







Electrical Installation - Basic vocational knowledge (Institut für Berufliche Entwicklung, 201 p.)

- ➔  **7. Mounting and connection of motors**
 -  **7.1. Placement of electric motors**
 -  **7.2. Connection of three-phase motors**
 -  **7.3. Installation of motor protection switches**
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Electrical Installation - Basic vocational knowledge (Institut für Berufliche Entwicklung, 201 p.)

7. Mounting and connection of motors

7.1. Placement of electric motors

Prior to mounting an electric motor, by means of the rating plate it will have to be checked, whether the motor is suited for the connection and whether it is not damaged.

In particular it will have to be confirmed, whether the values indicated on the rating plate are in accordance with the necessary values.

Rating plates are predominantly placed on the stator's enclosure. Only in exceptional cases the rating plate will be on the motor's end shield or terminal box resp.

Electric motors are to function for a long time. Therefore it will be important to observe the following principles during erection already:

- Electric motors are to be mounted shock-proof.**
- Ventilation openings serving for cooling the motor must be left uncovered.**
- No axial pressures must effect the motor's shaft.**
- The machine to be driven must be balanced.**

When aligning machine sets equipped with couplings the two shaft ends must be positioned axially against each other, i.e. there must not be any deviations in horizontal or vertical direction.

Deviations in direction during mounting of motors must never be compensated by the couplings!

For aligning the motor and the machine, a gauge according to fig. 7.1. has proved to be useful. A water level will not be suited for aligning the coupling.

After both machines have been roughly aligned without special facilities, the gauge according to fig. 7.1. will be put on both shaft ends. The distance between the centres of the gauge is to be small at that. If both shaft ends are turned synchronously to each other the position of the centres relative to each other must

not change during a full revolution.

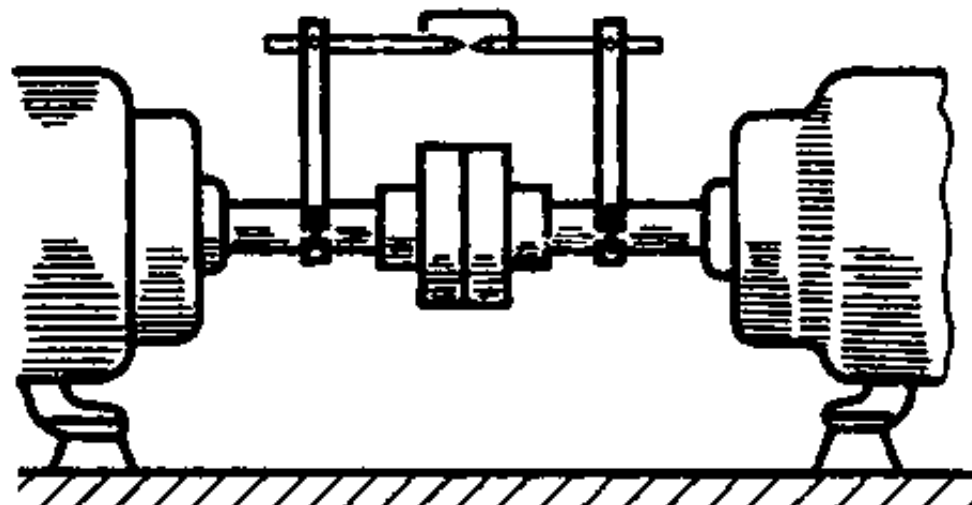


Fig. 7.1. Aligning directly coupled machines by a gauge

The axial play of machines with slide bearings may cause the distance of the gauge's two centres from each other to change permanently. This will be prevented by putting a steel centre into the centre of the shaft of the non-driven shaft end and fixing it to the end shield via a tie.

At flexible couplings the distance required between the two halves, which must be equal in any position of the shaft, is measured by means of spacing gauge.

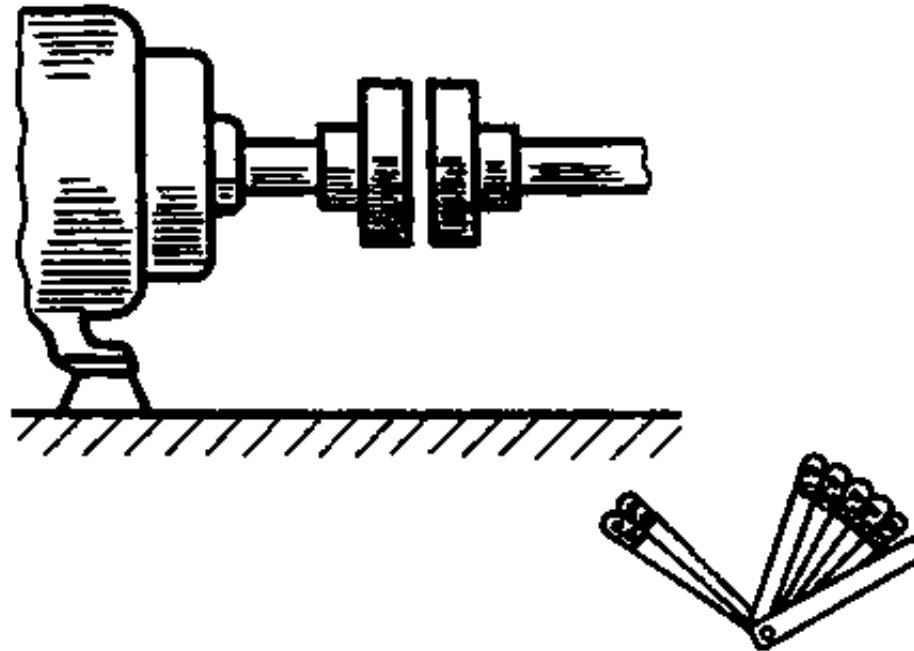


Fig. 7.2. Applying a spacing gauge

In case of rigid couplings the coupling halves must be positioned tightly adjacent to each other.

Only after both machines have been aligned they will be fixed, and the coupling will be bolted.

Prior to aligning motors equipped with transmission devices like couplings, pinions or belt pulleys, the transmission device, e.g. belt pulley, will be mounted onto the shaft end.

For mounting transmission devices, mounting tools are to be employed resp. the part to be mounted is to be heated. For mounting, the shaft ends of the motors have got centrings with threaded bores.

Driving on transmission devices by hammer blows is not permitted, since the shaft, the bearings and other parts of the motor may be damaged!

For pulling off transmission devices a puller is being employed.

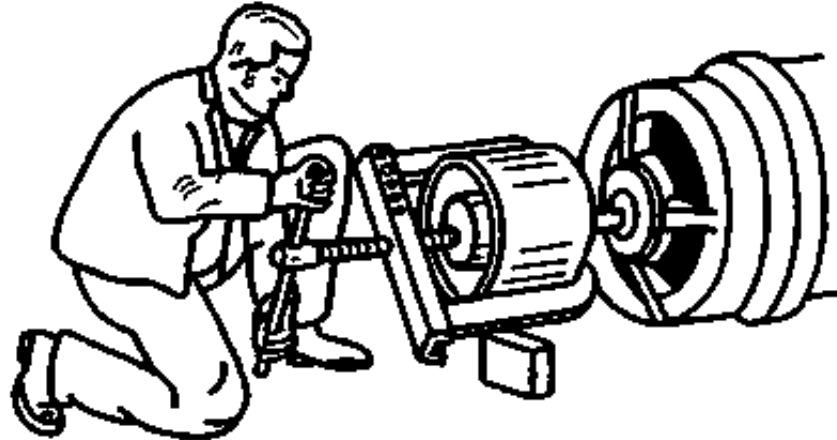


Fig. 7.3. Pulling off a belt pulley

After the transmission device has been mounted onto the shaft, the motor is to be bolted to the holding bars resting in loose condition on their foundation. By water level the motor will now be aligned in longitudinal and transverse direction.

Differences in height are being compensated by placing iron wedges underneath. Wooden wedges are not to be employed since they are easily pressed together resp. are swelling up when the foundation is poured!

Thereafter the motor belt pulley is being aligned with the belt pulley to be driven.

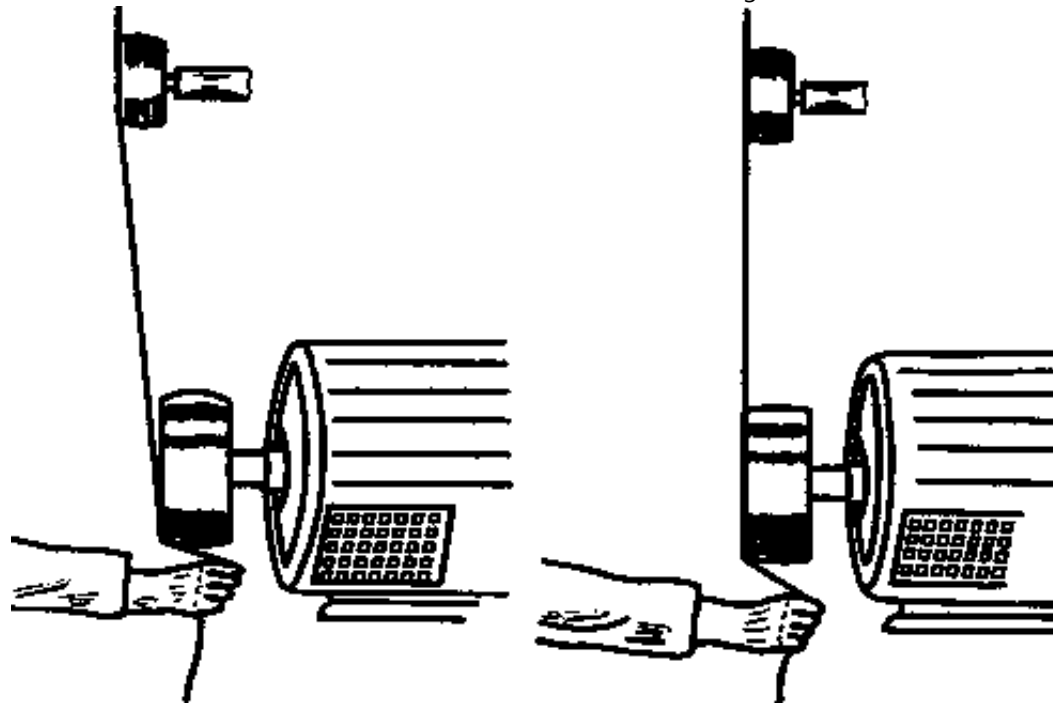


Fig. 7.4. Aligning a belt pulley

The front faces of the belt pulley and the counter pulley must be exactly parallel!

After alignment of the belt pulley the position of the motor will be rechecked in both directions. Only after the motor has been exactly positioned, the foundation may be poured.

7.2. Connection of three-phase motors

Most of the practically used motors are three-phase squirrel-cage motors.

The wiring of the motors takes place under consideration of the designed connections, like

- **star connection,**
- **delta connection,**
- **star-delta connection to the terminals of the motor terminal board.**

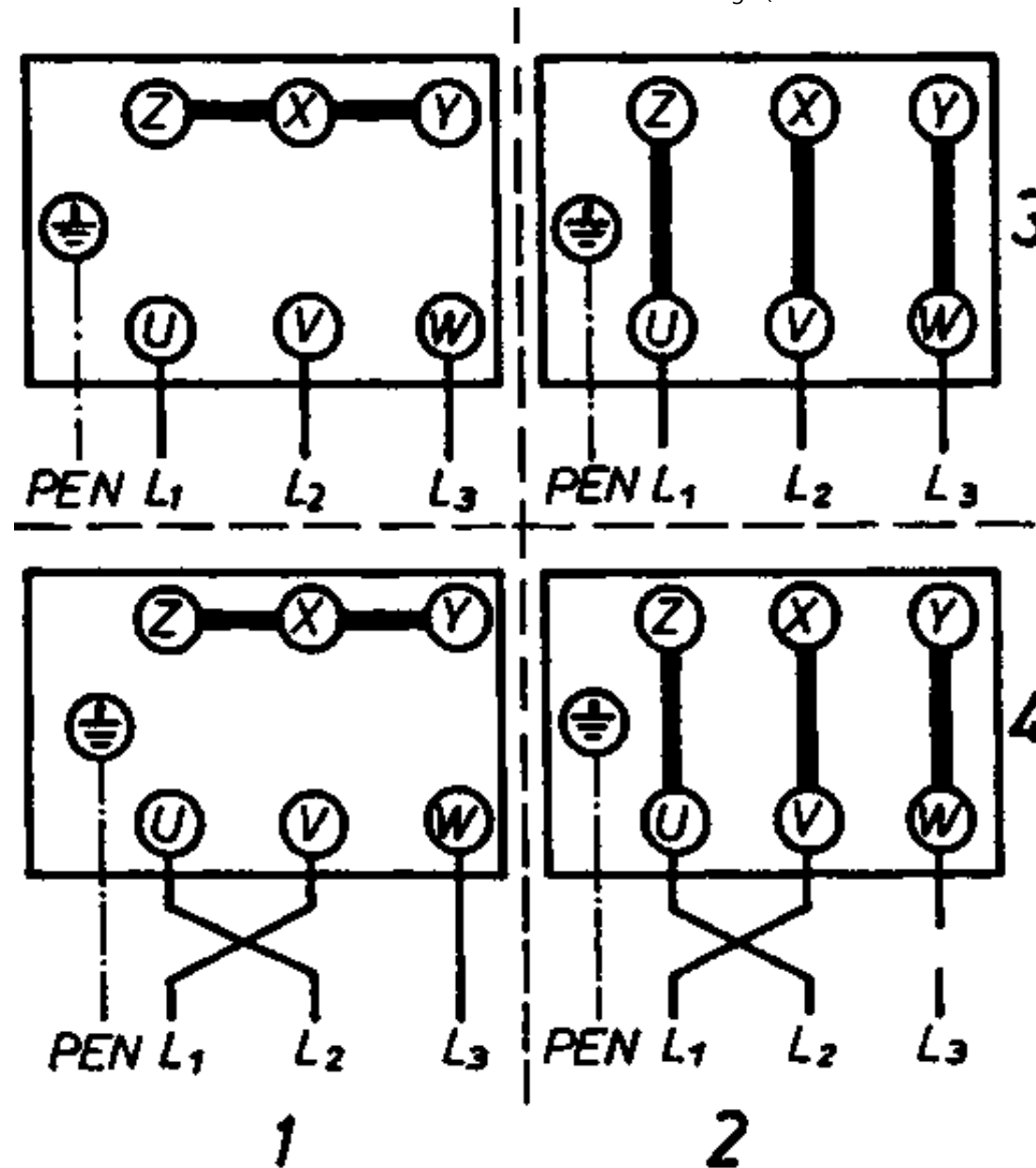


Fig. 7.5. Position of bridges in a three-phase squirrel-cage motor

1 star connection, 2 delta connection, 3 clockwise rotation, 4 anti-

clockwise rotation

In case of star connection the bridges are placed via the winding ends **z, x, y** at the terminal board.

In case of delta connection the bridges are placed via the beginnings and ends of the windings **u-z, v-x, w-y** at the terminal board.

A reversion of rotation will be achieved by changing of two phase conductors!

If motors are connected via flexible connecting lines the conductors will have to be prepared for connection accordingly. The conductor ends are provided with tinned lugs or cable terminals will be applied in case of larger conductor cross sections.

How to make terminal lugs at flexible conductors may be seen from fig. 7.6.

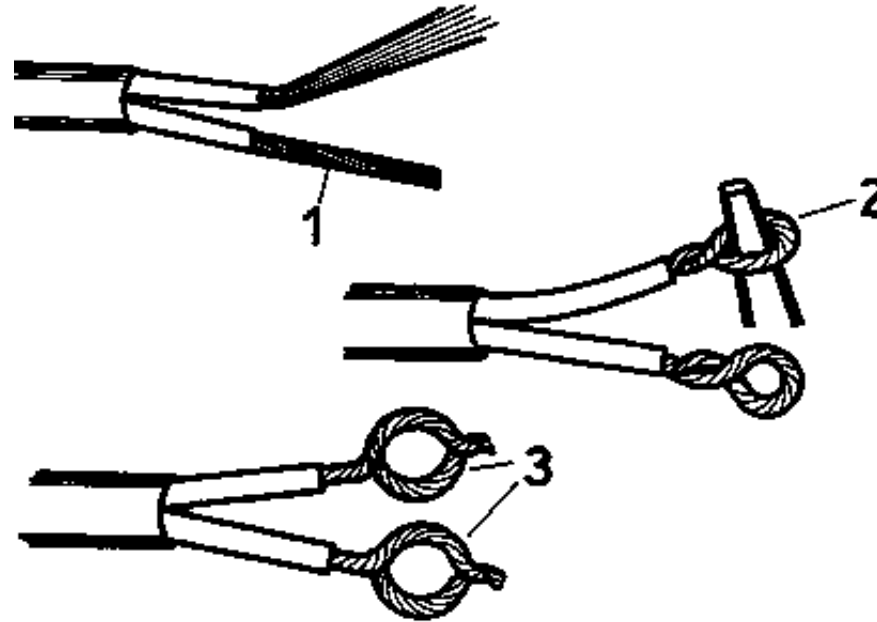


Fig. 7.6. Fitting terminal lugs to flexible conductors

1 twisting of the cleaned and prepared conductor end, 2 making the lug by means of an arbor, 3 making the lug by separating the conductor

If terminal lugs are being bent at solid conductors the following quality requirements will have to be observed:

- The conductor must not be damaged during treatment by round nose pliers.**
- The terminal lug must be closed.**
- The terminal lug must be placed on the connecting stud so that the end of the lug is positioned in tightening direction.**

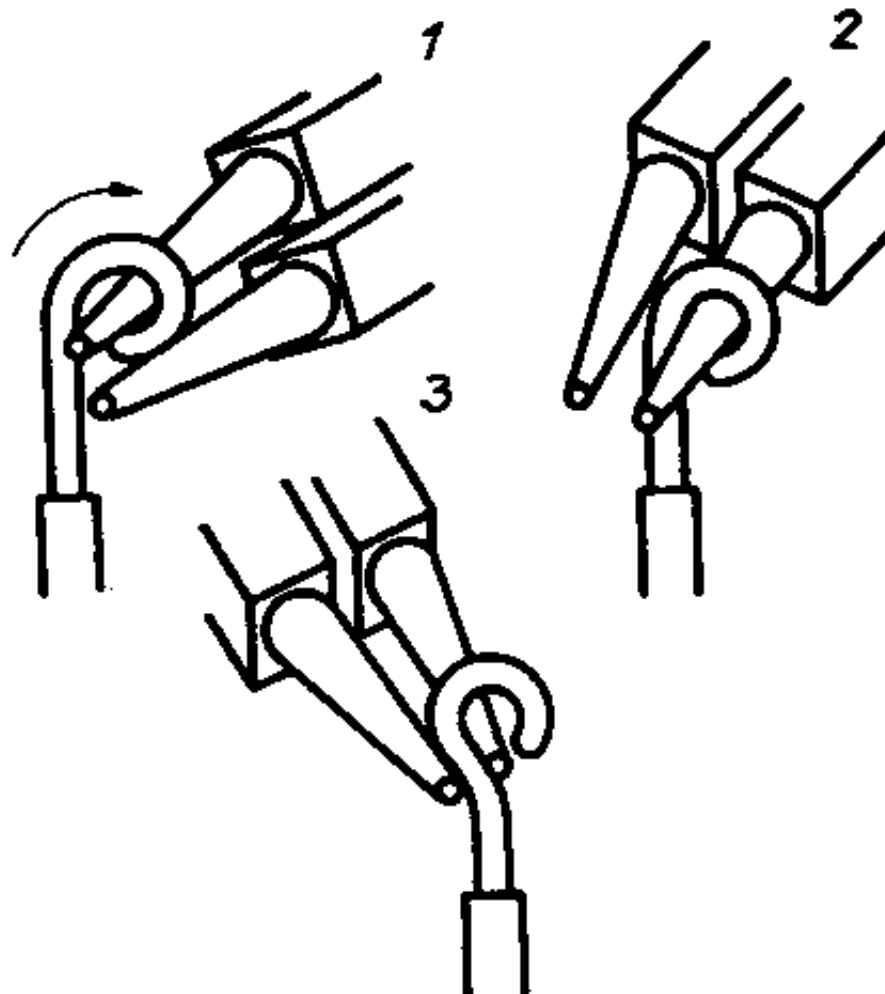


Fig. 7.7. Bending of terminal lugs

1 pre-bending the lug, 2 repositioning of round nose pliers, 3 completing the lug

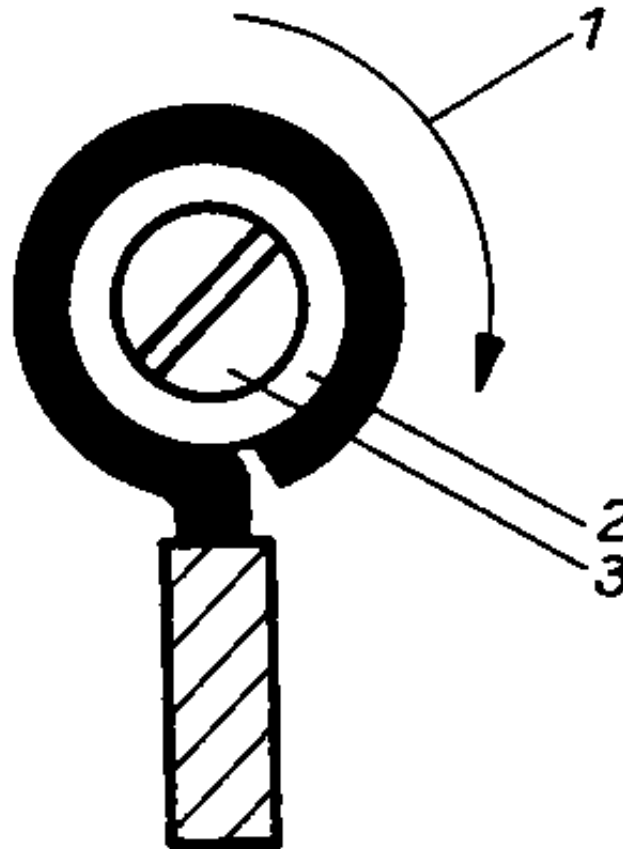


Fig. 7.8. Terminal lug

1 rotational direction, 2 washer, 3 screw

Terminal lugs will be bent on conductors up to a cross section of 16 mm^2 . In case of bigger cross sections cable terminals will be fitted!

The functioning of the protective measure employed will be dependent on proper connection of the protective conductor to the marked connection point of the protective conductor.

Table 7.1. Diameter of terminal lugs for metric threading

Size of thread	M4	M5	M6	M8	M10	M12
Diameter of terminal lug mm	4,2	5,2	6,3	8,3	10,5	12,5

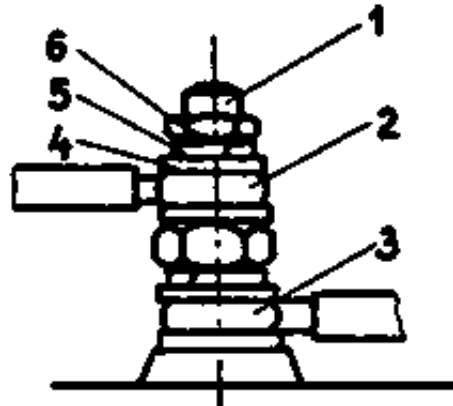


Fig. 7.9. Arrangement of terminal accessories at the stud of the motor

1 stud, 2 terminal lug, 3 end of winding, 4 washer, 5 spring washer, 6 nut

The firm fit of the cable clamping arrangement (pull relief) in front of the motor terminal box is important too. It will prevent the connecting cable from being torn of the connection stud in case of tensile stress.

Motors which vibrate during operation or the position of which will be frequently changed are to be connected via flexible cable.

This flexible cable is to be kept as short as possible. Therefore the fixed connection line will be terminated in a motor transition box, and a flexible cable will then be run from there to the motor.

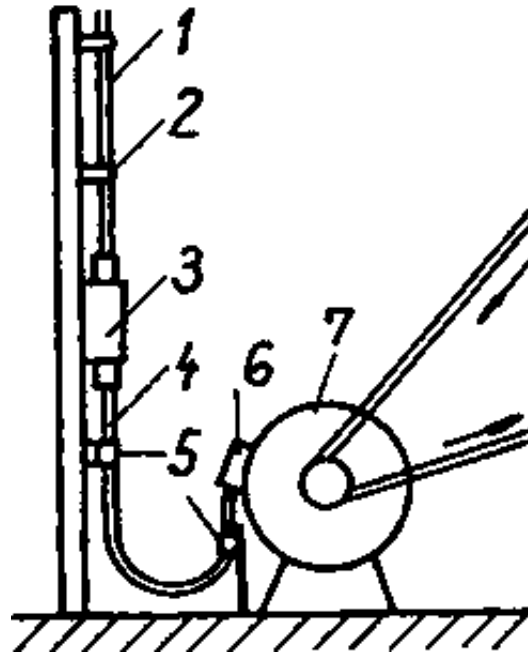


Fig. 7.10. Connecting a motor via a motor transition box

1 motor supply line, 2 damp room spacing clips, 3 motor transition box, 4 flexible connection cable, 5 pull relief clamps, 6 terminal box of motor, 7 motor

7.3. Installation of motor protection switches

Three-phase motors with a power of up to approx. 2.2 kW are generally starting directly.

However, protective arrangements are needed protecting the motor against overload and short-circuits.

This is accomplished by motor protection switches installed in the supply line to

the motor. These have got thermal overcurrent releases against overload and a tripping magnet for possibly occurring short-circuits. Series fuses provide protection against short-circuits on motors being not equipped with magnetic instantaneous tripping. So called "sluggish" fuses serve that purpose being able to conduct the expected motor starting current without responding.

Motor protection switches are jack switches and are manufactured in three-pole version. They have got trip-free release, i.e. after release they cannot be kept in turn-on position by retaining the switch knob or button. This is achieved by mechanical uncoupling in the motor protection switch.

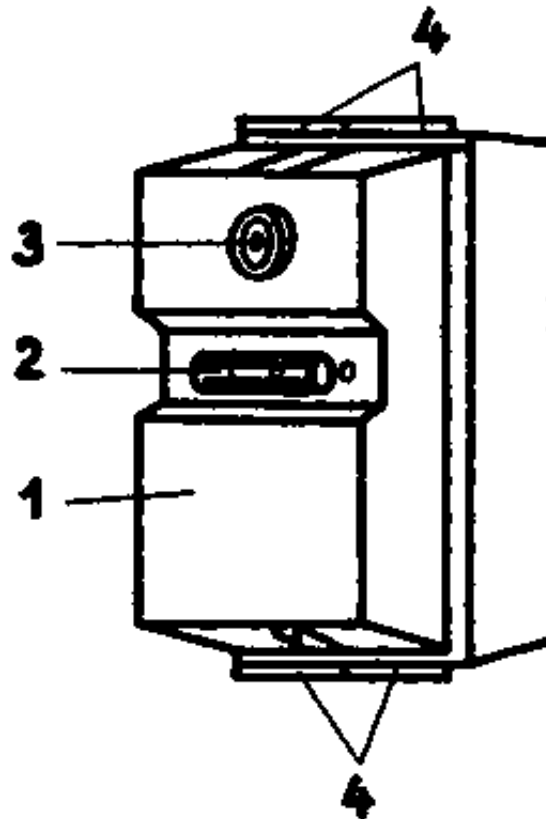


Fig. 7.11. View of a motor protection switch

1 casing, 2 switching device, 3 signal lamp, 4 cable entries

On the switch insert there are the dials for setting the overcurrent and short-circuit releases.

The overcurrent release will be adjusted to the rated motor current.

The tripping magnet for short-circuit protection will be set according to the data of the project plans.

The rated motor current may be read on the motor's rating plate!

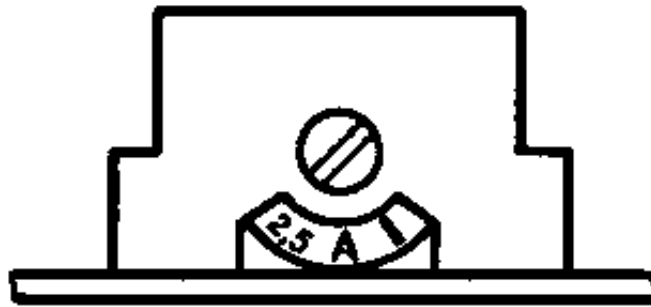


Fig. 7.12. Setting the thermal overcurrent release at the motor protection switch

The motor protection switch is exactly to be matched to the motor current!

Table 7.2. Coordination of current fuses with setting ranges of overcurrent releases

Setting range of overcurrent release

series fuse instantaneous

time-

Setting range of overcurrent release (A)	Series fuse instantaneous (A)	Time delayed
0,16 - 0,25	-	-
0,25 - 0,4	2	-
0,4 - 0,6	2	-
0,6 - 1,0	4	-
1,0 - 1,6	6	4
1,6 - 2,5	10	6
2,5 - 4	16	10
4 - 6	20	16
6 - 8	-	16
8 - 10	-	16

7.4. Star-delta start of three-phase motors

When switching on a motor a current will flow through the stator's winding being many times stronger than the rated motor current. This current is called starting current. It will highly stress the electrical network. On increasing rotational speed the starting current will decrease until the rated current is reached at the rated rotational speed.

By star-delta starting a reduction of the starting current will be achieved. This starting connection is the most frequently applied starting method for asynchronous squirrel-cage motors of greater power.

The star-delta starting operation is practically executed via

- automatic star-delta switches,
- star-delta contactor combinations.

The stardelta hand switch (cam switch) is hardly to be met any more in actual operation. Functioning of the star-delta starting necessitates that the motor is suitable for this method of starting, i.e. with a three-phase four-wire system of 380/220 V every winding of the motor must be designed for 380 V.

Table 7.3. Connection of three-phase squirrel cage motors to mains

Voltage stated on rating plate	voltage of feeding mains	motor connection
380/220 V	3 x 220 V	delta connection
	380/220 V	star connection
380 V		delta connection
(660/380 V)	380/220 V	star-delta starting
660 V	660 V	delta connection
		star-delta starting

A star-delta contactor combination consists of the following electrotechnical units:

- 3 contactors (network, star and delta contactors),
- 1 time relay (pull-in delayed),
- 1 three-pole thermal overcurrent release,
- 3 fuse elements or automatic cut-outs for the main circuit,

- 1 fuse element or automatic cut-out for the control circuit,
- 4 signal lamps, e.g. 24 V
- 1 motor 380 V

The mode of function of a star-delta starting circuit is shown as an all-pole representation (circuit diagram) in fig. 7.13. and 7.14. as well as a general wiring diagram in fig. 7.15.

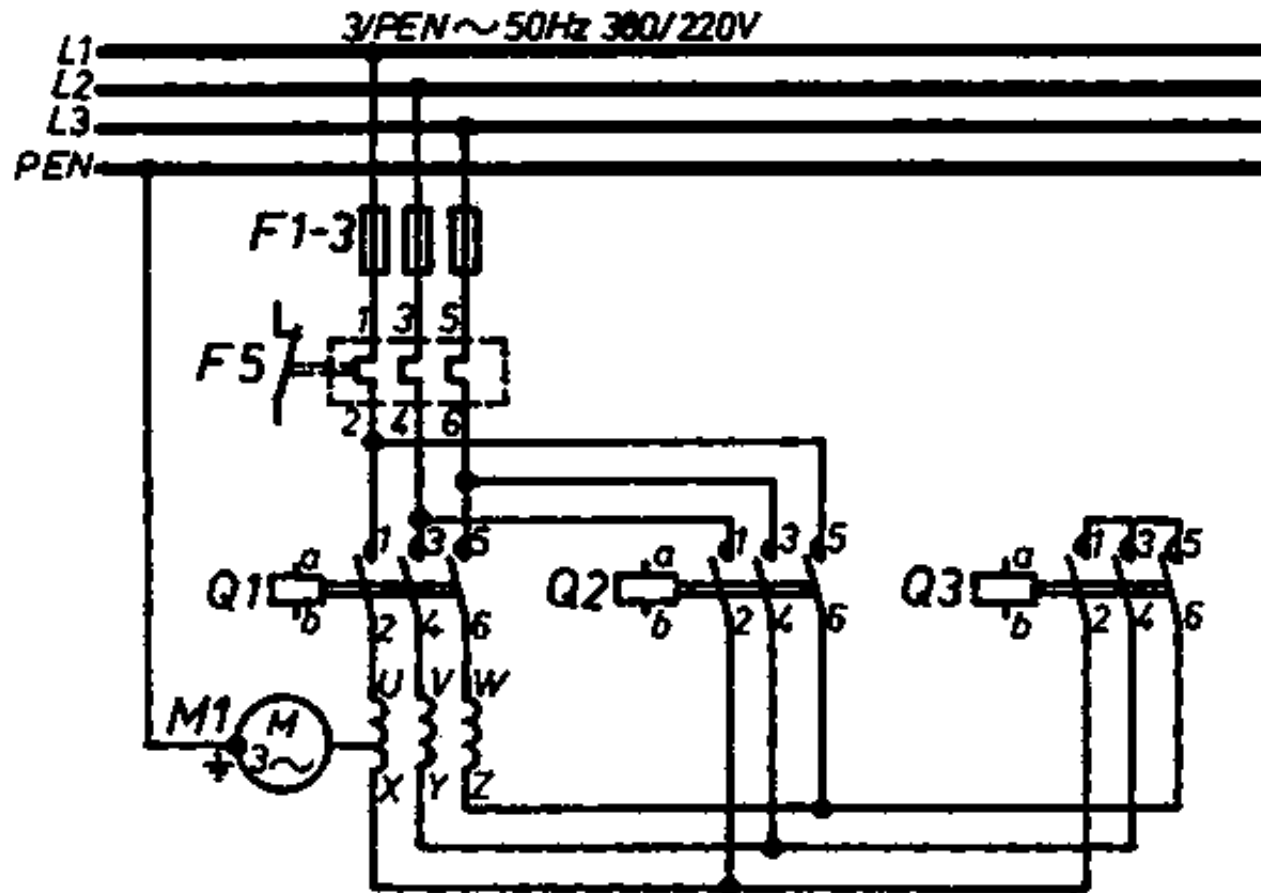


Fig. 7.13. Star-delta connection, all-pole representation of power part (circuit diagram)

F1...F3 fuses, F5 thermal overcurrent release, Q1 network contactor, Q2 delta contactor, Q3 star contactor, M1 three-phase motor

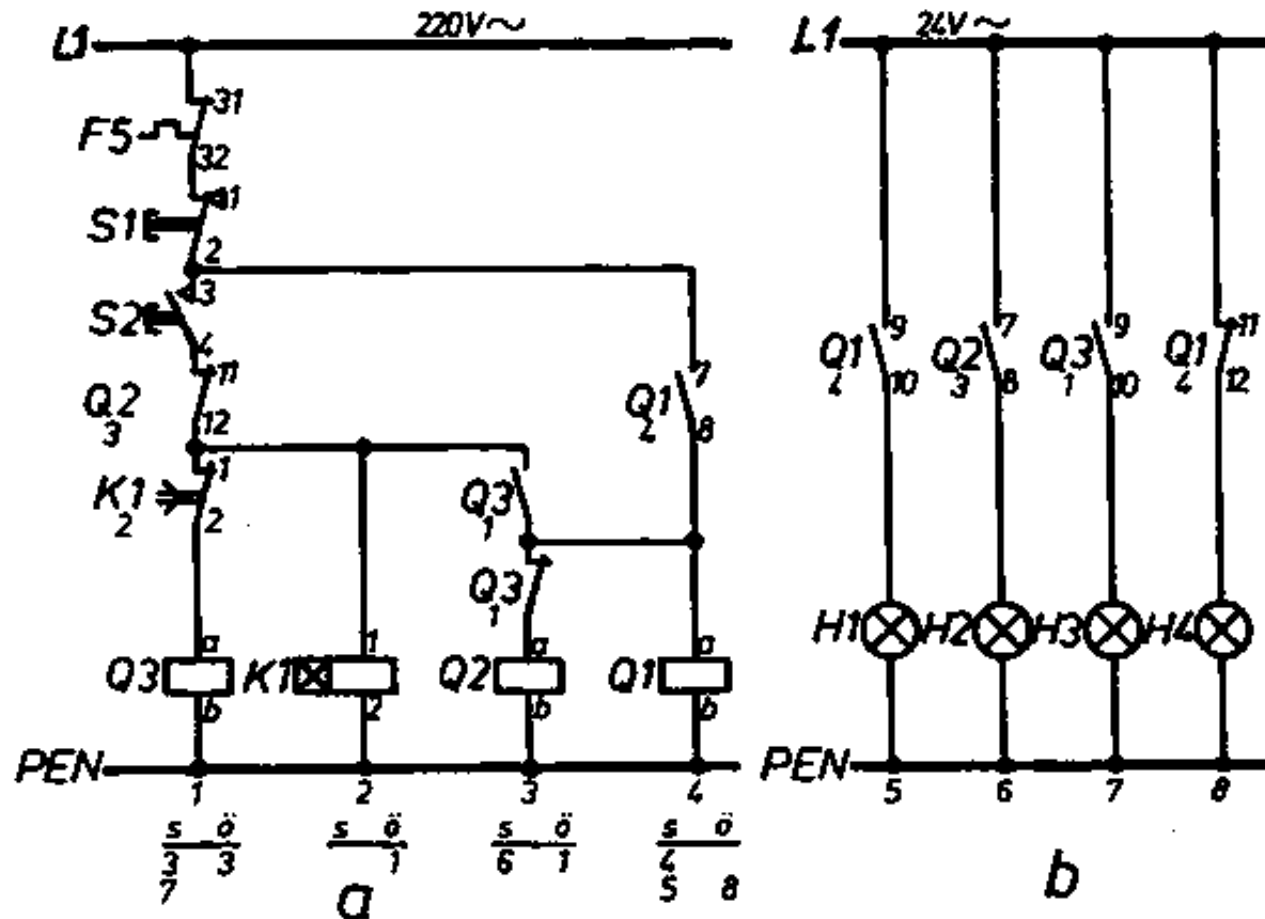


Fig. 7.14. Circuit diagram of an automatic star-delta contactor circuit with indication

a control, b indication (e.g. 24 V~)

S1 OFF key, S2 ON Key, Q1 network contactor in current path 4, Q41

normally open contact of Q1; Q2 delta contactor in current path 3, Q32 normally open and closed contacts of Q2, Q3 star contactor in current path 1, Q13 normally open and closed contacts of Q3, K1 pull-in-delayed time relay in current path 2, K21 normally closed contact of K1, F5 thermal overcurrent protection, H1 ... H4 signal lamps, 1 ... 8 numbering of current paths, $\overline{\text{---}}$ normally closed contacts, --- normally open contacts (to be shown for each contactor in the current paths concerned)

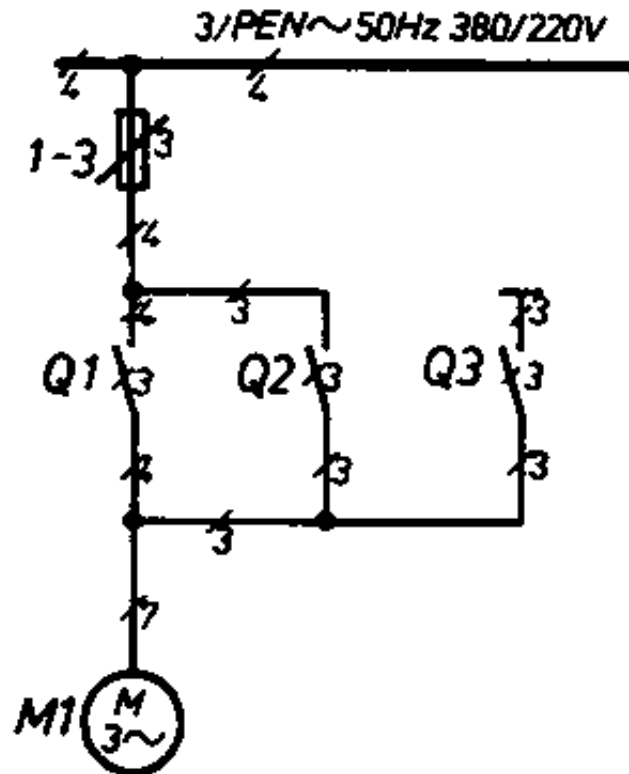


Fig. 7.15. Star-delta connection (general wiring diagram of power part)

Switching sequence for fig. 7.14.

Key S2 is actuated!

Time stage 1

The circuit for Q3 is closed via F5, S1, S2, Q₃₂, K₂₁ and star contactor Q3 in current path 1 responds, closes the normally open contact Q₁₃ and opens the normally closed contact Q₁₃.

Thereby the circuit to the delta contactor Q2 in current path 3 is interrupted.

Simultaneously the time relay K1 in current path 2 starts operating. Further by the normally open contact Q₁₃ in current path 3 the network contactor Q1 in current path 4 is pulled up. In current path 4 the normally open contact Q₄₁ is closed and via F5, S1 of the line connection and the normally open contact Q₄₁ the network contactor Q1 in current path 4 and the star contactor Q3 in current path 1 are pulled up, and the motor starts in star connection. By switching on star contactor Q3 in current path 1 and the network contactor Q1 in current path 4 the normally open contact Q₄₁ in current path 5 and the normally open contact Q₁₃ in current path 7 will be closed.

Signal lamp H1 will indicate the network contactor and signal lamp H3 the star contactor to be switched on.

At the same time signal lamp H4 will go out which indicates the star-delta circuit not to be operating.

Time stage 2

When the time set at time relay K1 in current path 2 has elapsed, in current path 1 the normally closed contact K₂₁ will open and the circuit to the star contactor Q3 will be interrupted. The normally closed contact Q₁₃ in current path 3 will be re-closed and current is flowing via holding contact Q₄₁ of the network contactor in current path 4 and the conductor connection to current path 3 as well as normally closed contact Q₁₃, so that the delta contactor Q2 in current path 3 pulls up. The motor runs in delta connection. Simultaneously the normally closed contact Q₃₂ in current path 1 will be opened and star contactor Q3 in current path 1 cannot be switched on via S2.

At the same time of opening of contacts Q₃₂ and K₂₁ in current path 1 and drop out of star contactor Q3 the normally open contact Q₁₃ will be reopened and signal lamp H3 will go out. By switching on delta contactor Q2 in current path 3, however, the normally open contact Q₃₂ in current path 6 will be closed and signal lamp H2 (for the delta connection) will light. The wiring to the star-delta connection is made according to available drawings resp. the instructions of the maker. In case of star-delta starting of the motor the bridges on the motor terminal board will have to be removed. The motor supply line from network contactor Q1 is to be connected to the beginnings of windings U, V, W. The lines for the star-delta change-over from contactors Q2 and Q3 are to be connected to the ends of winding X, Y, Z. The protective conductor is to be clamped to the point provided and marked for this purpose. The coordination of the motor's accessories is to be taken from table 7.4. After the motor is wired, it will have to be checked

whether it runs in correct rotational direction. If the motor runs opposite to the desired direction of rotation, two phase-conductors will have to be exchanged in the motor supply line. In case the direction of the rotating field cannot be ascertained by test run of the motor, this can be found out also by connecting a phase-sequence indicator to the motor supply line. For switching capacities of more than 10 kW application of an auxiliary contactor for extinguishing the arc of the star contactor will be appropriate. Further examples of switching arrangements of motors are to be taken from the textbook "Circuits, Formulas and Tables of Electrical Engineering", section 4.

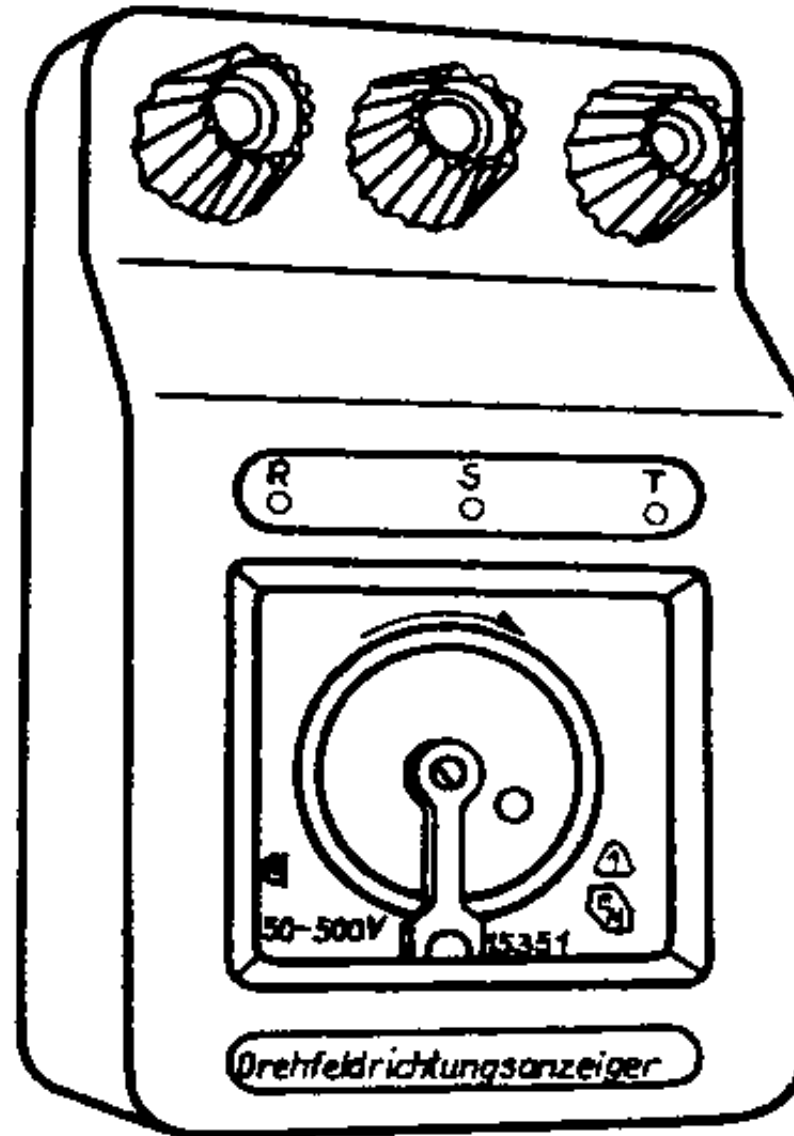


Fig. 7.16. Phase-sequence indicator

Table 7.4. Choice of accessories for three-phase motors with 380 V rated voltage

Motor	I_n	fuse	contactor	temperature	motor	flexible
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P_n	"	"	"	relay/type setting range	protection switch	connection to motor
(kW)	(A)	(A)	(A)	(A)	(A)	(A)
0,16	0,42 - 0,68	2	16	0,4 ... 0,68	0,4 - 0,6	4 x 1,5
0,25	0,7 - 1,0	4	16	0,65 ... 1,1	0,6 - 1,0	4 x 1,5
0,4	1,0 - 1,6	4	16	1,0 ... 1,7	1,0 - 1,6	4 x 1,5
0,6	1,5 - 2,0	6	16	1,0 ... 1,7	1,6 - 2,5	4 x 1,5
				1,6 ... 2,8		
0,8	1,9 - 2,4	6	16	1,6 ... 2,8	1,6 - 2,5	4 x 1,5
1,1	2,4 - 3,0	6	16	1,6 ... 2,8	1,6 - 2,5	4 x 1,5
				2,6 ... 4,5	2,5 - 4	
1,5	3,4 - 4,2	10	16	2,6 ... 4,5	2,5 - 4	4 x 1,5
					4 - 6	
2,2	4,7 - 5,6	10	16	4,3 ... 7,5	4 - 6	4 x 1,5
3,0	6,5 -	16	16	4,3 ... 7,5	6 - 8	4 x 1,5

	7,5					
4,0	8,4 - 9,6	20	16	7,2 ... 12,5	8 - 10	4 x 1,5
5,5	11,2 - 12,6	25	16	7,2 ... 12,5	10 - 16	4 x 1,5
7,5	15 - 17	35	25	10-16/16-25	10 - 16	4 x 1,5
					16 - 25	
10	19,8 - 21,4	50	25	16 ... 25	16 - 25	4 x 2,5
13	25,6 - 27	50	40	25 ... 40	-	4 x 4
17	33 - 35	63	40	25 ... 40	-	4 x 6
22	43 - 45	80	63	40 ... 60	-	4 x 6
30	58 - 61	100	63	40 ... 64	-	4 x 10
40	78 - 82	125	100	64 ... 100	-	4 x 16
55	116 - 114	160	200	100 ... 140	-	4 x 25
75	145 - 155	200	200	140 ... 200	-	4 x 50

100	193 - 207	260	250	160 ... 280	-	4 x 70
125	240 - 255	300	250	160 ... 280	-	4 x 95
160	304 - 328	350	400	280 ... 400	-	4 x 150
200	370 - 400	430	400	250 ... 420	-	4 x 185
250	460 - 500	500	630	420 ... 600	-	-
320	590 - 610	600	630	-	-	-

7.5. Summary

Prior to mounting electric motors it has to be checked, whether the motor will be suited for the connection in question and that the motor is not damaged.

The motor and the machine to be driven are to be exactly aligned. This holds also for transmission devices. Motors for connection to three-phase current up to a power of 2.2 kW are directly started. For starting the motor a multi-section rotary switch is employed to which a motor protection switch is series connected. The overcurrent release of the motor protection switch is to be set to the rated current of the motor.

Three-phase asynchronous motors with squirrel-cage of bigger power are

switched on via a starting circuit. The mostly used starting arrangement is the star-delta connection.

In case of star connection of three-phase motors, bridges are being laid over the ends of the winding.

In case of delta connection bridges are connecting the opposite beginnings and ends of the winding.

If star-delta starting is to be employed, the bridges will have to be removed.

