Building Physic
KU Leuven & Energy Ville

EnergyVille

A Library for Linear Modelling of Energy Systems

9 novembre 2017

Vincent reinbold

Sommaire

Outline

Context and Benefits

Research Directions

Research on microgrids and smart buildings

- Optimization of energy demand
- Solutions for generation
- Storage management
- Economic feasibility
- Environmental assessments

Outline

Scientific Issues

Topology, Energy Management and Sizing Optimization
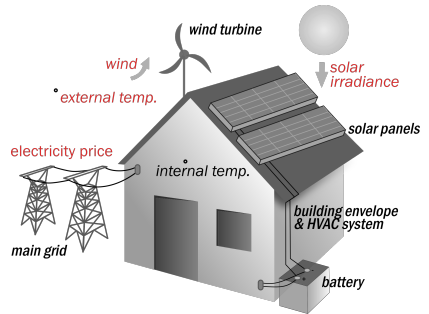
Topology, Energy Management and Sizing Optimization

What are the Problems ?

- **Real Time Control**
- **Energy Management :** Unit Commitment
- **Continuous Sizing :** Sections, Capacities, Nominal Values, etc.
- **Topology Optimization :** Network, Storage Position, etc.
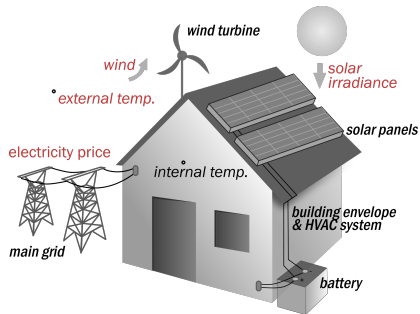
Topology, Energy Management and Sizing Optimization

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Subjected to Uncertainties

Topology, Energy Management and Sizing Optimization

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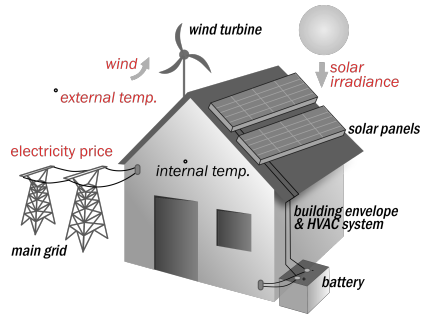- **Energy Management :** Unit Commitment
- **Continuous Sizing :** Sections, Capacities, Nominal Values, etc.
- **Topology Optimization :** Network, Storage Position, etc.

Minimize Cost, subjected to :

- **Forecasts :** generation, loads, occupancy, weather
- **Informations :** GIS, BIM, measurements
- Energy balance,
- Load/Storage Management,
- **Physical limits :** the models

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Library for Linear Modelling of Energy System
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Conclusion

Scientific Issues

Time and Space Scales

Time Scale

- Generation Following
- Daily Management
- Seasonal Study
- Life Cycle Analysis

Space Scale

- **Building** : Loads Control, DHW and envelop Sizing
- **District Scale** : Aggregate Loads, Storage, Local Generation
- **City/Region Scale** : Network, Generation

Time and Space Scales

Time Scale

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Space Scale

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| 1s | 1m | 1h | 1D | 1M | 1Y | 20Y |

$$60 \times 60 \times 24 \times 30 \times 12 \times 20 \approx 6{,}2.10^8$$

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State of the art and Proposal

State of the Art

What are the Approaches?

- ❧ **Network scheduling and sizing → Optimization**
- ❧ Approaches
- ❧ Available methods
- ❧ Models

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Conclusion

State of the art and Proposal

State of the Art

What are the Approaches ?

- ❧ **Network scheduling and sizing → Optimization**
- ❧ **Approaches**
  - ✦ Fully-Centralized
  - ✦ Aggregations, Multi-level
  - ✦ Fully-Distributed (decomposition)
- ❧ Available methods
- ❧ Models

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Conclusion

State of the art and Proposal

State of the Art

What are the Approaches?

- 🍃 Network scheduling and sizing → Optimization
- 🍃 Approaches
- 🍃 Available methods
  - 🌱 Deterministic
  - 🌱 Heuristic
  - 🌱 Rule-based
  - 🌱 Hybrid
- 🍃 Models

State of the art and Proposal

State of the Art

What are the Approaches?

🌿 Network scheduling and sizing → Optimization

🌿 Approaches

🌿 Available methods

🌿 Models
  - ☘ LP, MILP
  - ☘ QP, QCQP, SDP
  - ☘ NLP, MINLP
  - ☘ Stochastic,

Linear & Mixed Integer Linear & Quadratic Programming
▼ Modelling physic
▲ Convergence propriety, problem size

Non-Linear Programming
▼ Convergence speed/quality
▼ Time Consuming Simulation, Jacobians, etc.
▲ Accurate Modeling,
Stochastic
▼ Modeling, Convergence, Speed
▲ Uncertainties, Robust

State of the art and Proposal

State of the Art

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- 🌿 Network scheduling and sizing → Optimization
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State of the art and Proposal

Proposal - One Tool to Gather and Optimize DES

Main Objective

Develop an Oriented Object python package for the Mixed-Integer Linear Modeling of District Energy Systems.

🌿 **Linear & Mixed Integer Linear (& Quadratic) Programming**
  - 🌱 Convergence, Speed, Matrix size
  - 🌱 Energy Management, Topology and Sizing Problems,
  - 🌱 Compatible with Centralized, Aggregative or Decentralize Methods, Stochastic/Robust optimization (hybrid).

🌿 **Object Oriented (Python and solver API)**
  - 🌱 To make the modeling and post-processing easier (vs. GAMS, AMPL, etc.)
  - 🌱 To gather and share models

🌿 **Multi-Physic Modeling**
  - 🌱 **Thermal** Building Structure, Network, Storage
  - 🌱 **Electrical** Grid Connection, co-generation, *power-to-gaz*
  - 🌱 **Fluid-Mechanics** Pipes, DHW, Substations, etc.

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Conclusion

Introduction

Outline

Definitions

Integer Program

An optimization model is an Integer Program if any of its decision variables is discrete

- ❦ If all variables are discrete, the model is a pure integer program
- ❦ Otherwise, the model is a mixed-integer program

Standard Mixed-Integer Linear Programming (MILP) Formulation

$$min_{x,y} \quad c^\top x + d^\top y$$

$$s.t. \quad Ax + Ey \begin{Bmatrix} \geq \\ = \\ \leq \end{Bmatrix} b$$

$$x_{min} \leq x \leq x_{max}$$

$$y \in 0; 1^{n_y}$$

Definitions

Linear vs. Non-Linear Programming

- An IP model is an Integer linear program (ILP) if its (single) objective function and all its constraints are linear

- Otherwise, it is an integer nonlinear program (INLP)

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Conclusion

Introduction

The concept

Basic Ideas

- The **Unit** integrates his own **Quantities**, **Contraints** and **Objectives**
- **Connexions** between Units create **Global Constraints**
- The Problem is created by **aggregating Units** and **Connecting them**
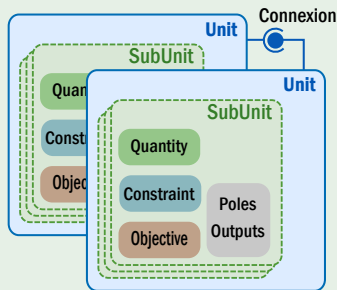
Outline

LLMSE : Library for Linear Modelling of Energy Systems

Quick View to the Source

The Source :

LLMSE : Library for Linear Modelling of Energy Systems

Quick View to the Documentation

The Documentation :
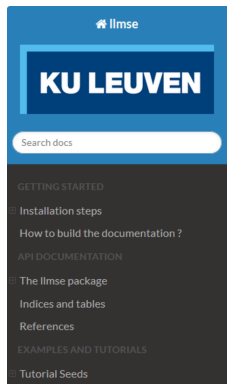
Docs » Welcome to the LLMES's documentation!   View page source

Welcome to the LLMES's documentation!

This is the documentation of the LLMES's python package (Library For Linear Modeling of Energetic Systems). This project is about the mixed linear modeling of energetic systems in python using gurobipy and SciPy packages. Gurobipy is a wrapper allowing to model and solve mixed integer linear programming within python language. More information here : Gurobi Python API Overview.

Getting Started

- Installation steps
  - Installing Python distribution (Anaconda)
  - Install LLMSE from source
  - Install Gurobi Solver
  - Install dependencies
- How to build the documentation ?

Sidebar:

⌂ llmse

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Search docs

GETTING STARTED

Installation steps

How to build the documentation ?

API DOCUMENTATION

The llmse package

Indices and tables

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EXAMPLES AND TUTORIALS

Tutorial Seeds

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Conclusion

A Practical Implementation

Outline

A Practical Implementation

A Practical Implementation

1. Instantiation of the Model

```
1   # time horizon and time step definition
2   th = Time(end=23, freq='H')
3   # Model instantiation
4   mgm = MGModel(name='Smart—Building Example')
5   # Thermal envelope instanciation
6   bui = SingleZoneBuilding(th, name='BUI0', ... )
7   # Battery instantiation
8   sb0 = SimpleBattery(th,  name='SB0', emax=10, emin=0,
9   pcmax=10, pdmax=10)
10  # Wind Turbine instantiation
11  wt0 = WindTurbine(th, name='WT0', ...)
12  # Main Grid Connection
13  mg0 = MainGridt(th, name='MG0', pmax=20, pmin=20,
14  cout=cout, cin=cin)
```


RC - thermal envelop

2. Aggregation of variables, constraints and objectives

3. Multi-physic connections between units

4. Optimization

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Main grid

RC - thermal envelop

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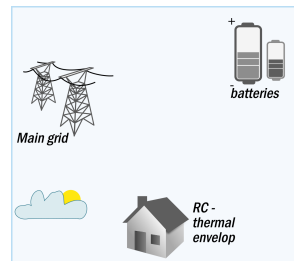Conclusion

A Practical Implementation

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+
batteries

Main grid

RC - thermal envelop

2. Aggregation of variables, constraints and objectives

3. Multi-physic connections between units

4. Optimization
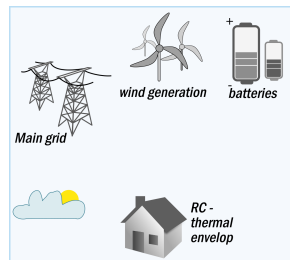
A Practical Implementation

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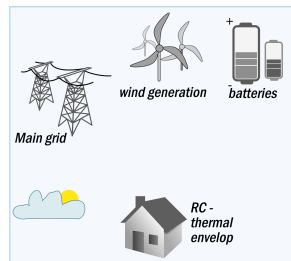

wind generation

batteries

Main grid

RC - thermal envelop

2. Aggregation of variables, constraints and objectives

3. Multi-physic connections between units

4. Optimization

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A Practical Implementation

A Practical Implementation

1. **Instantiation of the Model**

2. **Aggregation of variables, constraints and objectives**

   15 mgm.addunit(th, bui, sb0, wt0, mg0)

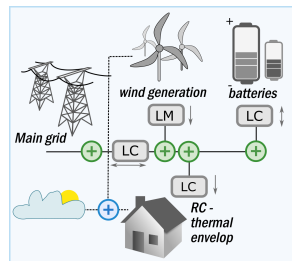3. Multi-physic connections between units

4. Optimization

wind generation   *batteries*

Main grid

RC - thermal envelop

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Library for Linear Modelling of Energy System
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Conclusion

A Practical Implementation

A Practical Implementation

1. **Instantiation of the Model**

2. **Aggregation of variables, constraints and objectives**

3. **Multi-physic connections between units**

```
16  mgm.addEffortConnection(...) # introduce equality
17  mgm.addFluxConnection(...)  # introduce conservation equality
```
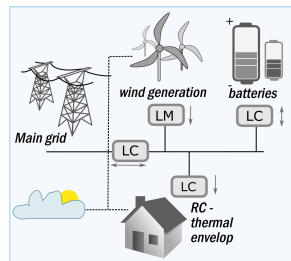
4. **Optimization**

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Conclusion

A Practical Implementation

# A Practical Implementation

1. Instantiation of the Model
2. Aggregation of variables, constraints and objectives
3. Multi-physic connections between units
4. Optimization

```
18   mgm.update()
19   mgm.optimize()
```

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A Practical Implementation

A Practical Implementation

1. **Instantiation of the Model**
2. **Aggregation of variables, constraints and objectives**
3. **Multi-physic connections between units**
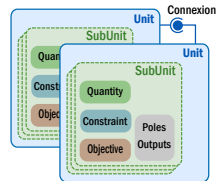4. **Optimization**
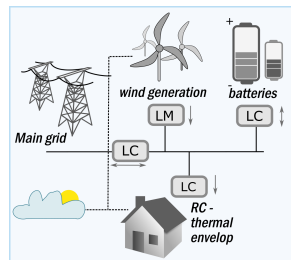
Smart-Grid Example (24h)

- 19 lines of code ($\approx 1\,000$ in total) $\equiv 4\,000$ lines in LP language
- 1 400 variables, 2 400 constraints
- Optimization time ≤ 1 *s*
  (i7-6600U, 2.60GHz, 8GB / Python 2.7 / Gurobi 6.5)

Conclusion - A General Tool for Modeling Optimization Problems

1. **Oriented Object Tool for Optimization**
   - ✦ Make the Optimization Formulation Easier
   - ✦ Develop, Share and Gather Models For DES
   - ✦ **Documentation** and **Post-Processing** Easier using Python
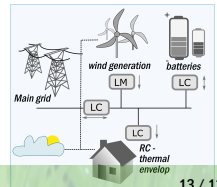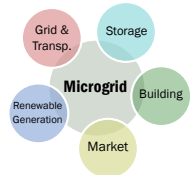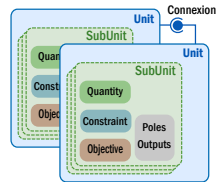2. Application for District Energy System

Conclusion - A General Tool for Modeling Optimization Problems

1. **Oriented Object Tool for Optimization**
2. **Application for District Energy System**
   - ⚘ (In development) **Modeling of Pipes, Network, Thermal Storage**
   - ⚘ (In development) **Social, Environmental and Economical models**
   - ⚘ **Topology and Sizing Optimization**
   - ⚘ **Comparison with NL models**

Conclusion - A General Tool for Modeling Optimization Problems

1. **Oriented Object Tool for Optimization**
2. **Application for District Energy System**

Perspectives

- **Develop**/**Feed** Models and Examples for the Library,
- Building a **community**
- Real **Implementation** & Measurements