an innovative team of world-class electrical engineers, computer scientists, technicians and support personnel – experts in the design, implementation and support of computer hardware and software to provide fast, reliable, accurate, and cost-effective study of power systems.

# Innovation

The RTDS Simulator is a tailored and customized solution built with cutting edge technology. We've developed special tools for a special industry, driven by a need to have more flexible, accurate and affordable tools to test power system designs and equipment. We teach you how to use these tools, how they work and what they're doing. The result is an accurate and safe representation of your system. Proven over time, the RTDS Simulator represents the real world – your world.

# Dedication

We're dedicated to helping you do your job better and increasing the positive impact this has on people and economies. When you improve the reliability and efficiencies of your power system, it impacts more than just the system itself. It improves the community that the system supports. This is what drives our team and keeps us strong - knowing that what we do affects the success of so many.



## Achievements

- Developed and introduced the world's first fully digital real time simulator.
- Provided affordable, fully digital technology, which enabled a wider group of users to access real time simulation.
- Revolutionized the way protective relay testing is performed, adding more complex and thorough testing, as well as fast, efficient batch testing.
- Enhanced the way real time studies and controls testing are performed, providing larger systems and improved accuracy.
- Introduced the world's first portable real time simulator.
- Installed the world's largest real time simulator for power system studies.

# Partnership

Being an integral part of the power systems world, RTDS Technologies speaks your language. We are always developing new innovations to stay ahead of the industry. We offer fast, knowledgeable technical support and one-on-one training around the globe by our developers, application experts and technicians, as well as our network of local engineers.

## Support

RTDS Technologies offers a comprehensive Hardware Warranty and Software Maintenance program that includes:

**Technical Support** – When you have questions or need expert advice, we'll provide you with the answers. Fast and knowledgeable, our support staff will quickly get you moving again.

**Software** – You'll receive continuous updates of all newly developed features and models.

**Hardware** – Our standard warranty is one year to fix or replace any failures. This can also be extended over the lifetime of the product.

## Accountability

Our Component Exchange Program offers a 50% reduction on new purchases. You'll enjoy the benefits of the most cutting-edge equipment, easier access to new models and features and the best support in the industry. After the new equipment is installed, we'll take back the old components and ensure responsible environmental disposal.



$$e_m(t) = \frac{1}{C} \int_{t-\Delta t}^t i_{km}(t) dt + e_x(t - \Delta t) - e_m(t - \Delta t)$$

$$\begin{bmatrix} Y_{AB} \\ Y_{BA} \\ Y_{BB} \end{bmatrix} \begin{bmatrix} e_A(t) \\ e_B(t) \end{bmatrix} = \begin{bmatrix} i_A(t) \\ i_B(t) \end{bmatrix} = \begin{bmatrix} I_A \\ I_B \end{bmatrix}$$

$$\left[ \frac{\partial^2 e(x,t)}{\partial x^2} \right] = [L'] [C'] \left[ \frac{\partial^2 e(x,t)}{\partial t^2} \right]$$

$$\left[ \frac{\partial^2 i(x,t)}{\partial x^2} \right] = [C'] [L'] \left[ \frac{\partial^2 i(x,t)}{\partial t^2} \right]$$

$$\phi_k = [P_k] ([N] i - \theta)$$

$$[C] = \left\{ [P] - [P][A]([A]^T [P][A])^{-1} [A]^T \right\} N_{ss} B^{-1} \frac{\Delta t}{2} [N_{ss}]^{-1}$$

# Our Customers

Real Time Digital Simulation...depended on by many of the world's key manufacturers of protective relays, controllers, and power electronic systems, as well as the world's most progressive utilities and universities.

## Utilities

Public and private power companies responsible for generation (conventional and/or renewable), transmission and/or distribution of electricity. Both developing and well established. You are the power supplier to your customers and you require confidence that your equipment and grid can handle any situation.

### KEY APPLICATIONS:

**Protection System Testing** – By modeling a portion of your system and connecting protective relays, you can test contingencies in your simulated network and evaluate the protection performance before installing them in the real world. Know how your system will respond to faults and test repeat scenarios, all while representing your network, and testing your relays and your settings. Experiment with and test IEC 61850 compliant devices.

**Control System Testing** – Conduct investigations on key installations using physical controls or controls duplicated in the virtual world. Gain a better understanding of your system through different scenarios and adapt as needed.

**Large Scale Simulation** – By seeing as much of your complex, large-scale power network as possible, simulation is part of your key system strategy for reducing risk and ensuring system reliability and security.

**Studies** – You have many scenarios that don't require real time, but still benefit from the speed and fast acquisition of knowledge. This exploratory testing is aided by real time simulation and by representing large parts of your system.

**Training and Maintenance** – Using the RTDS Simulator to represent your network, engineers and technicians can work with and test your physical protection and control equipment under live operating conditions. Changes and modifications can be made and tested first in the lab instead of the field.

### USER BENEFITS:

Reduced downtime of your systems, prevention of equipment damage, a more favorable reputation, and residual increased revenue.

$$i_L(t) = \frac{\Delta t}{2L} v(t) + I_h(t - \Delta t)$$

$$i_C(t) = \frac{2C}{\Delta t} v(t) - I_h(t - \Delta t)$$



## Manufacturing

A company that makes and/or manufactures parts and equipment for power systems. You are a dynamic driving force for innovation with tight timelines and ongoing development requirements.

### KEY APPLICATIONS:

**Protection Systems** – When you're looking to improve the security and reliability of protection devices you can test it in closed-loop. Prove new ideas and concepts as part of your research and development process. With more of a micro focus, you can do repetitive, automated testing as needed.

**Control Systems Testing** – When you need to find ways to strengthen and regulate areas of a network, you can use the RTDS Simulator to test various controllers, from generators and HVDC, to FACTS, renewables and SMART Grid devices.

**Research** – A flexible environment and a wide frequency spectrum allow for a nimble research and development process.

### USER BENEFITS:

Reduced research and development time, reduced time to market, the ability to test quicker and more easily, improved quality control, increased credibility and reputation with your customers, the ability to do customized testing based on your customer's needs, the ability to demonstrate and prove equipment to customers as a sales tool, increased revenue.

$$\phi_s(t) = \phi_s(t - \Delta t) + \frac{\Delta t}{2} (V_s(t) + V_s(t - \Delta t))$$

$$\omega = \left( \sqrt{\delta^2 + 1} - \delta \right) \frac{2}{\Delta T}$$

$$\omega = \frac{1}{\sqrt{LC}}$$

$$X_L = \sqrt{2} \left( \frac{v}{i} \right) (2\pi f \cdot \Delta T \cdot F)$$

$$X_C = \frac{\sqrt{2} \left( \frac{v}{i} \right)}{(2\pi f \cdot \Delta T \cdot F)}$$

## Academic

Academic departments in electrical/power systems, in the categories of research and education. You are leaders in your field and you need a flexible platform to experiment with and develop new technologies.

### KEY APPLICATIONS:

**Research** – As the leading draw for the academic industry, innovative power systems research using the RTDS Simulator can strengthen your institution.

**Education** – You have the ability to provide hands-on education for students to experiment and demonstrate the behaviour of electrical power systems and connect real world devices in a practical lab studies environment.

**Protection and Control Testing** – You can test new hypotheses to see how your system will react in a realistic, but simulated power system environment.

**Additional applications** – Testing microgrids and renewables, running Power-Hardware-In-the-Loop (PHIL) are all possible using the RTDS Simulator.

### USER BENEFITS:

Improved reputation of your institution as cutting edge, the ability to do more and train students on industry standard tools, an increased ability to attract students, being seen as strong leaders in the industry, opportunity for development, exploration and innovation.

$$f(x) = a_0 + \sum_{n=1}^{\infty} \left( a_n \cos \frac{n\pi x}{L} + b_n \sin \frac{n\pi x}{L} \right)$$

$$\tau = \sqrt{LC}$$

$$e_k(t) - e_m(t) = \frac{1}{C} \int_{t-\Delta t}^t i_{k,m}(t) dt + e_k(t - \Delta t) - e_m(t - \Delta t)$$

$$\begin{bmatrix} [Y_{AA}] & [Y_{AB}] \\ [Y_{BA}] & [Y_{BB}] \end{bmatrix} \begin{bmatrix} [e_A(t)] \\ [e_B(t)] \end{bmatrix} = \begin{bmatrix} [I_A(t)] \\ [I_B(t)] \end{bmatrix} - \begin{bmatrix} [I_A] \\ [I_B] \end{bmatrix}$$

# SIMULATOR OVERVIEW

The RTDS Simulator allows you to test protection and controls in real time, where an hour in the real world equals an hour in the simulator. Utilizing modular custom computing hardware and software, simulations performed encompass results from DC up to electromagnetic transients. Inherently, these results include information regarding the system load flow and transient stability, as well as that of harmonics and faster disturbances. The proprietary operating system used by the RTDS guarantees "hard real time" during simulations; therefore ensuring a true replica of the real world signals.

## Increased Accuracy and Flexibility

Equipment can be thoroughly test-driven and customized. Problems are discovered faster when solutions are designed and tested immediately.

## Reduced Time to Market

New power system network designs or upgrades can be evaluated and accurately tested.

## Reduced Costs

Contingencies can be planned for and modeled, and component interactions can be better analyzed and understood.

The RTDS performs simulations for the study and analysis of small to very large and complex electrical power networks. Applications include:

- Closed-loop testing of protective relays and control systems.
- Studying general AC system operation including behaviour of generation and transmission systems.
- Investigating power system equipment interaction.
- Studying interaction between integrated AC/DC systems.
- Developing FACTS devices and associated controls.
- Educating and training of power system personnel.
- Integration and operation of distributed generation and renewables.
- Investigation and testing of SMART Grid initiatives including wide area protection and control.



# HARDWARE AND SOFTWARE

## HARDWARE

The RTDS Simulator's parallel processing architecture is designed specifically for power system simulation. Some key features are:

### Real Time

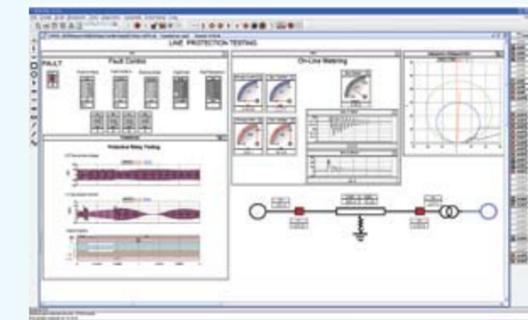
The custom design ensures continuous hard real time operation. For each increment in time, all of the equations representing the power system are computed (and all I/O updated) in real world time exactly equal to the timestep.

### Modularity

The RTDS Simulator is a modular design, ensuring you receive the hardware required for your specific needs. It best utilizes your investment and allows for future expansion.

### Input and Output (I/O)

The simulator provides the most direct data path possible from the processor to the I/O. This structure allows the use of hundreds of I/O channels at minimum cost, without significantly impacting the timestep or creating communication bottlenecks. The I/O is modular, customizable and easily expanded as required.



## SOFTWARE

The RTDS software is your link to the simulator hardware. The main elements of the software are the graphical user interface, RSCAD, and the libraries of power and control system component models.

### RSCAD Graphical User Interface

RSCAD represents a family of software tools consisting of individual modules that accomplish the different tasks involved in operating the simulator. Through RSCAD, you have the ability to organize and share simulation projects and cases; assemble circuit diagrams using predefined or user-defined power and control system component models; automate or interact with simulator operation; and analyze and post-process simulation results.

### Component Model Libraries

Extensive libraries of power and control system component models have been designed and tested by RTDS Technologies and subsequently validated by other users. Much care has been given to ensuring that the library components operate efficiently, since the length of their code directly impacts the minimum achievable simulation timestep. Component Builder enables new models to be created and integrated with the predefined components already available.

The comprehensive component libraries, as well as the user-defined capability ensure the ability to meet study requirements now and in the future. The Small Timestep Subnetwork, Real Time Network Solution, Embedded Valve Groups, and Improved Firing are just a few of the advanced features developed and implemented specifically for the RTDS Simulator. These algorithms provide the accuracy and efficiency needed to realistically simulate your complex power system networks and devices in real time.

# TESTING

## Reliability, Security, Confidence

The RTDS Simulator provides the most advanced and comprehensive testing available. It is the ideal tool for thoroughly designing, studying, and testing protection schemes and control systems. Real time simulation is the only means for testing control equipment, and a digital simulator represents the most flexible and efficient method of performing such tests. All aspects of the simulated network can be controlled allowing the steady state operation to be defined, allowing virtually any type of fault to be introduced and all in a repeatable manner.

The modular structure of the RTDS hardware enables the appropriate configuration to be allocated. I/O peripherals, such as high precision input and output with optical isolation, are designed to make interfacing and testing easy.

## Closed Loop Testing of Protective Relays

Closed-loop testing on the RTDS Simulator is the only method capable of:

- Initially simulating the protection and control and later interfacing the physical equipment for final verification.
- Providing maximum testing efficiency (i.e. more contingencies can be investigated in less time).
- Studying the true interaction of the protection system with the power system.
- Fully evaluating the interaction of more than one protection device.

It provides a proven power system representation including advanced models critical for relay testing such as instrument transformers and internal faults on lines, generators, transformers, etc. The RTDS Simulator has been used for testing all types of relay devices used to protect power systems apparatus (e.g. lines, generators, busbars, transformers, etc.). This testing includes:

- Relay algorithm simulation, prototype testing, validation, type testing, relay selection, and pre-commissioning.
- Testing single relays and more complex multi-terminal systems with relay interaction.
- Testing single and multiple protective relay schemes either at low levels (i.e. +/- 10 Vpk) or at standard secondary levels (e.g. In=5 A, Vn=67 V). For conventional secondary level testing, amplifiers are connected in the test loop between the RTDS Simulator and the protective relay.
- Testing IEC 61850 compliant devices using GOOSE messages to exchange trip, reclose, breaker status and various other signals.
- Testing IEC 61850-9-2 compliant devices using sampled values of voltage and current.
- Wide area protection and control development and testing.

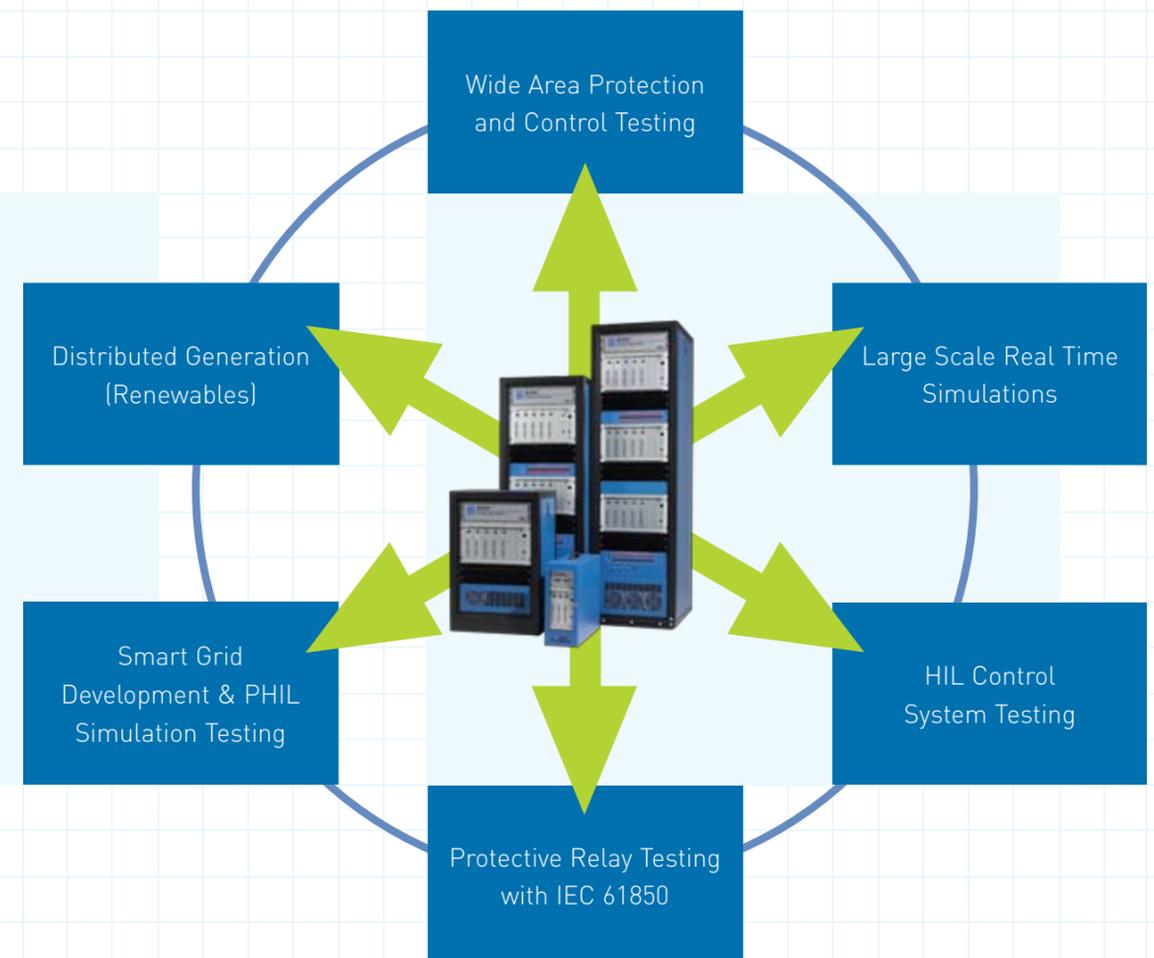
## Closed Loop Testing of Control Equipment

The simulator has been used for control system development, verification, prototype testing, validation, type testing, and pre-commissioning. Closed-loop controller testing often requires interfacing large numbers of analogue and digital signals to exchange data between the physical controls and the simulated system.

During real time simulations, control systems can either be internally represented or the physical controller can be interfaced to the simulator through analogue and digital I/O for closed-loop operation. The flexible I/O structure used by the RTDS facilitates the high volume of signal exchange required when testing complex controllers. The modular design allows additional I/O to be added if interfacing requirements expand. Components such as the Embedded Valve Group with Improved Firing, the Real Time Network Solution, Small Timestep Subnetworks, and the Switched Filter component provide the necessary features to fully and efficiently utilize the simulator for control system testing.

The RTDS Simulator has been used extensively to test various types of controllers:

- Generator excitation systems
- Power system stabilizers
- HVDC controls (conventional and VSC based)
- SVC controls (conventional and VSC based)
- FACTS controls (conventional and VSC based)
- Wide area protection and control
- Machine drives
- Other specialized control equipment



### Studies and Education

Whether studying a specific power system or providing education and training, the RTDS Simulator provides you with access to a convenient, safe and realistic power system model. Linking theory and practical operation, simulation studies can involve nearly any network configuration, including models that represent the fundamental dynamics of an entire utility's network. Regardless of the size of the power system, the RTDS Simulator provides an interactive learning environment where the user can play an active part in the simulation. Users are able to follow their engineering intuition and in turn increase their understanding of the system under study.

### Power-Hardware-In-the-Loop (PHIL) Testing

PHIL testing involves interconnecting the digital simulation with physical power system equipment. Power amplifiers, typically voltage amplifiers specialized for 4-quadrant power range operation, are used to amplify signals from the RTDS Simulator applied physical equipment. The resulting current flowing in the physical network is measured and injected back into the RTDS Simulator to close the loop. PHIL is used to test new apparatus, typically machines or new forms of generation (e.g. wind or solar) under realistic power system conditions. PHIL is also used to expand the representation of physical microgrids whereby part of the network is simulated and part is built up of actual equipment.



## ADDITIONAL APPLICATIONS, RENEWABLES AND SMART GRIDS

### Renewables

The next generation of power systems is seeing an increase in solar, wind and other renewables due to environmental impacts. But these systems don't behave the same way traditional generation does, typically working on a smaller scale with smaller generating stations and more fluctuations in production. Integrating these new generation sources creates new challenges. What if you could predict how your power grid would react to any situation? Our Real Time Digital Simulator allows you to test power system conditions in a realistic and safe environment, so you'll know exactly how your system will respond. Simulation testing will prove ways to incorporate renewables while maintaining the integrity of your existing power system, and help you develop strategies and equipment to deal with new issues that may arise.

### Smart Grids

More and more we're seeing new and different ideas being incorporated into power systems including renewables, making them more robust and intelligent. From smart metres that are programmed to shut off and manage peak loads to wide area protection and control for a broader view, the RTDS Simulator allows you to study the impacts and reactions of smart grids on your system.



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