Optimal Transmission Switching (OTS)

The Optimal Transmission Switching deals with changing the transmission network topology in order to improve voltage profiles, increase transfer capacity, and reduce the market power of some market participants. The topology is changed, primarily by the deliberate outage of some specific transmission lines. Further, one may also consider, the use of phase shifters (which change the angle difference between two adjacent buses) and other Flexible Alternating Current Transmission System (FACTS) devices (which can, among others, increase/decrease the impedance of two adjacent buses). The change in topology can be done by one or combination of the following actions:

- Deliberate outage of some specific transmission lines
- Adding phase shifters (these devices can change the angle difference between two connected buses)
- Adding Flexible Alternating Current Transmission System (FACTS) devices (these devices can increase/decrease the impedance of two connected buses in the system)
- Adding reactive series impedance (these devices can increase the impedance of two connected buses in the system)

References

1- R. P. O'Neill, R. Baldick, U. Helman, M. H. Rothkopf and W. Stewart, "Dispatchable transmission in RTO markets," in IEEE Transactions on Power Systems, vol. 20, no. 1, pp. 171-179, Feb. 2005.

2- N-1 DCOPF formulation: Hedman, Kory W., et al. "Optimal transmission switching with contingency analysis." Power Systems, IEEE Transactions on 24.3 (2009): 1577-1586.

Models

The idea of topology dispatch has been studied for several decades [1,2,3,4], although it has gained much attention recently thanks to [4, 5], who have demonstrated how it can provide the electricity market with greater efficiency and competition. This idea was further developed in [6,7,8,11] by not only considering the normal operation but also the N-1 contingencies and financial transmission rights (FTR) and Flexible Alternating Current Transmission System (FACTS) devices. The unit commitment problem constrained by transmission system is solved in [10]. Much of this early modelling work has been performed using linear programming (LP) approximations of the alternating-current power flow and can be applied to large-scale transmission systems. An alternative LP formulation has been studied by [9].

In order to capture the complexity of the alternating-current transmission, a variety of non-linear models have been suggested. [14] proposes an SOCP relaxation and [15] extends it. [16] have experimented with the sparse variant of the method of moments for two formulations, lift-and-branch-and-bound using SDP relaxations, and certain piece-wise linearisations. [12,17] studies a variety of heuristics based on non-linear optimisation. Generally, convergent methods considering the line-use decision within the alternating current model [14,15,16] have turned out to be challenging.

Methods

For mixed-integer linear-programming (MILP) models, there has been much recent progress in general-purpose optimisation software based on branch-and-bound-and-cut. Often, modest instances considering either piece-wise linearisations or uncertainty, can be solved exactly using the general-purpose software. Decompositions, such as Benders decomposition, Lagrangian relaxation, or column generation [10,11] are frequently used beyond that.

For mixed-integer non-linear programming (MINLP) models, the methods are an active area of research [12,13,14,15,16,17], considering the limitations of the general-purpose non-linear programming optimisation software. [16] surveys three convergent approaches, based on piece-wise linearisation of certain higher-dimensional surfaces, based on the method of moments, and based on combining lifting and branching. The preliminary conclusion is that the combining lifting and branching may be the most promising.

See also Transmission expansion planning, which is structurally very closely related, although the uncertainty is often modelled differently. Note also one would often [11] like to expand the network knowing that one can perform switching later.

Software

PowerTools (http://hhijazi.github.io/PowerTools/) is a mathematical programming library for Power Systems optimization. PowerTools is an open source c++ mathematical modeling platform linking to state-of-the-art optimization solvers. It implements problems such as Optimal Power Flow, and Optimal Transmission Switching, while benefiting from cutting-edge research results. These include smart on/off constraints modeling, efficient bound propagation, domain-specific cut generation techniques and tight convexification procedures providing global optimality guarantees. PowerTools is still under active development, future versions will include Gas expansion and Unit Commitment models, decomposition methods, multi-threading, and support to additional solvers such as Cplex, Bonmin and others. Note that PowerTools is already used by another open-source project for Smart Grid simulation: http://nicta.github.io/SmartGridToolbox/

Surveys (of pioneering work):

[1] H. Glavitsch, “State of the art review: switching as means of control in the power system,” International Journal Electric Power Energy Systems, vol, 7(2): 92-100, 1985.
[2] A. A. Mazi, B. F. Wollenberg, and M. H. Hesse, “Corrective control of power system flows by line and bus-bar switching,” IEEE Trans. Power Syst., vol. 1(3): 258-264, 1986.
[3] R. P. O'Neill, R. Baldick, U. Helman, M. H. Rothkopf and W. Stewart, "Dispatchable transmission in RTO markets," in IEEE Transactions on

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[4] Hedman, Kory W., et al. "Optimal transmission switching with contingency analysis." Power Systems, IEEE Transactions on 24.3 (2009): 1577-1586.

Optimization Methods:

MIP (CPLEX):

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Grid Resiliency

smartwire: http://www.smartwires.com/
They are using plexus to find the optimal location of the impedance in the system using LPs
Software:
- PowerTools by Hijazi: http://hhijazi.github.io/PowerTools/

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