

## Whither dynamic congestion management ?

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### Proposal

Irrespectively of regulatory and other implementation aspects, the essential task of the System Operator (SO) is to maintain system security (or reliability) at a specified level, without discriminating between the different actors of the electricity market and while minimising the resulting collective costs for the end-users.

Part of this job is carried out ahead in time, from several hours before the fact to a few months, or even a few years, in the context of operation planning and/or expansion planning. However, because the power system state is largely unpredictable by the SO, a significant part of his task needs to be carried out in real-time and on the basis of real-time information (provided by the control centre SCADA and short term forecasts). In present-day practice, this real-time security control activity is typically done at a rate of a quarter of an hour, and with a temporal horizon of a few hours. In our discussion we consider that Congestion Management (CM) refers to this latter context and to *all* the decisions and actions taken by the operators of the system so as to maintain the security level at a pre-specified level; the control actions can directly affect the active power injections (e.g. by purchasing positive or negative amounts of power from generators and/or consumers) or act only on the network status (e.g. by switching, tap changing, VAR control...).

The framework and software tool that has been advocated for a long time to support this CM activity is the optimal power flow approach, more precisely the Security Constrained Optimal Power Flow (SCOPF). From a conceptual point of view, what this approach helps to do is to take a decision at a certain point in time, which given the current state of affairs minimises the instantaneous costs (i.e. the costs incurred at the current time-step) and satisfies feasibility and security constraints. We call this approach the *static congestion management* approach, and suggest that it could be inappropriate for several complementary and more or less obvious reasons, and therefore leads to objections from almost all parties.

The argument is that intrinsically CM is not well modelled as a static optimisation problem, and that a more appropriate approach is to formulate it as a dynamic programming problem. In this latter case, the optimisation process takes into account information gathered at present

and past time steps and optimises the decision taken by evaluating its impact not only on the current interval but also on the future time steps within the optimisation period. This allows to take into account in a better way dynamic feasibility constraints and uncertainties about future states. Generically, we will refer to this approach as *dynamic congestion management*, not to confuse with dynamic security assessment (and control).

We will try to convince some readers that such a "dynamic congestion management" could alleviate in principle many practical difficulties encountered in static congestion management, and therefore deserves further research and development. We will also briefly discuss some recent results from computer science which are promising in terms of practical feasibility of solving large scale dynamic programming problems.

### Arguments in favour of dynamic programming

We discuss briefly some problems which we believe are not sufficiently well addressed by the SCOPF formulation.

#### Arbitration between immediate and delayed actions

In the context of security control when a congestion arises, one important question is to decide whether it should be managed immediately or whether acting can (and should) be post-poned because the cost of acting now is too high compared to the actual risk incurred by not doing so. In the context of slow<sup>1</sup> dynamics (e.g. thermal overloads, slow voltage collapses), this is also related to the arbitration between so-called preventive (pre-contingency) and corrective (post-contingency) controls. Clearly, the realization of a good compromise between preventive and corrective control is an essential although intrinsically difficult task in security control, especially because of the difficulty to estimate costs of consequences and probabilities of occurrence of the dangerous contingencies. Notice that the arbitration between immediate and delayed control actions should not only take into account the probabilities and severities of contingencies, but also the dynamics of loads and markets driving the operating state of the system since these will determine the likely electrical state of the system in the next period as well as the costs of acquiring future control resources.

<sup>1</sup>Slow enough to allow operator intervention.

We refer the interested reader to [1] for some ideas on how the arbitration between preventive and corrective control can be addressed partially by a modified SCOPF formulation. However, we believe that the “complete” solution of the security control problem would actually require a stochastic dynamic programming formulation.

#### *Multiplicity of (quasi-)equivalent solutions*

It has been reported that with the OPF approach to CM quite often we have a rather flat objective function around the (local) optimum found by the OPF algorithm. Because of this situation, the choice of one out of a large set of equivalent solutions is carried out in a way which is not dependent on the objective specified, but rather on the algorithmic implementation of the optimisation procedure. Moreover, when these algorithmic solutions are deterministic they are typically biased, in favour or against one particular market player. Even if one can use randomisation tricks to mitigate this problem, one can (and some will) always argue that decision making is arbitrary, non-transparent and in the worst case discriminating, and it is rather difficult to counter such arguments.

Since the arbitrary choice between quasi-equivalent solutions may lead to the systematic penalising of some actors in favour of some of their competitors, and hence leads to a risk of non-acceptance of new tools, one way of circumventing this problem is to include into the optimisation criterion a set of terms which penalise discrimination. This can be done by favouring solutions which in the long run (i.e. over a certain to be agreed upon period of time) equally share the effort of CM over the different actors. In other words, rather than optimising at a given time period a criterion taking into account only instantaneous costs for the SO, one should optimise over a period of time the integral of this cost plus a term measuring overall discrimination.

#### *Gaming of the CM approach by market players*

Another problem, which has been encountered in the past, is related to the fact that individual market players may be in a situation where they can game against the SO and its way of managing congestion. What these actors do is essentially taking into account the possible future situations, and especially the likely congestion, to decide whether to offer on the ancillary or on the base markets and how to fix their prices. In other words, these game players actually use some kind of (stochastic) dynamic programming formulation to optimise their decisions. Since in this game, what one player gains the other lose, we believe that the SO should also use the same dynamic programming strategy, so as to be also able to take into account the expected situation in the upcoming hours.

#### *Sub-optimality of SO induced costs*

Perhaps the most obvious motivation for the SO (and hence for the system users also) to use the dynamic programming approach to manage congestion is that it may lead to substantial reductions of costs, just like the dynamic programming formulation of unit commitment is typically able to reduce substantially operating and fuel costs of generating companies.

Of course, there are many (correct or incorrect) ways to reduce costs, but the dynamic programming approach allows to do this in a rational and in principle transparent way, without sacrificing security.

#### **CM as a practicable dynamic programming problem**

The CM problem is complex because the power system and its environment are complex, large scale, non-linear, uncertain, etc. Switching from a static (SCOPF) formulation (which is still not really used in most control centres) to a dynamic formulation, recalls the story of the dynamic state estimator advocated by academic researchers while the static one was still not accepted by the industry [2]. Just like in dynamic state estimation, modelling issues and algorithmic problems may jeopardise the idea of dynamic congestion management.

Reference [3] (under construction) aims at explaining how some recent Computer Science achievements concerning dynamic programming, could be exploited in the context of the present discussion as well as other challenging power system problems. More specifically, randomised optimisation algorithms allow to fight against the so-called curse of dimensionality in dynamic programming [4], and so-called reinforcement learning methods provide anytime algorithms providing solutions which gradually and gracefully improve through time.

A specific power system oriented research direction which might prove fruitful consists of trying to combine dynamic programming and SCOPF approaches into a single framework. For example, one could try to use reinforcement learning to learn cost functions (and possibly constraints) to inject at time  $t$  into the SCOPF formulation so as to ensure a good temporal consistence.

#### **References**

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- [4] J. Rust, “Using randomization to break the curse of dimensionality,” *Econometrica*, vol. 65, no. 3, pp. 487–516, 1997. [Online]. Available: [citeseer.ist.psu.edu/rust96using.html](http://citeseer.ist.psu.edu/rust96using.html)

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IREP Symposium 2004  
Cortina d'Ampezzo (Italy)

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## Outline

### The proposal

- Static congestion management
- → Dynamic congestion management

### Some arguments in favor of Dynamic CM

- Immediate vs. delayed actions
- Multiple solutions of SCOPF based static CM
- Market power, gaming
- Sub-optimality of static CM

### Feasibility and needs for research

## Congestion management

- Real-time decision making by system operators to
  - maintain system security above minimum
  - minimize economic impact
  - avoid discrimination and market bias
- Remarks
  - time step typically of 15 to 30 minutes
  - objectives monitored over a longer term

## Static CM

- Problem formulation
  - At time  $k$ , compute decision  $u_k$  to
    - satisfy *instantaneous* security constraints and
    - minimize *instantaneous* costs
  - Given  $x_k$ , select  $u_k$  in  $U(x_k)$  to minimize  $c_k(x_k, u_k)$
- Notation
  - $k$  : discrete time index (say 15 minutes time step)
  - $x_k$ : electrical state vector at time  $k$  (estimated)
  - $u_k$ : decision variables at time  $k$  (to determine)
  - $c_k(x, u)$  : instantaneous cost function,
  - $U(x)$  : constraints on decision variables
- NB: Constraints  $U(x)$  include feasibility and all kinds of security constraints deemed relevant (N, N-1, static, dynamic...)

## Dynamic CM

### ➤ Problem formulation

- (Assuming a state transition model :  $x_{k+1} = f(x_k, u_k, w_k)$  )
- At time  $k$ , compute a *sequence* of decisions  $(u_k, u_{k+1}, \dots, u_{k+T-1})$  to
  - satisfy security constraints and
  - minimize cost induced *over the whole time interval* ( $k, k+T-1$ )

### ➤ Remarks

- Apply  $u_k$  and refresh the sequence at the next time step
- Time step of 5 to 30 minutes
- Time horizon  $T$  of several hours to a few days
- (and we neglect faster dynamics)

## Argument/Question No1

- ### ➤ Dynamic Congestion Management can in principle reach a better security/cost tradeoff (over the long term) than static congestion management

*Would savings be significant ?*

## Argument/Question No2

- In dynamic CM one can include constraints and/or penalization terms to
  - allocate impact on market participants in a non discriminating way (whatever that means...)
  - fight against gaming and market power

***What is the impact of this on the overall security/cost tradeoff ?***

## Computational feasibility ?

Try to combine existing model-based tools

- SCOPF, DSA, DSE

with stochastic optimization and approximation techniques to solve stochastic dynamic programming problem

Can be used on-line or off-line