the **world standard** for real time digital power system simulation

Simulation and closed-loop testing of Marine Systems

The RTDS® Simulator is the world standard for real time power system simulation — used by electric utilities, protection and control equipment manufacturers, and research institutions worldwide for the closed-loop testing of power system protection and control equipment. The controlled and flexible digital simulation environment is a critical tool for the development, testing, and implementation of power system principles and technologies. This includes the modelling and testing of all-electric ship networks and components. The accurate modelling and simulation of the power system of an all-electric ship is a critical requirement in both system analysis and production of prototype equipment.

Real time power system simulation

The RTDS Simulator consists of custom hardware and software, specifically designed to perform real time ElectroMagnetic Transient (EMT) simulations. It operates continuously in real time while providing accurate results over a frequency range from DC to 3 kHz. Its fully digital parallel processing hardware is capable of simulating complex networks using a typical time step of 25-50 μs, and also allows for small timestep subnetworks that operate with timesteps in the range of 1-4 μs for simulation of fast switching power electronic devices (e.g. VSC bridges with PWM switching).

Because the simulation operates in real time, shipboard protection, control, and power equipment can be connected in a closed loop with the RTDS Simulator.

Simulating the all-electric ship

The power system of an all-electric ship or subsea vessel differs significantly from a terrestrial power system in having no slack bus, tight coupling among diverse components, apparent DC isolation between load zones and generation zones, and a different philosophy of grounding [1]. In order to fully predict the behavior of a ship's power system and its associated controls, detailed, large scale real time simulations must be performed. Each component and its behavior in the entire system must be taken into consideration when designing an all-electric ship. Therefore, the ability to quickly and accurately perform tests is needed. Using the RTDS Simulator, analytical studies can be performed much faster than with offline EMT simulation programs.

RSCAD, the RTDS Simulator software suite, features a diverse model library including all the components necessary to model the all-electric ship:

- Freely configurable two– and three-level voltage source converter (VSC) models
- Synchronous machine model with internal faults
- Two– and three-winding transformers with tap-changers, saturation and hysteresis, internal faults
- Dynamic load models
- Composite control system models including generator controls (exciters, governors, and PSS models)
- Frequency dependent transmission line/cable models for submarine applications

The RTDS Simulator is also capable of simulating large networks entirely in the **small timestep** (1-4 μs) by linking small timestep subnetworks with travelling wave transmission line models. RSCAD also includes **Distribution Mode**, which allows the user to simulate very large networks within one tightly-coupled area. Both Distribution Mode and small timestep subnetworks have a full suite of input/output capabilities, allowing the user to interface the real time simulation environment with external protection and control devices.

Examples of marine-related applications of real time simulation

The RTDS Simulator allows the simulated shipboard environment to be interfaced with real physical equipment in a closed loop. The closed-loop interaction of the protection, control, or power equipment with the ship's network model provides insight on the performance of the equipment and its effect on the system.

- Closed-loop testing of a prototype 5 MW HTS superconducting ship propulsion motor under realistic sea conditions
- Closed-loop evaluation of an industrial power electronic building block controller in an all-electric ship
- Implementation of a wide-area differential protection scheme on board an all-electric ship
- Examining the dynamic response of a notional destroyer-class all-electric ship during a crashback maneuver
- Closed-loop testing of controls for a Modular Stacked DC system for long distance subsea applications

See our full list of marine-related papers:
www.rtds.com/technical-publications

Hardware in the loop testing of shipboard protection and control equipment

The RTDS Simulator offers the most advanced and effective means available for testing shipboard protection and control systems. The digital simulation allows protection equipment to be subjected to virtually all possible faults and operating conditions.

A model of the power system is implemented on the RTDS Simulator that includes the shipboard power system components (e.g. motors, generators, turbines, loads, etc.), plus the required protection and control functions not included in the equipment under test. Conventionally, power system signals are input and output from the Simulator via the analogue and digital input and output cards. High-level communication protocols are also available

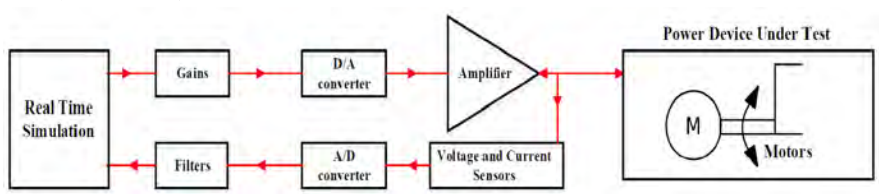
DNP3 and IEC 60870-104 **MODBUS** **High-speed TCP/UDP** **IEC 61850** **IEEE C37.118**

Power hardware in the loop testing of shipboard power equipment

The RTDS Simulator has been successfully used for performing power hardware in the loop (PHIL) experiments in a wide range of applications, including the testing of shipboard equipment such as PEBB-based converter systems and MW-range HTS motors.

PHIL simulation involves the real-time simulation environment exchanging power with real, physical power equipment, such as renewable energy hardware, electric vehicles, batteries, motors and loads.

Learn more about PHIL with the RTDS Simulator at:
www.rtds.com/PHIL



References

[1] K. Miu, V. Ajjarapu, K. Butler-Purry, D. Niebur, C. Nwankpa, N. Schulz, A. Stankovic, "Testing of shipboard power systems: a case for remote testing and measurement," in Proc. of 2005 IEEE Electric Ship Technologies Symposium, pp. 195-201