Capacitors in Low Voltage AC Drives

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Agenda

• Capacitors in Industrial Low Voltage (200V-690V) AC Drives
  • Aluminum Electrolytic
  • Metallized Film
  • Ceramic Disc
  • MLCCs
  • Tantalum Polymer and Hybrid Polymer

• Future Trends - Impact of WBG Semiconductor Devices
Six-Pulse AC Drive and Capacitor Types Typically Used

- AL Electrolytic
- MPP Film
- Ceramic Disc
Line Filter Capacitors for AFE Rectifiers in Regenerative AC Drives

- Failure mode of line filter capacitors requires protection such as integrated fusing, thermal cut-out and/or diagnostics based on measured voltage, current...
DC Link Capacitors - Requirements

- Capacitance value selection criteria ~ 25-40 µF/A
  - Voltage ride-through with 6-pulse front-end rectifier
  - Power quality (voltage unbalance, harmonics)
  - Inverter output torque bandwidth
  - Ripple current, lifetime

- Aluminum electrolytic capacitor preferred due to low volume
  - MPP film capacitors have << 20% of the capacitance for the same volume

- Series connection required to meet voltage requirements
  - 500-1200VDC can be achieved with 2 capacitors in series
  - Multiple parallel paths needed for ripple current capability

477A VFD – 8 x 76φ x 150H capacitors
100A VFD – 8 x ?φ x ?H capacitors
MPP Film Capacitors for DC Link Applications

• Film capacitor advantages
  • High ripple current capability
  • Series connection not required
  • Long life

• Trends in power conversion where film capacitors can be used
  • AC drives with active front-end rectifiers
    • DC bus is regulated by closed-loop control
  • High PWM frequency rectifiers
    • WBG semiconductor devices
    • Multi-level converters

Courtesy: Electronic Concepts
MPP Film and Ceramic Disc Capacitors for EMC Filters

• Safety rated (Type X or Y) capacitors required for regulatory compliance
  • Capacitance ranges from 0.2µF - 5µF
  • Voltage rating (500VAC, 1600VDC)

• Capacitors subjected to high dv/dt with long motor leads, high switching frequency

• High temperature and high humidity tolerance required
  • Comply with 85% RH / 85°C, 1000 hours reliability test

• Ceramic disc capacitors used when low capacitance required for high frequency EMC filtering
MPP Film Capacitors for DC Link Snubbers

- Snubber capacitors used to reduce voltage overshoot on power devices upon short-circuit recovery
  - Capacitance $\sim 0.1 - 1\mu$F

- High peak and RMS current requirement
  - Double metallized PP film

- High temperature and high humidity tolerance required
  - Comply with 85% RH / 85°C, 1000 hours test
Line Filter Capacitors for AFE Regenerative AC Drives

• Typical IGBT based AFE, 4kHz PWM frequency
  • ~ 50 µF for a 100A AC drive

• High peak current capability required
  • Resonance on soft AC lines, control instability

• Capacitor failure mode requires additional protection
  • Integrated fusing, thermal cut-out, voltage/current sensing

• With WBG power devices, high PWM frequency, capacitance required is reduced (e.g. <10µF at 16kHz PWM for 100A AC drive)
MLCC Capacitors and Alternatives

- Capacitance and voltage
  - 0.1-100 µF, 6-50VDC
- Advantages
  - Low ESR, small size
- Applications
  - SMPS output
  - Gate drive
  - IC buffer
- Tantalum solid polymer
  - Size, ESR
  - High temperature/humidity reliability

- Polymer hybrid
  - SMPS output
  - Low ESR, high life
Future Trends

• Aluminum Electrolytic
  • Higher DC voltage such that series connection is not required

• Hybrid DC Link
  • Mix of aluminum electrolytic with parallel DC link film capacitors to meet ripple current and energy storage requirements

• WBG Semiconductor Converters (AFE) with high PWM frequency
  • DC link film capacitors
  • LCL filter with low capacitance MPP film (integral protection not required)