Effect of the Cable Capacitance of Long Control Cables on the Actuation of Contactors

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Technical Paper

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The problem of cable capacitance with long control cables also often occurs in large-scale installations such as with crane systems in container terminals.

0. Introduction:

The contactor is the most important switching device in industrial and commercial applications. Its importance has further increased due to the influence of automation. This has given rise to some significant advancements in the development of contactors, of which the user is often not aware. For example, the power required for switching has been considerably reduced in recent years due to the use of integrated actuation electronics.

Despite the many benefits made possible by the reduced power consumption, such as

- Energy savings

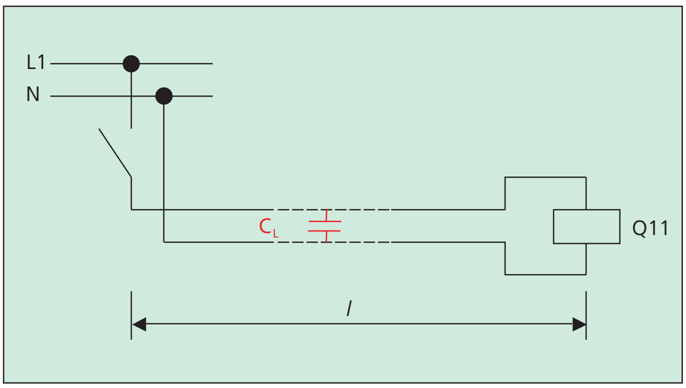
- Use of smaller control transformers

- Longer service life of control contacts

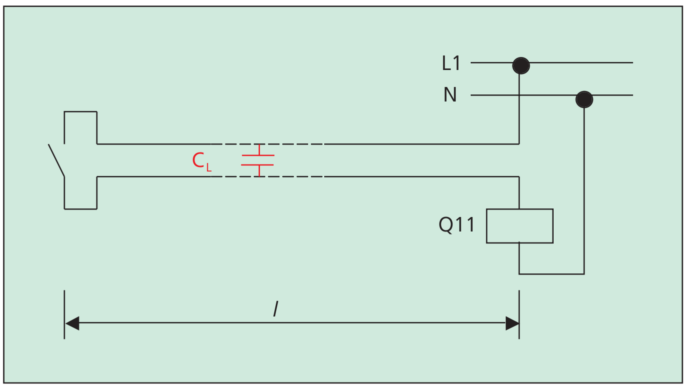
the reduced power requirements must be particularly taken into account with applications involving long control cables. Reliable contactor disconnection on actuation of the command device also depends on cable length, due to the cable capacitance between the command device and the contactor coil.

1. Cable capacitances

In certain circumstances, long control cables in AC actuated control circuits may prevent the disconnection of contactors due to the cable capacitance present.
Even if the command contacts are open, the coil current can still flow due to the cable capacitance so that the contactor remains in the On position if sufficient sealing current is present.
The effect of cable capacitance depends on the design of the control current circuit:



No effect of cable capacitance C_L if the command contact is located close to the power supply. There may be a slight off-delay due to C_L.



Effect of cable capacitance C_L if the command contact is located away from the power supply. The coil current continues to flow even when the command contact is opened.

1.1 Capacitance of control cables

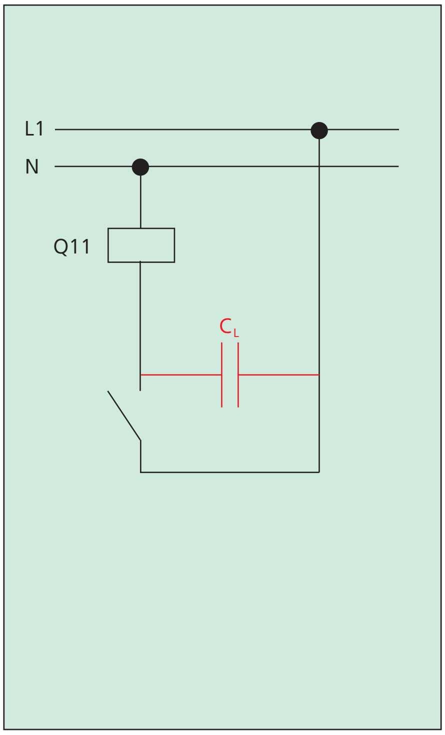
A guide value for control cable capacitances between two conductors is approx. 0.3µF per km for two-wire control, and approx. 0.6µF per km between three conductors for three-wire control. The following equation should be used:

C_L = 0.3 (µF/km) x l (km)
Two-wire control (1.3)

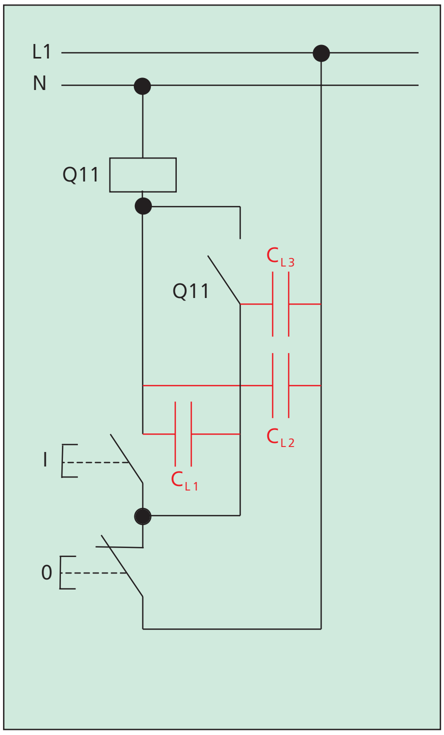
C_L = 0.6 (µF/km) x l (km)
Three-wire control (1.4)

On disconnection, C_{L2} and C_{L3} are switched in parallel (C_{L1} is bridged by Q11).

However, the specific values depend on the cable used and may therefore vary. If necessary, obtain the cable capacitance from the manufacturer. When laying control cables together with other lines (e.g. in the cable duct), the cable capacitance can no longer be calculated. The capacitive currents must be measured.



Two-wire control:
C_L = 0.3 (µF/km) x l (km) (1.3)



Three-wire control:
C_L = 0.6 (µF/km) x l (km) (1.4)

2. Limit capacitance of a contactor

The maximum capacitance at which the contactor stays switched on in the new condition despite the off command can be calculated using the equation below:

$$C_{max} = \frac{b}{1+a} \cdot \frac{P_H \cdot 10^6}{\omega \cdot U_C^2} \; [\mu F] \quad (2.0)$$

with

$$a = \frac{U_{AB}}{U_C} = 0.4$$

$$b = \frac{I_{AB}}{I_C} = 0.25...0.35$$

U_{AB} = minimum drop-off voltage in V
I_{AB} = Sealing current with a minimum drop-off voltage in A
P_H = Rated sealing current of the contactor in VA
U_C = Rated control supply voltage in V

At 50 Hz and a permissible rated control supply voltage 110% times rated voltage based on equation 2.0:

$$C_{max} = 500 \cdot \frac{P_H}{U_C^2} \; [\mu F]$$

At 60 Hz the values must be reduced by 20%.

3. Determining the maximum permissible control cable lengths

In order for a contactor to switch correctly, C_L must be less than C_{max}.

If equations (1.3) and (1.4) are related to equation (2.1), the following values are produced for 50 Hz networks:

$$l_{perm} = 1.7 \cdot 10^6 \cdot \frac{P_H}{U_C^2} \quad [m]$$

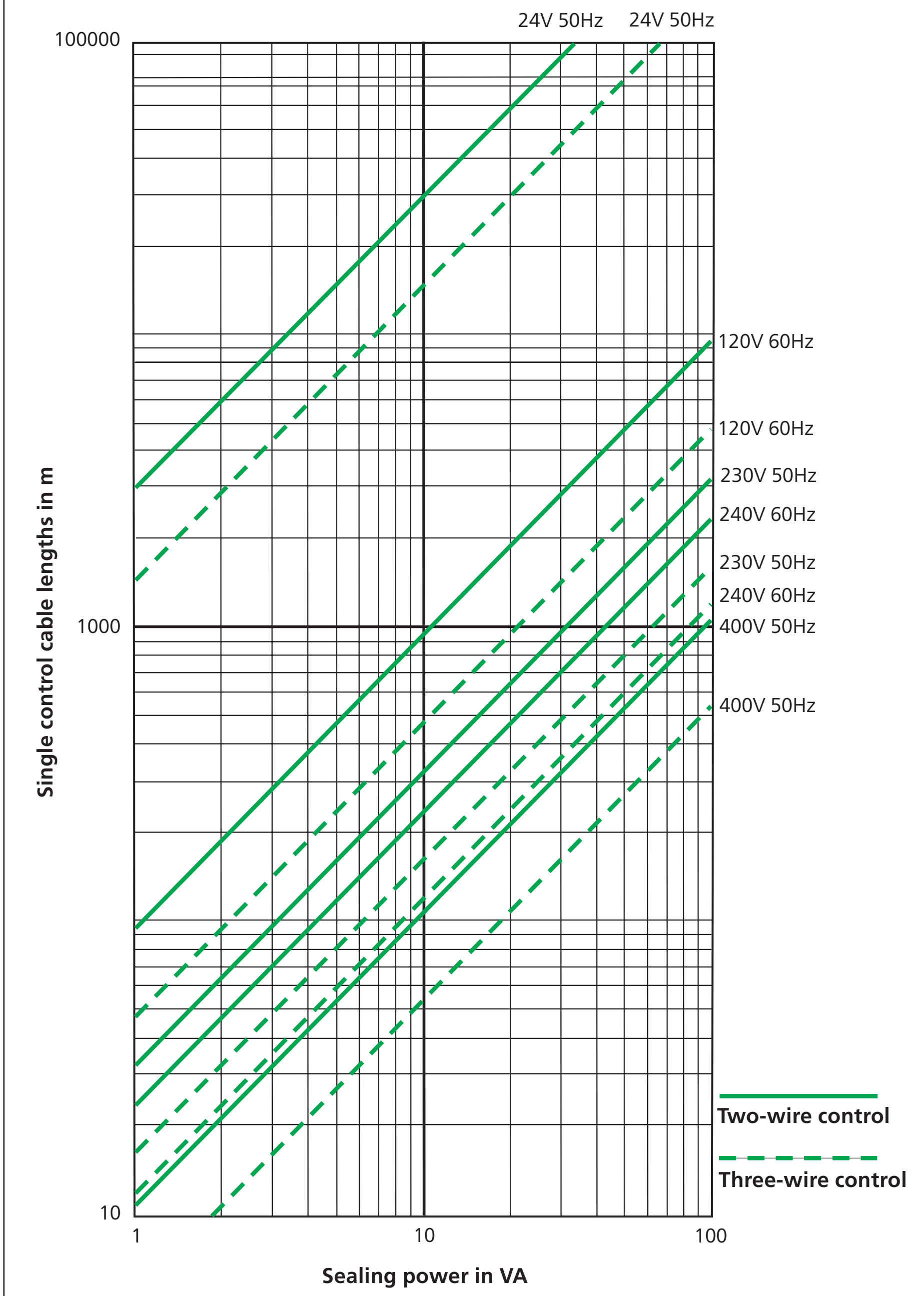
Two-wire control (3.0)

$$l_{perm} = 0.85 \cdot 10^6 \cdot \frac{P_H}{U_C^2} \quad [m]$$

Three-wire control (3.1)

l_{perm} = maximum permissible control cable length in m.

With 60Hz networks the values for (3.0) and (3.1) must be reduced by 20%.



Permissible single control cable length with a rated actuation voltage of 110% UC in relation to the contactor sealing power

Contactor	Sealing power VA	Maximum permissible cable length in m for Two-wire control 50Hz	Three-wire control 50Hz	Two-wire control 60Hz	Three-wire control 60Hz
Uc = 230 V					
DILE(E)...; S(E)00	4.6	148	74	118	59
DILM7...DILM15; DILA	4	129	64	103	51
DILM17...DILM32	8	257	129	206	103
DILM40...DIL65	16	514	257	411	206
DILM80; DILM95	26	836	418	668	334
DILM115; DIL150	3.5	112	56	90	45
DILM185...DILM250	4.3	138	69	111	55
DILM300...DILM500	4.3	138	69	111	55
DILM580...DILM1000	7.5	241	121	193	96
DILH1400	7.5	241	121	193	96
DILH2000	15	482	241	386	193
Uc = 120 V					
DILE(E)...; S(E)00	4.6	543	272	434	217
DILM7...DILM15; DILA	4	472	236	378	189
DILM17...DILM32	8	944	472	756	378
DILM40...DIL65	16	1889	944	1511	756
DILM80; DILM95	26	3069	1535	2456	1228
DILM115; DIL150	3.5	413	207	331	165
DILM185...DILM250	4.3	508	254	406	203
DILM300...DILM500	4.3	508	254	406	203
DILM580...DILM1000	7.5	885	443	708	354
DILH1400	7.5	885	443	708	354
DILH2000	15	1771	885	1417	708

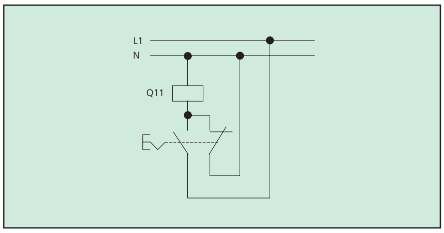
Maximum permissible single control cable length for a rated control supply voltage of 230V and 120V and a maximum control supply voltage of 1.1 x U_C for 50 Hz and 60 Hz mains frequency.

4. Measures to counteract excessive cable capacitance

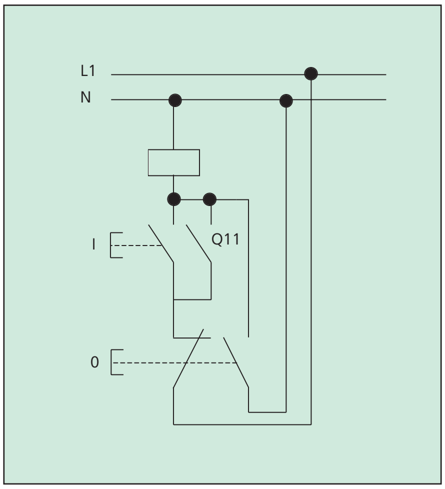
Several solutions are possible if the engineering of an installation determines that the contactors will not drop out due to excessive cable capacitance:

- Use of contactors with higher coil sealing power
- Use of DC operated contactors
- Reduction of the control supply voltage (allow for voltage drop)
- Laying the supply cable near the command contacts
- An additional NC contact for two-wire control and NO contact for three-wire control are used to short the coil.

An additional cable is required for this. This considerably increases the break times of the contactors



Three-wire control



Two-wire control

- Parallel switching of a resistance. The resistance is calculated as follows:

$$R = \frac{1000}{C_L} \; [\Omega] \quad C_L \text{ in } \mu F \qquad (4.1)$$

The power of the resistance is:

$$P = \frac{U_C^2}{R} \; [W] \qquad (4.2)$$

It must be taken into account that the resistor increases the total heat dissipation of the circuit.

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