Analysis Tool Covering Wide Application Range

Portunus supports transient thermal simulations

Nowadays simulation tasks go beyond the investigation of individual component behaviour. Despite electrical engineers naturally preferring different software tools to their colleagues developing mechanical components, virtual tests have to consider more than electrical values. This article lists the requirements for system simulation software and how they are met by the software package Portunus.

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Simulator Functions

Simulation tasks can be roughly divided into component and system analysis. While component design tools are quite often largely dedicated to special needs, system simulation packages follow a more general approach. Modern packages should (but do not always) fulfil the following requirements

- Easy-to-use graphical user interface following a clear software philosophy,
- Flexibility regarding the model implementation,
- Fast and stable solver algorithms,
- Support of different analysis types,
- Powerful visualisation and debugging features,
- Data exchange with other software packages / automation options.

With the simulation package Portunus a new product has come to market. Due to fortunate circumstances its developers could combine long-term experiences in software development and the freedom of creating a product without compatibility issues.

Portunus supports the simulation of systems from different physical domains. Analyses can be performed in the time domain (with the option of a preceding initialisation run), frequency domain, quiescent domain and for the operating point. Models can be built-up by means of networks (electrical, mechanical, thermal etc.), block diagrams, state machines, macro components and C-code.

Portunus facilitates debugging in several ways. Results can be displayed during the simulation run in diagrams or tables. A number of models offer animation features, i.e. their appearance changes during the simulation run depending on model values like state, voltage, current or temperature. To reduce calculation time this feature can be de-activated. Display and animation functions are completed by a so-called 'Replay' mode, in which the results of the last simulation run are displayed stepwise (Figure 1).

The graphical user interface allows the definition of virtual experiments by means of automated parameter variations and user interactions. The results can be displayed simultaneously in a single diagram or table.

User interactions may require artificial slowing of the simulator performance in order to give the user sufficient time to adjust the settings. For this purpose the so-called 'Time Scaling' function allows a defined ratio of run time and simulation progress providing the simulator can solve the equations fast enough.

Software Philosophy

One of the most critical points of software development is the clear definition of software structure and internal and public interfaces. Obeying the rules of lean programming has a major impact on the functionalities and capabilities of the product.

Portunus uses a single kernel to solve the algebra-differential equation system derived from networks and block diagrams. This guarantees numerical stability by avoiding signal delays. The solver algorithms must happen sequentially but the interrelations are managed by a step-size control.

In Portunus the core object is the schematic which does not only hold information about models, parameters, connections, outputs and variable definitions but also keeps the settings for experiments, user interaction and 'time scaling'. The graphical user interface is one application with the option to display or hide docking windows for the features listed above.

To integrate Portunus into design flows an automation interface is available allowing the use of tools like Excel or Matlab for pre- and post-processor purposes. The available commands let the user load and save schematics, modify parameters and control simulation runs. To shorten calculation time

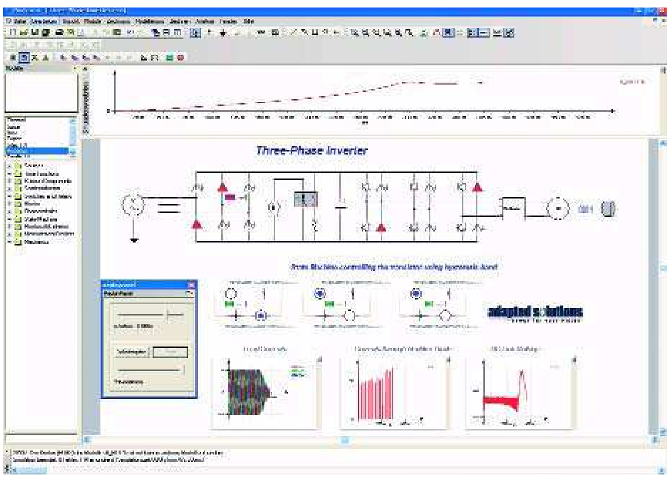

Figure 1: Electric Drive Model: Symbol Animation, Result Display, Replay Mode

Portunus may be run in a 'hidden' mode.
Beside the automation interface Portunus allows the data import from leading CAE tools like SPEED (SPEED laboratory, UK) for electric motors, InCa (Cedrat SA., France) for bus bars and Motor-CAD (Motor Design Ltd., UK) for thermal networks. Simulation results can be exported directly into Excel, Matlab and Origin without writing an intermediate file. Additionally a file export using the csv-format is possible.
Portunus comes with a comprehensive set of model libraries that can be expanded by the user. The standard version already includes electrical and mechanical models, time functions, blocks, state machine components as well as measurement and analysis devices. Two types of semiconductor models are available: 'Switch models' can be used for fast system analysis without consideration of semiconductor transients. For more physics-based simulations the SPICE (3F5) model set has been incorporated. To analyse thermal networks, a "Thermal Library" has been created in co-operation with Motor Design Ltd. (UK). It contains models for all heat transfer mechanisms, i.e. conduction, convection, radiation, heat storage, power and temperature sources as well as measurement devices.

Applications

Due to the flexible modelling options provided by Portunus, the potential application range is comprehensive and exceeds merely power electronics and drives. In the following we present three examples.
The combination of control components, electrical and thermal networks at the example of a M3.2 rectifier is shown in Figure 2. The variation of the junction temperature due to the periodic current flow can be clearly seen.

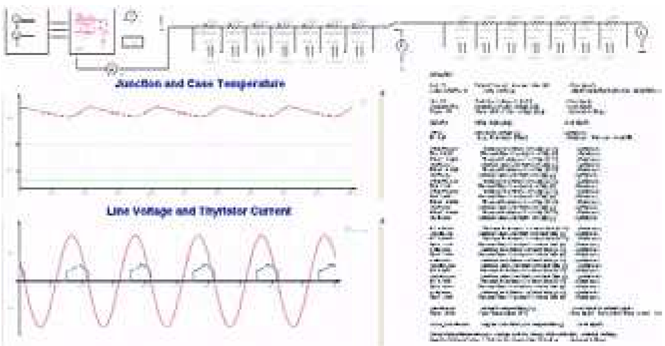

Figure 2: Model of a controlled rectifier including the thermal network for the calculation of junction temperature

Figure 3 shows how time functions, electrical networks and block diagrams are used for the design of a net feeding inverter (full bridge). The inverter, which is coupled to the net via a LC filter, is modelled by a controlled voltage or current sources. This is possible as the filter has a huge damping effect at the pulse frequency of the full bridge. Different control strategies such as current and power control have been investigated thereby taking advantage of the possibility to run both transient and AC analyses for the same schematic. AC simulations have been run to determine frequency responses and optimum parameters according to Ziegler/Nichols and Nyquist criteria. Transient simulations with the line voltage made up of the fundamental component and harmonics verify the design.

Within a joint project by Cummins Generator Technologies, Motor Design and the University of Edinburgh the "Thermal Library" has been used to further develop models for Cummins STAMFORD range of synchronous generators. Based on an existing spreadsheet application thermal models have been created for stator, rotor and

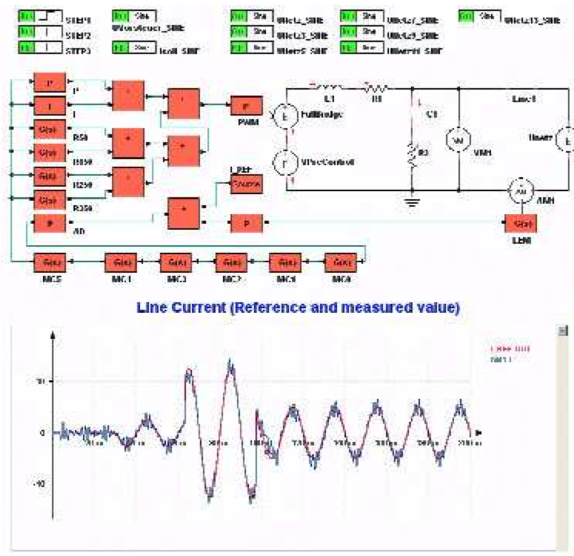

Figure 3: Net Feeding Inverter – Current Control

the heat transfer between them (see Figure 4). With the help of Portunus sub-sheets each part of the generator can be divided into as many subsections (layers) as possible. The parameters are calculated by the spreadsheets and exported to Portunus using the ActiveX interface. Due to the scalability of the topology, models can be used for the whole STAMFORD range of low-volts generators from 7.5 kVA to 2.5 MVA. By using Portunus a number of limitations of the spreadsheets could be overcome: As Portunus supports transient thermal simulations, analysis is no longer restricted to steady-state behaviour. Displaying the thermal network diagram increases clarity and allows for easy extension of the model. The next steps are to include the calculation of temperature-dependent losses. The aim is for a multi-physics solution, in this case linked electromagnetic and thermal simulations in order to provide improved accuracy in loss prediction. This is important when solving for transient state, both electro magnetically and thermally.

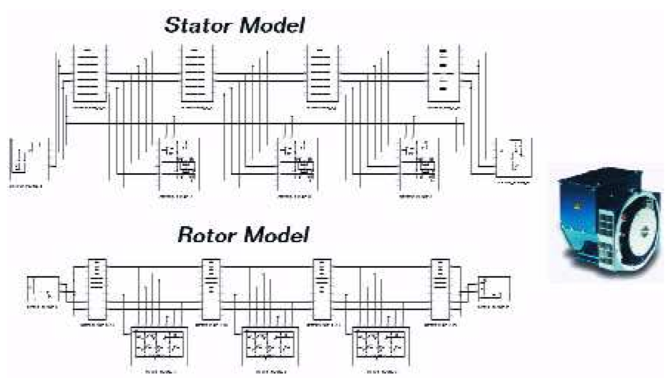

Figure 4: Parts of the Cummins Generator Model

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