COST

Thomas Triboulet EDF R&D

W4

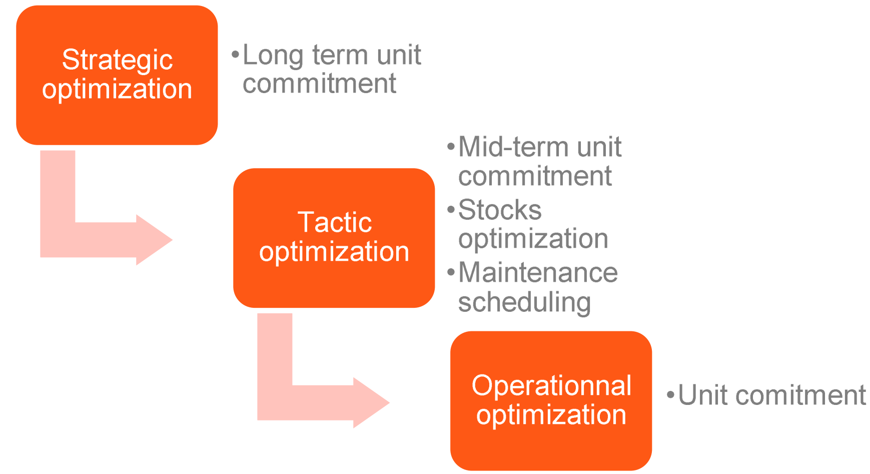
Feburary 29th 2016

Off the shelf-software

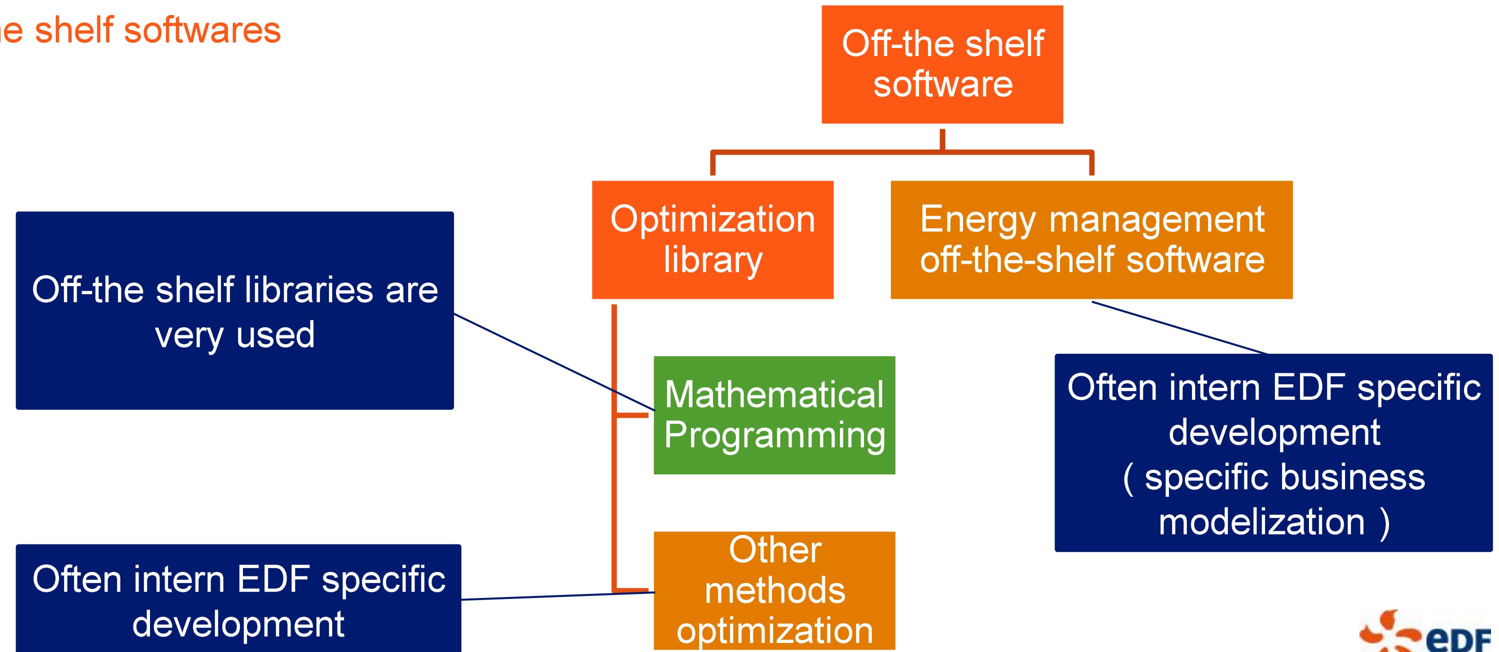
- EDF context
- MILP softwares
- Other methods optimization libraries
- Off the shelf energy management software

Matching softwares and business problems?

- Optimization at EDF : many different problems



- Differerent off-the shelf softwares

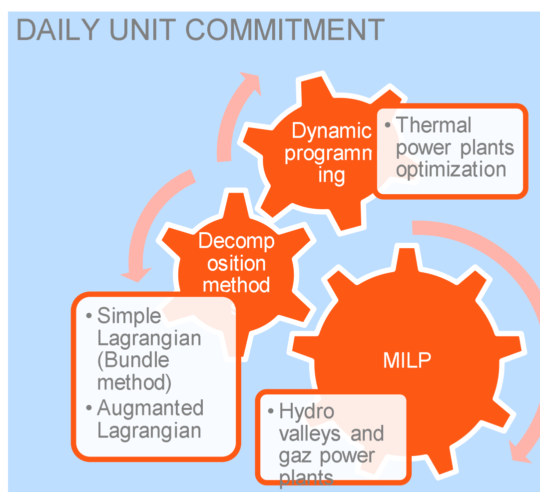


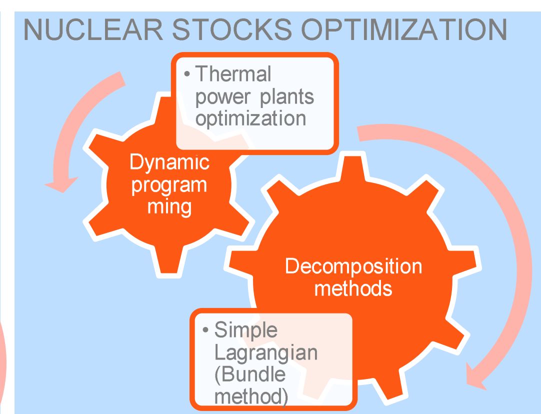
Methods used at EDF

	Dynamic Programming	MILP	LP/QP	Decomposition methods	Metaheuristics
Strategic Optimization	Long term stocks optimization	Long term Unit commitment	Long term Unit commitment simulation		
Tactic optimization	Stocks mid-term optimization	Mid-term Unit commitment	Mid-term Hydro valleys optimization	Nuclear stocks optimization Maintenance sheduling (research)	Nuclear maintenance scheduling
Operationnal optimization	Unit commitment (thermal)	Unit commitment (hydro & gaz)	Weekly unit commitment (weekly hydro)	Unit commitment	Tested (research)

- Many problems use a combination

of different resolution algorithms





Intern development or off the shelf libraries ?

	Dynamic Program-ming	MILP	LP/QP	Decomposition methods	Metaheuristics
Strategic Optimization	Intern development	Off the shelf software	Off the shelf software		
Tactic optimization	Intern development	Off the shelf software	Off the shelf software	Intern development (with academic partners)	Intern development
Operationnal optimization	Intern development	Off the shelf software	Off the shelf and intern development	Intern development (with academic partners)	Off the shelf software

Several reasons are taken into account to decide to develop or use off-the shelf library :

- Simplicity of interfaces with business modelization treatments
- Needs to specialize algorithm
- Amount of work needed to redevelop algorithm

MILP

Use case

- Industrial problems
  - Tactic optimization, long term unit commitment
    - ➡ [2010] Latest improvement of EDF Mid-term power generation management, G.Dereu, V. Grellier
  - Hydro valley short term optimization
  - Gaz plants short term optimization
- Very used for studies and PoC
  - Easy formulation for optimization non specialists
  - Easy development (for example modelers)
  - Optimality reached for small problems

Used software

- Commercial resolution software
  - Best solver will depend on the kind of tested problem
- Open source software
  - Important gap between commercial and open source, when used as black box solution
  - SCIP tested to customize branch and bound (nuclear logistic)

EDF MILP examples of problems caracteristics

- Average dimensions for industrial versions of EDF software
  - Research and study versions of software often deals with bigger problems

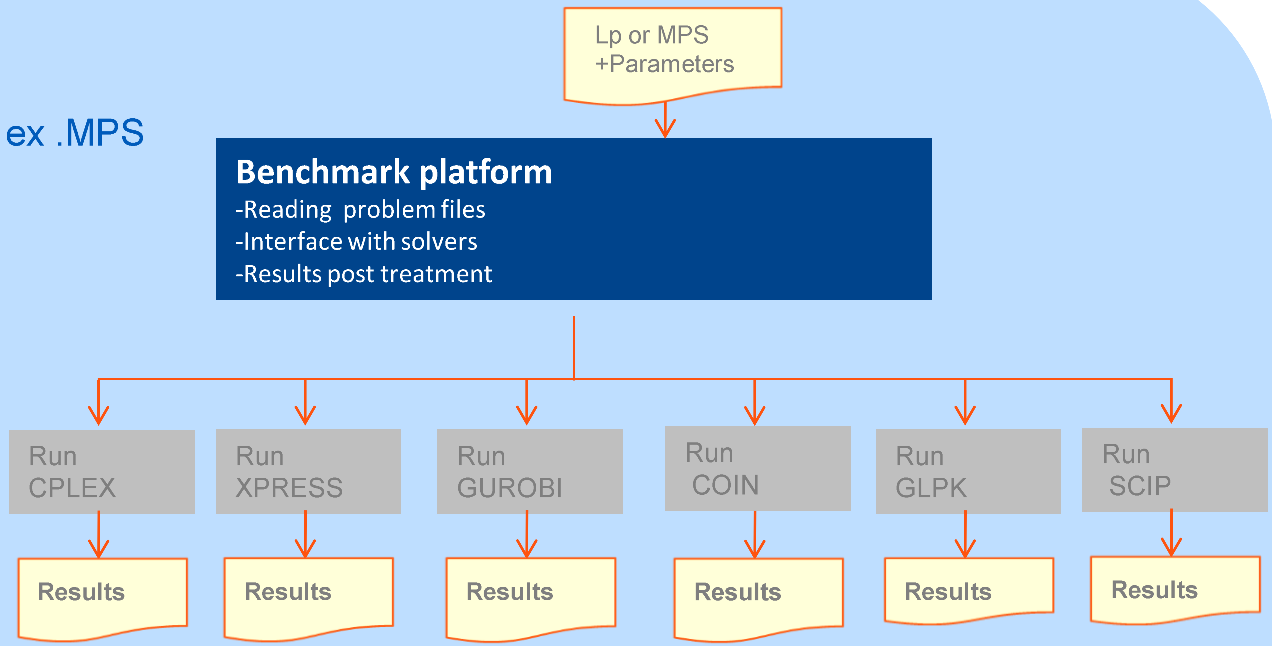
	Average size of problems per instance provided to solver			
	Number of variables	Number of integer variables	Number of constraints	Non zero elements in matrix
Long-term unit commitment	65 000	24 000	120 000	260 000
Midterm unit commitment	25 000	15 000	25 000	75 000
Gaz power plant (short term unit commitment)	15 000	8 000	60 000	227 000
Hydro power plant (short term unit commitment)	20 000	7 000	15 000	75 000

Long-term and midterm unit commitment: Time horizon is divided in time periods for non anticipativity reasons

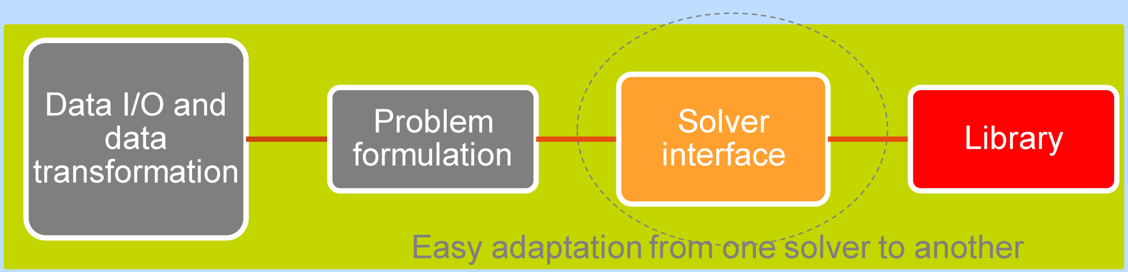
Gaz and hydro power plant (short term unit commitment): Decomposition per unit production of global unit commitment problem

Benchmarking mathematical programming solvers (1/3)

- Easy approach
  - Generate I/O file : ex .LP, ex .MPS



- More precise
  - Integrating tested library directly in tool



Hot start taken into account

Data exchange time more precisely taken into account

Benchmarking mathematical programming solvers (2/3)

Parametrization

- Execution context (stopping criteria, parallelization…) easy to transpose
- Algorithm parameters more complicated to tune
  - Automatic tuners (provided by commercial solvers) or help of the editor can improve

Comparison criteria

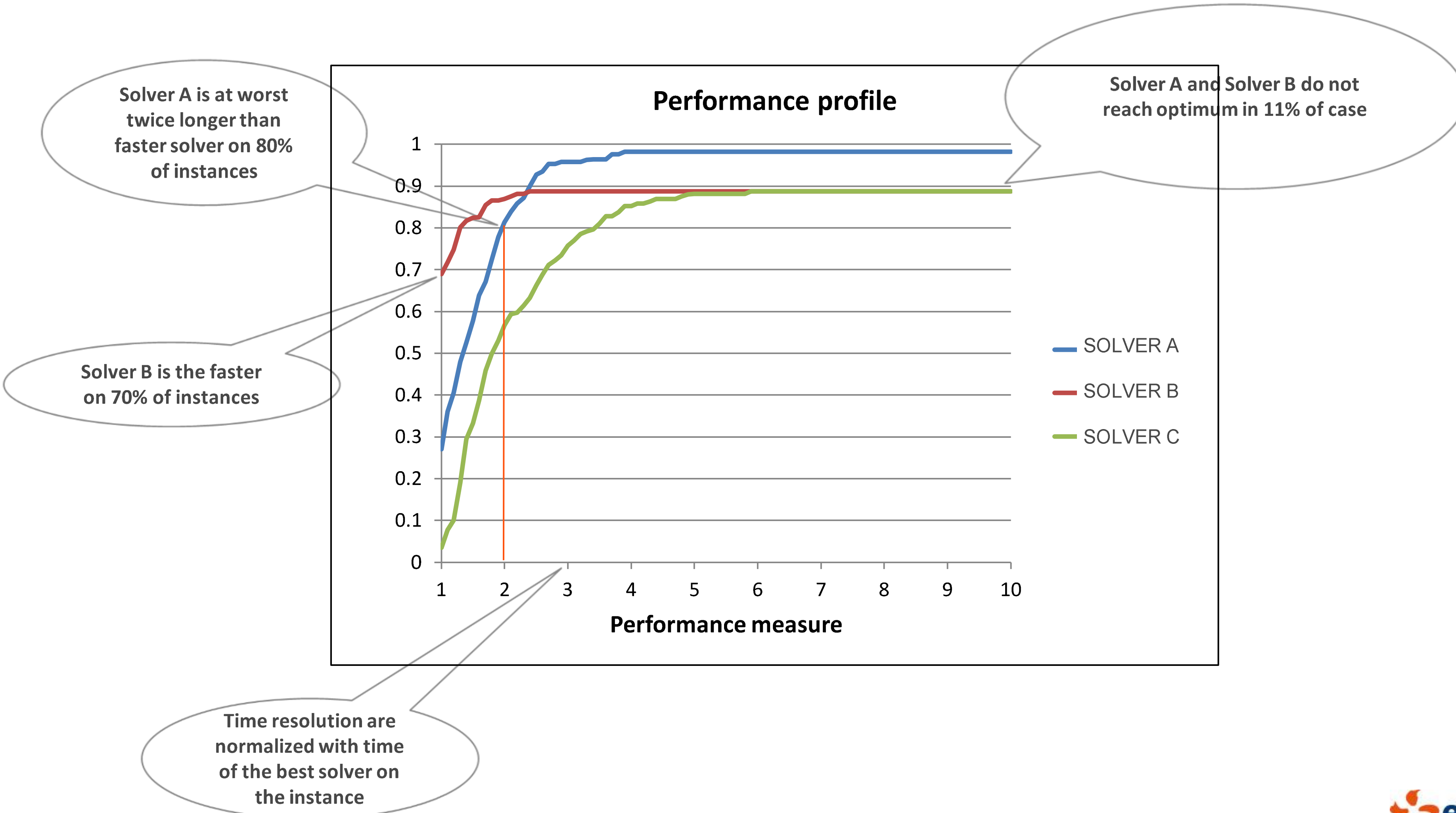
- Mainly
  - Computation time
  - Optimality
- How to compare on several data set :
  - Data instance size variability?
  - Resolution time variability?

Comparison tools

- Reference benchmarks by Hans Mittelman : http://plato.la.asu.edu/bench.html
  - Use geometrical means
- Alternative Elizabeth D. Dolan, J. J. Moré (2001). *Benchmarking optimization softwares with Performances Profiles*
  - Compare advantage and inconvenient of several metrics
  - Propose a comparison performance profiles

Benchmarking mathematical programming solvers (3/3)

- Performance profile
  - Repartition function of a performance measure



Challenges for MILP software

- Optimization parallelization
  - Significative rise of number of cores per machine
  - On the tested problems, very often : no significative improvement when activating multithreading possibilities

- Computation reproducibility
  - When using maximum time resolution stopping criteria, reproducibility not reached
  - « Replayibility » can be a workaround to reproduce results :
    - ➡ 1st run : stopping criteria = maximum time
    - ➡ 2nd run : stopping criteria = number of optimization steps in the first run (stored in the 1st run and provided to the 2nd run)

Continuous LP/QP

Use case

- Short and mid-term unit comitment
  - Mid term optimization (hydro stocks, …)
  - Weekly optimization

Used softwares

- Commercial
  - CPLEX, XPRESS, GUROBI
- Open source
  - COIN Time resolution nearer from commercial solvers for continuous resolution than for mixed integer resolution
- Intern solutions
  - Quadratic barrier method developed, with good performances (weekly optimization)
  - Quadratic barrier method specific for bundle methods (INRIA partnership)

Other softwares

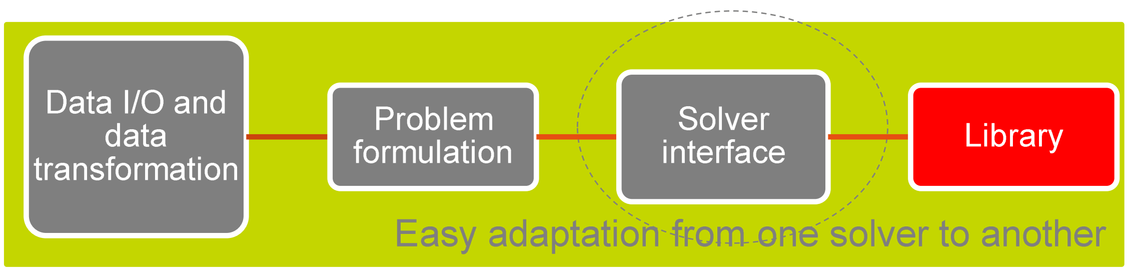
- Non-exhaustive
  - GLPK, SCIP …

Other optimization libraries benchmarks

Less information available :

- EDF : no real performances benchmarks done
  - Less used at EDF softwares
  - Benchmarking less easy (formulation adaptation)
- Available benchmarks on Hans Mittleman page :
  - NLP, MIQP, SDP

MATHEMATICAL PROGRAMMING LIBRARIES

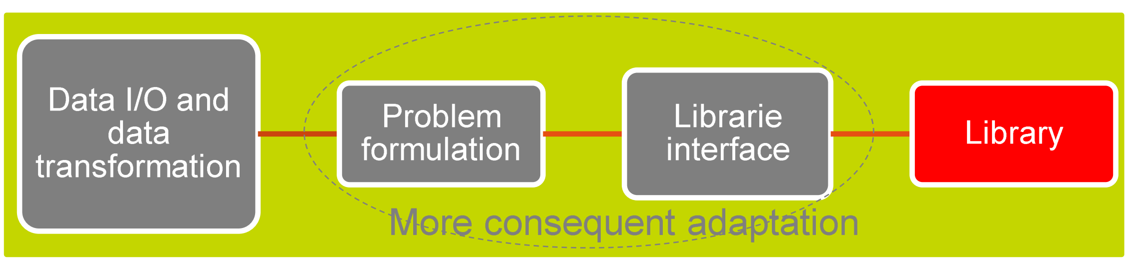


Easy adaptation of interfaces

Parametrization adaptation

Modelization adaptation can improve but is not necessary

OTHER OPTIMIZATION LIBRARIES



Interfacing different from one library to an other.

Modelization adaptation necessary

Chanced constraint programming

Use case

- Not currently used in industrial problems at EDF

- Tested for combinatorial problems research and development tools
  - Routing vehicules
  - Nuclear maintenance scheduling
    - ➡ [2006] When constraints programming and local search solve the scheduling problem of EDF nuclear power plant outages, *M. Porcheron, I.Khemmoudj, H.Bennaceur*

Used softwares

- Already tested :
  - CPLEX CP Optimizer
  - Chip (Cosytec)

Other existing softwares

- Non exhaustive :
  - Google OR tools
  - OSCAR
  - CHOCO

Dynamic programming

Use case

- Thermal power plants optimization
- Mid-term stochastic optimization (stock tractic computation)
  - Nuclear, hydro, emission quotas stock optimization
  - Financial options

Used software

- Intern specific developments, no commercial or open source solution used
  - Small part of algorithm mutualized (generic algorithm) vs specific problem (transition graph and transition cost computation)
- Intern project started to mutualize in library several algorithm using dynamic programming
  - Stochastic dynamic programming, SDDP, Longstaff Schwarz
  - Challenging design : intricate exchanges between library and specific problems (good skills in development needed to integrate the library).
  - Less plug and play use than mathematical programming approach

Stochastic and robust optimization

Use case

- Industrial
  - Long term and mid term unit commitment, stock optimization,
- Prospective for more combinatorial problems
  - Short-term unit commitment.
    - ➡ [2015] Decomposition algorithm for large-scale two-stage unit-commitment, *Van Ackooij W., Malick J.*
  - Nuclear maintenance scheduling

Used software

- No off-the shelf library, specific development
  - Needs to specialize development

Other existing softwares

- Not exhaustive
  - AIMMS

Decomposition approaches

Use case

- Mid-term unit commitment problems

- Short term unit commitment problems

Used software

- Specific development
  - Augmented Lagrangian, Dantzig Wolf decomposition …
  - Bundle methods (INRIA partnership) mutualized in an intern library
    - ➡ [2005] A primal-proximal heuristic applied to French Unit-commitment problem, *L. Dubost, C.Lemarechal, R.Gonzalez*

EDF

Non linear optimization

Use case

- Hydro-valley optimization
  - MIQP linearized for efficiency reasons
    - ➡ [2010] The short-term electricity production management problem at EDF, *Doukopoulos G., Charousset S., Malick. J, Lemarechal C.*

Used software

- Off-the shelf softwares not really used (at EDF) for these problems for the moment

Existing software

- NLP
  - LSGRG2 (Excel solver), Knitro, Algencan, …
- MINLP
  - BonMin, BiqCrunch

Meta-heuristics

Use cases

- Different maintenance tasks scheduling
  - [COST, 2014] Scheduling of EDF nuclear power plants outages, *D. Defossez, G.Petrou*
- Coal plants combustion multi objective optimization
  - [2015] Using a genetic algorithm and CFD to identify low NOx configurations in an industrial boiler, *J.Y. Lucas, O. Juan, Dal-secco, M.L. Louisy, P. Plion, L. Porcheron*
- Unit comitment (hybridation with decomposition method), hydro valley optimization

Used or tested software

- Paradiseo (different metaheuristics)
  - White box (open source), with high possibilities to parameter
  - Good skills in C++ development needed (object specialization approach)
- LocalSolver (studies and PoC)
  - Easy formulation (not necessarily linear) and interface
  - Black box approach

(Paradiseo and LocalSolver: COMPLEMENTARY APPROACHES)

- Intern developments : enable specialization

Energy management on the shelf software (1/2)

Panorama

- More long-term tools or mid-term unit commitment tools
  - Less specific expectations when modelization long-term unit commitment or mid-term optimization

- Examples of long-term or mid-term unit commitment tools
  - PSR, created by M.V.F. Pereira and implementing its SDDP algorithm
    - ➡ [1991] Multi-stage stochastic optimization applied to energy planning, *M.V.F. Pereira, L. M. V.G. Pinto*
  - Plexos (Energy Examplar) : heuristic approach for stocks management + MILP solver
  - SINTEF ProdRisk implements SDDP

- Examples of short term unit commitment tools
  - Alstom E-terra commit (MILP based)
  - Artelys Energy planner (MILP based)
  - PSR NCP (MILP based)
  - Plexos (MILP based)

} SIMILAR METHODOLOGY APPROACH

Energy management on the shelf software (2/2)

EDF uses case

- Mainly used for subsidiary companies or for prospective studies
  - EDF foreign subsidiary companies, Economic departments
  - Less expensive than specific developments

Used software

- PLEXOS (AUZ)
  - Short and mid-term optimization
- PSR (BR)
  - Mid-term unit commitment

Intern solutions

- Specific development preferred for the more strategic problems for several reasons :
  - Specific needs : Development of specific constraints (ex nuclear power plants, ancilliary services)
  - Evolutivity : Source access for evolutions and studies
  - Performances : Short term off-the shelf software algorithms not adapted to large scale problems (frontal MILP approaches)

Benchmarking softwares

MATHEMATICAL PROGRAMMING LIBRARIES

Data I/O and data transformation — Problem formulation — Solver interface — Library

Easy adaptation from one solver to another

- Easy adaptation of interfaces
- Parametrization adaptation
- Modelization adaptation can improve but is not necessary

OTHER OPTIMIZATION LIBRARIES

Data I/O and data transformation — Problem formulation — Librarie interface — Library

More consequent adaptation

- Interfacing different from one library to an other.
- Modelization adaptation necessary

ENERGY SYSTEM OPTIMIZATION

Even data and business modelization can change

Data I/O and data transformation — Modelization — Resolution

- Business data different
- Business modelization different
- Optimization method not always the same

Thanks for your attention