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Value of a Generator Construction Option in a Transmission Network under Demand Uncertainty

Background

Whether to build a new power plant at a community or transmit from another community to meet its demand is a significant decision for generation and transmission planners as such a decision has significant consequence on labor and capital requirements as well as the entire transmission network.

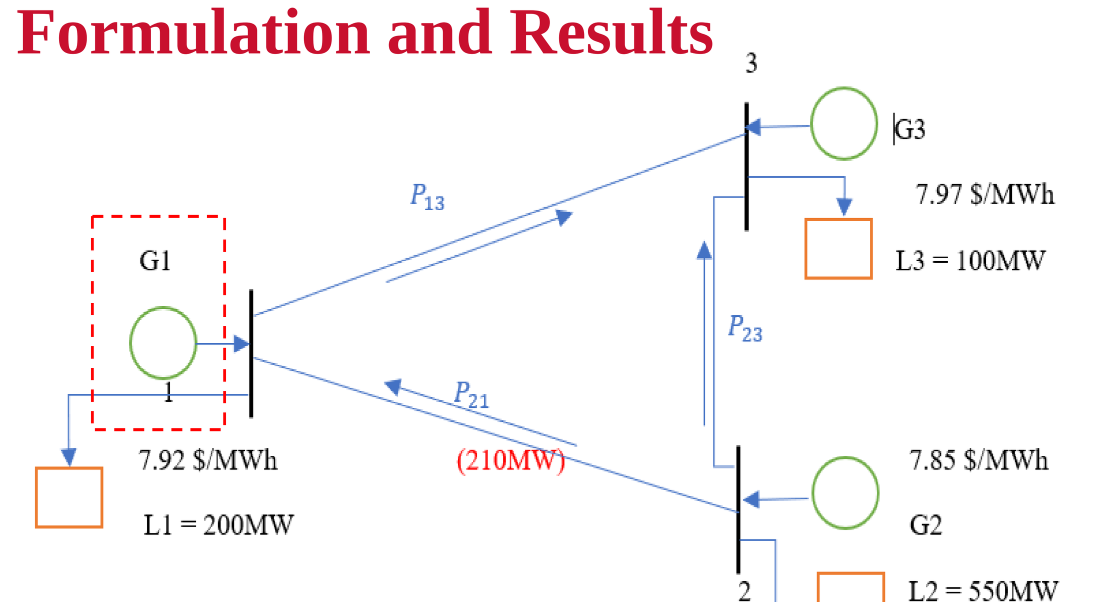
Volatile electricity demand

Electric power operations are uncertain and often volatile. For example, the recent power outage in Texas led to a residential bill that is as high as $17,000 for a few days of electricity. The locational marginal price for some communities remained near $9,000/MWh for several days

Research Question

- Adding a generator to a network changes the total power flow
- As a result, the locational marginal prices at different nodes also change
- Ultimately, some nodes get a monetary benefit from the added generator
- ***What is the value of license for the generator considering the benefit?***

Model Formulation and Results



3-bus network

Objective Function: minimize $(MC_1 \times G_1 + MC_2 \times G_2)$

Decision variables are G_1, G_2, G_3 and $\theta_1, \theta_2, \theta_3,$ and P_{12}, P_{13}, P_{23}

Constraints:

100×[Bx]θ= P_{gen} - P_{load}

$P_{ij} = 100 * B_{ij}(\theta_i - \theta_j)$
$= 100 * (\theta_i - \theta_j)/(-x_{ij})$

MC_i = marginal cost of bus *i*
G_i = generation at bus *i*
θ_i = phase angle for bus *i*
P_{ij} = Power-flow in line *i-j*
P_{load_i} = demand load at bus *i*

Power-flow in each branch:

$P_{ij} = 100 * B_{ij}(\theta_i - \theta_j) = 100 * (\theta_i - \theta_j)/(-x_{ij})$

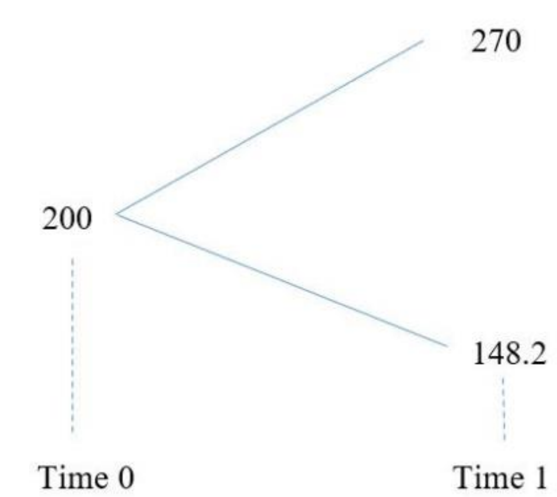
Transmission limit constraints:

$$100 * (\theta_i - \theta_j)/x_{ij} \le P_{ijmax}$$
$$100 * (\theta_j - \theta_i)/x_{ij} \le P_{ijmax}$$

Results:

When the load is 200 MW or 148.2 MW at bus 1, the LMP at all buses will be 7.85 $/MWh. Whereas when the load at bus 1 is 270 MW in case 1, the values of LMP at buses 1, 2 and 3 are 8.045 $/MWh, 7.85 $/MWh and 7.97 $/MWh, respectively. And the values of LMP at buses 1, 2 and 3 in case 2 are 7.92 $/MWh, 7.85 $/MWh and 7.89 $/MWh, respectively

Demand lattice



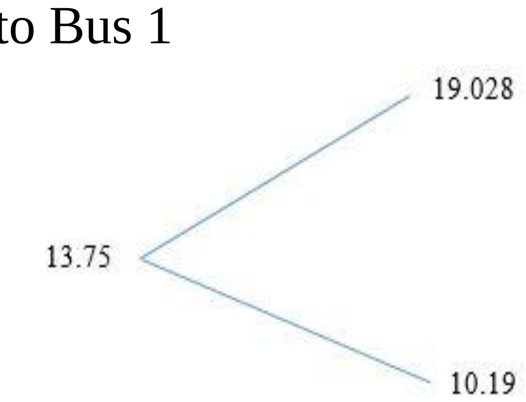
Demand lattice (in MW)

Drift $(\mu) = 15\%/year$
Risk free discount rate (r_f) = 4.879%
Volatility $(\sigma) = 30\%/year$
Time step $(\Delta t) = 1\ year$
Up-factor (u) = $e^{\sigma\sqrt{\Delta t}} = 1.35$
Down factor (d) = $1/u = 0.741$
Initial demand at bus 1 = 200 MW
Total construction cost = $100,000
Risk neutral probability , $q = (e^{r_f} - d)/(u - d) = 0.5074$

Evaluation of license

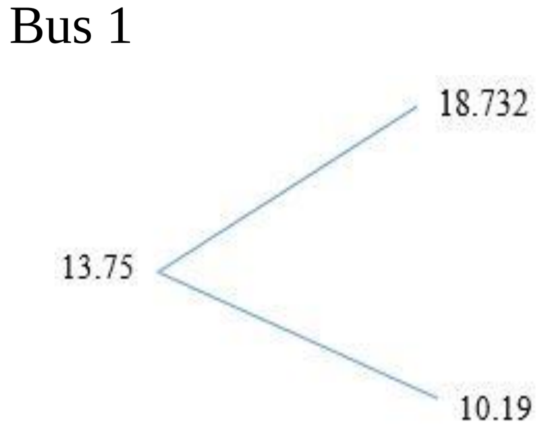
Bus-based license evaluation

Case 1: Not adding a generator to Bus 1

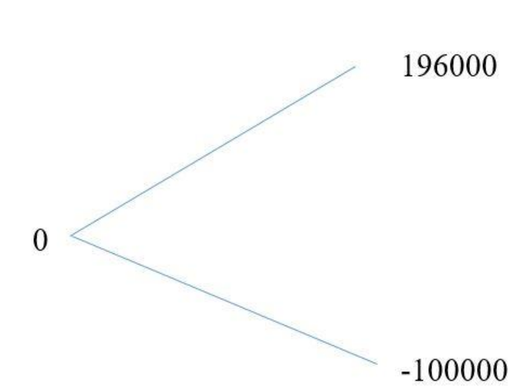


Cost lattice ($ million)

Case 2: Adding a generator to Bus 1



Cost lattice ($ million)

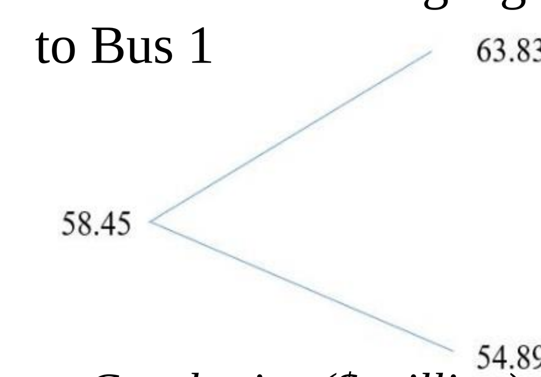


Net benefit after paying the construction cost (in $)

The expected net benefit in the risk neutral world after one year from the starting period is- $196000 \times 0.5074 - \$100\,000 \times 0.4926 = \$50{,}190.4$ At the starting period, discounted expected net benefit in the risk neutral world is- $50190.4 \times e^{-0.04879} = \$47{,}800.4$

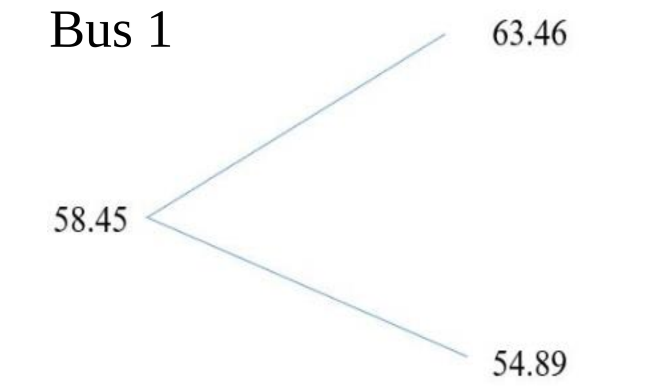
Grid-based license evaluation

Case 1: Not adding a generator to Bus 1

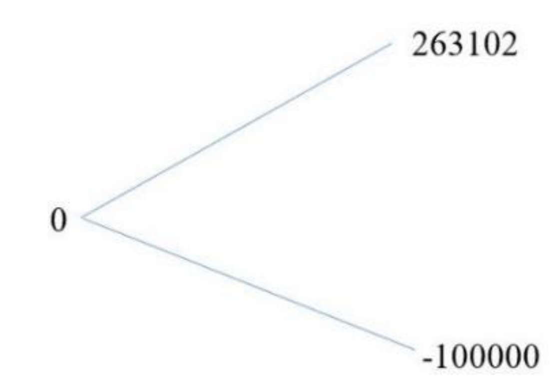


Cost lattice ($ million)

Case 2: Adding a generator to Bus 1



Cost lattice ($ million)



Net benefit after paying the construction cost (in $)

The expected net benefit in the risk neutral world after one year from the starting period is - $263102 \times (0.5074) - 100000 \times (0.4926) = \$84237.9548$

At the starting period, discounted expected net benefit in the risk neutral world is: $84237.9548 \times e^{-0.04879} = \$80226.64$

Economic consequence

- Adding a generator at bus 1 not only reduces the LMP at bus 1 but also reduces the LMP at bus 3.
- Due to the added benefit of bus 3, the license value is much higher when the whole grid's cost is considered

Future Research

- Adding transmission lines to the network and check how it impacts the whole power flow
- Building a power plant is a long-term project. The binomial lattice model can be expanded for 30 years to enhance the practicality of the model

References

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