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Sandia National Laboratories

Power Electronics in Grid-tied Energy Storage Systems

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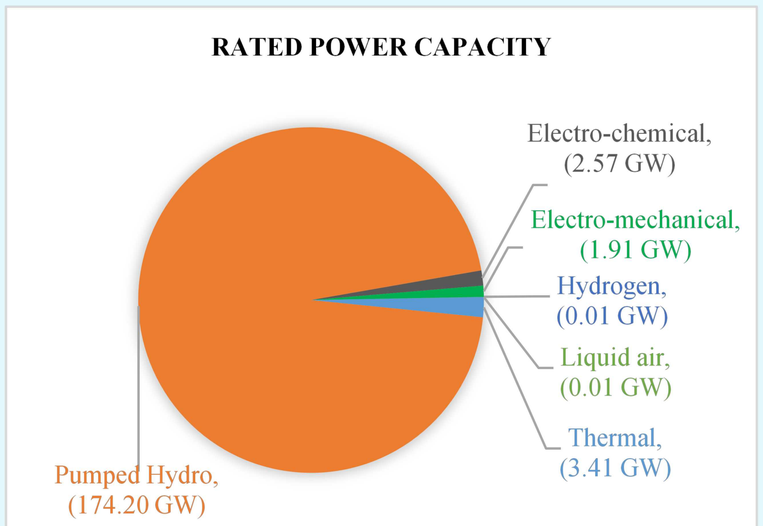
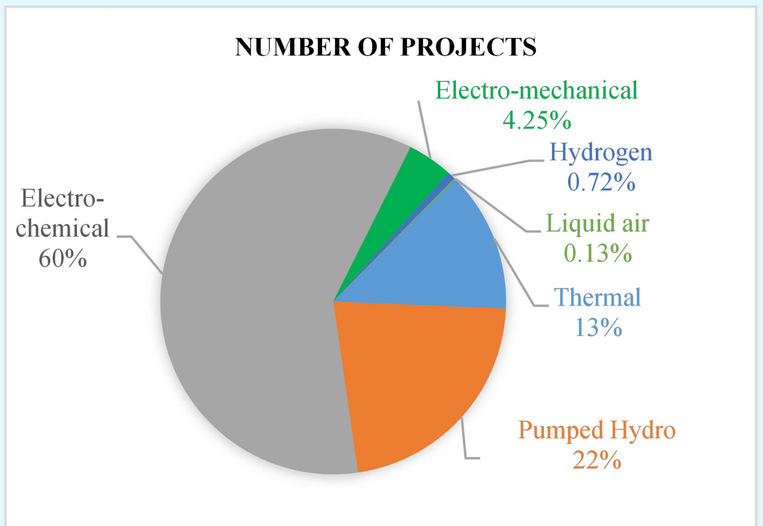
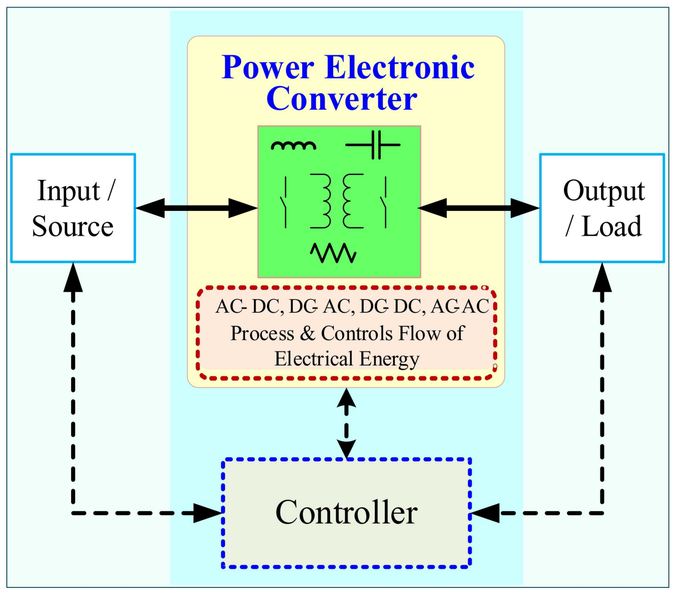
Global Energy Storage Projects by Technology Type
(including Operational, Announced, Under-construction projects up to 2016)

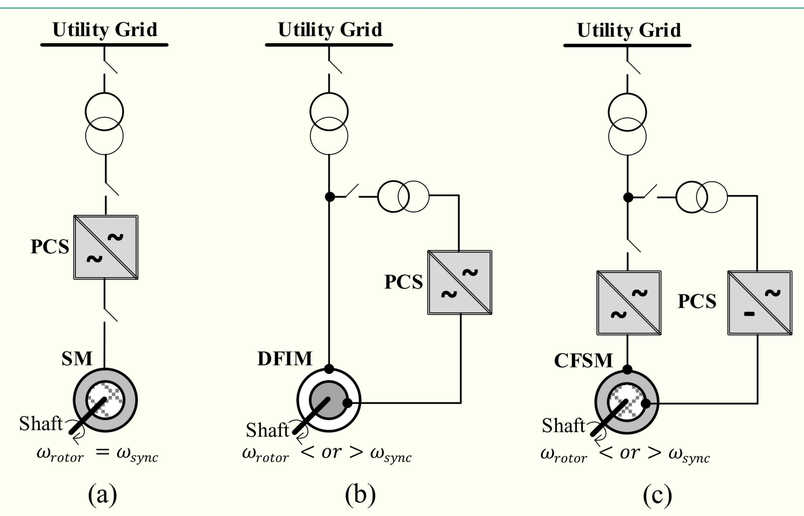




Electric Power Conversion System (PCS)

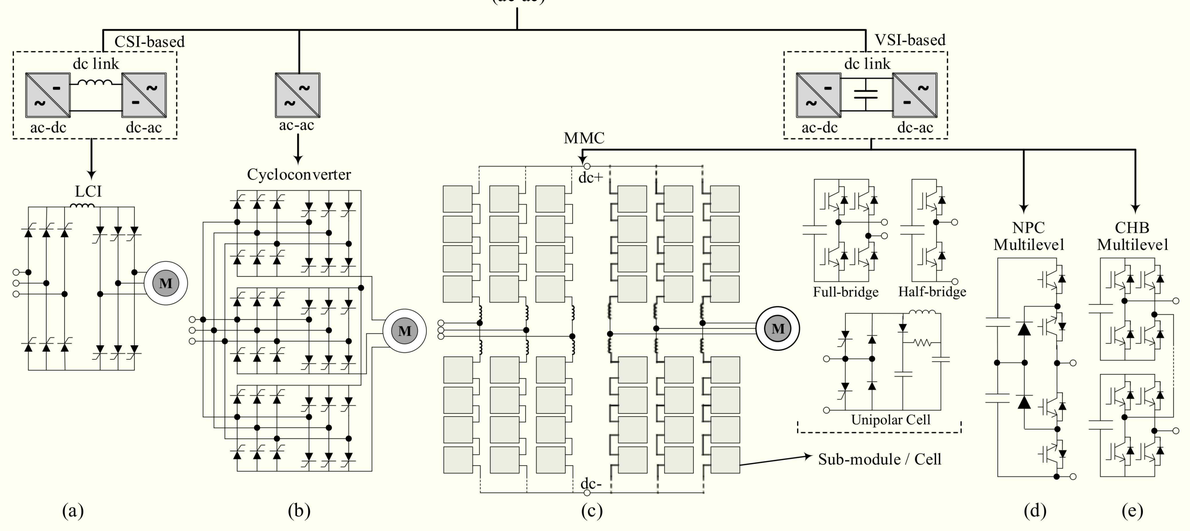


PCS in Pumped Hydroelectric Energy Storage (PHES)



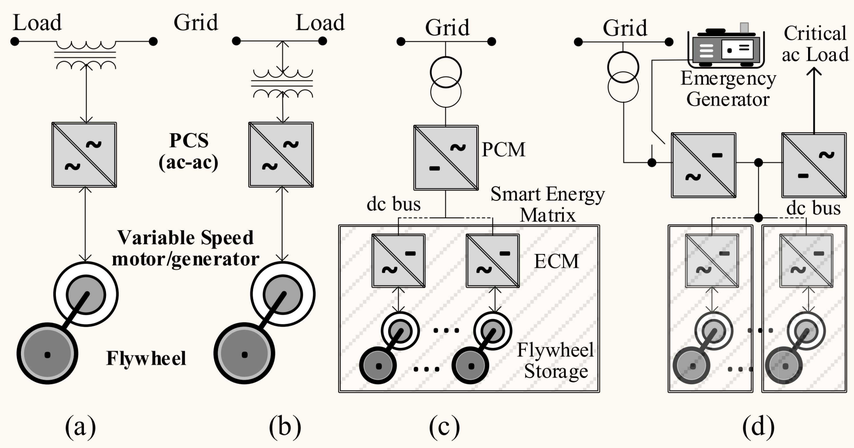
Typical PCS configurations in PHES system - (a) PCS with fully-fed synchronous machine, (b) PCS with asynchronous doubly-fed induction machine (DFIM) , (c) Converter-fed synchronous machine (CFSM).

PE Converters in PHES Applications
(ac-ac)



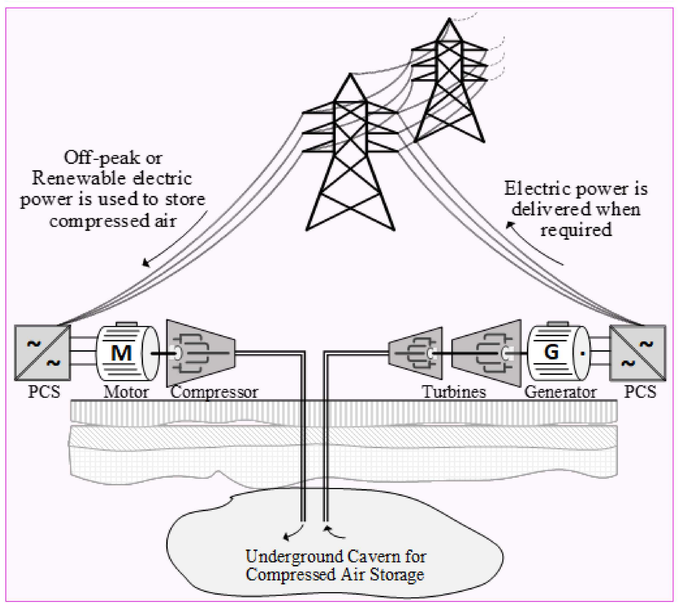
A few power electronic converter topologies used in PCS for PHES applications – (a) Current source inverter based load-commutated inverter (LCI), (b) direct ac-ac power conversion using thyristor based three-phase to three-phase bridge cycloconverter, (c) two-stage power conversion (ac-dc-ac) using modular multilevel converter (MMC) where identical sub-modules/cells may have various topologies as shown to the right, (d) a single-phase dc-ac three-level neutral point diode-clamped (NPC) converter, (e) a single-phase dc-ac cascaded H-bridge (CHB) converter – both (d) and (e) can be extended to three-phase ac-dc-ac power conversion where the rectifier (ac-dc) stage may/may not have identical topologies to that of the inverter (dc-ac) stage.

PCS in Flywheel Energy Storage (FESS)

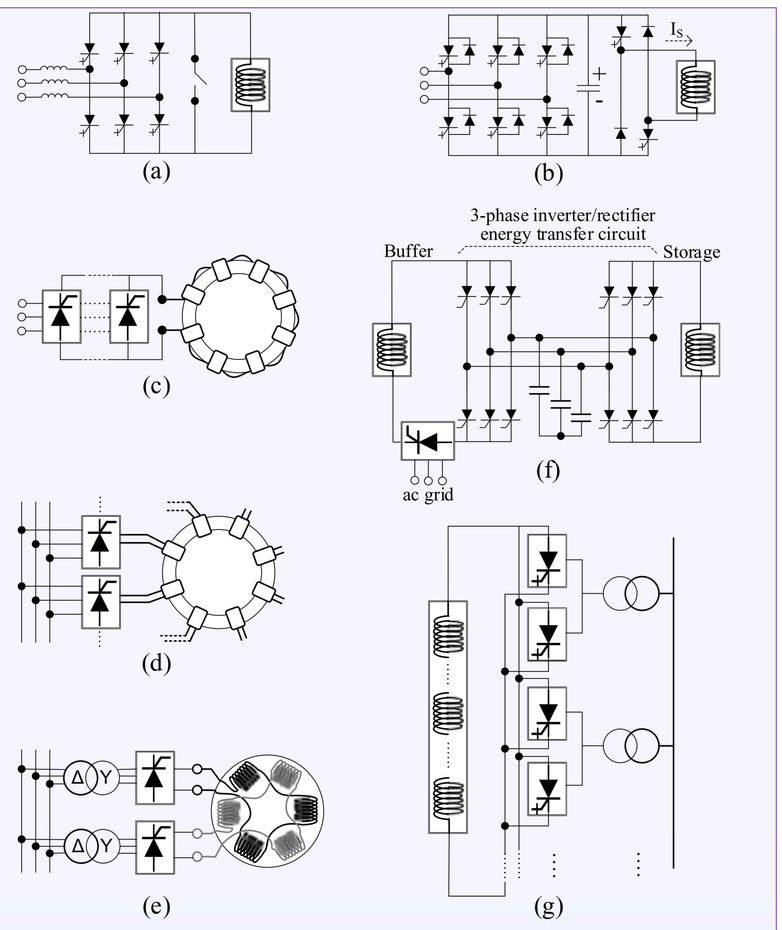


Power converters in grid-connected flywheel energy storage systems (FESS) – (a) series voltage compensation, (b) parallel voltage compensation, (c) array of flywheel storage modules connected to a central inverter via a common dc-bus, (d) flywheel modules for UPS applications.

PCS in Compressed Air Energy Storage (CAES) with underground air storage

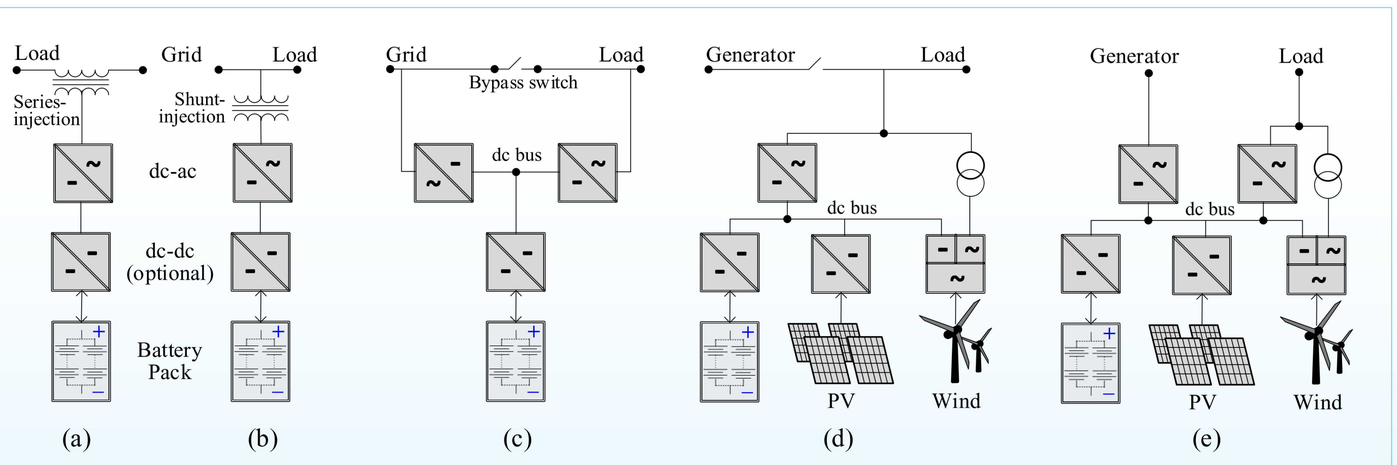


PE Converter Configurations in Superconducting Magnetic Energy Storage (SMES)



Power converter topologies and configurations for SMES applications – (a) GTO-based CSI with a bypass switch, (b) VSI and dc-dc chopper with dc-link, (c) One coil type SMES fed by multiple power converters, (d) Modular converter connected to single coil unit, (e) modular converter connected to multiple coils in series, (f) inverter/rectifier energy transfer circuit with grid-tied inverter for pulse-power applications, (g) a GTO-based 100 MW modular hybrid CSI for SMES.

PCS in Battery Energy Storage Systems (BESS)



Various grid-connected BESS configurations – (a) series injection and (b) shunt injection in grid-connected parallel configuration, (c) grid-connected series configuration with a bypass switch, (d) grid-independent (microgrid) parallel hybrid configuration with renewable energy sources, (e) grid-independent (microgrid) series hybrid configuration with renewable energy sources.

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