LMP Project outline and key questions to be discussed

August 23, 2018

- we take the structure of the grid from 118 bus RTS test case (i.e. node connections and reactances);
- assume some costs for generators and utilities of consumers + constraints on demand and supply (`Q1: How do we do that? A separate question -- how do we assume fixed costs?`);
- formulate a Unit commitment with DC flow formulation
  - `Q2: seems like I need help with flow equations. Are they correct?`;
  - `Q3: am I right with this DC flow? is omitting reactive power -- fair?..`
- solve the problem in this setting with a standard solver (CBC or Gurobi – we'll see what will work out);
- calculate different pricing schemes and try to compare them on (hopefully) nice graphs:
  - figures that will allow to compare amounts of out-of-market corrections vs. price level;
  - `Q4: are we interested in looking at prices/consumers' costs geographical structure under different pricing schemes?`
- generate some more variants of demand/supply distribution over existing grid and see if anything changes

Is this what we discussed? Overall, I have a feeling that I miss some industrial or field-specific expertise, what's interesting and what's not. `Q5: I am not sure I completely can see a story behind this. Or is it just too early for that? I was just wondering what we were looking for in modeling results...`

1 Data preparation

First, I parse the data of the 118 bus ieee rts test case and wrap a data structure around it (I'd make a parser – I believe, it is just several lines of code)

- read the data to a dataframe (or how it is called in Julia);
- calculate necessary matrices – bus admittance matrix (for G 's and B 's) for sure. Probably, something else (e.g. I am not sure if I need to calculate this kind of *connectedness* matrix, that was called A in the lectures on DC-OPF).

2 What we have, in the dataset:

- buses – both load (demand) and generation (as far as I understand – for some specific operation mode);
- branches – including resistance, reactance;
- grid structure (src-dest node for each branch);

For your convenience, I attached both the data and description.

3 What we do NOT have:

- production costs;
- demand utility (i.e. any proxy for consumers' bids);
- surprisingly, I do not see any constraints on maximum flows through branches;
- min and max demand and generator volumes.

So, no surprise – these are flow data, not market data.

4 Based on our conversation, what we can do:

4.1 Assume some data that we miss:

- generators' and consumers' bids, $d^{\max}$'es and $p^{\max}$'es. a separate question, how do we do that – in per-units or not; based on some real data or not;
- generators' fixed costs of start-up (if this is something that we are going to focus on);

4.2 Formulate the following unit-commitment problem

market surplus optimization (consumers' surplus minus generators' costs):

$$\text{maximize}_{d_i,p_g} \sum_{i\in d} b_i d_i - \sum_{g\in g}(c_g p_g + c_g^{su} z_g)$$

under the following constraints:

$$\begin{aligned}
\sum p_g - \sum d = \sum_j f_{ij}^p &\leftarrow \text{nodal power balance (active), node } i\\
\sum q_g - \sum q_d = \sum_j f_{ij}^q &\leftarrow \text{nodal power balance (reactive), node } i\\
f_{ij}^p = V_i V_j\left[G_{ij}\cos\theta_{ij} + B_{ij}\sin\theta_{ij}\right] - G_{ij}V_i^2 &\leftarrow \text{active power flow}\\
f_{ij}^q = V_i V_j\left[G_{ij}\sin\theta_{ij} - B_{ij}\cos\theta_{ij}\right] + (B_{ij} - B_{ij}^s)V_i^2 &\leftarrow \text{reactive power flow}\\
\left(f_{ij}^p\right)^2 + \left(f_{ij}^q\right)^2 \leq f_{ij}^{\max} &\leftarrow \text{maximum flow constraint}\\
p_g^{\min} z_g \leq p_g \leq p_g^{\max} z_g &\leftarrow \text{minimum active power production}\\
q_g^{\min} z_g \leq q_g \leq q_g^{\max} z_g &\leftarrow \text{minimum reactive power production}\\
V_i^{\min} \leq V_i \leq V^{\max} &\\
\theta^{\min} \leq \theta_i \leq \theta^{\max} &\\
\theta_{ij} = \theta_i - \theta_j \quad ; \quad \theta_1 = 0 \quad ; \quad z_g \in \{0,1\} &
\end{aligned}$$

(I am embarrassed to admit that I am not quite sure regarding flow equations. Could you pls recommend to read something on the derivation of these?).

4.3 Decide, what we want to demonstrate with this illustration – and simplify

I suppose, we want to land different pricing mechanisms to more or less real grid, in particular, to "catch" effects of:

- presence of lines' impedance, in the network of more complicated topology
- maybe some effects concerning different load and demand allocation?
- are we interested in congestion? I mean, maximum flow constraints for branches?

Why I am thinking about this – I am trying to understand the simplest possible setting that would still allow to look at these effects. So, what do we start with? DC approximation? I.e. voltages=1, resistances=0, (reactance as it is in the source data) voltage angles are small ($\cos\theta_{ij} = 1$, $\sin\theta_{ij} = \theta_{ij}$). Reactive power is not in the objective, so I can omit this reactive part altogether (although, I am not sure what to do with my max flow constraint). In this case I am left with MILP, right? it seems like this is exactly what we want.

4.4 Calculate different pricing schemes in this simple setting

Starting with:

- Plain LMPs (λ's)
- DPA
- IP, IP+
- "ELMP" (just relax integrality constraints and calculate uplifts to ensure incentive compatibility)

4.5 Maybe simulate different bids – consumers' (b_i) and generators' (p_i) ones

to see if the relative position of different pricing methods changes depending on the grid configuration.