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Analyzing the Impact of Demand Response on Short-Circuit Current via a Unit Commitment Model

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Grid SCC Security & DR

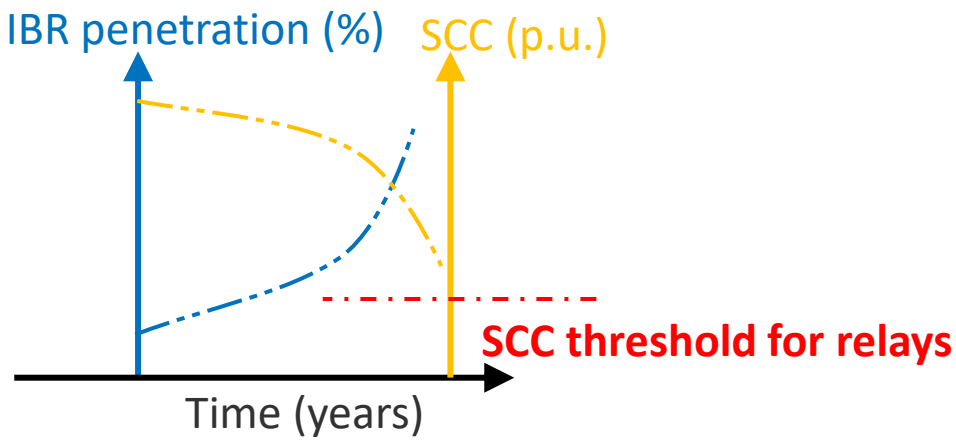
- **The Core Challenge:** The global energy transition replaces Synchronous Generators (SGs) with Inverter-Based Resources (IBR), drastically reducing the system's Short-Circuit Current (SCC) level and potentially disabling protective relays.

SGs: 5–8 p.u. SCC

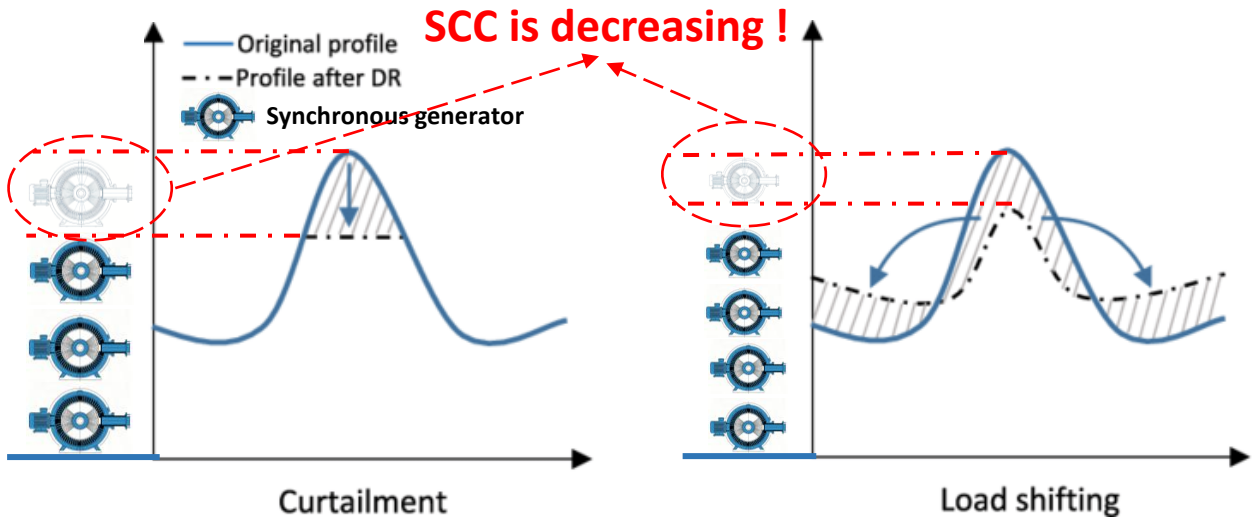
Electromechanical physics

IBR: 1–3 p.u. SCC

Electronic converters



- **The "Double-Edged Sword" of DR:** Demand Response (DR) is economically beneficial to grids, but may reduce system load, leading to fewer SGs being online. This exacerbates the SCC deficiency.



DR Lowers Cost

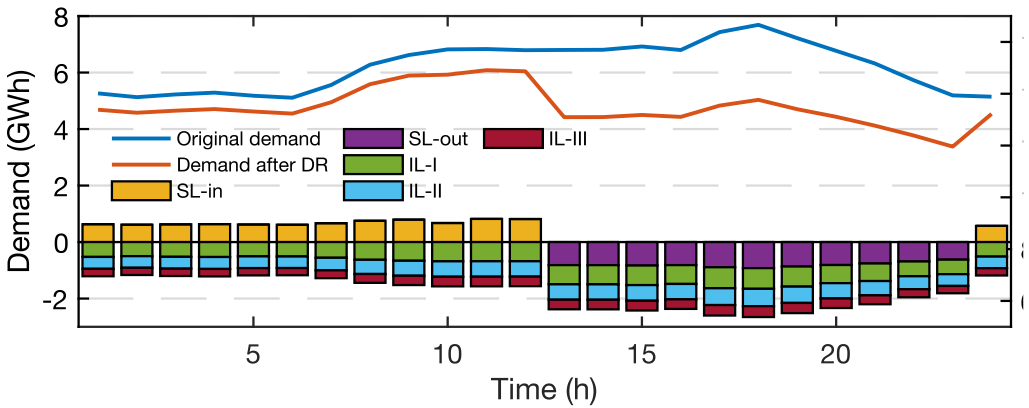


Fig 1. System demand in the case of no SCC constraints.

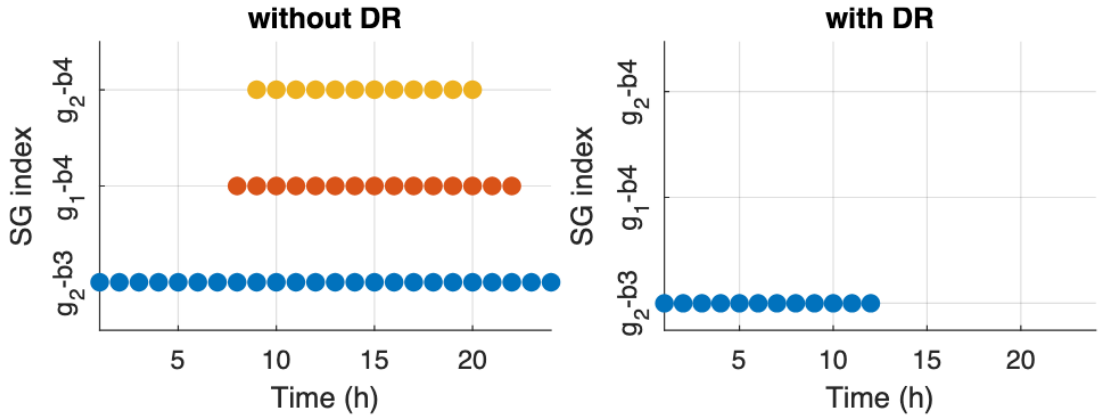


Fig 2. Generators whose commitment state is affected by DR.

- Interruptible load is curtailed for compensation to lower electricity costs.
- Shiftable load moves from peak hours to off-peak to reduce bills.

The reduced load lowers generator dispatch:

- one (●) is shut down for half of the day.
- two (●●) are shut down throughout the day.

System scenarios	w/o DR w/o SCC cons	with DR w/o SCC cons
Average load level	6.21 GW	4.79 GW
System operating costs	1.23 m€	0.86 m€

- DR is active, with 22.87% of the load curtailed.
- Operating costs are reduced by 30.08%.

How about SCC of the system ? >>

DR Lowers Cost but Sacrifices SCC

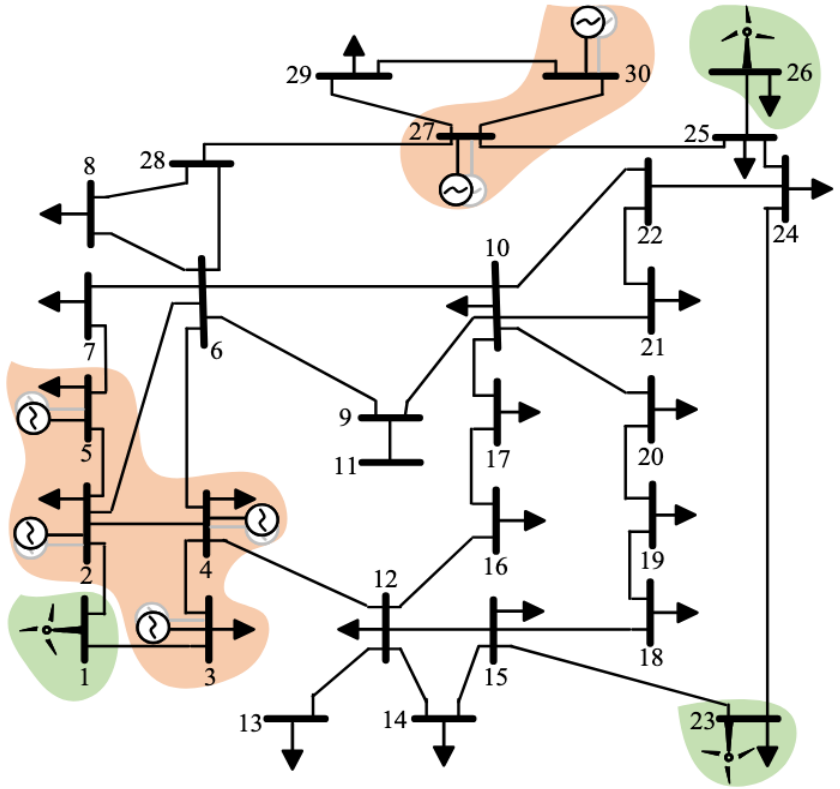


Fig 3. Modified IEEE 30-bus system

SCC constraints

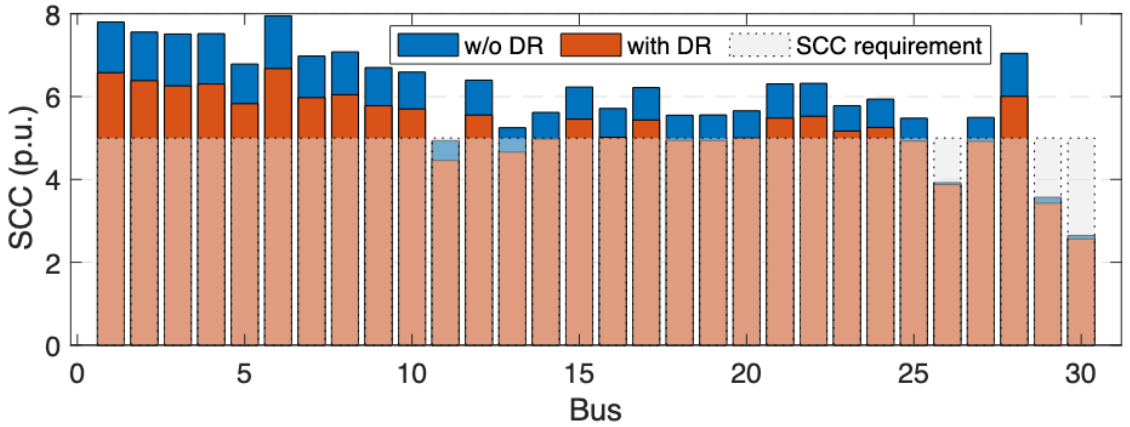


Fig 4. Unconstrained minimum SCC level at each bus.

SCC security level for buses: 5 p.u.

Table 1. Buses with Inadequate SCC Level

DR implementation	Bus index
without DR	11, 26, 29, 30
with DR	11, **13**, **14**, **18**, **19**, **20**, **25**, 26, **27**, 29, 30

DR leads to insufficient SCC in more buses.

Explicit SCC constraints are required ! >>

Coordinate DR with SCC Security

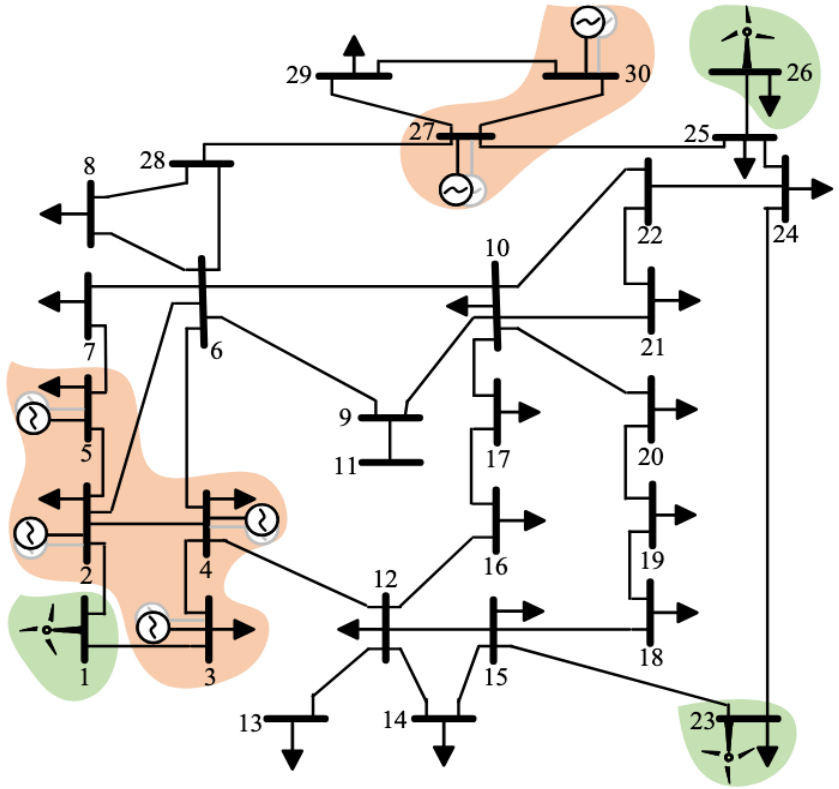


Fig 3. Modified IEEE 30-bus system

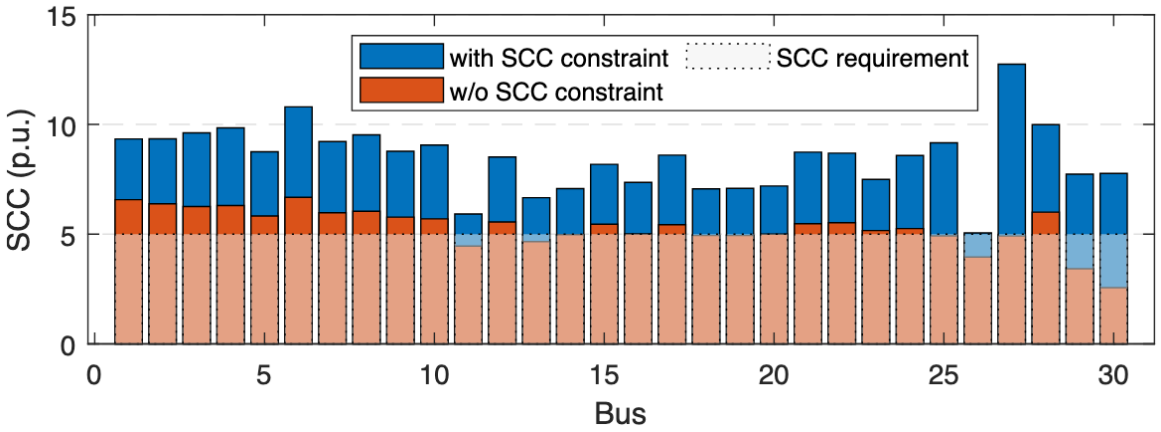


Fig 5. Constrained minimum SCC level at each bus.

SCC constraints eliminate security risks across the network.

System scenarios	w/o DR w/o SCC cons	with DR w/o SCC cons	with DR with SCC cons
System operating costs	1.23 m€	0.86 m€	0.94 m€

SCC constraints

Coordinating DR with SCC constraints achieves an economically efficient system while ensuring SCC security.

Conclusions and Future Work

Key Takeaways:

- DR poses threats to SCC security, which may lead the protective relays to be unreliable.
- Coordination between DR mechanisms and SCC constraints yields a win-win operational solution that reduces operating costs while maintaining sufficient SCC for power grids.

Future Directions:

- Investigate more system stability issues caused by market mechanisms, in order to promote the formation of a cost-effective grid with stability secured.
- Explore a specialized “short-circuit current service market”, a novel incentive-based framework that adequately compensates resources for providing SCC services, ensuring long-term SCC adequacy.

Thanks for your time !

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