Motor Control Simulation

1 Simulation operating modes

Immediately after the program has been started, the main menu appears on the screen. The mouse pointer is visible in the form of a hand. The operating modes can be selected from the menu bar at the top of the screen by means of the left mouse button. Alternatively, the operating modes can be selected by pressing the corresponding hotkeys on the keyboard. These keys are shown underlined. The main circuit is visible in the upper half of the screen. The line width can be altered using the OPTIONS in the menu bar. The motor with a digital speed display is shown in the lower half of the screen. Additional audio motor noise can be switched on by selecting *Sound on* in the menu OPTIONS.

1.1 DEMO mode

The current motor circuit is displayed in the menu bar at the top of the screen. Motor control is automatic in DEMO mode. This simulation shows possible practice examples for realizing an external control facility. The automatic process here shall be dealt with in exercises in the next chapter and will be replaced by a real control unit. None of the control elements can be activated in DEMO mode. The process can only be observed.
Move the mouse pointer to the DEMO option button and briefly click the left mouse button.
The mouse pointer moves immediately and simulates the steps for starting the motor circuit. The DEMO mode can be aborted by pressing any key or the left mouse button.

1.2 MANUAL mode

All functions of the current motor circuit can be tested in the MANUAL mode, without a control unit connected. All actuators and operating elements are activated with a mouse click, and the response is observed. The status of the operating elements is displayed by LED's. At the same time, it is transmitted to the PC adapter, where real measurements can be performed.
The main menu of the program is shown in the bar at the top of the screen.
Move the mouse pointer to the OPTIONS button and briefly press the left mouse button. A list of options which can be set now appears in a window. Check whether the parallel interface to which your PC adapter is connected is displayed. If required, you can change the entry using the mouse. Also check whether the *Lettering on* option is active, so that consistent conditions apply for the following description.

Click on the MANUAL button in the menu bar at the top. The program is now in the manual mode.
10 switches now appear on the left-hand edge of the screen and 10 LEDs appear on the right. The simulation has a total of 10 switches or inputs. The motor contactors and signal lamps are labeled with K and H respectively. The corresponding actuator is activated by clicking on a switch with the mouse. The switches can also be actuated using the PC keyboard. To actuate a switch, press Shift together with the corresponding number, e.g. [0] for switch KO. In this example the contactor KO was triggered. Only the contactors which are visible on the screen can be operated. The system is operated by the buttons SO to S4. They can also be actuated by clicking the mouse button or by pressing the corresponding number key on the keyboard. However, they function as switches when the keyboard is operated. Their status is displayed by the LEDs on the right side of the screen. The off-button SO functions as an NC contact and supplies a 1-signal when inactive. Buttons Sl to S4 function as NO contacts. These four operator buttons also have NC contacts, S5 to S8. The fuse also has a NC contact, S9.
The status of the LED's can be measured directly from the appropriate outputs of the PC adapter.
The numbers of the switches coincide with the numbers of the terminals on the PC adapter. The numbers of the switches on the left side of the screen also coincide with the numbers of the inputs of the PC adapter, with which the system in the next chapter is externally controlled.
In the MANUAL operating mode, you can test the switching sequences within the current motor circuit.

1.3 EXTERNAL mode

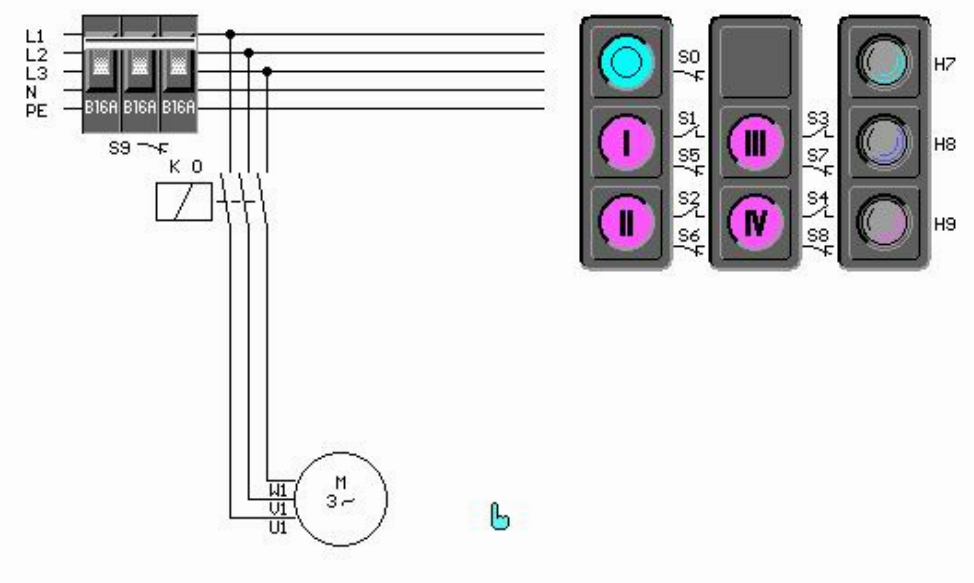
The EXTERNAL mode is similar to the MANUAL mode in terms of screen configuration and operation. However, the actuators are no longer activated via switches but via the inputs of the PC adapter. The operating states of the inputs are indicated by LED's. Check whether the correct parallel interface has been selected in the OPTIONS menu. To activate an actuator, a 1-signal (24 V for PLC and 5 V for TTL mode) has to be applied to the corresponding PC adapter input. For example, if input 7 of the PC adapter is supplied with a 1-signal, the LED H7 lights up.

2 Motor Circuits

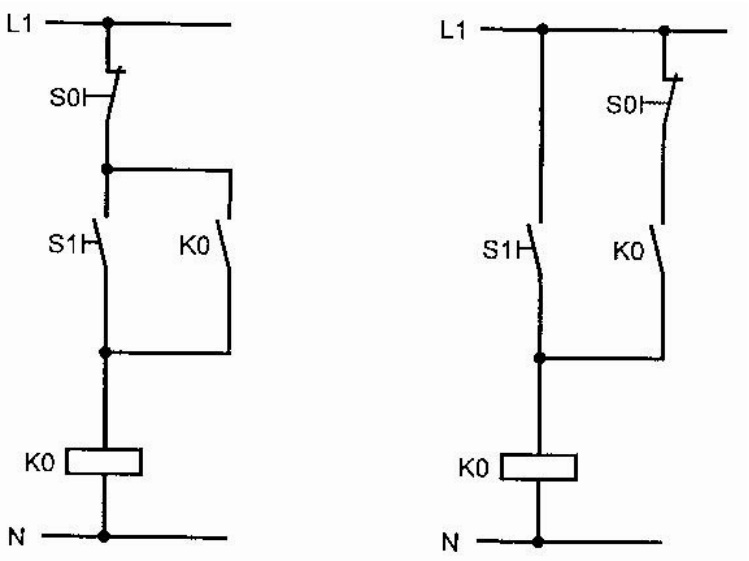
In the option menu one of the seven motor circuits can be selected. The current circuit is shown at the top of the screen.

In the following chapters the controls for various circuits are to be developed. The logic diagram has been selected as the representational form, because it is the easiest to apply to the various types of control. There is a demonstration mode DEMO provided for each circuit to present the various exercises.
In the MANUAL operating mode the circuit can be dealt with in detail.
After developing the control program (logic diagram) the real control system is set up. If a control system is to be assembled out of simulog plug-in elements, these can be taken 1:1 from the logic diagram. When a PLC is used as a control unit then the logic diagram is programmed into the PLC memory either directly or as a statement list. A master copy for the drafting of assignment lists for the respective inputs and outputs can be found on page 19.
In chapter 4, Control Examples, you will find additional tips for putting other kinds of controls into operation.

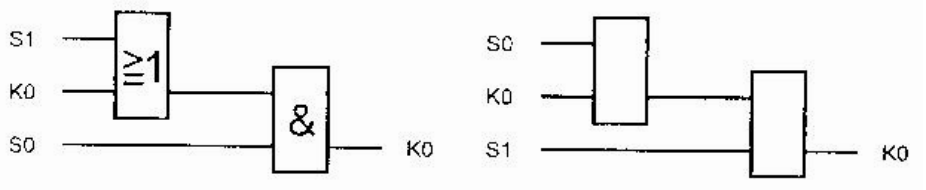
2.1 Self-holding



The circuit with a storage function in a contactor control operation is called the self-holding circuit. An NO contact of the contactor is connected parallel to the on-button as a self-holding contact. An NC contact is used as the off-button, which interrupts the holding current circuit when activated and thus cancels the self-holding action.
Two different control circuits for a self-holding function are shown below. What is the difference between the two circuits?



The two circuit diagrams should not be converted into function diagrams. Since the S0 is designed as an NC contact, it must be polled for 1-signals. Correctly complete the function diagram on the right.



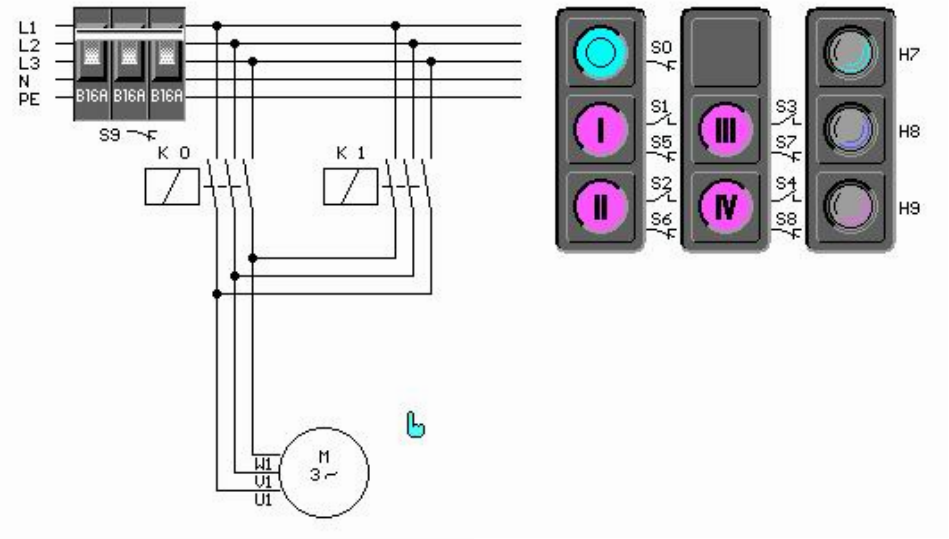
Now the PLC has to be programmed, i.e. the discrete control has to be assembled and tested.
Notes on putting the various controls into operation can be found in Chapter 4.

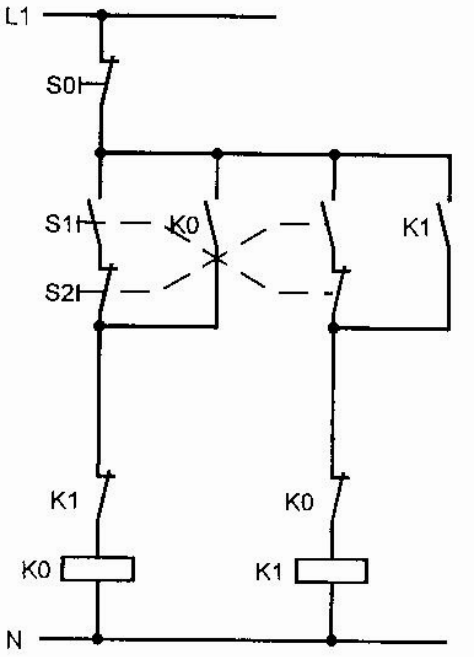
Further possibilities:

Naturally an RS storage element can also be programmed to perform a self-holding function. In order for the PLC to process all commands one after the other, the last command processed has priority. In the case of reset priority, the reset switching condition of the RC storage element has to be programmed last.

2.2 Reversing Circuit

We start with the main circuit and the circuit diagram for a reversing control circuit without direct switchover. This means switch-off has to be performed before switchover.

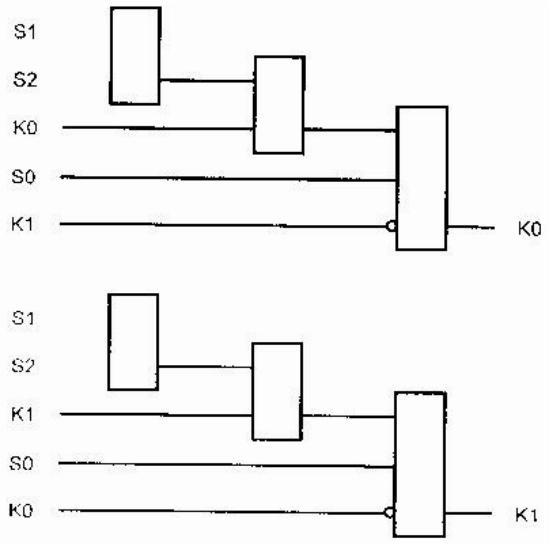




The pushbuttons and the contactors arc interlocked (latching). For pushbutton latching there arc two different possibilities:

1. Only the NO contacts of the pushbutton are connected to the PLC. If the NC contact of the pushbutton is needed within the program, then the signal is simply programmed to negate when polled (i.e. it is negated by the programming language).

2. All NC and NO contactors of the pushbuttons are connected to the inputs of the PLC and programmed as 1-signal generators without negation in accordance with the circuit diagram.
Both possibilities are standard procedures in practice. However, the second possibility provides greater reliability, because when the pushbutton is activated the NC contact always opens first because of the leading make action, before the NO contact closes and thus the latching command (see circuit diagram) is always issued before the switch-on command.
The contactor latching also has to be set up in the reversing control circuit. In the PLC program (function diagram) this is performed by negative polling of the mutual outputs, which act as 0- signal generators because they have not been set.
Naturally, outside the PLC even more contactor latching has to be carried out in actual operations using their auxiliary contacts.
Complete the following function diagram. But here you have to assume that the pushbutton SO is only available via an NC contact and that pushbuttons Sl and S2 are only available via NO contacts.



Now the PLC has to be programmed, i.e. the discrete control circuit must be set up and tested.
Notes on putting the various controls into operation can be found in Chapter 4.

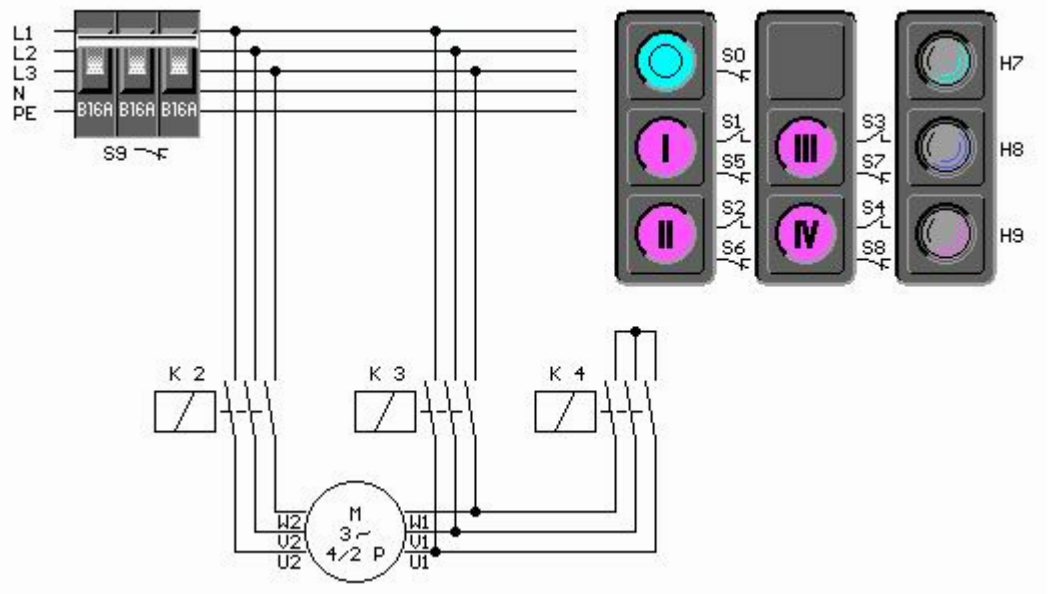
Further possibilities:

Naturally, instead of polling NO contacts Sl and S2 with negation, you can also poll the corresponding pushbutton NC contacts S4 and S5 directly.
Which modifications have to be carried out in the logic diagram, in order to permit a direct reversal of the rotation direction?

2.3 Dahlander Circuit

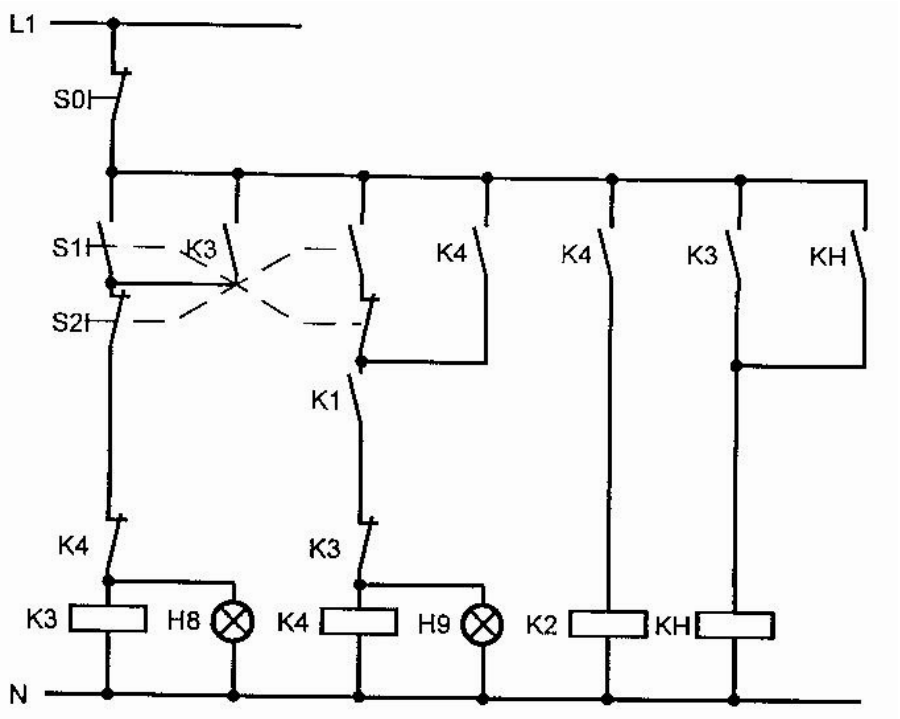
Switching condition for a Dahlander motor

When the mains is connected to terminals 1U, IV and 1W the motor rotates at low speed. By connecting the mains to terminals 2U, 2V and 2W and connecting terminals 1U, IV and 1W with a star bridge the motor runs at high speed.
A Dahlender circuit operating in clockwise rotation is produced according to the switching conditions provided above for the main circuit.
Slow speed: Contactor K3
Fast speed: Contactors K2 and K4

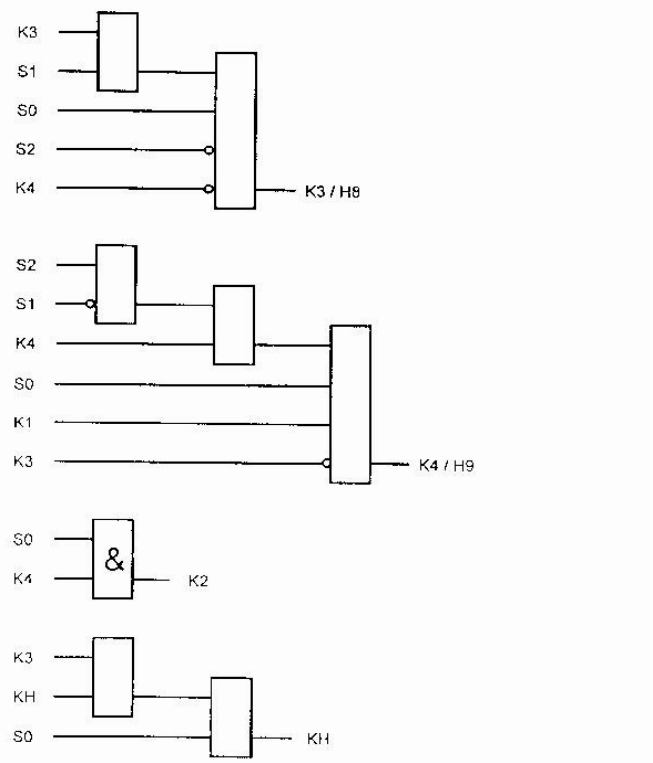


Switching conditions for the control circuit

Control of a Dahlander circuit must always be designed so that during switchover the respective switching stage has been completed and released before the next switching stage can be switched on. This fixed sequence is necessary to prevent switching overlaps from arising between low and high speed in the main circuit. Switching overlaps between the main contactors at low speed and the star contactor at high speed would lead to a short-circuit in the main circuit.
The control circuit depicted also has the following function:
The higher speed can only be switched on via the low speed. Direct switchover between the two speeds is not permitted.



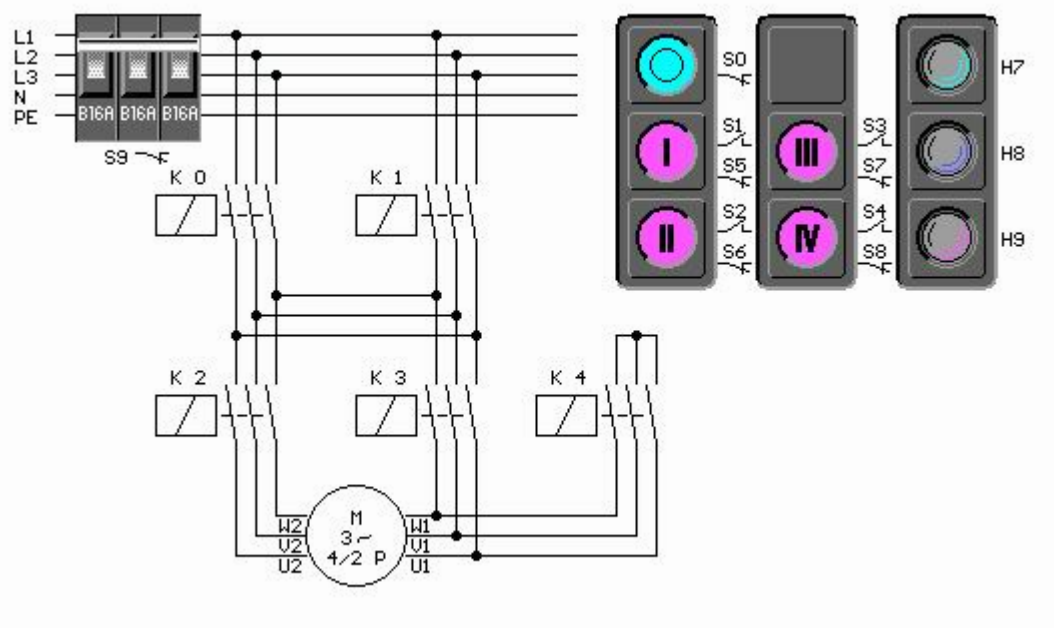
Complete the following function diagram and make an assignment list for your PLC. The indicator lamps H8 and H9 should be triggered parallel to contactors K3 and K4. The auxiliary contactor KH is realized within the PLC control program using a marker.



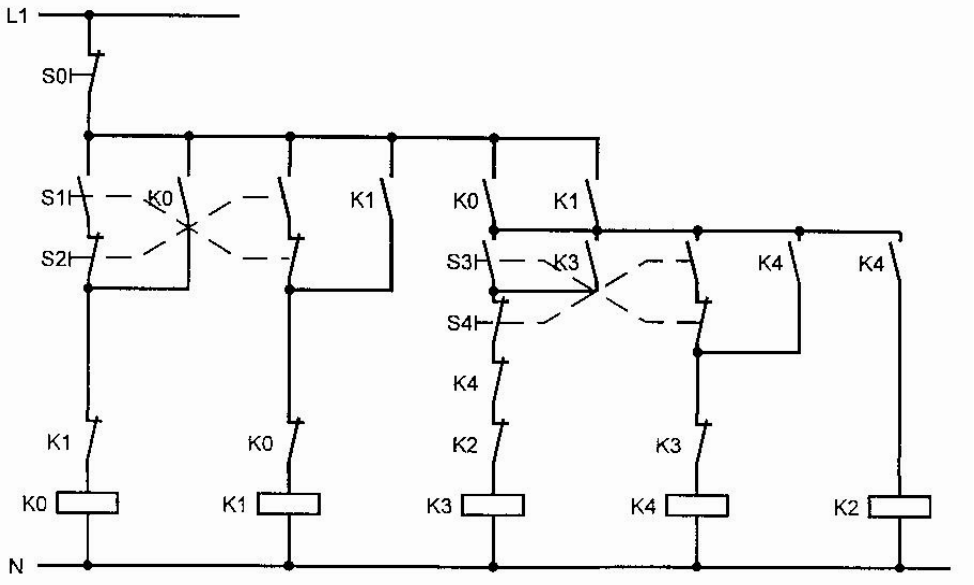
2.4 Reversing Dahlander Circuit

The main circuit of a reversing Dahlander circuit is depicted with the following contactor functions:

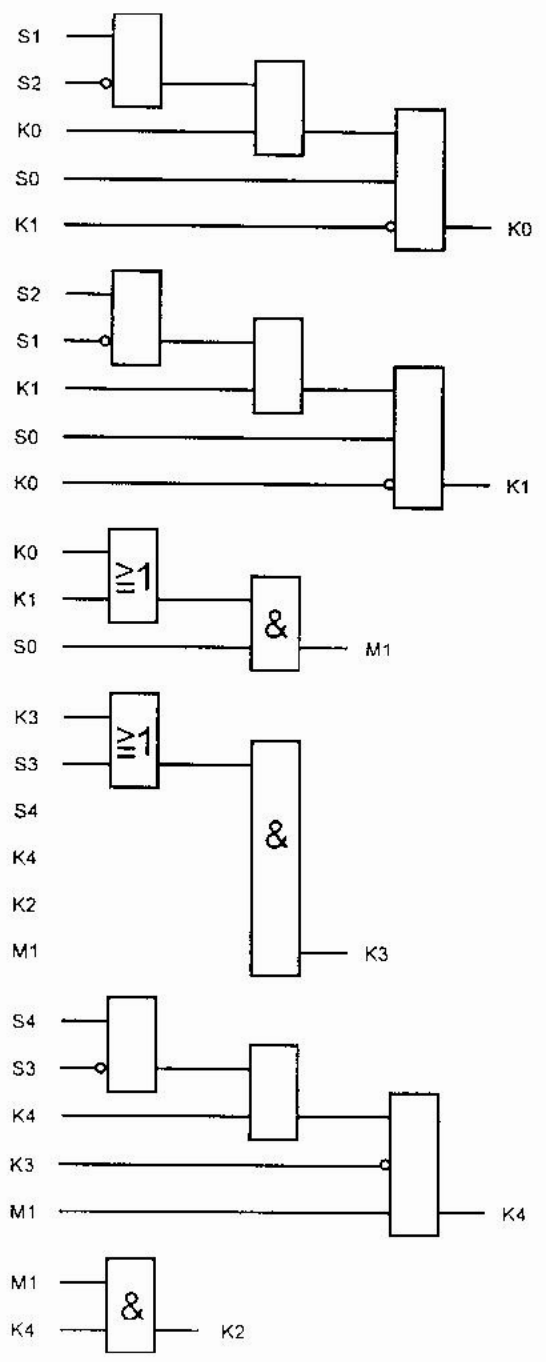
K0 = Reversing contactor - clockwise
K1 = Reversing contactor - counterclockwise
K2 = Mains contactor for high speed
K3 = Mains contactor for low speed
K4 = Star contactor for high speed



Control circuit diagram



After determining the rotation direction, the low or the high speed is switched on each time from 0. Switchover from a low initial speed setting to the high speed should be possible, but switching the setting back from the high to the low speed should not. Reversal of rotation direction and switch back to low speed are only possible if the motor has been switched off first.
Complete the function diagram and draw up an assignment list for using the PLC as a control unit.

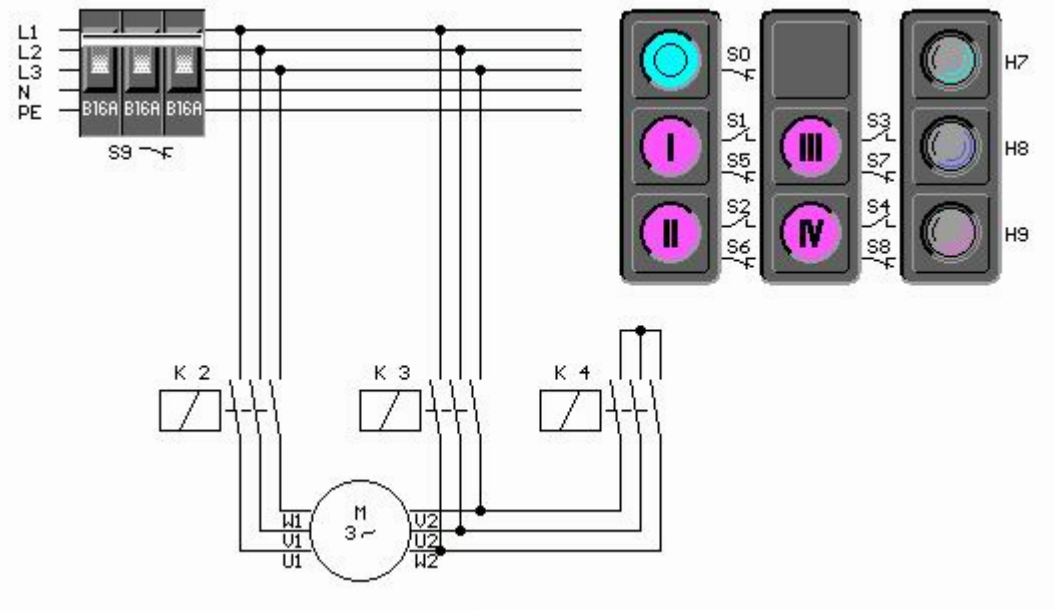


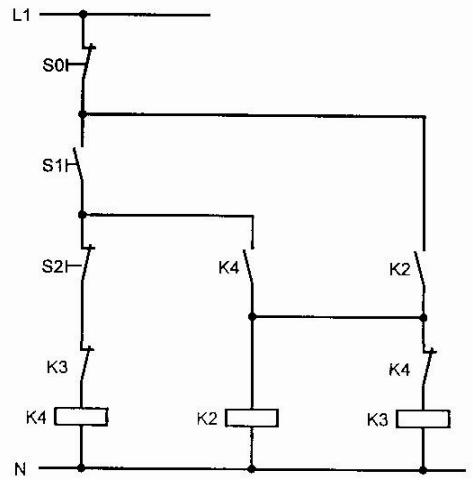
Here there is also the alternative of polling the NC contacts S5 to S8 for the latching of the pushbuttons.

2.5 Star-delta Circuit

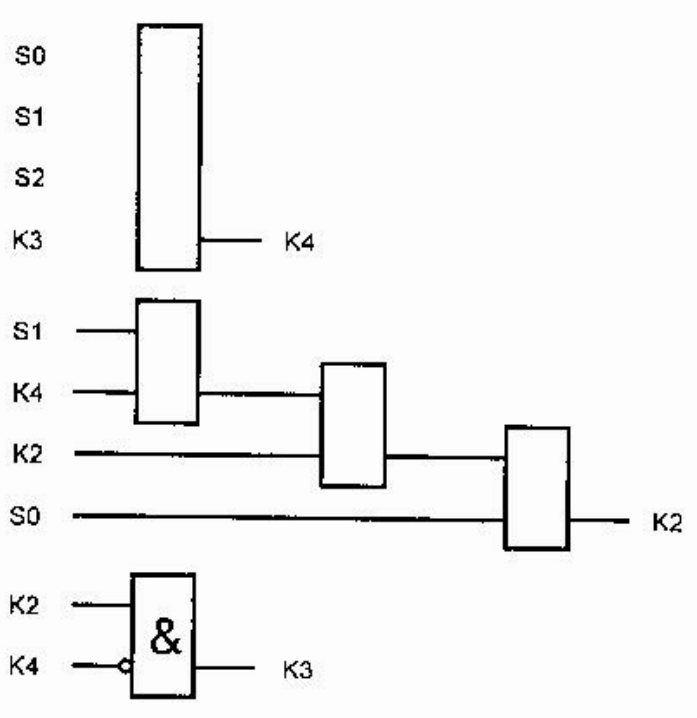
Main circuit:

The motor starts in clockwise rotation direction in the star circuit configuration, if the star contactor K4 and the mains contactor K2 are activated.
In delta connection the motor runs, if the delta contactor K3 and the mains contactor K2 are activated.
During switchover the star contactor has to deactivate first and then the delta contactor.
What happens ifK3 and K4 are deactivated simultaneously?





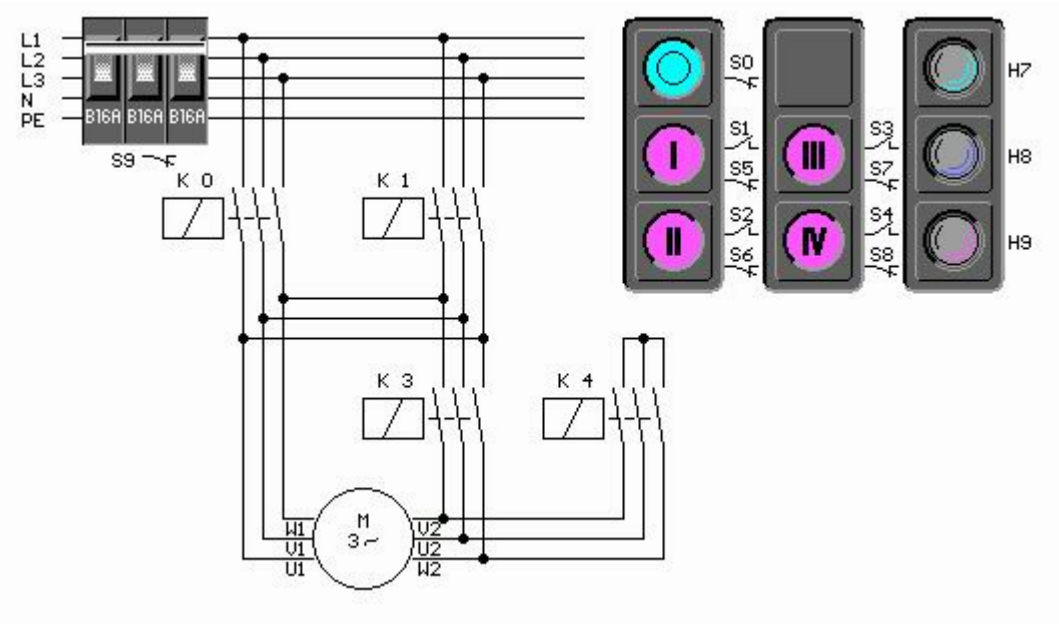
All of the controls for star-delta circuits must fundamentally be designed so that during switchover from star to delta, the star contactor must deactivate first, before the delta contactor may be activated. Otherwise switching overlaps cause short-circuits in the main circuit.
Pushbutton Sl activates the star contactor K4. K4 then activates the mains contactor K2. K4 and K2 are self-holding. The delta contactor K3 is latched by an NC contact of the star contactor K4.
By actuating pushbutton S2 the star contactor K4 releases. This cancels the latching of the delta contactor K3 and K3 activates. Switch off is performed using pushbutton S0.
Complete the function diagram and draw up an assignment list for using the PLC as a control unit.



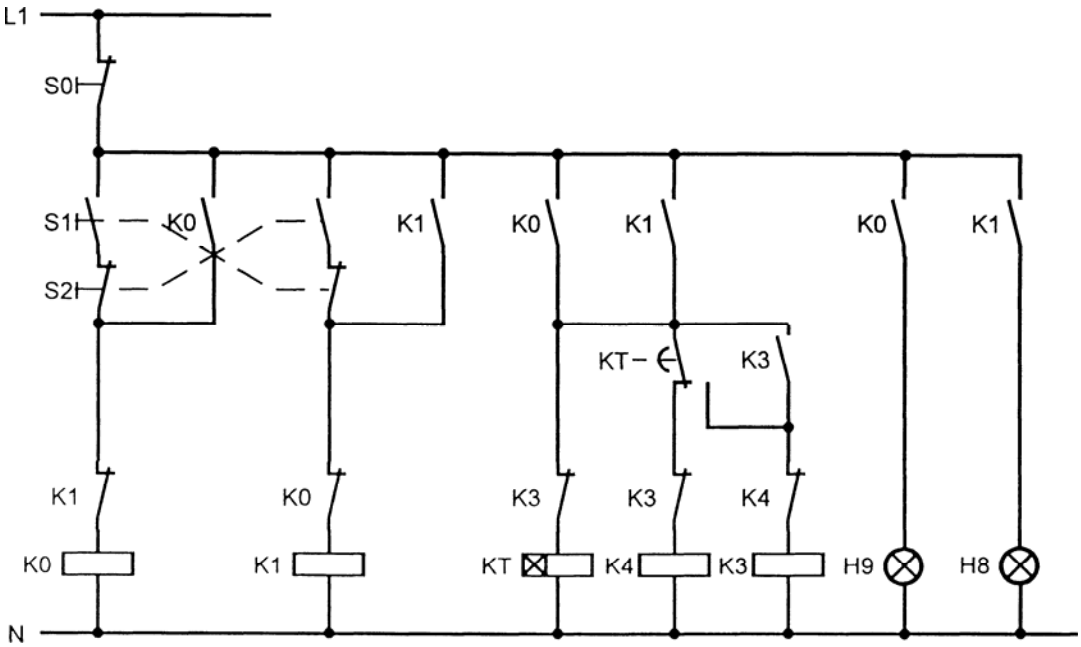
Further possibilities:
Develop an automatic switchover operation by including a time function from the existing circuit diagram. Pushbutton S2 is omitted and replaced by a timer.

2.6 Reversing Star-Delta Circuit

The main circuit of a reversing star-delta circuit is depicted with the following contactor functions:
K0 = Mains contactor - clockwise rotation
Kl = Mains contactor - counterclockwise rotation
K3 = Delta contactor
K4 = Star contactor



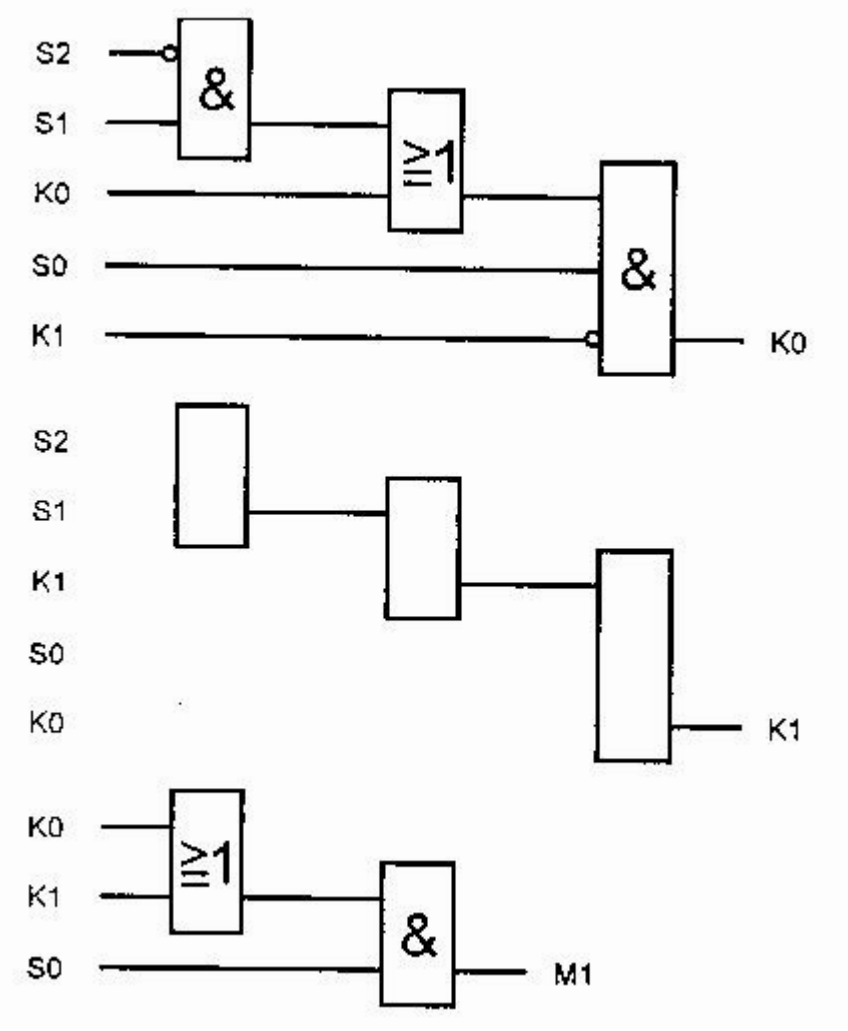
Control circuit:

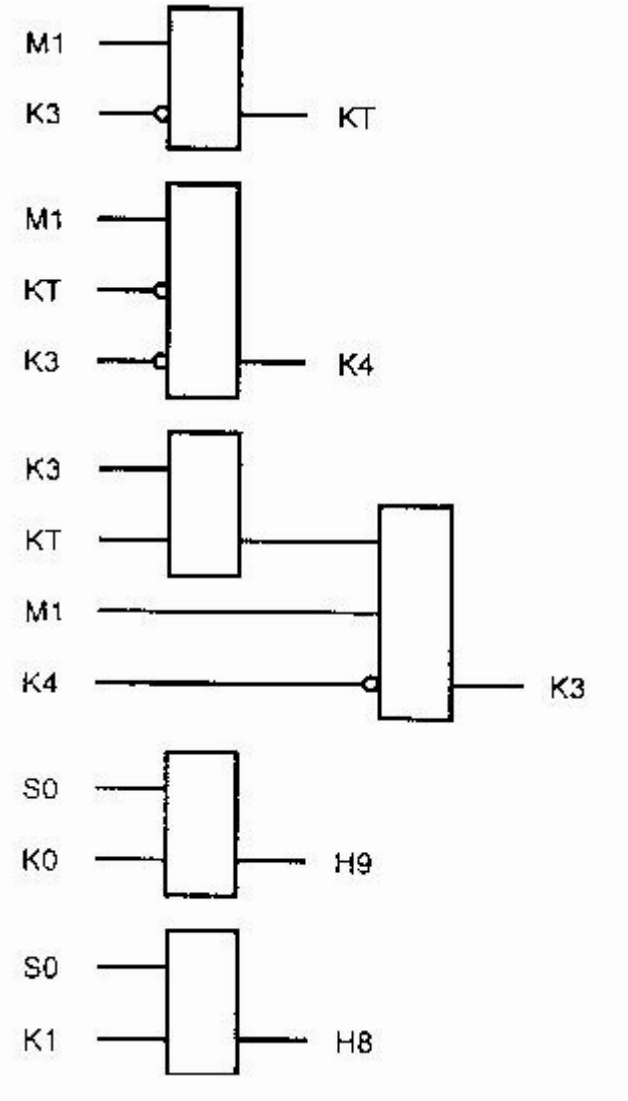


The mains contactor K0 is activated for clockwise rotation of the motor by actuating pushbutton S1. K0 is self-holding. For counterclockwise rotation the mains contactor K1 is activated by pressing pushbutton S2. K1 is self-holding. Both contactors are interlocked, i.e. pushbutton and contactor are latched.

The mains contactor K0 or the mains contactor K1 activates the star contactor K4 and operates the time relay KT. With a changeover contact KT deactivates the star contactor with time delay and then activates the delta contactor K3. K3 is self-holding and deactivates the time relay. The star contactor K4 and delta contactor

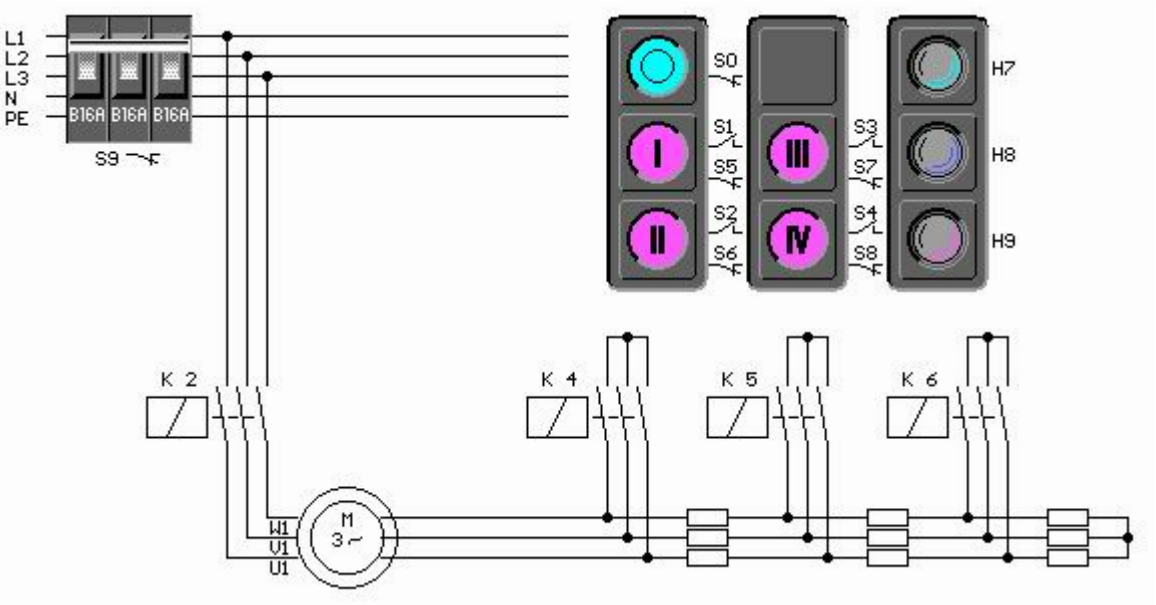
K3 are interlocked. The clockwise rotation direction is signaled by the light indicator H9 and counterclockwise rotation is signaled by the light indicator H8. Complete the function diagram and draw up an assignment list for using the PLC as a control unit.



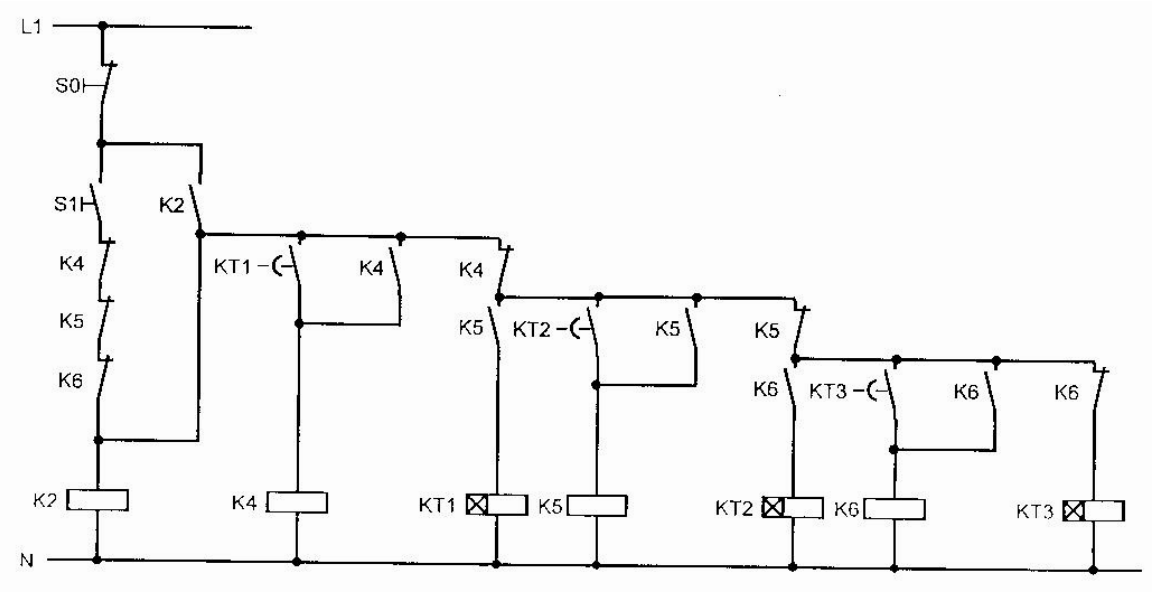


2.7 Slip-ring rotor with step starter

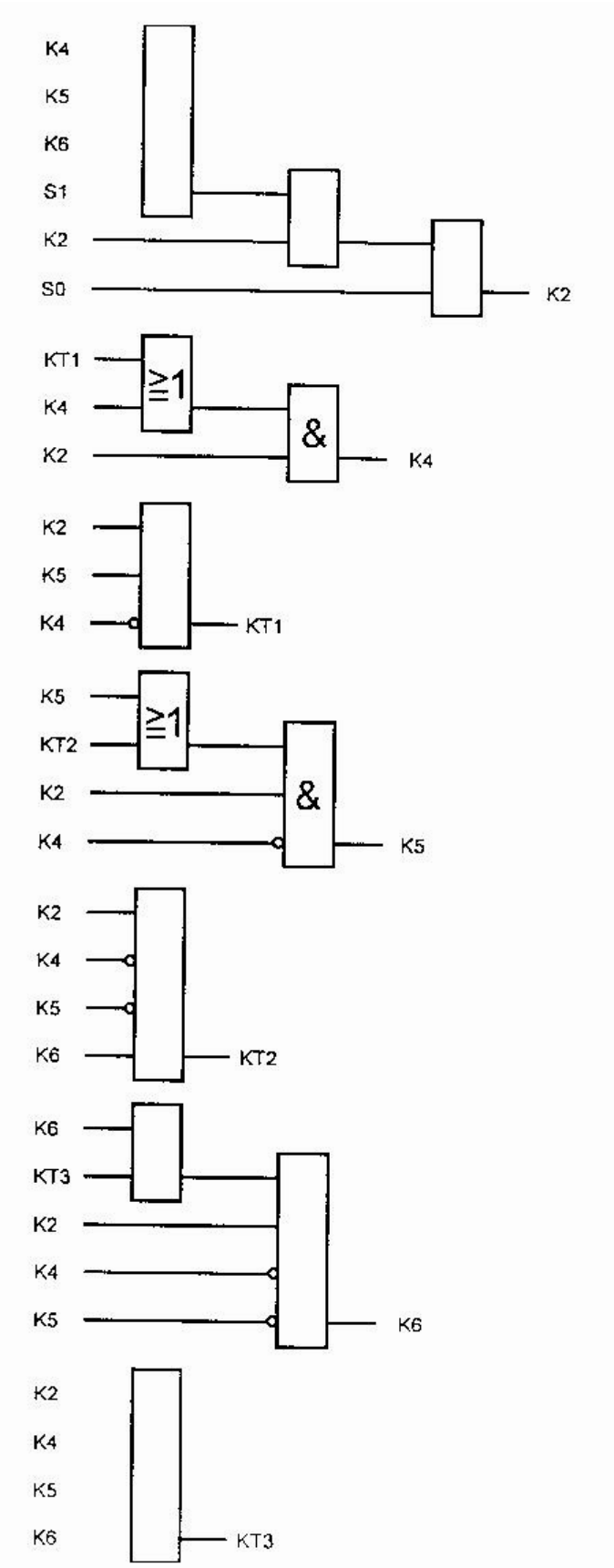
When the motor is switched on with mains contactor K2 the motor starts with all the step resistors in the rotor circuit connected. During run up the step resistors are short-circuited to the rotor one after the other with a time delay of 1s.



Control circuit:



Complete the function diagram and draw up an assignment list for using the PLC as a control unit.


K4
K5
K6
S1
K2
S0
K2
KT1
≥1
K4
K2
&
K4
K2
K5
K4
KT1
K5
≥1
KT2
K2
&
K4
K5
K2
K4
K5
K6
KT2
K6
KT3
K2
K4
K5
K6
K2
K4
K5
K6
KT3

Assignment list for the inputs and outputs

System input	Active for	Control output	Description	Commentary
K0	1		Mains contactor	
K1	1		Mains contactor	
K2	1		Mains contactor	
K3	1		Mains contactor	
K4	1		Star contactor	
K5	1		Step contactor	
K6	1		Step contactor	
H7	1		Light indicator red	
H8	1		Light indicator yellow	
H9	1		Light indicator green	

System output	Contact NO/NC	Control in	Description	Commentary
SO	NC		Pushbutton 0	
Sl	NO		Pushbutton I	
S2	NO		Pushbutton II	
S3	NO		Pushbutton III	
S4	NO		Pushbutton IV	
S5	NC		Pushbutton I	
S6	NC		Pushbutton II	
S7	NC		Pushbutton III	
S8	NC		Pushbutton IV	
S9	NC		Fuse	

Marker/ Timer	Active for 1/0	Control	Description	Commentary
KH	1		Auxiliary contactor	
KT	1		Timer	

NO == Normally Open supplies a 1-signal when activated
NC = Normally Closed supplies a 0-signal when activated