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

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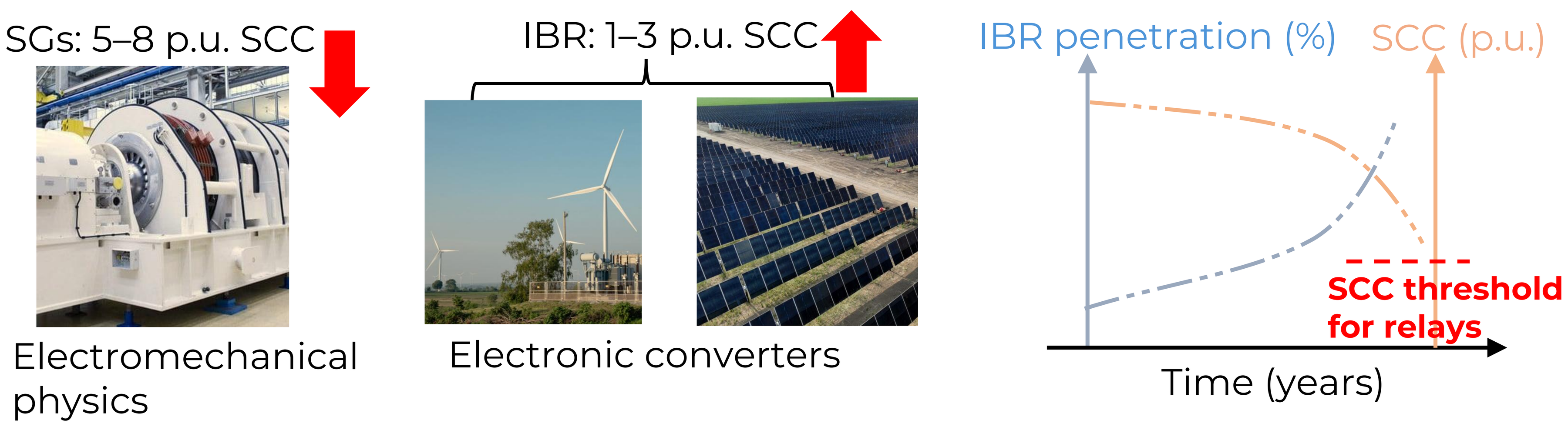
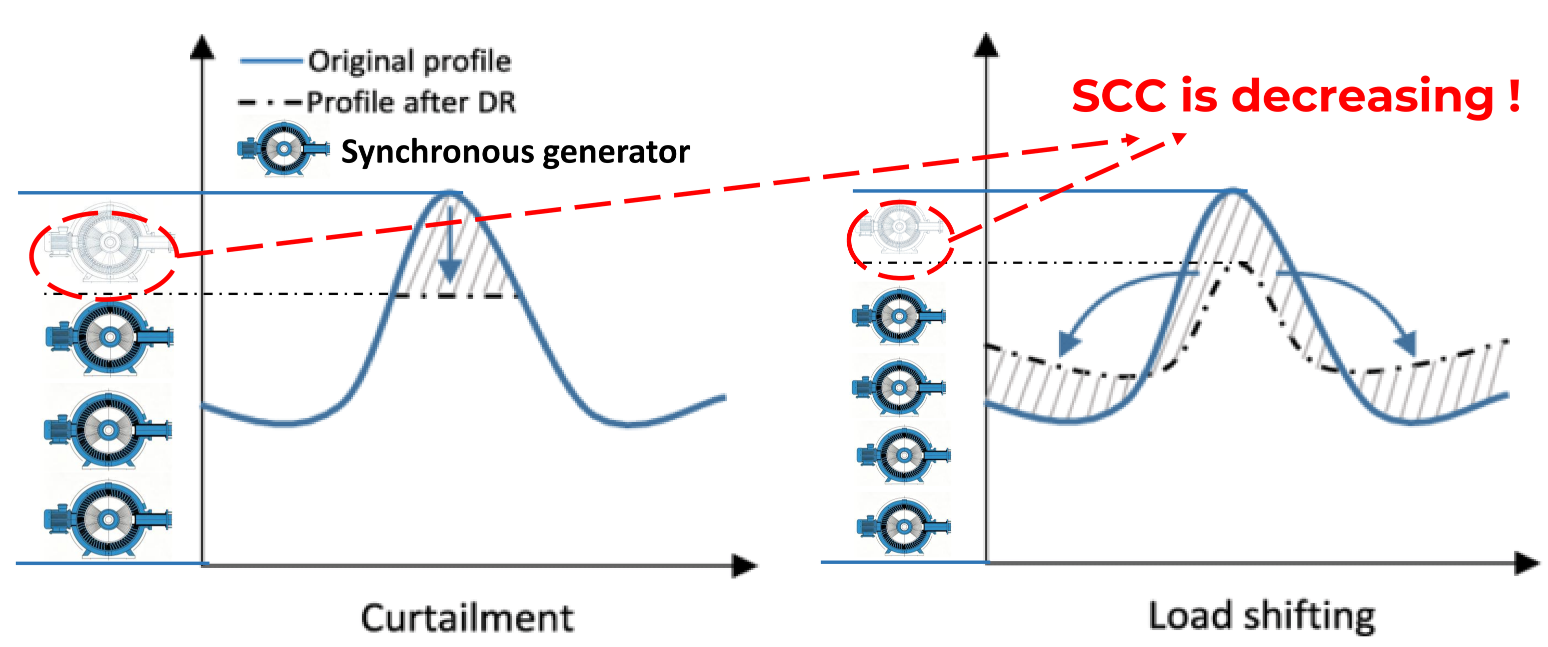
INTRODUCTION

- **Reduced SCC and Unreliable Protective Relay:** Inverter-based resources (IBR) displace synchronous generators (SGs). IBR deliver limited short-circuit current (SCC), reducing system-wide SCC and endangering relay protection.



- **Demand Response Further Reduces SCC:** Demand response (DR) might reshape load profiles and alter SG commitment, worsening inadequate SCC concerns.



- **Contribution:** We developed a unit commitment (UC) model which incorporates DR and SCC constraints to explore the role of DR on securing sufficient SCC levels in the system.

METHODOLOGY

SCC Constraint

$$I_{b_{SC}} = \frac{\sum_{g\in\mathcal{G}} Z_{b\Psi(g)} I_g u_g + \sum_{c\in\mathcal{C}} Z_{b\Phi(c)} I_c \alpha_c}{Z_{bb}}$$

offline training

$$I_{b_L} = \sum_g k_{bg} u_g + \sum_c k_{bc}\alpha_c + \sum_m k_{bm}\eta_m \ge I_{b_{\lim}}$$

$$\eta_m = u_{g_1}\cdot u_{g_2}, \quad \text{s.t. } \{g_1, g_2\} = m$$

$$m \in \mathcal{M} = \{g_1, g_2 \mid \forall g_1, g_2 \in \mathcal{G}\}$$

Demand Response

The interruptible load (IL) is curtailed in exchange for financial compensation. Its curtailment is within a range and a continuous time interval:

$$0 \le P^{\text{curt}}_{n,t} \le \beta_{1,n} P^{\text{base}}_t, \quad P^{\text{curt}}_{n,t-1} + P^{\text{curt}}_{n,t} \le \beta_2 P^{\text{base}}_t$$

The shiftable load (SL) can move from peak to off-peak periods. It can only move out or in at single period and the total shift volume must be constant:

$$z^{\text{in}}_t + z^{\text{out}}_t \le 1$$

$$0 \le P^{\text{in}}_t \le \beta_3 P^{\text{base}}_t z^{\text{in}}_t, \quad 0 \le P^{\text{out}}_t \le \beta_4 P^{\text{base}}_t z^{\text{out}}_t$$

$$\sum_t P^{\text{in}}_t - \sum_t P^{\text{out}}_t = 0$$

SCC Constrained UC Model with DR

The UC is to minimize the sum of system operating cost and energy payments (C^{E}) borne by users:

$$\min \sum_t \left[\sum_g \left(c^{\text{nl}}_g u_{g,t} + c^{\text{m}}_g P_{g,t} + C^{\text{st}}_{g,t} + C^{\text{sh}}_{g,t} \right) + C^{\text{E}}_t \right]$$

RESULTS

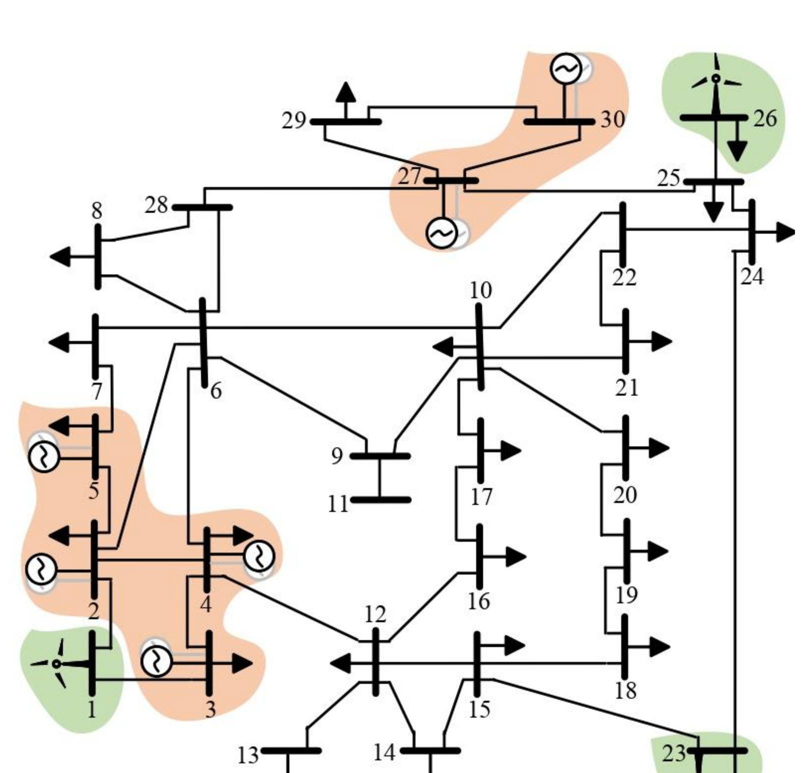


Figure 1: Modified IEEE 30-bus system.

- The simulations are conducted based on a modified IEEE 30-bus system.
- SCC security level: **5 p.u.**
- Optimization / Solvers: julia, JuMP, GUROBI OPTIMIZATION

Scan for more !

arXiv GitHub

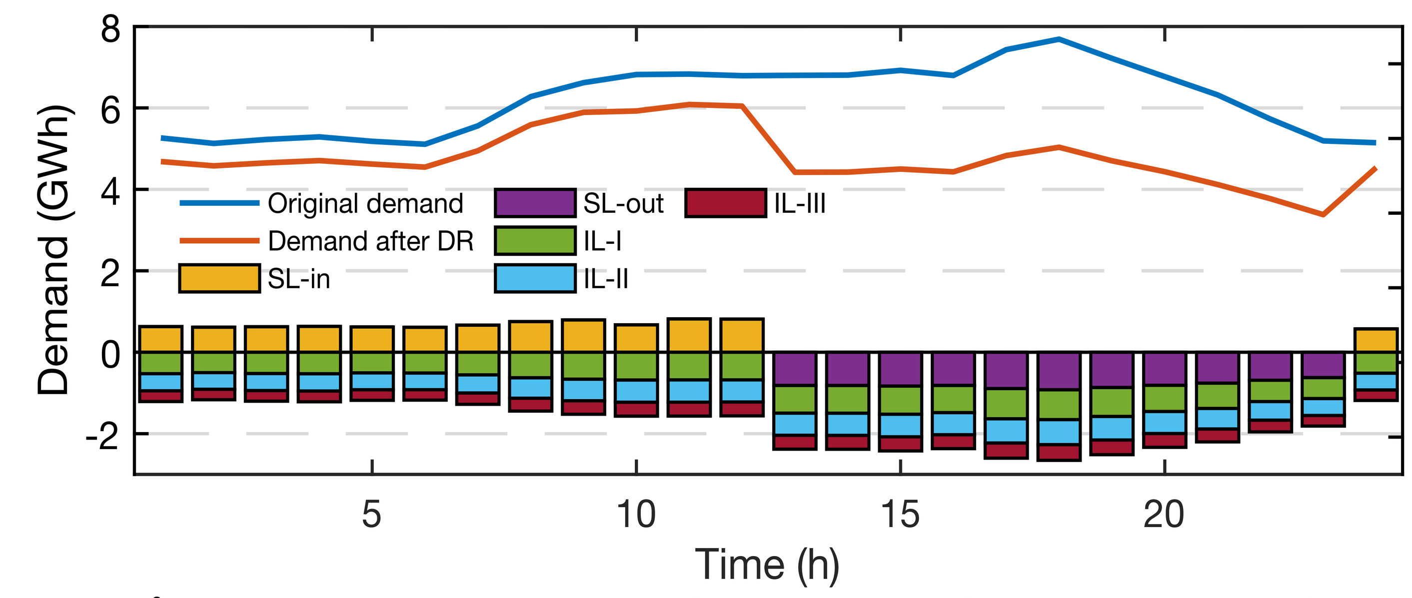


Figure 2: System demand in the case of no SCC constraints.

DR reshapes the load profile through 22.87% load curtailment and load shifting

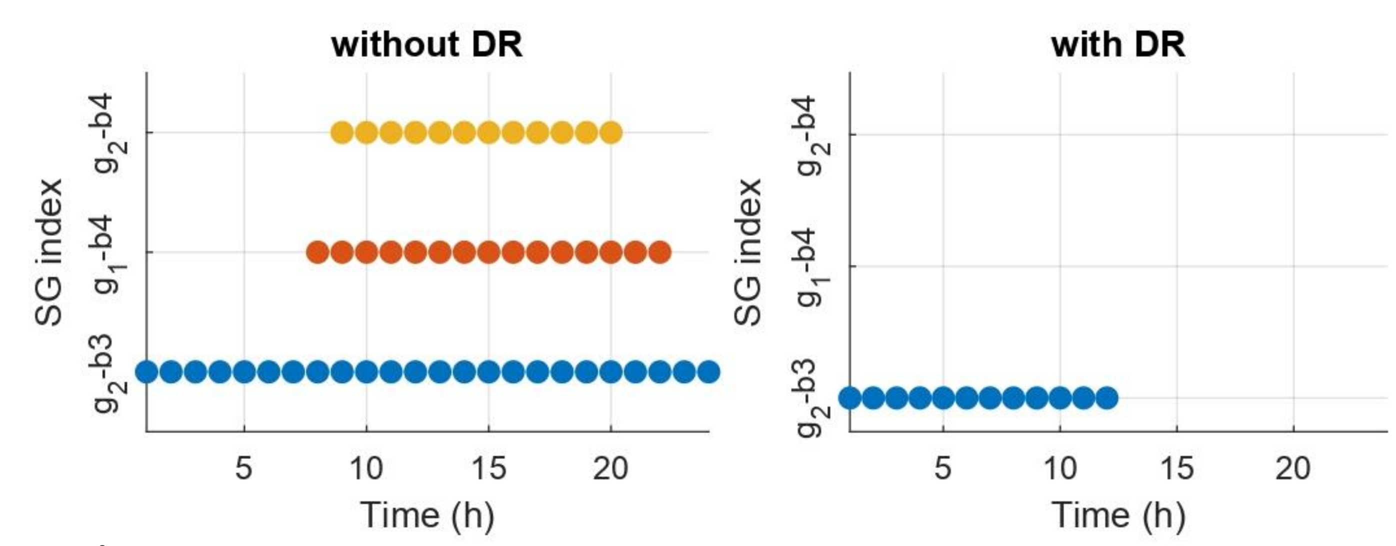


Figure 3: Generators whose commitment state is affected by DR.

SGs that supply substantial SCC are less committed

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

Add SCC constraints

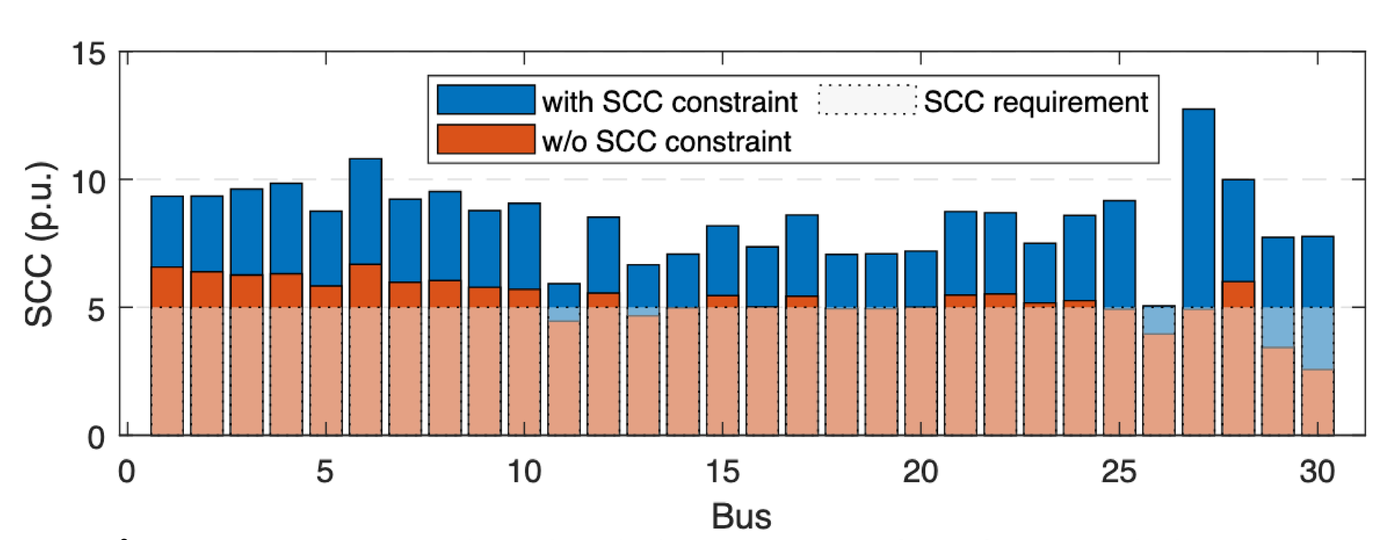


Figure 4: Constrained minimum SCC level at each bus.

Coordination with DR ensures adequate SCC at lower costs

Table 2. Costs of System Operation

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€

CONCLUSIONS AND FUTURE WORK

- ✓ DR is compatible with SCC constraints, allowing operators to appropriately schedule thermal units.
- ✓ Considering DR, ensuring sufficient SCC would not significantly increase system operating costs.
- o Investigate more system stability issues caused by market mechanisms, in order to promote the formation of a cost-effective grid with stability secured.
- o Explore a specialized "short-circuit current service market", an incentive-based framework that adequately compensates resources for providing SCC services, ensuring long-term SCC adequacy.

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