Fusion energy could be a viable answer to clean energy needs in the future and a new experimental fusion reactor called ITER is being built in France. The EUFORIA project, says Pär Strand, is using high performance computing for physics modelling and simulation of the fusion process for ITER.

Modelling Plasma Fusion for ITER Applications

Much excitement and anticipation surrounds the development of the France-based ITER fusion reactor, a massive scientific experiment that aims to demonstrate the possibilities of producing commercial energy from fusion, the power generated by nuclear fusion reactions.

ITER is based on the ‘tokamak’ concept of magnetic confinement, in which plasma is contained in a doughnut-shaped vacuum vessel. The fuel – a mixture of deuterium and tritium, two isotopes of hydrogen – is heated to temperatures in excess of 150 million°C, forming a hot plasma. Strong magnetic fields are used to keep the plasma away from the walls; these are produced by superconducting coils surrounding the vessel, and by an electrical current driven through the plasma.

ITER is the next generation of experimental fusion device and it is hoped it will point the way to fusion as a sustainable energy source for the future. To exploit the full potential of the device and to guarantee optimal operation, a high degree of physics modelling and simulation is needed, even in ITER’s current construction phase. The EUFORIA (EU Fusion fOR Iter Applications) project is developing a comprehensive framework and infrastructure for modelling ITER relevant fusion plasmas. EUFORIA focuses on core and edge physics transport and turbulence simulations, aiming at linking Grid and High Performance Computing (HPC), to the fusion modelling community.

EUFORIA comprises two different phases that were developed in parallel from the start of the project to become fully integrated in its later stages.

The first was a development and deployment phase consisting of the adaptation and optimisation of a selection of codes covering both edge and core physics for Grid and HPC environments as appropriate. Within this is the deployment of the computational infrastructure, where access to Grid computing and high performance computing is being developed for the project members.

The second phase is a standardisation and integration activity. It has one technology-driven part which develops the technologies and tools to provide user transparent methods for resource allocation and scheduling and dynamic coupling of physics codes. Additionally, there is an on-user and physics-driven component, where technology for building complex workflows with the optimised codes as components and standardised data structures and transfer methods are being utilised to expand the physics cases for ITER development.

Grid and HPC infrastructure

EUFORIA maintains and develops infrastructure to support Grid computation as well as targeting HPC. The Grid services deployed in EUFORIA are based on gLite (to support serial batch jobs and data management) augmented by the middleware developments of Interactive European Grid. The Grid infrastructure allows users to run MPI parallel jobs and start interactive sessions on their local desktop on remote Grid-enabled clusters. EUFORIA has also deployed several Roaming Access Servers dedicated to the users of Migrating Desktop, which is used to make the connection between the simulation workflow orchestration tool and the Grid infrastructure, facilitating coupled computation. The Grid infrastructure has been set up with the idea that sustainability and long-term perspectives will be a real issue.

The European HPC ecology is much more diverse than the existing Grid infrastructure and in order to support access to HPC resources EUFORIA has secured a
programming environment for the code developers involved in the project. Users are provided with the appropriate tools to utilise the available HPC resources, as well as runtime access for testing and evaluating applications on HPC machines at the three HPC centres involved in the project.

**Code adaptation and optimisations**
EUFORIA is set up to help fusion modellers utilise modern computing infrastructures in an efficient manner. From the start of the project a selection of codes relating to edge and core transport and turbulence in fusion plasmas were promoted as candidate EUFORIA codes. These codes were initially selected because of their potential to enhance fusion modelling activities. A second reason was the gains foreseen in porting these codes to new infrastructure or optimising to give better performance.

A number of codes have been ported to the HPC environment and a subset of these codes has been further optimised, reaching significant performance gains and improved scaling in some cases. Indeed some codes have been improved from only being able to run on a single computer to running on several thousand processors in a DEISA environment. In addition to supporting the code set on HPC, several have been created or are in the process of being installed in the EUFORIA Grid environment. The Grid porting and optimisation work overlaps with the HPC porting and optimisation work as one aim of the project is to produce codes that can run in parallel on either HPC or Grid resources. The EUFORIA Grid has the technology and capability to allow the running of parallel applications.

The selected codes have all benefited from the work in the form of error corrections and performance improvements. Furthermore, there is now also a better understanding of how the codes behave and what factors limit their performance.

**Workflows, visualisation and middleware amendments**
The toolset employed in EUFORIA is based on a number of existing tools already developed in support of the European Infrastructure (Migrating Desktop, Roaming Access Server, gLite, UNICORE, Vine Toolkit) and coupling these to modelling tools adopted (Kepler) and developed within the Fusion community (Universal Access Layer). In addition to this, the integration effort also covers visualisation tools, monitoring middleware, authentication and authorisation technology. Since the overall architecture covers support for a number of different systems and solutions it is a challenging task. The outcome is a significant improvement of the architecture which simplifies the connection between the workflow engine based on KEPLER and the various GRID/HPC infrastructures.

A major milestone is to combine all the previous achievements to demonstrate the feasibility of using equally GRID and HPC infrastructure for the scientific community. A pilot project was designed for this goal and to foster a collaboration environment between EUFORIA, the DEISA (the Distributed European Infrastructure for Supercomputing Applications) consortium and EGEE (Enabling Grids for E-scieneCE), Europe's leading Grid computing project, in order to ensure a wide adoption of the tools developed and deployed by EUFORIA in the infrastructure of DEISA and EGEE. The activity has already demonstrated that the underlying technology of EUFORIA can transparently orchestrate and access running either in HPC or Grid simultaneously.

**Dissemination and training**
EUFORIA is active in the development of training for the European fusion community. This training is in many forms, from creating guide documents to teaching users parallel programming and how to use the Grid effectively – with specific direction for using the tools developed in EUPHORIA. Week long training courses and workshops conducted via video-conference are also available. This training has an emphasis on best practice and performance optimisation with an overall aim to encourage new users onto the infrastructures and computational resources that EUPHORIA has access to.

The second year of the project developed a number of courses around Europe, focussed on new programmers and inexperienced Grid and HPC users, while others targeted more experienced users.

Following the collaboration with DEISA in the early part of the project EUFORIA has undertaken joint/collaborative training with the Goal Orientated Training in Theory (GOTTIT) project and are actively working with both DEISA and HPC-EUROPA to organise future joint training sessions.

EUFORIA has created links and collaborative activities with a range of projects supporting the European computing infrastructure such as DEISA, PRACE and EGEE. The strength of this collaboration is building every year and EUPHORIA can be viewed as a vital catalyst for expanding fusion research via Grid and HPC infrastructure.★

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**At a glance**
**Full Project Title**
EU Fusion fOR Iter Applications (EUFORIA)

**Project Partners**
- Chalmers University of Technology, Sweden (coordinator)
- CSC - Tieteenliiken laskenta
- OY, Abo Akademi University, Finland • CEA
- Université de Strasbourg, France • Karlsruhe Institut für Technologie, Max-Planck-Institut
- University of Ljubljana, Slovenia • Poznan
- Supercomputing and Networking Centre, Poland
- Barcelona Supercomputing Centre / Centre for Energy Research in Environment and Technology
- Superior Scientific Investigation Council, Spain
- The University of Edinburgh, UK

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After a PostDoc at Oak Ridge National Laboratory, Dr Pär Strand returned to Sweden, first as a Researcher at the IMEGO institute before returning to CHALMERS where he continued working on modelling of Fusion Plasmas. Currently he is an Associate Professor at Chalmers and serves as the Leader of the Integrated Tokamak Modelling Task Force under EFDA. He is the Coordinator of the EUFORIA project.