Capacitors for High Power Inverters and Converters
What is an Inverter?

An electronic device or circuitry that changes direct current (DC) to alternating current (AC)

![Diagram of inverter process]

DC Input → INPUT FILTER → DC TO DC → DC LINK → DC TO AC CONVERSION → L/C OUTPUT HARMONIC FILTER → AC Output

CONTROL CIRCUIT
What is a Converter?

An electronic device or circuit that changes alternating current (AC) to direct current (DC)
FAST DC EV CHARGER LEVEL-3

Level 3 chargers require higher power components.

CONTROL CIRCUIT
LEVEL 3 20kW to 240kW

DC Link Selection
550C, 947D, 944U, 944I, BLH, Custom

AC Harmonic Filter Selection
ALH, PC, PFCH

<table>
<thead>
<tr>
<th>AC INPUT FILTER</th>
<th>AC-TO-DC RECTIFIER</th>
<th>DC LINK CAPACITOR</th>
<th>DC – HVDC VARIABLE</th>
<th>DC OUTPUT FILTER CAPACITOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>400-480 VAC LINE</td>
<td>~</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 ~
Solar Inverter

DC Vin → INPUT FILTER → DC TO DC BOOST → DC LINK → DC TO AC CONVERSION → L/C OUTPUT HARMONIC FILTER → LOAD

- DC
- CHARGE
- BATTERIES / SUPERCAPS
- CONTROL CIRCUIT
- AC

SCREW TERMINAL, POWER FILM, & PLUG IN
SNUBBER
SF, PC, PFCH, & ACF
Uninterruptible Power Supply - UPS

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Variable Frequency Drive - VFDA

INVERTER CONTROL CIRCUIT
SPEED CONTROL CIRCUIT

INPUT FILTER
AC TO DC RECTIFIER
DC LINK
DC TO AC CONVERSION
L/C OUTPUT HARMONIC FILTER
MOTOR

LINE
AC
AC
AC
AC

SF, PC, PFCH, & ACF
SNUBBER
SCREW TERMINAL, POWER FILM, & PLUG IN
SF, PC, PFCH, & ACF
Capacitors for Inverters/Converters

- Input Filter Capacitors
- DC Link Capacitors
- Snubber Capacitors
- AC Harmonic Filter Capacitors

**Power Film DC Link**
CDE offers the most advanced metallized film technology for long life and high reliability in DC link applications. Available in a variety of package styles, our technology combines high capacitance and very high ripple current capability needed for today’s inverter designs for wind, solar, fuel cells, UPS systems, medical power and more.

**Screw Terminal and Snap-in Capacitors**
CDE is the industry’s leading manufacturer of screw terminals aluminum electrolytic capacitors for inverter applications. We excel at designing high ripple current screw terminal and snap-in capacitors for critical power electronics applications.

**IGBT Snubber Modules**
Low inductance snubbers protect IGBT modules from overvoltage transients. Choose from our board-mount or direct-mount styles for maximum protection.

**AC Harmonic Filter Capacitors**
Choose from single phase (Type PC) and 3-Phase (Type PFCH) fluid filled AC capacitors designed for filtering harmonics at the input or inverter output. Oil filled types contain an environmentally friendly fluid and their built-in safety pressure interrupter ensures open circuit failure mode at end of life. Use axial type ACF for the same high performance filtering where dry construction is preferred.

https://www.cde.com/solutions/inverters/
Capacitors Typically used in High Power Inverters, Converters

- Aluminum Electrolytic
- DC Film
- Snubbers
- AC Film

- INPUT FILTER
- DC TO DC
- DC LINK
- DC TO AC CONVERSION
- L/C OUTPUT HARMONIC FILTER
- CONTROL CIRCUIT

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The DC-link capacitor's purpose is to provide a more stable DC voltage, limiting fluctuations as the inverter sporadically demands heavy current. A design can use different technologies for DC-Link capacitors such as aluminum electrolytic, film, and ceramic types.

Generally, High Capacitance and High Ripple Current are required for the DC Link.
Aluminum Electrolytic Capacitors

More Capacitance for the Buck
Typically, aluminum electrolytic capacitors are the best option for power electronics applications requiring high capacitance (100’s of μF to Farads), up to 550 Vdc.

- 4 to 10 times the capacitance per dollar of film capacitors
## Screw Terminal Capacitors for (DC Link), Bus Mount

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Form Factor</th>
<th>Temperature (°C)</th>
<th>Voltage (Vdc)</th>
<th>Load Life (h)</th>
<th>Load Life (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500C</td>
<td>Long Life</td>
<td></td>
<td>-40°C - 95°C</td>
<td>6.3V - 550V</td>
<td>5,000</td>
<td>85°C</td>
</tr>
<tr>
<td>520C</td>
<td>High Ripple Current/Long Life</td>
<td></td>
<td>-40°C - 85°C</td>
<td>200V - 500V</td>
<td>8,000</td>
<td>85°C</td>
</tr>
<tr>
<td>550C</td>
<td>High Ripple Current/Long Life</td>
<td></td>
<td>-40°C - 105°C</td>
<td>200V - 500V</td>
<td>10,000</td>
<td>105°C</td>
</tr>
<tr>
<td>DCMC</td>
<td>High Capacitance, 85°C</td>
<td></td>
<td>-40°C - 85°C</td>
<td>6.3V - 550V</td>
<td>2,000</td>
<td>85°C</td>
</tr>
</tbody>
</table>
## Typical High-Ripple Lifetimes

4700 µF 450 V Comparison 60 °C, 12 A @ 120 Hz, 400 V

<table>
<thead>
<tr>
<th>Type</th>
<th>Case Size (in)</th>
<th>Life (years)</th>
<th>Price (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCMC</td>
<td>3x5(\frac{1}{8})</td>
<td>4.6</td>
<td>100</td>
</tr>
<tr>
<td>500C</td>
<td>3x5(\frac{5}{8})</td>
<td>9.5</td>
<td>110</td>
</tr>
<tr>
<td>520C</td>
<td>3x5(\frac{5}{8})</td>
<td>23.7</td>
<td>130</td>
</tr>
<tr>
<td>550C</td>
<td>3(\frac{1}{2})x5(\frac{5}{8})</td>
<td>48.8</td>
<td>142</td>
</tr>
</tbody>
</table>
Snap-in Capacitors for (DC Link) Board Mount

Broad, power-focused selection including:

- High voltage: up to 600 Vdc
- Long life: 8,000 hrs
- High ripple current: Up to 20 Arms
Power Aluminum Electrolytic Competitors

- United Chemi-Con
- Jianghai
- TDK EPCOS
- Nichicon
- Kemet
- Elna America, Inc.
- Hitachi Chemical
Power Film: DC Link Capacitors

More Ripple Current for the Buck
Typically, DC film capacitors are more economical than aluminum electrolytics in high voltage (>600 Vdc), high ripple current capacitor DC Link applications.

Standard DC Link film caps meet bus voltage applications between 450 – 1300 Vdc. Custom DC Link designs available up to 100 kVdc.

No need to place capacitors in series
  • Eliminates need for balancing resistors

Dry construction – no electrolyte

Non-polar
## Film Capacitors for Inverter and Converter (DC link)

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Form Factor</th>
<th>Temperature (°C)</th>
<th>Voltage (Vdc)</th>
<th>Capacitance Range (µF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>944L</td>
<td>DC Link/Low Inductance</td>
<td></td>
<td>-40°C - 95°C</td>
<td>800V - 1400V</td>
<td>33µF - 220µF</td>
</tr>
<tr>
<td>947D</td>
<td>DC Link/Cylindrical/Bus Mount</td>
<td></td>
<td>-40°C - 85°C</td>
<td>900V - 1300V</td>
<td>130µF - 1500µF</td>
</tr>
<tr>
<td>UNL</td>
<td>DC Link/Board Mount/Cylindrical</td>
<td></td>
<td>-40°C - 85°C</td>
<td>400V - 1500V</td>
<td>4.7µF - 100µF</td>
</tr>
<tr>
<td>BLH</td>
<td>DC Link for Harsh Environments 85%RH, 85 °C, AEC-Q200</td>
<td></td>
<td>-40°C - 85°C</td>
<td>450V - 1200V</td>
<td>1µF to 170µF</td>
</tr>
</tbody>
</table>
Highlighted Capabilities

- Capacitance: up to 50,000 uF
- Voltage (DC): up to 100,000 VDC
- Current (Peak): up to 100,000 amp
- Inductance (nH): As low as 25nH
- Energy Density: Up to 3 J/cc
- Metal cases or isolated plastic cases available
- Water-cooled construction available
- Wide variety of terminations available
Snubber
The word **snub** means to rebuff, spurn, repulse, give someone the cold shoulder, shortened at the end.

**Snubber**: A device used to protect switching devices from overvoltage during turnoff.

During turn off, a voltage transient appears across the switch that may exceed its voltage rating. The voltage transient is proportional to the amount of stray inductance (L) and the rate in change in current with time.

\[ V_{\text{transient}} = -L \frac{di}{dt} \]
Snubbers

Discrete Axial Leaded Snubbers
High dV/dt – 940C, 941C PPA, PPS
Very High dV/dt: 942C, 943C

Radial Leaded Box Snubbers
High dV/dt: PSB

Direct Mount IGBT Snubbers
Capacitor Type: SCD, PMB, PMC
Clamp Type w diode: SCM
Dual Clamp Type: SCC
DC Power Conversion Film Competitors

ASC Capacitors

Electronic Concepts

KEMET

TDK EPCOS

VISHAY

AVX

ELECTRONICON

WIMA
AC Harmonic Filtering
Inverter switching result in harmonics that are odd numbered multiples of the fundamental switching frequency (3rd, 5th, 7th, etc.).

These harmonics combine with the fundamental frequency and cause distortion of the waveform.

These undesirable frequencies are filtered out using tuned circuits consisting of capacitors and inductors.
# AC Harmonic Filter Capacitors

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Form Factor</th>
<th>Temperature (°C)</th>
<th>Voltage (Vdc)</th>
<th>KVAR</th>
<th>Capacitance Range (μF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALH</td>
<td>AC Filter Capacitors for Harsh Environments</td>
<td><img src="#" alt="Image" /></td>
<td>-40°C - 105°C</td>
<td>160V - 450V</td>
<td>-</td>
<td>220 nF - 50 μF</td>
</tr>
<tr>
<td>PC</td>
<td>AC Harmonic Filter/Single Phase/Stud Mount</td>
<td><img src="#" alt="Image" /></td>
<td>-40°C - 70°C</td>
<td>300V - 700V</td>
<td>-</td>
<td>20 μF - 125 μF</td>
</tr>
<tr>
<td>PCD</td>
<td>AC Power Conversion Capacitors</td>
<td><img src="#" alt="Image" /></td>
<td>-40°C - 70°C</td>
<td>240V - 600V</td>
<td>-</td>
<td>20 μF - 125 μF</td>
</tr>
<tr>
<td>AMPO</td>
<td>1-Phase and 3-Phase Rectangular</td>
<td><img src="#" alt="Image" /></td>
<td>-40°C - 55°C</td>
<td>240V - 600V</td>
<td>2.5 - 25</td>
<td>18.4 μF - 575.6 μF</td>
</tr>
<tr>
<td>MMPO</td>
<td>1-Phase and 3-Phase, Large Welded Case</td>
<td><img src="#" alt="Image" /></td>
<td>-40°C - 55°C</td>
<td>240V - 4800V</td>
<td>25 - 200</td>
<td>2.9 μF - 1,414.7 μF</td>
</tr>
<tr>
<td>PFCH</td>
<td>AC Harmonic Filter/3-Phase/Cylindrical</td>
<td><img src="#" alt="Image" /></td>
<td>-40°C - 55°C</td>
<td>240V - 600V</td>
<td>0.5 - 30</td>
<td>1.9 μF - 268.6 μF</td>
</tr>
</tbody>
</table>
Highlighted Capabilities

KVAR up to 15,000
Vrms up to 8,500
Irms up to 5,000
Frequency up to 500 KHz
Available in drawn or custom welded metal cases
Water-cooled construction available
Wide variety of terminations available
AC Harmonic Filter Competitors
CDE’s COMPETITIVE ADVANTAGE

• We excel in capacitor technologies across all stages of power conversion, especially high power.
  • Broad portfolio of standard part offerings (DC Link, Snubber, Filters)
  • Board-level and bus mounted solutions
    • DC Film
    • AC Film
    • Aluminum Electrolytic
• Power-focused manufacturer’s reps
• Application engineers available to assist with optimal capacitor selection and design
• Extensive custom design and manufacturing capability to optimize performance, fit, reduce size and cost, modeling of capacitor performance
Thank You!