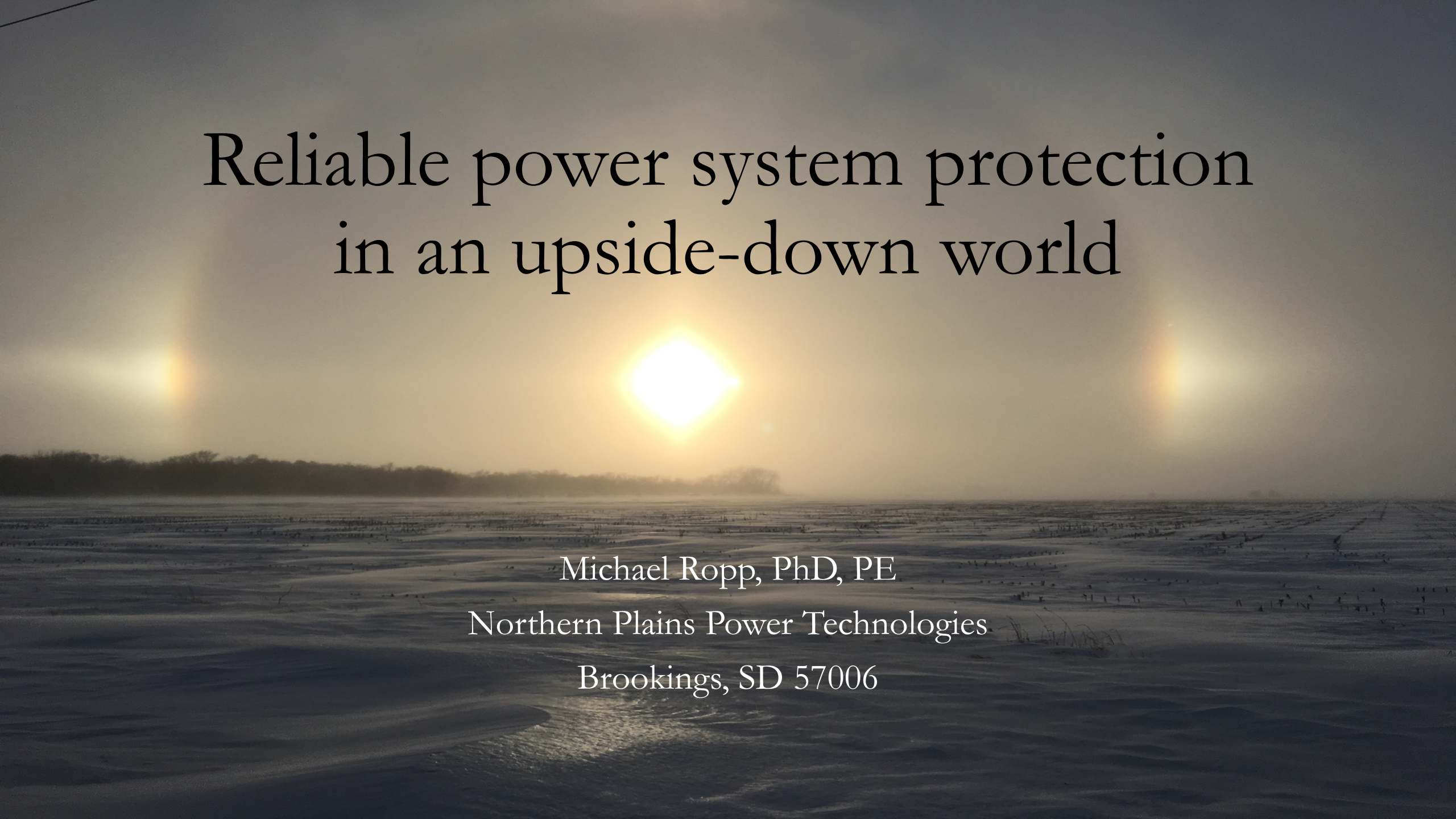

Reliable power system protection in an upside-down world

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What's upside-down about it? (Spoiler: just about everything.)

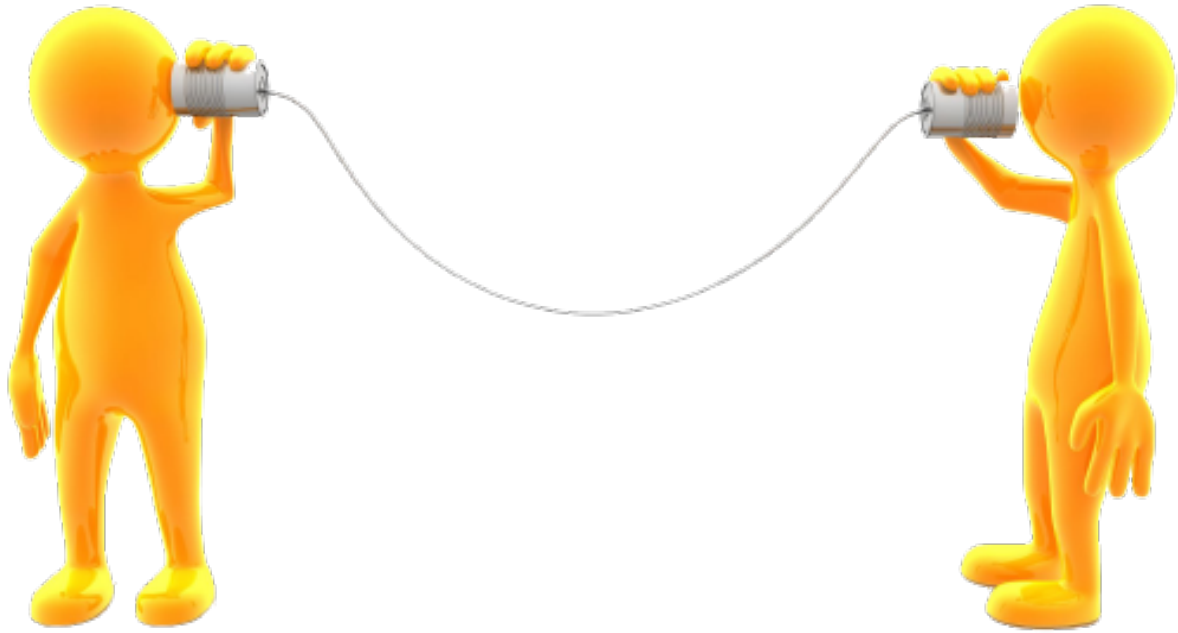
When the system is inverter-dominated and there are multiple source buses:

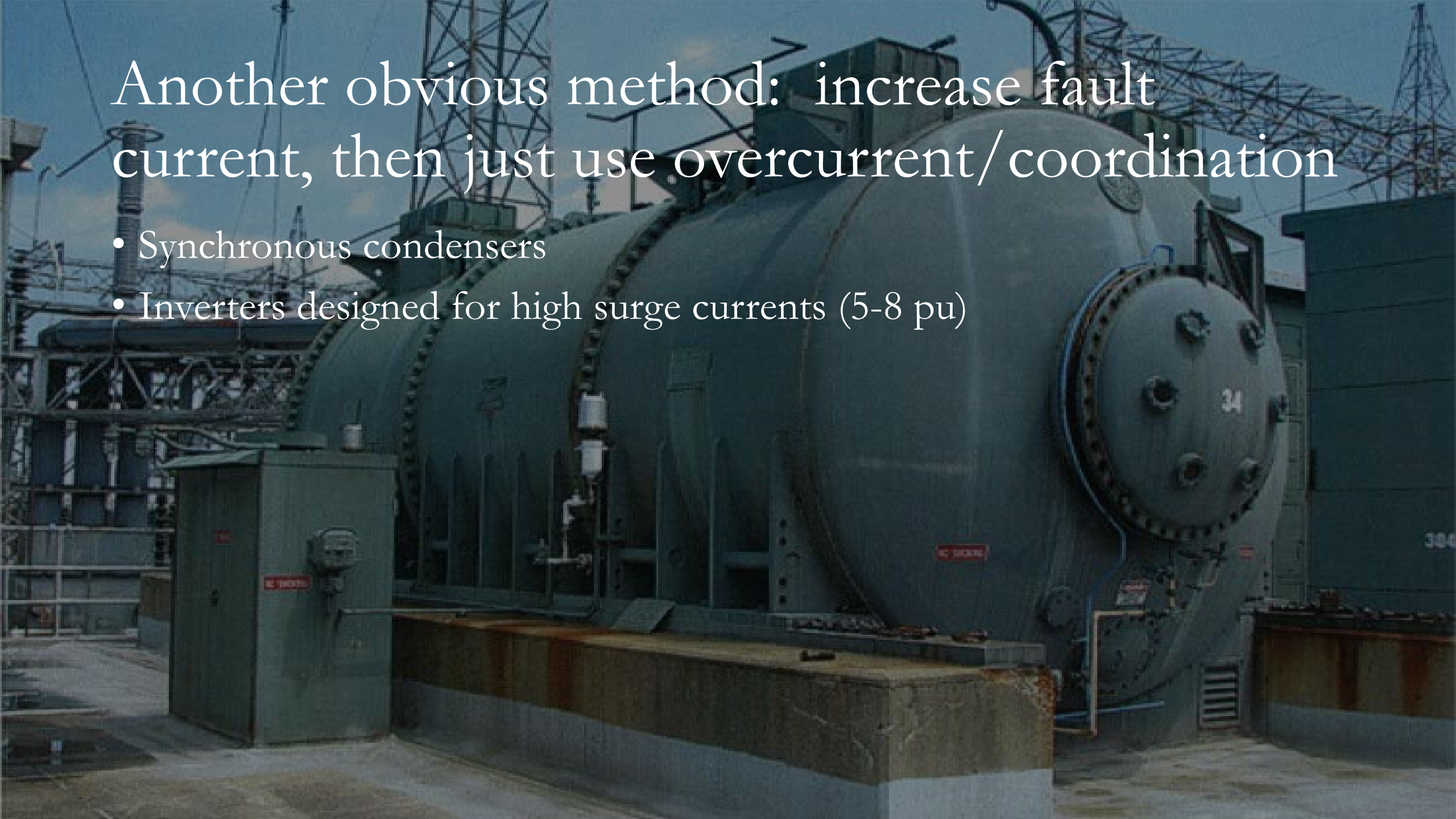
- Fault currents drop.
- Fault currents from a given source are nearly constant everywhere in the system.
- System inertia drops.
- Frequency is coupled to vars, not watts.
- Voltage is coupled to loading.
- Fault current may come from any direction.

The key challenge is not <u>detecting</u> the fault, it's <u>locating</u> the fault.

The obvious option: communications

- With a FLISR-like system, these become possible:
  - Differential protection
  - Voltage gradients (for multiple source buses)
  - Single-phase open detection
  - High-Z fault detection?
  - Tons of other benefits
- Issues:
  - Required BW
  - Cost
  - The more relays, the better





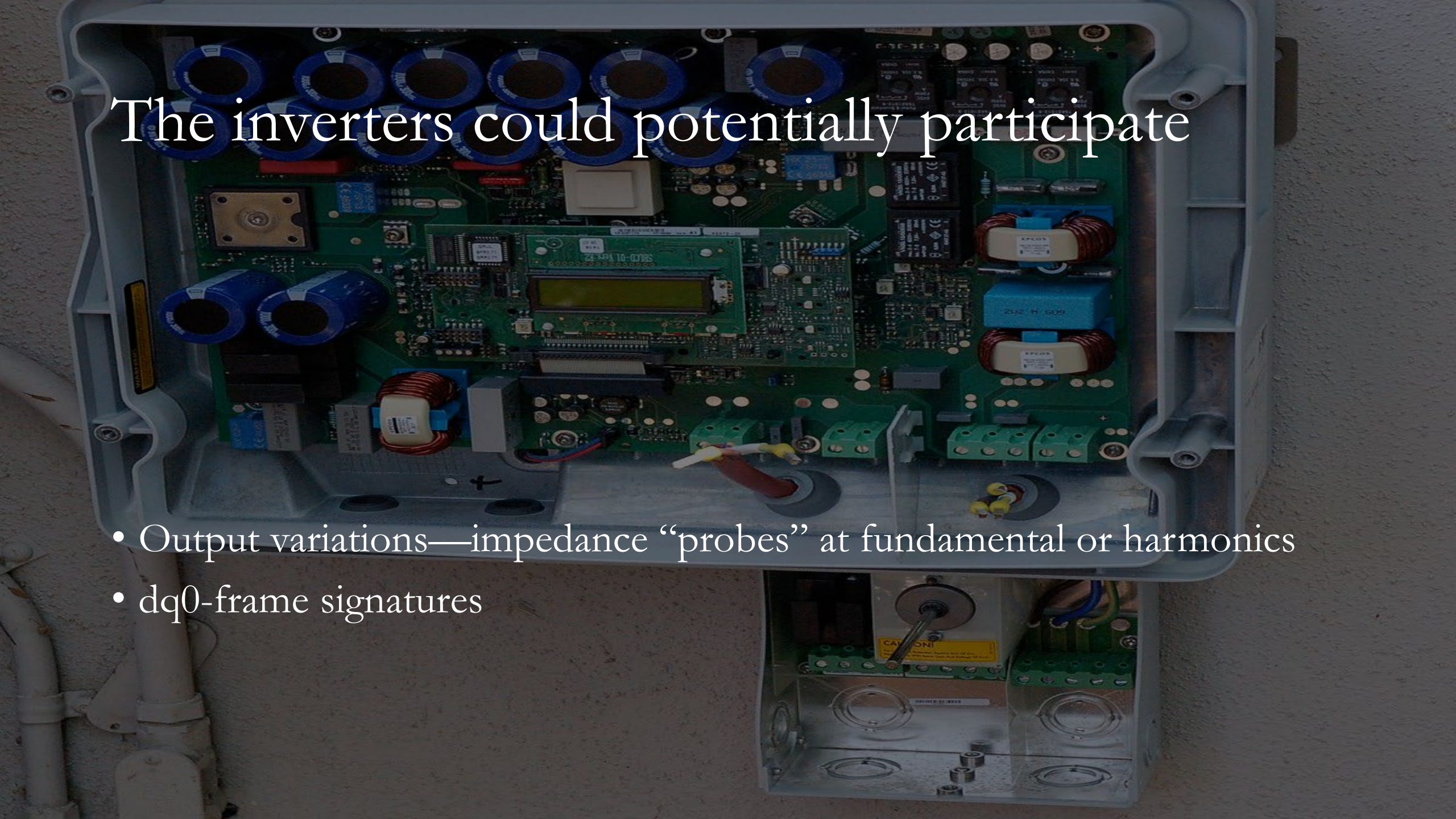
Another obvious method: increase fault current, then just use overcurrent/coordination

- Synchronous condensers
- Inverters designed for high surge currents (5-8 pu)

Can it be done without communications and without raising fault currents?

- Comms allow us to see the patterns of Vs and Is along the circuit.
- Without that system—level pattern visibility, fault location in an all-inverter system becomes *extremely* challenging.
- Situation becomes even worse with multiple source buses.
- Impossible? Perhaps not…

The inverters could potentially participate



- Output variations—impedance “probes” at fundamental or harmonics
- dq0-frame signatures

Conclusion

My $0.000002 worth: we really need to keep working toward low-cost, secure, high-speed, ubiquitous comms in distribution.

Thank you! Questions?

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