MV Drives
Managing safe application in medium voltage variable speed drives
Safety strategy
Risk management

<table>
<thead>
<tr>
<th>Risk</th>
<th>Personal</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Image of a risk scenario]</td>
<td>[Image of a person]</td>
<td><strong>Eliminate the risk</strong></td>
</tr>
<tr>
<td>[Image of a risk scenario]</td>
<td>[Image of a person]</td>
<td><strong>Keep distance to the risk</strong></td>
</tr>
<tr>
<td>[Image of a risk scenario]</td>
<td>[Image of a person]</td>
<td><strong>Contain the risk</strong></td>
</tr>
<tr>
<td>[Image of a risk scenario]</td>
<td>[Image of a person]</td>
<td><strong>Personal protection against the risk</strong></td>
</tr>
</tbody>
</table>

- Risk reduction
  - Technical
  - Organizational
  - Personal
Agenda

- Safe construction
- Functional safety
- Motors in hazardous areas
- Arc fault protection
Agenda

- Safe construction
- Functional safety
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Medium voltage drives
Safe construction

Control unit with user-friendly control panel for local operation:
- Keypad with multi-language display
- Main supply on/off pushbuttons
- Emergency off pushbutton

Control equipment separated from the main voltage areas

Electro-mechanically interlocked doors for safety

DC bus grounding switch for safety
Agenda

- Safe construction
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Functional safety
Stop functions

- EOFF (IEC 60204-1, stop category 0)
  - Stopping by immediate removal of power to the machine actuators

- ESTOP (IEC 60204-1, stop category 1)
  - A controlled stop with power available to the machine actuators to achieve the stop and then removal of power when the stop is achieved

- STO / Safe Torque Off (IEC 60204-1, stop category 2)
  - A controlled stop with power left available to the machine actuators
# Functional safety

## Available functions

- **SIL** = Safety Integrity Level
- **PL** = Performance Level

<table>
<thead>
<tr>
<th>Category</th>
<th>Function</th>
<th>SIL</th>
<th>PL</th>
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<tbody>
<tr>
<td>0</td>
<td>EOFF</td>
<td>SIL3</td>
<td>PLe</td>
</tr>
<tr>
<td>1</td>
<td>ESTOP</td>
<td>SIL3</td>
<td>PLe</td>
</tr>
<tr>
<td>2</td>
<td>STO</td>
<td>SIL3</td>
<td>PLe</td>
</tr>
</tbody>
</table>
Agenda

- Safe construction
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- Motors in hazardous areas
- Arc fault protection
Motor supply voltage
Common mode current phenomena

Symmetrical sinusoidal 3 phase supply voltage.
Sum of phase voltages is zero.
Motor supply voltage
Common mode current phenomena

Symmetrical sinusoidal 3 phase supply voltage.
Sum of phase voltages is zero.

Typical drive symmetrical 3 phase supply voltage to motor.
Sum of phase voltages is variable.
Motor supply voltage
Common mode current, sparking risks

High frequency circulation current.

Capacitive discharge current
- Motor frame grounded
- Shaft is not grounded via machinery

High frequency shaft grounding currents
- Asymmetric, unshielded motor cabling
- Incidental grounding of the motor shaft through the gearbox or driven machinery
- Poor stator grounding.
Variable speed drives
Motor cable recommendation

Symmetric, shielded cables

- Controlled high frequency current flow due to low impedance return path (draining transformer effect)
- Decreased low frequency interference due to symmetricity
- Minimized interference to other equipment
- Reduced motor shaft currents
MV drives
Limitation of common mode currents

- Output sine filter
  - Actively controlled LC low pass filter
  - Eliminates virtually all inverter switching harmonics to the motor
  - Keeps motor and bearings common mode voltage free
  - Eliminates the harmonic losses in the motor.
MV drives with sine filter
Compatibility with new and existing motors

- Output sine filter
  - Motor efficiency as under DOL operation
    - no motor de-rating required
  - No voltage reflections, no common modes
    - saves motor insulation and bearings
  - No high frequency components
    - use of standard cables
    - no limitation of cable length
    - no EMC problems
  - No switching harmonics
    - no additional motor noise
Agenda

- Safe construction
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Introduction
Arc fault safety and MV drives

- Arc faults can cause most severe danger for people

- MV Drives Requirements:
  - Standards
    - IEC and NEMA do not require arc fault resistant panels
    - Standards are based on the principle arc fault prevention
  - Customers
    - There is a trend towards arc fault resistant equipment, especially by oil and gas industry
    - Typically requirement accordance with IEC switchgear standard
Standards
MV drives & arc fault protection

- General
  - Main focus – arc prevention (clearance and creepage)
  - IEEE 1566 / IEC 60204-11, limited arc fault withstand requirements for switchgears (system component)
- UL 347 (a)
  - Limited to component failures, not generic “36 Breakdown of component test”
- IEC 61800-5-1
  - Requires consideration of breakdown of components, including insulation systems. Testing or calculations possible.

(MV) drives specific standards partly address arc faults, but not as specific as switchgear standards. Therefore ABB uses IEC 62271-200 for arc fault testing.
IEC 62271-200
High-voltage switchgear and controlgear

- IAC (Internal Arc Classification)
  - Accessibility type
    - A – restricted
    - B – unrestricted
  - Accessibility area
    - F – front
    - L – lateral
    - R – rear
  - Arc fault current withstand
    - Prospective current in kA
  - Arc fault withstand time
    - Typical values, 100ms, 500ms and 1s
Arc fault protection
Challenges for MV drives

- Basic challenges:
  - Reaction on arc fault
  - Detection of arc fault

- Challenges, especially compared to switchgears
  - ASD design is not as standardized as switchgears. Design depends highly on manufacturer.
  - Mechanical design alternatives (air cooled, water cooled, .. )
  - Various integration levels of system components
Challenges for MV drives

- Detection of arc fault based on short circuit current

<table>
<thead>
<tr>
<th>Transformer Type</th>
<th>5 Winding Transformer</th>
<th>7 Winding Transformer</th>
<th>16 Winding Transformer</th>
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<tbody>
<tr>
<td>uk (prim to one sec)</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>ik [pu, relative to In]</td>
<td>2.5</td>
<td>1.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Detection possible</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

- Critical for multiwinding transformer arrangements
Challenges for MV drives

- Arc fault withstand current = network short circuit current
  - Requirements are independent of ASD power rating
  - Arc fault requirements same as for switchgear

- Critical for:
  - Integrated transformer solutions
  - Transformer less solutions
Arc Fault
ABB’s approach - the 4 safety classes

- **Class I - protection based on arc prevention**
  This has been the standard for MV drives since many years and follows the guidance of the relevant IEC and NEMA standards. In the unlikely case of an arc fault there is a high risk of a severe danger, especially for high power equipment.

- **Class II - protection based on cabinet structure**
  This is the single method in the industry, which has been applied so far to achieve IAC classification for MV drives. Only a few products are available on the market with this classification (including products from ABB). In the event of an arc fault, the arc is captured in a safe zone. After the event the drive is most likely destroyed.

- **Class III - protection based on arc fault limitation and elimination**
  This solution can be applied for low power MV drives. The solution is based on external current limiting fuses. ABB applies this solution in combination with Class I and II, to low power MV drives connected directly to the grid.

- **Class IV - fast arc elimination**
  This is a unique ABB patented method, which combines fast optical arc fault detection and ABB MV drives “protection firing” system. An arc fault is detected and eliminated within 4 – 8ms. Despite highest level of personal safety, the equipment remains undamaged and can be immediately restarted after inspection.
Arc Fault
Class II and class IV protection

“Class II”
Classification 23kA, 0.5s IP54

“Class IV”
Classification 28kA, 0.5s with arc elimination
No damage after test IP42
Arc Monitoring option
Arc Guard System TVOC

- Arc monitoring option
  - Can be installed inside the drive cabinet
  - Light detection in case of arcing
  - Fast opening of MCB
  - Options available for all ACS MV drives
  - Arc Guard can be added to any drive as a faster detection of an arc fault to limit damage. In this case the converter remains on a "class I" safety level (non certified).
  - Arc Guard is used as part of class IV protection as a standard
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