A Guided-Construction approach to large scale power plant scheduling

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Outline

- scheduling strategies
- EDF particularities
- selected strategy
- dynamic programming

Complex scheduling problem options:

1. local search
2. constraint programming
3. mixed integer programming models

Easy scheduling problem options:

1. complete enumeration
2. dynamic programming
3. heuristics
4. network flows
5. linear programming models

Message: MIX

ROADEF computational Challenges 2007, 2008, and 2010
allow MIP-solvers (CPLEX et al)
many participants rely on local search methods.

Problem owners:

2007 France Telecom: schedule maintenance personnel: skilled technicians, complex tasks
MIP model for technician–job matching

2008 Amadeus: rescheduling aircraft assignment, flight delays or cancelations, passenger routing
NETWORK flows

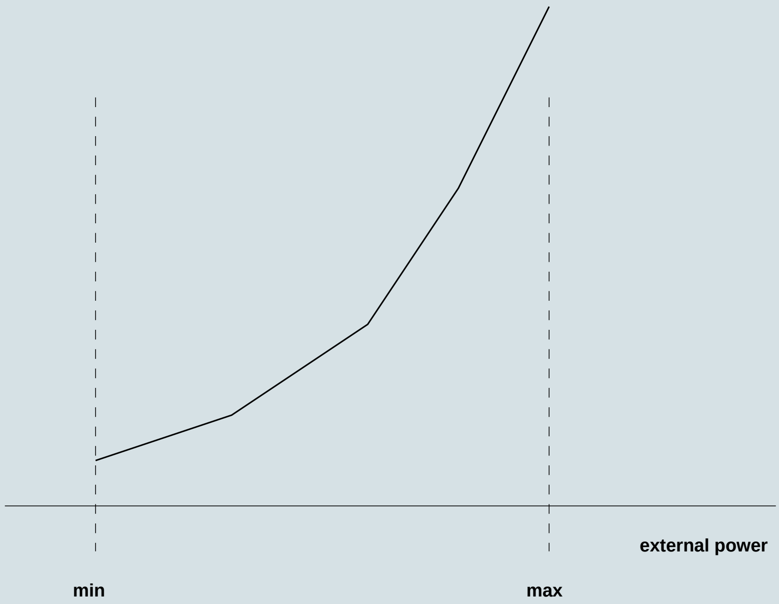
2010 Électricité de France (EDF): large scale plant scheduling: down times, refueling and production

EDF

- 10–80 energy production plants
- a time scale (2–5 years) divided in weeks w, time slots τ
- 5–6 maintenance periods per plant, fixed duration (5–15 weeks)
- a window $[es, ls]$ for the start time of each maintenance period
- scenarios σ (10–500), energy demands $D(\sigma, \tau)$
- refuel at the start of maintenance
- maintenance and production periods alternate

Further we are given

external energy capacity,
with min/max capacity per (σ, τ), and
price function – continuous, piece-wise linear, convex, depending on (σ, τ)



The goal is to solve three subproblems:

1. fix start times of maintenance periods,
2. choose refuel amounts
3. generate a valid production plan for each plant, time slot, scenario,

so as to minimize
total refueling cost plus
average external energy cost minus
the average value of fuel remaining.

Solutions to 1 and 2 hold for all scenarios

Problem 1, maintenance schedule

- time scale is weeks
- for single plant: enough production time
- for multiple plants:
  - *spacing* constraints
  - *resource* constraints
  - *overlap* constraints
  - *power reduction* constraints

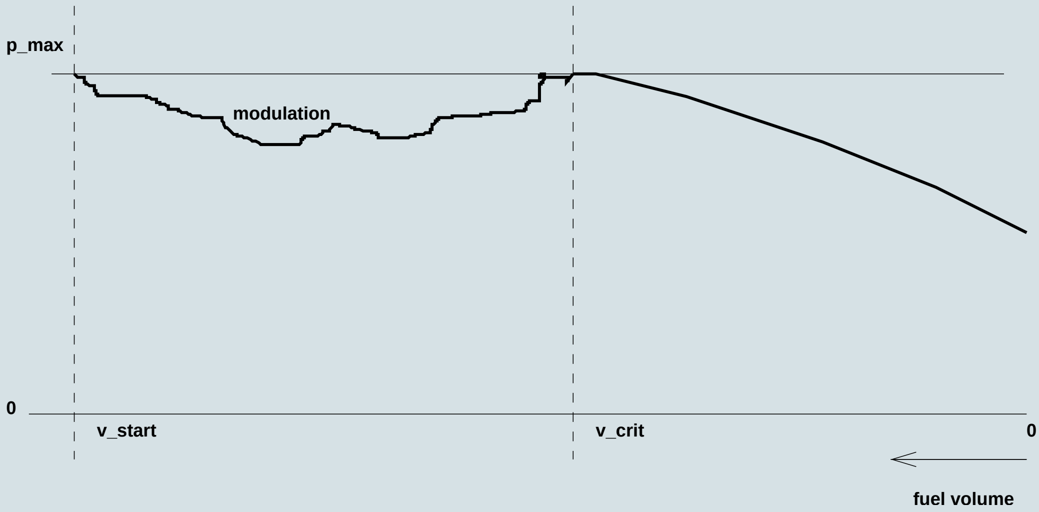
Problem 2, refueling

- effectively single plant problem
- bounds on refueling amount
- bounds on fuel volume AFTER refueling
- upper bound on fuel level BEFORE refueling

actual fuel volumes depend on scenario!!

Problem 3, production
For single plant:

- bounds on energy production, per time slot τ
- limited production BELOW maximum production rate (modulation)
- strict production regime, once volume drops below *threshold*



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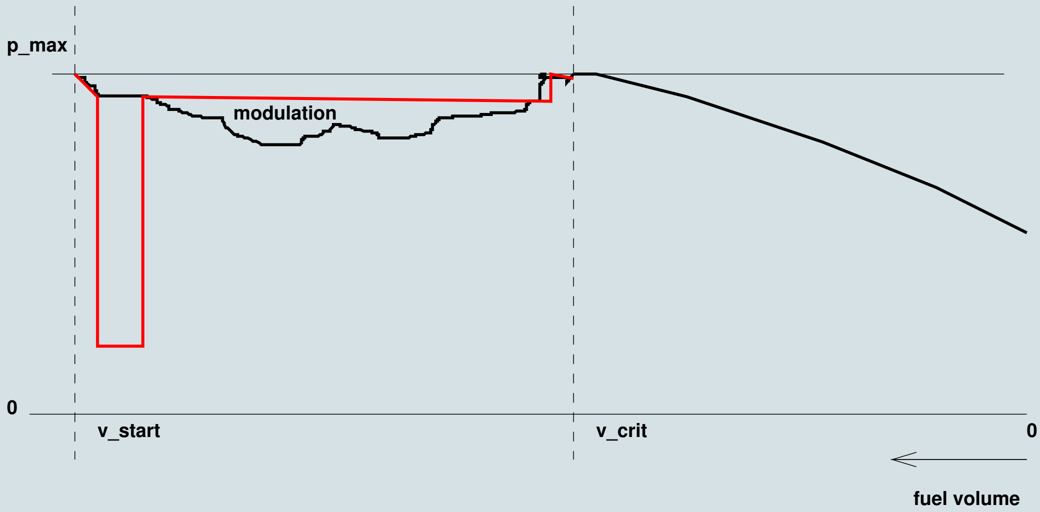

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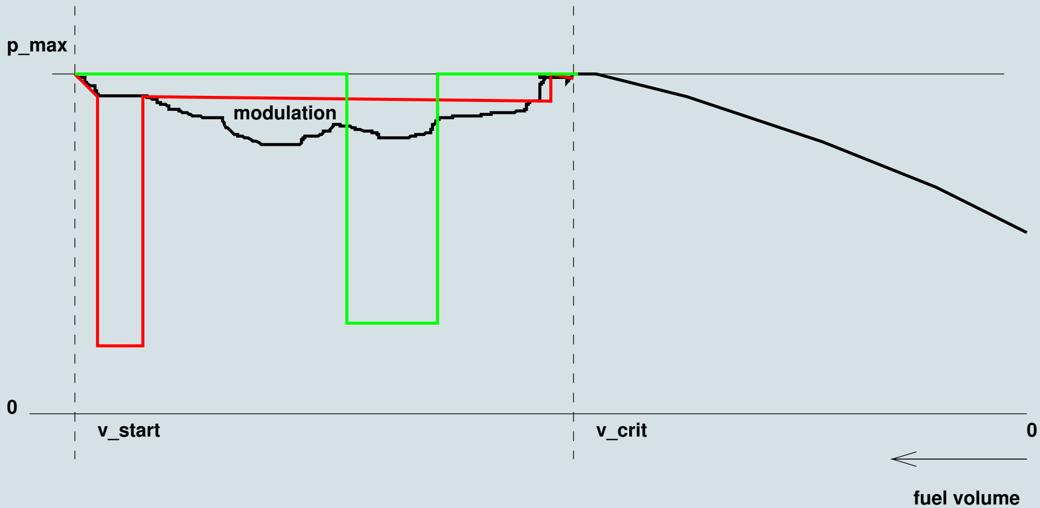


Considerations:

- external power is expensive
- hedge against different demand scenarios, use modulation
- scheduling one plant is doable
- scheduling multiple plants is sometimes necessary
- fixed maintenance plan and modulation periods: minimum cost production per scenario is LP

Strategy

1. start by a maximum production plan for each plant, forget about interaction (DP)
2. improve the schedule, one plant at a time (DP)
3. if plan still infeasible, change multiple plants simultaneously (MIP , time-index model)
4. if maintenance plan feasible, check for excessive production; adapt production levels (10 percent less refuel)
5. if production feasible, find cheapest variant for each scenario by using modulation (LP)
6. if time permits, repeat process with randomization

Implementation in C/JAVA:

Building block: single plant schedule
optimizing weighted combination of

- production,
- modulation,
- and penalties on undesired idle periods

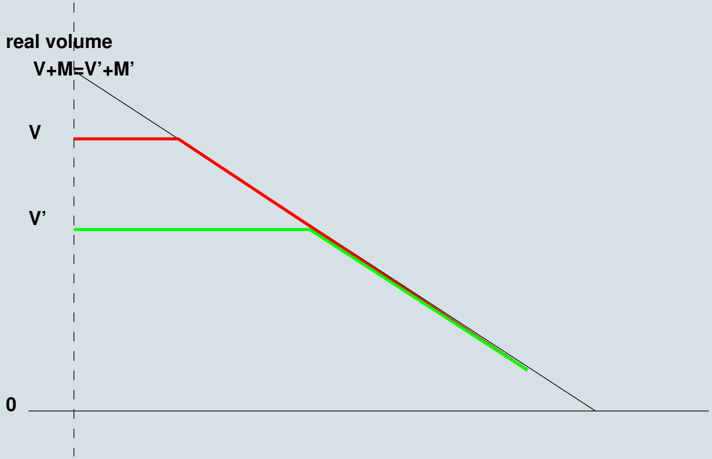
Dynamic Programming
with states (p, i, w, V, M)
($p$lant, $i$dle period, start $w$eek, production start Volume, reservation for Modulation),

state transitions

$$(p, i, w, V, M) \longrightarrow (p, i + 1, w', V', M')$$

Consider M as *virtual* fuel!

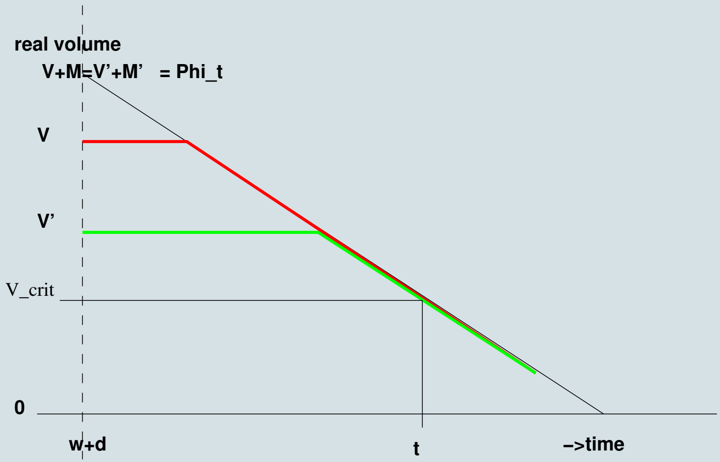
Observe: from states (p, i, w, V, M) and (p, i, w, V', M'), with $V + M = V' + M'$,
producing at maximum production rate
consuming real and virtual fuel
we arrive in week $q > w + d$ at the same *remaining* fuel volume!!
Assume that virtual fuel is consumed first:



Discretize state space into states (p, i, w, Φ_t) to capture states (p, i, w, V, M) with

$$\Phi_t \leq V + M < \Phi_{t+1}$$

Φ_t such that starting production in week $w + d$,
from real+virtual fuel volume Φ_t
the volume *THRESHOLD* is hit exactly at start of time slot t:



if $(p, i, w, \Phi_t).reachable \equiv$TRUE then it has value, fuel volume, and modulation $(p, i, w, \Phi_t).\text{val}$, $(p, i, w, \Phi_t).V$, and $(p, i, w, \Phi_t).M$.

From (p, i, w, Φ_t) we can reach $(p, i+1, q, .)$ by stopping production in week $q' \leq q$, with fuel left $\lambda_{q'}$,
refueling by amount ρ (whatever is allowed) ending up with real volume V'.

decision variables are q' and ρ, and modulation amount M'

value of new position is based on parameters that promote/discourage

1. choice of maintenance start q
2. fuel turned into energy production $(V - \lambda_{q'})$;
3. new modulation capacity M';
4. refuel amount ρ;
5. fuel leftover $\lambda_{q'}$;

Conclusions:

- programming in C leaves more control and speed
- large gap between type A and type B problems
- difficult to control running times
- model does scale

results follow in last session

Suggestions? Questions??

Thank you!