Western Cape Government

Western Cape Education Department
Directorate: Curriculum FET

ELECTRICAL TECHNOLOGY
(Power Systems)
MOTOR STARTERS REVISION
2024
Grade 12

	TERMINOLOGY	
	Interlocking contact	An **interlocking contact** refers to a type of electrical contact used in systems that require certain conditions to be met before a specific action can occur. It's typically used in safety, control, or automation systems to prevent conflicting actions or operations. Interlocking contacts ensure that two or more devices or circuits do not operate simultaneously in a way that would cause damage or pose a safety risk. interlocking contacts are mechanisms (either mechanical or electrical) that ensure safe, orderly, and non-conflicting operations within complex systems.
	Hold-out contact	A **hold-out contact** is an electrical contact designed to prevent certain actions from happening until specific conditions are met, effectively "holding out" or blocking certain operations. This type of contact is often used to ensure safe operation in control systems by preventing circuits from being energized until it's appropriate to do so. a hold-out contact may keep a motor off until another part of the system is in the correct position. This ensures that components operate in the right order and prevents accidents or damage.
	Hold-in contact	A **hold-in contact** (also called a "seal-in" contact or "latching" contact) is an electrical contact that maintains a circuit's energized state even after the initial activation signal is removed. This type of contact is commonly used in control circuits, particularly in conjunction with relays and contactors, to keep a device powered on until a deliberate stop action is taken.
	On-delay timer	An **on-delay timer** is a type of timer commonly used in control circuits to delay the activation of a connected device or circuit for a specific amount of time after a triggering signal is received. ➢ **Trigger Signal**: When the control circuit (such as a push button, relay, or sensor) sends a signal to the timer, it starts counting down the preset time. ➢ **Timing Period**: During the countdown, the output remains switched off. ➢ **Output Activation**: After the preset delay period elapses, the timer switches the output on.

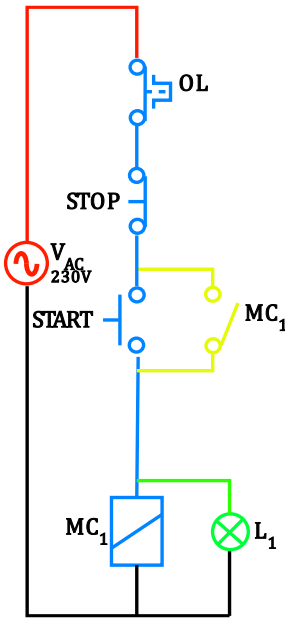
		Sequential Control: Ensuring operations occur in the correct sequence, such as turning on a conveyor belt only after a motor starts. **Safety**: Allowing time for other components to stabilize (e.g., motors to reach speed or pressure to equalize) before activating connected equipment. **Process Control**: Introducing a delay in industrial processes where timing is critical for proper operation.
	Off-delay timer	An **off-delay timer** is a type of timer used in control circuits to delay the deactivation of a connected device or circuit after the input signal is removed. This timer ensures that the output remains active for a specified duration after the controlling signal has been turned off ➢ **Trigger Signal**: When the control input (like a push button, relay, or sensor) is activated, the output of the timer is immediately energised. ➢ **Timing Period**: During this countdown, the output remains energized (active). ➢ **Output deactivation:** Once the countdown expires, the output is switched off. **Lighting Control**: Keeping lights on for a few seconds or minutes after a person leaves a room. **Motor Stopping**: Allowing a fan or motor to run briefly after a process completes for cooling or clearing materials. **Safety Systems**: Providing a delay before cutting off equipment to ensure complete operation of a cycle or process.
	Latching	**Latching** is a control mechanism in electrical and automation systems where a circuit remains in a specific state (on or off) after being activated, even if the original trigger signal is removed. Latching is often implemented using relays**,** contactors**, or** programmable logic controllers (PLCs)**.**

1. DIRECT ONLINE STARTER WITH OVERLOAD

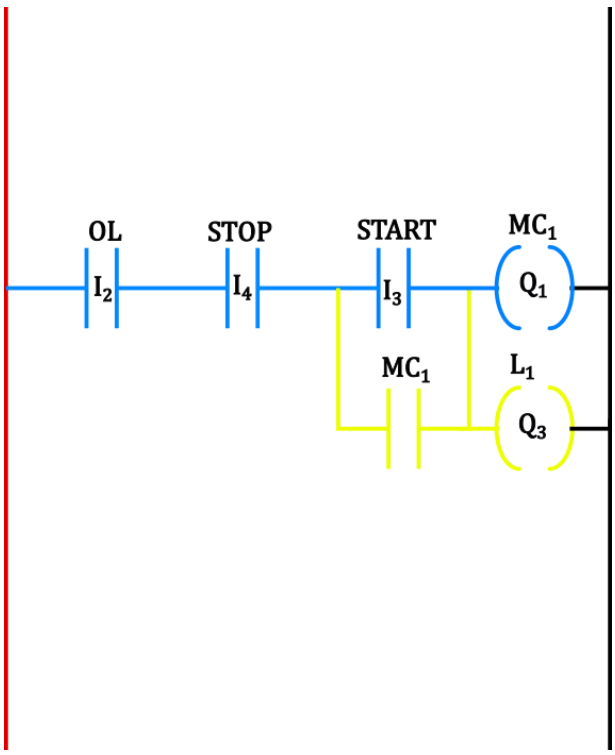
The direct online starter (DOL) is the simplest starter and serves as the building block of most of the other starters commonly encountered. DOL means that power is applied directly to a motor.

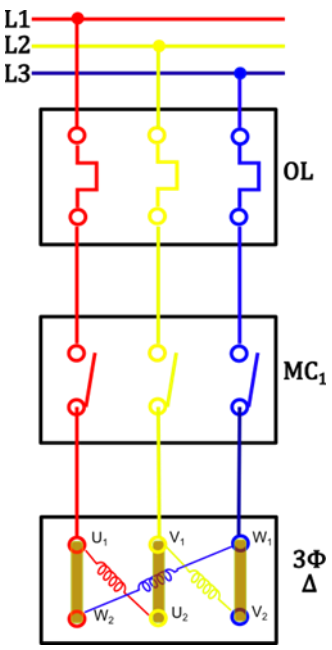
The operating principle of this starter is:

- START button is pushed.
- The coil of the main contactor MC1 is energised.
- Hold-in contact MC1 closes and latches the starting circuit.
- The three main contacts of main contactor MC1 close connecting the live lines to the motor.
- The motor starts to run.
- When STOP is pressed power is cut off, MC1 is de-energised and the motor stops.



Control circuit of the Direct-on-Line Starter

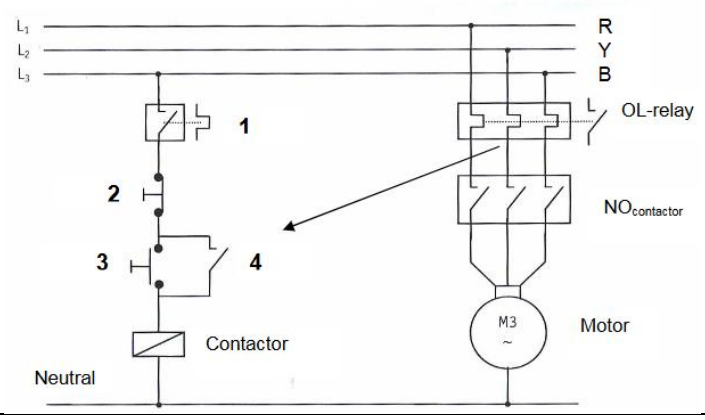




Main circuit of the Direct-on-Line Starter

NSC QUESTIONS – DIRECT-ON-LINE

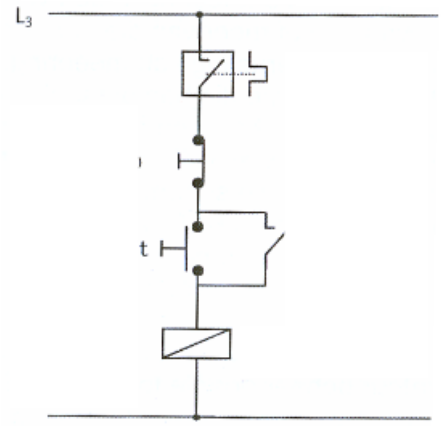
1. **The figure below shows both the main circuit and control circuit of a three-phase direct-on-line motor starter**

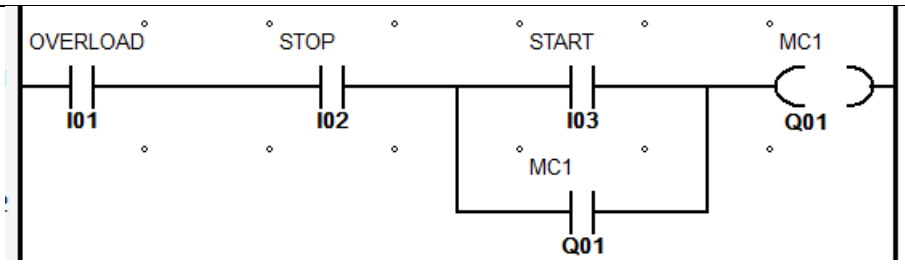


1.1 List the parts numbered 1 to 4.

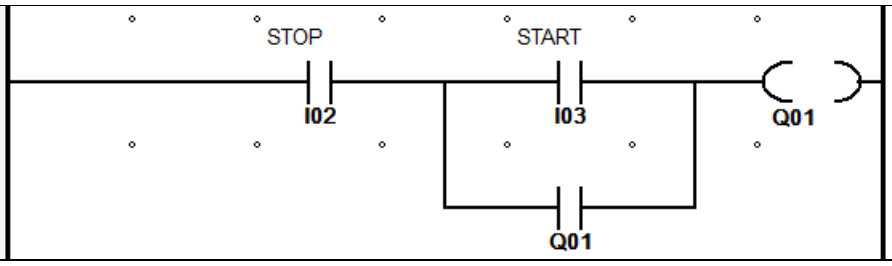
1 – Overload contacts
2 – Normally closed stop
3 – Normally open start
4 – Normally open hold-in

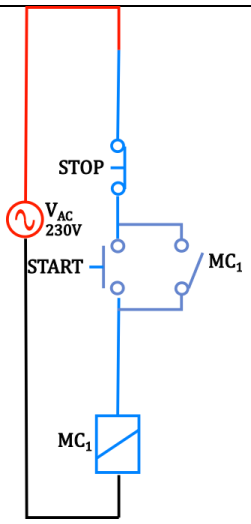
2. **Draw the ladder logic programme of the diagram in the figure below.**



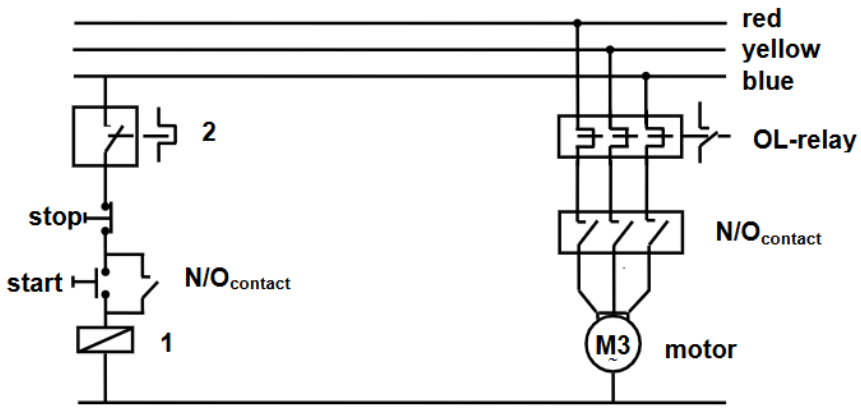


3. **Draw the relay control circuit of the ladder logic diagram in the figure below.**





4. **The circuit diagram shown in FIGURE 10.1 represents the control circuit and the power circuit of a direct-on-line-starter.**



4.1 **Identify the component labelled 1.**

Coil of contactor

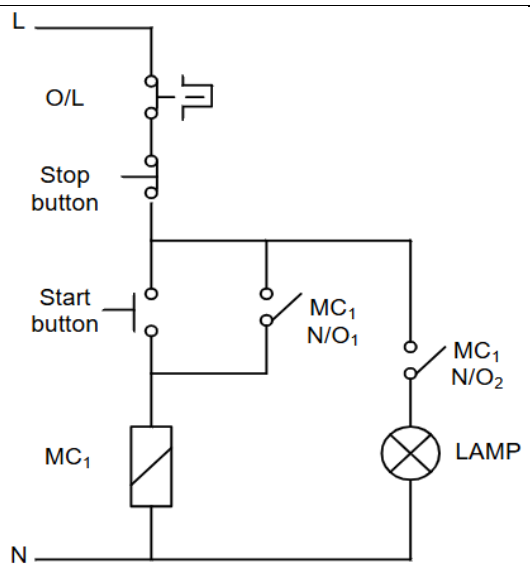
4.2 **Explain what occurs to the three-phase induction motor if one phase fails.**

The motor will keep on operating, but to maintain the same output Power the current on the other two phases will increase. If the protection is set correctly, it will engage, protecting the motor from permanent damage.

4.3 **Describe the protection that the component labelled 2 offers to the motor.**

The overload relay is designed to protect the motor and motor wiring against current fault onditions. It will open and cut power to the motor.

5. **Draw a ladder logic diagram that will execute the same function as the control circuit in the figure below.**

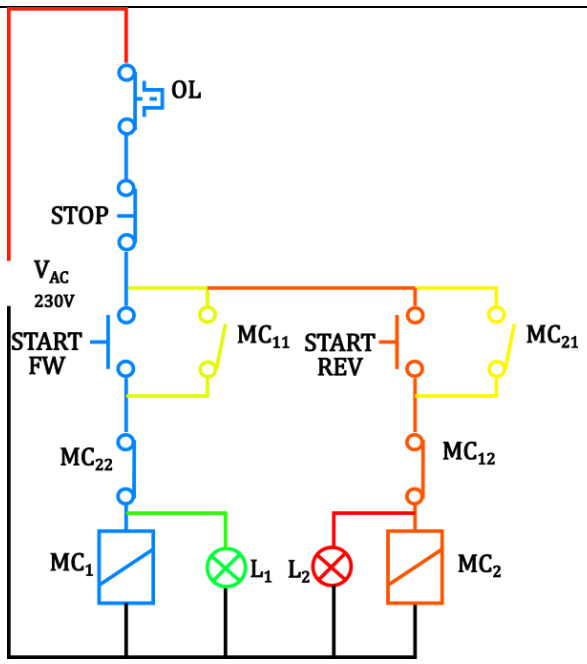


2. FORWARD AND REVERSE STARTER WITH OVERLOAD

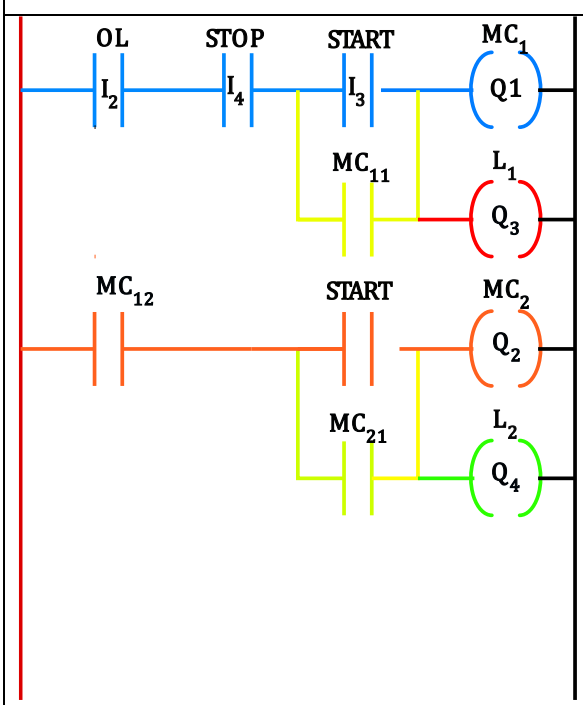
The forward-and-reverse starter is designed to change the direction of rotation of a motor by either pushing a FWD or a REV button. It is important to have additional protection built in to prevent a fault condition when accidentally pushing both buttons simultaneously. Large motors may require a delay timer to ensure that the motor come to a complete standstill before changing direction.

The principle of operation is as follows:

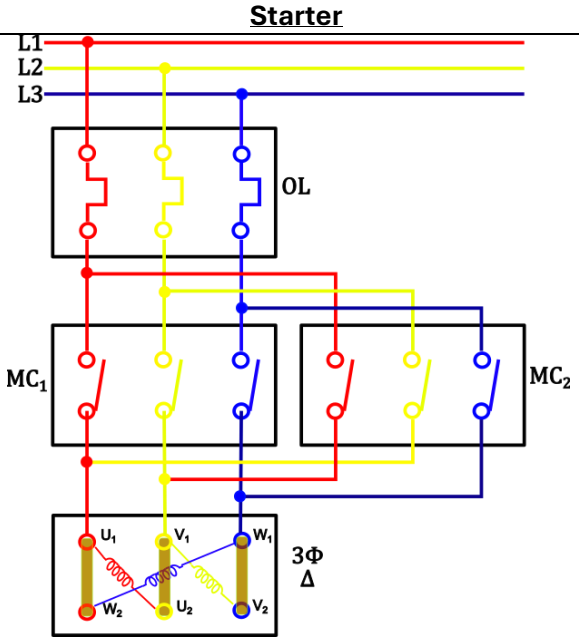
- FWD button is pushed;
- The coil of main contactor MC1 is energised;
- The interlocking hold-out contact MC12 opens and prevent the REV contactor from receiving power even if the REV button is pushed;
- The hold-in contact MC11 latches the starting circuit;
- The main contacts of MC1 close and the motor run FWD;
- To change direction, STOP must be pressed. MC1 is de-energised, the motor stops and interlocking hold-out contact MC12 closes again;
- When REV is pressed, MC2 is energised, MC22 opens and prevents MC1 from being energised;
- MC21 latches the REV start circuit;
- The motor runs in reverse.



Control circuit of the Forward-and-Reverse Starter

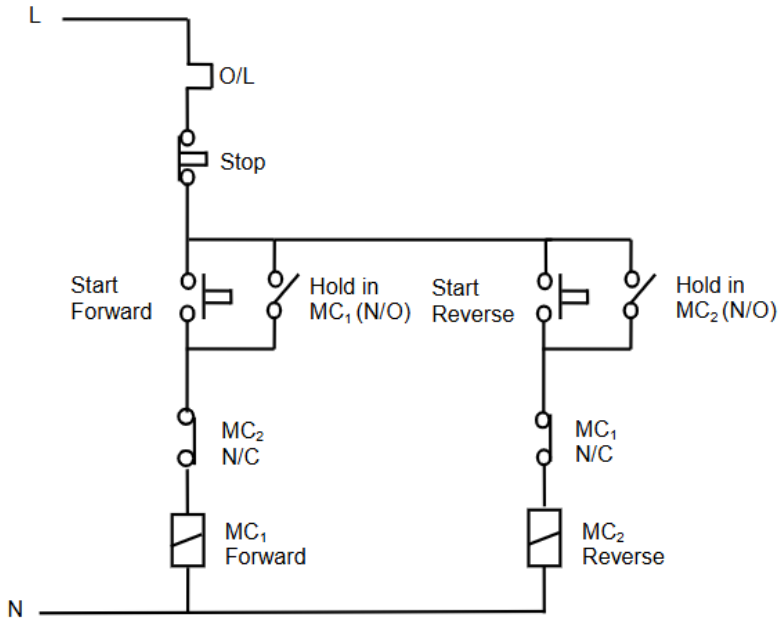
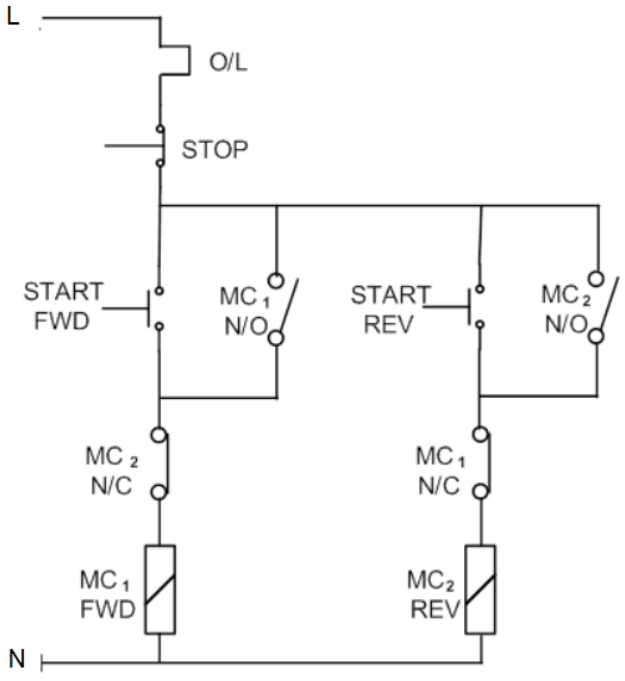


Ladder Logic implementation of the Forward-and-Reverse Starter Control circuit

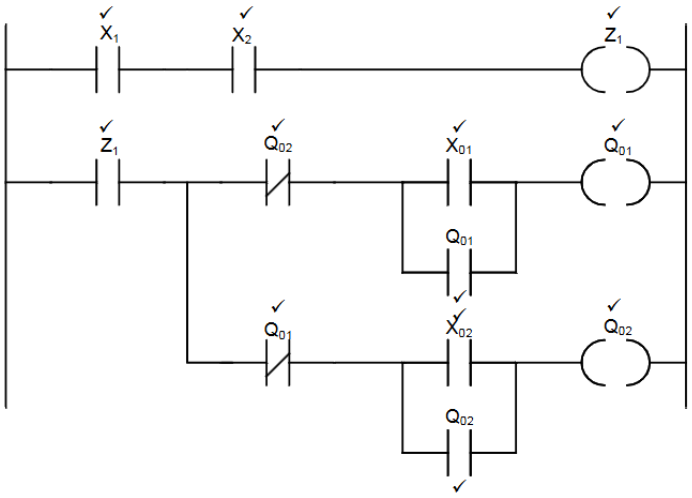


Main circuit of the Forward-and-Reverse Starter

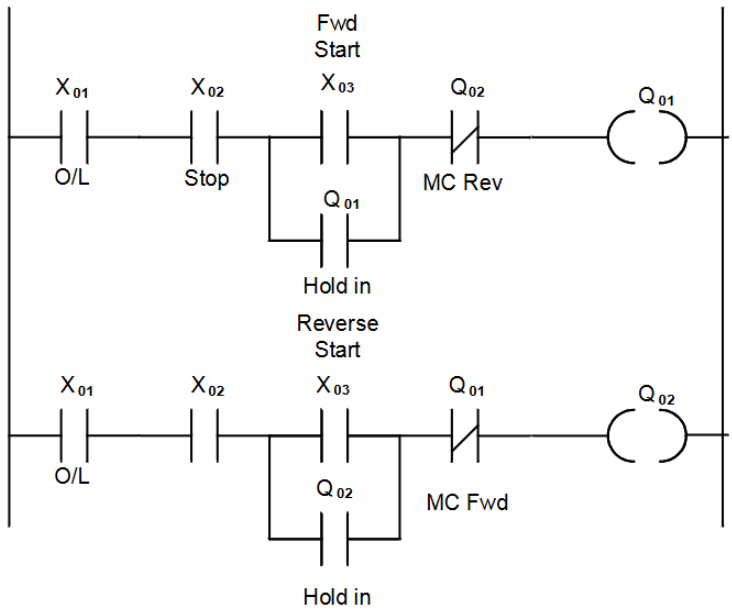
NSC QUESTIONS – FORWARD-AND-REVERSE

1.	**Refer to the circuit diagram in FIGURE 4.1**
	
1.1	**Describe how the contact O/L protects the motor.**
	If the motor draws a greater current than the setting on the overload, the overload will trip (activate), and power will be removed from the control circuit, which will shut down the motor.
1.2	**Describe how interlocking is used in the starter.**
	In the forward direction, the MC1 coil is energized. The normally closed contact of MC1 is now open. The open contact of MC1 now prevents the MC2 coil from being energized. Only after the MC1 coil is de-energized will MC2 close. The closing of the normally closed MC1 contact (when it is de-energized) allows the MC2 coil to be energized when the reverse switch is pressed. Similarly, the normally closed MC2 (N/C) contact prevents the MK1 coil from being energized while the motor's direction of rotation is reversed.
1.3	**Describe the function of a no-volt coil in a motor starter.**
	The function of the no-voltage coil in a motor is to prevent the motor from automatically starting when power is restored after a power interruption.
1.4	**State how the direction of rotation of a three-phase motor may be reversed.**
	By swapping the connections of any two of the three phases.
2.	**Refer to the figure below and answer the questions that follow.**
	

2.1	**Draw the ladder logic diagram that will execute the same function in a PLC system.**



Labels	Description
X_1	O/L
X_2	Stop
Z_1	Marker/flag
Q_{02}	Reverse MC2
Q_{01}	Forward MC1
X_{01}	Start forward
X_{02}	Start reverse



2.2	**Give ONE example where the circuit in FIGURE 6.6 may be used in an electrical application.**
	Lifts *Cranes* *Conveyor belts*

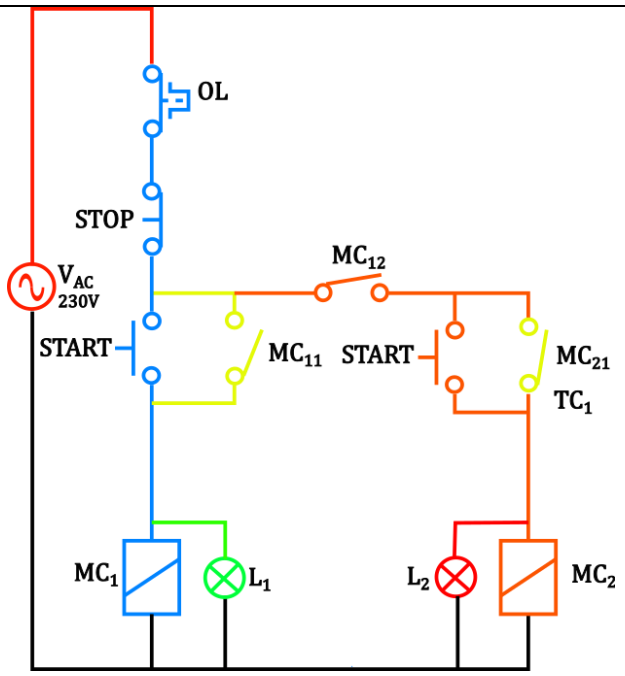
3. MANUAL SEQUENCE MOTOR CONTROL STARTER WITH OVERLOAD

The purpose of the manual sequence starter is to allow a device to be started after a first device are already running.

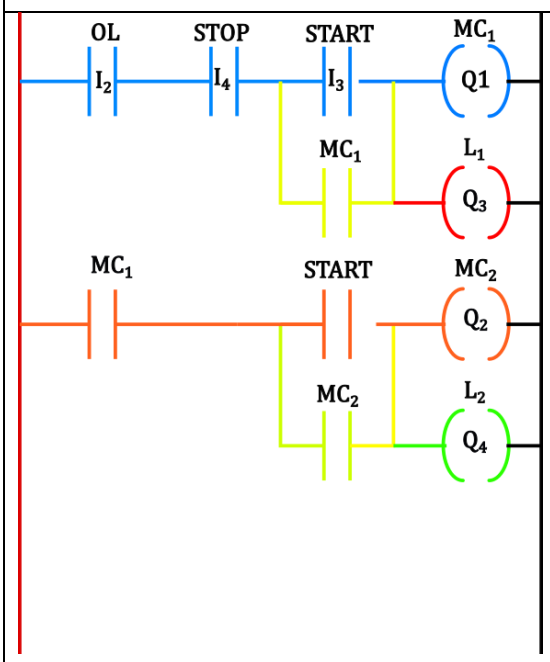
An example is a cooling fan that first need to run at full speed before a large motor may be started. In the example in the two figures, a single-phase fan runs and afterwards a three-phase motor may start up by pressing a second start button.

The principle of operation is as follows:

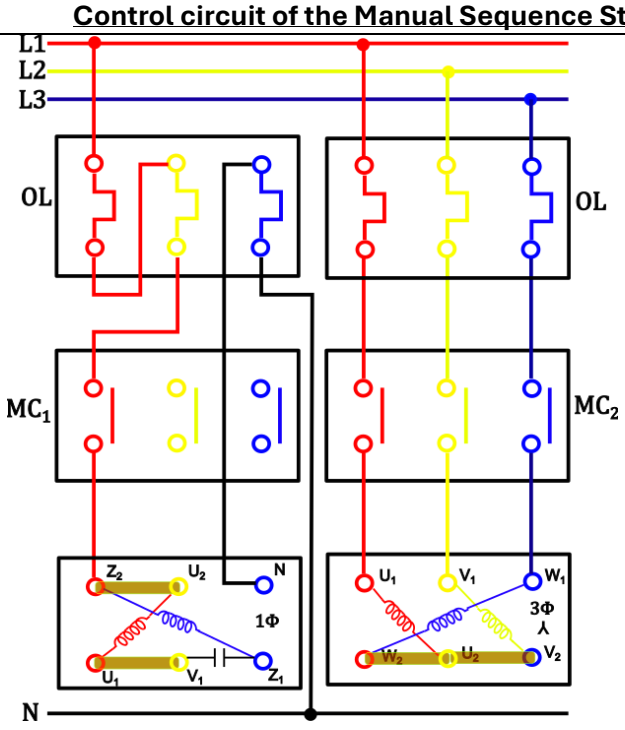
- START button for the fan is pressed;
- The fan main contactor MC1 is energised and the main contacts of MC1 closes;
- The fan starts to run;
- Contact MC11 closes and latches the start circuit;
- Contact MC12 closes and allows power to be supplied to the three-phase motor start circuit;
- When the START for the motor button is pressed, the coil of main contactor MC2 is energised;
- Hold-in contact MC21 latches the motor starting circuit;
- The main contacts of MC2 closes;
- The three-phase motor starts to run.



Control circuit of the Manual Sequence Starter

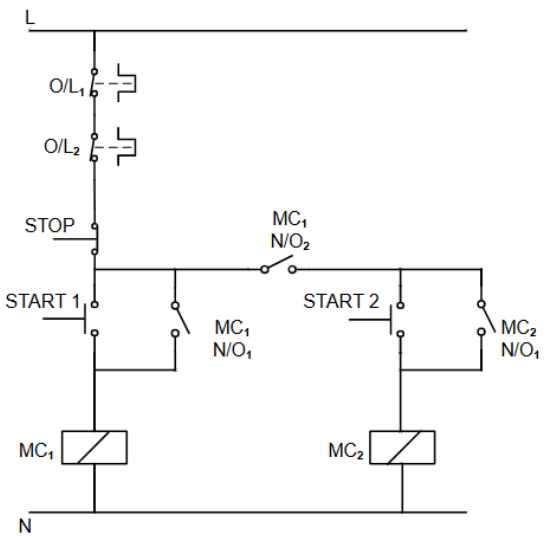
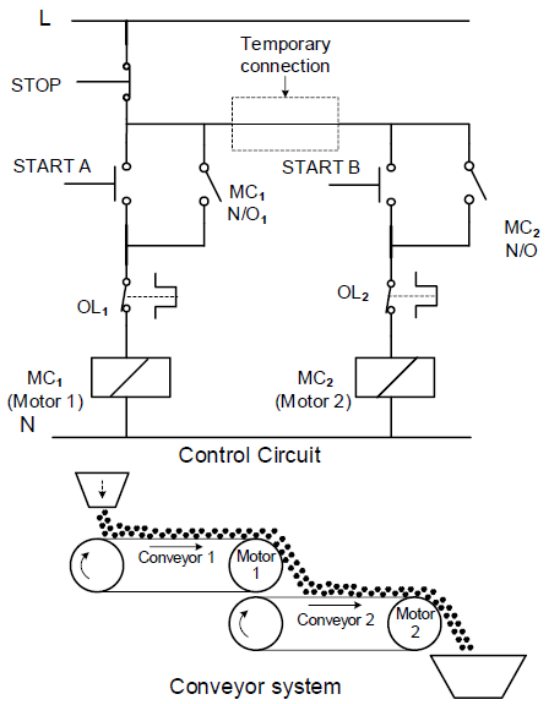


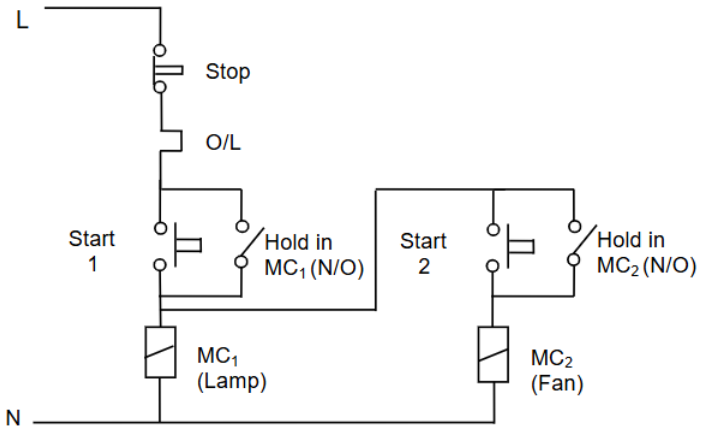
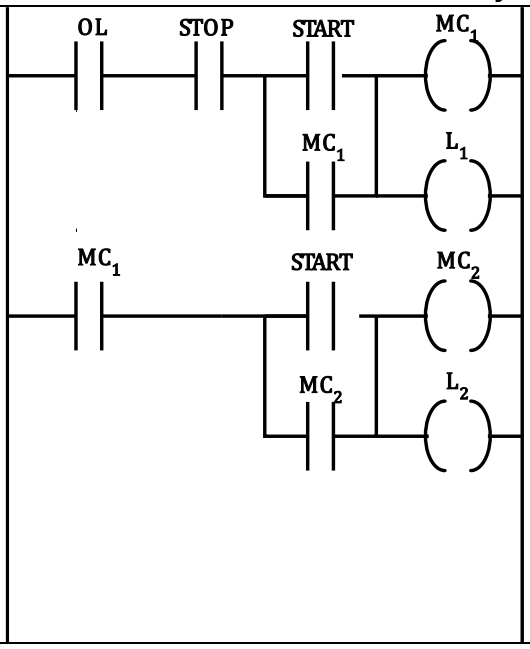
Ladder Logic implementation of the Manual Sequence Starter control circuit



Main circuit of the Manual Sequence Starter

NSC QUESTIONS – MANUAL SEQUENCE

1.	**Refer to the figure below and answer the questions that follow**
	
1.1	**Name the component that prevents MC1 from automatically energising when the power is restored after a power failure.**
	MC1N/O1
1.2	**State the function of MC1 N/O2.**
	MC1N/O2 is a hold-out contact ensuring that MC2 can only be energised if MC1 is energised.
1.3	**Explain the purpose of wiring O/L1 and O/L2 in series with the supply.**
	If either motor 1 or motor 2 is overloaded the whole circuit will be isolated. If any one of the two overload relays are activated by either O/L1 or O/L2 it will cut the power to the whole circuit.
1.4	**Explain the operation of the circuit.**
	When START 1 is pressed MC1 will energise. This will immediately close contacts MC1N/O1 (hold-in) and MC1N/O2 (hold-out) and START 1 button can be released. Only after MC1N/O2 is closed you can press START 2. When START 2 is pressed, MC2 will energise closing contact MC2N/O1 so that the start button can be released. When the STOP button is pressed, MC1 will de-energise opening contact MC1N/O2 and de-energising MC2.
1.5	**Explain how the circuit operation will be affected if contact MC2 N/O1 is faulty and permanently closed.**
	If contact MC2N/O1 is faulty and permanently closed, contactor MC2 will immediately energise when MC1 is energised, without pressing START button 2.
2.	**Refer to the figure below and answer the questions that follow.**
	

2.1	**Identify the motor starter control circuit in the figure above.**
	Manual sequence starter . NOTE: Two DOL starters
2.2	**Explain the function of MC1 with reference to the main (power) circuit.**
	MC1 is a contactor that energises and de-energises motor 1 in the main (power) circuit whenever the start or stop button is pressed .
2.3	**State the advantage of having two overload relays in the circuit.**
	Each motor is protected by its own overload relay independently .
2.4	**Explain the disadvantage of connecting the overloads as shown in the control circuit in the figure when MC1 and MC2 are controlling the two motors on the conveyor belt system.**
	If motor 2 is overloaded and switched off by the overload, motor 1 will continue operating and feeding material onto conveyor 2 . This will cause a pile up of material on conveyor 2 .
2.5	**Currently, MC2 can be energised either before or after energising MC1. Explain how the control circuit can be altered to prevent MC2 from being energised without energising MC1 first.**
	By connecting a N/O contact of MC1 in the place of the temporary connection MC2 will only be able to energise after MC1 is energised.
3.	**Refer to the circuit in the figure below.**
	
3.1	**MC1 switches on a lamp and MC2 closes a contactor that energises a fan. Draw the PLC ladder diagram that would execute the same function of the relay control circuit in the figure.**
	
3.2	**State what programming function must be included in the ladder diagram to automate the starting of the fan (MC2).**
	A time function must be included in the diagram after incorporating the second start function.

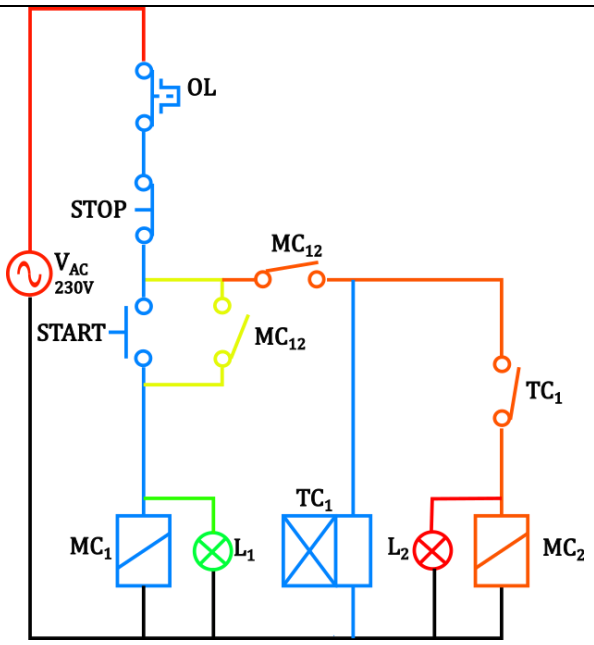
4. AUTOMATIC SEQUENCE MOTOR CONTROL STARTER WITH OVERLOAD

The purpose of the automatic sequence starter is to allow a device to start automatically a preset time after a first device are already running.

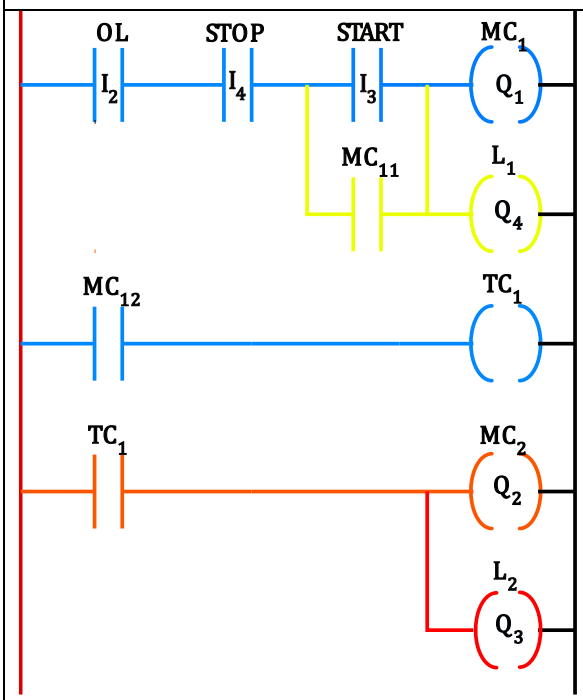
An example is a cooling fan that first need to run at full speed before a large motor may be started. In the example in the two Figures, a single-phase fan runs, and a time, such as 10 seconds later three-phase motor starts up.

The principle of operation is as follows:

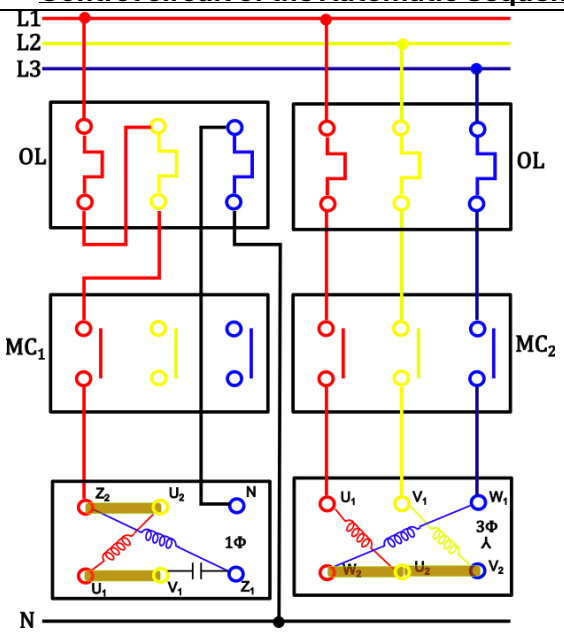
- START button is pushed.
- The coil of the fan main contactor MC1 is energised and the main contacts of MC1 closes.
- The fan starts to run.
- Contact MC11 closes and latches the start circuit.
- The timer coil is energised and the time starts to count down to the preset time.
- After the countdown time elapses, timer contact TC closes and the coil of main
- Contactor MC2 is energised.
- The main contacts of MC2 closes.
- The three-phase motor starts to run.



Control circuit of the Automatic Sequence Starter



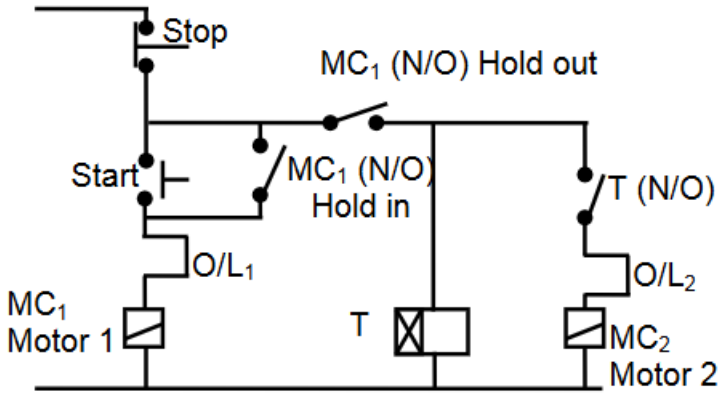
Ladder Logic implementation of the Automatic Sequence Starter control circuit



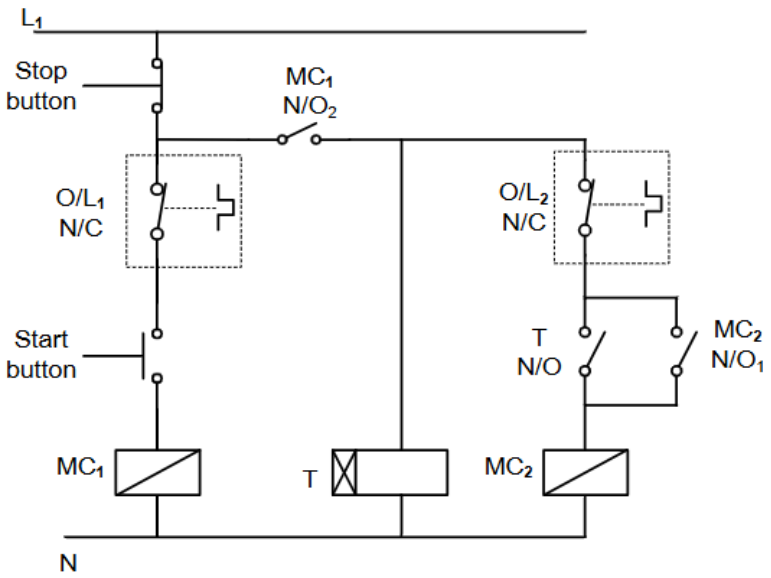
Main circuit of the Automatic Sequence Starter

NSC QUESTIONS – AUTOMATIC SEQUENCE

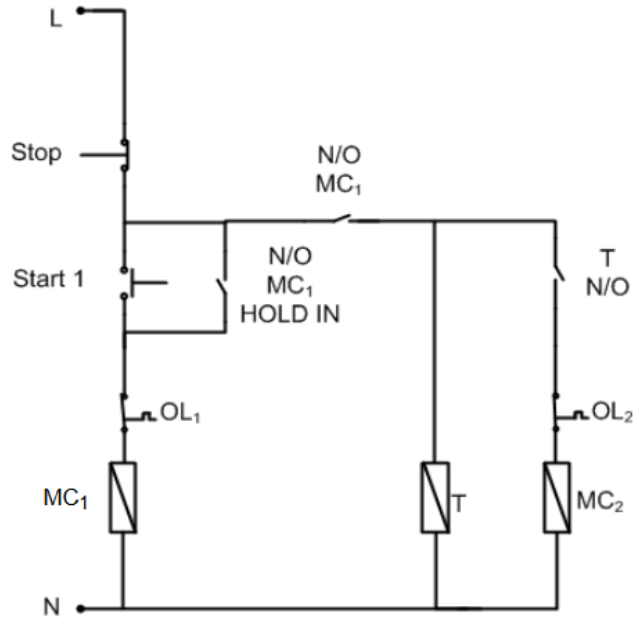
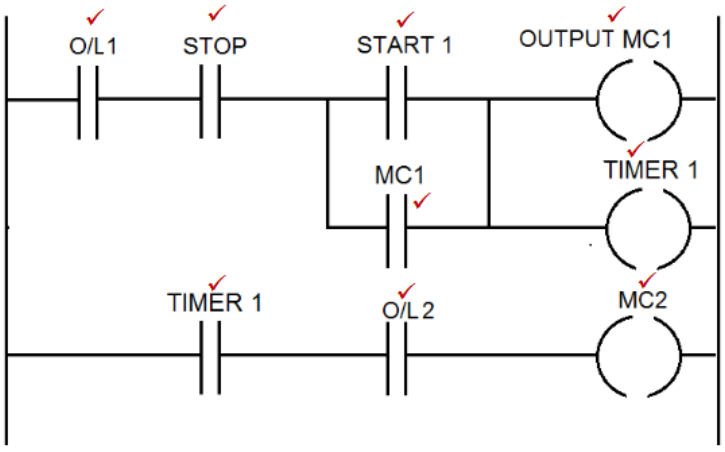
1.	**The control circuit in th figure below represents an automatic sequence starter**



1.1	**Describe the function of the timer in the circuit.**
	The timer determines the time when the second motor is switched on after the first motor.
1.2	**Describe the starting sequence of the starter if the timer is set on one minute.**
	When the start button is depressed this will energise the coil of the contactor that starts motor 1. The contactor MC1 will now close starting motor 1. The N/O of MC1 (hold in) will close keeping the contactor closed when the start button is released. The N/O of MC1 (hold out) will now close energising the timer coil. The timer contactor will begin to time through. After one minute the N/O on the timer will close energising the coil of contactor 2 starting motor 2.
2.	**The circuit in the figure below is used to control TWO three-phase motors. Answer the questions that follow.**



2.1	**Identify component T.**
	Timer
2.2	**Explain the purpose of having TWO overload units in the circuit.**
	Each overload unit monitors the current drawn by each motor independently.
2.3	**Identify the error in the circuit.**
	The MC1N/O1 auxiliary contact (Hold contact) connected in parallel with the start button is omitted.
2.4	**Describe how this error affects the operation of the circuit.**
	The moment the start button is released MC1 will de-energise, opening MC1N/O2, disconnecting the parallel section of the control circuit, disabling timer T1, thus MC2 will not be energised.

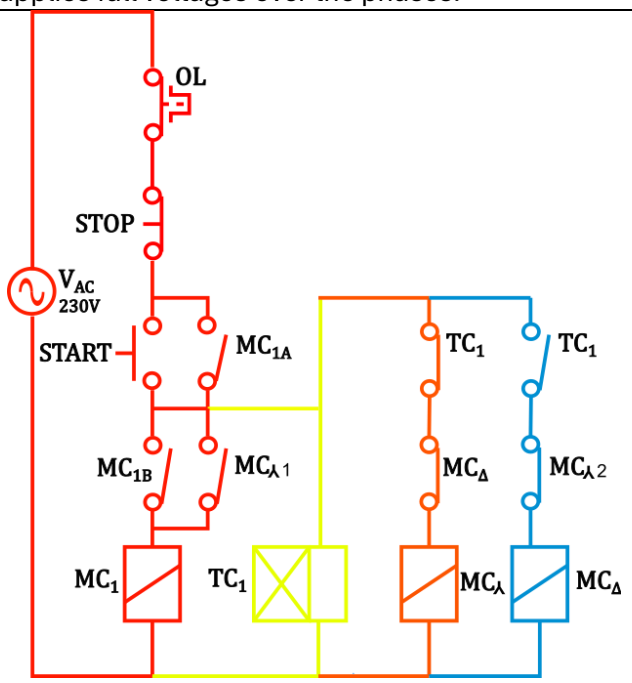
3.	**Refer to the figure below and answer the questions that follow.**
	
3.1	**Draw the ladder logic diagram that will execute the same function in a PLC system.**
	
3.2	**Give ONE example where the circuit in FIGURE 6.7 may be used in an electrical application.**
	Motor starter with a time delay

5. AUTOMATIC STAR-DELTA MOTOR CONTROL STARTER WITH OVERLOAD

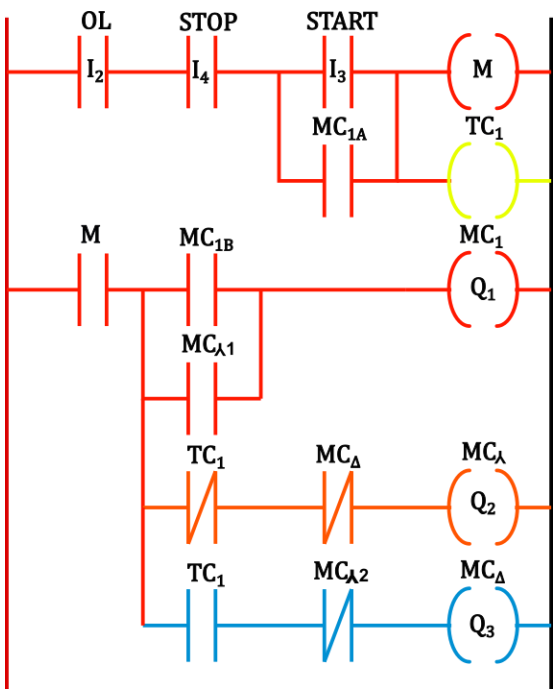
The purpose of the star-delta starter is to create a soft start of a three-phase induction motor by limiting the inrush current when starting from stand-still.
The motor initially starts in star, with a lower voltage of the three phases and once the motor is running at speed, it switches automatically to delta and applies full voltages over the phases.

The principle of operation of the starter is as follows:

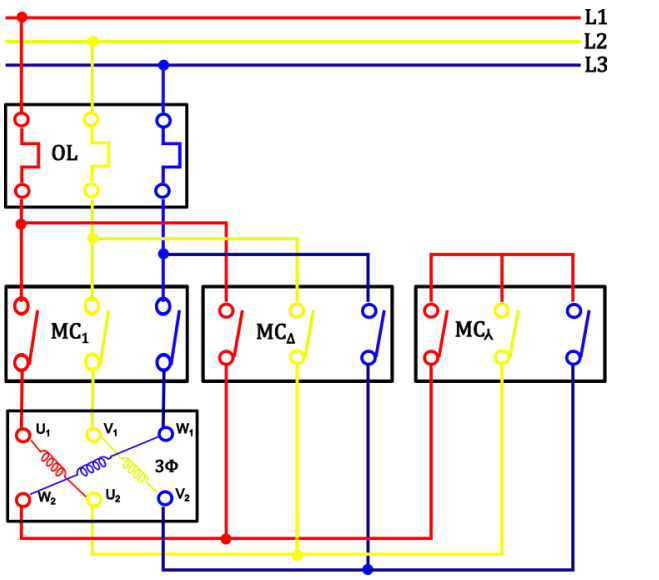
- When the START button is pressed.
- Contactor coil MCλ is energised; contact MCλ1 closes; contact MCλ2 opens and main contacts MCλ close to put the motor into star.
- Timer TC1 is energised simultaneously and the countdown towards the switchover time starts.
- MC1 is energised, the three main contacts MC1 close and the three-phase motor starts running in star.
- The start circuit is latched by contacts MC1A and MC1B which close.
- After the timer countdown elapses, contact TC1 N/C open and TC1 N/O closes.
- MCλ is de-energised and contact MCλ2 closes.
- MCΔ is energised and motor switches to delta.
- When the STOP button is pressed, power is cut to both the control and the main circuits.



Control circuit of the Automatic Star-Delta Starter

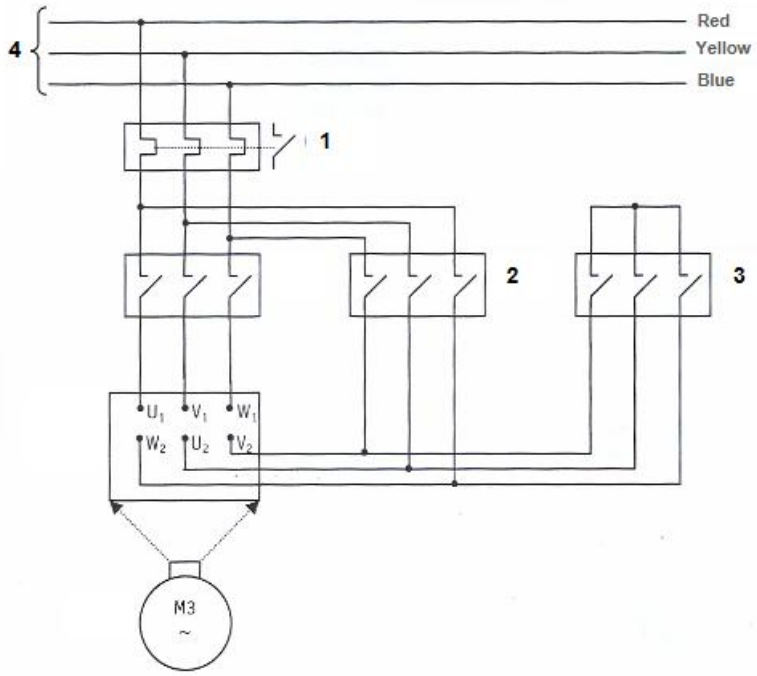
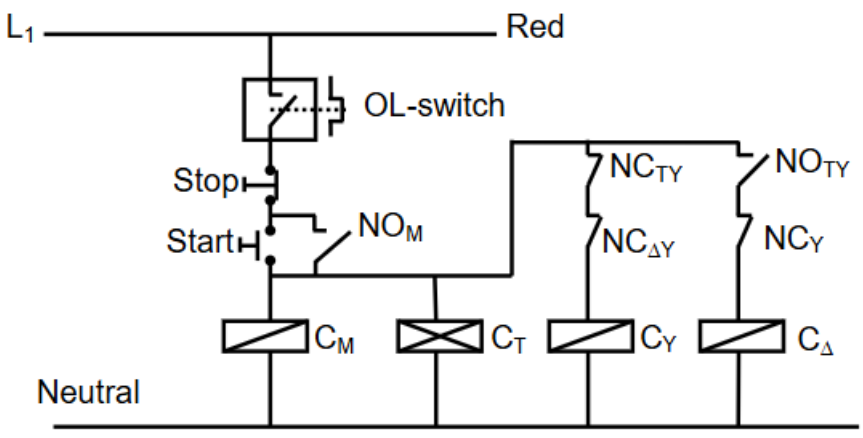


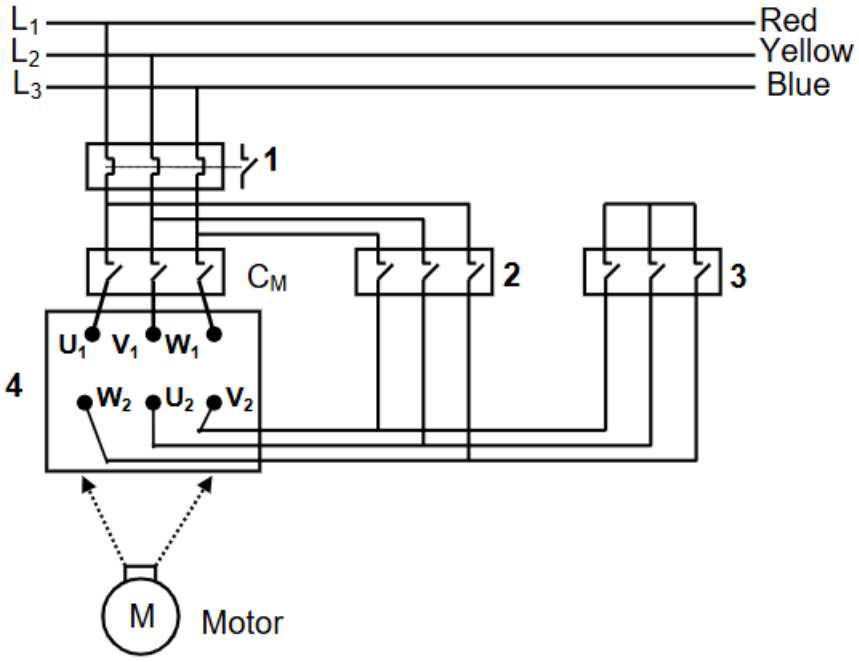
Ladder Logic implementation of the Automatic Sequence Starter control circuit



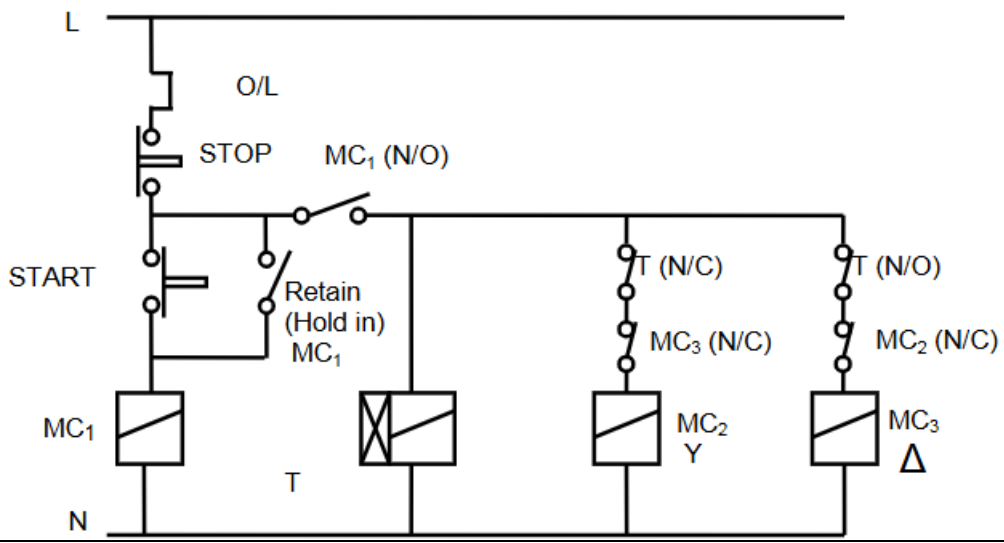
Main circuit of the Automatic Star-Delta Starter

NSC QUESTIONS – AUTOMATIC STAR-DELTA

1.	**With reference to the power circuit of the star-delta starter shown in the figure below, answer the questions that follow.**
	
1.1	**Label 1 to 4**
	1. Overload relay *2. Delta contactor* *3. Star contactor* *4. Three- phase supply*
1.2	**Describe the function of part 1 in the diagram.**
	The overload relay is designed to protect the motor and motor wiring under over current fault conditions. It will open and remove power from the motor.
1.3	**On which motor is a star-delta starter used and why?**
	The starter is used to limit the starting current of squirrel cage induction motors
2	**The diagrams in the figures below show a star-delta control and power circuit. With reference to these diagrams, answer the questions that follow.**
	



2.1	**With reference to the power circuit of the star-delta starter, label parts 1 to 4.**
	1- overload *2- delta contactor* *3- star contactor* *4- terminal box or stator connection*
2.2	**Explain the term normally open with reference to the control circuit.**
	Normally open contacts are contacts open in the de-energised state closed in the energised state.
2.3	**Describe the starting sequence of the control circuit. Refer to interlocking.**
	When the N/O start is depressed the main contactor, the timer contactor and the star contactor are all energised supplying the motor which is now connected in the star mode with power. The timer contactor now begins to time through. Once timed through to a preset time the N/C timer contacts open de-energising the star contactor. The N/O timer contacts close energising the delta contactor. This now connects the motor to delta. *The N/C star and delta contacts provide interlocking to prevent both contactors been energised at the same time.*
3.	**The figure below represents the control circuit of a star-delta starter.**



3.1	**State the function of a star-delta starter.**
	The function of a star-delta starter is to reduce the starting current of a motor at start-up.
3.2	**State the mode the motor will be connected in when running at full load.**
	Delta

3.3	**Explain the function of the contacts Retain (Hold in) MC1.**
	The retain (hold in) MC1 is the contact that will keep power on the main contactor when energised. The contactor is activated once the start button has been pressed. When the start is released power will remain on the main coil through the retain contactor MC1. *MC1 opens automatically (the contactor is spring loaded) when supply to the coil is removed, thus preventing automatic restarting when power returns after a power failure.*
3.4	**State, with a reason, what would happen to contact T (N/C) when the timer contactor is energised.**
	When the timer coil is energised the timer will begin to time through. Contact T (N/C) will only open when the timer has timed through a preset time.
3.5	**Describe the interlocking that prevents the star and delta contactors from being energised at the same time.**
	Contacts MC2 (N/C) & MC3 (N/C) in series with the star and delta contactors are normally closed. When MC2 is energised – MC2 (N/C) will disconnect MC3 and prevent it from being accidentally activated. While MC3 is de-energised, MC3 (N/C) will remain closed, allowing power to be transferred via T(N/C) and MC3 (N/C) to MC2. Timer T (N/C) will only transfer power via MC3 to MC2 while T is timing through. Once T times out and activates, T (N/O) closes and T(N/C) opens. MC2 is deactivated when T(N/C) opens, removing power from it and MC2 resets (The contactor is spring loaded). When MC2 resets, MC2 (N/C) closes and MC3 is able to be energised through T(N/O) and MC2 (N/C) which is now closed. This energises MC3 which in turn opens MC3 (N/C) thus preventing MC2 from being energised.