Models of congestion management in zonal markets

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Outline

Models of congestion management

- Total re-optimization
- Minimal re-dispatch
- Heuristic

Next research agenda

- Reactive topology control
- Proactive topology control

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How to model congestion management ?

Two possible approaches :

1. Mathematical optimization
2. Heuristics

I prensent three models :

1. Total re-optimization
2. Minimal re-dispatch
3. PTDF-based heuristic

Total re-optimization

Idea

Find the dispatch that minimizes total production cost while respecting day-ahead net positions and network constraints

$$\min \sum_{g \in G} P_g Q_g v_g$$

$$\text{s.t.} \sum_{g \in G(n)} Q_g v_g - \sum_{l \in L(n,\cdot)} f_l + \sum_{l \in L(\cdot,n)} f_l = \sum_{c \in C(n)} Q_c, \quad n \in N$$

$$\sum_{g \in G(z)} Q_g v_g - p_z^{\text{DA}} = \sum_{c \in C(z)} Q_c, \quad z \in Z$$

$$-F_l \leq f_l \leq F_l, \quad \forall l \in L$$

$$f_l = B_l(\theta_{m(l)} - \theta_{n(l)}), \quad \forall l \in L$$

Minimal re-dispatch

Idea

Find the dispatch that minimizes the deviation with the previous dispatch while respecting net positions and network constraints

$$
\begin{aligned}
\min \quad & \sum_{g \in G} |v_g - v_g^{\mathrm{DA}}| \\
\text{s.t.} \quad & \sum_{g \in G(n)} Q_g v_g - \sum_{l \in L(n,\cdot)} f_l + \sum_{l \in L(\cdot,n)} f_l = \sum_{c \in C(n)} Q_c, \quad n \in N \\
& \sum_{g \in G(z)} Q_g v_g - p_z^{\mathrm{DA}} = \sum_{c \in C(z)} Q_c, \quad z \in Z \\
& -F_l \leq f_l \leq F_l, \quad \forall l \in L \\
& f_l = B_l(\theta_{m(l)} - \theta_{n(l)}), \quad \forall l \in L
\end{aligned}
$$

Heuristic

Idea

For each congested line, decrease the production of the generator that influences the most the flow on this line (using the PTDF). Restore power balance by increasing the dispatch of generators that don't contribute to congestion.

Heuristic (2)

Algorithm 1: RCH (Remove Congestion Heuristic)

Input: initial dispatch v

Output: new dispatch that respects network constraints

let L_{cong} be the set of congestionned lines sorted by congestion magnitude
while $L_{cong} \neq \emptyset$ **do**
    for *every* $l \in L_{cong}$ **do**
        let N_{sorted} be the set of nodes sorted w.r.t. $\text{PTDF}_{l,n}$
        for $n \in N_{sorted}$ *untill* $f_l \geq F_l$ **do**
            for $g \in G(n)$ *untill* $f_l \geq F_l$ **do**
                $v_g = \max\{v_g - \frac{(f_l - F_l)}{\text{PTDF}_{l,n}}, 0\}$
            restore power balance
    update L_{cong}

Results of one snapshot on CWE

Cost of re-dispatch	
Total re-optimization	163,721 €
Minimal re-dispatch	888,578 €
Heuristic	1,670,110 €

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Coming up

How to model transmission switching in zonal markets ?

Two cases :

1. Reactive topology control
   The topology can be optimized to relieve congestion
2. Proactive topology control
   The day-ahead schedule is established for the best topology

Reactive Transmission Switching

Idea

In the case of re-dispatch with optimization, add a binary variable to model the state of each line

$$
\begin{aligned}
\min \quad & \sum_{g \in G} P_g Q_g v_g \\
\text{s.t.} \quad & \sum_{g \in G(n)} Q_g v_g - \sum_{l \in L(n,\cdot)} f_l + \sum_{l \in L(\cdot,n)} f_l = \sum_{c \in C(n)} Q_c, \qquad n \in N \\
& \sum_{g \in G(z)} Q_g v_g - p_z^{\text{DA}} = \sum_{c \in C(z)} Q_c, \qquad z \in Z \\
& - z_l F_l \leq f_l \leq z_l F_l, \qquad \forall l \in L \\
& f_l - B_l(\theta_{m(l)} - \theta_{n(l)}) \leq M(1 - z_l), \qquad \forall l \in L \\
& f_l - B_l(\theta_{m(l)} - \theta_{n(l)}) \geq -M(1 - z_l), \qquad \forall l \in L
\end{aligned}
$$

Proactive Transmission Switching with N-1 security

$$
\begin{aligned}
P = \{ & p \in \mathbb{R}^{|Z|} : \exists(\bar{v}, f, \theta) \in [0,1]^{|G|} \times \mathbb{R}^{|L|} \times \mathbb{R}^{|N|} : \\
& \sum_{g \in G(z)} Q_g \bar{v}_g - p_z = \sum_{c \in C(z)} (1 - x_c) Q_c, \quad z \in Z \\
& \sum_{g \in G(n)} Q_g \bar{v}_g - \sum_{l \in L(n,\cdot)} f_l + \sum_{l \in L(\cdot,n)} f_l = \sum_{c \in C(n)} (1 - x_c) Q_c, \quad n \in N \\
& - F_l \le f_l \le F_l, \quad \forall l \in L \\
& f_l = z_l B_l (\theta_{m(l)} - \theta_{n(l)}), \quad \forall l \in L \}
\end{aligned}
$$

- Adaptive Robust Optimization with MIP recourse

$$
d(\bar{p}, p) = \max_{u \in U} \min_{p \in P} |\bar{p} - p|
$$

Thank you

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