

PSMA Capacitor Committee and IEEE PELS Capacitor Workshop:
The Impact of Wideband Technologies on Application of Capacitors
- A Deep Dive on Capacitor Technology -

Capacitors in Low Voltage AC Drives

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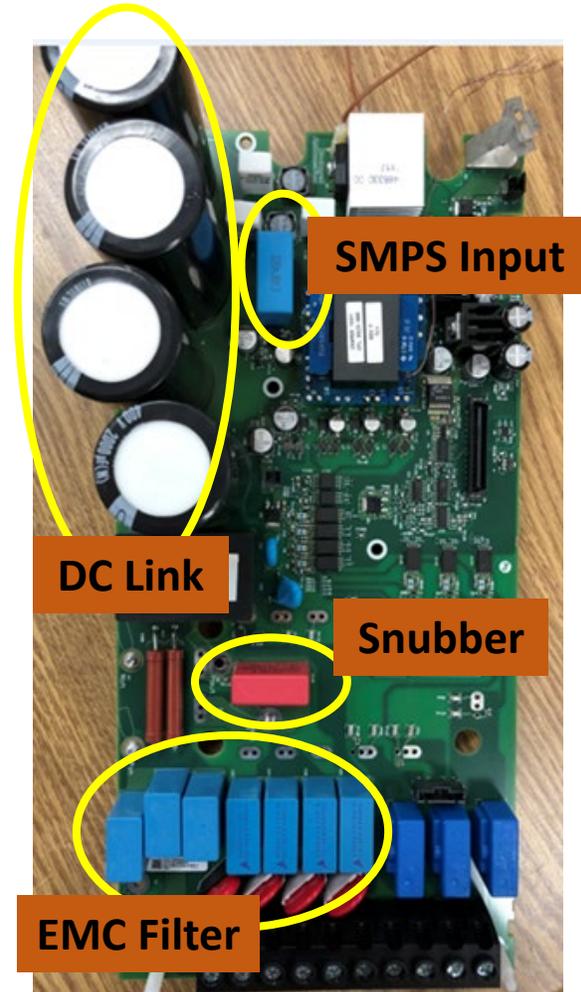
Mequon WI

March 16, 2019

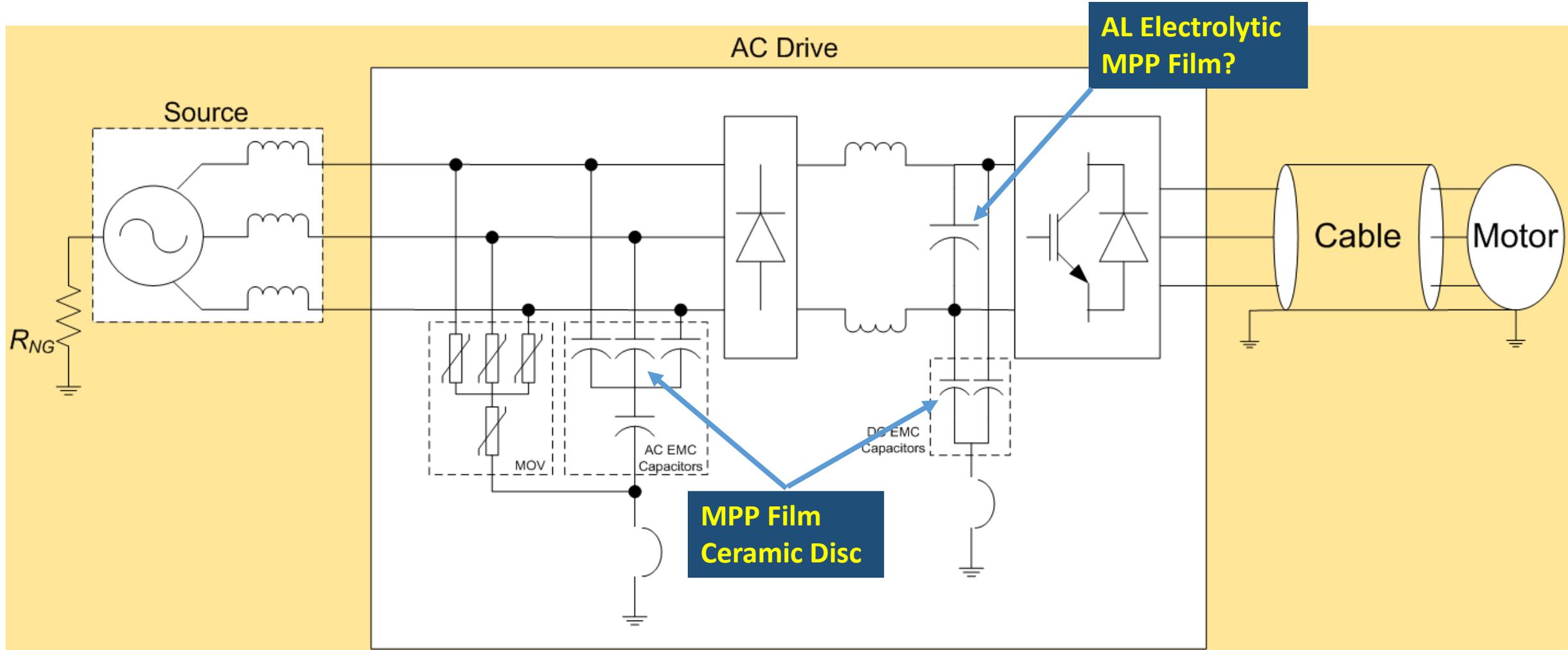
Agenda

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

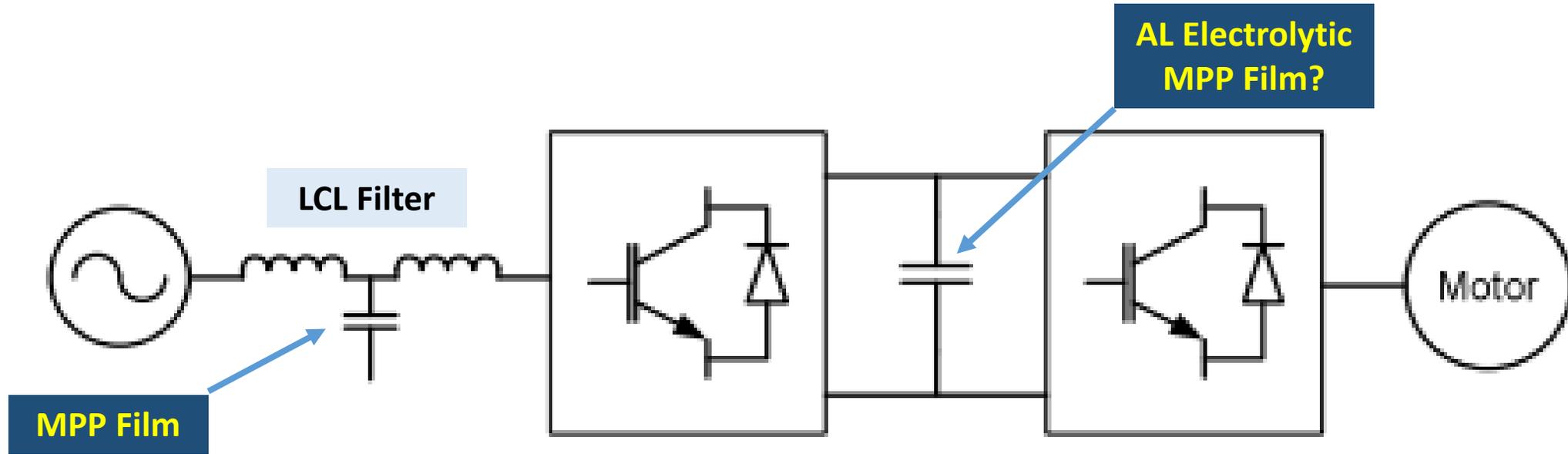
- Future Trends - Impact of WBG Semiconductor Devices



Six-Pulse AC Drive and Capacitor Types Typically Used



Line Filter Capacitors for AFE Rectifiers in Regenerative AC Drives

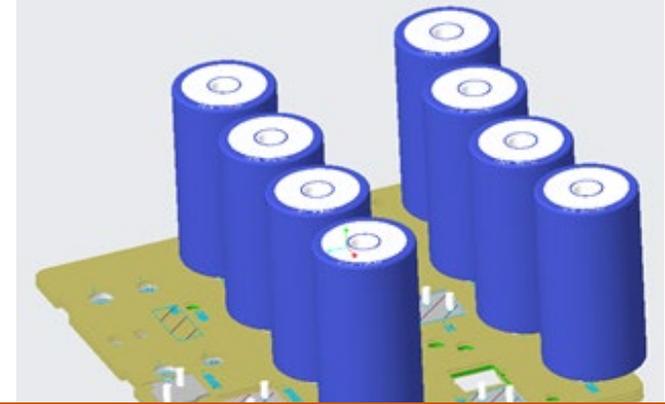


- Failure mode of line filter capacitors requires protection such as integrated fusing, thermal cut-out and/or diagnostics based on measured voltage, current

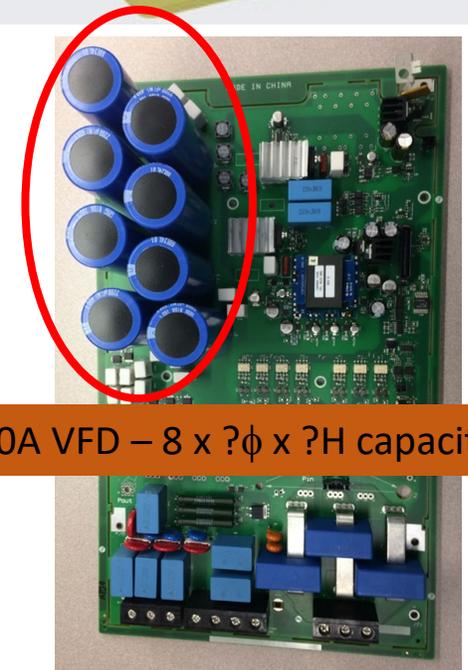


DC Link Capacitors - *Requirements*

- Capacitance value selection criteria $\sim 25\text{-}40 \mu\text{F/A}$
 - 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 $\ll 20\%$ 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 76 ϕ 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

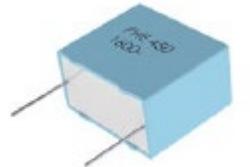


Courtesy: Electronic Concepts



MPP Film and Ceramic Disc Capacitors for EMC Filters

- Safety rated (Type X or Y) capacitors required for regulatory compliance
 - Capacitance ranges from $0.2\mu\text{F}$ - $5\mu\text{F}$
 - 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



Courtesy: KEMET



Courtesy: Vishay



MPP Film Capacitors for DC Link Snubbers

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



Courtesy: ASC Capacitors

Line Filter Capacitors for AFE Regenerative AC Drives



- Typical IGBT based AFE, 4kHz PWM frequency
 - $\sim 50 \mu\text{F}$ 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.* $<10\mu\text{F}$ at 16kHz PWM for 100A AC drive)



Courtesy: Electronic Concepts



Courtesy: Vishay

MLCC Capacitors and Alternatives

- Capacitance and voltage

- 0.1-100 μF , 6-50VDC

- Advantages

- Low ESR, small size

- Applications

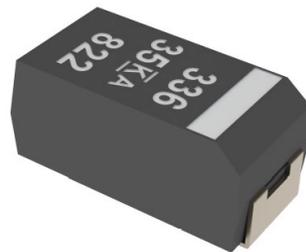
- SMPS output
- Gate drive
- IC buffer

- Tantalum solid polymer

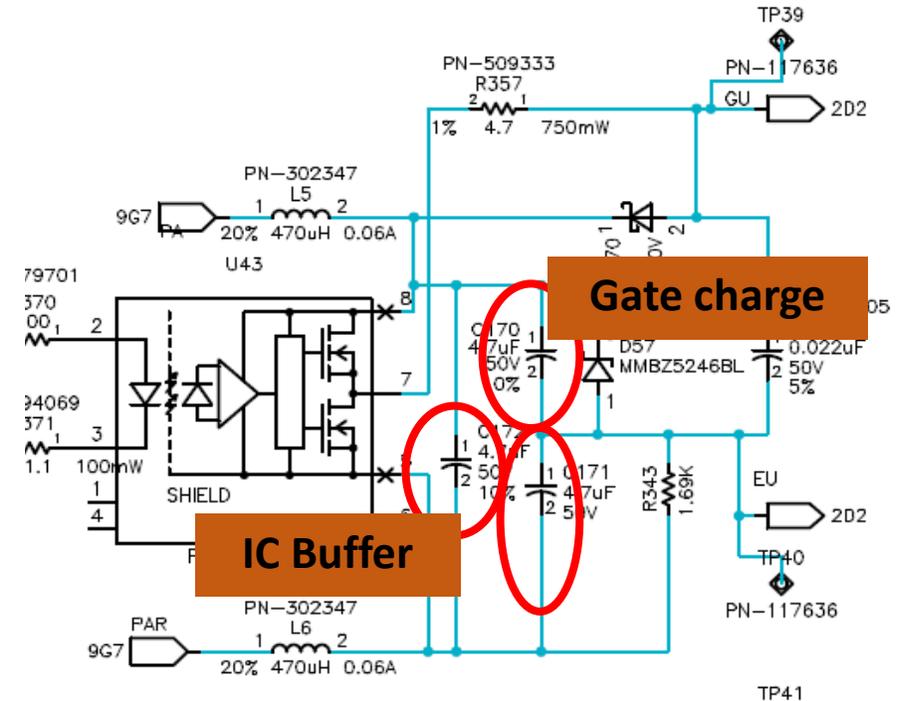
- Size, ESR
- High temperature/humidity reliability



Courtesy: KEMET



Courtesy: KEMET



Gate charge

IC Buffer

- Polymer hybrid

- SMPS output
- Low ESR, high life



Courtesy: Panasonic



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)