Reducing the active losses in an energy transportation network

Problem submitted by IREQ

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TransÉnergie, a division of Hydro-Québec, operates a high-tension power transmission network that includes 415 substations and plants linked through 765 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.

In general the available active production is greater than the loads and the exports. The unit commitment for alternators may depend upon varied goals : minimization of production costs, limits on electrical quantities before and after failures, maximization of the transfer capacity, reduction in transport losses, and so on.

In this project we will focus on reducing the losses. The losses depend upon (a) the electrical resistance of energy transportation equipments, essentially lines and transformers, and (b) currents flowing through these equipments. These currents vary throughout the day. The behaviour of the loads and imports-exports, and hence the currents flowing through the network, is such that the reduction in losses should be monitored once every hour.

For a given transfer of active power between two network nodes, reducing the losses amounts to reducing the current by adjusting the tensions of the nodes. The tensions are particularly sensitive to the flow of reactive power. The reactive power is provided or absorbed by the alternators and by many devices spread throughout the network : shunt inductances, shunt condensators, static compensators, and synchronous compensators. The tensions are also directly controlled by variable ratio transformers, and even by line switching. The adjustment of a controlling factor depends upon its type and is continuous, discrete, or even binary. The allocation of the active production is assumed to be fixed; hence the active production is not included among the controlling factors.

The tension control, however, is subject to operational constraints, which commercial software does not take into account : (a) only a few control factors may be adjusted by the staff at the network control centre, given the time constraints and the adjustment delays; (b) the adjustments are sequential and not instantaneous; and (c) after each adjustment, the electrical quantities must be within their short-term limits (broader than the steady-state limits). Therefore the reduction in losses must be planned over an horizon greater than the current hour, if possible over a 24-hour sliding horizon.

The problem that we submit can be formulated as follows : one wishes to minimize the active losses of the transport network, on a 24-hour horizon, while respecting

- the constraints on the flow of power throughout the network (expressed as equations),
- the limits on control factors,
- the steady-state limits on electrical quantities (tensions, active power, reactive power), and
- operational constraints.