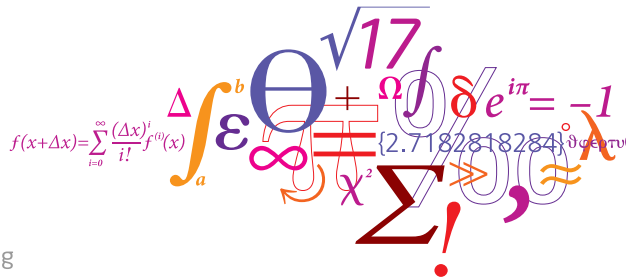# Market power in electricity markets

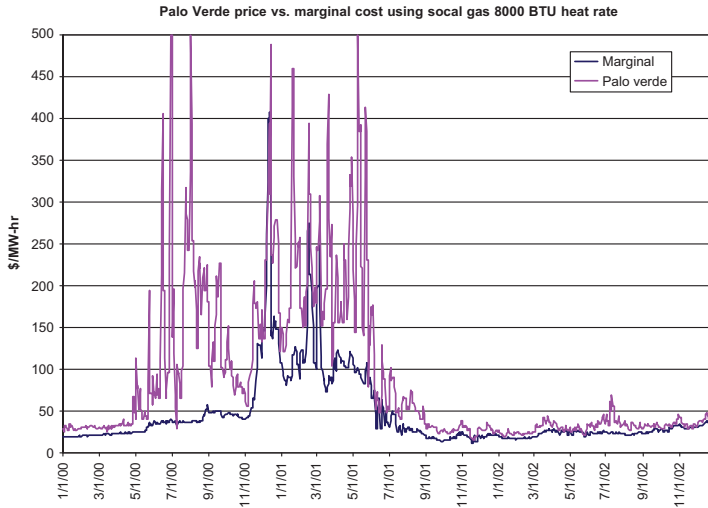Strategic behavior, free-riders, spiteful bidders, ...

Vladimir Dvorkin

Technical University of Denmark (DTU)

California energy crisis

Palo Verde price vs. marginal cost using socal gas 8000 BTU heat rate

California energy crisis

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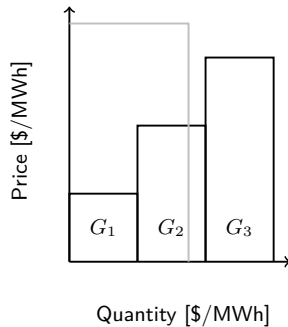
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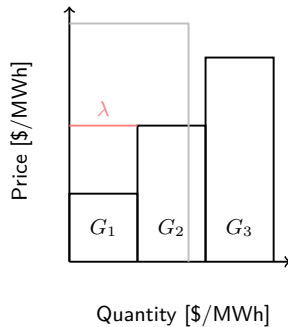
👉 Check this little documentary
https://www.youtube.com/watch?v=dvLZBv8HsO4

Outline

- Illustrative example

- Modeling market power

- Numerical experiments
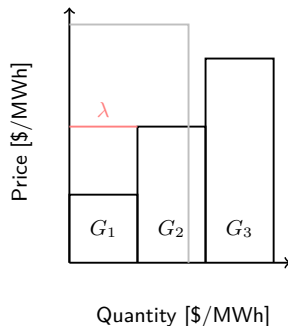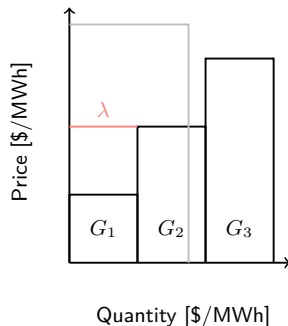
- References

Let's make a thought experiment

Quantity [$/MWh]

Quantity [$/MWh]

Let's make a thought experiment

☺ Assume that you are a trader and operate unit G_1

Quantity [\$/MWh]

Let's make a thought experiment

- Assume that you are a trader and operate unit G_1
- You need to chose the price bid that maximizes your profit. What is your objective function?

Quantity [\$/MWh]

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☺ Assume that you are a trader and operate unit G_1

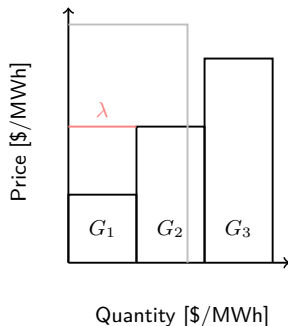☺ You need to chose the price bid that maximizes your profit. What is your objective function?

$$(\lambda - c_1)p_1 \leftarrow \mathsf{max}$$

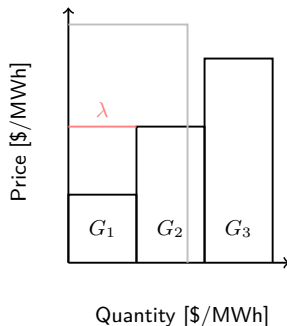where λ - price, c_1 - cost and p_1 - scheduled quantity of unit G_1

Quantity [$/MWh]

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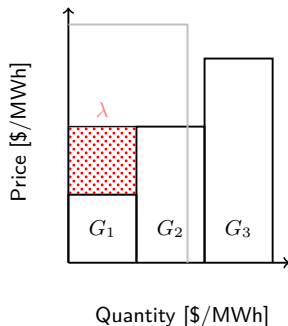
- What is your profit if you bid your true marginal cost?

Quantity [$/MWh]

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DTU

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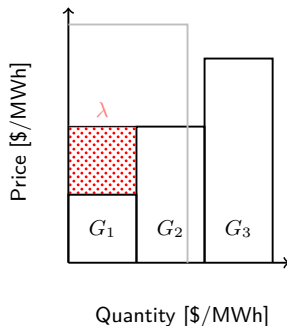- What is your profit if you bid your true marginal cost?

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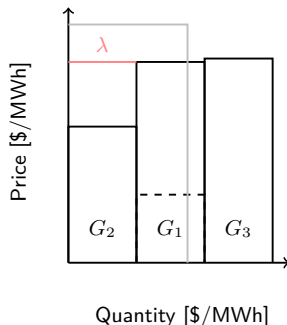- Is their an incentive to deviate?

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☺ What is your profit if you bid your true marginal cost?

☺ Is their an incentive to deviate? - Yes!

Quantity [$/MWh]

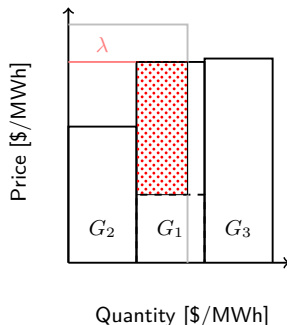# Let's make a thought experiment

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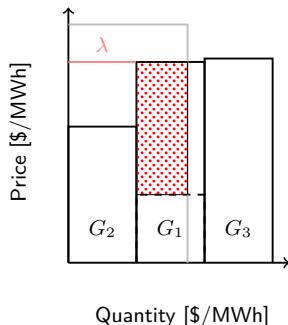- You need to chose the price bid that maximizes your profit. What is your objective function?

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Market power in electricity markets   7.5.2018

Let's make a thought experiment

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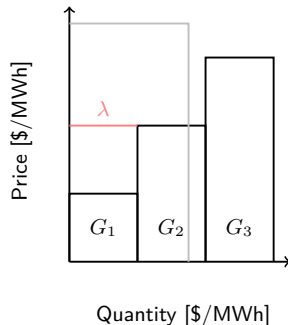
☞ Is their an incentive to deviate? - Yes!

Some observations:

– By bidding strategically, G_1 can significantly increase its profit

– Unit G_2 is a free-rider

– Operating cost can be drastically increased!

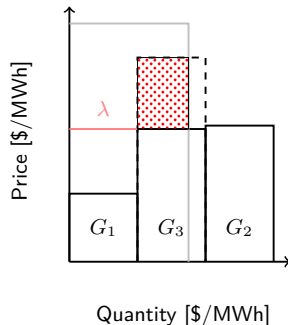Price [$/MWh] (vertical axis), Quantity [$/MWh] (horizontal axis), with λ, G_2, G_1, G_3

Let's make a thought experiment

☻ What about G_3 that is currently out of market? Can you do something to make it profitable?
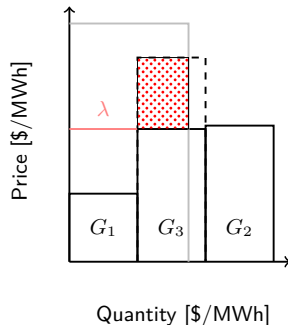

Quantity [\$/MWh]

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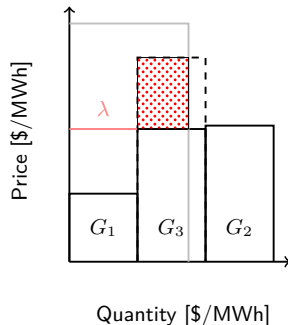- What is your objective function in this case?

Quantity [$/MWh]

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- What about G_3 that is currently out of market? Can you do something to make it profitable?
- Sure you can! But it will take some time
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$$(\lambda - c_2)p_2 \leftarrow \min$$

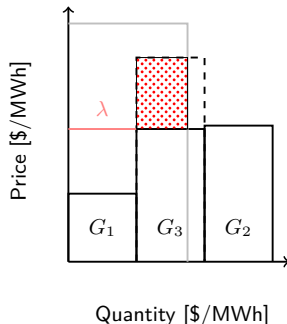where λ - price, c_2 - cost and p_2 - scheduled quantity of unit G_2

Quantity [$/MWh]

Let's make a thought experiment

Price [$/MWh]

G_1 G_3 G_2

Quantity [$/MWh]

- What about G_3 that is currently out of market? Can you do something to make it profitable?
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Some observations:

– Market power is not only about profit maximization. It could be exercised to damage others' standing

– Indeed, G_3 is a spiteful bidder!

– G_3 is interested in the short-term loss-making strategy to gain more significant long-term benefits

☛ Through trials and errors?

How can we compute the optimal bidding strategy?

👉 Through trials and errors? - Quite realistic! By trying different strategies, a trader can learn the ones that bring the largest benefit

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DTU

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- 👉 In this case, we need to build a decision-making tool that will take into account all possible strategies and produce the optimal one (up to precision of our believes...)
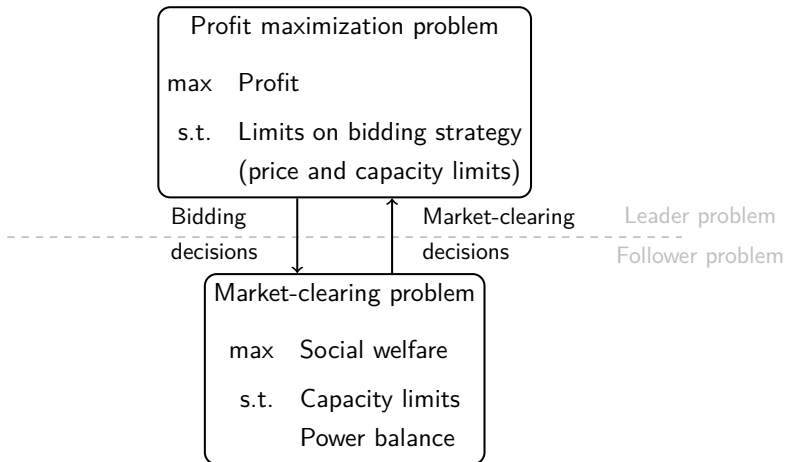
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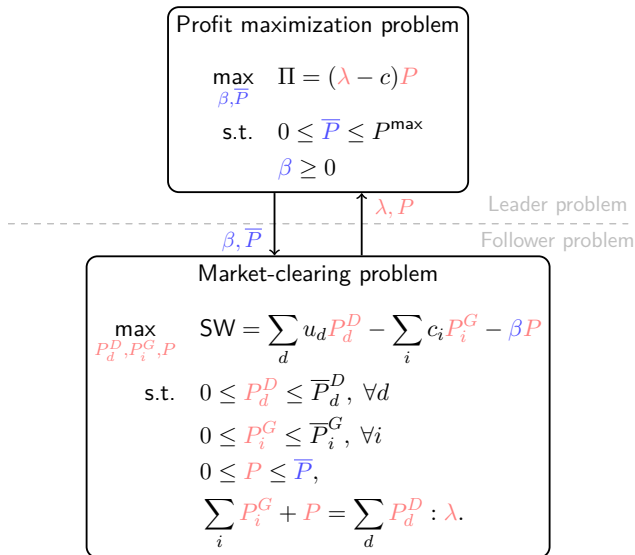## How can we compute the optimal bidding strategy?

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☛ We will solely focus on *Stackelberg game*

Stackelberg game

Profit maximization problem

$$\max_{\beta, \overline{P}} \quad \Pi = (\lambda - c)P$$

$$\text{s.t.} \quad 0 \leq \overline{P} \leq P^{\mathsf{max}}$$

$$\beta \geq 0$$

Leader problem

$\beta, \overline{P}$ — λ, P

Follower problem

Market-clearing problem

$$\max_{P_d^D, P_i^G, P} \quad \mathsf{SW} = \sum_d u_d P_d^D - \sum_i c_i P_i^G - \beta P$$

$$\text{s.t.} \quad 0 \leq P_d^D \leq \overline{P}_d^D, \ \forall d$$

$$0 \leq P_i^G \leq \overline{P}_i^G, \ \forall i$$

$$0 \leq P \leq \overline{P},$$

$$\sum_i P_i^G + P = \sum_d P_d^D : \lambda.$$

- 👉 Three-node system with one wind and two conventional units

- 👉 Loads are inelastic, and the price-cap is set to 200$/MWh

- 👉 We are aiming at studying the market power of unit G_2
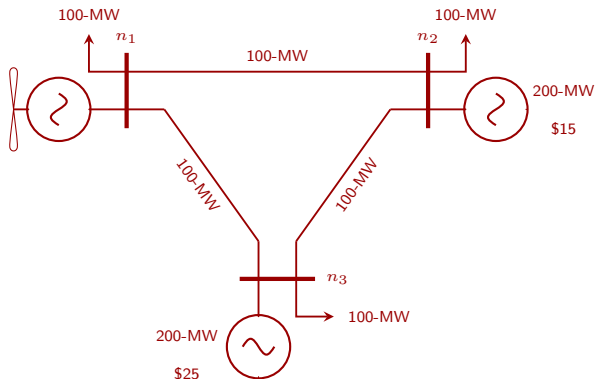
👉 We will study the market outcomes under different wind penetration levels

👉 Three cases:

– G_2 - **non-strategic**, i.e. it enters the market with actual production cost. This corresponds to the *perfect competition*

$$\max \quad (\lambda - c_2)p_2$$
$$\text{s.t.} \quad \beta = c_2$$

where λ - price, c_2 - cost, p_2 - scheduled quantity, β - price bid

– G_2 - **strategic and profit-maximizer**. It aims at finding such price bid that maximizes its profit

$$\max \quad (\lambda - c_2)p_2$$
$$\text{s.t.} \quad \beta \geq 0$$

– G_2 - **strategic and spiteful**. It aims at finding such price bid that minimizes rivals' profits

$$\min \quad (\lambda - c_1)p_1 + (\lambda - c_3)p_3$$
$$\text{s.t.} \quad \beta \geq 0$$

Let's study the market power of the unit at node two

G_2 - non-strategic

Optimal bid [\$/MW]

Profits [\$1000]

Cost [\$1000]

Wind penetration [MW]

- G_1
- G_2
- G_3

G_2 - non-strategic | G_2 - strategic, profit-maximizer

Optimal bid [$/MW]

Profits [$1000]

Cost [$1000]

Wind penetration [MW]

G_1
G_2
G_3
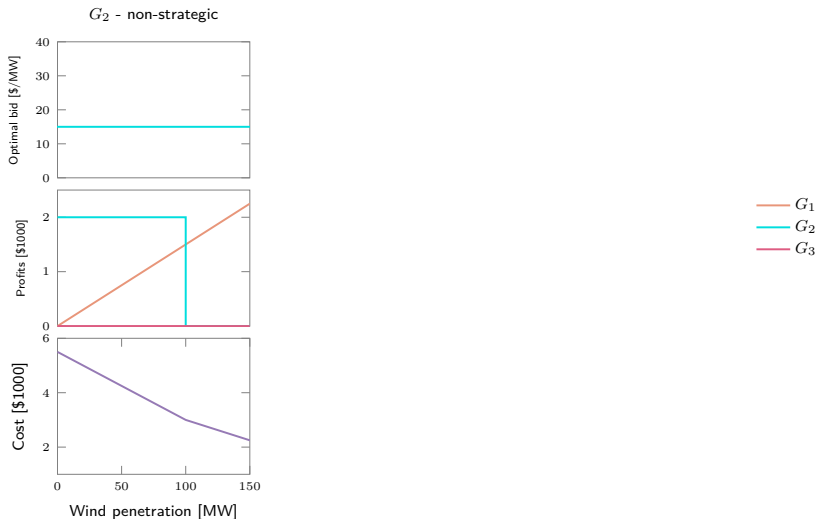
Let's study the market power of the unit at node two

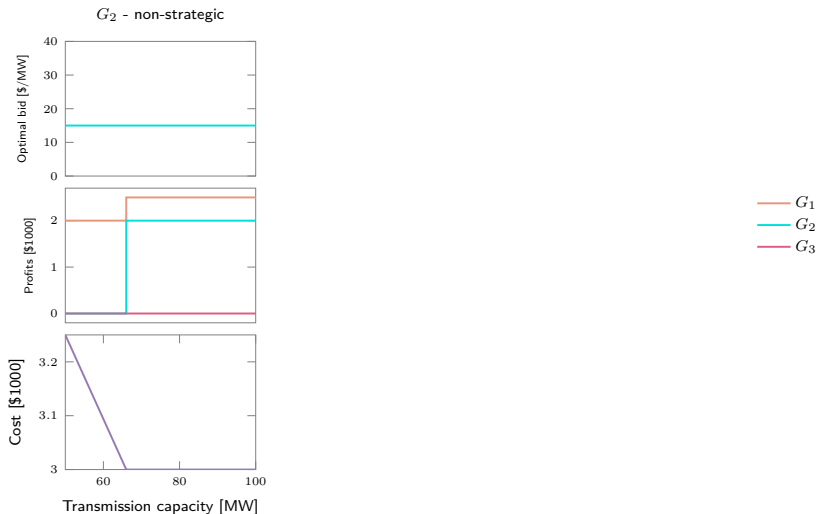# Let's study the market power of the unit at node two
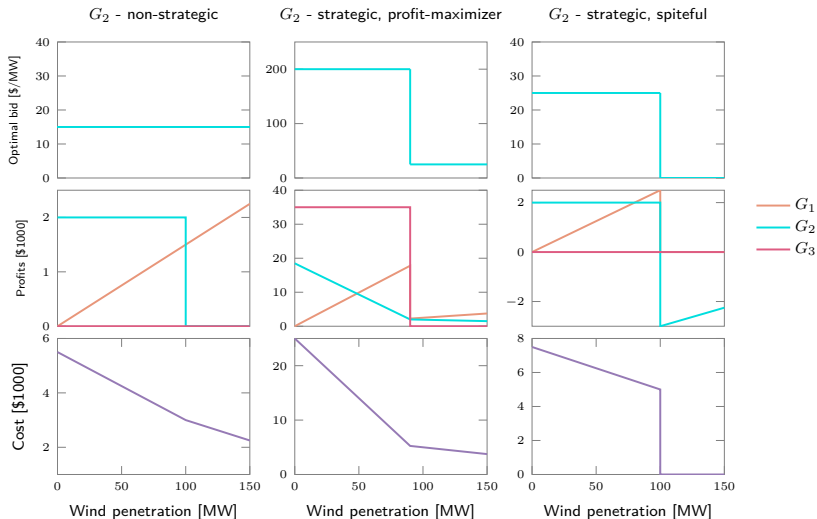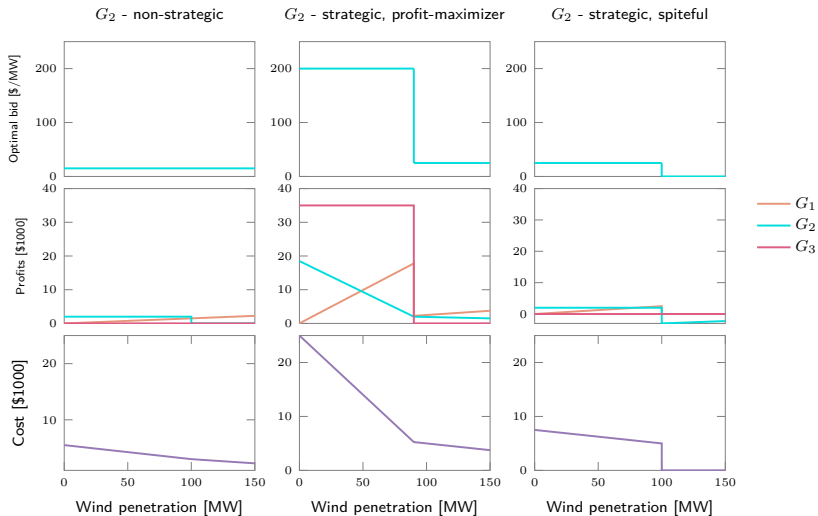
Impact of network congestion
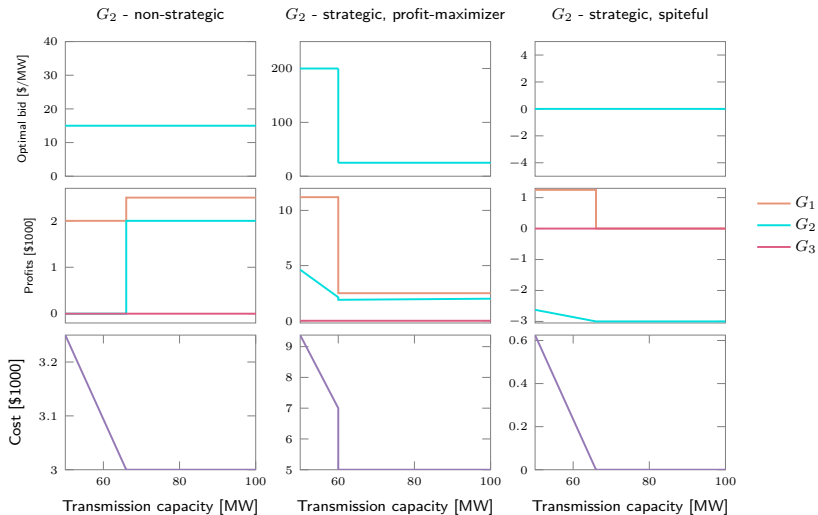
👉 Let's fix wind power capacity to 100 MW

👉 By varying transmission capacity of lines 1-2 and 3-2, we will see how strategy of unit G_2 and market outcomes change

G_2 - non-strategic

G_2 - non-strategic G_2 - strategic, profit-maximizer

Optimal bid [$/MW]

Profits [$1000]

Cost [$1000]

Transmission capacity [MW]

G_1
G_2
G_3

Main findings

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DTU

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- ☛ The degree of market power depends on the position of the unit relatively to the price-setter, congestions in the grid and many other aspects...

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☛ From Enron's audiotapes

- *What's happening?*
- *There's a fire under the core line. It's been derated from 4500 to 2100.*
- *Burn, baby, burn! That's a beautiful thing.*

Main findings

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– *What's happening?*
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👉 By modeling the strategic behavior of generation companies, regulators can identify the ways to reduce their market power and enhance the efficiency of the existing design.

☛ *Anticipation of real-time market outcomes:* optimize day-ahead decisions considering their projection on the balancing market

Possible extensions

👉 *Anticipation of real-time market outcomes:* optimize day-ahead decisions considering their projection on the balancing market

👉 *Asymmetry of information:* We don't perfectly know other's bidding strategies, system demand, network topology, etc.

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☞ *Anticipation of real-time market outcomes:* optimize day-ahead decisions considering their projection on the balancing market

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☞ And many other options (check references)

Thank you for your attention!

Market power in power systems studies

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