## All about Motors

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All about Motors
Motor protection

Selection aids

The Moeller selector slide enables you to determine quickly and reliably which motor starter is most suitable for the application. All you need are the operating voltage, the motor rating, the various short-circuit ratings and coordination types.

The selector slide can be used for dimensioning devices with short-circuit coordination types 1 and 2. Standard cable cross-sections and permissible cable lengths are stated for the tripping of protective devices in compliance with standards. They can vary according to the installation requirements. The selector slide has several variants of the movable section with numerical values for DOL and reversing starters or star-delta starters. The selector slide can be obtained free of charge. If you prefer to use the selector slide online, this is available on the Internet at:

www.moeller.net/en/support/slider/index.jsp
All about Motors
Motor protection

Overload relay with manual reset
These should always be used where continuous contact devices are required (e.g. pressure and position switches), to prevent automatic restarting. The reset button can be fitted as an external feature in order to make it accessible to all personnel. Moeller overload relays are always supplied with manual reset but can be converted to automatic reset by the user.

Overload relays with automatic reset
These can be used only with pulsed contact devices (three-wire control) such as pushbuttons etc., because on these, the cooling of the bimetal strips cannot lead to automatic reconnection.

Special circuitry
Special circuitry such as is found in star-delta starters, individually compensated motors, current transformer-operated relays etc. may require that the relay setting deviates from the rated motor current.

Frequently recurring operating cycles
These make motor protection difficult. The relay should be set higher than the rated motor current in view of its shorter time constant. Motors which are rated for a high frequency of operation will withstand this setting to a certain degree. Although this will not ensure complete protection against overload, it will nevertheless provide adequate protection against non-starting.

Backup fuses and instantaneous releases
These are needed to protect not only the motor, but also the relay, against the effects of short circuits. Their maximum rating is shown clearly on every relay and must be adhered to without fail. Higher ratings — chosen for instance according to the cable cross-section — would lead to the destruction of the motor and relay.

To what current must the overload relay be set?
To the rated motor current - no higher, no lower. A relay set too low will prevent the full utilization of the motor; set too high, it will not guarantee full overload protection. If a correctly set relay trips too frequently, then either the load on the motor should be reduced or the motor should be exchanged for a larger one.

When is it right for the overload relay to trip?
Only when the current consumption of the motor increases due to mechanical overloading of the motor, undervoltage or phase failure when the motor is at or nearly full load, or when the motor fails to start due to a stalled rotor.
When does the overload relay fail to trip in good time although the motor is at risk?
With changes in the motor which do not cause an increase in current consumption: Effects of humidity, reduced cooling due to a reduction in speed or motor dirt, temporary additional external heating of the motor or bearing wear.

What causes destruction of the overload relay?
Destruction will take place only in the event of a short circuit on the load side of the relay when the back-up fuse is rated too high. In most cases, this will also endanger the contactor and motor. Therefore, always adhere to the maximum fuse rating specified on every relay.

3-pole overload relays should be so connected in the case of single-phase and DC motors so that all three poles of the overload relay carry the current, whether in single-pole or 2-pole circuits.

An important characteristic feature of overload relays conforming to IEC/EN 947-4-1 are the tripping classes (CLASS 10 A, 10, 20, 30). They determine different tripping characteristics for the various starting conditions of motors (normal starting to heavy starting).
## Pick-up times
Response limits of time-delayed overload relays at all-pole load.

<table>
<thead>
<tr>
<th>Type of overload relay</th>
<th>Multiple of current setting</th>
<th>Reference ambient temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>A ( \geq 2 \text{ h} ) starting from cold state of relay</td>
<td>B ( \leq 2 \text{ h} )</td>
<td>C Tripping class</td>
</tr>
<tr>
<td>10 A</td>
<td>10 A</td>
<td>( \geq 2 )</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
<td>( \leq 4 )</td>
</tr>
<tr>
<td>30</td>
<td>20</td>
<td>( \leq 12 )</td>
</tr>
</tbody>
</table>

| Non-ambient temperature compensated thermal relays and magnetic relays | 1.0 | 1.2 | 1.5 | 7.2 | + 40 °C |
| Ambiant temperature compensated relay | 1.05 | 1.2 | 1.5 | 7.2 | + 20 °C |

In the case of thermal overload relays with a current setting range, the response limits must apply equally to the highest and the lowest setting of the associated current.
Response limits of 3-pole thermal overload relays at 2-pole load

<table>
<thead>
<tr>
<th>Type of thermal overload relay</th>
<th>Multiple of current setting</th>
<th>Reference ambient temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A ( t &gt; 2 \text{ h}, \text{starting from cold state of relay} )</td>
<td>B ( t \leq 2 \text{ h} )</td>
</tr>
<tr>
<td>Ambient temperature compensated, without phase-failure sensitivity</td>
<td>3 poles 1.0</td>
<td>2 poles 1 pole 1.32 0</td>
</tr>
<tr>
<td>Non-ambient temperature compensated, without phase-failure sensitivity</td>
<td>3 poles 1.0</td>
<td>2 poles 1 pole 1.25 0</td>
</tr>
<tr>
<td>Ambient temperature compensated, with phase-failure sensitivity</td>
<td>2 poles 1.0 0.9</td>
<td>2 poles 1 pole 1.15 0</td>
</tr>
</tbody>
</table>

In the case of thermal overload relays with a current setting range, the response limits must apply equally to the highest and the lowest setting of the associated current.

Overload capacity

Overload relays and releases have heating coils which can be thermally destroyed by overheating. The making and breaking currents of the motor flow in thermal overload relays which are used for motor protection. These currents are between 6 and 12 \( \times I_e \) (rated operational current), depending on the utilization category and the size of the motor.

The point of destruction depends on the frame size and design and is usually approximately 12 to 20 \( \times I_e \).

Short-circuit rating of the main circuit

With currents that exceed the breaking capacity of the motor starter in relation to the utilization category (EN 60947-1), it is permissible for the current flowing during the operating time of the protective device to damage the motor starter.

The permissible behaviour of starters under short-circuit conditions is determined in the so-called types of co-ordination (1 and 2). It is common practice to state in the details of protective devices which type of co-ordination is ensured by them.
All about Motors
Motor protection

Type 1 coordination
In the event of a short circuit the starter must not endanger persons and installations. It does not have to be fit for renewed operation without repair.

Type 2 coordination
In the event of a short circuit the starter must not endanger persons and installations. It must be fit for renewed operation. There is a risk of contact welding for which the manufacturer must give maintenance instructions.

The tripping characteristic of the overload relay must not differ from the given tripping curve after a short circuit.

Short-circuit withstand strength of the auxiliary switch
The manufacturer details the required overcurrent protective device. The combination is subjected to three test disconnection’s at 1000 A prospective current with a power factor between 0.5 and 0.7 at rated operational voltage. Welding of the contacts may not occur (EN 60947-5-1, VDE 0660 Part 200).

Motor protection in special applications

Heavy starting duty
An adequate tripping delay is essential in order to allow a motor to start up smoothly. In the majority of cases, overload relays ZB, motor-protective circuit-breakers PKZ(M) or circuit-breakers NZM can be used. The tripping delays can be taken from the tripping characteristics in the Moeller Main Catalogue, Industrial Switchgear.

In the case of especially high-inertia motors, whose run-up time exceeds the tripping delay of the above devices, it would be completely wrong to adjust an overload relay which tripped out before the run-up time expired, to a current level higher than the rated motor current. This would, it is true, solve the starting problem, but the motor would no longer be adequately protected during normal operation. However, there are other solutions to the problem:

Current transformer-operated overload relays ZW7
The ZW7 consists of three special saturable core current transformers, supplying an overload relay Z.... It is used principally for medium and large motors.

Up to two times rated current $I_e$, the transformation ratio $I_1/I_2$ of the saturable core current transformers is practically linear. Within this range it does not differ from the normal overload relay, i.e. it provides normal overload protection during normal operation. However, within the transformer characteristic range ($I > 2 \times I_e$), the secondary current no longer increases proportionally to the primary current. This non-linear increase in the secondary current produces an extended tripping delay if overcurrents greater than twice rated current occur, and hence permits longer starting times.

Adjusting the current transformer-operated overload relay ZW7 for lower rated motor current
The setting ranges quoted in the Moeller Main Catalogue, Industrial Switchgear apply when the incoming cable is looped once through the transformer relay.
All about Motors
Motor protection

If the current transformer-operated overload relay ZW7 is required to provide protection to a motor of below 42 A rating (minimum value in the setting range of 42 A to 63 A), the necessary range adjustment is achieved by looping the incomer several times through the aperture in the relay. The change in the rated motor current quoted on the rating plate is inversely proportional to the number of loops.

Example:
With the ZW7-63 relay, which has a setting range from 42 A to 63 A, a motor rating of 21 A to 31.5 A can be accommodated by looping the leads twice through the relay.

Bridging of motor protection during starting
For small motors the bridging of the motor protection during starting is more economical. Because of the additional parallel contactor, the overload relay does not carry the full current during starting. Only when the motor has reached full speed is the bridging contactor switched off and the full motor current is then carried by the overload relay. Provided it has been set correctly to the rated motor current, this will ensure full motor protection during operation. Starting must be monitored.

The motor is a limiting factor with regard to the tripping delay of the current transformer-operated relay and the bridging period. One must ensure that the motor is able to tolerate the high temperature generated by direct starting, for the prescribed starting time. Motor and starting procedure have to be selected carefully when dealing with machines having a very large rotating mass, which are practically the only ones subject to this problem when direct starting is used.

Depending on the operating conditions adequate protection of the motor winding may no longer be given by an overload relay. In that case it must be weighed up whether an electronic motor-protective relay ZEV or a thermistor overload relay EMT 6 in conjunction with an overload relay Z meets the requirements.

Star-delta starter (Y △)
1 operating direction
Changeover time with overload relay in position
A: < 15 s  B: > 15 < 40 s  C: > 40 s

Setting of the overload relay
0.58 × Ie  1 × Ie  0.58 × Ie
Full motor protection in Y (star) Only partial motor protection in Y position Motor not protected in Y (star) position
All about Motors  
Motor protection

**Multi-speed switches**
- 2 speeds: One tapped winding
- 2 separate windings
- 3 speeds: 1 x tapped winding + 1 winding

Attention must be paid to short-circuit protection of the overload relays. Separate supply leads should be provided if required.

**Heavy starting duty**
- Current transformer-operated overload relays ZW7
- Bridging of motor protection during starting
- Bridging during starting using bridging relay

For medium and large motors
- Automatic cut out

For small motors; no protection during starting
All about Motors
Motor protection

Individually compensated motor

- $I_e$: Rated motor operational current [A]
- $I_a = I_e \times \cos \varphi$ [A]
- $I_w$: Active current
- $I_b$: Reactive current
- $I_c$: Rated capacitor current [A]
- $I_{EM}$: Setting current of overload relay [A]
- $\cos \varphi$: Motor power factor
- $U_e$: Rated operational voltage [V]
- $P_c$: Rated capacitor output [kvar]
- $C$: Capacitance of capacitor [μF]

Capacitor connected
to contactor terminals

Setting $I_{UL}$ of overload relay

$I_{UL} = I_a$

Capacitor does not relieve loading of cable between contactor and motor.

Capacitor connected
to motor terminals

$I_{UL} = \sqrt{\frac{U_e^2}{3} - (I_b - I_c)^2}$

Capacitor relieves loading of cable between contactor and motor; normal arrangement.
Thermistor overload relay for machine protection

Thermistor overload relays are used in conjunction with temperature-dependent semiconductor resistors (thermistors) for monitoring the temperature of motors, transformers, heaters, gases, oils, bearings etc. Depending on the application, thermistors have positive (PTC thermistors) or negative (NTC thermistors) temperature coefficients. With PTC thermistors the resistance at low temperature is small. From a certain temperature it rises steeply. On the other hand, NTC thermistors have a falling resistance-temperature characteristic, which does not exhibit the pronounced change behaviour of the PTC thermistor characteristic.

Temperature monitoring of electric motors

Thermistor overload relays EMT6 comply with the characteristics for the combination of protective devices and PTC sensors to VDE 0660 Part 303. They are therefore suitable for monitoring the temperature of series motors. When designing motor protection, it is necessary to differentiate between stator-critical and rotor-critical motors:

- **Stator-critical motors**
  Motors whose stator winding reaches the permissible temperature limit quicker than the rotor. The PTC sensor fitted in the stator winding ensures that the stator winding and rotor are adequately protected even with a stalled rotor.

- **Rotor-critical motors**
  Squirrel-cage motors whose rotor in the event of stalling reaches the permissible temperature limit earlier than the stator winding. The delayed temperature rise in the stator can lead to a delayed tripping of the thermistor overload relay. It is therefore advisable to supplement the protection of rotor-critical motors by a conventional overload relay. Three-phase motors above 15 kW are usually rotor-critical.

Overload protection for motors in accordance with IEC/EN 60204. These standards specify that motors above 2 kW used for frequent starting and stopping should be adequately protected for this type of duty. This can be achieved by fitting temperature sensors. If the temperature sensor is not able to ensure adequate protection with stalled rotors, an overcurrent relay must also be provided. Generally, where there is frequent starting and stopping of motors, intermittent operation and excessive frequency of operation, the use of overload relays in conjunction with thermistor overload relays is to be recommended. In order to avoid premature tripping out of the overload relay in these operating conditions, it is set higher than the predefined operational current. The overload relay then assumes stalling protection; the thermistor protection monitors the motor winding.

Thermistor overload relays can be used in conjunction with up to six PTC sensors to DIN 44081 for direct monitoring of temperatures in Ex e motors compliant to the ATEX directive (94/9 EC). Copies of PTB certification are available on request.
# Protection of current and temperature-dependent motor-protective devices

<table>
<thead>
<tr>
<th>Protection of the motor under the following conditions</th>
<th>Using bimetal</th>
<th>Using thermistor</th>
<th>Using bimetal and thermistor</th>
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<tr>
<td>Overload in continuous operation</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Extended starting and stopping</td>
<td>(+)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Switching to stalled rotor (stator-critical motor)</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switching on stalled rotor (rotor-critical motor)</td>
<td>(+)</td>
<td>(+)</td>
<td>(+)</td>
</tr>
<tr>
<td>Single-phasing</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Intermittent operation</td>
<td>–</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Excessive frequency of operation</td>
<td>–</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Voltage and frequency fluctuations</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Increased coolant temperature</td>
<td>–</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Impaired cooling</td>
<td>–</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

- Full protection
- (+) Partial protection
- No protection
Three-phase automatic starters

Automatic stator starters three-phase current with startup resistors

Single or multi-step resistors are connected upstream of the three-phase squirrel-cage motors to reduce the starting current and torque.

With single-step starters, the starting current is approximately three times the motor full-load current. With multi-step starters, the resistors can be so designed that the starting current is only 1.5 to 2 times the motor full-load current, with a very low level of starting torque.

Three-phase autotransformer starters with starting transformers

This type of starting is preferable where the same starting torque is to be obtained as with the primary resistance starters but the starting current taken from the mains is to be further reduced. A reduced voltage \( U_a \) (approximately 70% of the rated operational voltage) is supplied to the motor when starting via the starting transformer. Thus, the current taken from the mains is reduced to approximately half the direct starting current.

Three-phase automatic rotor starters with starting resistors

Resistors are connected in the rotor circuit of the motor to reduce the starting current of motors with slip-ring rotors. The current taken from the mains is thus reduced. In contrast to stator resistance starters, the torque of the motor is practically proportional to the current taken from the mains. The number of steps of the automatic starter is determined by the maximum permissible starting current and by the type of the motor.

---

I: Line current
\( M_d \): Torque
\( n \): Speed
① Reduction of the line current
② Reduction of the torque
## Important data and features of three-phase automatic starters

<table>
<thead>
<tr>
<th></th>
<th>Stator resistance starter (for squirrel-cage motors)</th>
<th>Rotor starter (for slipring rotors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Type of starter</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Type of starter</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Number of starting stages</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Voltage reduction at the motor</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Starting current taken from mains</td>
<td></td>
</tr>
<tr>
<td>5a</td>
<td>Starting current at the motor</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Starting torque</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Current and torque reduction</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Approximate price (for similar data, DOL starting = 100) with overload relay, enclosed</td>
<td></td>
</tr>
</tbody>
</table>

### Notes:
- Star-delta switches: Normally 1
- With starting resistors: Normally 1
- With starting transformers: Selectable (no longer selectable when current or torque have been determined)
- Rotor resistance starter:
- Current reduction: less than torque reduction
- Current reduction: much greater than torque reduction, from pull-out torque to rated speed almost proportional
- Approximate price:
  - DOL starting = 100: 150 – 300
  - DOL starting = 100: 250 – 500
  - DOL starting = 100: 500 – 1500
  - DOL starting = 100: 500 – 1500
Switching of capacitors

DIL contactors for capacitors – individual switching

Individual compensation

Group compensation

When capacitors are switched on, contactors are heavily stressed by transient current peaks. When a single capacitor is switched on, currents up to 30 times the rated current can occur; these can, however, be reliably switched by Moeller DIL contactors.

When installing capacitors, the VDE specification 0560 part 4 (Germany) and the standards which apply to each country should be observed. According to these, capacitors not directly connected to an electrical device which forms a discharge circuit, should be equipped with a rigidly connected discharge device. Capacitors connected in parallel to the motor do not require a discharge device, since discharging is performed via the motor winding. No switch-disconnectors or fuses must be installed between the discharge circuit and the capacitor.

A discharge circuit or discharge device must reduce the residual voltage of the capacitor to less than 50 V within a minute of the capacitor being switched off.
All about Motors
Engineering notes

Contactor for capacitor DILK... – Individual and group compensation

In the case of group compensation where capacitors are connected in parallel, it must be noted that the charging current is taken not only from the mains but also from the capacitors connected in parallel. This produces inrush current peaks which can exceed 150 times the rated current. A further reason for these peak currents is the use of low-loss capacitors as well as the compact construction, with short connecting elements between contactor and capacitor.

Where standard contactors are used, there is danger of welding. Special contactors for capacitors such as those available from Moeller in the DILK... range, which can control inrush current peaks of up to 180 times the rated current, should be used here.

If no special contactors are available, the inrush currents can be damped by additional inductances. This is achieved either by longer incoming leads to the capacitors or by inserting an air-cored coil with a minimum inductance of approximately 6 μH (5 windings, diameter of the coil approximately 14 cm) between contactor and capacitor. The use of series resistors is another way of reducing high inrush currents.

Use of reactors
Frequently the capacitors in group compensation are provided with reactors to avoid harmonics. The reactors also act to limit the inrush current and normal contactor can be used.
Circuit documents serve to explain the function of circuits or electrical connections. They provide information for the construction, installation and maintenance of electrical installations.

The supplier and the operator must agree on the form in which the circuit documents are to be produced: paper, film, diskette, etc. They must also agree on the language or languages in which the documentation is to be produced. In the case of machines, user information must be written in the official language of the country of use to comply with EN 292-2.

The circuit documents are divided into two groups:

### Classification according to the purpose

Explanation of the mode of operation, the connections or the physical position of the components. This support covers:

- Explanatory circuit diagrams,
- Block diagrams,
- Equivalent circuit diagrams,
- Explanatory tables or diagrams,
- Flow diagrams, tables
- Time flow diagrams, tables
- Wiring diagrams,
- Device wiring diagrams,
- Interconnection diagrams,
- Terminal diagrams,
- Assignment diagrams.

### Classification according to the type of representation

- Simplified or detailed
- Single-line or multi-line representation
- Connected, semi-connected or separate representation
- Topographical representation

In addition to this, there is the process-orientated representation with the function chart (see previous pages).

Examples for drawing up circuit documents are given in IEC 1082-1, IEC/EN 61082-1.

### Circuit diagrams

Diagrams indicate the voltage-free or current-free status of the electrical installation. A distinction is drawn between:

- Block diagram: Simplified representation of a circuit with its main parts, which shows how the electrical installation works and how it is subdivided.
- Circuit diagram: Detailed representation of a circuit with its individual components, which shows how the electrical installation works.
- Equivalent circuit diagram: Special version of an explanatory circuit diagram for the analysis and calculation of circuit characteristics.
Wiring diagrams show the conductive connections between electrical components. They show the internal and/or external connections, but, in general, do not give any information about the mode of operation. Instead of wiring diagrams, wiring tables can also be used.

- **Unit wiring diagram**: Representation of all the connections within the device or combination of devices.
- **Interconnection diagram**: Representation of the connections between the device or combination of devices within an installation.
- **Terminal diagram**: Representation of the connection points of an electrical installation and the internal and external conductive connections connected to them.
- **Assignment diagram (location diagram)**: Representation of the physical position of the electrical equipment, which does not have to be to scale.

You will find notes on the marking of electrical equipment in the diagram as well as further diagram details in the section "Specifications, Formulae, Tables".
All about Motors
Power supply

4-conductor system, TN-C-S

- L1
- L2
- L3
- N

- PEN

- PE

1. Protective earth conductor
2. Protective earth terminal in enclosure (not totally insulated)

Overcurrent protective device in the supply is required for compliance to IEC/EN 60204-1

5-conductor system, TN-S

- L1
- L2
- L3
- N

- PEN

- PE

1. Protective earth conductor
2. Protective earth terminal in enclosure (not totally insulated)

Overcurrent protective device in the supply is required for compliance to IEC/EN 60204-1
**All about Motors**

**Power supply**

3-conductor system, IT

![Diagram of a 3-conductor system, IT](image)

Overcurrent protective device is required in the supply for compliance to IEC/EN 60204-1

For all systems: use the N conductor only with the agreement of the user.

Separate primary and secondary protection

Earthed control circuit. In non-earthed control circuit, remove link and provide insulation monitoring.
Combined primary and secondary protection
Earthed control circuit. In non-earthed control circuit, remove link and provide insulation monitoring.
Maximum ratio of U1/U2 = 1/1.73
Circuit not to be used with STI/STZ (safety and isolating transformers).
All about Motors
Control circuit supply

Separate primary and secondary protection, with insulation monitoring on the secondary side

1. Clear button
2. Test button

DC power supply with three-phase bridge rectifier
All about Motors

Contactor markings

The contactors in contactor combinations have, in accordance with EN 61346-2 for equipment and function, the code letter Q, as well as numerical identification, which shows the function of the component (e.g. Q21 = mains contactor with anticlockwise rotation for high speed).

The following table shows the marking used in this Wiring Manual and in Moeller circuit documentation.

<table>
<thead>
<tr>
<th>Type of component</th>
<th>Mains contactors</th>
<th>Step contactors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard motor</td>
<td>One speed</td>
</tr>
<tr>
<td></td>
<td>2 speed/4 speed</td>
<td>Low speed</td>
</tr>
<tr>
<td></td>
<td>High speed</td>
<td>Star</td>
</tr>
<tr>
<td></td>
<td>Forward</td>
<td>Upper</td>
</tr>
<tr>
<td></td>
<td>Reverse</td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td>Up</td>
<td>Hoist</td>
</tr>
<tr>
<td></td>
<td>Reverse</td>
<td>Down</td>
</tr>
<tr>
<td></td>
<td>Star</td>
<td>Delta</td>
</tr>
<tr>
<td></td>
<td>Starting stage</td>
<td>Notes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Mains contactors</th>
<th>Step contactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL</td>
<td>Q11</td>
<td>Q17</td>
</tr>
<tr>
<td>DLUL</td>
<td>Q12</td>
<td>Q18</td>
</tr>
<tr>
<td>SDAIN</td>
<td>Q13</td>
<td>Q19</td>
</tr>
<tr>
<td>SDAIUL</td>
<td>Q14</td>
<td>Q20</td>
</tr>
<tr>
<td>UPIL</td>
<td>Q15</td>
<td>Q21</td>
</tr>
<tr>
<td>UPILUL</td>
<td>Q16</td>
<td>Q22</td>
</tr>
<tr>
<td>UPSDAIN</td>
<td>Q17</td>
<td>Q23</td>
</tr>
<tr>
<td>UPSDAIUL</td>
<td>Q18</td>
<td>Q24</td>
</tr>
<tr>
<td>ATAPE</td>
<td>Q19</td>
<td>Q25</td>
</tr>
<tr>
<td>DLT</td>
<td>Q20</td>
<td>Q26</td>
</tr>
<tr>
<td>DLT UL</td>
<td>Q21</td>
<td>Q27</td>
</tr>
<tr>
<td>XLUL</td>
<td>Q22</td>
<td>Q28</td>
</tr>
<tr>
<td>XLULUL</td>
<td>Q23</td>
<td>Q29</td>
</tr>
<tr>
<td>ATAPE</td>
<td>Q24</td>
<td>Q30</td>
</tr>
<tr>
<td>DLT</td>
<td>Q25</td>
<td>Q31</td>
</tr>
</tbody>
</table>

With contactor combinations which are made up of several basic types, the basic type is always maintained. Thus, the circuit diagram for a reversing star-delta starter, for example, is formed by combining the basic circuit of the reversing contactor and that of the standard star-delta starter.
All about Motors
Direct-on-line start of three-phase motors

Typical circuits with DIL contactors
Fuses without overload relay

Fuses with overload relay

[^1]: Protective device in the supply line in accordance with Moeller Main Catalogue, Industrial Switchgear or AWA installation instructions.
[^2]: Fuse size in accordance with data on the rating plate of the overload relay.
[^3]: Fuse size in accordance with Moeller Main Catalogue, Industrial Switchgear (Technical data for contactors)
All about Motors
Direct-on-line start of three-phase motors

Typical circuit with bridging of overload relay during starting

Without overload relay

- Control circuit device
  - I: ON
  - 0: OFF
  - For connection of further control circuit devices → section "Pulse encoder", page 8-37

- Method of operation:
  - Actuation of pushbutton I energizes the coil of contactor Q11.
  - The contactor switches on the motor and maintains itself after the button is enabled via its own auxiliary contact Q11/14-13 and pushbutton 0 (three-wire control contact).
  - Contactor Q0 is de-energized, in the normal course of events, by actuation of pushbutton 11.
  - In the event of an overload, it is de-energized via the normally closed contact 95-96 on overload relay F2.

With overload relay

- The short-circuit capacity of the contacts in the circuit has to be considered when selecting F0.
- Double actuator
Application on drive motors with heavy starting duty

For connection when used with motor-protective circuit-breakers PKZM... and circuit-breakers NZM(H)... → section "Fuses with overload relays", page 8-29
All about Motors
Direct-on-line start of three-phase motors

Function

Actuation of pushbutton I energizes bridging contactor Q14 which then maintains itself via Q14/3-14. At the same time, voltage is applied to the timing relay K1. The mains contactor Q11 is closed via Q14/44-43 and maintains itself via Q11/14-13. When the set time has elapsed, which corresponds to the starting time of the motor, bridging contactor Q14 is disconnected by K1/16-15. K1 is likewise disconnected and, exactly like Q14, cannot be energized again until after the motor has been switched off by pressing pushbutton 0. The normally closed contact Q11/22-21 prevents Q14 and K1 closing whilst the motor is running. In the event of an overload, normally closed contact 95-96 on overload relay F2 effects de-energization.

For connection of further control circuit devices → section "Pulse encoder", page 8-37
All about Motors
Direct-on-line start of three-phase motors

Two directions of rotation, DRUL reversing contactor
Fuses without overload relay
Short-circuit protection and overload protection by means of motor-protective circuit-breaker PKZM or circuit-breaker NZM.
Fuse size in the supply line in accordance with Moeller Main Catalogue, Industrial Switchgear or AWA installation instructions.

Fuses with overload relays
Short-circuit protection\(^1\) for contactor and overload relay by means of fuses F1.
Short-circuit protection\(^1\) for contactor by means of fuses F1.

\(^1\) Fuse size in accordance with data on the rating plate of the overload relay F2
All about Motors
Direct-on-line start of three-phase motors

Changing direction of rotation after actuation of the 0 push-button

Changing direction of rotation without actuation of the 0 push-button

Q11: Mains contactor, clockwise
Q12: Mains contactor, anticlockwise

Control circuit device
(Three-way pushbutton)
I = Clockwise
0 = Stop
II = Anticlockwise
All about Motors
Direct-on-line start of three-phase motors

Operating principle: Actuation of pushbutton I energizes the coil of contactor Q11. It switches on the motor running clockwise and maintains itself after pushbutton I is enabled via its own auxiliary contact Q11/14-13 and pushbutton 0 (three-wire control contact). The normally closed contact Q11/22-21 electrically inhibits the closing of contactor Q12. When pushbutton II is pressed, contactor Q12 closes (motor running anticlockwise). Depending on the circuit, direction can be changed from clockwise to anticlockwise either after pressing pushbutton 0, or by directly pressing the pushbutton for the reverse direction. In the event of an overload, normally closed contact 95-96 of overload relay F2, normally open contact 13-14 of the motor-protective circuit-breaker or the circuit-breaker will switch.

Operating direction and two speeds (reversing contactor)
Special circuit (tapped winding) for feed drives, etc.
FORWARD: feed or high speed
RETRACT: high speed only
STOP: tapped winding

![Diagram of motor control circuit]
All about Motors
Direct-on-line start of three-phase motors

Operating principle: Forward travel is initiated by pressing pushbutton I or II according to the speed required. Pushbutton I switches on the feed motion via Q17, which maintains itself via its normally open contact 13-14. If the feed movement is to occur at high speed, star contactor Q23 is energized via pushbutton II which energizes high speed contactor Q21 via its normally open contact Q23/13-14. Both contactors are maintained via Q21/13-14. A direct switch over from feed to high-speed during the forward travel is possible.

High speed reverse is initiated by pushbutton III. Contactor relay K1 picks up and energizes star contactor Q23 via K1/14-13. High-speed contactor Q22 is energized via normally open contacts K1/43-44 and Q23/44-43, and is maintained via Q22/14-13. The reverse motion can only be stopped via pushbutton 0. Direct changeover/reversal is not possible.
All about Motors
Direct switch-on with PKZ2 motor-protective circuit-breaker

Reversing

Instead of the high-capacity contact modules S-PKZ2, contact module SE1A ... PKZ2 can also be used provided a switching capacity of the circuit-breaker of 30 kA/400 V is sufficient.
All about Motors
Direct switch-on with PKZ2 motor-protective circuit-breaker

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S11</td>
<td>RMQ-Titan, M22-…</td>
<td>Q1</td>
<td>PKZ2/ZM-…</td>
</tr>
<tr>
<td>Q12</td>
<td>S/EZ-PKZ2</td>
<td>Q11</td>
<td>S/EZ-PKZ2</td>
</tr>
<tr>
<td>F0</td>
<td>FAZ</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

① Stop

① remove links with position switches
All about Motors

Direct switch-on with PKZ2 motor-protective circuit-breaker

Two speeds

Instead of the high-capacity contact modules S-PKZ2, contact module SE1A…-PKZ2 can also be used provided a switching capacity of the circuit-breaker of 30 kA/400 V is sufficient.
All about Motors
Direct switch-on with PKZ2 motor-protective circuit-breaker

<table>
<thead>
<tr>
<th>Version 1</th>
<th>Version 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 (Q17/1)</td>
<td>L1 (Q17/1)</td>
</tr>
<tr>
<td>Q17 1.3</td>
<td>Q17 1.3</td>
</tr>
<tr>
<td>Q14 1.14</td>
<td>Q14 1.14</td>
</tr>
<tr>
<td>Q21 1</td>
<td>Q21 1</td>
</tr>
<tr>
<td>Q2 1.14</td>
<td>Q2 1.14</td>
</tr>
<tr>
<td>S11 n&gt;</td>
<td>S11 n&gt;</td>
</tr>
<tr>
<td>Stop n&lt;</td>
<td>Stop n&lt;</td>
</tr>
<tr>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

S11  RMQ-Titan, M22… –
Q1, Q2  PKZ2/2M…/5 –
Q21  S-PKZ2 n>
Q17  S-PKZ2 n<
S11  RMQ-Titan, M22… –
All about Motors
Control circuit devices for direct-on-line start

Typical example of circuits with contactors DILM…

Pulse encoder

Illuminated pushbutton actuators

Two two-way pushbuttons

Double actuator pushbutton with indicator light

T0-1-15511 spring-return switch with automatic return to position 1

T0-1-15366 spring-return switch with automatic return to rest position

Maintained contact sensors

Changeover switch T0-1-15521 with fleeting contact in the intermediate position

MC5 pressure switches
Star-delta switching of three-phase motors

All about Motors

Star-delta starters with overload relay

Arrangement in the motor line

In a standard circuit configuration, the star-delta starter with overload relay, including a thermally delayed overcurrent relay are situated in the cables leading to the motor terminals U1, V1, W1 or V2, W2, U2. The overload relay can also be operated in a star circuit as it is usually connected in series with the motor winding and the relay current flowing through it = rated motor current
\[ \times 0.58. \]
For the complete circuit diagram see section "Automatic star-delta starters SDAINL", page 8-40.

Arrangement in the mains supply line

Instead of the arrangement in the motor line, the overload relay can be placed in the mains supply line. The section shown here indicates how the circuit differs from that on section "Automatic star-delta starters SDAINL", page 8-40. For drives where the F2 relay trips out when the motor is starting in the star circuit, the F2 relay rated for the rated motor current can be switched in the mains line. The tripping delay is thus increased by approximately four to six times. In the star circuit the current also flows through the relay but here the relay does not offer full protection since its limit current is increased to 1.73 times the phase current. It does, however, offer protection against non-starting.
Configuration in the delta circuit

Instead of the arrangement in the motor line or mains supply line, the overload relay can be placed in the delta circuit. The section shown here indicates the modified circuit diagram from section “Automatic star-delta starters SDAINL”, page 8-40. When heavy, long-starting procedures are involved (e.g. for centrifuges) the F2 relay, rated for relay current = rated motor current × 0.58, can also be connected in the connecting lines between delta contactor Q15 and star contactor Q13. In the star circuit no current then flows through relay F2. This circuit is used wherever exceptionally heavy and long starting procedures are involved and when saturable core current transformer-operated relays react too quickly.
All about Motors
Star-delta switching of three-phase motors

Automatic star-delta starters SDAINL

Position A
- F2 = 0.58 × Δ
  with F1 in position B t1 ≤ 15 s
- Motor protection in 'Y' and Δ configuration

Position B
- Q1 = Δ
  t2 > 15 – 40 s
- Only partial motor protection in 'Y' configuration

Rating of switchgear
- Q11, Q15 = 0.58 × Δ
- Q13 = 0.33 × Δ
Further notes on the configuration of the overload relay: section "Automatic star-delta starters SDAINL", page 8-40.

**SDAINLM12 to SDAINLM55**

**Pushbutton actuators**
- K1: Timing relay approx. 10 s
- Q11: Mains contactor
- Q13: Star contactor
- Q15: Delta contactor
- Double actuator

**Function**
Pushbutton I energizes timing relay K1. The normally open contact K1/17-18 (instantaneous contact) which applies voltage to star contactor Q13, which closes and applies voltage to mains contactor Q11 via normally open contact Q11/14-13.

Q11 and Q13 maintain themselves via the normally open contacts Q11/14–13 and Q11/14–43. Q11 applies voltage to motor M1 in star connection.

**SDAINLM70 to SDAINLM260**

The diagram shows the connection diagram for the star-delta switching of three-phase motors, including the timing relay and contactors for starting in star and delta configurations.
All about Motors
Star-delta switching of three-phase motors

5DAINLM12 to 5DAINLM260
Two-wire control
For connection of further control circuit devices
section "Control circuit devices for star-delta starting", page 8-51

Double actuator
Control circuit device
I = ON
0 = OFF
When the set changeover time has elapsed, K1/17-18 opens the circuit of Q13 and after 50 ms closes the circuit of Q15 via K1/17-28. Star contactor Q13 drops out. Delta contactor Q15 closes and switches motor M1 to full mains voltage. At the same time, normally closed contact Q15/22-21 interrupts the circuit of Q13 thus interlocking against renewed switching on while the motor is running. The motor cannot start up again unless it has previously been disconnected by pushbutton 0, or in the event of an overload by the normally closed contact 95-96 of overload relay F2, or via normally open contact 13-14 of the circuit-breaker.

Automatic star-delta starters SDAINL EM

Pushbutton actuators

Maintained contact sensors

K1: Timing relay approx. 10 s
Q11: Mains contactor
Q13: Star contactor
Q15: Delta contactor

Double actuator
Control circuit device
I = ON
0 = OFF
All about Motors
Star-delta switching of three-phase motors

For connection of further control circuit devices → section "Control circuit devices for star-delta starting", page 8-51

Function
Pushbutton I energizes star contactor Q13, normally open contact Q13/14-13 applies voltage to mains contactor Q11, which closes and applies mains voltage to motor M1 in star connection. Q11 and Q13 maintain themselves via normally open contact Q11/14-13 and Q11 additionally via Q11/44-43 and pushbutton 0. Timing relay Q11 is energized at the same time as mains contactor K1. When the set changeover time has elapsed, K1 opens the circuit of Q13 via changeover contact 15-16 and closes the circuit of Q15 via 15-18. Star contactor Q13 drops out.

Delta contactor Q15 closes and switches motor M1 to full mains voltage. At the same time, normally closed contact Q15/22–21 interrupts the circuit of Q13, thus interlocking against renewed switching on while the motor is running.

The motor cannot be started up again unless it has previously been disconnected by pushbutton 0, or in the event of an overload, by normally closed contact 95–96 of overload relay F2, or via the normally open contact 13–14 of the circuit-breaker.
All about Motors
Star-delta switching of three-phase motors

Automatic reversing star-delta starter SDAIUL

Reversing

Rating of switchgear
Q11, Q12: \( I_i \)
F2, Q15: \( 0.58 \times I_i \)
Q13: \( 0.33 \times I_i \)

The maximum motor output is limited by the upstream reversing contactor, and is lower than with automatic star-delta starters for only one direction of operation.

Standard version: Relay current = motor rated current \( \times 0.58 \)
For other arrangements of overload relay, see section "Star-delta starters with overload relay", page 8-38
All about Motors
Star-delta switching of three-phase motors

Changing direction of rotation after actuation of the 0 pushbutton

Three-way pushbutton
Control circuit devices
I = Clockwise
0 = Stop
II = Anticlockwise
For connection of further control circuit devices
section "Control circuit devices for star-delta starting", page 8-51

Function
Pushbutton I energizes contactor Q11 (e.g. clockwise). Pushbutton II energizes contactor Q12 (e.g. anticlockwise). The contactor first energized applies voltage to the motor winding and maintains itself via its own auxiliary contact 14-13 and pushbutton II. Normally open contact 44-43 fitted to each mains contactor energizes star contactor Q13, which energizes and switches on motor M1 in the star connection. At the same time, timing relay K1 is triggered. When the set changeover time has elapsed, K1/17-18 opens the circuit of Q13, which drops out. K1/17-28 closes the circuit of Q15.

Delta contactor Q15 energizes and switches motor M1 to the delta configuration, i.e. full mains voltage. At the same time, normally closed contact Q15/22–21 interrupts the circuit of Q13, thus interlocking against renewed switching on while the motor is running. Motor direction can be changed, either after pressing pushbutton 0, or by direct actuation of the reverse button, depending upon the circuit. In the event of an overload, disconnection is effected by normally closed contact 95–96 of overload relay F2.

Changing direction of rotation without actuation of the 0 pushbutton

Three-way pushbutton
Control circuit devices
I = Clockwise
0 = Stop
II = Anticlockwise

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All about Motors
Star-delta starting with motor-protective circuit-breakers PKZ2

With $I_{cc} > I_{cn}$ short-circuit proof installation required.
All about Motors
Star-delta starting with motor-protective circuit-breakers PKZ2

2 × RMQ-Titan, M22-… with indicator light M22-L… T0-1-8 rotary switch
**All about Motors**

Star-delta starting with motor-protective circuit-breakers PK22

<table>
<thead>
<tr>
<th>S11</th>
<th>RMQ-Titan, M22-…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>PKZ2/ZM-…</td>
</tr>
<tr>
<td>△Q15</td>
<td>S/EZ-PK22</td>
</tr>
<tr>
<td>YQ13</td>
<td>D600 M Ue ≈ 500 V AC</td>
</tr>
<tr>
<td>YQ13</td>
<td>S/EZ-PK22 Ue ≈ 660 V AC</td>
</tr>
<tr>
<td>K1</td>
<td>ETR4-11-A</td>
</tr>
<tr>
<td>Q11</td>
<td>S/EZ-PK22</td>
</tr>
<tr>
<td>F0</td>
<td>FAZ</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Setting</th>
<th>l</th>
<th>l Y (s)</th>
<th>15 – 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor protection</td>
<td>l Y + △</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
All about Motors
Control circuit devices for star-delta starting

Automatic star-delta starters SDAINL

Pulse encoder

Illuminated pushbutton actuators
Two two-way pushbuttons

Double actuator pushbutton with indicator light
Spring-return switch T0-1-15511
Spring-return switch T0-1-15366 with automatic return to rest position.

Two-wire control

Changeover switch T0-1-15521 with fleeting contact in the intermediate position

E.g. selector switch
Rotary switch T
LS position switches
MCS pressure switches
All about Motors
Control circuit devices for star-delta starting

Three-phase reversing contactor DIULRR
Reversing star-delta starter SDAIUL

Two-way pushbutton\(^1\) without self-maintaining circuit (inching) for use only with reversing contactors

Three-way pushbutton with indicator light. Reversing after actuation of pushbutton 0

Spring-return switch\(^1\)
Changeover switch\(^1\)
Switch T0-1-8214, without self-maintaining circuit (inching)
Automatic return to 0 only for reversing contactors

Position switches
Connected by removing the links between contactor terminals Q11/13 and Q12/22 and between Q12/13 and Q11/22 and interposing the position switches.

\(^1\) Overload relays always with manual reset
### All about Motors
#### Pole-changing motors

The speed is determined by the number of poles on induction motors. Several speeds can be obtained by altering the number of poles. The usual types are:

| 2 speeds: 1:2 | 1 reversible tapped winding |
| 2 speeds | 2 separate windings |
| 3 speeds | 1 reversible tapped winding 1:2, 1 separate winding |
| 4 speeds | 2 reversible tapped windings 1:2 |

The various tapped winding configurations give differential output ratios for the two speeds:

<table>
<thead>
<tr>
<th>Type of connection</th>
<th>Output ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \triangle/y )</td>
<td>1/1, 5–1:8, 0.3/1</td>
</tr>
</tbody>
</table>

The \( \triangle/y \) configuration comes nearest to satisfying the most common requirement for constant torque. It has the additional advantage that, because nine terminals are available, \( \gamma/y \) starting can be used to provide smooth starting or to reduce the starting current for the low speed condition (§ section “Motor windings”, page 8-56).

#### 2 speeds – separate windings

In theory, motors with separate windings allow any combination of speed and any output ratio. Both windings are arranged in \( y \) connection and are completely independent of one another. Preferred speed combinations are:

<table>
<thead>
<tr>
<th>Motors with tapped winding</th>
<th>1500/3000</th>
<th>–</th>
<th>750/1500</th>
<th>500/1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motors with separate windings</td>
<td>–</td>
<td>1000/1500</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Number of poles</td>
<td>4/2</td>
<td>6/4</td>
<td>8/4</td>
<td>12/6</td>
</tr>
<tr>
<td>Code no. low/high</td>
<td>1/2</td>
<td>1/2</td>
<td>1/2</td>
<td>1/2</td>
</tr>
</tbody>
</table>

The code numbers are prefixed to the main notations to denote increasing speed. Example: 1U, 1V, 1W, 2U, 2V, 2W. Comparable to EN 60034-8.
All about Motors
Pole-changing motors

Motor circuit

Circuit A
Selection of low and high speed only from zero. No return to low speed, only to zero.

Circuit B
Selection of either speed from zero. Switching from low to high speed possible. Return only to zero.

Circuit C
Selection of either speed from zero. Switching back and forward between low and high speed (high braking torque). Return also to zero.

3 speeds
The 1:2 speeds - tapped windings - are supplemented by the speed of the separate winding. This speed can be below, between or above the two tapped winding speeds. The circuit must consider it (figure, page 8-84).

Preferred speed combinations are:

<table>
<thead>
<tr>
<th>Speeds</th>
<th>1000/1500/3000</th>
<th>750/1000/1500</th>
<th>750/1500/3000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of poles</td>
<td>6/4/2</td>
<td>8/6/4</td>
<td>8/4/2</td>
</tr>
<tr>
<td>Connection</td>
<td>X</td>
<td>Y</td>
<td>Z</td>
</tr>
</tbody>
</table>

= separate winding (in the circuit diagrams)
All about Motors
Pole-changing motors

Motor circuit

<table>
<thead>
<tr>
<th>Circuit A</th>
<th>Circuit B</th>
<th>Circuit C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection of any speed only from zero. Return only to zero.</td>
<td>Selection of any speed from zero and from low speed. Return only to zero.</td>
<td>Selection of any speed from zero and from low speed. Return to low speed (high braking torque) or to zero.</td>
</tr>
</tbody>
</table>

4 speeds
The 1:2 speeds - tapped windings - can follow in sequence or overlap, as the following examples show:

<table>
<thead>
<tr>
<th>1st winding</th>
<th>2nd winding</th>
<th>3rd winding</th>
</tr>
</thead>
<tbody>
<tr>
<td>500/1000</td>
<td>1500/3000</td>
<td>500/1000/1500/3000</td>
</tr>
</tbody>
</table>

or

<table>
<thead>
<tr>
<th>1st winding</th>
<th>2nd winding</th>
<th>3rd winding</th>
</tr>
</thead>
<tbody>
<tr>
<td>500/1000</td>
<td>750/1500</td>
<td>500/750/1000/1500</td>
</tr>
</tbody>
</table>

For motors with 3 or 4 speeds the non-connected winding has to be opened at certain pole ratios to avoid inductive circulating currents. This is achieved with additional motor terminals. A range of rotary switches is equipped with this connection (section “Multi-Speed Switches”, page 4-7).
All about Motors
Motor windings

Tapped winding
2 speeds

Motor circuit
2 speeds
2 separate windings

Tapped winding
with $\triangle$ starting at low speed

Motor circuit X
2 windings, medium and high speed – tapped winding

Motor circuit Y
2 windings, low and speed – tapped winding

→ figure, page 8-61  
→ figure, page 8-61  
→ figure, page 8-65

→ figure, page 8-61  
→ figure, page 8-61  
→ figure, page 8-65

→ figure, page 8-43  
→ figure, page 8-38  
→ figure, page 8-83
All about Motors
Motor windings

Tapped winding
3 speeds

Motor circuit X
2 windings, medium and high speed – tapped winding

Motor circuit Y
2 windings, low and high speed – tapped winding

Motor circuit Z
2 windings, low and medium speed – tapped winding

Motor circuit
Tapped winding

with \( \Delta \) starting at

low speed

Low speed

High speed

Low speed

High speed

or 2

or 2

or 2

Separate winding

Low speed

Medium speed

High speed

Separate winding

Separate winding

Separate winding

figure, page 8-65

figure, page 8-74

figure, page 8-83

figure, page 8-85

figure, page 8-85

figure, page 8-87
All about Motors
Multi-speed contactors

Certain operating sequences for multi-speed motors may be necessary, or undesirable, depending on the nature of the drive. If, for example, the starting temperature rise is to be reduced or high inertia loads are to be accelerated, it is advisable to switch to low speed first and then to high speed.

It may be necessary to prevent switching from high to low speed in order to avoid oversynchronous braking. In other cases, it should be possible to switch each speed on and off directly. The operating sequence and indexing facilities of rotary switches allow for these possibilities. Multi-speed contactor starters can achieve these circuits by interlocking with suitable control circuit devices.

Fuse protection of the overload relays
When a common fuse is used in the supply line, it must not be larger than the back-up fuses specified on the rating plate of either overload relay, otherwise each relay must be protected by its own back-up fuse, as shown in the diagram.
Multi-speed contactors

Fuseless surface mounting

Multi-speed motors can be protected against short circuits and overloads by motor-protective circuit-breakers PKZ or circuit-breakers NZM, which provide all the advantages of a fuseless circuit. Normally, the fuse in the supply line protects the switches from welding.
All about Motors
Multi speed switches of three-phase motors

Tapped winding, non-reversing, 2 speeds

Multi-speed contactors UPIL
Fuseless, without overload relay, with
motor-protective circuit-breaker or
circuit-breaker.

→ section “Motor windings”, page 8-56
Synchronous speeds
One multi-speed winding
### All about Motors
Multi speed switches of three-phase motors

<table>
<thead>
<tr>
<th>Motor terminals</th>
<th>1U, 1V, 1W</th>
<th>2U, 2V, 2W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of poles</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>rpm</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>Number of poles</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>rpm</td>
<td>750</td>
<td>1500</td>
</tr>
<tr>
<td>Number of poles</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>rpm</td>
<td>1500</td>
<td>3000</td>
</tr>
</tbody>
</table>

**Contacts**
- Q17
- Q21, Q23

**Rating of switchgear**
- Q2, Q17: $I_1$ (low speed)
- Q1, Q21: $I_2$ (high speed)
- Q23: $0.5 \times I_2$
All about Motors
Multi speed switches of three-phase motors

Circuit A (→ figure, page 8-55)
One three-way pushbutton

For connection of further control circuit devices (→ figure, page 8-69, → figure, page 8-70, → figure, page 8-71

Function

Pushbutton I energizes mains contactor Q17 (low speed), which maintains itself via its normally open contact 13-14. Pushbutton II energizes star contactor Q23 and via its normally open contact 13-14 mains contactor Q21. Q21 and Q23 maintain themselves via normally open contact 13-14 of Q21.

Speed can be changed either after pressing pushbutton 0 (circuit A) or directly by pressing the appropriate pushbutton (circuit C), depending upon the circuit. The motor can be switched off either by pressing pushbutton 0, or in the event of an overload, by normally open contact 13–14 of the circuit-breaker.
All about Motors
Multi speed switches of three-phase motors

Circuit C (➔ figure, page 8-55)
One three-way pushbutton

For connection of further control circuit
devices ➔ figure, page 8-72
All about Motors
Multi speed switches of three-phase motors

Two separate windings, non-reversing, two speeds

Multi-speed contactor UPDIUL, fuseless without overload relay

Rating of switchgear
Q1, Q17 = \( I_1 \) (low speed)
Q2, Q21 = \( I_2 \) (high speed)

Motor windings → section "Motor windings",
page 8-56.
All about Motors
Multi-speed switches of three-phase motors

Two separate windings, non-reversing, two speeds
Multi-speed contactor UPDIUL, with fuses and overload relay

Fuse size in accordance with data on the rating plate of overload relays F2 and F21. If overload relays F2 and F21 cannot be protected by a common fuse, then use circuit figure, page 8-59.
Motor windings section "Motor windings", page 8-56.
All about Motors
Multi speed switches of three-phase motors

Circuit A (figure, page B-55)
One three-way pushbutton

Circuit C (figure, page B-55)
One three-way pushbutton

Q17: Mains contactor, low speed
Q21: Mains contactor, high speed

Three-way pushbutton
I: Low speed (Q17)
0: Stop
II: High speed (Q21 + Q23)

For connection of further control circuit devices (figure, page B-73.)
All about Motors
Multi speed switches of three-phase motors

Operating principle
Actuation of pushbutton I energizes the coil of contactor Q17, which switches on the low speed of the motor and, after pushbutton I is released, maintains itself via its auxiliary contact 13-14 and pushbutton 0.

Speed can be changed either after pressing pushbutton 0, or directly by pressing the appropriate pushbutton, depending upon the circuit. The motor is switched off either by pressing pushbutton 0, or in the event of an overload, by normally closed contact 95–96 of overload relays F2 and F21.
All about Motors
Control circuit devices for UPDIUL multi-speed contactors

Two separate windings, non-reversing, two speeds

Circuit A (figure, page 8-55)
One three-way pushbutton with indicator lights

Control circuit devices
I: Low speed (Q17)
0: Stop
II: High speed (Q21)
All about Motors
Control circuit devices for UPDIUL multi-speed contactors

Circuit A (figure, page 8-55)
Two three-way pushbuttons

Control circuit devices
I: Low speed (Q17)
II: High speed (Q21)
Stop

Remove existing links and rewire
All about Motors
Control circuit devices for UPDIUL multi-speed contactors

Circuit A (figure, page 8-55)
TO-1-B210 changeover switch
Always set overload relay to manual reset

Circuit B (figure, page 8-55)
One three-way pushbutton
All about Motors
Control circuit devices for UPDIUL multi-speed contactors

Circuit B (figure, page 8-55)
Two three-way pushbuttons

Control circuit device for circuit B
Control circuit devices for UPDIUL multi-speed contactors

Circuit C (figure, page 8-55)
Two three-way pushbuttons

Control circuit device for circuit C
All about Motors
Multi-speed switches of three-phase motors

Tapped winding, non-reversing, 2 speeds
Multi-speed contactors UPSDAINL
Star-delta starting at low speed
Fuseless
Without overload relay

Rating of switchgear
Q1, Q17 = I₁ (low speed)
Q2, Q21 = I₂ (high speed)
Q19, Q23 = 0.5 × I₂
All about Motors
Multi speed switches of three-phase motors

With fuses and overload relays

Rating of switchgear
F2, Q17 = \( I_2 \) (low speed)
F21, Q21 = \( I_2 \) (high speed)
Q19, Q23 = 0.5 \( \times I_2 \)
F1 = \( I_2 \)

Overload relays F2 and F21 are not used on multi-speed contactors without motor protection. If F2 and F21 cannot be protected by a common fuse, then use circuit on figure, page 8-59.

Motor windings → section "Motor windings", page 8-56.
All about Motors
Multi speed switches of three-phase motors

Function
Actuation of pushbutton I energizes the coil of star contactor Q23. Its normally open contact 13–14 energizes the coil of contactor Q17. The motor runs in star at low speed. The contactors are maintained via auxiliary contact Q17/13–14. At the same time, timing relay K3 is triggered. When the set time has elapsed, K3/15–16 opens the circuit of Q23, which drops out, the coil of delta contactor Q19 is energized and maintains itself via Q19/13–14. The timing relay is de-energized via normally closed contact Q19/32–31.

Circuit
Low speed selected only from zero, high speed only via low speed without actuation of the Stop button. Three-way pushbutton
I. Low speed (Q17, Q19)
0. Stop
II. High speed (Q21, Q19, Q23)

Q17: Mains contactor, low speed
K3: Timing relays
Q23: Star contactor
Q19: Delta contactor
Q21: Mains contactor, high speed

The motor runs in delta at low speed. Actuation of pushbutton II de-energizes the coil of Q17 and via Q17/22–21 energizes the coil of Q21. This state is maintained by Q21/43–44. The coil of star contactor Q23 is re-energized by normally open contact Q21/14–13. The motor runs at high speed.

Pushbutton 0 (= Stop) effects disconnection.
All about Motors
Multi-speed switches of three-phase motors

Tapped winding, reversing, 2 speeds
(direction preselected)

Multi-speed contactors UPRUL
Overload relays F2 and F21 are not used on multi-speed contactors without motor protection.

Rating of switchgear
Q11, Q12 = I₂ (low and high speed)
F2, Q17 = I₁ (low speed)
F1, Q21 = I₂
Q23 = 0.5 × I₂ (high speed)
All about Motors
Multi speed switches of three-phase motors

Function
Contactor Q11 is energized by pressing pushbutton I. Contactor Q11 selects the direction and maintains itself after release of pushbutton I via its auxiliary contact 14–13 and pushbutton 0. Speed-selection buttons III and IV are made operative by Q11/44–43. Pushbutton III energizes Q17, which maintains itself via its contact 14–13. Pushbutton IV

energizes high-speed contactors Q23 and Q21. Auxiliary contact Q17/14–13 makes low-speed pushbutton III inoperative. Pushbutton 0 must be pressed before any change in speed or direction.

Control circuit device
- O: Stop
- I: Forward (Q11)
- II: Back (Q12)
- III: Slow (Q17)
- IV: Fast (Q21 + Q23)

Connection
Change of direction FORWARD–REVERSE after actuation of Stop button, optionally followed by SLOW–FAST with no return to low speed.

Five-way pushbutton
All about Motors
Multi-speed switches of three-phase motors

Tapped winding, reversing, 2 speeds
(Direction and speed selected simultaneously)

Multi-speed contactor UPIUL
Fuseless without overload relay

Rating of switchgear
Q1, Q17, Q18 = I1
(low speed)
Q2, Q21, Q22 = I2
Q23 = 0.5 \times I2
(high speed)
All about Motors
Multi-speed switches of three-phase motors

Multi-speed contactor UPIUL
With fuses and overload relays

Rating of switchgear
F2, Q17, Q18 = I₁
(low speed)
F21, Q21, Q22 = I₂
Q23 = 0.5 × I₂
(high speed)

Overload relays F2 and F21 are not used on multi-speed contactors without motor protection
All about Motors
Multi-speed switches of three-phase motors

Circuit
Simultaneous selection of direction and speed via one pushbutton. Always operate Stop button before changeover.

Q17: Slow forward
Q18: Slow back
Q21: Fast forward
Q23: Star contactor
K1: Contactor relay
Q22: Fast back
Function
Desired speed and direction can be selected by actuation of the appropriate pushbutton. Contactors Q17, Q18, Q21 and Q23 maintain themselves by their contact 14–13 and can be de-energized only by actuation of pushbutton 0. Contactors Q21 and Q22 can maintain themselves only when Q23 has picked up and contact Q23/13–14 or 44–43 is closed.
All about Motors
Multi-speed switches of three-phase motors

Tapped winding, medium and high speed,
Non reversing, 3 speeds, 2 windings
Multi-speed contactor U3PIL

Synchronous speed

<table>
<thead>
<tr>
<th>Winding</th>
<th>1</th>
<th>2</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor terminals</td>
<td>U1, U2, W1, W2</td>
<td>U1, U2, W1, W2</td>
<td>U1, U2, W1, W2</td>
</tr>
<tr>
<td>Number of poles</td>
<td>12</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>rpm</td>
<td>500</td>
<td>750</td>
<td>1500</td>
</tr>
<tr>
<td>Number of poles</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>rpm</td>
<td>750</td>
<td>1500</td>
<td>3000</td>
</tr>
</tbody>
</table>

Rating of switchgear
Q2, Q11: \( I_L \) (low speed)
Q1, Q17: \( I_L \) (medium speed)
Q3, Q21: \( I_L \) (high speed)
Q23: \( 0.5 \times I_L \)

Rating of switchgear

Multi-speed contactor U3PIL with overload relay — figure, page 8-85
All about Motors
Multi speed switches of three-phase motors

Function
Pushbutton I energizes mains contactor Q11 (low speed), pushbutton II mains contactor Q17 (medium speed), pushbutton III star contactor Q23 and via its normally open contact Q23/14–13 mains contactor Q21 (high speed). All contactors maintain themselves by their auxiliary contact 13–14. Speed sequence from low to high is optional. Switching in steps from high to medium or low speed is not possible. The motor is always switched off by pressing pushbutton 0. In the event of an overload, normally open contact 13–14 of the motor-protective circuit-breaker or circuit-breaker can also switch off.
All about Motors
Multi-speed switches of three-phase motors

Tapped winding, low and high speed, Non-reversing, 3 speeds, 2 windings

Multi-speed contactor U3PIL
Multi-speed contactor U3PIL without overload relay → figure, page 8-83

Synchronous speed

<table>
<thead>
<tr>
<th>Winding</th>
<th>2</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor terminals</td>
<td>1U, 1V, 1W</td>
<td>2U, 2V, 2W</td>
<td>3U, 3V, 3W</td>
</tr>
<tr>
<td>Number of poles</td>
<td>12</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>rpm</td>
<td>500</td>
<td>750</td>
<td>1000</td>
</tr>
<tr>
<td>Number of poles</td>
<td>8</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

Rating of switchgear
F2, Q17: $I_1$ (low speed)
F3, Q11: $I_2$ (medium speed)
F4, Q21: $I_3$ (high speed)
Q23: $0.5 \times I_0$
All about Motors
Multi speed switches of three-phase motors

Function
Pushbutton I energizes mains contactor Q17 (low speed), pushbutton II mains contactor Q11 (medium speed), pushbutton III star contactor Q23 and via its normally open contact Q23/14–13 mains contactor Q21 (high speed). All contactors maintain themselves by their auxiliary contact 13–14.

Speed sequence from low to high is optional. Switching in steps from high to medium or low speed is not possible. The motor is always switched off by pressing pushbutton 0. In the event of an overload, normally closed contact 95–96 of overload relays F2, F21 and F22 can also switch off.
All about Motors
Multi-speed switches of three-phase motors

Tapped winding, low and medium speed, Non-reversing, 3 speeds, 2 windings

Multi-speed contactor U3PIL

Rating of switchgear

<table>
<thead>
<tr>
<th>Winding</th>
<th>2</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor terminals</td>
<td>1U, 1V, 1W</td>
<td>2U, 2V, 2W</td>
<td>3U, 3V, 3W</td>
</tr>
<tr>
<td>Number of poles</td>
<td>12</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>rpm</td>
<td>500</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>Number of poles</td>
<td>12</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>rpm</td>
<td>500</td>
<td>1000</td>
<td>3000</td>
</tr>
</tbody>
</table>

Synchronous speed

<table>
<thead>
<tr>
<th>Number of poles</th>
<th>8</th>
<th>4</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>rpm</td>
<td>750</td>
<td>1500</td>
<td>3000</td>
</tr>
</tbody>
</table>

Contacts

- Q17
- Q21
- Q23

Rating of switchgear

F2, Q17: \( I_1 \) (low speed)
F4, Q21: \( I_2 \) (medium speed)
F3, Q11: \( I_3 \) (high speed)
Q23: \( 0.5 \times I_3 \)
**All about Motors**

Multi speed switches of three-phase motors

**Circuit of motor winding: Z**

**Circuit A**

- Selection of any speed from zero. No return to low speed, only to zero.

**Circuit B**

- Selection of any speed from zero or from low speed. Return only to zero.

**Function**

- Pushbutton I energizes mains contactor Q17 (low speed), pushbutton II mains contactor Q23 (low speed) and via its normally open contact Q23/14-13 mains contactor Q21 (high speed), pushbutton III mains contactor Q11. All contactors maintain themselves by their auxiliary contacts 13-14.

- 4-way pushbutton
  - 0: Stop
  - I: Low speed (Q17)
  - II: Medium speed (Q21 + Q23)
  - III: High speed (Q11)

- Speed sequence from low to high is optional. Switching in steps from high to medium or low speed is not possible. The motor is always switched off by pressing pushbutton 0. In the event of an overload, normally closed contact 95–96 of overload relays F2, F21 and F22 can also switch off.
All about Motors
Multi speed switch with motor-protective circuit-breakers PKZ2

<table>
<thead>
<tr>
<th>Number of poles</th>
<th>12</th>
<th>8</th>
<th>4</th>
<th>12</th>
<th>8</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>rpm</td>
<td>500</td>
<td>750</td>
<td>750</td>
<td>1000</td>
<td>1500</td>
<td>3000</td>
</tr>
</tbody>
</table>
All about Motors

Multi speed switch with motor-protective circuit-breakers PKZ2

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8

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Circuit A figure, page 8-55

Circuit C figure, page 8-55

---

<table>
<thead>
<tr>
<th>511</th>
<th>RMQ-Titan, M22-…</th>
<th>–</th>
<th>–</th>
<th>–</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1, Q2</td>
<td>PKZ2/IM-…/S</td>
<td>n&gt;</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Q2, Q17</td>
<td>PKZ2/IM-…/S</td>
<td>n&lt;</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Q23</td>
<td>DILIM</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Q23</td>
<td>S/EZ-PKZ</td>
<td>(\gamma n &gt; U_0 \leq 500) V</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(\gamma n &gt; U_0 \leq 660) V</td>
<td>F0</td>
<td>FAZ</td>
</tr>
</tbody>
</table>
All about Motors
Three-phase current-automatic stator starters

Three-phase automatic stator resistance starter DDAINL with mains contactor and resistors, 2-stage, 3-phase version

Rating of switchgear:
- Starting voltage: \(0.6 \times U_e\)
- Inrush current: \(0.6 \times\) direct switching system
- Tightening torque: \(0.36 \times\) direct switching system
- \(Q_1, Q_{11}: 0.6 \times I_e\)
- \(Q_{16}, Q_{17}: 0.6 \times I_e\)

When using \(F_1\) instead of \(Q_1\), use \(F_2\).
All about Motors
Three-phase current-automatic stator starters

DDAINL three-phase automatic stator resistance starter with mains contactor and resistors, 2-stage, 3-phase version

Q16: Step contactor
K1: Timing relay
Q17: Step contactor
Q11: Mains contactor

Two-wire control
Always set overload relay to manual reset
All about Motors
Three-phase current-automatic stator starters

Function
Pushbutton I energizes step contactor Q16 and timing relay K1. Q16/14-13 – self-maintaining through Q11, Q11/32-31 and pushbutton 0. The motor is connected to the supply with rotor resistors R1 + R2. When the set starting time has elapsed, normally open contact K1/15-18 energizes Q17. Step contactor Q17 bypasses the starting stage R1. At the same time, normally open contact Q17/14-13 energizes K2. When the set starting time has elapsed, K2/15-18 energizes mains contactor Q11. This bypasses the second starting stage R2, and the motor runs at the rated speed. Q11 maintains itself via Q11/14-13. Q16, Q17, K1 and K2 are de-energized by normally closed contacts Q11/22-21 and Q11/32-31. The motor is switched off with pushbutton 0. In the event of an overload, normally closed contact 95-96 of the overload relay F2 or normally open contact 13-14 of the motor-protective circuit-breaker switch off the motor.

Step contactor Q17, resistor R2 and timing relay K1 are omitted in single-stage starting circuits. Timing relay K2 is connected directly to Q16/13 and resistor R2 is connected by means of its terminals U1, V1 and W1 to Q11/2, 4, 6.
All about Motors
Three-phase current-automatic stator starters

Three-phase automatic stator resistance starter ATAINL with mains contactor and starting transformer, 1-stage, 3-phase

When using F1 instead of Q1, use F2.

Rating of switchgear

<table>
<thead>
<tr>
<th>Starting voltage</th>
<th>Tightening</th>
<th>Inrush current</th>
<th>Q1, Q11</th>
<th>Q16</th>
<th>Q13</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7 × Ue (typical value)</td>
<td>= 0.49 × direct switching system</td>
<td>6</td>
<td>Ie</td>
<td>0.6 × Ie</td>
<td>0.25 × Ie</td>
</tr>
<tr>
<td>Ie</td>
<td></td>
<td>10 s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qp/h</td>
<td></td>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Function
Pressing pushbutton I simultaneously energizes star contactor Q13, timing relay K1 and, via normally open contact Q13/13–14, step contactor Q16, and are maintained via K1/13-14. When K1 has elapsed, normally closed contact K1/55–56 de-energizes star contactor Q13, and – via normally open contact Q13/13–14 – Q16 de-energizes. The starting transformer is disconnected, and the motor runs at the rated speed.

The motor cannot start up again unless previously switched off by actuation of pushbutton 0, or in the event of an overload, by normally closed contact 95–96 of the overload relay F2. With two-wire control, overload relay F2 must always be set to manual reset. If the motor has been switched off by F2, the motor cannot start up again unless the manual reset is released.
All about Motors
Three-phase automatic rotor starters

DAINL three-phase automatic rotor starters
Three stage, rotor three phase

When using F1 instead of Q1, use F2.
All about Motors
Three-phase automatic rotor starters

2-stage, rotor 2-phase

When using F1 instead of Q1, use F2.

Rating of switchgear

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inrush current</td>
<td>(0.5 \times I_e)</td>
</tr>
<tr>
<td>Tightening torque</td>
<td>(0.5) to pull-out torque</td>
</tr>
<tr>
<td>Q1, Q11</td>
<td>(I_e)</td>
</tr>
<tr>
<td>Step contactors</td>
<td>(0.35 \times I_{rot})</td>
</tr>
<tr>
<td>Final step contactors</td>
<td>(0.58 \times I_{rot})</td>
</tr>
</tbody>
</table>
All about Motors
Three-phase automatic rotor starters

With mains contactor, style 3-stage, rotor 3-phase

Q11: Mains contactor
K1: Timing relay
Q14: Step contactor
K2: Timing relay
Q12: Step contactor
Q13: Final step contactor
K3: Timing relay

Double actuator
I: ON
D: OFF

For connection of further control circuit devices:
section "Control circuit devices for star-delta starting", page 8-51
All about Motors

Three-phase automatic rotor starters

Function
Pushbutton I energizes mains contactor Q11; normally open contact Q11/14–13 transfers the voltage, Q11/44–43 energizes timing relay K1. The motor is connected to the supply with rotor resistors R1 + R2 + R3 in series. When the set starting time has elapsed, normally open contact K1/15–18 energizes step contactor Q14, which short-circuits starting stage R1 and via Q14/14–13 energizes timing relay K2. When the set starting time has elapsed, K2/15–18 energizes step contactor Q12, which short-circuits starting stage R2 and via Q12/14–13 energizes timing relay K3. When the set starting time has elapsed, K3/15–18 energizes final step contactor Q13, which is maintained via Q13/14–13. Step contactors Q14 and Q12 as well as timing relays K1, K2 and K3 are de-energized via Q13. Final step contactor Q13 short-circuits the rotor slip rings: the motor operates at the rated speed.

The motor is switched off either by pushbutton 0, or in the event of an overload, by normally closed contact 95–96 of the overload relay F2 or normally open contact 13–14 of the motor-protective circuit-breaker or circuit-breaker.

Step contactor Q13 and Q12 with their resistors R3, R2 and timing relays K3, K2 are omitted in single-stage or two-stage starting circuits. The rotor is then connected to the resistance terminals U, V, W2 or U, V, W1. The references for step contactors and timing relays in the wiring diagrams are then changed from Q13, Q12 to Q12, Q11 or to Q13, Q11 as appropriate. When there are more than three stages, the additional step contactors, timing relays and resistors have appropriate increasing designations.
All about Motors
Switching of capacitors

Contactors for capacitors DIL

Individual circuit without quick-discharge resistors

Individual circuit with quick-discharge resistors

R1 discharge resistors fitted in capacitor
R1 discharge resistors fitted to contactor
All about Motors
Switching of capacitors

Function
Pushbutton I actuates contactor Q11, which picks up and maintains itself via its own auxiliary contact 14-13 and pushbutton 0. Capacitor C1 is thus energized. Discharge resistors R1 are not active when contactor Q11 is energized.
Actuation of pushbutton 0 effects de-energization. Normally closed contacts Q11/21–22 then switch discharge resistors R1 to capacitor C1.

Maintained contact sensors
In the case of actuation by means of power factor correction relay, check that this has sufficient power to actuate the contactor coil. Interpose a contactor relay if necessary.

Double actuator
For connection of further control circuit devices:
section “Control circuit devices for star-delta starting”, page 8-51
All about Motors
Switching of capacitors

Capacitor contactor combination
Capacitor contactor with pilot contactor and series resistors. Individual and parallel circuit with and without discharge resistors and with series resistors.

On the version without discharge resistors, resistors $R_1$ and the connections to the auxiliary contacts 21–22 and 31–32 are omitted.
**All about Motors**

**Switching of capacitors**

**Function**

Actuation by two-way pushbutton S11.

Pushbutton I energizes pilot contactor Q14, which switches capacitor C1 in with bridged series resistors R2. Normally open contact Q14/14-13 energizes mains contactor Q11. Capacitor C1 is then switched in with bridged series resistors R2. Q14 is maintained via Q11/14-13 when Q11 has closed.

Discharge resistors R1 are not operative when Q11 and Q14 are energized. Pushbutton 0 effects de-energization. Normally closed contacts Q11/21–22 and 31–32 then switch discharge resistors R1 to capacitor C1.

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Q11: Mains contactor
Q14: Pilot contactor
Actuation by two-way pushbutton S11

Actuation by selector switch S13, two-wire control S12 (power factor correction relay) and two-way pushbutton S11
All about Motors
Duplex pump control

Fully automatic control with two pumps

Starting sequence of pumps 1 and 2 can be selected by control switch S12.

Control circuit wiring with two float switches for basic and peak loads (operation is also possible with two pressure switches)

P1 Auto = Pump 1 constant load, Pump 2 peak load
P2 Auto = Pump 2 constant load, Pump 1 peak load
P1 + P2 = Direct operation independent of float switches (or pressure switches)

Legend:
- Cable with float, counterweight, pulleys and clamps
- Storage tank
- Inlet
- Pressure pipe
- Outlet
- Centrifugal or reciprocating pump
- Pump 1
- Pump 2
- Suction pipe with filter
- Well
The duplex pump control is designed for operation of two pump motors M1 and M2. Control is via float switches F7 and F8.

Operating mode selector switch S12 in position P1 auto:
The system operates as follows: When the water level in the storage tank falls or rises, F7 switches pump 1 on or off (basic load). If the water level drops below the range of F7 (discharge is greater than intake), F8 starts pump 2 (peak load). When the water level rises again, F8 is deactivated. Pump 2 continues running until F7 stops both pumps.

The operating sequence of pumps 1 and 2 can be determined using operating mode selector switch S12: Position P1 auto or P2 auto.

In position P1 + P2, both pumps are in operation, independent of the float switches (Caution! Tank may possibly overflow).

On the version of duplex pump control with automatic load sharing (T0(3)-4-15915), S12 has a further position: the sequence of operations is automatically reversed after each cycle.
All about Motors

Fully automatic pump control

With pressure switch for air tank and domestic water supply without water failure (run dry) safety device

With 3-pole pressure switch MCSN (main circuit)

F1: Fuses (if required)
Q1: Motor-protective switch, manual (z. B. PKZ)
F7: Pressure switch MCSN, 3-pole
M1: Pump motor
1: Air or pressure tank
2: Non-return valve
3: Pressure pipe
4: Centrifugal (or reciprocating) pump
5: Suction pipe with filter
6: Well
All about Motors
Fully automatic pump control

With single-pole pressure switch MCS (control circuit)

F1: Fuses
Q11: Contactor or automatic star-delta starter
F2: Overload relay with reclosing lockout
F7: Pressure switch MCS, 1-pole
M1: Pump motor

1. Air or pressure tank
2. Non-return valve
3. Centrifugal (or reciprocating) pump
4. Pressure pipe
5. Suction pipe with filter
6. Well
All about Motors
Fully automatic pump control

With 3-pole float switch SW (main circuit)

F1: Fuses (if required)
Q1: Motor-protective circuit-breakers, manual (z. B. PKZ)
F7: Float switch 3-pole (circuit: pump full)
M1: Pump motor
HW: Highest level
NW: Lowest value

1. Cable with float, counterweight, pulleys and clamps
2. Storage tank
3. Pressure pipe
4. Centrifugal (or reciprocating) pump
5. Outlet
6. Suction pipe with filter
7. Well
All about Motors
Fully automatic pump control

With 1-pole float switch SW (control circuit)

- F1: Fuses
- Q11: Contactor or automatic star-delta starter
- F2: Overload relay with reclosing lockout
- F8: Float switch 1-pole (circuit: pump full)
- S1: Changeover switch
  MANUAL-OFF-AUTO
- F9: Float switch 1-pole (circuit: pump full)
- M1: Pump motor
  ①: Cable with float, counterweight, pulleys and clamps
  ②: Storage tank
  ③: Pressure pipe
  ④: Centrifugal (or reciprocating) pump
  ⑤: Outlet
  ⑥: Suction pipe with filter
  ⑦: Water-failure monitoring by means of a float switch
  ⑧: Well
All about Motors
Off position interlock of the loads

Solution using NZM circuit-breakers
Off position interlock for control switches (Hamburg circuit) with auxiliary contact VHI (S3) and undervoltage release. Cannot be used with motor operator.
All about Motors
Fully automatic main transfer switch with automatic reset

Off position interlock for control or master switches by means of auxiliary contacts VHI (S3), NHI (S1) and undervoltage release. Cannot be used with motor operator.

1. Emergency-Stop
2. Off position interlock contacts on the control or master switches
All about Motors
Fully automatic main transfer switch with automatic reset

Changeover device to DIN VDE 0108 – Power systems and safety power supply in buildings for public gatherings:

Automatic resetting, the phase-monitor is set to:
- Pick-up voltage \( U_{an} = 0.95 \times U_n \)
- Drop-out voltage \( U_b = 0.85 \times U_n \)

Function

Main switch Q1 is closed first, followed by main switch Q1.1 (auxiliary supply).
Phase monitor K1 is energized via the main supply and immediately energizes contactor relay K2. Normally closed contact K2/21–22 blocks the circuit. Contactor Q12 (auxiliary supply) and normally open contact K2/13-14 closes the circuit of contactor Q11, which energizes and switches the mains supply on the load. Contactor Q12 is also interlocked against mains supply contactor Q11 via normally closed contact Q11/22-21.