Optimization of Dynamic Transfer Limits in an Energy Transportation Network

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Abstract

TransÉnergie, a division of Hydro-Québec, operates a transmission network consisting of almost 300 substations and plants linked through 600 power lines. These lines transport the energy produced by around 400 alternators towards the load regions and the out-of-province transportation networks. The load regions have their own networks, operated by Hydro-Québec Distribution. The distribution networks are not considered in this project.

The power transfer capacity of the transportation network is limited. Those limits (in megawatts) are of an electrical nature (thermal limits, transient stability limits, and voltage stability limits). In order to facilitate the operation of the network (which has a radial topology), the limits are associated with bundles of lines, called corridors, and with a few crucial nodes in the network.

The transportation network has been designed to transport the peak load (∼38 GW): all the network components are then used, and the output of nearly all the alternators is maximal. Except during the few weeks per year corresponding to this peak load, the network may be and is actually incomplete because of maintenance operations. The overall production and the load depend upon the weather conditions, the transfers between the network and the neighbouring networks, and the time of day (they vary from hour to hour). The power transfer in the network thus varies a lot, and so do its limits.

The work of a team of TransÉnergie engineers consists of determining the limits for all potential network states. In order to facilitate their work, they subdivide the network into five subnetworks that are reasonably independent from one another.

In the jargon, a topology is defined as the portion of the subnetwork through with electricity actually flows, i.e., the complete subnetwork minus the equipments that are out of commission. A configuration is defined as a topology including (a) the global transfer levels in the subnetwork and the

neighbouring subnetworks, (b) specific productions, (c) the load distribution in the subnetwork (or elsewhere), (d) the reserves level, (e) the voltage levels, and (f) parameters characterizing the load and depending upon the weather. In the course of a study, it is not necessary to consider the transfers, productions, loads, reserves, and parameters, as continuous variables. Thus a configuration may be described by a vector whose components (called "elements") take discrete values. Finally, one may associate a probability with a configuration.

The number of possible configurations is huge. Even if (a) the values of many configuration components can be fixed, and (b) many configurations do not translate into realizable networks (which implies that their limits don't have to be computed), the number of configurations remains daunting.

It is impossible to compute limits for all configurations, even with the clusters available at IREQ (or those that will soon be available at TransÉnergie). Also one should not burden the network operators with too many limits. Until now, the engineers have considered a restricted number of configurations (i.e., basic ones) and a restriced number (∼50) of values for one, two, or three elements within these configurations. The outcome of a change of value for an element (called restriction or bonus, depending on its sign) is expressed as a gap between this outcome and the limit in a basic configuration. To ensure that as many configurations as possible can be realized in a secure manner, one computes the global outcome of a set of variations as the sum of the individual outcomes, although we know that this sum is an overestimate. The approach taken has the following consequences: (a) the limits are conservative; (b) the greater the difference between the network considered and the basic network, the further the limits are from their optimal values; (c) the security margin of the restrictions depends upon the associated variations. In short, the operating limits are often conservative and opportunities to transport more electricity are lost.

Our goal is to find a restricted set of variations (∼100), corresponding to restrictions or bonuses, that maximizes the limits for a set of subnetwork configurations while fixing some of the restrictions and taking the configuration probabilities into account.