Industrial Controls
SIRIUS Controls

Star-delta (Wye-delta) Switching of Three-phase Induction Motors
Transient Current Peak Reduction using a Preferred Circuitry Configuration for Clockwise and Counterclockwise Motor Rotation

Functional Example No. CD-FE-III-001-V10-EN

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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

Star-delta (wye-delta) starting continues to be used for switching on 3-phase induction motors. When this type of connection method is used, the starting current is reduced to 1/3 of the current required for direct switching.

When switching from a star (wye) circuit to a delta circuit, transients can occur in the motor, which, further intensified by an unfavorable constellation of line frequency and inductor field, lead to the development of larger current peaks than is the case if the stopped motor is directly switched into a delta connection. In an unfavorable case, the following problems could occur:

- Short-circuit devices could trip,
- The delta contactor could become welded or be subject to high contact erosion,
- The motor could be subject to extreme dynamic overloading.

A preferred circuitry configuration for star-delta (wye-delta) starters is described in this Functional Example. When the main circuit is connected in a favorable manner, it is possible to reduce the transient currents and current peaks that develop when the motor is switched over from a star (wye) connection to a delta connection.

2 Function

Two different types of motor connections are often listed in star-delta (wye-delta) starter circuit diagrams: One for clockwise and one for counterclockwise motor rotation. When installing the motor, care should be taken to ensure that the transient current peaks are as small as possible. Correct wiring of the motor terminal board is essential.

1.1 Description of the Functionality for Clockwise Motor Rotation

2.1.1 The Preferred Circuitry Configuration is Implemented

The vector diagram illustrated below shows the voltages that develop in a motor with clockwise rotation when the motor is switched from a star (wye) to a delta connection. In this case, the motor terminals are correctly connected according to the preferred circuitry configuration, meaning that phase L1 is connected to the motor terminals U1 and V2, L2 is connected to V1 and W2, and L3 is connected to W1 and U2:

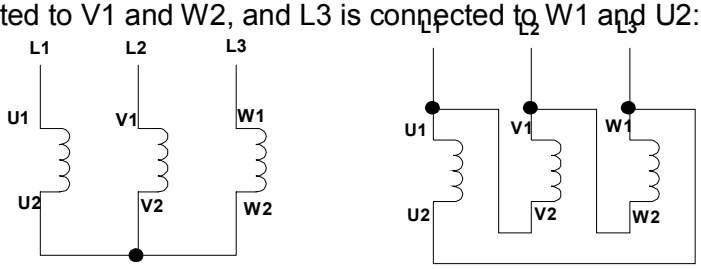


Fig. 1: Correct connection of the motor phases for clockwise rotation

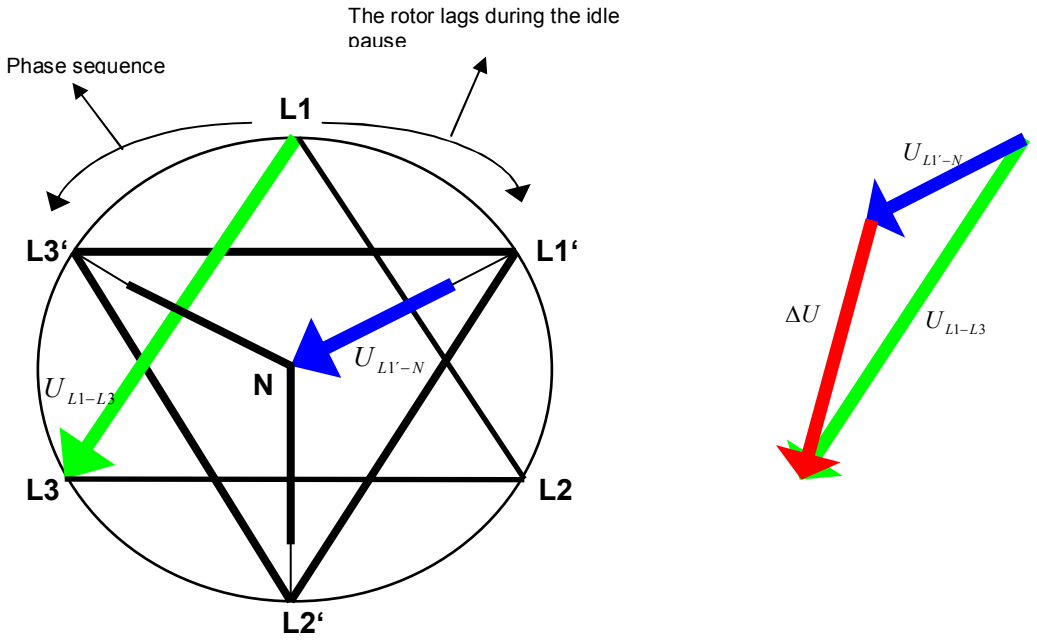


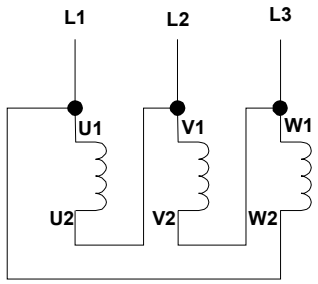
Fig. 2: Vector diagram for switching from a star (wye) connection to a delta connection for clockwise motor rotation when the motor phases are correctly connected

During the idle changeover delay, the rotor lags behind the phase sequence. The magnetic field induces a damped residual voltage, which is listed here in the voltage

vector diagram for phase L1: $U_{L1'-N}$. When switching over to a delta connection (Fig. 1 and Fig. 2), the stator winding carrying this residual voltage is supplied with the line voltage U_{L1-L3}. Thanks to the favorable vector position of the residual voltage $U_{L1'-N}$ and the line voltage U_{L1-L3}, which have approximately the same values, the differential voltage ΔU is relatively small. Thus, the current peaks resulting from this voltage also remain small.

2.1.2 The Preferred Circuitry Configuration is not Implemented

The motor also rotates clockwise when the motor terminals are connected as follows: Phase L1 is connected to motor terminals U1 and W2, L2 is connected to V1 and U2,



and L3 is connected to W1 and V2.

Fig. 3: Incorrect connection of the motor phases also resulting in clockwise motor rotation

Both the lagging residual voltage and the damped residual voltage are active in the stator. When the motor is switched to a delta connection, the phase winding with the vector $U_{L1'-N}$ is supplied with the line phase U_{L1-L2}. However, each of these voltages has a different vectorial direction. The differential voltage ΔU is high, thus causing a correspondingly high transient current peak. Switching from a star (wye) connection to a delta connection therefore results in the following vector diagram:

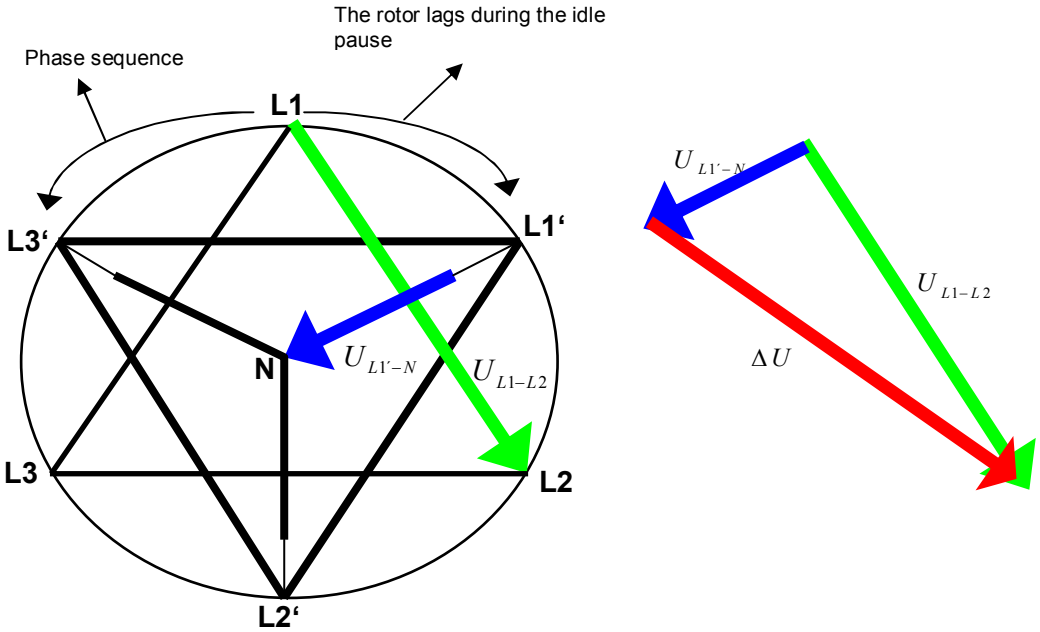


Fig. 4: Vector diagram for connecting the motor phases according to Fig. 3, resulting in a large transient current peak

2.2 Changing the Direction of Rotation from Clockwise to Counterclockwise

When the motor rotates *counterclockwise* it is sufficient to exchange two phases in any position. Then the same conditions would prevail as described above for clockwise rotation. In order to also keep the transient current peak as small as possible in this case when switching from a star (wye) connection to a delta connection, the wiring must be carried out as illustrated below:

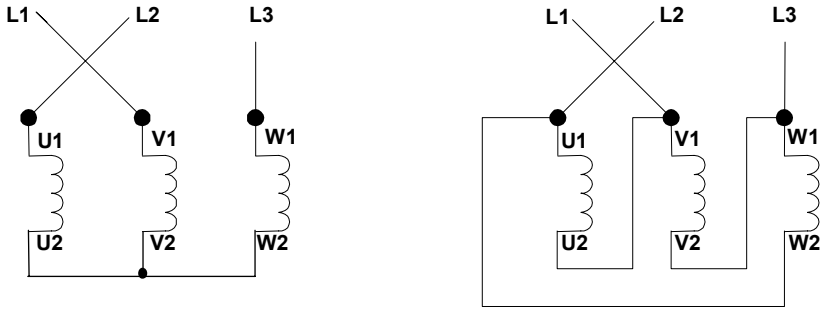


Fig. 5: Correct connection of the motor phases for counterclockwise rotation of the motor

Refer to Section 3 for information regarding the wiring of the main current and the control current. The circuit diagrams for contact assemblies for star-delta (wye-delta) starting with clockwise and counterclockwise motor rotation are illustrated in the preferred circuitry configuration.

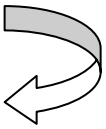
2.3 Device Rating for Standard Start-up

Star (wye) contactor:	$I_{e\ Motor}$ x 0.33
Line/delta contactor:	$I_{e\ Motor}$ x 0.58
Overload relay:	$I_{e\ Motor}$ x 0.58

2.4 Favorable and Unfavorable Circuitry Configurations

The different types of connection combinations are summarized here together with the delta connection wiring.

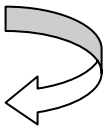
Unfavorable versions	Rewiring ⇨	**Favorable versions**



Circuitry configuration, clockwise, unfavorable			
U1:	L1	U2:	L2
V1:	L2	V2:	L3
W1:	L3	W2:	L1

⇨

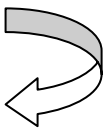
Circuitry configuration, clockwise, favorable			
U1:	L1	U2:	L3
V1:	L2	V2:	L1
W1:	L3	W2:	L2



Circuitry configuration, clockwise, unfavorable			
U1:	L2	U2:	L3
V1:	L3	V2:	L1
W1:	L1	W2:	L2

⇨

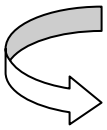
Circuitry configuration, clockwise, favorable			
U1:	L2	U2:	L1
V1:	L3	V2:	L2
W1:	L1	W2:	L3



Circuitry configuration, clockwise, unfavorable			
U1:	L3	U2:	L1
V1:	L1	V2:	L2
W1:	L2	W2:	L3

⇨

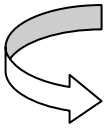
Circuitry configuration, clockwise, favorable			
U1:	L3	U2:	L2
V1:	L1	V2:	L3
W1:	L2	W2:	L1



Circuitry configuration, counterclockwise, unfavorable			
U1:	L1	U2:	L2
V1:	L3	V2:	L1
W1:	L2	W2:	L3

⇨

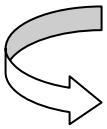
Circuitry configuration, counterclockwise, favorable			
U1:	L1	U2:	L3
V1:	L3	V2:	L2
W1:	L2	W2:	L1



Circuitry configuration, counterclockwise, unfavorable			
U1:	L3	U2:	L1
V1:	L2	V2:	L3
W1:	L1	W2:	L2

⇨

Circuitry configuration, counterclockwise, favorable			
U1:	L3	U2:	L2
V1:	L2	V2:	L1
W1:	L1	W2:	L3



Circuitry configuration, counterclockwise, unfavorable			
U1:	L2	U2:	L3
V1:	L1	V2:	L2
W1:	L3	W2:	L1

⇨

Circuitry configuration, counterclockwise, favorable			
U1:	L2	U2:	L1
V1:	L1	V2:	L3
W1:	L3	W2:	L2

Comment: When two phases in the circuit are exchanged to change the direction of rotation, the connection is automatically switched from the more favorable connection to the less favorable one and vice versa.

$\wp$ = Transient current factor = transient current peak/starting current peak

In theory, the transient current factor has a maximum value of 2.

For example, measured:	Favorable connection:	$\wp$ = 0.8
	Unfavorable connection:	$\wp$ = 1.37

3 Assembly and Wiring

3.1 Main Circuit Overview

In the following graphic, the preferred circuitry configuration for the main circuit is illustrated for a star-delta (wye-delta) connection for clockwise and counterclockwise motor rotation.

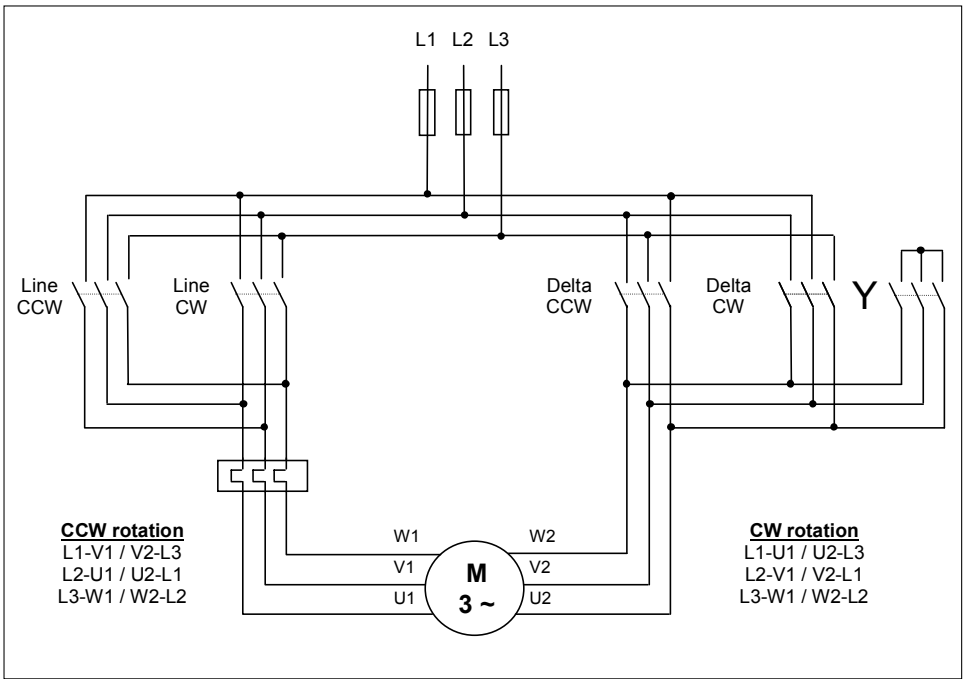


Fig. 6: Main circuit of the contactor assembly for star-delta (wye-delta) starting

1.1 Control Circuit Overview

The control circuit for the main circuit shown above is illustrated below.

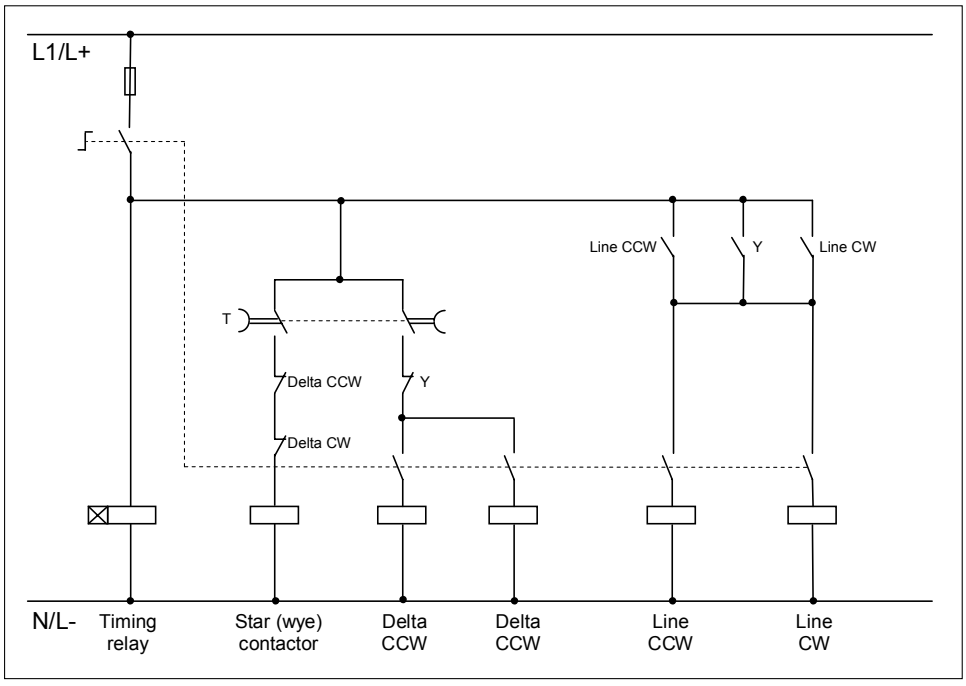
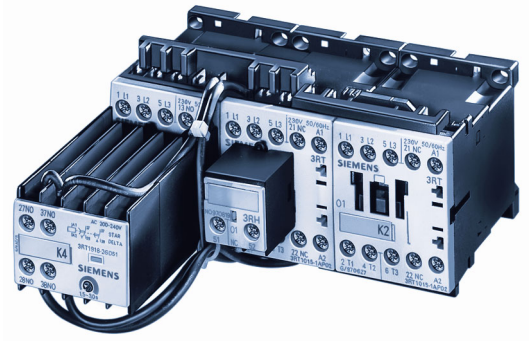


Fig. 7: Control circuit of the contactor assembly for star-delta (wye-delta) starting

4 Siemens – The Solution for Complete Contactor Assemblies for Star-delta Starting (Wye-delta Starting) up to 75 kW for one Direction of Rotation



Contactor assemblies			
3-phase motor AC-3/400 V		**Size**	**Completely wired and tested for AC 230 V, 50/60 Hz**
[kW]	**[A]**		**Order No.**
5.5	12	S00-S00-S00	**3RA14 15-8XB21-1AP0**
7.5	17	S00-S00-S00	**3RA14 16-8XB21-1AP0**
11	25	S0-S0-S0	**3RA14 23-8XC21-1AL2**
15/18.5	32/40	S0-S0-S0	**3RA14 25-8XC21-1AL2**
22/30	50/65	S2-S2-S0	**3RA14 34-8XC21-1AL2**
37	80	S2-S2-S2	**3RA14 35-8XC21-1AL2**
45	86	S2-S2-S2	**3RA14 36-8XC21-1AL2**
55	115	S3-S3-S2	**3RA14 44-8XC21-1AL2**
75	150	S3-S3-S2	**3RA14 45-8XC21-1AL2**

For further information, for example, regarding other voltages and/or accessories, please refer to the LV 1 catalog.

5 Contact Partner

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Personally from Mon. – Fri. 8:00 am to 5:00 pm (CET)
Telephone: +49 (911)-895-5900
E-mail: technical-assistance@siemens.com
Internet: http://www.siemens.de/lowvoltage

By fax, around the clock
Fax: +49 (911)-895-5907

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7 Bibliography

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

[2] L.Vercelli, Sprecher&Schuh AG, CH-5000 Aarau: "Rechts- und Linkslauf der Motoren bei Y-D-Anlauf" in ELEKTRONIK (CH) 2/1978, Seite 53 ["Clockwise and Counterclockwise Rotation in Motors For Star-delta Starting (Wye-delta Starting)" in ELEKTRONIK (CH) 2/1978, p. 53]