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Blackstart of Power Grids with Inverter-Based Resources

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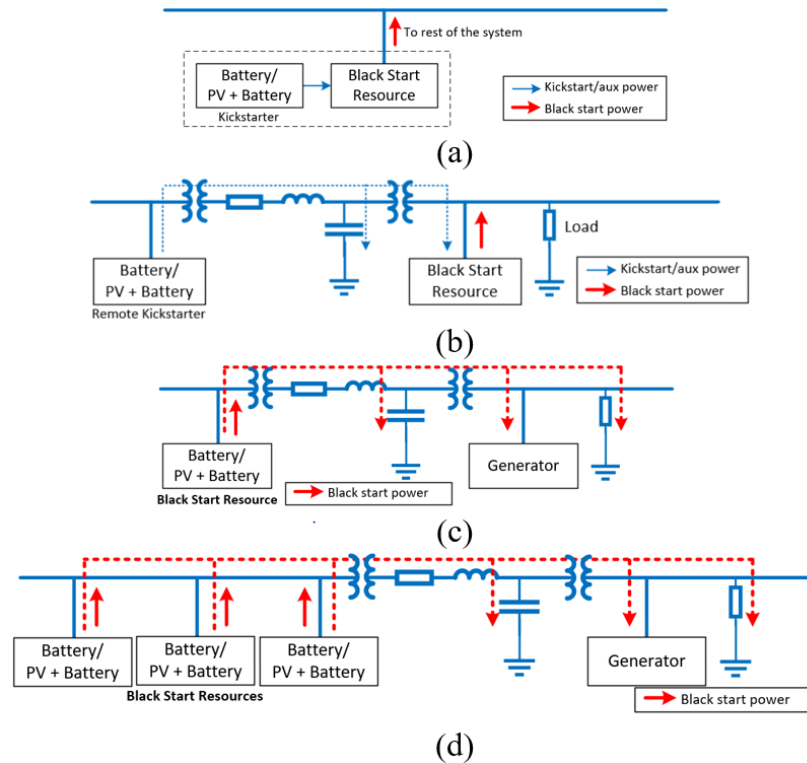
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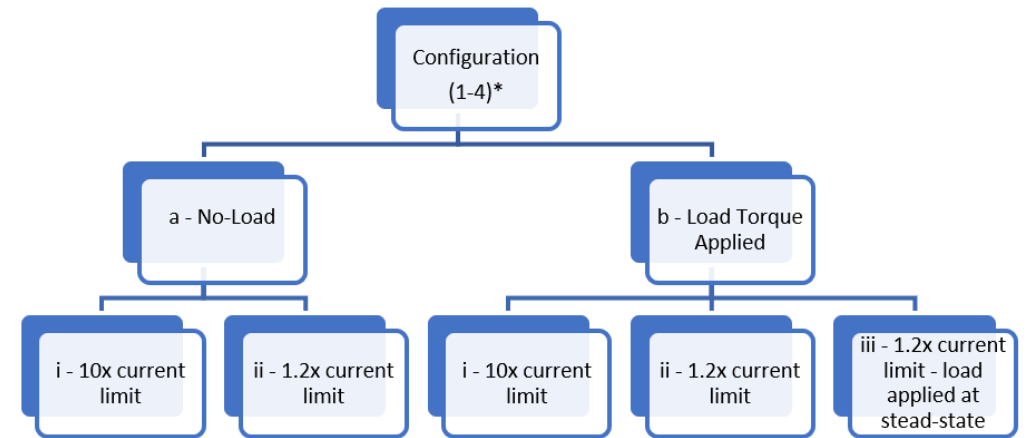
Background

- What did we do in this paper?
 - Performed simulations to evaluate the technical feasibility of inverter-based resource-(IBR-) driven blackstart
 - Developed a model of current-limited grid-forming inverters to simulate IBR-driven blackstart of a motor.
- Motivation
 - Interest in industry to understand the technical potential and associated costs of using IBRs for blackstart
 - Limited existing research on modeling/simulation to understand the performance of IBRs for blackstart.

Approach



- (a). Config. 1: On-site Kick-Start for a Blackstart
 (b). Config. 2: Remote Kick-Start for a Blackstart
 (c). Config. 3: Fully Functional Black-Start Resource
 (d). Config. 4: Collective Blackstart



- 11 simulations were performed
- 10 w/ full voltage applied at the beginning
- 2-b-iii with voltage ramped slowly

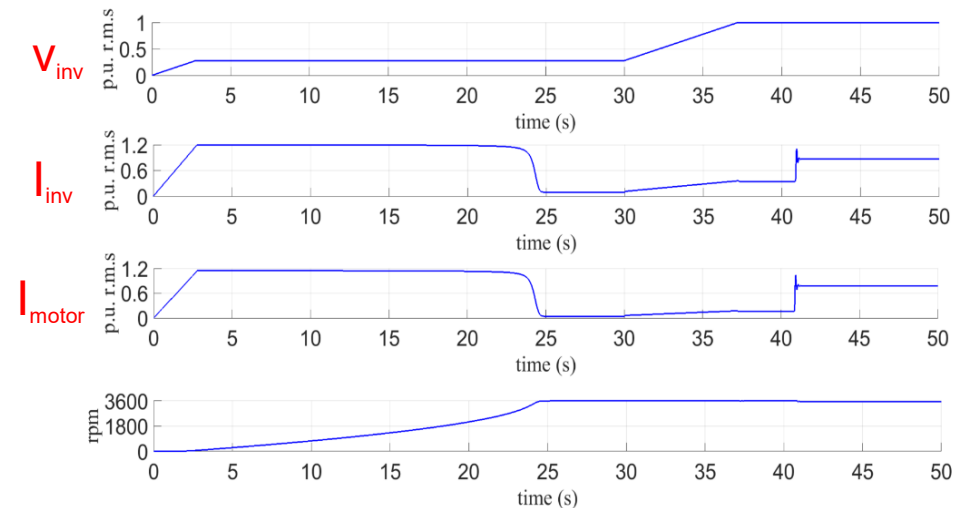
Results

Full Voltage Applied at t=0 Seconds

Simulation label from Fig. 5	Voltage (Mean 3-phase, voltage in p.u.)	Current (Mean 3-phase, current in p.u.)	Start Time (s)
1/a/i	0.98	4.00	1.86
1/b/i	0.97	4.03	4.50
1/b/ii	0.29	1.21	No start
1/b/iii	0.29	1.18	20.67
2-3/a/i	0.95	4.13	1.89
2-3/b/i	0.96	4.17	4.75
2-3/b/ii	0.28	1.21	No start
2-3/b/iii	0.27	1.19	22.43
4/b/ii	0.72	1.05 per IBR	Unstable
4/b/iii	0.71	1.03 per IBR	3.40

- No load, 1.2X current limit, **motor starts** (green shaded rows)
- Load applied after steady state, 1.2X current limit, motor stalls in 1/2-3-a/b-iii configuration but picks up load at 1.5X (see Fig. 7 in the paper); also picks up in Configuration 4 with three IBRs (green shaded rows)
- Load applied from the beginning, 1.2X current limit, **motor stalls** or reaches an unstable equilibrium point (red shaded rows)
- Ramped voltage, 1.2X current limit, **load pickup fails if applied from the beginning**. Load is **picked up if applied after steady state is reached**.

Ramped Voltage Applied



Conclusions/Future Work

- Under the ideal conditions simulated, **IBRs** with modest overcurrent limits (1.2–1.5 times rated current) **can blackstart** motors if unloaded or loaded after steady state is reached.
- IBRs might be able to start soft-starter equipped motors with significantly lower overcurrent limits.
- Future research should focus on **high-fidelity modeling** of IBR's **inverters**, **loads** to be blackstarted, and protective **relays**.

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