UIUC Capstone

Fundamentals of Energy Markets

The physics of energy markets

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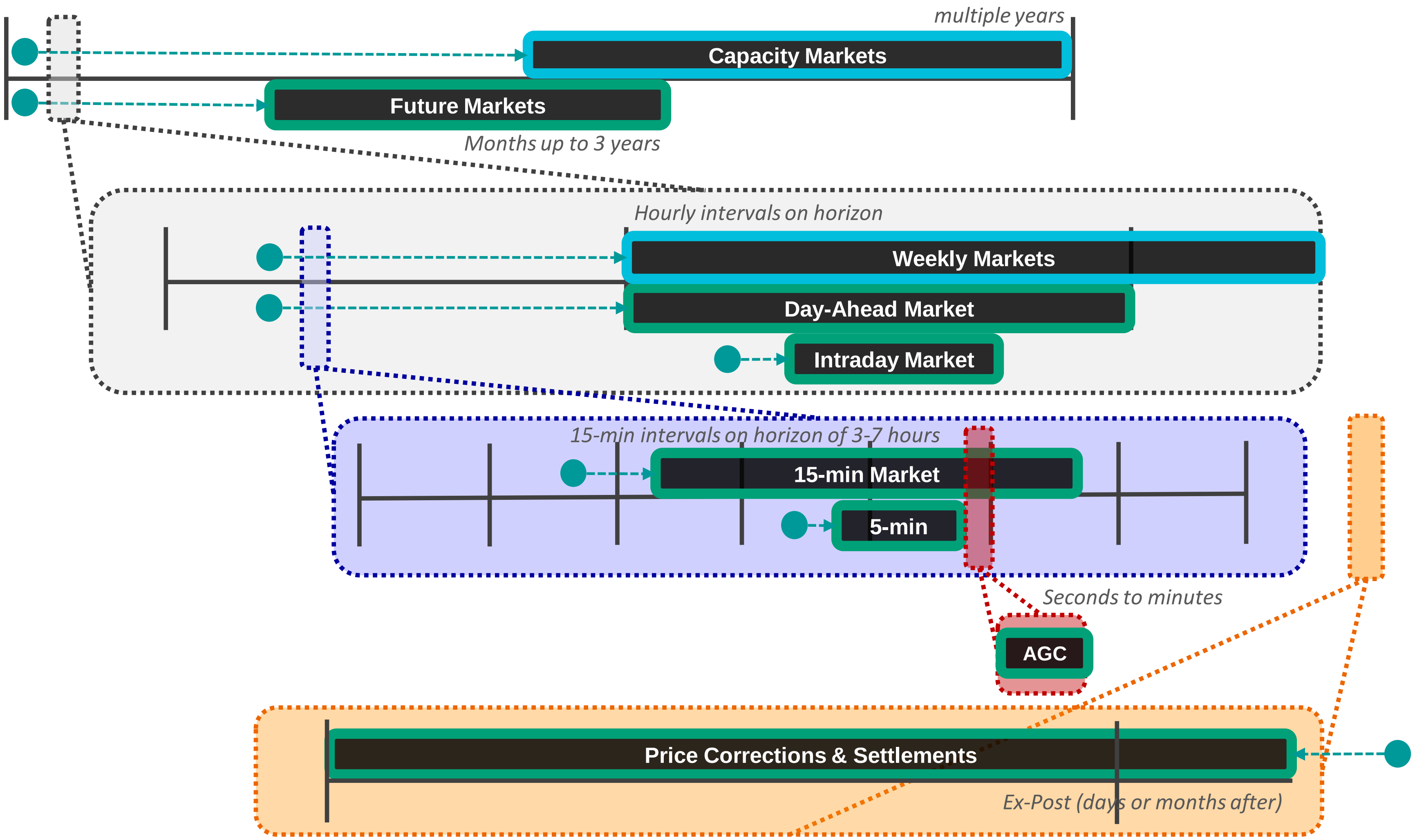
"What should we consider in our marketplace as a resources optimization problem to achieve **efficiency** and **reliability**?

The role of Resources Optimization on Energy Markets
Temporal Dependencies and Adaptability

Forward Markets Timeline:



- *Long term capacity*
- *Resource adequacy*

- *Outage Analysis & Reliability*
- *Energy & Reserve Scheduling*
- *Unit Commitment*
- *Reliability Analysis*

- *Near-term Reliability*
- *Synchronized Reserve*
- *Imbalance Energy*
- *Regulation & Flexibility*

- *Control Actions for Stability*
- *Reserve Activation*

- *Bilateral transactions*
- *Price Corrections*

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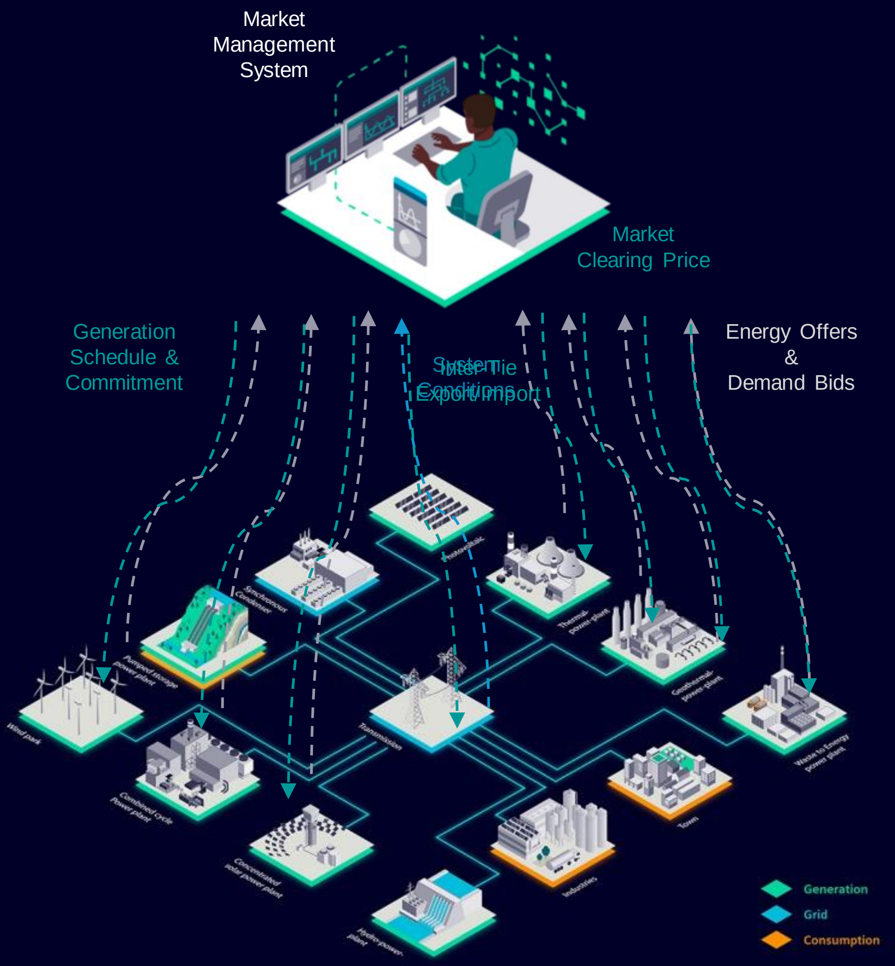
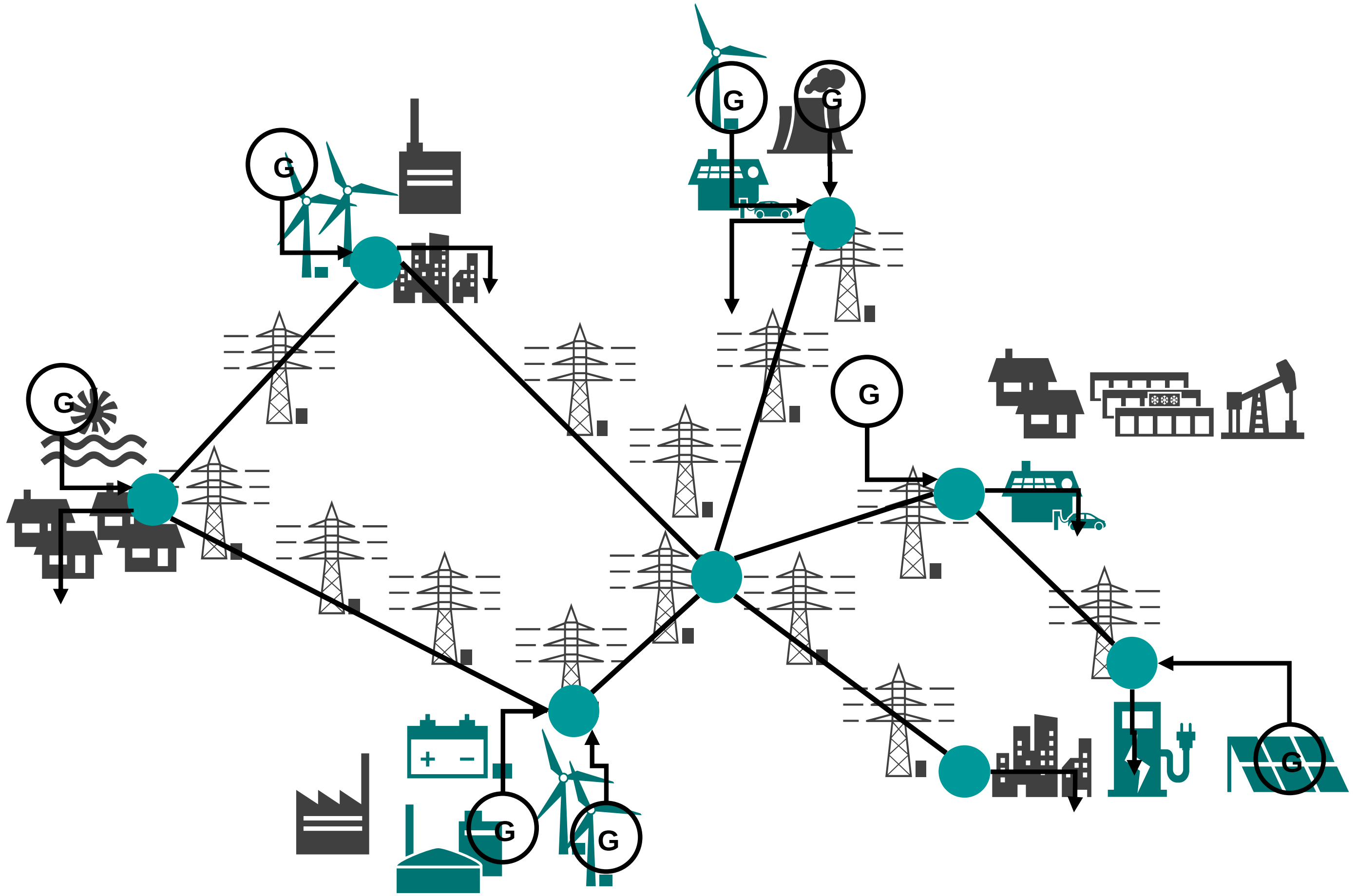
Optimal Power Flow Conceptualization
Static Analysis Background





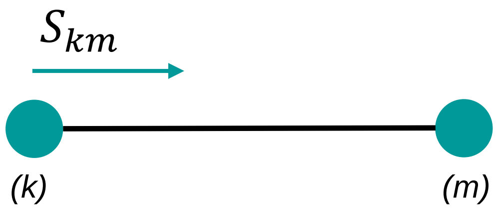
Network model with nodes and branches

Optimal Power Flow Conceptualization
Static Analysis Background

Basic AC Power Flow Model

Complex power injected into branch *km* at node *k :*

$$V_k = |V_k| e^{j\theta_k}$$

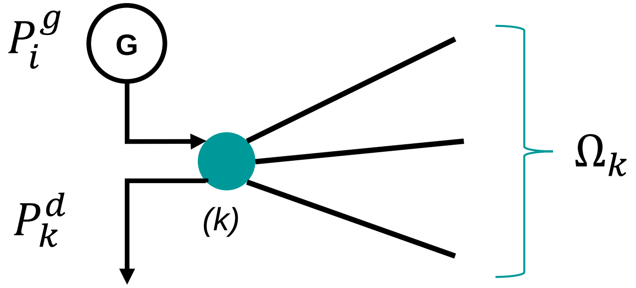


$$V_m = |V_m| e^{j\theta_m}$$

$$S_{km} = V_k I_{km}^*$$

$$S_{km} = (G_{kk} - jB_{kk})|V_k|^2 + (G_{km} - jB_{km})|V_k||V_m|(\cos\theta_{km} + j\sin\theta_{km})$$

Power balance at node *k :*



$$\sum_{km \in \Omega_k} S_{km} = \sum_{i \in G_k} P_i^g - P_k^d + j \sum_{i \in G_k} Q_i^g - Q_k^d$$

Basic Concepts from Energy Markets
Nonlinear Formulation Solution Space

Power Flow Linearization: DC model

$$S_{km} = (G_{kk} - jB_{kk})|V_k|^2 + (G_{km} - jB_{km})|V_k||V_m|(\cos\theta_{km} + j\sin\theta_{km})$$

Approximations:

$$|V_k| = 1$$

$$\cos\theta_{km} = 1 \quad \text{and} \quad \sin\theta_{km} = \theta_k - \theta_m$$

Yields,

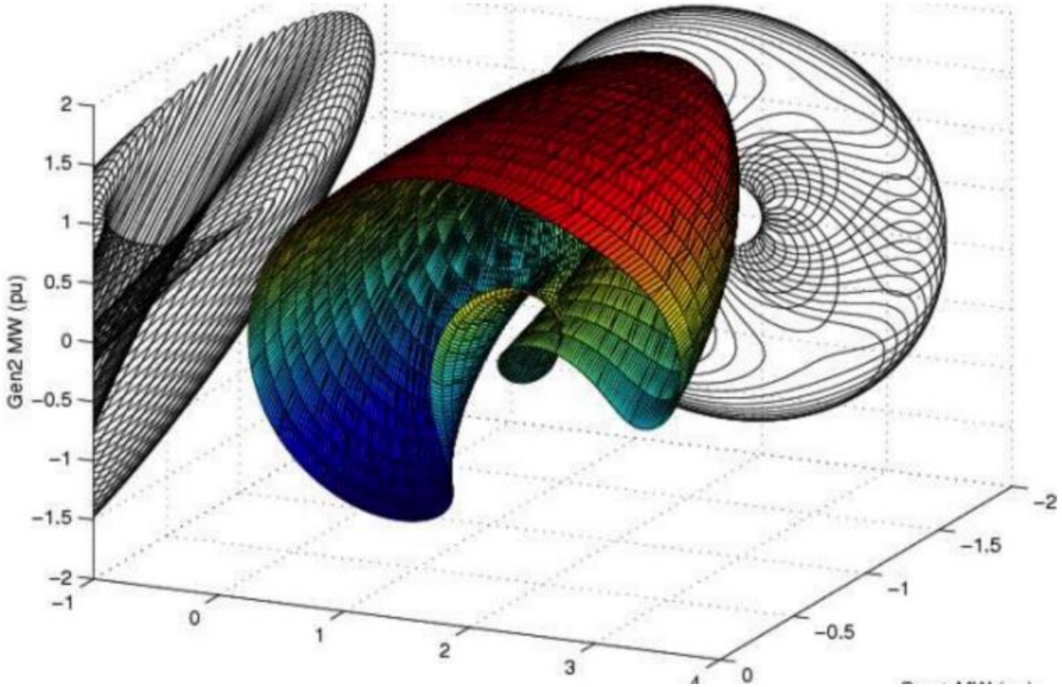
$$P_{km} = y_{km}(\theta_k - \theta_m)$$

$$\sum_{km\in\Omega_k} P_{km} = \sum_{i\in G_k} P_i^g - P_k^d$$

Finally, we make some remarks on why linear systems are so important.
The answer is simple: because we can solve them!

Richard Feynman

Solution space of a tree-bus system nonlinear power flow model:



Source: Hiskens, I.A. and Davy, R.J. "Exploring the Power Flow Solution Space Boundary", IEEE Transactions on Power Systems, vol. 16, no. 3, Aug. 2001

Cool Places to Look:

pandapower

Fraunhofer IEE

e²n Energiemanagement und Betrieb elektrischer Netze

http://www.pandapower.org/start/

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Thank You

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