Réduction des pertes d'un réseau de transport d'énergie

Problème #8 : IREQ

Cinquième atelier de résolution de problèmes de Montréal

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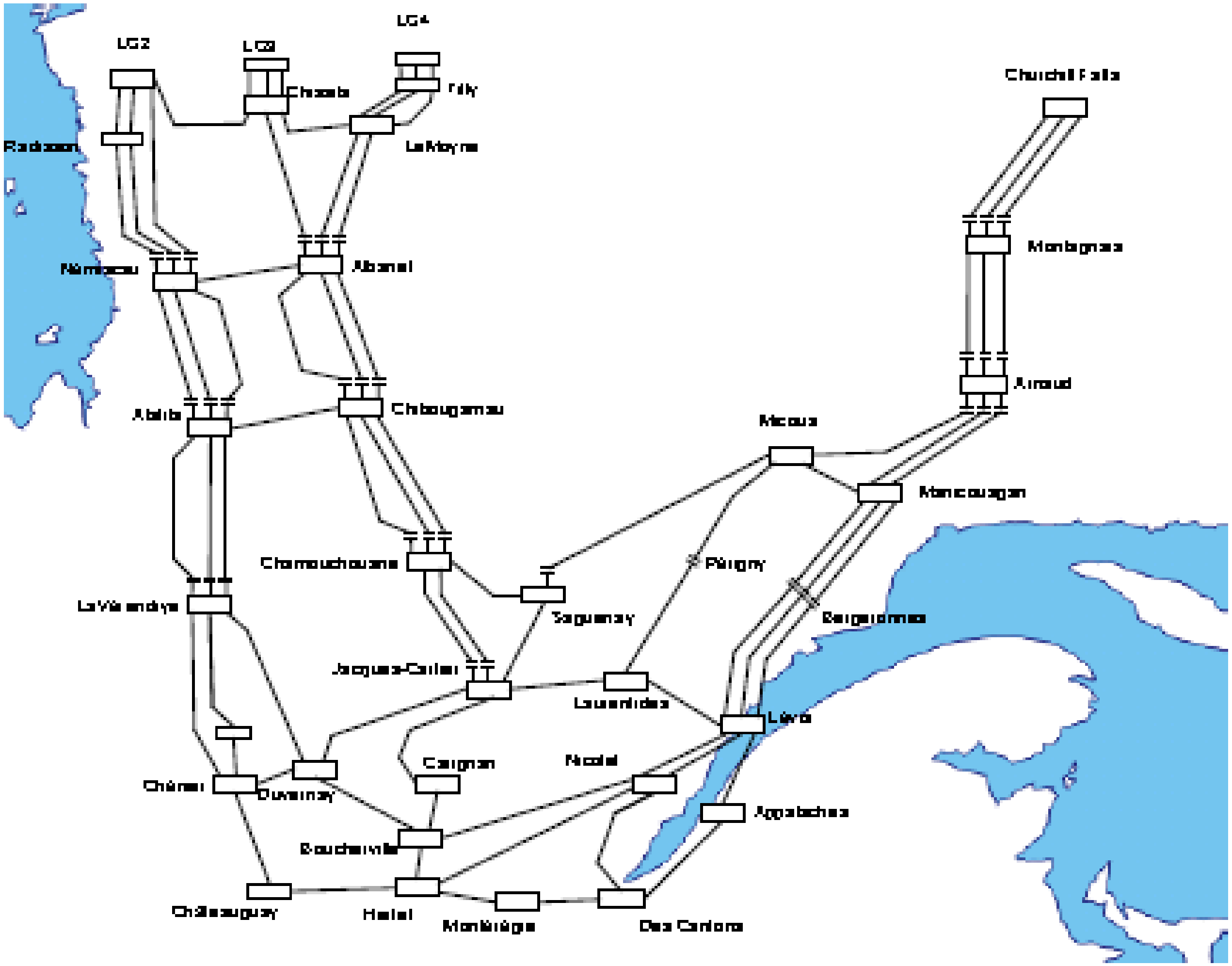
Outline

1) Problem context
2) Problem statement
3) Some additional operating constraints
4) General solution approach
5) Building the “long-term” plan
6) Dealing with the next hour

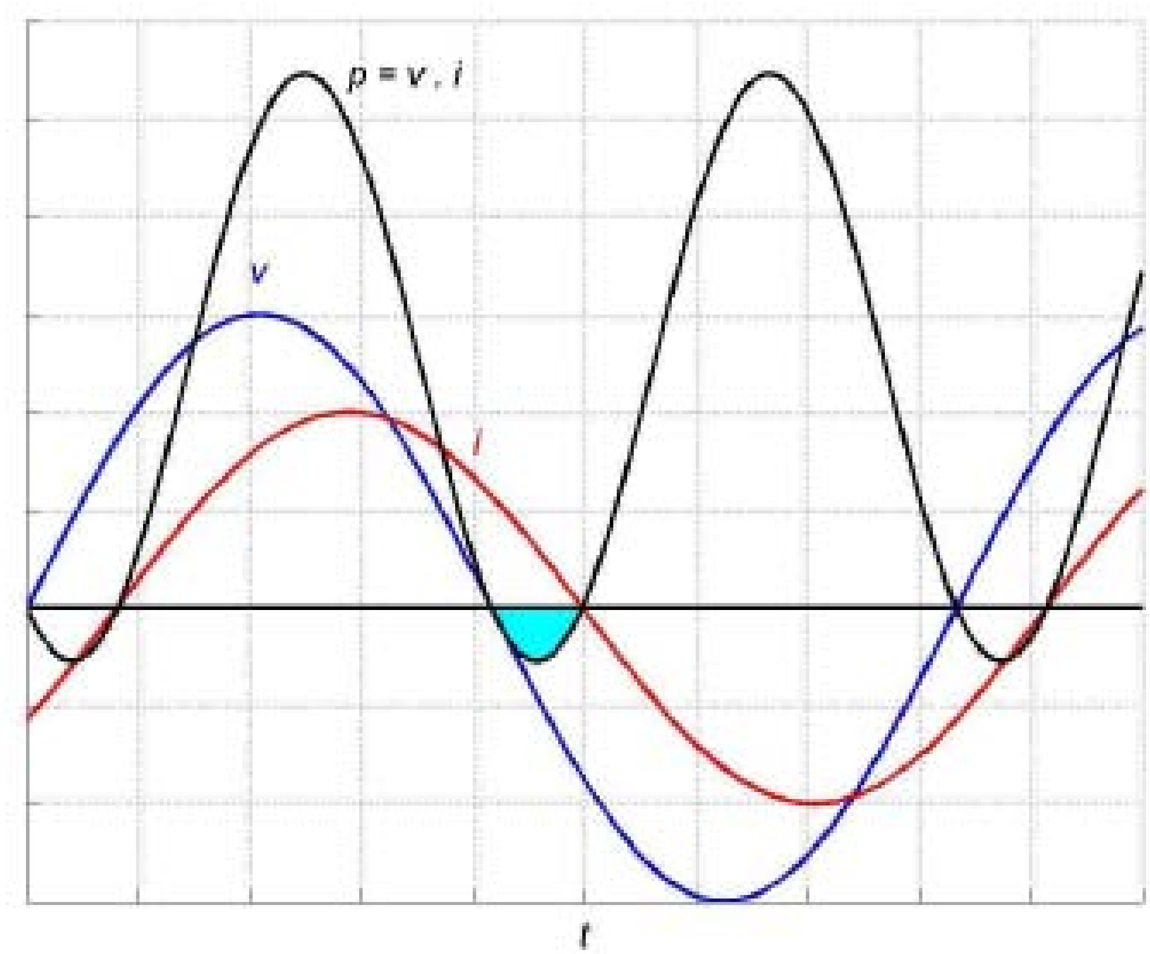
Problem context

- The transportation network of Hydro-Quebec
- Transit capacity: 44 GW
- 415 stations
- Overall: 34,000 km of lines and 765 lines
- Voltage levels: 69 to 765 kV
- Backbone 735 kV
- North : production
- South : load, import-export

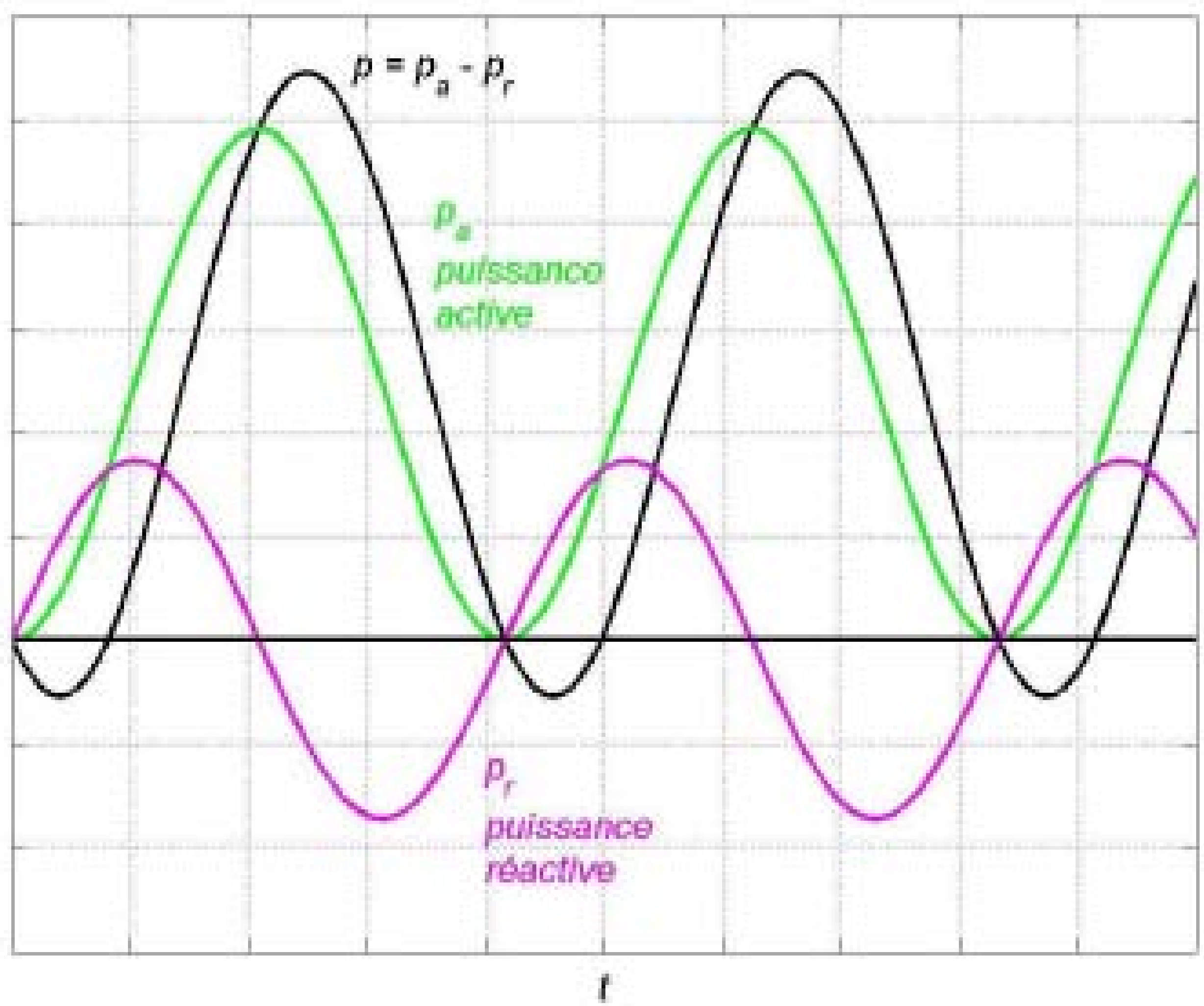
Problem context: the 735 kV network



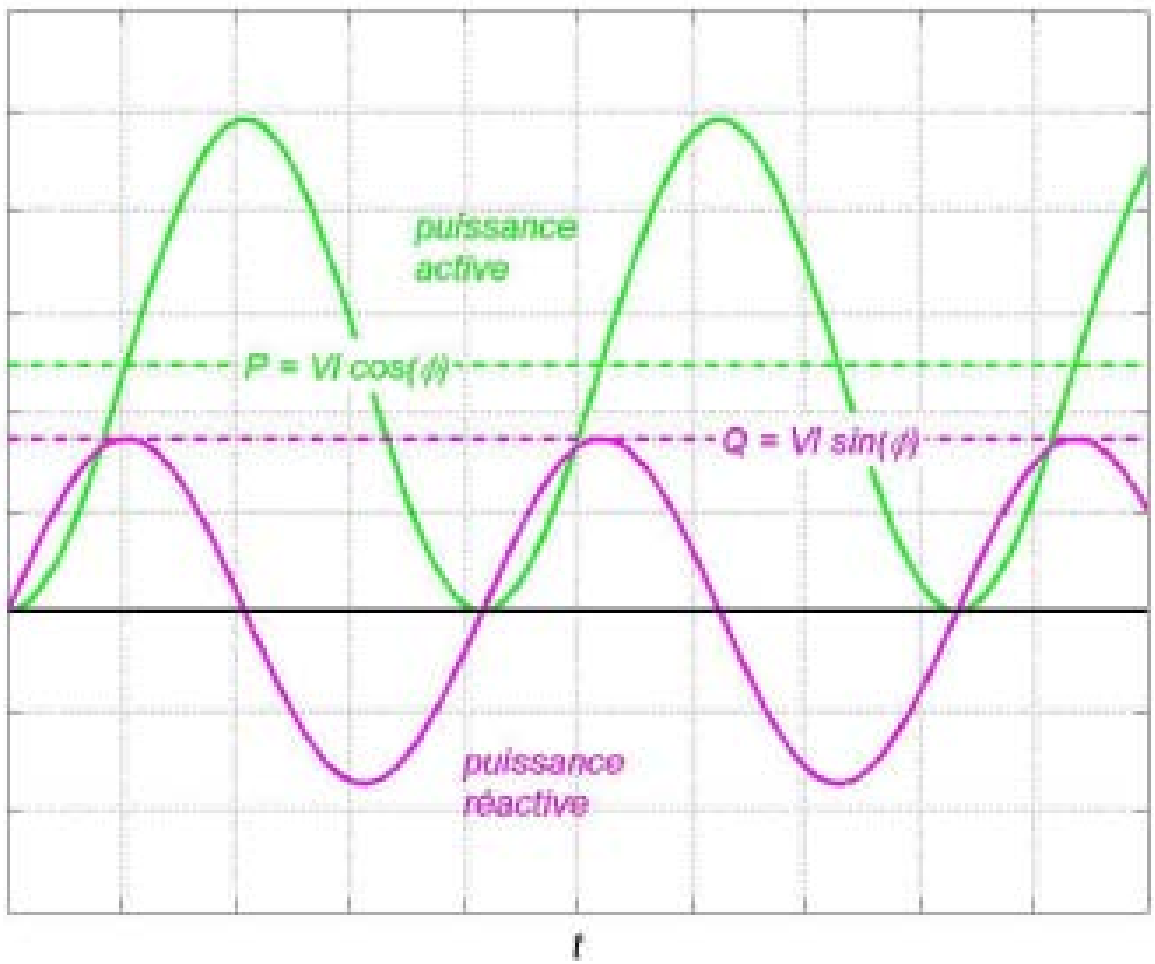
Problem context: instantaneous power



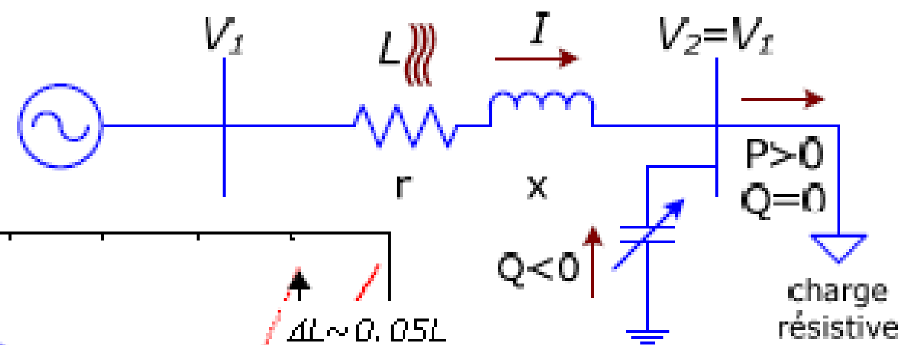
Problem context: power decomposition

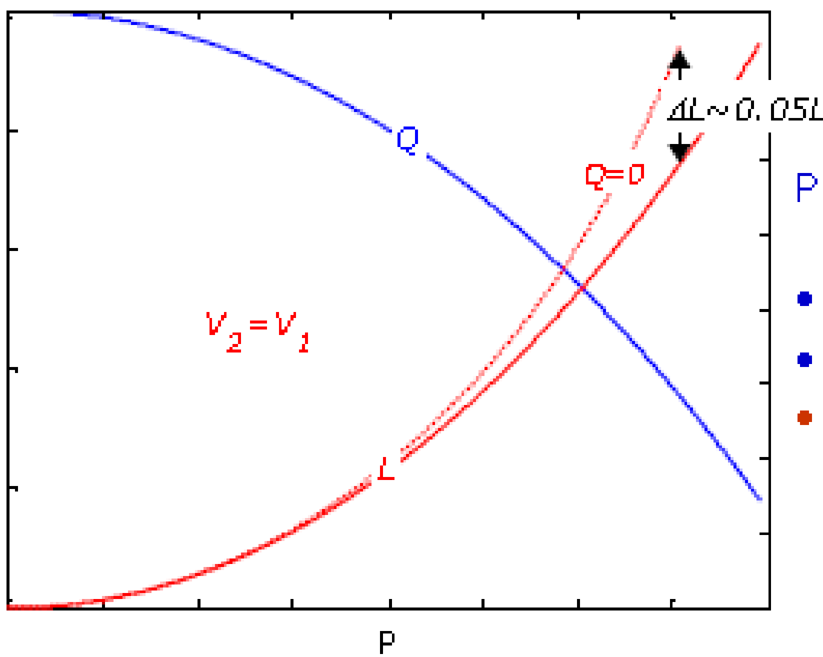


Problem context: power decomposition



Problem context: power flow

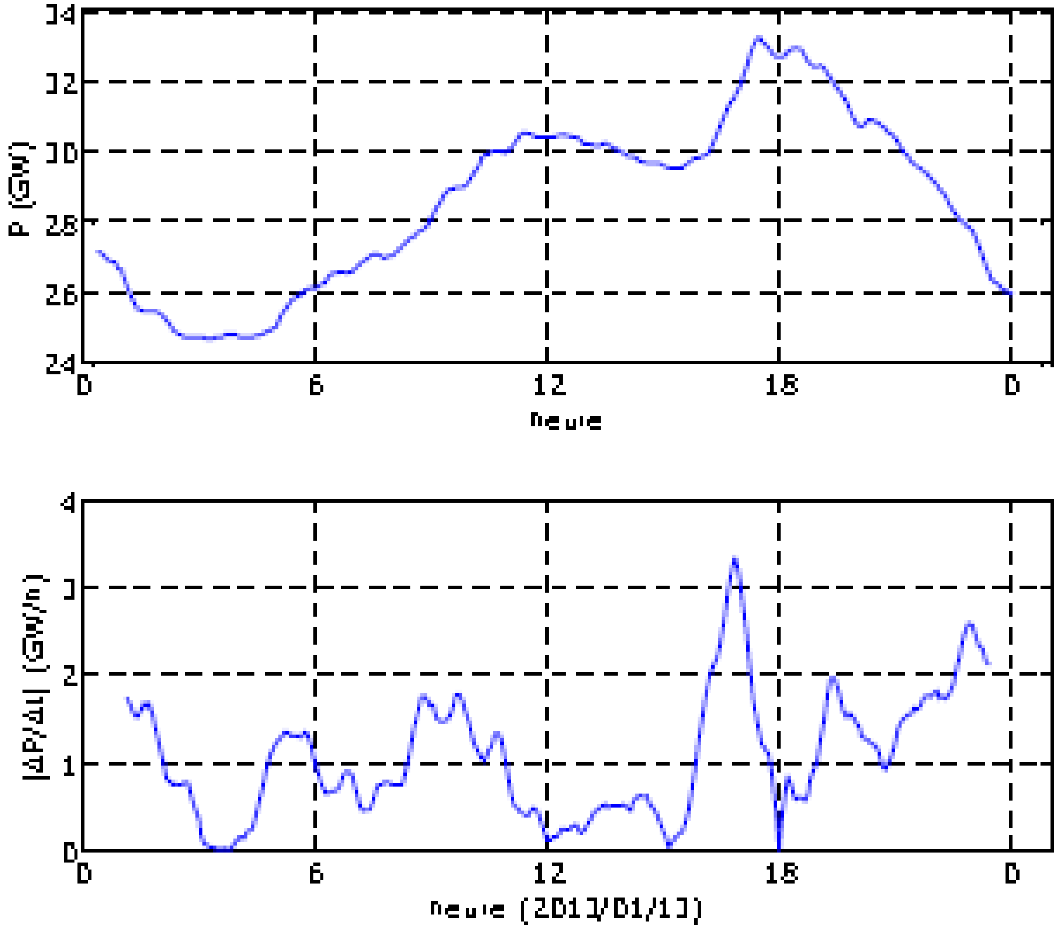




Potentiel de réduction des pertes:

- Génération: 165 TWh
- L ~ 8.25 TWh (≡ 4 alt.)
- ΔL ~ 400 GWh (idéal)

Problem context: active power ups and downs



Problem statement: control tools

Tools have deployed to generate or absorb reactive power in the transportation network:

- 170 shunt capacitators (binary)
- 120 shunt inductances (binary)
- 26 static compensators (continuous)
- 11 synchronous compensators (continuous)

Direct control:

- 190 transformers (discrete)

Problem statement: operational contraints

- No more than 10 control actions can be initiated at each hour
- Actions must be implemented sequentially
- Electrical limits on voltages, active power and reactive power must be enforced after each action
- Power flow must be feasible after each action

Problem statement

- Minimize the active power losses of the transportation network over a 24 hour-horizon
- While respecting the constraints given in the previous slide,

  as well as stationary regime constraints on voltages, active power and reactive power, and limits on control actions.

Additional operating constraints

- There is a need for an “intuitive” approach for the organization : the proposed solution approach should be “anchored”, as much as possible, on existing decision-support software:
  - LimSel, a tool that provides acceptable network configurations and limits in various settings;
  - Optimal Power Flow, linear programming tool.

Additional operating constraints

- Currently, operators are trained to operate the network in a safe and secure fashion (i.e., to avoid voltage and power violations),

  NOT TO MINIMIZE POWER LOSSES!

- The motto of the operators is:

Additional operating constraints

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  NOT TO MINIMIZE POWER LOSSES!

- The motto of the operators is:

  DON'T LOSE THE NETWORK !!!

General solution approach

- Generate a full 24-hour “long-term” plan under a “rolling horizon” scheme
- At first, each time step should correspond to an hour (a finer discretization might be implemented at a later stage for periods with steep ramps)
- The solution for the upcoming hour must be refined when all the relevant information is up-to-date (20 minutes before the hour).

The “long-term” plan

- Derived by performing a shortest path algorithm on a auxiliary configuration graph
- The configuration graph is made up of 24 layers of configurations plus a source (the current configuration) and a sink.
- There is a small set of vertices for each time period, arcs link vertices from period ***t*** to period **t+1**

The “long-term” plan

- In each time period, the first vertex corresponds to the network configuration suggested by LimSel
  - This is what must be done for security reasons
  - Incomplete (this only gives the major features, limits, contingency equipment)
  - list of equipments available for fine-tuning
- From this base configuration

  → we derive “possible” configurations

  (typically what operators would end up with)

The “long-term” plan

- We enlarge this set by generating "interesting" alternatives (small violations may be accepted)
  - We wish to capture the “big” decisions (lines, shunts, etc.)
  - These do not include decisions on continuous controls
- How this step will be performed needs further refinement!

The “long-term” plan

- The graph is completed by adding the arcs connecting successive pairs of vertex clusters
- Cost of arcs:
  - losses of period (t+1) (as computed by the Power Flow software)
  - + maintenance cost of the actions needed to perform the change in configuration
  - we also check the that the limit on the number of these changes is satisfied, otherwise the arc is removed

The next period

- We need first to complete the configuration provided by the long-term plan for the upcoming hour
- This is done using the Optimal Power Flow LP model
- At first, set all the shunts and “big controls” not appearing in the “long-term” configuration to 0
- If feasible, STOP;
- if infeasible, go to B&B (with all shunts and more)

The next period: B&B

- Branch-and-bound based on the Optimal Power Flow LP software
- We wish to exploit solutions of the continuous relaxation of the problem
- The search tree is intrinsically limited by the fact that we can perform at most 10 actions per hour
- Still need to find good rules to select variables on which one should branch on

Sequencing actions

- At the end of B&B, the configuration for the upcoming hour is fully defined
- The comparison with the current configuration yields the differences, which correspond to the actions to perform
- We must find a feasible sequence of these actions with respect to short-term limits (these are less constrained than long- or medium-term limits)
- In the following 50 minutes, we can start preparing for the next hour.

Updating the plan

- Preparing the complete solution for the next hour must be done within 10 minutes or so.
- In the following 50 minutes, we can start preparing for the next hour
  - Extend the plan by one hour
  - Reoptimize the trajectory
  - Possibly, start exploring “complete” solutions for the next hour

Conclusions

- A very interesting and challenging problem
- We believe that we have defined a solution approach that could work in practice

QUESTIONS?