The best preventive measure for very long motor cables: all-pole sine filter

AGENDA

Functional principle

Application

Function properties

Future Winding

NEW ALL-POLE SINE FILTER SF4

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APPLICATION
NEW ALL-POLE SINE FILTER SF4
Customer Application

Drives for pump systems

Requirements
- Motor cable length up to 150m per Drive
- Use of unshielded motor cables
- Motor cable laid in the water
- Installation of RCD’s 30 mA
- 3 Drives installed behind 1 RCD
- Conducted emissions EN 61800-3 C1
OVERVIEW
CURRENT AND VOLTAGE WAVEFORMS WITHOUT FILTER

Differential Mode

Add. Inverter losses

Motor noise & add. losses

Motor insulation faults

Bearing currents

Radiated EMI

Tripping RCD & conducted emissions

Motor insulation faults

Common Mode
The grid can be safely protected against disturbances of all frequencies with a line inductor or a harmonic filter and in addition an EMI-Filter.
Galvanic isolation of transformer opens the common mode path for lower frequencies. Higher frequencies are not blocked because of the parasitic capacitance of the transformer.

→ Effective against leakage currents <1kHz
→ heavy solution, no bearing current filter

Sine-wave filter must be installed in front of the isolation transformer to prevent overheating.
COMMON MODE MOTOR FILTERS
COMMON MODE CHOKE

- No switching frequency reduction, nearly no influence on voltage waveform at the motor
- Effective damping of very high frequency common mode disturbances. Improvement on conducted emissions >150kHz.
- No reduction of switching frequency leakage currents
- Very good bearing reduction, if amount and type of cores are probably design to the drive system.
- If wrong designed, resonances could lead to opposite effects*

Erhöhte Spannungsbelastung von Motoren durch Umrichter-
Ausgangsfilter
The common mode noise is optimally short-circuited through the DC link connection.
FIELD OF APPLICATION
NEW ALL-POLE SINE FILTER SF4
Installation

SF4 needs a direct contact to the DC-circuit of the Drive

For example: Circuit diagram Danfoss FC 302

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Allpole Sine Filter SF4
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TESTS:
- Measurement of conducted emissions
- Measurement of leakage currents
- False Tripping Test RCD
## Test description

<table>
<thead>
<tr>
<th>EIC 61800-3 Conducted emissions 150kHz - 30MHz</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>&gt; C3</th>
</tr>
</thead>
</table>

![Graph showing conducted emissions levels](image)

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Allpole Sine Filter SF4
APPLICATION
NEW ALL-POLE SINE FILTER SF4
Customer Application

### Test description

<table>
<thead>
<tr>
<th>RCD</th>
<th>Differential current measurement / RCD utilization in%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;30%</td>
</tr>
<tr>
<td></td>
<td>30-50%</td>
</tr>
<tr>
<td></td>
<td>&gt;50%</td>
</tr>
</tbody>
</table>

Type B RCCBs are optimized for systems with frequency converters. In the event of a fault, they also detect DC-currents and monitor a frequency range up to 100kHz.
# APPLICATION
## NEW ALL-POLE SINE FILTER SF4
### Customer Application

<table>
<thead>
<tr>
<th>Test description</th>
<th>Direct on / off switching on the RCD without false tripping</th>
<th>Direct on / off switching only possible via main switch with snap-action function. Connecting via RCD can lead to false tripping</th>
<th>RCD triggers when switching on / off</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTT</td>
<td>False-Tripping Test RCD - 10x on / off the system</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Due to the charging current of the system capacitances, a multiple of the nominal leakage current can flow in the moment of switch on/off.
Measurements

**Test BLOCKLab**
- RCD 30 mA
- Ext. EMI-Filter HLD 310-500/30
  Low leakage < 0,4 mA
- Drives
- Allpole Sinefilter SF4

**Test Customer Side**
- Pumps
### Test results BLOCK Lab

<table>
<thead>
<tr>
<th>Drive Power [kW]</th>
<th>fs [kHz]</th>
<th>f mop [Hz]</th>
<th>cable length</th>
<th>Cy int. EMI-Filter</th>
<th>ext. EMI-Filter</th>
<th>Motorfilter</th>
<th>IEC 61800-3</th>
<th>RCD</th>
<th>FTT</th>
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<tbody>
<tr>
<td>2x 4.0 / 1x 2.7</td>
<td>4</td>
<td>10</td>
<td>150</td>
<td>No</td>
<td>HLD 310-500/30</td>
<td>SF4-CD006</td>
<td>C1</td>
<td>17 %</td>
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**Requirement IEC 61800-3 C1 fulfilled!**

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Allpole Sine Filter SF4
Test results BLOCK Lab

<table>
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<tr>
<th>Drive Power [kW]</th>
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<th>f mot [Hz]</th>
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<th>ext. EMI-Filter</th>
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Requirement RCD 30mA fulfilled!
PROPERTIES
NEW ALL-POLE SINE FILTER
SF4

- New topology based on 4-limb technology for a compact design
- Reduction of bearing currents to an absolute minimum

Only all-pole sine filters fully eliminate
Drive-related bearing currents!

Amount of bearing current break downs

Bearing current amplitude
Properties

New All-Pole Sine Filter SF4

- New topology based on 4-limb technology for a compact design
- Reduction of bearing currents to an absolute minimum
- Enables the use of extremely long motor cable lengths (> 500 m)
- Use of unshielded motor cables possible
- Increased Motor Lifetime
- Less motor noise
- Improvement in system efficiency

<table>
<thead>
<tr>
<th>Imot / A</th>
<th>fmot / Hz</th>
<th>fs / kHz</th>
<th>Shielded motor cable/m</th>
<th>Frequency inverter</th>
<th>Motor cable</th>
<th>Motor</th>
<th>Entire system</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>17.04%</td>
<td>38.14%</td>
<td>40.00%</td>
<td>7.66%</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>8</td>
<td>50</td>
<td>37.04%</td>
<td>59.78%</td>
<td>38.59%</td>
<td>10.59%</td>
</tr>
<tr>
<td>22</td>
<td>50</td>
<td>4</td>
<td>10</td>
<td>5.56%</td>
<td>7.21%</td>
<td>1.71%</td>
<td>-3.50%</td>
</tr>
<tr>
<td>22</td>
<td>50</td>
<td>8</td>
<td>10</td>
<td>13.73%</td>
<td>1.04%</td>
<td>7.41%</td>
<td>-2.02%</td>
</tr>
<tr>
<td>22</td>
<td>50</td>
<td>4</td>
<td>50</td>
<td>6.59%</td>
<td>1.46%</td>
<td>2.06%</td>
<td>-1.00%</td>
</tr>
<tr>
<td>22</td>
<td>50</td>
<td>8</td>
<td>50</td>
<td>12.72%</td>
<td>1.61%</td>
<td>2.07%</td>
<td>-0.19%</td>
</tr>
<tr>
<td>22</td>
<td>50</td>
<td>8</td>
<td>100</td>
<td>21.64%</td>
<td>4.46%</td>
<td>1.01%</td>
<td>4.55%</td>
</tr>
<tr>
<td>22</td>
<td>50</td>
<td>8</td>
<td>150</td>
<td>23.20%</td>
<td>11.17%</td>
<td>3.70%</td>
<td>3.85%</td>
</tr>
</tbody>
</table>

Imot = Motor power
fmot = Motor revolving frequency
fs = Drive switching frequency
### ALL-POLE SINE FILTER
#### Nomenclature SF4

<table>
<thead>
<tr>
<th>SF4-Types</th>
<th>New nomenclature</th>
<th>Voltage</th>
<th>Protection class</th>
<th>Current @ 400 Vac</th>
<th>Derating @ 500 Vac</th>
<th>ta</th>
<th>Old nomenclature</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF4-CD006-500-2</td>
<td>500Vac</td>
<td>IP 20</td>
<td>6</td>
<td>5,5</td>
<td>45°C</td>
<td>SFA 500/6</td>
<td>Available</td>
<td></td>
</tr>
<tr>
<td>SF4-CD013-500-2</td>
<td>500Vac</td>
<td>IP20</td>
<td>13</td>
<td>12</td>
<td>45°C</td>
<td>SFA 500/13</td>
<td>Available</td>
<td></td>
</tr>
<tr>
<td>SF4-CD024-500-2</td>
<td>500Vac</td>
<td>IP 20</td>
<td>24</td>
<td>23</td>
<td>45°C</td>
<td>SFA 500/24</td>
<td>Available</td>
<td></td>
</tr>
<tr>
<td>SF4-CE046-500-2</td>
<td>500Vac</td>
<td>IP 20</td>
<td>46</td>
<td>43,5</td>
<td>45°C</td>
<td>SFA 500/46</td>
<td>Available</td>
<td></td>
</tr>
<tr>
<td>SF4-CD006-500-0</td>
<td>500Vac</td>
<td>IP 00</td>
<td>6</td>
<td>5,5</td>
<td>50°C</td>
<td></td>
<td>Available from Q4 / 2018</td>
<td></td>
</tr>
<tr>
<td>SF4-CD013-500-0</td>
<td>500Vac</td>
<td>IP 00</td>
<td>13</td>
<td>12</td>
<td>50°C</td>
<td></td>
<td>Available from Q4 / 2018</td>
<td></td>
</tr>
<tr>
<td>SF4-CD024-500-0</td>
<td>500Vac</td>
<td>IP 00</td>
<td>24</td>
<td>23</td>
<td>50°C</td>
<td></td>
<td>Available from Q4 / 2018</td>
<td></td>
</tr>
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<td>SF4-CE046-500-0</td>
<td>500Vac</td>
<td>IP 00</td>
<td>46</td>
<td>43,5</td>
<td>50°C</td>
<td></td>
<td>Available from Q4 / 2018</td>
<td></td>
</tr>
<tr>
<td>SF4-CE065-500-0</td>
<td>500Vac</td>
<td>IP 00</td>
<td>65</td>
<td>60</td>
<td>45°C</td>
<td>SFA 500/65</td>
<td>Available from Q4 / 2018</td>
<td></td>
</tr>
<tr>
<td>SF4-CE110-500-0</td>
<td>500Vac</td>
<td>IP 00</td>
<td>110</td>
<td>102</td>
<td>45°C</td>
<td>SFA 500/110</td>
<td>Available from Q4 / 2018</td>
<td></td>
</tr>
</tbody>
</table>

**SF4-CD006-500-2**

- Protection class (0=IP00; 2=IP20)
- Voltage (Vac)
- Current (A)
- Winding technology
- Winding material (C=CU; A=Alu)
- Phases (4=4-pole → All-pole)
- Sine filter
Future Winding
New Winding Technology

Future Winding
for next power generation

* COOLING

η: LOW LOSSES

∞ LONG LIFE

△◎ FREESTYLE

← Potential Control

& & HIGH CURRENT DENSITY

NETZDROSELN
LINE REACTORS

Sinusfilter
Sine Filters

Allpoligis Sinusfilter
All-Pole Sine Filters

Malte Heuermann
Allpole Sine Filter SF4
OVERVIEW
PASSIVE FILTER IN INVERTER SYSTEMS
The best preventive measure for very long motor cables:
all-pole sine filter