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BACKGROUND

- Second life battery refers to an electric vehicle's retired battery after it reaches 80-70% state of health.
- State of health is a quality indicator of the battery. It can be estimated based on capacity fade and/or resistance growth.
- The capacity that remains for the second-life battery can be used in energy storage systems for grid support applications (frequency and voltage regulation, smoothing intermittency of renewable generation, peak shaving and load leveling, power quality improvement, black start, etc.)

CHALLENGE

- Each second-life battery's module comes from a different first-life, different degradation behavior.
- Energy storage needs to accommodate more than one type of battery module.
- Battery Energy Storage System (BESS) needs to be modular, with scalable features.
- Use balancing to increase the system's lifetime.
- Minimum cost.

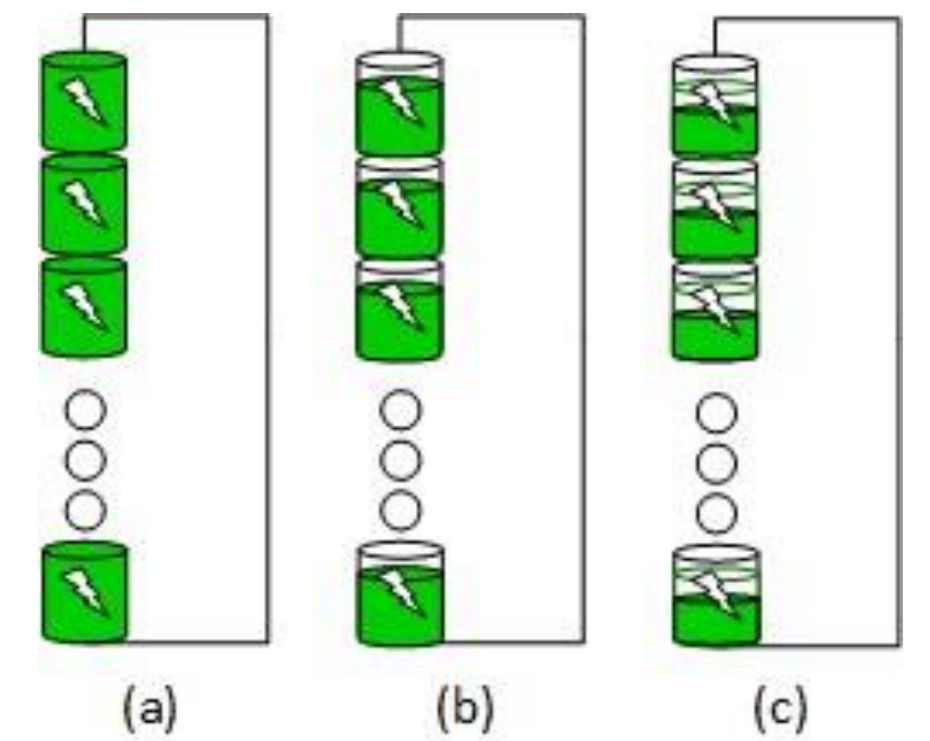


Fig. 1. (a) Battery modules with 100% SOH and 100% SOC; (b) 80% SOH and 100% SOC; (c) 80% SOH and 60% SOC.

BESS APPROACHES

- Two topologies: Inverter + DC-DC converters in cascade, Inverter + DC-DC converters in parallel.
- Passive-active balancing: passive balancing among the battery modules in a string and active balancing between clusters.
- A string should be built with batteries that have similar characteristics.
- Each cluster has its battery management system (BMS), which communicates to a central energy management system (EMS).
- Power share control, based on a weight function that takes as inputs the state of charge (SOC) and state of health (SOH) of the battery string.
- To increase BESS power, more clusters can be added, and inverters can be parallelized to meet the power rate.

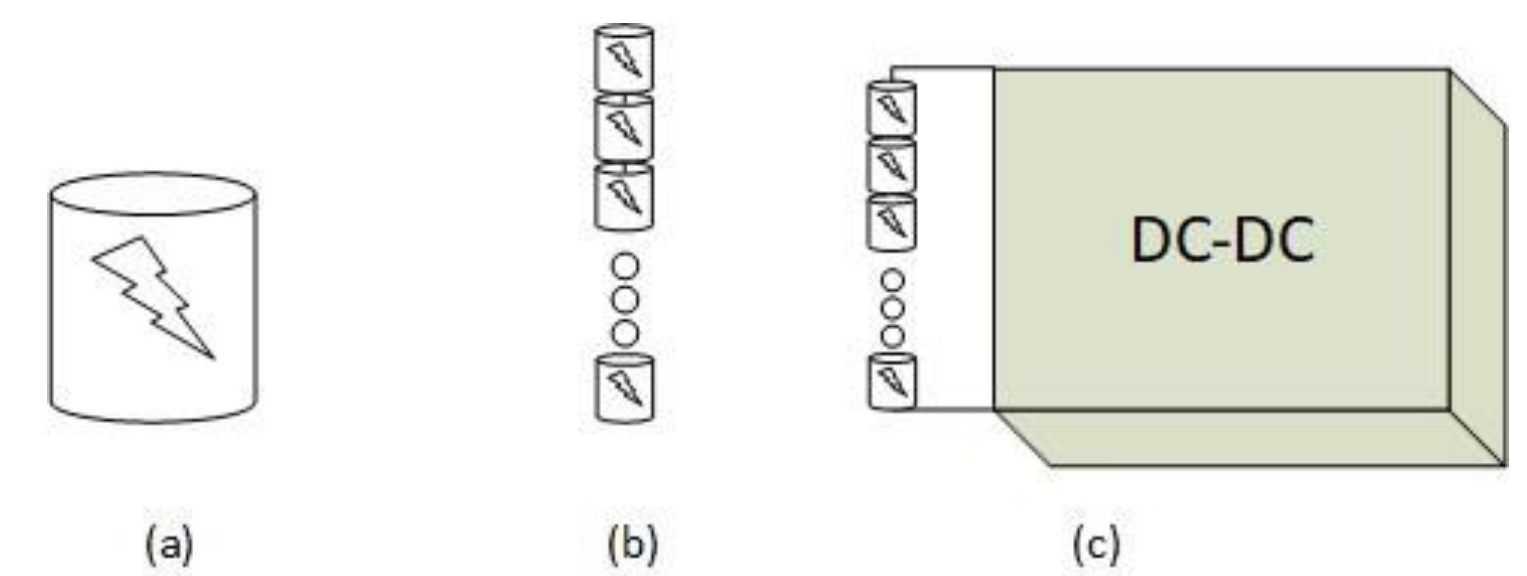


Fig. 2. (a) Battery module, cell connections; (b) string of battery modules; (c) cluster.

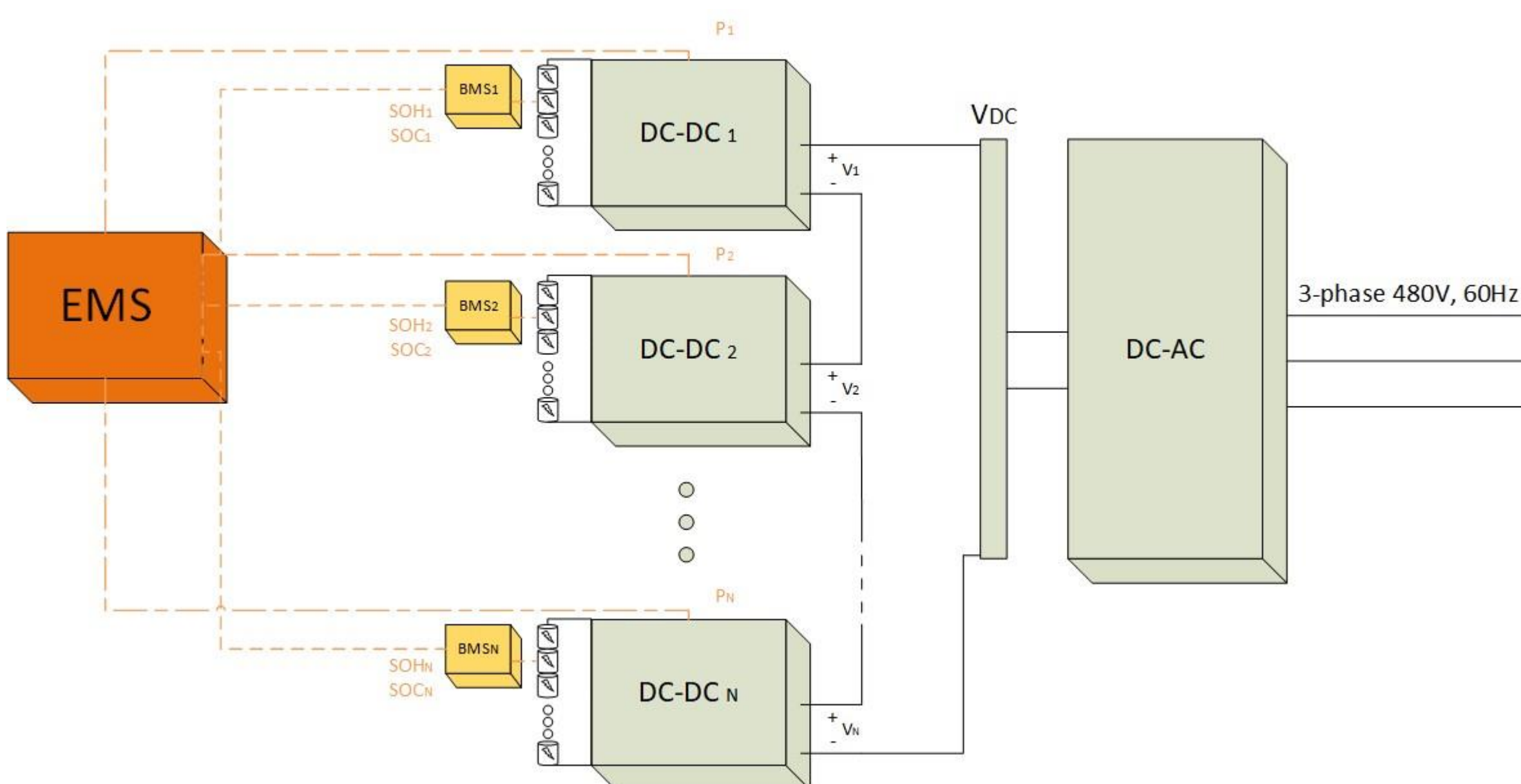


Fig. 3. BESS topology I: inverter + DC-DC converters in cascade.

- Each converter has a different voltage output, regulating the amount of power it will contribute.
- The sum of all voltage outputs equals the fixed dc link voltage.
- Converters have lower voltage rates, components can be smaller and cheaper.

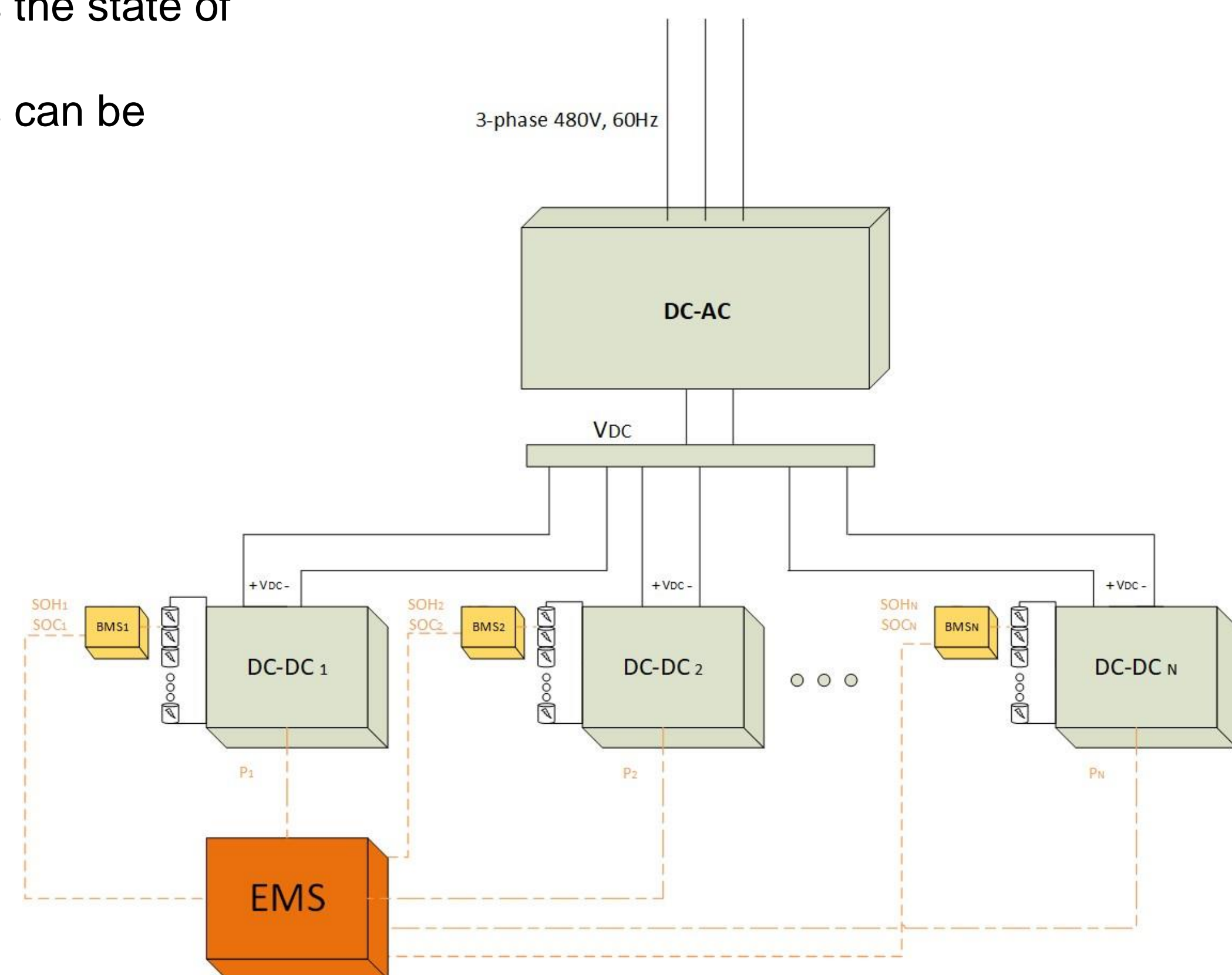


Fig. 4. BESS topology II: Inverter + DC-DC converters in parallel.

- Most common BESS topology.
- All converters have the same voltage output, equal to the dc link voltage.
- More options for dc-dc converters off-the-shelf.
- Simpler dc-coupling connection.

FUTURE WORK

- Select the most cost-efficient topology based on off-the-shelf components.
- Select control communication.
- Design a thermal management system.
- Design a user interface.
- Build a prototype.

