ITEA 3

Project Results

MODRIO

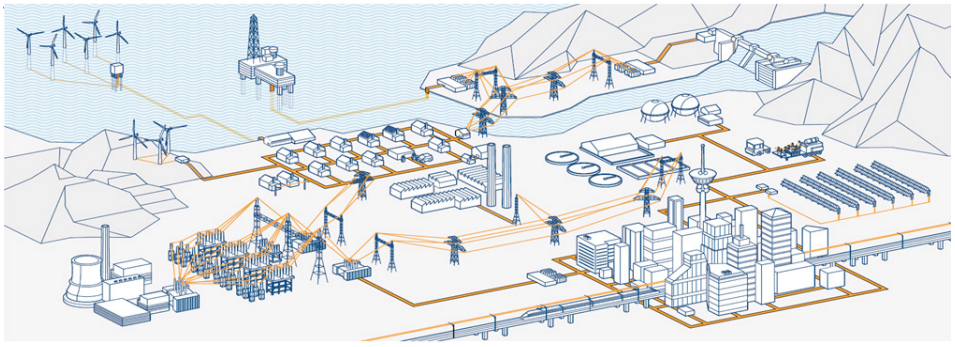
A pioneering project for CPS

EXECUTIVE SUMMARY

The objective of MODRIO is to extend modelling and simulation tools based on open standards from system design to system operation. The major outcome is a holistic modelling and simulation framework for cyber-physical systems design, diagnosis and operation assistance.

PROJECT ORIGINS

Ever increasing social expectations and stringent regulations concerning safety, dependability and environment within a global competitive market – this is the context in which operators of power plants, transportation systems and buildings need to improve systems maintenance and operation to comply with these new constraints while improving their economic efficiency. For all players, the multiplication of stakeholders means that uncertainties are rising. A new approach should emerge to rigorously address the diversity of situations and stakeholders, involve the operators early in the exploration of design alternatives and in the search for optimal solutions as well as assist the operators in the optimal operation and maintenance of their assets.



Power production

TECHNOLOGY APPLIED

The new approach is based on several types of models that capture:

- the system assumptions and requirements (physical, communications, functional, business, human interaction).
- the system uncertainties in the form of fault trees.
- the real physical nonlinear behaviours of the system, including mode switching.

A new modelling architecture was proposed that combines the three modelling approaches:

- Automatic observers to detect possible flaws in system design while performing massive simulations of the many possible variants of the system.
- Automatic generation of fault trees for safety and dependability analysis.
- Hybrid state machines to model and simulate switching between different operating modes.
- State estimators that use information provided by nonlinear models to provide accurate estimations of the system real state with uncertainties margins.
- Nonlinear model predictive controllers to optimise system operation such as the start-up or shutdown of power plants.

This new modelling architecture contributes to the development of new features in the already well-established Modelica standard for multi-domain physical modelling, the release of the FMI 2.0 standard for model interoperability and co-simulation, the development of the new FORM-L language for the modelling of assumptions and requirements, and the interoperability between deterministic and stochastic approaches through new links between the Figaro language and Modelica.

The new modelling architecture is now implemented in various levels of completion in several commercial and open source tools: CATIA/Dymola, SimulationX, OpenModelica, JModelica.org, Wolfram System Modeler, Simpack, Equa, LMS Imagine.Lab, LMS Virtual. Lab, xMOD, O3PRM.

MAKING THE DIFFERENCE

In the energy domain, the transition that is taking place is driving the need to be more flexible in operating power plants. With

renewable sources having priority on the grid, there is a need to stop and start the plants more frequently. Through MODRIO the energy companies will gain a tool to facilitate this transition in which deregulation of the energy market is coupled with the rise in intermittent sources of energy – renewables like wind and solar. ABB has used the MODRIO results to optimise the operation of 5% of the German electricity production. Vattenfall has used the results to optimise the start-up of power plants, with an estimated yearly gain of €850k per plant and per year. EDF intends to use the results to model the complete French energy system. In the aviation industry where verification of design process is rigorous, the use of modelling tools helps prepare for the proper operation of the system(s). For Dassault-Aviation, MODRIO has enabled many very useful breakthroughs for the design of next-generation aircraft, in particular results regarding the modelling of requirements and system architecture, associated with fast multi-core simulations, multi-mode modelling of system failures and safety analysis. In the rail domain, the industrial cooperation partners – Knorr-Bremse and Bombardier Transportation – focused the results on crosswind stability and friction brakes, where there is high economic potential once the brake distance management has become adequately reliable. In the area of connected driving, the simulation of autonomous vehicles and ADAS (Advanced Driver Assistance Systems) will be enhanced through a City Traffic Modelica Library while in the building sector EQUA Simulation AB produced the only building monitoring tool (IDA ICE) that leverages the information collected by the numerous sensors installed in modern buildings to provide unique diagnostic capabilities.

The time between the end of a project and the industrial application of those results takes some five years or so. The end of MODRIO signifies the beginning of the next phase – maturing technical innovations for industrial use. The evaluation of many design options, in which innovation and optimisation are central, with respect to operational aspects (economic, environmental, human and regulatory), will enable safety, dependability and economic performance to be fully integrated into engineering processes from their very early stages.

MAJOR PROJECT OUTCOMES

Dissemination

- 138 publications
- 140 presentations at conferences/fairs

Exploitation (partial list of new products)

- FMI 2.0 Import and/or Export in Dymola, LMS Imagine.Lab, LMS Virtual.Lab Motion, OpenModelica, PySimulator, Silver, Simpack, SimulationX and xMOD.
- Fault-trees generation and reliability analysis with SKELBO Figaro library, OpenModelica, SimulationX and Wolfram SystemModeler
- O3PRM editor: Probabilistic Relational Model Editor
- Model predictive control with Nonlinear Kalman Filter Modelica Library and LMS Imagine.Lab MPC Prototype
- JModelica.org for on-line dynamic optimisation
- Modelica_Requirements Library: Library for the modelling of requirements
- IDA ICE for building operations
- xMOD advanced multi-core co-simulation methods
- Sundials/ML Library: OCaml interface to the Sundials suite of numeric solvers

Standardisation

- Release of FMI 2.0
- 5 Modelica Change Proposal Ideas (MCPI-0008 to MCPI-0012)

Patents

- 1 patent application filed

ITEA is the EUREKA Cluster programme supporting innovative, industry-driven, pre-competitive R&D projects in the area of Software-intensive Systems & Services (SiSS). ITEA stimulates projects in an open community of large industry, SMEs, universities, research institutes and user organisations. As ITEA is a EUREKA Cluster, the community is founded in Europe based on the EUREKA principles and is open to participants worldwide.

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MODRIO

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Modelon AB
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SICS
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Wolfram MathCore AB

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September 2012

Project end
May 2016

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