EcosimPro PROOSIS

Modelling and Simulation Software

EcosimPro/PROOSIS · Newsletter Nº 11 · July 2015

FROM THE EDITORS

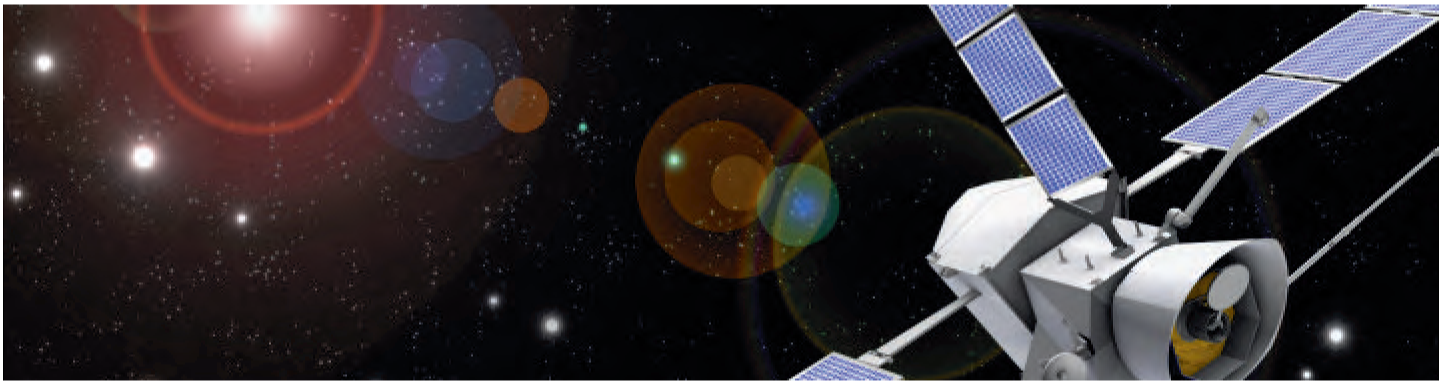
This new issue of our newsletter provides information on our simulation products to give readers an idea of what we do as well as how simulation can potentially be used to solve complex problems.

Over the last few months we have been working on a cryogenic simulation model so complex that the current version of EcosimPro could not create a mathematical model of that magnitude. In this case, we had to set up a sort of "crisis committee", to identify the enhancements we needed to add to EcosimPro to make it able to generate a model of more than half a million equations. The model would also have to be able to run more or less efficiently. The enhancements were then implemented (including using 64-bit compilers), and the problems were finally overcome. Released in February 2015, version 5.4.14 contained all these enhancements, and even better, any EcosimPro user today can benefit from them.

We must say that one of the tools that has helped us a lot with our product enhancements is the Bugzilla Database, which we use with our users, since they not only report errors found in the tool, but also propose new improvements that remain forever in this database, and that little by little we try to add to our new versions. The good news is that when the users see their request has been implemented, they realise that their ideas have been added to a new version that other users can also benefit from.

We trust you will find this latest newsletter of interest. Please do not hesitate to send us any questions you may have or to suggest subjects for future newsletters. We would love to hear from you.

Pedro Cobas (pce@ecosimpro.com)
Head of the Development Team EcosimPro/PROOSIS
EA Internacional

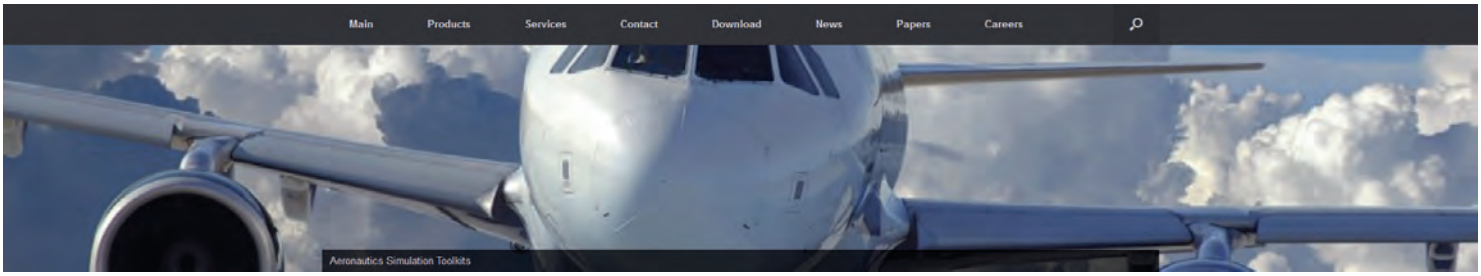


CONTENTS

1. NEW WEBSITE

Bernardo de Blas, EcosimPro/PROOSIS

A new website was uploaded in May 2015 to provide information to potential users about our products and services. To access it, type www.ecosimpro.com.



Home of the new web

This new website has been done with Wordpress, which is currently one of the most popular web design tools. There are also a number of widgets that shall be progressively incorporated to make browsing through the web pages more attractive.

The web includes detailed descriptions of the EcosimPro/PROOSIS toolkits and a wide variety of cases that serve to illustrate the potential of the tool and of all the toolkits.

The new web has been divided into the following sections:

- Main: Introduction to the simulation services and products of the EcosimPro/PROOSIS team.
- Products: Presentation of the various simulation products and toolkits in the fields of space, aeronautics and power-water and process.
- Services: Information on the various modelling assistance and support services.
- Contact: A contact form is provided, as well as a description of Empresarios Agrupados (EA) is included.
- Download: Area to download the free version, the brochures, videos, etc.
- News: This section includes current and old newsletters, as well as the news.
- Papers: This section includes many articles written by the users that show real cases in the different fields of application.
- Careers: Area dedicated to job offers.

We hope users like the new website and find it more attractive than the previous one. If you have any comments, please contact us at info@ecosimpro.com

2. NEW VERSIONS OF ECOSIMPRO AND PROOSIS

Pedro Cobas, EcosimPro/PROOSIS

The new versions of EcosimPro 5.4.14 and PROOSIS 3.6.14 hit the shelves in late January 2015. These new versions include new features in several areas, including:

- New 32- and 64-bit versions available. The new 64-bit version provides a greater calculation power, reduces simulation time and allows work on larger models.
- Compatibility with new 32- and 64-bit C++ compilers (Microsoft, Intel and GCC)
- New available solvers or upgrades of existing ones, such as Euler, Adams-Moulton and IDAS
- Automatic generation of simulation scripts for the automatic running of multiple experiments in batch mode.
- The generation of the HDF5 post-processing file has been optimised. It can now save very large (several GBs) simulation results. The reading of post-processing files has also been optimised (35% faster on average).
- New tool for the automatic analysis of the sturdiness of the

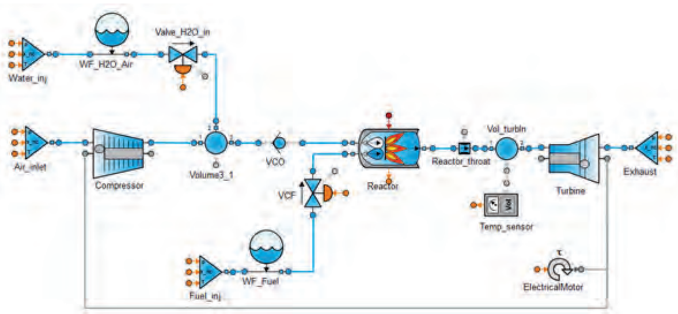
generated mathematical models
- New capability to read a post-processing simulation file from the experiment monitor or from Excel.
- The connection with Simulink has been improved to automatically generate an S-function and to export to HIL systems.
- The connection with Excel has been improved and is now more intuitive, sturdier and faster.

3. NEW VERSION OF THE FLUIDAPRO

José Moral & Javier Vila, EcosimPro/PROOSIS

The FLUIDAPRO toolkit, formed by a set of professional libraries developed for the simulation of complex fluid systems, has recently undergone a profound reworking that significantly improves the quality of both the technical side and of the renewed visual appearance of this tool.

The new features of this new version include the possibility of simplified simulation of certain combustion processes thanks to the new 'reactor' component. This component includes two injectors that can operate with liquids or gases and a chamber that calculates the composition and properties of the combustion products, which are transmitted downstream from the reactor. To do this, all the library components have been adapted to operate with combustion products.

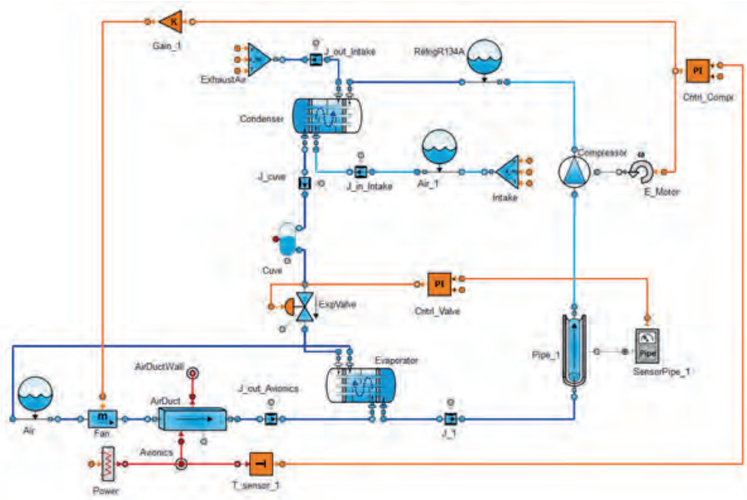


Model of a Gas Turbine with the new "Reactor" component

The following other significant improvements have also been introduced:

- Variable area in the pipe component as a function of its length
- Option of working with user-defined fluids in the Reactor component
- A basic vaporisation model has been added in the Reactor component
- Possibility of defining the non-condensable fluid with the properties of a real gas
- New option in the check valves to accelerate the simulation

Furthermore, new examples of use have been included to showcase the new capabilities. An important effort has gone into improving their documentation and the user manuals so as to facilitate the use of the libraries. The added models include refrigeration thermodynamic cycles under two-phase conditions, mixing of three lines with different working fluids, gas turbine cycles with water injection, and some examples in the space field.



Refrigeration Thermodynamic Cycle with FLUIDAPRO

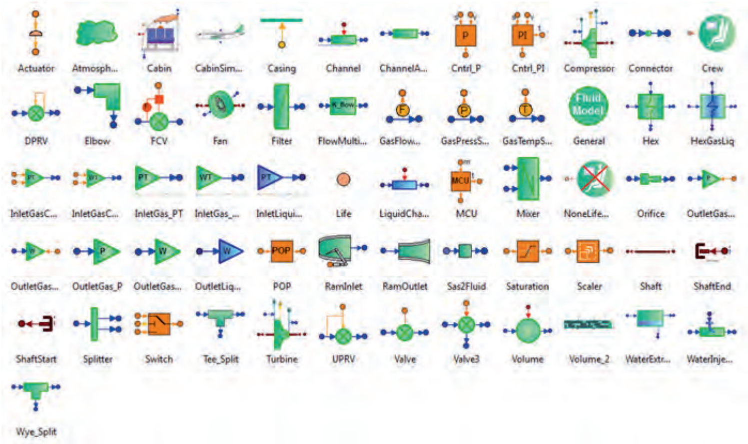
4. NEW ECS LIBRARY

Raúl Avezuela, EcosimPro/PROOSIS

A new ECS library is now available in PROOSIS. The PROOSIS ECS library is used for performance analysis and dynamic simulation of Environmental Control Systems (ECS) and other aircraft pneumatic systems.

The ECS library offers a set of typical components and subsystems for the modelling and simulation of the aircraft ECS such as ducts, valves, heat exchangers, fans, turbines, etc. It includes components to represent the cabin and the passengers as well.

The palette of components of the ECS library is shown in the following figure.

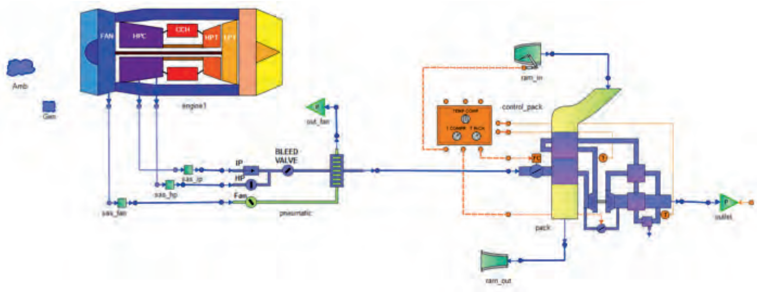


Component palette of ECS

The main features of the library are the following:

- Dynamic simulation and performance analysis of Environmental Control Systems
- Connection to the aircraft engine model
- Modelling of the control system of the ECS
- Easy customisation of the cabin layout
- Assessment of different cooling pack architectures
- Analysis of the comfort of the passengers
- Easy customisation or creation of new components

The ECS toolkit includes several application examples to allow the users to develop their own models. The following figure shows the schematic diagram of an aircraft engine model connected to the pneumatic system of the air conditioning pack for the ECS.

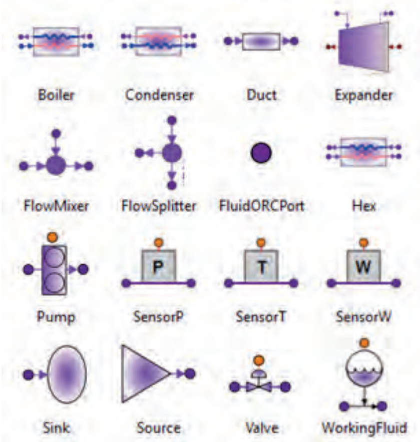


Motor model connected to the pneumatic system of ECS

5. NEW VERSION OF ORC LIBRARY

RAÚL AVEZUELA, ECOSIMPRO/PROOSIS

A new version of the ORC library (1.2) is now available which palette of components is shown in the figure. It further facilitates the calculation of fluid properties and is compatible with the new versions of PROOSIS (3.6.14) and the TURBO library (4.0). We especially want to highlight the implementation of a new way of calculating the thermo-physical properties of the working fluid based on the interpolation in look-up tables. This new feature allows the use of the library without requiring a license for the external software REFPROP (REFerence fluid PROPerties). In addition, a number of minor modifications have also been implemented to correct bugs and improve component modelling.



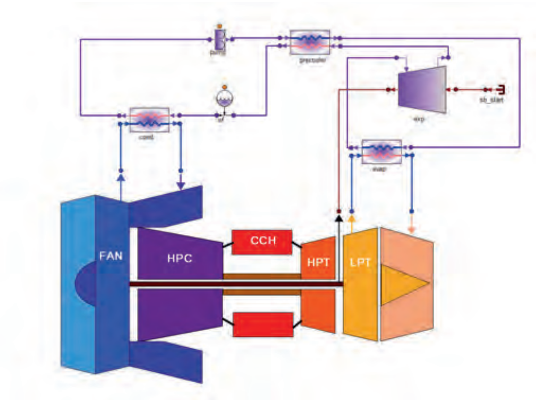
Component palette of ORC

The aim of the ORC library is to calculate the thermodynamic design and off-design of an ORC (Organic Rankine Cycle) and to study the overall performance of the aircraft engine when it is coupled to the ORC system.

The key features of the library are the following:

- Steady calculation and transient analyses can be performed
- The working fluid is selected from a list of coolants that are already defined in the library: R113; R245fa, R410a, R141b, R134a, water and ethanol. However users can use their own working fluid as well.
- The thermo-physical properties of the working fluids can be calculated either by means of external software REFPROP or by interpolating in fluid properties look-up tables
- ORC library components are compatible with those of the TURBO library. This allows the user to create a combined model in which components from both libraries interact
- Components can be used in thermo-design mode or in off-design mode, just by switching an input parameter

The following figure shows an application example of an unmixed turbo-fan engine coupled to an ORC cycle heat recovery system.



Motor model coupled to ORC cycle

6. COURSE ON AERONAUTICAL GAS TURBINE MODELLING

Fernando Rodríguez & David Castaño, EcosimPro/PROOSIS

The course on "Modelling Gas Turbines Engines with PROOSIS" will be held on 22nd, 23rd and 24th September in our Madrid offices. This course is aimed at engineers involved in the design, modelling and calculation of performance for aeronautical gas turbines.

The course includes an introduction to the modelling with PROOSIS and its TURBO toolkit. The components required to model aeronautical motors will be described, and practical exercises on typical systems such as turbojets, turbofans, turboshafts or turboprops will be done. In addition, a wide range of studies will be explained and completed, including the design, off-design, transients, optimisation studies, parametric studies and sensitivity studies. Finally, there will be an explanation about how to export the complete models, such as black boxes and the different possibilities for connection with other environments.

Engineers attending the course shall find that PROOSIS is a powerful simulation tool. Its unique features provide a complete environment to simulate both the different types of aeronautical engines and their associated systems: Control System, Electrical System, Environmental Control System, Fuel System, etc.

The inscription period for the course is now open. For further information, please contact us at djj@empre.es. The brochure can be downloaded from:
http://www.ecosimpro.com/wp-content/uploads/2015/05/201509_course_PROOSIS.pdf

7. COURSE ON SPACE PROPULSION SYSTEM MODELLING

José Moral & Javier Vila, EcosimPro/PROOSIS

The course "Space Propulsion System Modelling with EcosimPro/PROOSIS" will be held in our Madrid offices on 6th, 7th and 8th October. This course is aimed at engineers working on the design of space propulsion systems.

The course will start with an introduction to the use of EcosimPro that will help students become familiar with the graphic user interface and with the basic use of the programming language. The next step is the graphical creation of new models related to space propulsion, as well as the configuration of associated experiments that allow their simulation and the display of the results.

Once the basic concepts have been grasped, the second part of the course will focus on the modelling of space propulsion systems and subsystems. Students will learn about the main features of the ESPSS space propulsion libraries and will complete test models to check the simulation capabilities for fluid transient effects (water hammer), heat transfer,

combustion processes, turbo-machinery or tanks, among others.

The last part of the course will focus on the creation, simulation and analysis of complete typical space propulsion models. Systems such as the filling of a complex pipe network with homogenous two-phase flow, a fuel tank pressurisation system with associated control or the configuration for startup, stabilisation and shutdown of a rocket engine, including the corresponding valve opening laws, will be studied. The simulation capabilities of steady-state models of these systems under design and off-design conditions will also be displayed. Finally, the different possibilities of connection to external software will also be explained.

The inscription period for the course is now open. For further information, please contact us at djj@empre.es. The brochure can be downloaded from:
http://www.ecosimpro.com/wp-content/uploads/2015/05/201510_course_EcosimPro.pdf

8. ECOSIMPRO/ESPSS WORKSHOP IN LISBON

Pedro Cobas, José Moral & Javier Vila, EcosimPro/PROOSIS

The fourth EcosimPro/ESPSS user's workshop was held on 4th March 2015 in the Universidad Técnica de Lisboa, organised by the ESA (European Space Agency) and EA (Empresarios Agrupados). The session started with a presentation on the latest capabilities of EcosimPro 5.4.14, which was released in February. The progress made with the latest version of the ESPSS toolkit was later presented. Some of the issues encountered by ESPSS users that were solved by EA in recent months, as well as the feedback obtained from users for future upgrades, were also presented. To close this first part of the workshop, the new ongoing development projects in EcosimPro for future versions were presented, including the Montecarlo Simulation, the calculation parallelisation, 3D visualisation for spacecraft, new automatic testing tool, etc.

During the second part of the workshop, several companies that use EcosimPro/PROOSIS presented some of the problems they have faced with the tool. Different solutions for future versions were discussed.

The last part was a roundtable at which the users discussed new upgrades in future versions of ESPSS. The ESA and EA made a note of them to include them in future development processes.

The workshop was chaired by Johan Steelant and Francesco di Matteo, of the European Space Agency and responsible for ESPSS.

9. SYMPOSIUM ON FUSION TECHNOLOGY (SOFT)

Almudena Rueda & Jenifer Serna, EcosimPro/PROOSIS

EA participated in the 28th International Symposium on Fusion Technology (SOFT) held in San Sebastián, Spain. This symposium is the foremost event on an international scale in the field of fusion. It brought together a large number of scientists, against the backdrop of the development of ITER.

The symposium provided guests with access to information about ITER and the field of nuclear fusion as a whole in several communication sessions and presentations.

As part of this event, EA submitted the work performed in the modelling of the TBS (Test Blanket Systems), which involved the development of a set of simulation libraries in EcosimPro. The simulation of these systems is especially useful to provide support to engineering in areas such as the selection of alternatives, study of materials, testing of the system at different operating stages, etc. The characteristics of the modelled system, as well as the details of the model finally used and the results of the different simulations were explained in detail to a large number of guests interested in the subject.

10. VISIT OF COMAC-SADRI TO THE EA OFFICES

A delegation of COMAC, the top Chinese aircraft manufacturer, visited our headquarters in December 2014 through the COMAC-SADRI department in Shanghai, which is responsible for the aircraft ECS, among other systems. COMAC – SADRI has purchased our PROOSIS simulation tool and the ECS library to support the development of the ECS system of one of its latest-generation aircraft.

During the visit, COMAC-SADRI was given a presentation of our company, tools and experience with PROOSIS simulation, as well as the ECS and ECLS libraries (the latter was developed for manned space flights). They were also introduced to our customer care services in the field of simulation modelling.

11. PROPOSAL TO OBTAIN THE NQA 1 CERTIFICATE FOR THE PIPELIQ AND PIPELIQTRAN LIBRARIES

Nuclear quality code ASME NQA-1 establishes the need to develop a specific validation and verification plan for any computer program that is to be used in safety-related applications in new nuclear facilities. This plan is necessary to accept the program as a valid calculation tool, and will gradually be extended to other types of SW and uses.

EAI has developed the PIPELIQ and PIPELIQTRAN libraries to perform steady-state and transient hydraulic studies of water hammers. They shall be homologated with this code both for use in nuclear facilities and for their commercial distribution.

The verification and validation test plan for a nuclear safety-related computer program is based on the specification of requirements. It includes all the tests required to prove their compliance, including test cases, the execution sequence of the tests and the criteria for the acceptance of the program for the projected purpose.

The validation and verification procedure is done by comparing the results of the test cases against alternative methods such as manual calculations, the results of other accepted and validated codes or empirical data and data from technical bibliographical sources.

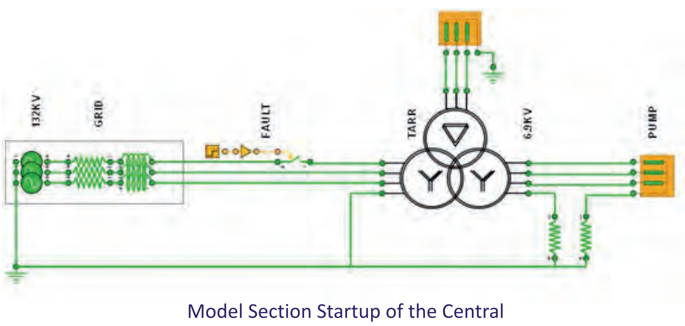
12. SIMULATION OF A SERIAL FAULT IN THE STARTUP SECTION OF A POWER PLANT WITH ELECTRIC_SYSTEMS LIBRARY

Víctor Pordomingo, EcosimPro/PROOSIS

A study of the emergency status of a power plant due to a serial fault in one of its sections is provided. An analysis of the fault effect, its detection and means to tackle it has been included. This requires a transient and simultaneous simulation of the three unbalanced phases of the system, using EcosimPro and ELECTRIC_SYSTEMS library.

The startup section of the plant is connected to the off-site network at 138 kV by means of the three-winding startup transformer with Ydy connection. This transformer feeds the motors of the plant cooling pumps at 6.9 kV. These have been simulated by means of static RL loads with values that depend on the situation to be replicated: startup or normal operation.

The purpose is to analyse the behaviour of the currents and voltages in the various busbars and in each phase whenever a serial fault occurs in the phase located upstream from the startup transformer. The behaviour is determined by the configuration of the various system neutrals: (1) The primary unit of the transformer in star connection has an earthed neutral. (2) The secondary unit, in delta connection, has no neutral. (3) The neutral of the load with a star connection to the above secondary unit is assumed to be earthed. (4) The secondary unit with star connection has earth insulation (floating), and (5) the motor neutral is not accessible (floating), so the following model is obtained:

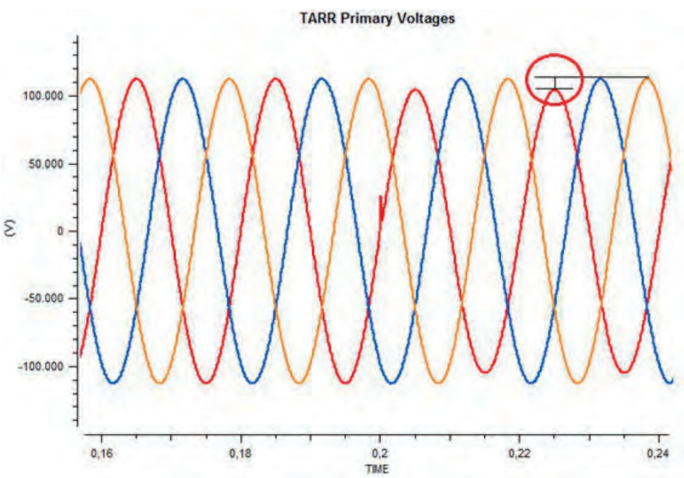


Model Section Startup of the Central

The figure shows the 132 and 6.9 kV busbars, the neutral connections in accordance with the above criteria, the serial fault that is programmed in phase A of the 132 kV busbars and the static load that simulates the motor. Once the components were configured with estimated values for this type of facility taken from the available documentation, the corresponding simulations were performed. The starting point was normal operation, and a serial fault was started at instant 0.2. The following results were obtained for the currents and voltages in the 132 kV and 6.9 kV busbars:

The serial fault interrupts the current in the startup transformer primary unit through the non-operational phase. However, the direct earthing allows the other two phases to preserve their original configuration with a peak of around 100 A. However, the type of transformer that is used causes the lead of one of the phases and the lag of the other, so the shift between them is reduced to only 60° instead of the usual 120°.

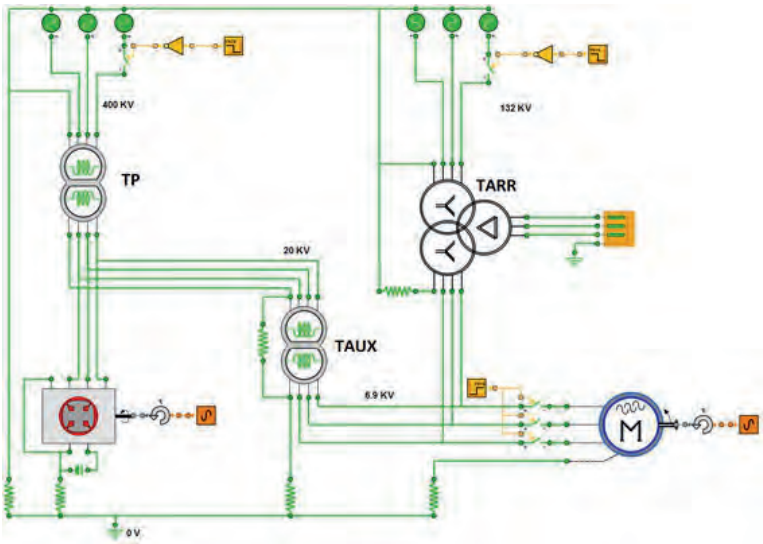
On the other hand, the insulated neutrals of the secondary unit and the motors, together with the intermediate winding in delta connection, makes the voltage phase unbalance hard to detect because the two operational phases tend to become balanced with the third one when the potential of the neutral oscillates. Unbalances smaller than 10% of the peak value could be encountered, as shown in the figure. In addition, there is an important voltage drop from the nominal values due to the impedance used for the modelling of the network itself and the losses in the transformer.



Voltage in primary windings TARR

Finally, considering all of the above, the on-load currents have no significant imbalances either, so the fault that occurs upstream is hard to detect at this level of the facility.

Subsequently, a more detailed model was developed. This model included the main and auxiliary network and the startup network, as well as the dynamic models of the induction motor for the pumps and synchronous unit for the generators. The results with this more detailed model confirmed the difficulty of detecting this type of fault, which had already been shown in the previous, more simplified model.



Extended mode with network startup, auxiliary and main

13. CRYOGENIC SIMULATION APPLICATIONS IN ITER PROJECT WITH CRYO LIBRARY

Ana Veleiro, EcosimPro/PROOSIS

The modelling phase of the cooling circuits of the ITER magnets responsible for confining the plasma in the Tokamak has concluded.

The magnets are the main users of the ITER cryogenic system; for this reason, and to ensure correct operation of the system, it is essential to have models that are capable of reproducing the dynamic behaviour of the system in different scenarios. The simulation of the circuits that cool the magnets allows analysis of the load that this cooling represents for the plant, and provides a guarantee that the cables-in-conduit that

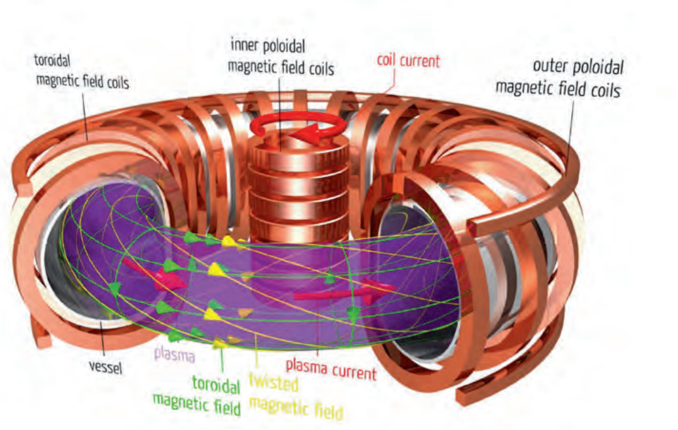
comprise the coils are maintained below the critical temperature that if exceeded would lead to the loss of the super-conductive properties and cause the reactor to shut down.

The models developed with Cryo library have also allowed us to analyze other scenarios, like the cooling of the magnets from an ambient temperature of 80 K. In this case, it is critical for the selected cooling strategy to guarantee a total system cooling time of less than 500 hours, while at the same time guaranteeing that there is no in-system temperature difference of more than 50 K, to prevent thermal stress in the structure.

Another scenario analyzed was the re-cooling of the magnets after a quench. In the event of a quench there is an increase in temperature and pressure in the magnet cooling system that forces the disconnection of the cooling via the auxiliary cold box, and the release of a certain quantity of coolant into the quench tanks to reduce the pressure in the circuits. The magnets then have to be immediately re-cooled directly from the cold box of the helium cooler before being reconnected to the supercritical helium circuit. The optimization of the time required to re-cool the system so it can become operational again is another especially important aspect.

The next step would be to model the remaining sub-systems with a view to obtaining a plant simulator that would provide the engineers with a tool for the design and optimization of plant control during the design and commissioning stage, and which could also be used for training operators. For this it is necessary to implement the models of the helium and nitrogen coolers, the lines that take the helium from the plants to the users and to other users such as the cryo-pumps, including the complex control systems that regulate the operation of the different users and the coolers. Given the complexity and size of the ITER plant, the integration of all the sub-systems into one model represents a challenge, due to the computational load on the simulation tools. It also means having to optimize the tool in order to be able to make the best use of the computer resources and maybe the need of using distributed simulation techniques to improve the simulation time of the model.

The complete model of the cryo-plant will allow optimization of the work in parallel of the coolers so that this will be more efficient. It will also provide a global view of the plant. Moreover, the future simulator can be put to other uses after the design phase, such as operator and engineer training for normal plant operation and failure situations.



Arrangement of the magnets in Tokamak

14. AIRCRAFT ENGINE SIMULATION WITH PROOSIS-TURBO AND EXCEL

Daniel Gordillo & David Castaño, EcosimPro/PROOSIS

Users of modelling and simulation tools often need to perform a large number of simulations on a single model. The purpose of this process is to evaluate the different results so as to establish the optimum solution (trial-and-error technique). Having an intuitive GUI is indispensable to facilitate the configuration, run the simulations and obtain the results.

Excel Add-in

In this type of situation, the direct connection between PROOSIS and Excel can be handy for the user. This capability simplifies and expedites the required simulations, in a known environment that most engineers are familiar with. Furthermore, it allows users that are not very knowledgeable of PROOSIS to perform all sorts of simulations, since this interface hides the complexity associated to the experiments generated in EL language.

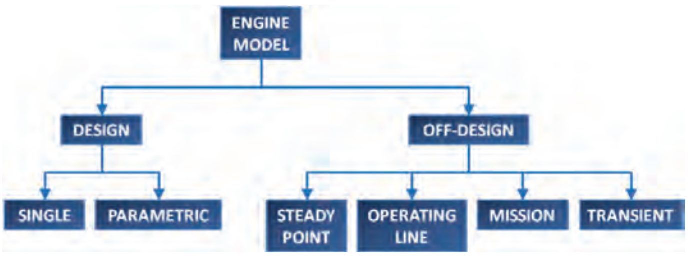
The creation of flexible experiments with adaptations so they can be handled from Excel yields extremely comprehensive simulation tools. The connection with the Microsoft software allows users to customise the graphical interface so as to facilitate the interaction with the PROOSIS-generated models.

Development of a new tool

In our case, the simplicity and flexibility of Excel has allowed its use as graphical interface for the design of a tool for the simulation of the design and actuations of turbojets and turbofans, submitted as a qualification project for the Escuela de Ingenieros Aeronáuticos de Madrid (ETSIA).

The correct adaptation of an experiment in EL language in PROOSIS and the graphical customisation of an Excel book were enough to obtain the end product. With this new tool, users can complete a wide range of calculations with the Excel toolbar, without any need for knowledge of PROOSIS or EL language.

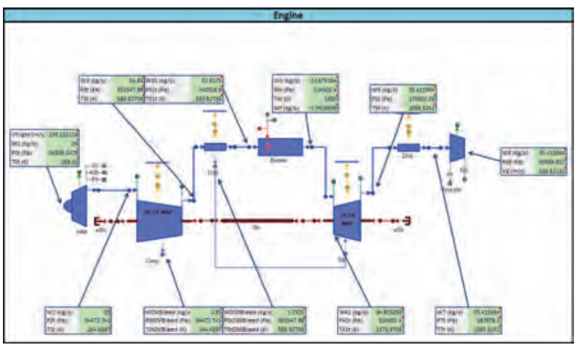
All the different possible calculations are shown in the following figure:



Possible calculations for Design and Performances

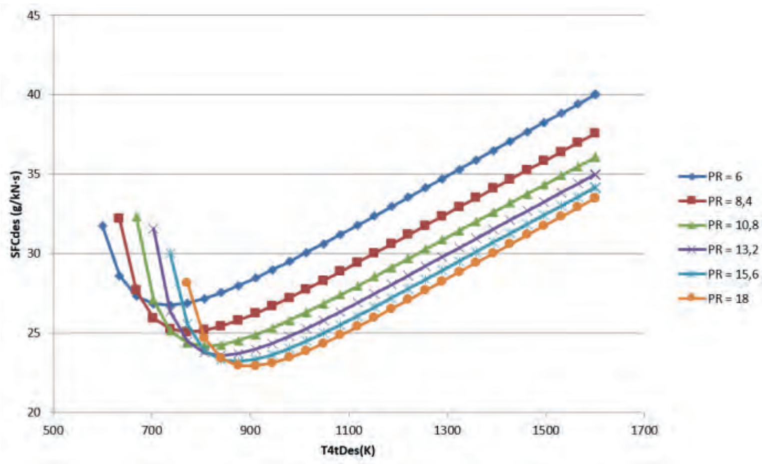
In addition, all the calculations allow different configurations for the inputs to be selected, so that end users enjoy a great degree of flexibility in their simulations.

Finally, simulations present results in a clear format, arranged intuitively in several calculation sheets.



Representation of the design point of Turbojet

The values obtained for the system performances are represented both graphically and numerically, depending on the requirements of the calculation.



Parametric study of influence of T4t and compression ratio (PR) in the specific fuel consumption (SFC)

Self-contained Excel tool

The new PROOSIS (v3.6.14) goes even further in the connection of the models to Excel. This version allows self-contained decks to be exported together with their Excel interface. In this way, they may be distributed among users without PROOSIS.

15. MEGAWATT HUNTING IN A POWER PLANT WITH THERMAL_BALANCE LIBRARY

Ramón Pérez Vara, EA

Empresarios Agrupados was asked to find the root cause of a loss of efficiency in the secondary circuit (Rankine steam cycle) of a power plant.

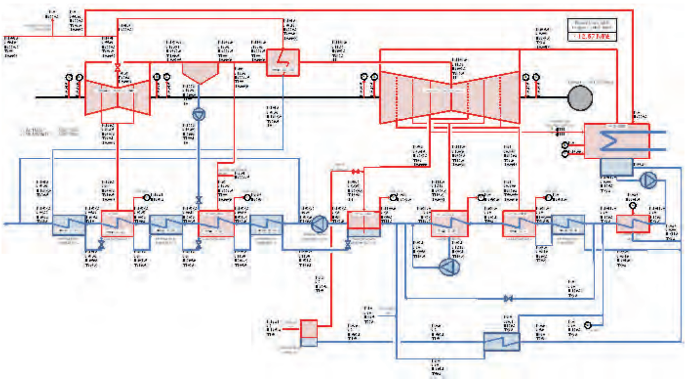
It was suspected that the duplex heaters of two of the three condensate trains were responsible for the loss of efficiency. Still, although it was fairly certain which equipment were causing the problem, the problem itself was far from solved, because it was necessary to determine the exact failure in order to facilitate inspection of the equipment during refuelling.

A plant energy balance model was developed using EcosimPro and Thermal_Balance library to simulate various scenarios with a high degree of approximation to the response of the cycle, both in rated operating conditions and in degraded operating conditions caused by wear or equipment malfunction.

Different equipment degradations and failures were postulated, applying an optimisation algorithm to each degradation or failure. This allowed changing the level of supposed degradation to minimize the difference between the values measured in plant and those calculated. Logically, the most likely cause of the problem would be the one that most reduces the deviation between the measured values and those calculated by the energy balance, after applying the optimisation algorithm.

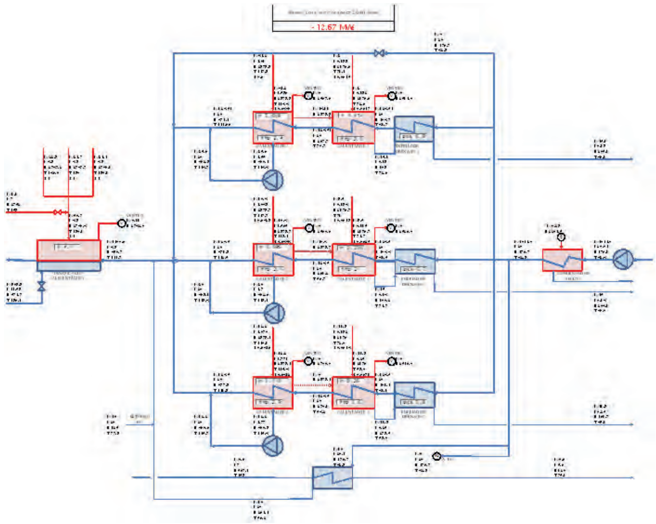
This fairly simple technique allowed identifying the cause of the failure. During the plant's refuelling outage, the equipment located in the zones identified by the simulation model was inspected and the exact type of failure that had been predicted by the model was found.

The plant energy balance simulation model developed in EcosimPro was linked to and run on an Excel spreadsheet to make post-processing of the results of the different scenarios easier, as shown in the following figure.



Model of thermal balance of the plant

To perform the analysis, a detailed model of the condensate trains had to be developed. The following figure shows the results of the energy balance of the trains supposing an operating failure in them.



Detailed model trains condensate

It is important to point out that the set of possible errors is not only decided by the model but basically by an expert deciding on the basis of his experience and physical perception. A sophisticated calculation model is a valuable tool but not if used improperly or if its results are poorly interpreted.

In this respect, the heat balance of the plant developed in EcosimPro enabled locating precisely the operating problem/failure in the condensate trains that was affecting the output of the power plant. This study demonstrates the flexibility and usefulness of EcosimPro for evaluating efficiency and power losses in power plants.

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