Joint Optimization of Production and Demand

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EDF

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Context of the study

Production:

- 59 nuclear plants
- 50 "classical" thermal power plants (coal, fuel, gas)
- 50 hydro valleys
- Wind power (about 3%) and photovoltaic (about 1%)


pictures from EDF documentation

Context of the study

Production:

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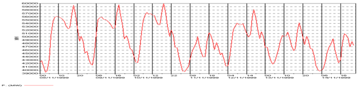
pictures from EDF documentation

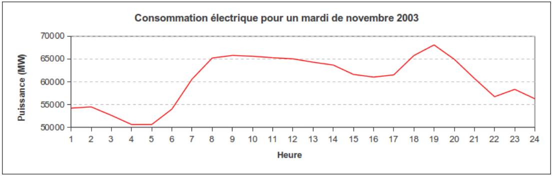
Demand:

- annual, weekly and daily cycles, coming from consumers, purchases / sales, network losses, own consumption of EDF.
- flexibility via shedding days and a peak and off-peak rates system



Current Approach

Demand is a set parameter of the problem.



Flexibility on the demand is used regardless to the production.

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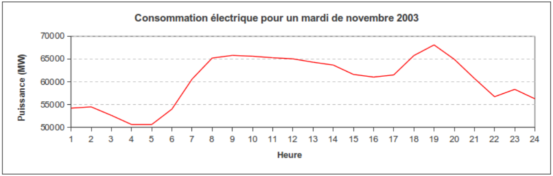

Flexibility on the demand is used regardless to the production.

The resulting demand is given to the new problem:

- Objective: Minimize the global cost of production
- Constraint 1: Reach the balance between production and demand
- Constraints 2: Respect of
  - the operation of the different plants
  - the terms of transactions on the markets

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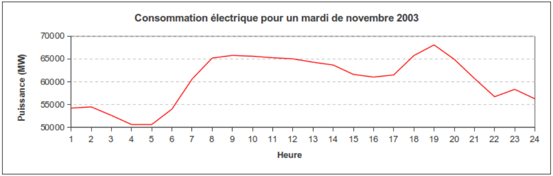

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The solution to this problem is a forecast planning for the production

A new context for the energy management

smart grids, intermittent energy sources → Global-local management

Legislator: regulatory constraints, rules

Producer:
Some commands on the demand are managed by the producer

↕

Clients:
Consumption, Reaction to the offers

↕

Competitors:
Quality of the offers

↔

Network managers:
Some commands on the demand are managed by the network manager

↔

Local players:
Some commands on the demand are managed by local players

Approach

- optimization of both production and demand via flexibilities: electric vehicles load, hot water and shedding

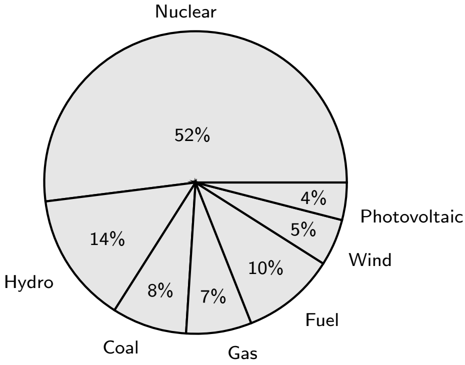
source: EDF website

- deterministic approach, over a week, with a time step of one hour

Production

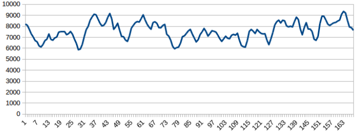
- Nuclear (5 plants)
- Coal (5 plants)
- Gas (2 plants)
- Fuel (2 plants)
- Hydro ("France lake")
- Photovoltaic
- Wind

Capacities of the mix:



Natural demand

Deterministic demand given over a week:



Flexibilities on hot water and electric vehicles

Flexibility on hot water (with x_t^{hw} the consumption of hot water at time step t):
The "natural" consumption is known. We place the new demand respecting:

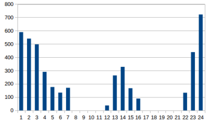
- the energy spent each day by the consumption of hot water (between 1:00 and 0:00 the next day)

$$\sum_{h=0}^{23} x_{24d+h}^{hw} = \sum_{h=0}^{23} natural\_demand_{24d+h}^{hw} \ , \forall d = 0..6$$

- the maximal power used in an hour

$$0 \leq x_{24d+h}^{hw} \leq \max_{h \in \{0,\ldots,23\}} natural\_demand_{24d+h}^{hw} \ , \forall d = 0..6 \ , \forall h = 0..23$$

example:



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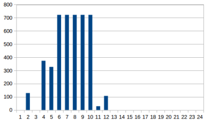
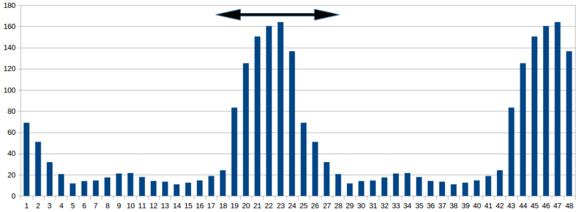


Flexibilities on hot water and electric vehicles

Flexibility on electric vehicles: same principle as for hot water, but the consumption is only moved between 18:00 and 6:00 the next day.



Shedding days

The consumption can be reduced some days, with a given profile in a region r. The manager has to choose each day for each region if a shedding is decided or not. Those reductions are penalized in the objective.

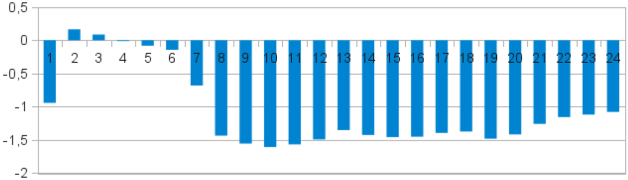


Figure: profile of the shedding

No constraint (only modification of the demand).
Penalization (with x_d^{sh} a boolean, 1 if a shedding is chosen at day d in region r):

$$\sum_{d=0}^{6} x_d^{sh} \sum_{r=0}^{3} \sum_{h=0}^{23} use\_value_{24d+h}^{cu}$$

Model

$x = x_R, x_B$: Production
$y = y_R, y_B$: Demand

$$\min_{x,y} \quad c_P^T(x_R, x_B) + c_D^T(y_R, y_B)$$

$$\text{s.t.} \begin{cases} A(x_R, x_B) \geq d(y_R, y_B) + d_0 \\ F_P(x_R, x_B) \leq f_P \\ F_D(y_R, y_B) \leq f_D \\ x_R, y_R \in \mathbb{R}^{N_R} \ , \ x_B, y_B \in \{0,1\}^{N_B} \end{cases}$$

c_P : proportional and staring production costs
c_D : costs of the flexibilities over demand
F_P : functionning of the plants
F_D : functionning of the flexibilities over demand

Constraints:

- balance between production and demand
- Thermal plants:
  - min and max power
  - minimal time on
  - minimal time off
  - maximal gradient
- Hydro plants: conservation of the water volume
- flexibility over the demand

Repartition of the production (2015)

Flexibility used	Nuclear	Hydro	Coal	Fuel and gas	Wind and photovoltaic
(capacity)	(52 %)	(14 %)	(8 %)	(17 %)	(9 %)
none	73.9 %	10.8 %	7.3 %	3.6 %	4.4 %
all together	74.4 %	10.7 %	7.6 %	2.7%	4.4 %

Figure: Repartition of the production with the current mix

Flexibility used	Global cost (index 100 without flexibility)	Propotional cost (idem)	Starting cost (idem)	Gain (in euro per movable MWh)
none	100	100	100	-
electric vehicles	98.90	98.78	105.38	23.06
hot water	97.11	97.16	93.89	9.81
shedding	99.99	99.99	100	
all together	96.37	96.41	93.89	

Figure: Management costs with the current mix

A new context: more fatal energy (2030)

Flexibility used	Nuclear	Hydro	Coal	Fuel and gas	Wind and photovoltaic
(capacity)	(23 %)	(13 %)	(10 %)	(7 %)	(46 %)
none	48.1 %	10.8 %	7.4 %	0.6 %	33.1 %
all together	50.0%	10.8%	5.6%	0.5%	33.1%

Figure: Repartition of the production with the forecast mix for 2030

Flexibility used	Global cost (index 100 without flexibility)	Propotional cost (id)	Starting cost	Gain (in euro per movable MWh)
none	100	100	100	-
electric vehicles	97.78	97.97	94.48	31.03
hot water	92.68	92.77	91.01	16.50
shedding	99.99	99.99	100	
all together	91.31	91.65	85.40	

Figure: Management costs with the forecast mix for 2030

Conclusion

- Global approach: Toward a global / local management
- First step: joint optimization production / demand.
- First results:
  - A gain up to 3.6% with a mix similar to the current one for the management costs.
  - This gain reaches 8.7% with the forecast mix for 2030.
  - With a larger part of fatal energy, some instances are no more solvable without those flexibilities.

Perspectives

Second step: introduction of uncertainties on:

- weather (impact on demand, wind and photovoltaic production, hydro supply...),
- potential failures,
- shedding, electric vehicles, hot water: reaction of the clients,

Method?

- robust,
- stochastic,
- probabilistic,
- ...

Perspectives

Third step: global-local gestion:

- problem of balance between players?
- multi-level approach?
- Risk management?