Motor Starting, Protection and Control

Keep things moving with protection and control - at every level.

Amr Younis – Technical and Design Promotion Manager
Agenda

- Introduction
- Motor Protection and Control components
- Motor Staring Methods
  - Direct Online
  - Star-Delta
  - Soft starters
  - VSD’s
- Coordination of Protection
Introduction
Motor Starting
Motor Starting Solutions
Why it’s important

Compressor
Ventilation
Water pump
Motors Starting

Why it’s important?

42% of all electricity is used by the industry

2/3 of this is used by electrical motors

= 28% of global electricity consumption
Motors Starting

Why it’s important?

300,000,000 electrical motors are currently installed worldwide.

90% are used in full-speed applications.
Motor starting
General characteristics

- Motor starting current: $I_a = 7.2 \times I_e$
- Thermal protection
- Thermal threshold: $I_p = 12 \times I_e$
- Tripping class

Graph shows the relationship between time ($t$) and current ($I$) with markers for motor starting current, thermal protection, and thermal threshold.
Motor Starting
Basic Motor Circuit Components
Motors Starting
Motor Protection & Control

- Disconnector
- Switch disconnector
- Switch Fuse
- Circuit Breaker (Magnetic)
- Manual Motor Starter
- Contactor
- Thermal Overload
- Electronic Overload
- Universal Motor Controller UMC
Motor Starting
Isolation
Motors Starting

Isolators

**Enclosed switches disconnector**

Why is isolation required?
To separate the electrical (input) source from the motor starter
Engineers can carry out maintenance/troubleshooting on the motor starter without risk of electrocution
Motor Starting
Control
Motors Starting
Contactors

AF Contactors

Electric switching device to control the operation
AF Contactors is used for switching ON and OFF motor loads according to IEC 60947-4-1
The full range has the following advantages
- Wide range operating coil 100-250 VAC/Dc
- Built-in Surge Suppressor
- Distinct operation (ON-OFF)
- 75-80% saving in power consumption
- 15-20% Space saving
Essential solutions
Get the essentials right with fast, reliable installations
## Continuous operation

Coil operating limits

<table>
<thead>
<tr>
<th>IEC standard requirement</th>
<th>Conventional coil</th>
<th>AF coil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uc</td>
<td>230 V</td>
<td></td>
</tr>
<tr>
<td>+10% 253 V</td>
<td>+10% 253 V</td>
<td>+10% 275 V</td>
</tr>
<tr>
<td>-15% 187 V</td>
<td>-15% 187 V</td>
<td>-15% 85 V</td>
</tr>
<tr>
<td></td>
<td>220 V</td>
<td></td>
</tr>
<tr>
<td></td>
<td>187 V</td>
<td></td>
</tr>
</tbody>
</table>

Uc = Control voltage
Examples of contactor duty

Motor control

- Direct on-line start (AC-3)
  - Making about 6 times nominal current
  - Breaking nominal current at opening

- Star-delta start
  - Star contactor making 3 times nominal current

- Inchng (AC-4)
  - Making 6 times nominal current
  - Breaking 6 times nominal current

Other application examples

- Heating resistance AC-1
  - Making/ breaking nominal current

- Capacitor switching (AC-6b)
  - Making 100 times In or more

- Dynamic breaking: making short time inrush current at cycle end
Contactors in AC Power circuits
Circuit diagram and main contacts arrangement

**Houses = low power:**
- Single phase connection, and load operated with a simple switch on the phase side

**Industry = high power:**
- 3-phase connection and load operated with a contactor

**Building, parking lots illumination**
- Three phase connection with 3-pole contactors
- Sometimes single phase connection with 2-pole or 4-pole contactors

**Generating set**
- 3-phase + neutral changeover with two 4-pole contactors
ABB Short-Circuit Protection Elements

Short Circuit Protection

**Circuit Breakers – Magnetic Only**

- Short Circuit Protection Only
- Magnetic only or Electronic trip units
- Requires additional Overload protection
- Protection: 12-14 In

**Switch Fuses**

- Short Circuit Protection Only
- Requires additional Overload protection

**Manual Motor Starters**

- Short Circuit only
- Short Circuit and Overload Protection
- 0.1-100 Ampere
Manual Motor Starter
Standard/ Premium main differences

<table>
<thead>
<tr>
<th>ABB’s standard range up to 32A MS116</th>
<th>ABB’s premium range up to 32A MS132 / MO132</th>
<th>ABB’s premium range up to 65A MS165 / MO165</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ IE3 ready</td>
<td>✓ IE3 ready</td>
<td>✓ IE3 ready</td>
</tr>
<tr>
<td>✓ World wide approvals</td>
<td>✓ World wide approvals</td>
<td>✓ World wide approvals</td>
</tr>
<tr>
<td>✓ Ics/Icu ratings up to 50 kA</td>
<td>✓ Ics/Icu ratings up to 100 kA</td>
<td>✓ Ics/Icu ratings up to 100 kA</td>
</tr>
<tr>
<td>✓ Coordination with AF contactors</td>
<td>✓ Coordinations with AF contactors</td>
<td>✓ Coordinations with AF contactors</td>
</tr>
<tr>
<td></td>
<td>✓ Trip position</td>
<td>✓ Trip position</td>
</tr>
<tr>
<td></td>
<td>✓ ATEX certified</td>
<td>✓ ATEX certified</td>
</tr>
<tr>
<td></td>
<td>✓ UL Type E/F ratings</td>
<td>✓ UL Type E/F ratings</td>
</tr>
<tr>
<td></td>
<td>✓ Combination motor controller</td>
<td>✓ Combination motor controller</td>
</tr>
</tbody>
</table>
Motor Starting
Overload Protection/Other protections
Overload relay

What is a trip class?

- Class 10: 4–10 s
- Class 20: 6–20 s
- Class 30: 9–30 s

Trip curve according to IEC 60947-4-1
**ABB Overload Protection offering range**

**Overload Relays**

<table>
<thead>
<tr>
<th>Thermal Overload - TF</th>
<th>Electronic Overload - EF</th>
<th>Universal Motor Controller – UMC100.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overload and phase failure protection using Bimetal trip unit</td>
<td>Overload and Phase failure Protection using Electronic trip unit</td>
<td>Motor Protection</td>
</tr>
<tr>
<td>Trip Class 10</td>
<td>Trip Class: Selectable 10-20-30</td>
<td>Motor Control</td>
</tr>
<tr>
<td>0.1-200 Ampere</td>
<td>0.1-800 Ampere</td>
<td>Motor Diagnostics</td>
</tr>
<tr>
<td>Country of Origin: Germany/China</td>
<td>Country of Origin: Germany/China</td>
<td>Communication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Country of Origin: Germany</td>
</tr>
</tbody>
</table>

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**Thermal overload relays**

**Basics TF series**

**Based on new technology**
- Separate STOP button
- Trip Class 10
- Operating temp. range -25 up to 60°C
- Manual/automatic reset selectable
- Test function
- Sealable cover for current setting, reset selection and test function
- Perfect match to the contactor
- Also available: ATEX certified types and kits for separate mounting
Electronic overload relays
Basics EF series

Based on electronic technology
- Separate STOP button
- Trip Class 10E, 20E, 30E selectable
- Operating temp. range -25 up to 70°C
- Manual/ automatic reset selectable
- Test function
- Sealable cover for current setting, reset selection and test function
- Perfect match to the contactor
- Also available: ATEX certified types and kits for separate mounting
Advanced solutions
UMC100.3 application example

Connection to DCS, ABB Ability™ 800xA and gateway for ABB Ability™ EDCS

Universal Motor Controller UMC100.3

Industrial Ethernet
- EtherNet/IP™
- Profinet IO
- Modbus TCP

Fieldbus
- Modbus RTU
- DeviceNet™
- Profinibus DP

Manual motor starter

Voltage module

Digital module

Analog / temperature module
Motor starter examples
Stand alone or combined

- Disconnect
- Short-circuit protection
- Overload protection
- Phase-failure
- Manual control

- Disconnect
- Short-circuit protection
- Overload protection
- Phase-failure
- Manual control

- Disconnect
- Short-circuit protection
- Overload protection
- Manual control

- Control

- Control

- Overload protection
Motor starting
Control (On/Off) operation and Indication

Motor Starter Control
- Start Pushbutton
- Stop Pushbutton
- Overload Relay
- Manual motor starter
- Circuit breaker

AF Contactor

Motor Starter Indication
- Starter ON
- Starter OFF
- Starter Tripped
Motor Starting
Direct Online Starters
Motors Starting
Electrical and Mechanical Characteristics

- High inrush current
- High torque during start

- Tst / Tn 1.5...2.5
- 7*In
- In (FLA)

Terminal box
Drive shaft
Cooling fan
Stator windings
Rotor
Stator

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Motors Starting
Motor Protection and Control

Direct Online Starters
- Traditional starting method
- Full voltage with no control of the start
- Compact and cost efficient solution
- Mostly used for small motors

Potential electrical problems
- Warm cables
- Tripping breakers

Potential mechanical problems
- Slipping belts
- Heavy wear and tear
- Damaged products
Motor Starting
Star Delta Starters
Motors Starting Methods
Star-Delta Starter

General Characteristics

- Low starting current (only at successful start)
- Transmission peaks at loaded start
- Low starting torque (often too low)
- Long starting time
- Always direct stop
- Many devices – complex wiring
- Double motor cables
Motor Starting
Soft Starters
Motors Starting Methods
Soft Starters (Starting and Stopping)

General Characteristics

- Adjustable starting current
- Correct starting torque matching the need
- Possibility to soft stop
- Medium long starting time
- Minimum mechanical wear.
Soft starters

Principal Function

Theory of Operation

Anti-parallel connected thyristors

Voltage reduction during starting

- Voltage reduction during starting
- Anti-parallel connected thyristors
Soft Starters
Principal Function

Theory of Operation

Soft Starters
Sometimes the benefits are really obvious

Conveyor Belts

https://www.youtube.com/watch?v=DFCDAsd6Hd4

Water Hammering

https://www.youtube.com/watch?v=NGzd6DZw-IE
# Soft Starters

**ABB Portfolio**

<table>
<thead>
<tr>
<th>PSR - Basic Range</th>
<th>PSE – Mid Range</th>
<th>PSTX – Advanced Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 3 - 105A</td>
<td>• 18 - 370A</td>
<td>• 30 - 1250A</td>
</tr>
<tr>
<td>• Built in bypass.</td>
<td>• Built in bypass.</td>
<td>• Built-in bypass.</td>
</tr>
<tr>
<td>• Flexible mounting.</td>
<td>• User friendly HMI</td>
<td>• User friendly and detachable HMI</td>
</tr>
<tr>
<td>• Optional communication.</td>
<td>• Torque control.</td>
<td>• Basic and advanced protection functions.</td>
</tr>
<tr>
<td>• Connection kits for Easy mounting with ABB MMS.</td>
<td>• Current limit (1.5-7*Ie)</td>
<td>• Motor Heating.</td>
</tr>
<tr>
<td></td>
<td>• Basic motor protection functions.</td>
<td>• Pump Cleaning</td>
</tr>
<tr>
<td></td>
<td>• Analogue output.</td>
<td>• Limp Mode</td>
</tr>
<tr>
<td></td>
<td>• Optional communication</td>
<td>• Motor Jogging and Breaking</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Torque Control</td>
</tr>
</tbody>
</table>
PSTX Softstarters
Why to use internal Bypass contactors

It’s the latest technology!

Reducing Panel size

Limp Mode

Reverse Staring and Pump cleaning

It’s not any option any more not to use the bypass contactor

- Eliminate harmonics effect
- Decrease heat generation
- Increase thyristors lifetime

https://www.youtube.com/watch?v=Gp4Rvj-c9Dc
Motor starting solutions
Different ways to start a motor

- **DOL**
  - 16 x FLA rpm
  - 8 x FLA rpm

- **Y/D**
  - 8-16 x FLA rpm

- **Softstarter**
  - 2.5-5 x FLA rpm

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Soft Starters
Parallel and Sequential Starting

Parallel Starting

Sequential Starting
Motor Starting
Variable Speed Drives
Motors Starting Methods
Variable Speed Drives

General Characteristics
- Full control of speed, current and torque
- Energy saving from reducing speed
- Mostly used for process control
- No Value for full speed applications
- Creates Harmonics
- Heat Dissipation

https://www.youtube.com/watch?v=E0BattO-NAs
Motors Starting Methods
Variable Speed Drives

https://www.youtube.com/watch?v=cap0baKxnwc
Low Voltage Drives

- Low voltage AC 0.75 to 5600 kW
- Low voltage DC 7.5 kW to 4.8 MW
- Industrial drives
- Industrial specific drives 0.37 to 400 kW
- Drives for HVAC
- Drives for Water
- Micro drives 0.18 to 4 kW
- Machinery drives 0.18 to 560 kW
- General purpose drives 0.75 to 355 Kw
- Motion control products 0.75 to 160 kW
The motor starting market

Which starter shall be select

- Full speed
- Constant speed
- Variable speed

Un-controlled start  "Semi-controlled" start  Controlled start

DOL  Y/D  Softstarter  Drive

Small motor ratings  Higher ratings  All ratings

Overlap

This picture doesn't represent any actual size of market, it just a visualization to explain the market split
Motor Starting
Coordination of Protection
Motors Starting
Coordination of Protection

**Coordination type 1**
- No risk for operators or installations
- Isolation is kept after inrush
- Before re-starting, starter repairing is necessary
- Other apparatus than contactor and overload relay shall not be damaged
- Cheaper
- Require more maintenance

**Coordination type 2**
- No risk for operators or installations
- Isolation is kept after inrush
- The starter is still working after short-circuit
- Before re-starting, a quick inspection is sufficient
- Light welding of contacts is allowed if they could be easily separated (by electrical operation or tool)
- Higher device size
- More economic in maintenance and parts
## Motors Starting

### Coordination Types

![Coordination Types Table](https://applications.it.abb.com/SOC/page/selection.aspx)
Coordination Type 2 for Soft starters

Semi-conductor fuses (High speed fuses) are the only type of fuses that are fast enough to achieve a fully type 2 coordination when using a soft starter. A separate overload relay for the motor protection is always required in combination with this type of fuse. If replacing the semi-conductor fuses with an MCCB, MMS or similar, type 1 coordination will be achieved instead.