



**HAL**  
open science

# Combinatorial optimization with multiple resources and energy constraints

Sandra Ulrich Ngueveu, Christian Artigues, Pierre Lopez

► **To cite this version:**

Sandra Ulrich Ngueveu, Christian Artigues, Pierre Lopez. Combinatorial optimization with multiple resources and energy constraints. PGMO's Days 2013, Oct 2013, Paris, France. , 2013. hal-01163045

**HAL Id: hal-01163045**

**<https://hal.science/hal-01163045>**

Submitted on 11 Jun 2015

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# COMBINATORIAL OPTIMIZATION WITH MULTIPLE RESOURCES AND ENERGY CONSTRAINTS

LAAS-CNRS

Optimisation sous contraintes de ressources énergétiques multiples (OREM)

Sandra Ulrich Ngueveu, Christian Artigues et Pierre Lopez

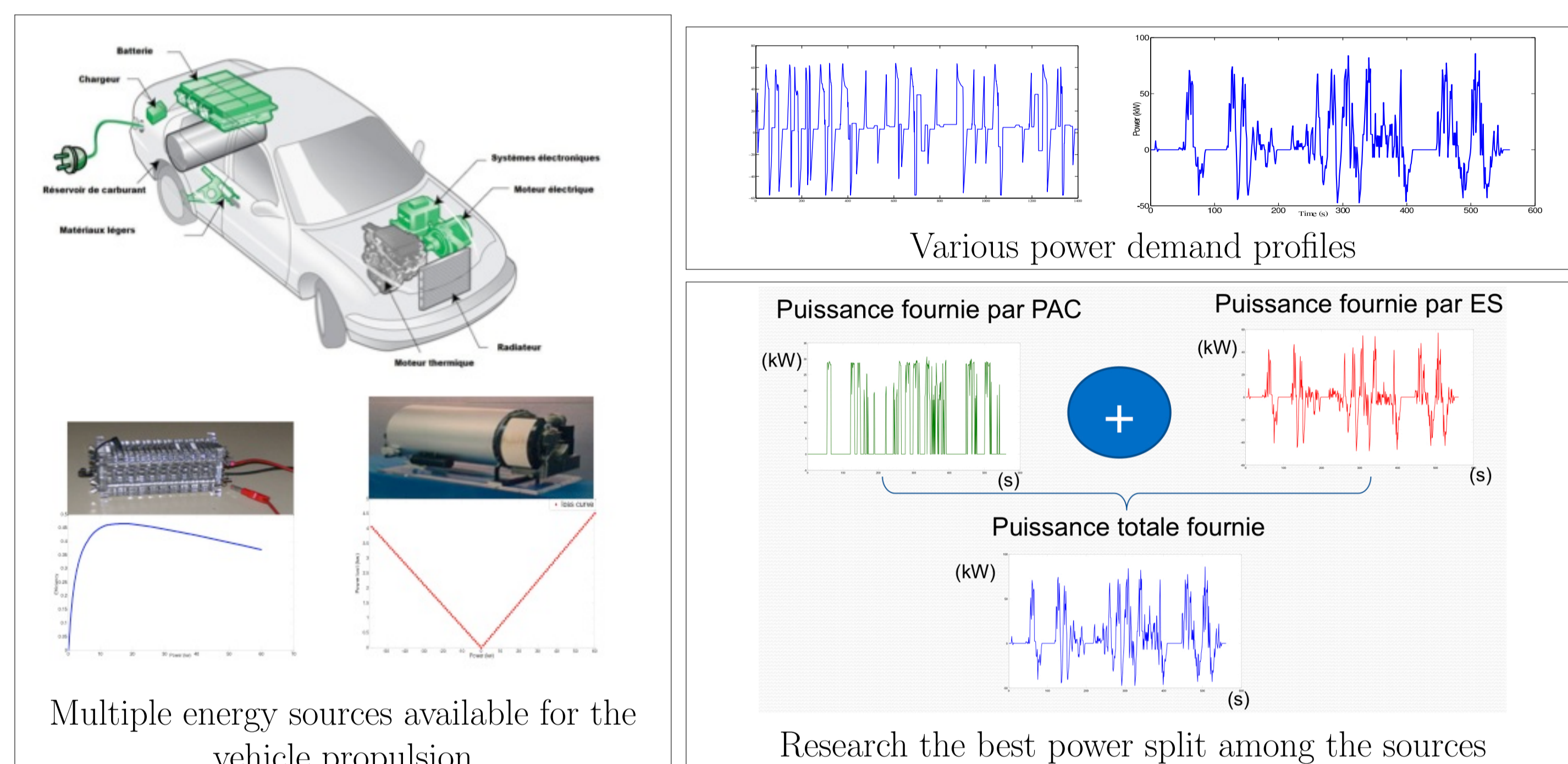
LAAS-CNRS, Toulouse, France

## Introduction

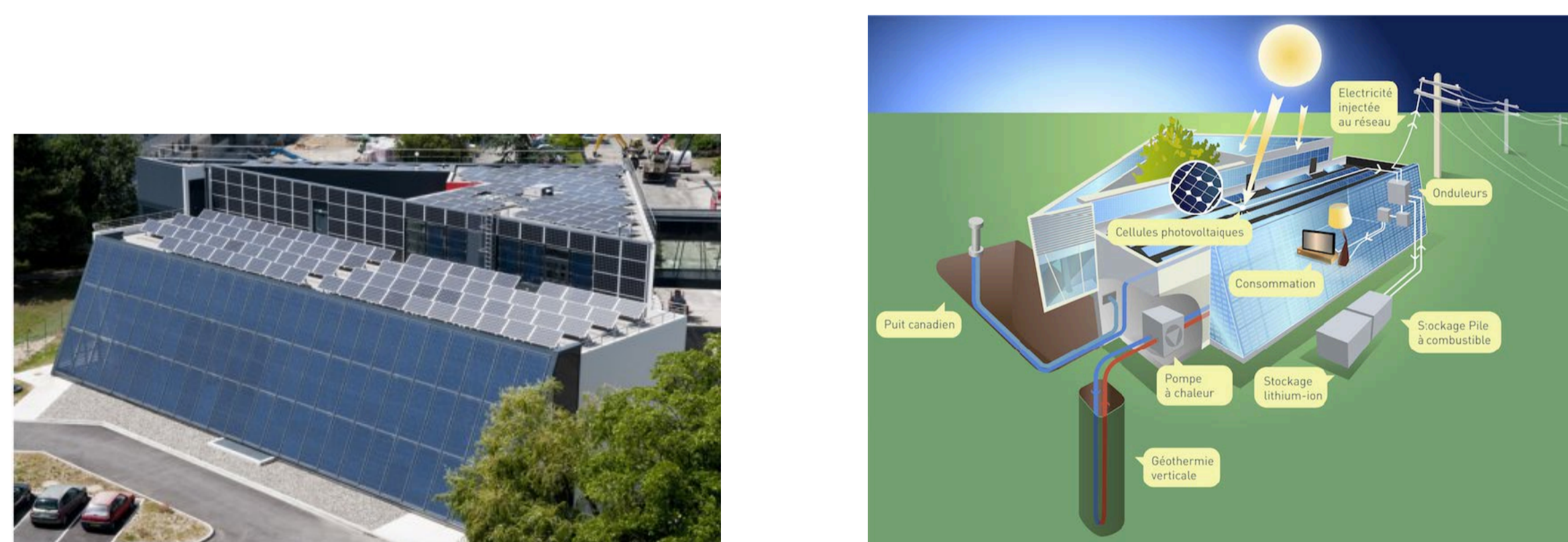
The integration of energy constraints in deterministic scheduling models, such as job-shop scheduling or resource-constrained project scheduling, yields a combinatorial optimization challenge. It follows that the literature on this subject is sparse. In the OREM project, we focus on a scheduling problem where activities must fit into time windows and require an energetic resource. Each activity has an energy demand. The energetic resource has a limited instantaneous availability (maximum available power). As soon as it is started and not completed, the activity must be assigned, at every time point, a power lying within an interval. For each activity, the total energy brought must fulfill its demand. At every time point, the power consumed by all activities cannot reach the resource availability.

## Some applications

### Hybrid-Electric Vehicles



### Smart grids in smart buildings



## Problem with a single resource

### Definition

For each task  $i \in A$ , find a feasible curve  $b_i(t)$ ,  $t \in \mathcal{T}$ .

### Parameters

- A resource availability  $B \in \mathbb{N}$  to respect
- A set of tasks  $A = \{1, 2, \dots, n\}$ .
- Minimum instantaneous consumption (demand)  $b_i^{\min} \in \mathbb{N}$
- Maximum instantaneous consumption (demand)  $b_i^{\max} \in \mathbb{N}$
- Energy required  $W_i$ ,
- Release date  $r_i \in \mathbb{N}$ ,
- Due date  $d_i \in \mathbb{N}$
- Time domain  $\mathcal{T}$ , Demand domain  $\mathcal{B}$

### Conceptual model and illustration

$$r_i \leq st_i \leq ft_i \leq d_i \quad (i \in A)$$

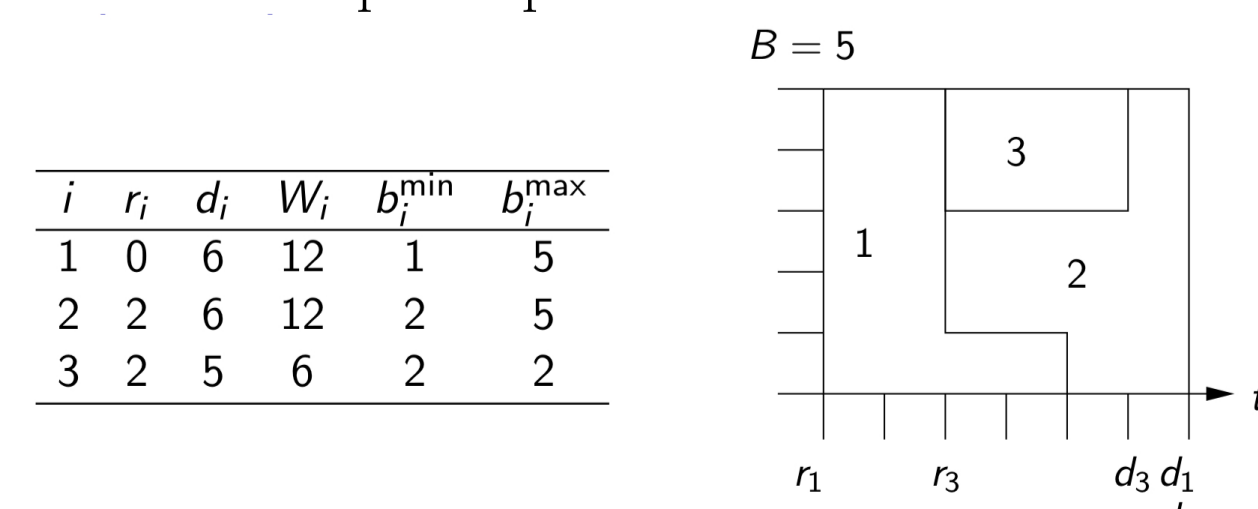
$$b_i^{\min} \leq b_i(t) \leq b_i^{\max} \quad (i \in A; t \in [st_i, ft_i])$$

$$b_i(t) = 0 \quad (i \in A; t \in \mathcal{T} \setminus [st_i, ft_i])$$

$$\int_{st_i}^{ft_i} b_i(t) dt = W_i \quad (i \in A)$$

$$\sum_{i \in A} b_i(t) \leq B \quad (t \in \mathcal{T})$$

Example of problem and solution :



## Mathematical formulation for the single-resource case

### Variables

- Demand curves  $b_i(t) : \mathcal{T} \rightarrow \mathcal{B}$ ,  $i \in A$
- Indicator of task started  $x_{it}$
- Indicator of task ended  $y_{it}$

### 4 variants

- Continuous time horizon  $\mathcal{T} \subseteq \mathbb{R}$  or Discrete time horizon  $\mathcal{T} \subseteq \mathbb{N}$
- Continuous demands  $\mathcal{B} \subseteq \mathbb{R}$  or Discrete demands  $\mathcal{B} \subseteq \mathbb{N}$

### Discrete-time mathematical model ([2])

$$\max \left( \sum_{i \in A} \sum_{r_j}^{d_j-1} b_{it} \right)$$

$$\sum_{t=r_i}^{d_i-1} x_{it} = \sum_{t=r_i+1}^{d_i} y_{it} = 1 \quad \forall i \in A$$

$$\sum_{s=r_i+1}^t y_{is} b_i^{\min} + b_{it} - \sum_{s=r_i}^t x_{is} b_i^{\min} \geq 0 \quad \forall i \in A, \forall t \in [r_i, d_i] \cap \mathcal{T}$$

$$\sum_{t=r_i}^{d_i-1} b_{it} = W_i \quad \forall i \in A$$

$$\sum_{i \in A} b_{it} \leq B \quad \forall t \in \mathcal{T}$$

$$\sum_{s=r_i+1}^t y_{is} b_i^{\max} + b_{it} \leq b_i^{\max} \quad \forall t \in \{r_i \dots d_i - 1\}, \forall i \in A$$

$$\sum_{s=r_i+1}^t y_{is} - \sum_{s=r_i}^t x_{is} \leq 0 \quad \forall t \in \{r_j + 1 \dots d_j\}, \forall i \in A$$

$$\sum_{s=0}^t x_{is} w_i - b_{it} \geq 0 \quad \forall t \in \{r_j + 1 \dots d_j\}, \forall i \in A$$

$$\sum_{s=0}^{r_i-1} x_{is} = \sum_{s=d_i+1}^T y_{is} = \sum_{s=0}^{r_i-1} b_{is} = \sum_{s=d_i}^T b_{is} = 0 \quad \forall i \in A$$

$$x_{it}, y_{it} \in \{0, 1\} \quad b_{it} \geq 0 \quad \forall i \in A, \forall t \in \mathcal{T}$$

## Methodology and Contributions expected

### Phase 1 : Solving the single-resource case

- Mathematical formulation of the different variants
- Identification of valid inequalities and dedicated separation procedures

### Phase 2 : Solving the multi-resource case

- Extension of the mathematical model and the valid inequalities to the multi-resource case
- Definition of patterns of resource consumption and procedure for feasible patterns generation with regard to predefined constraints
- Development of a column-generation-based algorithm to exploit the feasible patterns identified

### Phase 3 : Experimental Validation

- Introduction of more realistic consumption/production curves
- Tests on data sets of realistic power profiles for hybrid electric vehicles and mission profiles provided by the researchers in Electrical Engineering from LAPLACE
- Experimentations on the smart building ADREAM of the LAAS (<http://www.laas.fr/ADREAM/>)

### Expected Contributions

- Integration of energy sources selection in scheduling, taking into account constraints related to the efficiency of technological equipments and their dynamics, both related to the characteristics of each energy source.
- New hybridization of techniques and solution methods : combination of patterns generation (including dual solutions-based filtering) and propagation of resources constraints for the scheduling problem considered.

## References

- [1] C. Artigues, P. Lopez and A. Haït, The energy scheduling problem : industrial case study and constraint propagation techniques, Int. J. Prod. Econ., 143(1) :13-23, 2013
- [2] C. Artigues, P. Lopez, D. Rivreau, Raisonnement énergétique et inégalités valides pour un problème d'ordonnement sous contraintes d'énergie. ROADEF 2013, Tours, France.
- [3] M. Guemri, S. Caux, S.U. Ngueveu, and F. Messine. Heuristics and lower bound for energy management in hybrid-electric vehicles. In Proceedings of 9th International Conference of Modeling, Optimization and Simulation (MOSIM 2012), paper 169, 10 pages, Bordeaux, France, 2012.