Industrial Controls
SIRIUS Controls

Contactor Overvoltage Damping

Functional Example No. CD-FE-III-003-V20-EN

sirius

SIEMENS

Comments

Sirius Functional Examples are functional, tested automation configurations based on A&D standard products intended for simple, quick and economic implementation of automation tasks in low-voltage controls. Each of these Functional Examples covers a frequently occurring subtask of a typical customer problem within low-voltage controls.

1 Introduction

The most significant causes of overvoltage are switching operations in inductive circuits, e.g. contactor coils.

These overvoltages, voltage peaks up to 4 kV, can rapidly attain high values. The consequences include:

- Extreme contact erosion and, thus, premature wear of the contacts that switch the coil.
- Interference signals may be coupled, which, in some cases, could lead to fault signals in electronic controls and destruction of electronic modules.

Therefore, the switching overvoltages of the contactor coils are usually damped with a protective circuit.

The aim of this scientific paper is to provide users with a selection and dimensioning aid, and to list the advantages and disadvantages of the different types of protective circuits.

2 Overvoltage Development

Overvoltage develops when the contactor coil is switched off because the coil inductance attemps to continue the current flow during switch-off, whereupon the circuit closes via the self-capacitance of the magnetic coil. If the circuit has sufficient electric strength, current and voltage could flow in the form of a damped oscillation.
Due to the dynamic resistance of the switched-off coil, the oscillation amplitudes are in the range of up to several kV and the voltage rises are in the region of 1kV/µs.

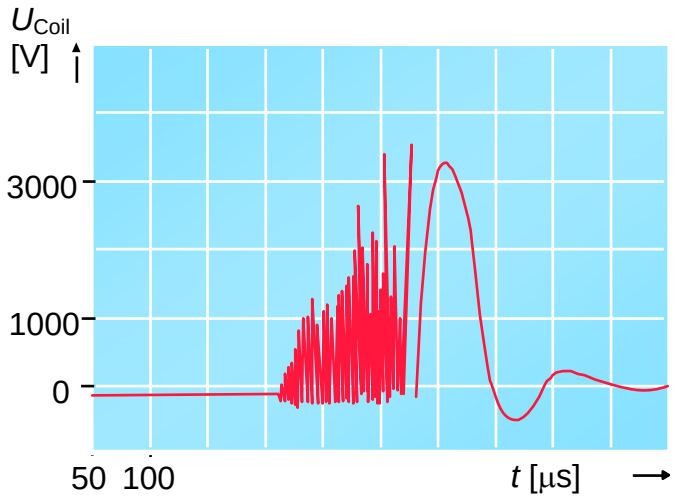

Fig. 1: Switching overvoltage of an unconnected contactor relay magnetic coil 230 V, 50 Hz, 10 VA

Fig. 1 shows the oscillogram of the power down cycle of a contactor relay magnetic coil causing a “shower discharge”. After a shower discharge phase of approximately 250 µs, a damped oscillation with a peak value of approx. 3.5 kV develops. The shower discharges also cause extreme erosion of the mechanical switching contact.
Furthermore, due to the very steep voltage shapes that develop on capacitive routes, considerable interference signals may be coupled in neighboring systems.
These make switching at the point of origin of the source of interference (i.e. the contactor coil) necessary. In this manner, overvoltage can be prevented directly at the source, thus protecting voltage-sensitive electronic components. The capacitive coupling of interference signals in the control wires of electronic circuitry is also avoided.

Overvoltage damping usually requires the following circuit components, which are switched parallel to the contactor coil:

- RC element (resistance and capacitor in series)
- Freewheeling diode, diode assembly
- Varistors

3 Types of Protective Circuits

3.1 Circuit with RC Elements

RC elements are used primarily for AC-operated contactors, however, they may also be used for DC-operated contactors.

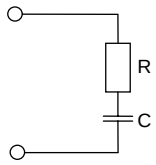

Fig. 2: Basic circuit diagram: RC element

The increase in the capacity at the coil reduces the amplitude to 2 to 3 times the control voltage and also reduces the steepness of the switching overvoltage, preventing further shower discharges. The voltage oscillates temporarily to 400 V before gradually running out. Thus, the RC circuit protects dv/dt sensitive output stages against unwanted through switching.

Correctly selected RC elements hardly influence the switching times of the contactors with a turn-off delay of less than 1 ms. However, optimum damping requires adaptation to the respective rated control voltage and rated frequency. Therefore, the RC elements must be selected according to the catalog.

In Figure 3, the voltage curve with the connected contactor relay magnetic coil from Fig. 1 is depicted with the appropriate RC element.

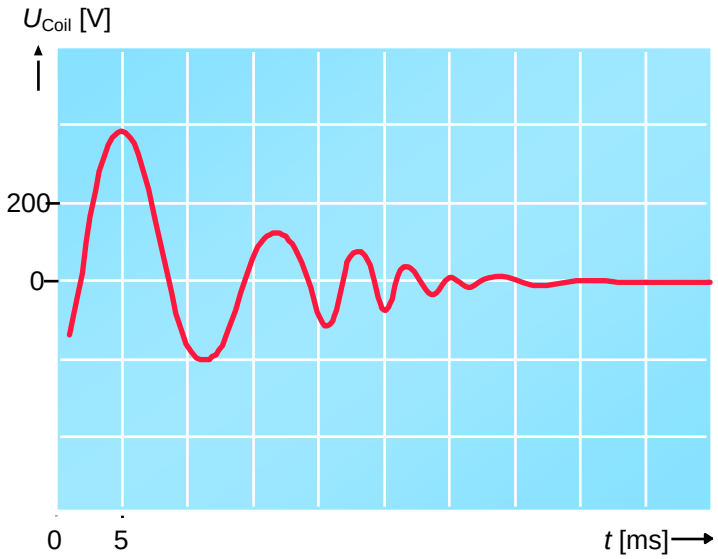

Fig. 3: Switching overvoltage of a contactor relay magnetic coil 230 V, 50 Hz, 10 VA for an RC element circuit with 110 Ω, 0.22 µF

3.2 Diode Circuit

Switch-off overvoltages can only be avoided when a diode circuit is used in the case of DC-operated contactors. Correct polarity must be ensured when connecting.

3.2.1 Freewheeling Diode Circuit

Switching overvoltages do not occur when a diode circuit is implemented; the diode limits to 0.7 V.
However, diodes cause an increase in the breaking delay, breaking time, by a factor of 6 to 9. This characteristic can be used to your advantage if, for example, a temporary voltage drop of around several milliseconds has to be bridged. In the case of contactors larger than size 0/S0, over 5.5 kW, freewheeling diodes can cause a two-stage switching off of the magnet system, which – in a worse case scenario – may cause contact welding. Therefore, freewheeling diodes are no longer recommended in this case.

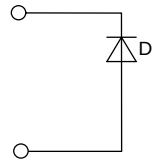

Fig. 4: Basic circuit diagram: freewheeling diode

In Figure 5, the voltage curve with the connected contactor relay magnetic coil from Fig. 1 is depicted with the appropriate freewheeling diode.

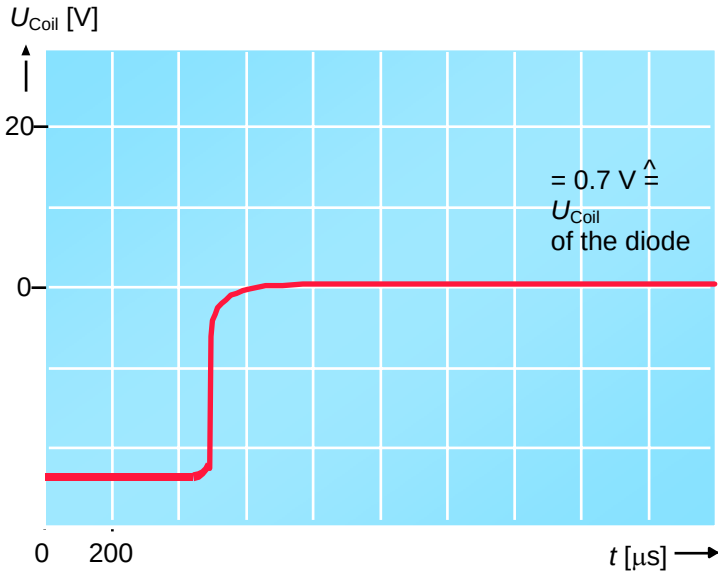

Fig. 5: Switching overvoltage of a contactor relay magnetic coil 24 V DC, 3 W for a freewheeling diode circuit

3.2.2 Circuit with One Diode / Zener Diode Diode Assembly

Switching overvoltages also do not develop in the case of a contactor coil circuit using a diode assembly consisting of a diode and a Zener diode, since the diode assembly limits the voltage to 10 V.
However, diode assemblies cause an increase in the breaking delay, the break time, by a factor of 2 to 6.

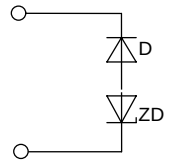

Fig. 6: Basic circuit diagram: diode assembly

In Figure 7, the voltage curve with the connected contactor relay magnetic coil from Fig. 1 is depicted with the appropriate diode assembly.

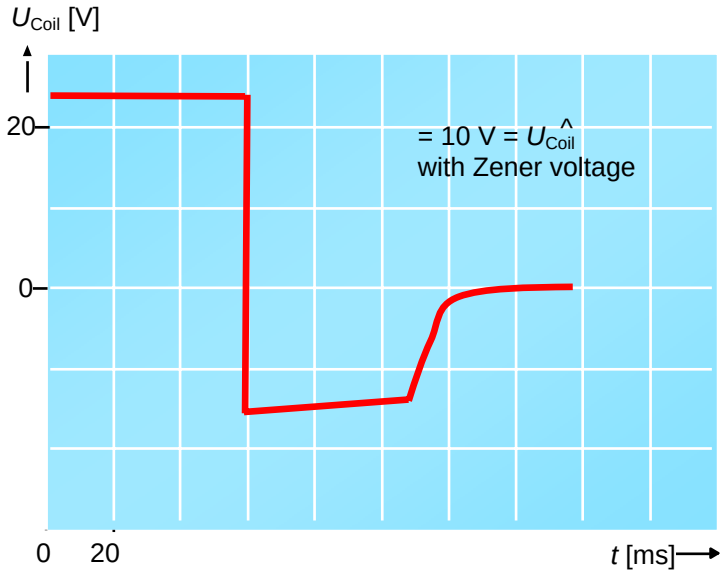

Fig. 7: Switching overvoltage of a contactor relay magnetic coil 24 V DC, 3 W with a diode assembly circuit

3.3 Varistor Circuit

When wired parallel to a coil, Varistors, voltage-dependent resistors, limit the maximum overvoltage, since they become conductive when a specific threshold voltage is exceeded. Until this point is reached, shower discharges also develop which are similar to those that develop when the magnetic coil is not connected. However, they are of a shorter duration. In contrast to the RC element, they do not reduce the steepness of the voltage rise. They are suitable for DC and AC-operated contactors and have little influence on switching times.

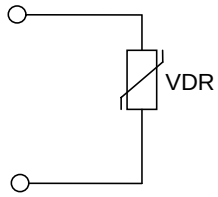

Fig. 8: Basic circuit diagram: varistor

In Figure 9, the voltage curve with the connected contactor relay magnetic coil from Fig. 1 is depicted with the appropriate varistor.

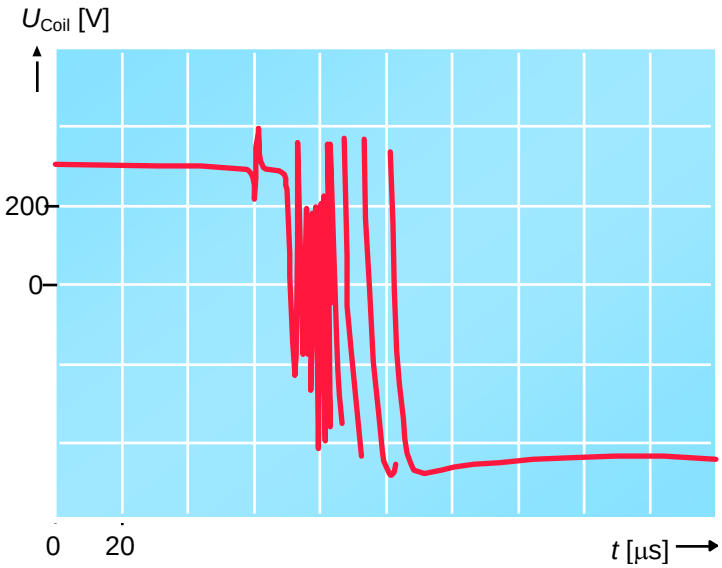

Fig. 9: Switching overvoltage of a contactor relay magnetic coil 230 V, 50 Hz, 10 VA With a 275-V varistor circuit (initial range: The voltage reduces to zero after approx. 3 ms)

3.4 Overview of Circuit Types

Load circuitry	Control supply voltage	Additional dropout delay	Defined induction voltage limiting	Advantages / Disadvantages	Preferred use
Diode	DC	Long	Yes (U_D)	Advantages: • Easily implemented • Reliable • Dimensioning uncritical • Small induction voltage Disadvantages: • Long dropout delay • Only suitable for sizes 00 / S00	Unstable control commands/ control supply voltage
Diode assembly	DC	Medium	Yes (U_{ZD})	Advantages: • Dimensioning uncritical Disadvantages: • Damping only above U_{ZD} (10 V)	In vicinity of EMC-critical components
Varistor	AC / DC	Short 2 – 5 ms	Yes (U_{VDR})	Advantages: • Energy absorption • Dimensioning uncritical • Easily implemented Disadvantages: • Damping only above U_{VDR}	Suitable for most standard applications, e.g. in SIMATIC environments
RC element	AC / DC	Very short 1 ms	No	Advantages: • HF damping thanks to energy storage • Very suitable for AC voltage • Level-independent damping Disadvantages: • High inrush current • Sensitive to harmonics	For critical switching times

4 Siemens – Overvoltage Damping Solutions

The following surge suppressors are available for 3RT1 contactors:

Surge suppressor	With LED	Without LED			
	for S00	for S00	for S0	for S2, S3	for S6 to S12
Noise supression diode	X	X	--	--	--
Diode assembly	--	X	X	X	--
Varistor	X	X	X	X	Integrated
RC element	--	X	X	X	X

4.1 Surge Suppressors for Contactors size S00 and S0

For contactors Type	Version	Rated control supply voltage U_s 1) AC operation V AC	DC operation V DC	DT	Order No. 2)	Pr pe	PU (UNIT, SET, M
Surge suppressors without LED (also for Cage Clamp terminals)							
	Size S00						
 3RT19 16-1DG00	**For plugging onto the front side of the contactors with and without auxiliary switch blocks**						
3RT1., 3RH1	**Varistors**	24 ... 48	24 ... 70	▶	**3RT19 16-1BB00**		
		48 ... 127	70 ... 150	▶	**3RT19 16-1BC00**		
		127 ... 240	150 ... 250	A	**3RT19 16-1BD00**		
		240 ... 400	--	▶	**3RT19 16-1BE00**		
		400 ... 600	--	A	**3RT19 16-1BF00**		
3RT1., 3RH1	**RC elements**	24 ... 48	24 ... 70	▶	**3RT19 16-1CB00**		
		48 ... 127	70 ... 150	▶	**3RT19 16-1CC00**		
		127 ... 240	150 ... 250	▶	**3RT19 16-1CD00**		
		240 ... 400	--	▶	**3RT19 16-1CE00**		
		400 ... 600	--	▶	**3RT19 16-1CF00**		
3RT1., 3RH1	**Noise suppression diodes**	--	12 ... 250	▶	**3RT19 16-1DG00**		
3RT1., 3RH1	**Diode assembly** (diode and Zener diode) for DC operation	--	12 ... 250	▶	**3RT19 16-1EH00**		
	Size S0						
 3RT19 26-1B0.00	**For fitting onto the coil terminals at top or bottom**						
3RT1. 2	**Varistors**	24 ... 48	24 ... 70	▶	**3RT19 26-1BB00**		
		48 ... 127	70 ... 150	▶	**3RT19 26-1BC00**		
		127 ... 240	150 ... 250	▶	**3RT19 26-1BD00**		
		240 ... 400	--	▶	**3RT19 26-1BE00**		
		400 ... 600	--	B	**3RT19 26-1BF00**		
3RT1. 2	**RC elements**	24 ... 48	24 ... 70	▶	**3RT19 26-1CB00**		
		48 ... 127	70 ... 150	▶	**3RT19 26-1CC00**		
		127 ... 240	150 ... 250	▶	**3RT19 26-1CD00**		
		240 ... 400	--	▶	**3RT19 26-1CE00**		
		400 ... 600	--	B	**3RT19 26-1CF00**		
3RT1. 2	**Diode assembly** For DC operation						
	• Connectable at the top (e.g. for contactor with overload relay)	--	24	▶	**3RT19 26-1ER00**		
		--	30 ... 250	▶	**3RT19 26-1ES00**		
	• Connectable at the bottom (e.g. for fuseless load feeders)	--	24	▶	**3RT19 26-1TR00**		
		--	30 ... 250	A	**3RT19 26-1TS00**		

1) Can be used for AC operation for 50/60 Hz. Please inquire about further voltages.

2) For packs of 10 units, the Order No. must be supplemented with "**Z**" and the order code "**X90**".

For contactors Type	Version	Rated control supply voltage U_s 1) AC operation V AC	DC operation V DC	Power consumption of LEDs at U_s	DT	Order No. 2)	Price per PU	PU (UNIT, SET
Surge suppressors with LED (also for Cage Clamp terminals)								
	Size S00							
 3RT19 16-1L.00	**For plugging onto the front side of the contactors with and without auxiliary switch blocks**							
3RT1, 3RH1.	**Varistors**	24 ... 48	12 ... 24	10 ... 120	▶	**3RT19 16-1JJ00**		
		48 ... 127	24 ... 70	20 ... 470	▶	**3RT19 16-1JK00**		
		127 ... 240	70 ... 150	50 ... 700	▶	**3RT19 16-1JL00**		
		--	150 ... 250	160 ... 950	A	**3RT19 16-1JP00**		
3RT1, 3RH1.	**Noise suppression diodes**	--	24 ... 70	20 ... 470	▶	**3RT19 16-1LM00**		
		--	50 ... 150	50 ... 700	▶	**3RT19 16-1LN00**		
		--	150 ... 250	160 ... 950	▶	**3RT19 16-1LP00**		

1) Can be used for AC operation for 50/60 Hz. Please inquire about further voltages.

2) For packs of 10 or 5 units, the Order No. must be supplemented with "**-Z**" and the order code "**X90**".

4.2 Surge Suppressors for Contactors Size S2 to S12

For contactors Type	Version	Rated control supply voltage U_s [1] AC operation V AC	DC operation V DC	DT	Order No. [2]
Surge suppressors without LED (also for Cage Clamp terminals)					
Sizes S2 and S3					
	For fitting onto the coil terminals at top or bottom				
 3RT19 26-1B0.00	3RT1. 3, 3RT1. 4 **Varistors**	24 ... 48	24 ... 70	▶	**3RT19 26-1BB00**
		48 ... 127	70 ... 150	▶	**3RT19 26-1BC00**
		127 ... 240	150 ... 250	▶	**3RT19 26-1BD00**
		240 ... 400	--	▶	**3RT19 26-1BE00**
		400 ... 600		B	**3RT19 26-1BF00**
 3RT19 36-1C.00	3RT1. 3[3], 3RT1. 4 **RC elements**	24 ... 48	24 ... 70	▶	**3RT19 36-1CB00**
		48 ... 127	70 ... 150	▶	**3RT19 36-1CC00**
		127 ... 240	150 ... 250	▶	**3RT19 36-1CD00**
		240 ... 400	--	▶	**3RT19 36-1CE00**
		400 ... 600	--	B	**3RT19 36-1CF00**
	3RT1. 3, 3RT1. 4 **Diode assembly** For DC operation				
	• Connectable at the top (e.g. for contactor with overload relay)		24	▶	**3RT19 36-1ER00**
			30 ... 250	▶	**3RT19 36-1ES00**
	• Connectable at the bottom (e.g. for fuseless load feeders)		24	▶	**3RT19 36-1TR00**
			30 ... 250	B	**3RT19 36-1TS00**
Sizes S6 ... S12					
 3RT19 56-1C.00	**For connecting to withdrawable coil with screw terminals with contactors with** **• 3RT1. ..-.A... conventional operating mechanism** **• 3RT1. ..-.N... solid-state operating mechanism**				
	3RT1. 5, 3RT1. 6, 3RT1. 7 **RC elements**	24 ... 48	24 ... 70	▶	**3RT19 56-1CB00**
		48 ... 127	70 ... 150	▶	**3RT19 56-1CC00**
		127 ... 240	150 ... 250	▶	**3RT19 56-1CD00**
		240 ... 400	--	▶	**3RT19 56-1CE00**
		400 ... 600		C	**3RT19 56-1CF00**

1) Can be used for AC operation for 50/60 Hz. Please inquire about further voltages.

2) For packs of 10 or 5 units, the Order No. must be supplemented with "**Z**" and the order code "**X90**".

3) Mountable only at the top for 3RT1. 3/AC operating mechanis

5 Contact Partner

Technical Assistance for Low-voltage Controls and Distribution

Personally from Mon. – Fri. 8:00 am to 5:00 pm (CET)
Telephone: +49 (911)-895-5900
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7 Bibliography

[1] Schalten, Schützen, Verteilen in Niederspannungsnetzen, Fachbuch Siemens [Switching, Protection and Distribution in Low-Voltage Networks" (Siemens refer ence book)]