Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.

2) The model answer and the answer written by candidate may vary but the examiner should assess the understanding level of the candidate.

3) The language errors such as grammatical, spelling errors should not be given importance (Not applicable for subject English and Communication Skills).

4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner should give credit for any equivalent figure/figures drawn.

5) Credits to be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate’s answers and model answer (as long as the assumptions are not incorrect).

6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate’s understanding.

7) For programming language papers, credit may be given to any other program based on equivalent concept.
1 Attempt any FIVE of the following: 20

1 a) Explain the concept of NO / NC contacts.

Ans:
An electromechanical relay is generally having the two contacts named as normally open (NO) and normally closed (NC). A NO contact is one that is open when the relay coil is not energized and closes when the relay is energized. Conversely, the NC contact is closed when the relay coil is not energized and opens when the relay is energized. When a set of contacts closes, it provides power flow, or continuity, in the circuit where it is used.

![Diagram of NO and NC contacts]

2 marks for description

2 marks for diagram

1 b) Define and draw the symbols of the following:
   a) Selector switch
   b) Limit switch

Ans:
   a) Selector Switch:

   ![Symbol of Selector Switch]

   OR

   (Any other valid symbol may please be considered)

   Definition: Selector switch is a manually operated multi-position switch, which is usually adjusted by a knob or handle and may have detents to hold in a given position. It is used for making or breaking or changing the connections in a circuit or to select among alternatives.

   1 mark for definition

   b) Limit Switch:

   ![Limit Switch Symbols]

   OR

   1 mark for symbol
**Definition:** Limit switch is a switch that operates as an automatic control to prevent a mechanism or process from going beyond a prescribed limit. It is a switch operated by the motion of a machine part or the presence of an object, for controlling machinery as a part of the control system, as a safety interlocks or to count objects passing a point.

1 c) State difference between two-wire and three-wire control.

**Ans:**

**Difference between Two-wire and Three-wire control:**

<table>
<thead>
<tr>
<th></th>
<th>Two-Wire Control</th>
<th>Three-Wire Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The control component offers only two-wires for its connection in control circuit.</td>
<td>The control components offer three-wires for their connection in control circuit.</td>
</tr>
<tr>
<td>2</td>
<td>The control device is usually a switch, may be automatic such as limit switch, float switch etc.</td>
<td>The control components are usually push-buttons (Start and Stop).</td>
</tr>
<tr>
<td>3</td>
<td>On supply failure, the motor stops, but when it restores, the motor restarts automatically without starter and may get damaged. Thus motor is not protected from No-volt condition.</td>
<td>On supply failure, the motor stops and when it restores, the motor can not start automatically. The operator need to start the motor using starter. The safe starting ensures the No-volt protection.</td>
</tr>
</tbody>
</table>

1 d) Explain AC servomotor and give its application.

**Ans:**

**AC servo motor:**

There are some special applications of electrical motor where rotation of the motor is required for just a certain angle and not continuously for long period of time. For these applications some special types of motor are required with some special arrangement which makes the motor to rotate a certain angle for a given electrical input (signal). Such motors can be ac or dc motors. These motors are used for position control or in servo mechanisms, hence are termed as servomotors. The AC servomotor consists of main and control winding and squirrel cage/drag cup type rotors. \( V_r \) is the voltage applied to the main or reference winding while \( V_c \) is that applied to control winding which controls the torque-speed characteristics. The 90\( \degree \) space displacement of the two coils/windings and the 90\( \degree \) phase difference between the voltages applied to them result in production of rotating magnetic field in the air gap, due to which the
force or torque is exerted on rotor and is set in motion.

**Applications**:
1. Process control equipment.  
3. Robotics.  
5. AC position control applications.  
6. Portable drilling machine.  
7. Sewing machine.

1 e) Draw and explain digital input module.

**Ans:**

**Digital input module:**

![Block diagram of AC input module](image)

**Explanation:**

**Power conversion:** The power conversion section usually consists of resistors and bridge rectifier. The bridge rectifier converts the incoming AC signal to a pulsating DC level. The DC level is passed through filters and other logic circuits in order to deliver a clean, de-bounced, DC input signal. The filtered DC signal goes on to the threshold detector.

**Threshold detection:** Threshold detection circuitry detects if the incoming signal has reached or exceeded a predetermined value for a predetermine time, and whether it should be classified as valid ON or OFF signal.

**Isolation:** Isolation section of the input circuit is usually made up of an optical isolator, or opto-coupler. In a 120VAC input module, isolation separates the high voltage, 120VAC input signal from the CPUs low voltage control logic.

**Logic section:** DC signal from the opto-coupler are used by the logic section to pass the input signal to the module’s input address LED and the CPU and then on to the input status file.

1 f) Give the advantages of PLC (any four).

**Ans:**

**Advantages of PLC:**
1. Increased productivity.
2. Improved product quality.
3. Increased accuracy.
4. Reduced manpower.
5. Reduction in personal injury or accidents.
6. Reduction in the cost of product due mass production.
7. Increased profit.
8. Achieves consistency in the manufacturing.
9. Centralized control of plant is possible.

1 g) Explain PI controller in brief.

**Ans:**

**PI Controller:**

![PI Controller Diagram]

This is a control mode that results from a combination of the proportional mode and the integral mode. The characteristics of the PI mode are:

1. When the error is zero, the controller output is fixed at the value that the integral term had when the error went to zero. This output is given by the equation:

   \[ V_{out}(t) = K_p e(t) + K_i \int_{0}^{t} e(\tau) d\tau \]

2. If the error is not zero, the proportional term contributes a correction, and the integral term begins to increase or decrease the accumulated value [initially \( V_{out}(0) \), depending on the sign of the error and the direct or reverse action.

2 Attempt any TWO of the following:

2 a) Draw and explain the power and control circuit diagram of forward-stop-reverse type DOL starter for 3-phase Induction Motor.

**Ans:**

**Forward-Stop-Reverse type DOL starter for 3-phase Induction Motor:**

![Power Circuit and Control Circuit Diagrams]

The power and control circuit of DOL starter with Forward-Stop-Reverse control are shown in figures (a) and (b) above respectively. In power circuit, two contactors (F and R) are used to provide electric supply with opposite phase sequence to motor. When contactor F is ON, the three-phase supply is connected to the motor in normal sequence. When the contactor R is ON, the three-phase supply is connected in reverse phase sequence to the motor.
with phase sequence L₁-L₂-L₃ is provided to motor and it runs in Forward direction. However, when contactor R is ON, the three-phase supply with reversed phase sequence L₁-L₃-L₂ is provided to motor and it runs in Reverse direction.

In control circuit, when push-button ‘For’ is pressed, the contactor coil ‘F’ get energized through ‘Stop’ push-button, pressed ‘For’ push-button and R₂ NC contact. Therefore, the contactor ‘F’ get closed and in power circuit, the three phase supply with phase sequence L₁-L₂-L₃ is provided to motor and it runs in Forward direction. The operation of contactor ‘F’ causes closing of NO contact ‘F₁’ and opening of NC contact ‘F₂’. The contact F₁ being connected in parallel with push-button ‘For’, it holds ON the contactor ‘F’ after releasing push-button ‘For’. Now even if somebody presses push-button ‘Rev’, the contactor ‘R’ cannot be energized as the NC contact F₂ is open. So if we wish to reverse the direction of rotation, we need to press ‘Stop’ push-button first to stop the motor. Pressing of ‘Stop’ push-button causes interruption of current of forward contactor coil ‘F’. Therefore, the contactor ‘F’ gets de-energized and NC contact F₂ regains its original closed state.

Then only the direction of rotation can be reversed by pressing push-button ‘Rev’. It causes the current to flow through contactor coil ‘R’, energizing contactor ‘R’ and closing its NO contacts. In power circuit, the contactor R get closed providing three-phase supply with reversed phase sequence L₁-L₃-L₂ to motor and it runs in Reverse direction.

Thus during transition from Forward to Reverse or vice-versa, we need to Stop the motor, hence this control is referred as ‘Forward-Stop-Reverse’ control.

2 b) Draw and explain the power and control circuit diagram of 3-Phase Induction Motor using autotransformer type starters.

Ans:

**Autotransformer type starter for 3-Phase Induction Motor:**

The power and control circuit for autotransformer starter with open-circuit transition are shown in figures (a) and (b) above. Four main contacts of Start
contactor (S) are used to connect the auto-transformer winding in open-delta, as shown in power circuit. The interlock is such that only one contactor (Start S or Run R) is ON at a time. When Start contactor S is ON, the contacts S₁ to S₅ are closed, the motor gets reduced voltage supply from open-delta connected auto-transformer and it starts. When Run contactor R is ON, the contacts R₁ to R₃ are closed and full line voltage is supplied to motor. The motor then continues to run with full rated supply voltage.

Referring to control circuit, when the ON push-button is pressed, the control relay CR is energized through normally-closed OFF push-button, pressed ON push-button and hold ON through contact CR₁. On energizing control relay CR, the contact CR₂ gets closed and the Start contactor coil S is energized through delay-in –opening type timer contact TR₁. The closing of contact S₆ energizes the timer TR. The instantaneous contact TR(INST) holds on the timer. The contactor S connects the motor to supply through open-delta connected auto-transformer. Thus motor is started with reduced voltage and accelerated. The operating time of timer TR decides the accelerating time for the motor.

After preset time delay, contact TR₁ get opened, de-energizing the Start contactor S. Therefore, the contact S₇ regains its original closed state. The delay-in-closing type timer contact TR₂ also get closed and therefore the Run contactor R get energized. Thus the motor get connected to rated supply voltage through the contacts R₁ to R₃. The motor continues to run with full supply voltage.

In this scheme, during transition from Start to Run, the Star contactor is de-energized first thereby disconnecting (open circuiting) the motor from supply and then Run contactor is energized thereby re-connecting motor to supply. Therefore, it is called as open circuit transition.

(Note: Any other valid scheme of Autotransformer starter, such as Closed-circuit transition, may please be considered for allotment of marks)

2 c) Draw and explain the block diagram of PLC.

Ans:

Programmable Logic Controller (PLC):

![Block diagram of PLC](image)

CPU: Central processing unit is the main part of any PLC. The CPU solves the user program logic by using real time input status from input module and
updates the status of output module. The CPU consists of – (i) Processor, (ii) Memory.
The processor is responsible for the complete program scan in a PLC. During Program scan processor communicate with the memory.
Memory is used in CPU are of two types RAM and ROM. RAM memory is used to store the data related to input status, output status, timers, counters, internal bit relay, numerical values etc. ROM memory is to store system program and user program.
**Input Modules:** The input modules examine the state of physical switches and other input devices and put their state into a form suitable for the processor. The PLC is able to accommodate a number of inputs.
**Output Modules:** The objective of the output module is ultimately to supply power to an external device such as a motor, light, solenoid, and so on, as required by the ladder diagram.
**Programming Unit:** The programming unit is an external electronic package that is connected to the programmable controller when programming occurs. The unit usually allows input a program in ladder diagram symbols. The unit then transmits that program into the memory of the programmable controller. The programming unit may be a PC or Handheld Terminal.

3 Attempt any FOUR of the following: 16

3 a) Draw Star/Delta starter circuit for 3-M. semiautomatic type & explain.

**Ans:**

**Semiautomatic Star-Delta Starter for 3-Induction Motor:**

![Power circuit diagram for a star-delta starter](Image)

![Control circuit for a semi-automatic star-delta starter](Image)

The power and control circuit of Semiautomatic Star-Delta starter for 3-induction motor is shown in the figure (a) and (b) respectively. In power circuit, three contactors are required to connect motor to supply and to connect its windings first in Star and then in Delta.

Referring to the control circuit, the motor is operated in following sequence:
i) When ON push-button is pressed, the Star-contactor coil S is energized through normally-closed OFF push-button, pressed ON push-button and NC contact D1. Therefore, Star contactor S is operated and motor windings are connected in star.
ii) After energizing Star-contactor S, the NO contact S₁ get closed and the Main-
contactor M get energized. In power circuit, the closing of M contactor
connects the motor to supply and it is started as star-connected motor. The M-
contactor is held ON through the closed NO contact M₁.

iii) The motor continues to run in star-connection as long as ON push-button is
kept pressed.

iv) When it is ensured that the motor has picked up 75% of its rated speed, the
pressed ON push-button is released. The opening of ON push-button causes
interruption of current in coil S and Star-contactor is de-energized. Therefore,
the contact S₁ is opened, however contactor M is held ON through closed NO
contact M₁.

v) After de-energizing Star-contactor S, the motor winding is disconnected from
star-connection and due to closing of NC contact S₂, the Delta-contactor D is
energized.

vi) On energizing contactor D, the motor is reconnected in delta-connection. Thus
motor then continues to run as delta-connected motor.

3 b) Draw the ladder diagram along with the truth table of XOR and OR gate.

**Ans:**

![Ladder Diagram and Truth Tables](image)

2 marks truth table

(Symbols are optional: No marks)

2 marks ladder diagram

3 c) Explain ON-Delay timer operation.

**Ans:**

**ON-Delay Timer (ODT):**
An ON-delay timer (TON) output instruction either provides time delayed action
or measures the duration for which some event occurs. Once the rung has
continuity, the timer begins counting time-based intervals and counts down until
the accumulated time equals the preset time. When these two values are equal,
the timer energizes the output and closes the timed out contact associated with
the output. The timed contact can be used throughout the program as either a
normally open or normally closed contact. If logic continuity is lost before the
timer times out, the timer resets the accumulated register to zero.

1½ marks description
1) T4:0 : This bit indicates timer file 4, timer 0, it stores timer information
2) Time base 1.0 : This bit indicates processor increments accumulated values in 1 second intervals.
3) Preset: It indicates delay for timer
4) Accumulator value gives current value of the timer as 0 which increases up to the preset value
6) EN : This bit is set , when input is true,
7) TT: This bit is set when timer is running other is reset
8) DN : This bit is set when accumulator value becomes equal to preset value and then respective output becomes ON

3 d) Compare P+D and PI controller (any for points).

**Ans:**

**Comparison Between P+D and PI controllers:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PD</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action equation</td>
<td>Proportional action cascaded with derivative action.</td>
<td>Proportional action cascaded with integral action.</td>
</tr>
<tr>
<td></td>
<td>$p = K_P e_p + K_P K_D \frac{de_p}{dt} + p_0$</td>
<td>$p = K_P e_p + K_P K_I \int_0^t e_p , dt + p_I(0)$</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Controller output will be zero if i) error Ep is zero and ii) if error is constant.</td>
<td>When the error is zero, the controller output is fixed at the value that the integral term had when the error went to zero. If the error is not zero, the proportional term contributes a correction, and the integral term begins to increase or decrease the accumulated</td>
</tr>
</tbody>
</table>
3 e) Explain with the block diagram the analog module of PLC.

Ans:

**Analog Input Module:**

**Description:**
Analog input module interfaces a PLC to analog input signals. It gives ability to PLC to monitor a continuously changing input signals such as pressure, temperature, flow etc. The module converts analog input signals to 16 bit binary values storage in the processor’s input status table. Analog modules are designed to accept current and voltage signals such as 0-10 Vdc, ±10 Vdc, 0-5Vdc and 0-20mA, 4-20mA etc. When signal reaches an input module, it is rich in different noise signals.

**Noise minimization:** The signal is freed from noise through noise minimization circuit. The signal is then digitized and sent to logic section through an isolation circuit.

**A/D Conversion:** It convert analog to digital signal required for further process.

**Optical Isolation:** It is used to protect CPU from high voltage coming from fault in the input section.

**Logic section:** The logic section allows the digitized signal to go to the CPU following the predetermined logic.

2 marks for diagram

2 marks for description
OR

Block diagram of Analog output module:

Explanation:-
- PU sends data to output module through different blocks. Optical isolation blocks isolate.
- PU circuit from high voltage o/p devices.
- Isolation section of the input circuit. Is usually made up of an optical isolator, or opt coupler. In a 120VAC input module, isolation separates the high voltage, 120VAC input signal from the CPUs low voltage control logic.
- DC signal from the opto coupler are used by the logic section to pass the input signal to the module’s input address LED and the CPU and then on to the input status file.
- This module accepts 16 bit status word, convert it into analog value using DAC.
- Analog signals are 0 to 10Vdc, -10Vdc to +10Vdc, 0 to 5Vdc 0 to 20mA, -20 to +20mA, 4mA to 20mA etc.
- These modules are selected to send output either a varying current or voltage signal, each represent particular operation.

3 f) Draw and explain the function of optoisolator.

Ans:
Optoisolator:

Opto-coupler or Opto-isolator is a safety component that transfers electrical signals between two isolated circuits by using light signal. A common type of opto-isolator consists of an LED and a phototransistor in the same package. Opto-coupler are mainly used in delicate system like between sensor and PLC. Opto-coupler functions as a galvanic isolation component, it maintains the connection between two devices or component without any direct conduction. An opto-isolator connects input and output sides with a beam of light modulated
by input current. It transforms useful input signal into light, sends it across the
dielectric channel, captures light on the output side and transforms it back into
electric signal.
Opto-isolators can pass DC or slow-moving signals and do not require matching
impedance between input and output sides. The main function of an opto-isolator
is to block high voltages and voltage transients, so that a surge in one part of the
system will not disrupt or destroy the other parts. In a 120VAC input module,
isolation separates the high voltage, 120VAC input signal from the CPUs low
voltage control logic.

4 Attempt any TWO of the following: 

4 a) Explain in detail the up and down counter of PLC.

Ans:
Up counter:

The up counter counts upward over a range of -32768 to +32767. Each time the
rung goes from false to true, the up counter increments accumulated value by
one count. When accumulated value equals or exceeds preset value the up
counter sets a done bit (DN). The accumulated value is retentive; count is
retained until reset by reset instruction.

Status Bits:
CU Bit: This status bit is true when UP counter instruction is true.
DN bit: This bit is true when accumulated value is equal to or greater than
the present value of the counter.
OV(Overflow) bit: when counter count value exceeds 32,767, this bit becomes
ture.
UN(Underflow): It will go true when counter counts below -32,768.
Down counter:

The up counter counts downward over a range of +32767 to -32768. Each time the rung goes from false to true, the up counter decrements accumulated value by one count. The DN bit is set as long as accumulated value is greater than or equal to preset value. When accumulated value is less than preset value the down counter resets a done bit (DN). The accumulated value is retentive; count is retained until reset by reset instruction.

Status Bits:
CD Bit: This status bit is true when DOWN counter instruction is true.
DN bit: This bit is true when accumulated value is equal to or greater than the present value of the counter.
OV(Overflow) bit: when counter count value exceeds 32,767, this bit becomes true.
UN(Underflow): It will go true when counter counts below -32,768.

4 b) Develop ladder diagram for following sequence of operation:
   i) When start button is ON, the system starts.
   ii) Lamp L1 start when the system is ON
   iii) Lamp L2 starts 10 sec, after L1 is ON
   iv) When stop button is ON, lamp L1 and L2 are OFF.

Ans:
Input Addresses:
START Button: I:0/0       STOP Button: I:0/1
Output Addresses:
Lamp L1: O:0/0               Lamp L2: O:0/1
Timer address:
ON Delay Timer T1: T4:0
Description:
Rung0: start button and stop button is used in series and output CR is used in parallel with start button. This logic acts like latch it stores status of start button and stop button. When start is pressed latch CR will be turned ON and remain ON irrespective of start. Similarly, when stop is pressed latch CR will be turned OFF and remain OFF irrespective of stop.
Rung1: when latch CR turn ON, it enables timer T1. Timer T1 starts counting internal pulses by incrementing accumulator. When accumulator value is greater than or equal to preset value i.e. after 10 sec. done bit will set.
Rung2: When latch CR turn ON, Lamp L1 will turn ON.
Rung3: when rung condition i.e. T4:0/DN is true Lamp L2 will turn ON i.e. after 10sec. of Lamp L1.
CR will be turned OFF if stop button is pressed hence Lamp L1 and L2.

4 c) Draw and explain power and control circuit for definite time-limit starter for slip-ring induction motor.

Ans:
Definite Time-limit Starter for Slip-ring Induction Motor:
This starter is used for automatic control of acceleration of slip-ring induction motor at the time of starting. In this starter, the accelerating contactors close after pre-set time delays determined by the timers. The time periods are so adjusted that when a resistance step is cut off, the resulting current peaks remain within limits. The time delay between energization of successive contactors can be obtained by using any of the following types of time-delay elements;

i) Individual timers
ii) Motor driven cam timer
iii) Timer heads mounted on contactors
iv) Flux decay relays

The power circuit is as shown below. The slip-ring induction motor is started by rotor resistance starter having resistance steps R1, R2, R3 and R4. At the time of...
starting, full resistance \( R_4 \) is inserted in each rotor phase. With preset time delays, the contactors are operated in sequence A-B-C-D and resistance is cut in steps as \( R_1\text{-}R_2\text{-}R_3\text{-}R_4 \) during starting and finally total resistance is cut-out from the rotor circuit.

![Power Circuit Diagram](image1)

The control circuit using individual timers is as shown in figure above. Pressing of ON-pushbutton energizes control relay CR. Contactor M and 1T also get energized as contact CR2 closes. Contactor M starts the motor with full resistance \( R_4 \) in the rotor circuit. When timer 1T times out, its delayed contact 1T closes to energize contactor A and timer 2T. Energization of contactor A causes cutting off of resistance \( R_1 \) from the three rotor phases and motor accelerates. When timer 2T times out, its contact 2T closes to energize contactor B and timer 3T. The closing of contactor B short second step of resistance i.e \( R_2 \) and the motor accelerates further. In this way, the contactors C and D are closed with time delay determined by timers 3T and 4T respectively and the resistance is cut-off in steps for further acceleration of motor. Finally, when contactor D is closed, the full resistance \( R_4 \) is cut off from each phase, shorting the rotor winding terminals and final acceleration of the motor.

5 **Attempt any TWO of the following:**

5 a) Draw the block diagram of digital output module and explain its working.

*Ans:*

**DC output module:**

![Block Diagram](image2)
AC output module:

Latch logic circuit and optical isolation circuit:
  i) If the status of output terminal is one and if CPU sends low voltage signal (12-18 V DC) to the latching circuit.
  ii) Latching circuit will latch that logic signal as a ON state and then send it to the optical isolation circuitry.
  iii) Same operation is performed for status is zero.
  iv) Optical isolation circuit will isolate low voltage signal of CPU and high voltage operating field devices.

Switching and filtering circuitry:
  i) In this block, power transistor/TRIAC is a solid state switching device used to provide high voltage operating signal to output field devices.
  ii) Power transistor/TRIACs are switched ON or OFF by the signal from optical isolation circuit.
  iii) DC/AC signals switched by power transistor/TRIAC are filtered to a safe level by filtering circuitry.
  iv) To indicate the status of the output LED is provided on output module.
  v) In some output module circuit, fuse is provided to protect the circuit from drawing higher current.

Controlled device (Load):
  i) Controlled device are the field output devices may operate from different voltages.
  ii) When the status of output is one in output data table then controlled device turns ON and when status is zero, then device turns OFF.

5 b) Explain the working of Derivative controller. And explain why derivative mode is not used alone.

Ans:

Derivative controller:

\[ p(t) = K_d \frac{de(t)}{dt} \]

The equation for D controller is:

For a given rate of change of error signal, there is a unique value of the controller output. When the error is zero, the controller output is zero. When the error is constant i.e. rate of change of error is zero, the controller output is zero. When the error is changing, the controller output changes by Kd % for even 1 % per second rate of change of error.
5 c) i) Explain the OFF-Delay Timer of PLC with neat diagram.

**Ans:**

**OFF-Delay Timer of PLC:**
The OFF delay timer is used to turn on/off an output after its rung condition has been off for preset time interval. It starts accumulating the time when the rung goes false and continues timing until one of the following condition occurs:

i. accumulated value equals its preset value

ii. a rung goes true

iii. a reset instruction resets timer

There are 3 memory words reserved for every timer for status, accumulator and preset.

1) T4:0 : This bit indicates timer file4, timer 0, it stores timer information

2) Time base 1.0: This bit indicates processor increments accumulated values in 1 second intervals.

3) Preset: It indicates delay for timer

4) Accumulator value gives current value of the timer as 0 which increases up to the preset value.

5) EN : This bit is set ,when input is true,

6) TT: This bit is set when rung condition fails and turns off

7) TT: This bit is set when timer is running other is reset

8) DN : This bit is set when accumulator value becomes equal to preset value and then respective output becomes ON. This bit is initially set when rung is true and turns off when accumulator value becomes equal to preset.  

1 mark for symbol

1 mark for waveform
5. c) ii) Draw the ladder diagram for (i) AND gate (ii) NOT gate.
   Ans:

   ![Ladder Diagram]

   2 marks for truth-tables

   (Symbols of gates are optional: NO marks)

   2 marks for ladder diagrams

6. Attempt any FOUR of the following:

6 a) List any four input and output of PLC.
   Ans:

<table>
<thead>
<tr>
<th>Inputs:</th>
<th>Outputs:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pushbutton</td>
<td>1. Lamp</td>
</tr>
<tr>
<td>2. SPDT switch</td>
<td>2. Motor</td>
</tr>
<tr>
<td>3. Limit switch</td>
<td>3. solenoid</td>
</tr>
<tr>
<td>4. Proximity switch</td>
<td>4. Relay</td>
</tr>
<tr>
<td>5. Pressure switch</td>
<td>5. Actuator</td>
</tr>
<tr>
<td>6. Temperature switch</td>
<td>6. Alarm</td>
</tr>
<tr>
<td>7. Level switch</td>
<td></td>
</tr>
<tr>
<td>8. Flow switch</td>
<td></td>
</tr>
<tr>
<td>9. Encoder</td>
<td></td>
</tr>
</tbody>
</table>

   OR Any other relevant answer.

6 b) Explain the offset in proportional controller.
   Ans:

   The main limitation of plain proportional control is that it cannot keep the
   controlled variable on set point. The proportional controller produces a
   permanent residual error in the controlled variable, when a change in load
   occurs. This is referred to as offset.

   Let us consider the level control system shown in Figure. The float-type
   proportional controller can only respond to a load change (change in the outflow
   of water) because it must experience a change in level before it can respond.
   Therefore, the only condition when this process will be on set point is when the
   load is 50%. In all other cases the level will have to travel up or down on its
   “operating line” as a function of the load. The difference between the actual
   value of the level and set point is called the offset, because this is the amount by
   which the process is off set point.

   ![Level Control System Diagram]

   3 marks for explanation

   1 mark for diagram
6 c) Describe the operation of pneumatic cylinder.

Ans:

**Pneumatic Cylinder:**
Pneumatic cylinders are one of the most common pneumatic actuators used in many industrial applications that require linear motion. A pneumatic Cylinder is an actuator that uses the energy of compressed air to convert it in mechanical energy, in the form of a linear movement.

1. Single-acting cylinders with one air inlet to produce a power stroke in one direction.
2. Double acting cylinders with two air inlets to produce extending and retracting power strokes.

**Single-acting Cylinder:** A single acting cylinder develops thrust in one direction only. The piston rod is returned by a fitted spring or by external force from the load or spring. They have a somewhat lower air consumption compared with the equivalent size of double acting cylinder. However there is a reduction in thrust due to the opposing spring force, and so a larger bore may be required.

![Diagram of Pneumatic Cylinder](image)

6 d) Draw the ladder diagram for star delta starter.

Ans:

![Ladder Diagram for Star Delta Starter](image)

4 marks for correct ladder diagram
6 e) Draw the block diagram of PID controller and explain its working.

**Ans:**

![PID Block Diagram](image.png)

Output Equation:

\[ P_O = K_P E_P + K_P K_I \int E_P \, dt + K_P K_D \frac{dE_P}{dt} + P_I(0) \]

**Explanation:**

PID is combination of 3 control action- proportional + integral + derivative. The proportional corrects instances of error, the integral corrects accumulation of error, and the derivative takes the corrective action in anticipation. The effect of the derivative is to counteract the overshoot caused by P and I. When the error is large, the ‘P’ and the ‘I’ will push the controller output. This controller response makes error change quickly, which in turn causes the derivative to more aggressively counteract the P and the I.

6 f) Explain its working of Solenoid valves with the help of neat diagram.

**Ans:**

**Solenoid valves:**

![Solenoid Valve Diagram](image.png)

A solenoid valve is an electromechanical device used to obtain mechanical movement in machinery by utilizing fluid or air pressure. The fluid or air pressure

1 mark for diagram

1 mark for equation

2 marks for explanation

2 marks for diagram
is applied to the cylinder piston through a valve operated by a cylindrical electrical coil. The electrical coil along with its frame and plunger is known as the solenoid and the assembly of solenoid and mechanical valve is known as solenoid valve.

In fig (a) is shown a single solenoid spring return valve in its de-energized condition. In this condition the plunger and valve spool position are as shown, port P is connected to port A and port B is connected to tank or exhaust, if air is used. The spring(S) pressure keeps the spool in this condition as long as the coil is de-energized. Fluid pressure from port P through port A is applied to the left side of the cylinder piston. Thus the cylinder piston moves in the left direction.

In fig (b) is shown a single solenoid spring return valve in its energized condition. When solenoid coil is energized, plunger is attracted and it pushes the spool against spring pressure. In this position of spool, port A gets connected to tank and port P gets connected to port B. Fluid pressure from port P through port B is applied to the right side of the cylinder piston. Thus the cylinder piston moves in the left direction. At the same time fluid in the other side is drained out to the tank.

2 marks for explanation