INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE — INRIA

Optimization of Electrical Production

The production of electricity in France is optimized everyday with the help of a mathematical software developed at Inria, in collaboration with EDF R&D. Substantial performance is achieved, in terms of robustness, computation time and overall production cost.

Notation – French Model

- n $[\simeq 200]$ existing power units
  - – thermal: nuclear 80%, fuel+coal 3%
  - – hydro-valleys 17%
- T $[= 96]$ time periods (2 days $\times$ 48 half-hours)
- Production schedule $p_i = (p_i^1, \dots, p_i^T) \in P_i$ of unit i — technological constraints
- Production cost $c_i(p_i)$ of unit i (fuel+coal only)
- Demand (known) d^t at time t – including spinning reserve

$$\boxed{\min_{p \in \prod_i P_i} \ \Sigma_i c_i(p_i)\,, \quad \text{subject to} \quad \Sigma_i p_i^t \geqslant d^t\,, \quad t = 1, \dots, T}$$

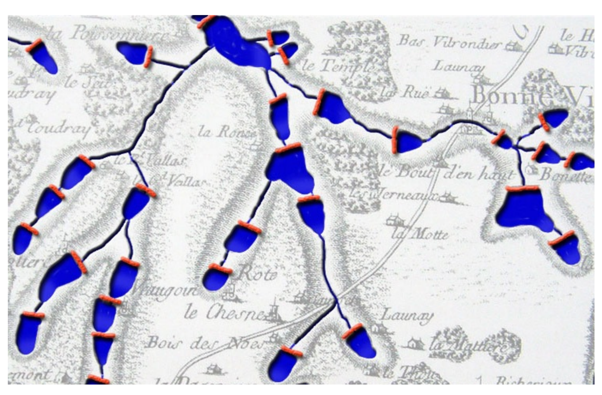
Thermal Units

- Control variable = output p
- Off or On
- $0 < p_{\min} \leqslant p \leqslant p_{\max}$
- Minimum duration at given level
- May or may not produce spinning reserve
- Ramping constraints when changing level
- etc.

too complex but discretized (4 values: 0, $p_{\min}$, p_{inter}, $p_{\max}$)

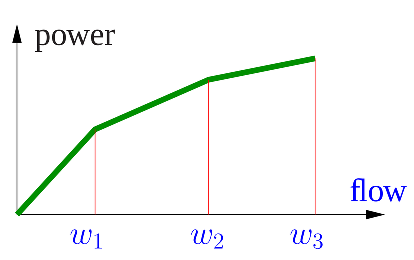
$\Longrightarrow$ amenable to dynamic programming

Hydro-Valleys



- Control variable = flow w through turbine
- Lake^{t+1} = Lake^t + Rain^t + $(w^{\downarrow})^{t-\tau} - (w_{\downarrow})^t$
  $w^{\downarrow}$, $w_{\downarrow}$: incoming, outgoing flows; τ: delay between lakes
- $\exists w < 0$: pumping upstream
- Nominal turbine speeds $\Longrightarrow$ w discrete $\in \{0,\, w_1,\, w_2,\, w_3\}$

too complex but
tolerable continuous approximation



$\Longrightarrow$ amenable to linear programming

+ postprocessing to adjust flows

Solution Approach

Problem = Large-scale + Heterogeneous

too complex but decomposable via Lagrangian duality

$$\min \textstyle\sum_i c_i(p_i) - \underbrace{u}_{\text{“price”}} \cdot \sum_i p_i \qquad \cancel{\textstyle\sum_i p_i \geqslant d}$$

For given u, this is n independent problems!

Centralized prices u

Decentralized productions $p_i(u)$

New Problem

Compute adequate prices to recover ignored constraints

Duality theory: this is to maximize a concave function of u

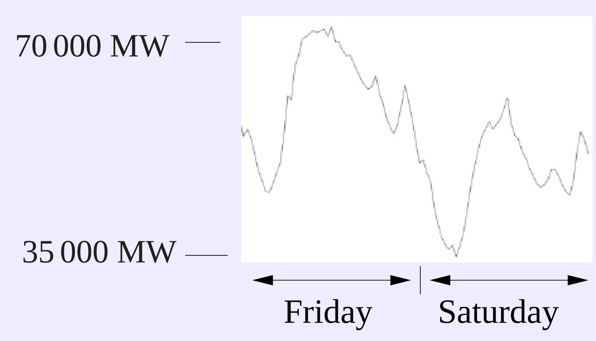
$$\textstyle\sum_i c_i(p_i(u)) - u \cdot \left(\sum_i p_i(u) - d\right)$$

Bottomline

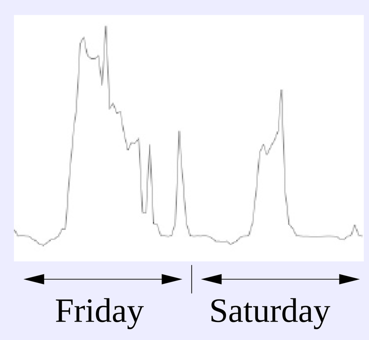
- Only heuristic suboptimal productions BUT:
- Relevant information on marginal prices
- Lower bound on optimal cost

Illustration

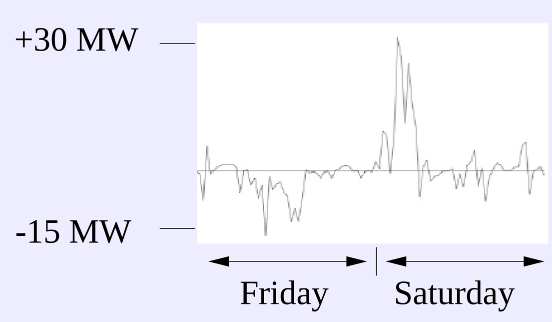
- Typical demand over two days



- Computed prices u



- Demand mismatch $\sum_i p_i - d$



- CPU time 10min Sun Blade 900MHz

Bipop – Claude Lemaréchal
Work initiated by the former research teams Promath, Numopt