Vision d'un industriel

Gilles Plessis - ENERBAT

SIMUREX 2 - Avril 2012

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Outline

- ▶ EDF challenges and tools for building energy systems
- ▶ Modelica for EDF
- ▶ Library for buildings and systems models from EDF
- ▶ Use cases
 - Multi-physic model and parametric analysis
 - Stochastic modeling : building properties & occupancy
 - MOR for LTI and LTV systems
 - Grey box modeling
 - Generating standalone executable
 - Modeling the building stock by aggregation
 - MOR for a building stock model – Test on 37 building in Nice
 - Dynamic calibration
 - Optimization by genetic algorithm
 - Hardware in the loop

EDF Challenges

► Conception & Prototyping

- New technologies (HP, PV, VIP...)
- New services (Energy management...)

► Sizing

- Tools for design office
- Building refurbishment operation

► Simulation

- Renewable energy potential
- LCA of building and systems
- Sustainable cities

► Diagnostic

► Optimization

- Control algorithm (load management)
- Smart grid optimization

Tools used and developed by EDF (2010)

Building energy simulation tools

Why Modelica ...?

► Language for modeling complex physical systems

- Non causal and equation based language
- Multi-physics modeling
- Standardized interactions between models
- Formal expression of the equations
 - The model follows the topology of the physical system
 - Easy to understand and improve

```
equation
  G*dT = Q_flow;
end ThermalConductor;
```

```
equation
  Q_flow - G*dT = 0;
end ThermalConductor;
```

```
equation
  Q_flow = G*dT;
end ThermalConductor;
```

► Normalized language

- Object-oriented programming (inheritance, maintainability...)
- Non proprietary language

```
model ThermalConductor
  extends Interfaces.Element1D;
  parameter ThermalConductance G
  "Constant thermal conductance of
  material";
  equation
    Q_flow = G*dT;
  end ThermalConductor;
```

Peter Fritzson, 2011. Introduction to Object-Oriented Modeling, Simulation and Control with Modelica. Tutorial for Modelica conference 2011

Modelica and Dymola Short History

Main advantages for EDF R&D

Development

- Reduce the developing time and increase the code efficiency
- Broad spectrum of mathematical, physical and engineering fields (time scales...)
- Focus on developing accurate physical models and avoid coding problems
- Risk limitation when developing stand alone applications
- Robust solution (symbolic calculation)

Use & Maintenance

- Increase the exchanges between the developers, practitioners and the external cooperation
- Increase the reliability of the corrective and preventive maintenance
- Boost the design of technologies using a multi-domains / multi-physics approach
- Better abstraction and increase reuse of models

Building and Energy tools based on Modelica

► Building libraries

- Buildings & BCVTB
- ATPlus library
- HumanComfort Library

► Thermodynamic Libraries

- Modelon libraries (AirConditioning, Hydraulics)
- TILSuite and StateViewer
- ThermoSysPro
- ThermoBondLib

► Fluid & thermal library from Modelica Standard Library

Model Library for buildings and systems from EDF

► Modèles de base

- Utilitaires (météo, matériaux, fluides, outils d'analyse, scénarios)
- Calculette solaire
- Thermique pure
- Thermo-hygro-aéraulique
- Thermodynamique
- Systèmes - Composants

NB: les modèles sont génériques

► Assemblages dont études et bâtiments types

- Thermique Pure
- Thermo-hygro-aéraulique
- Systèmes

NB: les modèles sont pré-paramétrés par défaut mais restent modifiables

Focus on thermal elementary components

► Architecture des classes

- Elements (physique)
 - Interfaces
 - Conditions limites
 - Modèles d'échanges
 - Capacités thermiques
 - Capteurs
- Composants (spécifique métier)
 - Conduction homogène, 1 nœud 1D, 1 seul matériau
 - paroiNCouchesHomogènes, m nœud 1 D n matériaux
 - ParoiComplete ajout de convection
 - ParoiRad ajout du rayonnement
 - Vitrage générique et spécifique DVitrage
- ZonesThermiques

One-zone thermal model

► Modèle de base : monozone sur terre plein vitré

Building and system example

- ▶ Maison type
- ▶ Météo
- ▶ Systèmes
 - Chauffage PAC R/O
 - Réseau d'eau chaude
 - Emetteurs
- ▶ Contrôle
- ▶ Scénarios
 - Consigne
 - Apports internes

Use case: Multi-physic model of a PV generator

► Fields

- Conception and prototyping

► Description

- Electrical part
 - Two-diode model
- Thermal part
 - Multi layer conduction
 - Radiation to the surrounding
 - Sun rays absorption

► Advantages

- Increase reuse of models
- Ease of modeling
- Reduce the development time

Use case: Complex multi-physics model and parametric analysis

► Fields

- Conception and prototyping

► Description

- Components

- Building model
- Heat pump & SHW
- Control and scenarios

- Parameter sensitivity

► Advantages

- Ease of modeling (same topology)
- Reduce the development time

Use case: Stochastic modeling

► Fields

- Simulation, sizing and diagnostic
- Load management

► Description

- Residential Low Energy Building
- 1/ **Uncertainty estimation**
 - Building properties $\lambda \rightarrow \mathcal{N}(0.03, 0.005)$
 - Air change rate $\rightarrow \mathcal{N}(0.5, 0.05)$
- 2/ **Occupancy modeling**

Use case: Fast simulation using model order reduction (MOR)

Fields

- Simulation, optimization...

Description

- MOR of models for time consuming studies

Advantages

- Preserve the dynamic behavior
- Reduce the simulation time (~30 to 100 times faster)

Low Energy Building

Use case: Model Order Reduction for linear time variant

► Fields

- Simulation, optimization...

► Description

- MOR of models for time consuming study

► Advantages

- Preserve the dynamic behavior
- Reduce the simulation time (~5 times faster)

Linear Time Variant

$$\begin{cases} \dot{X} = A(t) \cdot X + B(t) \cdot U \\ Y = C(t) \cdot X + D(t) \cdot U \end{cases}$$

Use case: Grey box modeling

► Fields

- Conception & prototyping, Sizing...

► Description

- Parametric analysis from reduced $p_i, k_i, K_i \dots = f(\text{Building Age}, U_{bat} \dots)$

► Advantages

- Ensuring accuracy
- Few parameters from typological studies or early design stages

Validation over a week for a Low Energy Building

Use case: Generating standalone executable

► Fields

- Conception, sizing, simulation...

► Description

Using studies and/or models to generate executables

► Advantages

- Reduce the development time
- Improved reactivity
- Diversity (1 model → x executables)

Use case: Modeling the building stock by aggregation

Fields

- Simulation, optimization, conception (building stock and smart-grid)

GV	SH	Inertie	%SV	abs fenetre	trans fenetre
336	95	1	0.08	0.13	0.6
837.64	150	1	0.08	0.13	0.6
678.48	135	1	0.08	0.13	0.6
1757.34	135	1	0.08	0.13	0.6
2070.21	135	0	0.08	0.13	0.6
335.98	95	1	0.08	0.13	0.6
1757.34	135	1	0.08	0.13	0.6

Description

- Typology and greybox model
- Meteo file : Nice
- Electric heating + controller
- Stochastic behavior of the occupants
- Variable time step solver

Use case: MOR for a building stock model – Test on 37 buildings in Nice

► Fields

- Simulation, optimization, conception (building stock and smart-grid)

► Description

- Aggregation of greybox model
- Linearization
- MOR and parametric study

Energy
consumption
discrepancy 5...7%

Power load max
discrepancy 20%

Use case: Dynamic calibration

► Fields

- Diagnostic, fitting to experiments

► Description

- Greybox model
- Sollicitations: heating load and weather data
- Experiment: 4 days and time step 60s
- Initialization $GV=300\text{W}/^{\circ}\text{C}$ & $SH\ 225\text{ m}^2$

GV	Error
300	361218
217882	375.631
79.1635	5.6837
79.1828	5.6805
79.1828	5.6805

Use case: Optimization by genetic algorithm

Fields

- Conception, prototyping, sizing and optimization...

Description

- Sizing of windows to minimize the heat demand

Advantages

- Increase reuse of models

Tuner parameters	name	value	difference to start	min	max
	zoneRDC.fenetreS.S	11.249266862170089	-3.3137829911211725e-5	0	12
	zoneRDC.fenetreW.S	9.6422287390029329	8.0821087390029334	0	12
	zoneRDC.fenetreN.S	1.7595307917888563	-0.7741892082111439	0	12
	zoneRDC.fenetreE.S	11.401759530791789	6.920819530791789	0	12
	zoneET.fenetreS.S	6.3695014662756595	-4.1289985337243404	0	12
	zoneET.fenetreW.S	8.7507331378299114	6.5689131378299113	0	12
	zoneET.fenetreN.S	6.9325513196480939	-0.6099686803519058	0	12
	zoneET.fenetreE.S	8.9032258064516121	5.0909058064516124	0	12

Criteria	name	scaled criteria	diff. to start	unscaled criteria	usage	demand value
	BesoinRDC.It	4.6256316065514839e+3	49.9%	4.6256316065514839e+3	minimize	1
	BesoinET.It	5.5683367745934329e+3	-59.8%	5.5683367745934329e+3	minimize	1
	Sum of squared criteria	5.2402842194817662e+7	-73.9%			

Use case: Hardware in the loop

► Fields

- Conception, prototyping, optimization...

► Description

- Testing control devices for HVAC systems by emulation (real time and accelerated simulation)

► Advantages

- Reuse basic models

Questions ??

Team project

C. Muresan, A. Kaemmerlen, H. Bouia,
D. Covalet, M. Schumman, S. Filfli...

CHANGER L'ÉNERGIE ENSEMBLE