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Transmission and Distribution Grids: Key Enablers for the Energy Transition

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EEM'25, Plenary session 7

Content

Decarbonization challenges

Rapid growth of renewables + electrification

Deviations in power balances

Space-time analysis

Correcting deviations

Rigidity-flexibility binomial

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Decarbonization challenges

Rapid growth of variable renewables

Electrification of transport, heating, and industry

Context

Grids are the backbone of electricity systems (more than a century)

- Renewables deployment and consumption electrification are accelerating
- As decarbonisation advances, the role of electricity becomes more prominent

Grids are lagging behind

- Delayed action leads to prolonged dependence on fossil fuels, increased emissions and costs to society

Rapid growth of variable renewables

Much of the new renewable production (solar and wind) differs from conventional:

- High variability at different temporal resolutions
- Not dispatchable and low mechanical inertia
- May be decentralized without compromising efficiency

Electrification of transport, heating, and industry

Much of the new consumption (EV, heating, storage) differs from conventional:

- High coincidence factors
- Flexible, it can be managed without compromising comfort
- Can be reversible

Higher risk of congestion

Decentralized production:

- Reduces the expected value μ of local imbalances ($\mu_C + \mu_P < \mu_C$, $\mu_P < 0$)
- Increases the variance σ^2 of local imbalances, $\sigma_C^2 + \sigma_P^2 > \sigma_C^2$, and therefore the relative value of deviations σ/μ

The electrification of consumption:

- Increases both μ_C and σ_C^2 and therefore also μ and σ^2 of the local imbalances
- It increases $\mu + \mathrm{n}\sigma$ and therefore the risk of grid congestion, whatever the probabilistic guarantee n.

Reduced stability margin

The electricity system is a transmission system:

- It responds to deviations in the balance of power with changes in the speed of the generators' rotors (frequency)
- It does not allow changes in speed without losing (margin of) stability

New renewable production reduces the relative inertia of the system:

- It increases the natural oscillation frequency of the rotors
- It increases the risk of instability -- loss of synchronism or system integrity

Deviations in power balances

Risk of congestion

Stability margin

Mitigating the risk of congestion

Resources are committed for the expected value of the net load at different levels of spatial aggregation:

- As $\mu_C + \mu_P < \mu_C$ e $\sigma_C^2 + \sigma_P^2 > \sigma_C^2$, there will be fewer resources available to manage larger imbalances.

The solution is to:

- Reinforcing the grid, creating larger balancing areas
- Dynamically adapting the grid to the imbalances
- Dynamically adapting the imbalances to the grid (flexibility services)

Mitigating the risk of congestion

The need for system flexibility will increase very fast:

- Needs to double between 2022 and 2030, to meet national climate goals

Grid operators need to

- Coordinate investment in the grid (that needs to double by 2030) with grid enhancing technologies to unlock demand response and energy storage through digitalisation

Ensuring stability margin

Fewer conventional resources will be committed (lower inertia)

- The risk of loss of synchronism will increase

The solution is to:

- Reduce fault clearing times of protections and relax RoCoF
- Increase system rigidity, strengthen tie-lines between balancing areas (increase synchronization torque)
- Deploy storage to provide synthetic inertia
- Mobilize consumers to offer regulation reserve (FFR)

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Correcting deviations

Space-time analysis

Rigidity-flexibility binomial

Space-time analysis

The electrical system does not allow deviations in the balance

All power imbalances must be closed in space-time:

- To close in space, one needs interconnection/grid capacity
  (the excess here is used to make up for the shortfall there)
- To close in time, one needs storage/resource management capacity
  (the excess now is used to make up for the shortfall in the future)

Higher rigidity, more flexibility

It's a binomial, not a paradox

Higher rigidity of grid connections, to close balances in space

- The grid must be able to serve higher consumption and withstand larger deviations in the power balance (+grids)

More flexibility of resources, to close balances in time

- More resources have to help resolve congestions and participate in frequency regulation (+markets)

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