Complex Renewable Energy Networks

(SoSe 2017, FIAS & Goethe-Universität Frankfurt)

HomeWork Sheet IV

To be prepared for the exercise session on Wednesday, 28.06.2017.

Problem IV.1 (generation investment and screening curves). Consider the generation investment optimisation problem at a single node with inelastic demand from slides 18-24 in Lecture 8. In this problem we will demonstrate the relationship between the optimisation problem and the screening curve.

In this problem we had S generators with optimised capacities G_s^*, variable costs o_s and fixed costs c_s. They are ordered according to variable cost $o_{s-1} < o_s$. The final generator $s = S$ with $c_S = 0$ and $o_S = V$ (Value of Lost Load) corresponds to load shedding.

Recall that the market price is set by the variable cost of the generator at the top of the merit order, so that $\lambda = o_m$ if $\sum_{s=1}^{m-1} G_s^* \leq d < \sum_{s=1}^{m} G_s^*$. At the optimum we had the relation

$$c_s = \sum_{t|\lambda_t^* > o_s} (\lambda_t^* - o_s)$$

Show that this can now be translated to a statement involving probabilities for the load:

$$c_s = \sum_{m=s+1}^{S} (o_m - o_s) P\left(\sum_{s'=1}^{m-1} G_{s'}^* \leq d < \sum_{s'=1}^{m} G_{s'}^*\right)$$

What happens at $s = S$?

Using the substitution $\theta_m = P\left(d \geq \sum_{s'=1}^{m} G_{s'}^*\right)$ and noting that for $s = S$, $\theta_S = 0$ since load shedding capacity G_S^* can be built at no cost, show that these equations can be rewritten recursively

$$c_s + \theta_s o_s = c_{s+1} + \theta_s o_{s+1} \qquad \forall s = 1, \ldots S-1 \ .$$

This equation defines our screening curve. It allows us to solve for the θ_s for $s = 1, \ldots S-1$ in terms of the costs c_s and o_s, which thus allows us to find the G_s^* if we have the demand duration curve (see the next question).

Problem IV.2 (duration curves and generation investment). Let us suppose that demand is inelastic. The demand-duration curve is given by $d(z) = 1000 - 1000z$ where $z \in [0, 1]$ represents the probability of time the load spends above a certain value, i.e. $P(d > 750) = d^{-1}(750) = 0.25$. Suppose that there are three different types of generation with a variable cost of 10, 20 and 50 €/MWh, together with load-shedding at 1000€/MWh. The fixed costs of these generation types are 15, 5 and 1 €/MWh, respectively. Find the optimal mix of generation in this system. (Hint: first find the θ_s.)