Sustainable Energy Transition

An Operations Research Perspective

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Center for Operations Research and Econometrics CORE

Founded by Prof. Jacques DRÈZE in 1966.

It now houses about 35 professors, three endowed chairs and 50 doctoral and postdoctoral researchers.

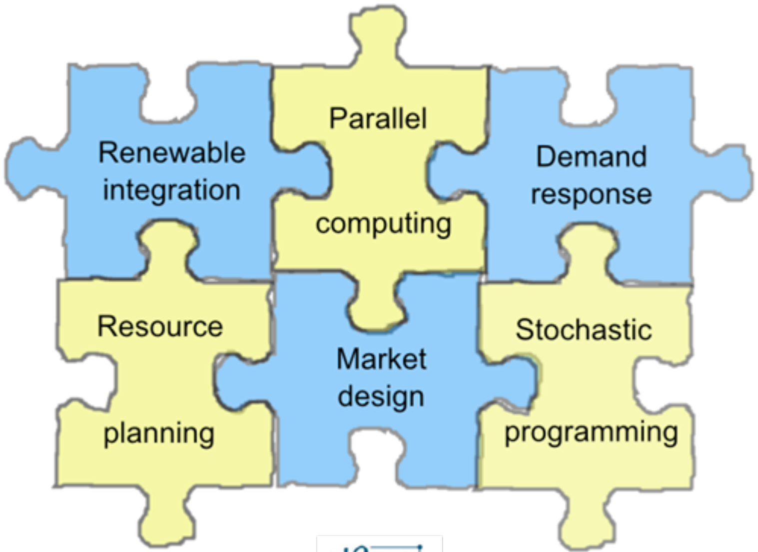
Leading interdisciplinary research institute in the fields of economic theory, game theory, **operations research** and econometrics.

Contributions and expertise in:

- Integer programming, convex and large scale optimization
- Regulation and risk management in the gas and electricity industries
- Environmental economics
- Other related disciplines

Engie Chair: Solving the sustainability puzzle

Engie Chair research problems and methodology



High-fidelity economic dispatch and unit commitment

ColorPower: residential demand response business models based on quality differentiated service

Rewarding flexible capacity in the Belgian electricity market

Motivation: Energy access and energy transition in Africa

600 million Africans do not have access to electricity

600GW will be required by 2030 to close the access gap, current projections amount to 220GW

Energy sector transitioning worldwide towards renewable and distributed energy

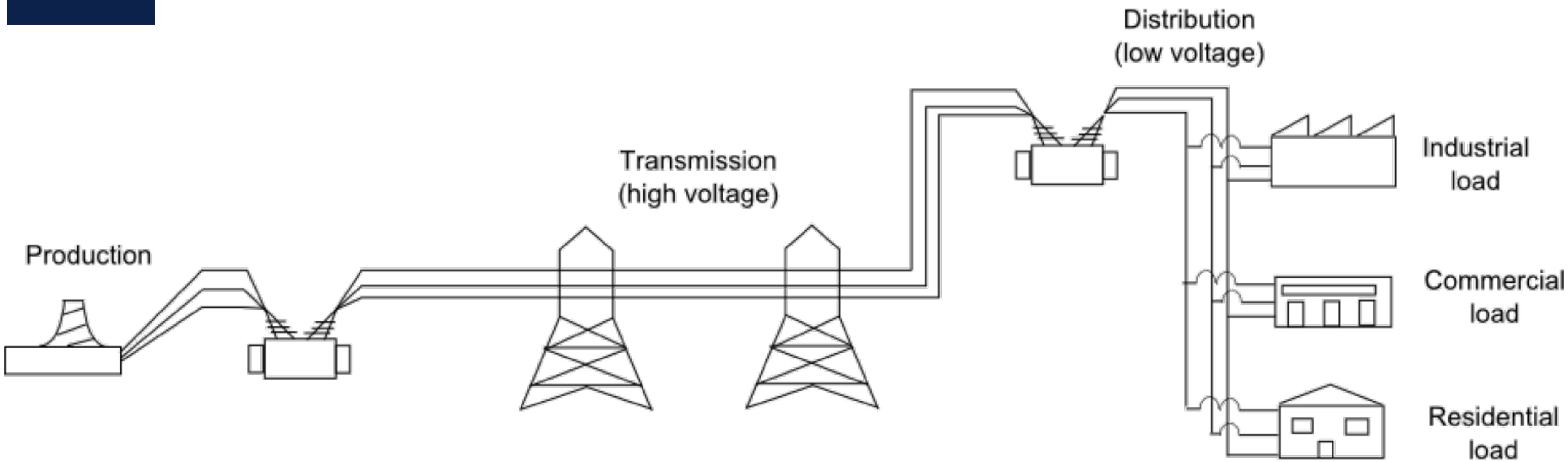
Opportunity

- use renewable and distributed energy to close energy access gap in Africa

Idea

- Use **operations research** to enhance decision processes in the **transition** to and in the **operation** of future power grids

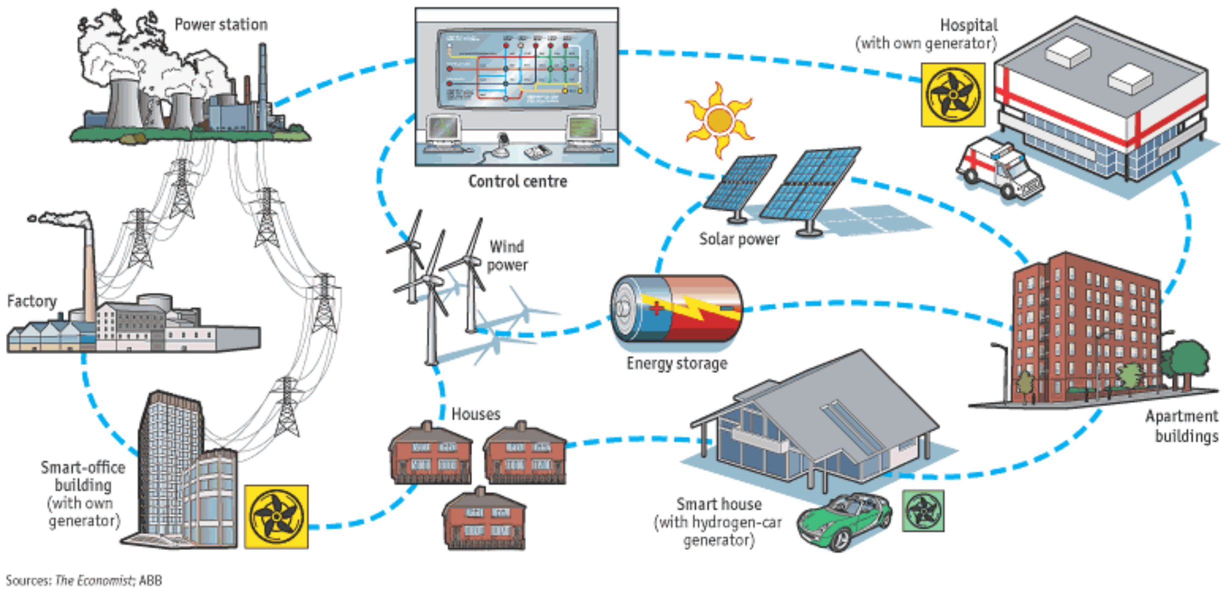
Current power systems



- Centralized production, always available
- Unidirectional power flow in distribution
- Consumers do not participate in markets or operations

Future power systems

- Distributed production, intermittent availability
- Distributed storage
- Bidirectional power flows in distribution
- Active participation of consumers in markets and operations
- Communications layer across the grid



Power systems in Africa

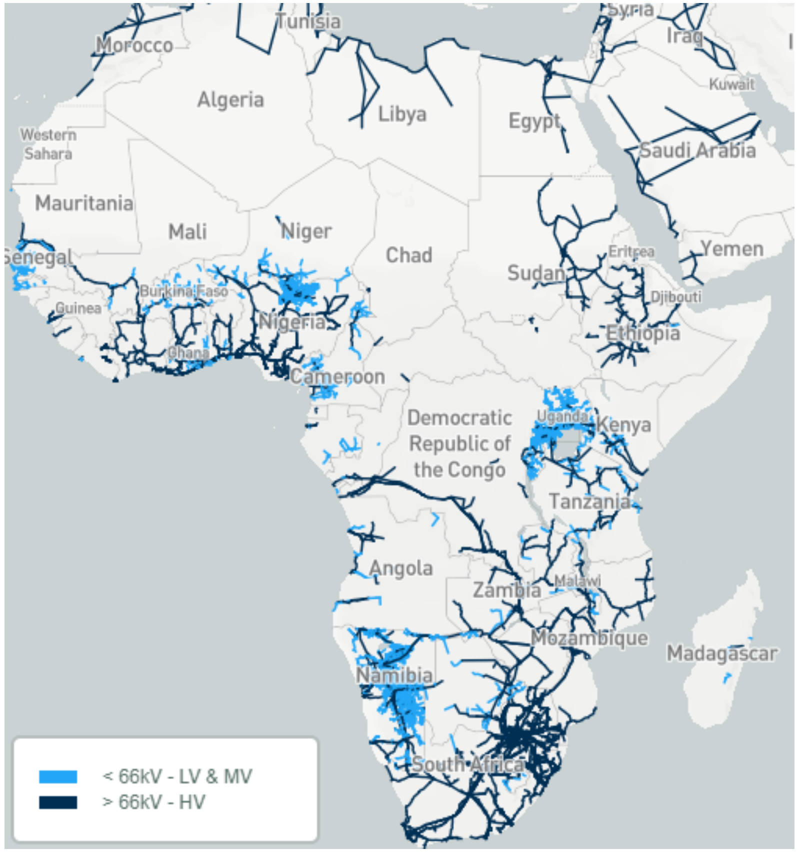
Significant energy access gap

Low-reliability

Interconnections present between certain countries

Renewable energy is competitive to conventional technologies

Large-scale renewable energy projects in study, construction and operations



Source: http://africagrid.energydata.info/

The future of African grids

Need and opportunity to transition towards a renewable energy powered future with access for all citizens

African Renewable Energy Initiative (AREI)

- Mobilizing at least 10 billion USD cumulatively from 2015 until 2020

Goal 1: Ensure universal access to sufficient amounts of clean, appropriate and affordable energy for all Africans by 2030

Goal 2: Help African countries leapfrog towards renewable energy systems that support their low-carbon development strategies

Challenge: transitioning while enhancing economic and energy security for Africans

Operations research

Making decisions by solving optimization problems:

$$\min_x f(x), \text{ subject to } x \in X$$

Optimization problems arise in fields from circuit design to economic theory

Started as a discipline on its own by multidisciplinary work during World War II

Important developments:

- Polynomial interior point methods for **convex problems**
- Branch-and-bound and branch-and-cut algorithms for **combinatorial problems**

Operations research in power systems

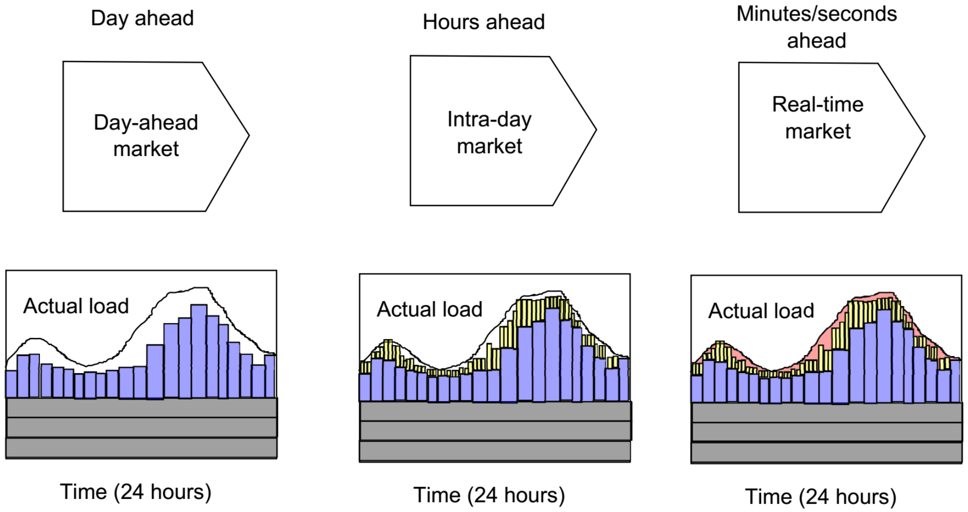
Power system operations worldwide rely on combinatorial optimization

Short-term optimization problems:

- Schedule production centrally (USA)
- Decide acceptance of producer bids (Europe)

Medium-term optimization problems:

- Maintenance scheduling
- Hydro-thermal coordination (Brazil)



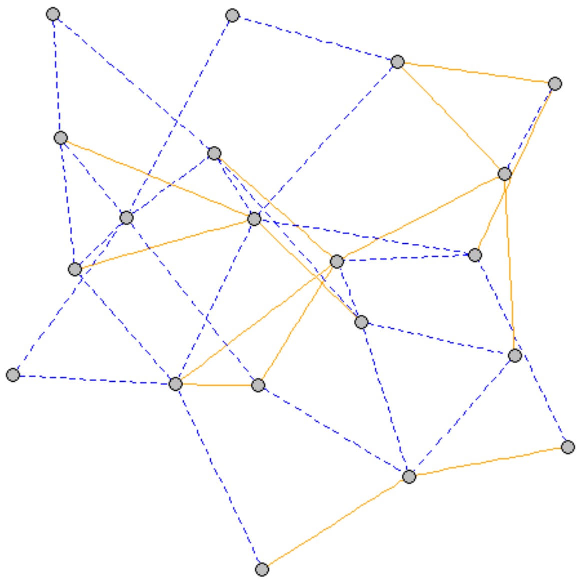
Short term scheduling of power system operations based on solving sequential optimization problems. Problems seek to minimize operation cost for satisfying an estimate demand, which becomes more precise as we get closer to real operation.

Operations research for transitioning to future power systems in Africa

How do we expand the transmission grid to accommodate new projects and estimated future demand?

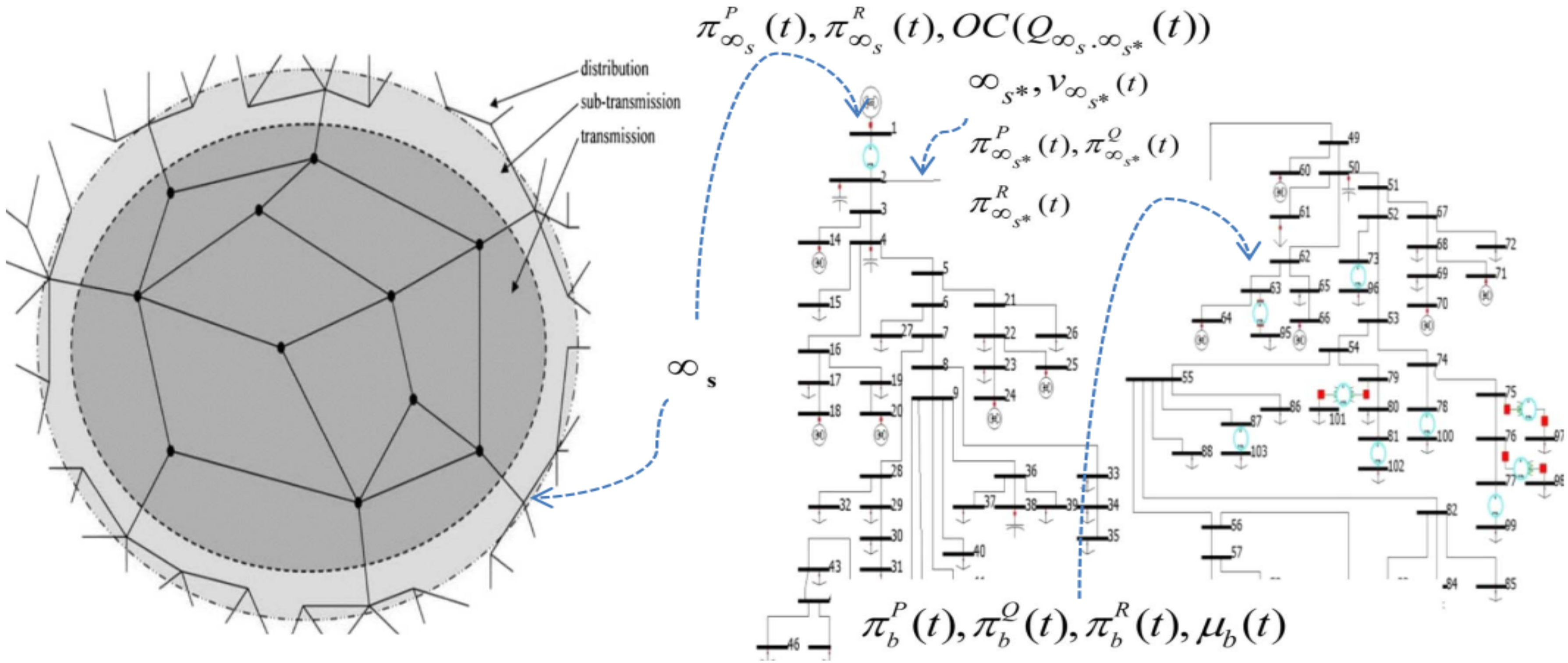
Transmission Expansion Planning problem (TEP)

TEP is a combinatorial problem: for 100 candidate transmission lines, there are 2^{100} different possible decisions



A transmission expansion planning instance. Vertices correspond to producers or consumers, continuous edges to existing lines and dashed edges to candidate lines.

Operations research for future power systems: co-optimizing transmission and distribution



Source: M. Caramanis *et al.*, "Co-Optimization of Power and Reserves in Dynamic T&D Power Markets With Nondispatchable Renewable Generation and Distributed Energy Resources," 2016.

Case study: Scheduling solar energy storage in Burkina Faso

September 2017: Burkina Faso commissioned the largest solar installation of West Africa, poised to cover **4% of the country's national consumption**

Solar power only available on a cyclical and uncertain pattern, backup with conventional generators, batteries

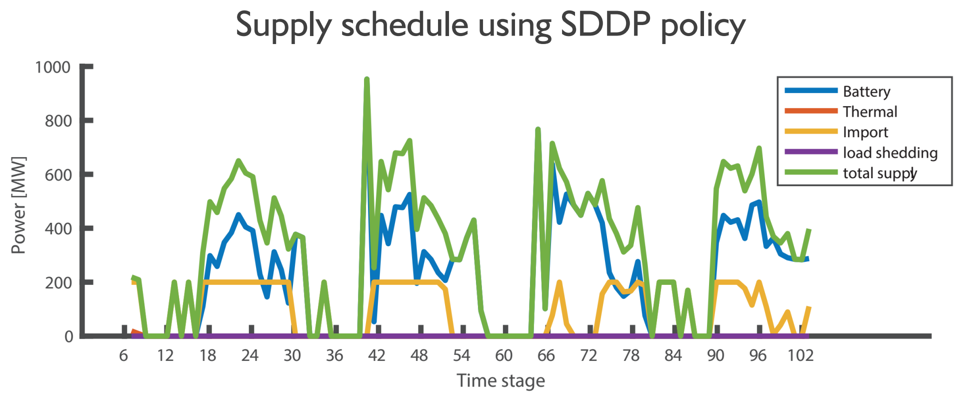
Using storage optimally can reduce CO_2 emission, reduce operation costs and improve reliability

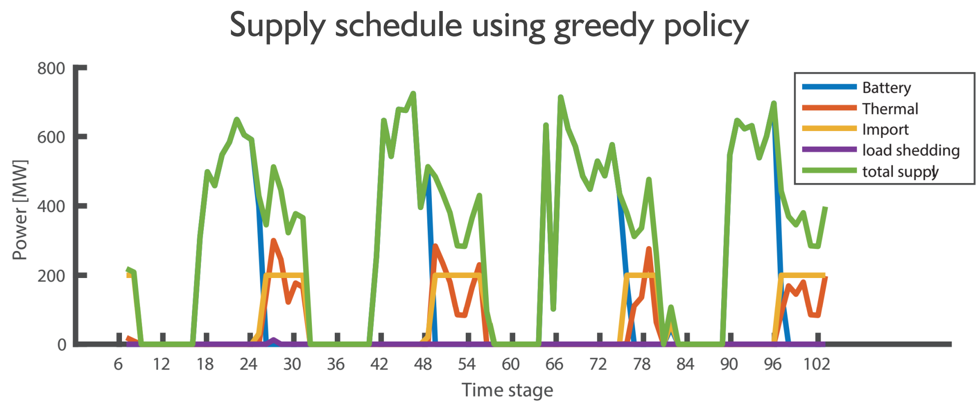
Problem is analogous to hydro-thermal coordination: uncertain production (rainfall/cloudiness), storage (dams/batteries) and backup

Approach: use **hydrothermal coordination algorithm** (SDDP) to schedule energy storage

Scheduling results

- Test case: 2400MW solar, 1000MW/5000MWh battery, 15-minute resolution, 4-day horizon
- Greedy policy: charge battery when there is excess energy, discharge when there is scarcity
- Using SDDP allows to operate the system using less thermal generation (reducing CO2 and fuel costs)
- Overall, SDDP achieves savings of 24% over the greedy policy





Conclusions

- Africa currently faces an important energy access gap
- A revolutionary transformation of the African energy grid will take place in the next 10-15 years
- Operations research can be an enabling tool in this transformation
  - Upgrading the current grid
  - Operating the future power grid
- Operations research algorithms can provide significant advantages over heuristic decision policies

Thank you for your attention

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