



Battery Energy Storage Systems (BESS) Capacitor Solutions

Battery energy storage systems (BESS) buffer intermittent renewable generation, provide grid stabilization services, and enable peak shaving for commercial and industrial facilities.

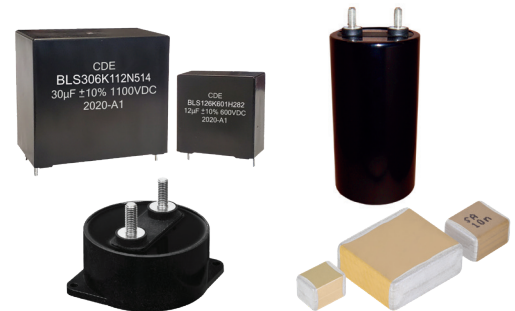
At the heart of every BESS is the power conversion system (PCS) — a bidirectional inverter that converts between DC battery voltage and AC grid voltage. The PCS places demanding requirements on capacitors: high ripple current at the DC link, safety certification at the grid interface, and voltage spike protection throughout. Selecting the right capacitor technology for each stage is critical to achieving the 20+ year operational life that BESS deployments require.

Knowles (including the Cornell Dubilier brand) offers a complete portfolio of film, aluminum electrolytic, polymer, MLCC, and supercapacitor solutions that address every capacitor “job” in a modern BESS PCS.

CAPACITOR JOBS IN BATTERY ENERGY STORAGE

Job 1: DC Link Energy Storage

Buffer energy between the battery bank and inverter stage, absorb ripple current from PWM switching, and maintain DC bus voltage stability — all at voltages ranging from 800 V to 1500 V in utility-scale systems.



REQUIREMENTS:

- High capacitance (100s of μF) for energy buffering
- Very low ESL ($<15\text{ nH}$) for fast-switching SiC/GaN inverters
- High ripple current handling (60–90 A RMS at 55°C or higher)
- Extended operational life (100,000+ hours) to support 20+ year system targets
- Self-healing capability for reliability and benign end-of-life behavior

RECOMMENDED PRODUCTS:

Product	Technology	Key Spec	Why It Fits
944L Series	Film	33–220 μF , 800–1400 Vdc, 10–15 nH ESL, up to 90 A ripple	Purpose-built for high-power inverters, low ESR, 5000 hr life @ 85°C and 100,000+ hr when properly derated
BLS Series	Film	125°C rated, AEC-Q200	Highest temperature rating for outdoor enclosures and demanding environments
StackiCap	MLCC	250 V–1.2 kV, high capacitance, low ESR	HF decoupling close to SiC switches; supports compact, low-inductance layouts
Type 947C/944U/UNL	Film	DC link polypropylene power film for inverters	Proven DC link families for renewable and industrial inverters, wide capacitance/voltage range
Type MDL Modules	Film	600–4,200 μF , 900–1,300 Vdc DC link modules	High-energy DC link blocks for large BESS inverters, optimized for ripple current and life
Type BLH	Film	Board-mount DC link for harsh environments	Rugged DC link option for compact PCS designs in outdoor cabinets

Design Note: Optimal DC link designs combine film capacitors for bulk energy storage with MLCCs (such as StackiCap) placed within 10 mm of switching devices for high-frequency filtering.



Job 2: Grid Interface EMI Filtering

Filter conducted emissions and protect against grid transients while meeting stringent EMC and interconnection standards (e.g., IEEE 1547, IEC 61000-3-12). BESS PCS must also meet safety requirements at the grid point of common coupling.

REQUIREMENTS:

- X1/Y2 safety certification per EN60384-14
- Voltage ratings up to 500 Vrms and 1500 Vdc for modern grids
- High dV/dt capability for grid transients and switching events
- Compact footprint for high power density layouts

RECOMMENDED PRODUCTS:

Product	Technology	Key Spec	Why It Fits
X1/Y2 Safety MLCCs	Ceramic	310–500 Vrms, up to 1500 Vdc rating	Industry-leading voltage rating, certified for X1/Y2 safety applications
2720 Case Size MLCCs	Ceramic	5 mm creepage distance	Meets safety spacing without bulky film capacitors in constrained layouts
Harsh Environment Safety Film	Film	X1/Y2 rated, high dV/dt	Ruggedized film capacitors for extreme temperature and vibration environments



Design Note: Use safety-certified X1/Y2 MLCCs at the grid interface to help meet IEEE 1547 and regional EMC standards while maintaining compact PCS designs.

Job 3: Inverter Snubber Circuits

Protect IGBT and SiC MOSFET switches from voltage spikes during commutation. Modern SiC devices switch faster than IGBTs, creating higher dV/dt stress that demands purpose-built snubber solutions.

REQUIREMENTS:

- Voltage rating $>2\times$ bus voltage (1500 V+ for 800 V systems)
- High dV/dt capability (>1000 V/ μ s)
- Low ESR for pulse current handling
- Fast response to transient events

RECOMMENDED PRODUCTS:

Product	Technology	Key Spec	Why It Fits
HV MLCCs	Ceramic	1 kV–1.5 kV, C0G/X7R dielectrics	Fast transient response, compact footprint near devices
Snubber Film	Film	0.1–5 μ F, 630–3000 V	High pulse current, self-healing construction
IGBT Snubber Modules	Film	Board- and direct-mount snubbers	Optimized layout to minimize inductance and overvoltage stress in power stages



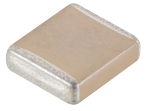


Job 4: Resonant Circuits (LLC Topology)

Many modern PCS designs use LLC resonant converters for soft switching, achieving efficiencies above 98%. The resonant tank capacitor directly impacts converter efficiency — loss factor ($\tan \delta$) and stability matter.

REQUIREMENTS:

- Very low loss factor ($\tan \delta < 0.001$)
- Stable capacitance vs. temperature and voltage
- Precise tolerance ($\pm 5\%$ or better)
- High ripple current rating



RECOMMENDED PRODUCTS:

Product	Technology	Key Spec	Why It Fits
C0G HV MLCCs	Ceramic	630–1500 V, ultra-low $\tan \delta$	C0G has the lowest loss among ceramic dielectrics for LLC tanks
944L Film	Film	Low-loss polypropylene	High capacitance with excellent Q and low dissipation factor

Job 5: Auxiliary Power and Control

BESS systems include battery management systems (BMS), thermal management controllers, and communication interfaces — all requiring reliable power filtering and decoupling.

REQUIREMENTS:

- Wide temperature range operation (-40°C to $+85^{\circ}\text{C}$ typical)
- Long operational life matching BESS warranty periods
- Stable capacitance across temperature and bias



RECOMMENDED PRODUCTS:

Product	Technology	Key Spec	Why It Fits
X7R MLCCs	Ceramic	Wide temp range, compact footprints	General decoupling and filtering in control and low-voltage rails
Aluminum Polymer	Polymer	Low ESR, 10,000+ hr life	Bulk filtering with extended life for control power stages
Screw Terminal (DCMC/3186/550C)	Aluminum electrolytic	High ripple current, high capacitance	Ideal for auxiliary DC links and BMS/aux power bulk storage in larger frames
Snap-in (380LX/381LX/SLP/SLPX)	Aluminum electrolytic	Up to 600 Vdc, high energy density	Cost-effective bulk storage for smaller BESS and auxiliary inverters

Job 6: AC Harmonic Filtering at Grid Interface

Filter harmonic currents at the inverter input/output to meet IEEE 1547, IEC 61000-3-12, and utility-specific power quality requirements. BESS PCS must maintain low THD and support grid stability across operating conditions.

REQUIREMENTS:

- High AC voltage capability and harmonic current handling
- Long life under continuous AC stress
- Safe failure mode (open circuit) with pressure interrupters where required



RECOMMENDED PRODUCTS:

Product	Technology	Key Spec	Why It Fits
Type PC	Film	Single-phase fluid-filled AC filter	Designed for AC harmonic filtering with safety pressure interrupter
Type PFCH	Film	Three-phase fluid-filled filters	For 3-phase harmonic mitigation at BESS PCS grid connection points



Job 7: Supercapacitor Backup and Hybrid BESS

Next-generation BESS increasingly pair batteries with supercapacitors to handle short-duration, high-power events, extend battery life, and provide robust backup for control and protection systems

REQUIREMENTS:

- Extremely high cycle life (hundreds of thousands to millions of cycles)
- High power density and fast charge/discharge capability
- Wide operating temperature range and long calendar life



RECOMMENDED PRODUCTS:

Product	Technology	Key Spec	Why It Fits
DSM Series	Supercapacitor modules	9–60 V, 0.15–36.6 F, integrated balancing	Higher-voltage supercapacitor storage for peak shaving, ride-through, and hybrid BESS rails
DGH/DSF Series	Supercapacitors	3-cell devices up to 9.0 WVDC	Backup for BMS, control logic, and memory; energy harvesting and short-term hold-up

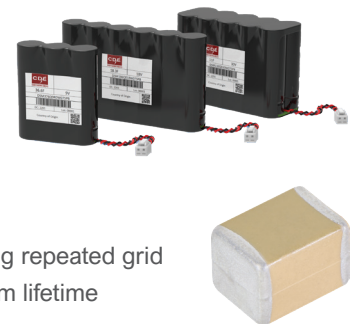
Design Note: Supercapacitors can supplement batteries for rapid charge/discharge, backup power, and extended system cycle life, with 500,000+ charge/discharge cycles and 10-year operating life in many designs.

Job 8: Grid-Forming Inverter and Black-Start Support

Grid-forming BESS inverters establish voltage and frequency reference for weak or “islanded” grids, requiring extremely fast transient response and robust support for black-start and fault ride-through.

REQUIREMENTS:

- Very fast response to grid disturbances and transient events
- High pulse power capability on DC and auxiliary rails
- Reliable operation during repeated grid events across the system lifetime



RECOMMENDED PRODUCTS:

Product	Technology	Key Spec	Why It Fits
DSM/DGH/DSF Supercaps	Supercapacitors	High power, high cycle life energy storage	Supports grid-forming functions, fast frequency response, and black-start assistance
HV MLCCs & StackiCap	MLCC	High-frequency decoupling at critical nodes	Low inductance decoupling for control and power stages in grid-forming PCS designs