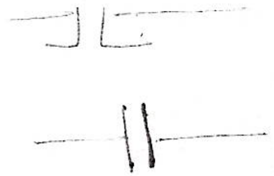
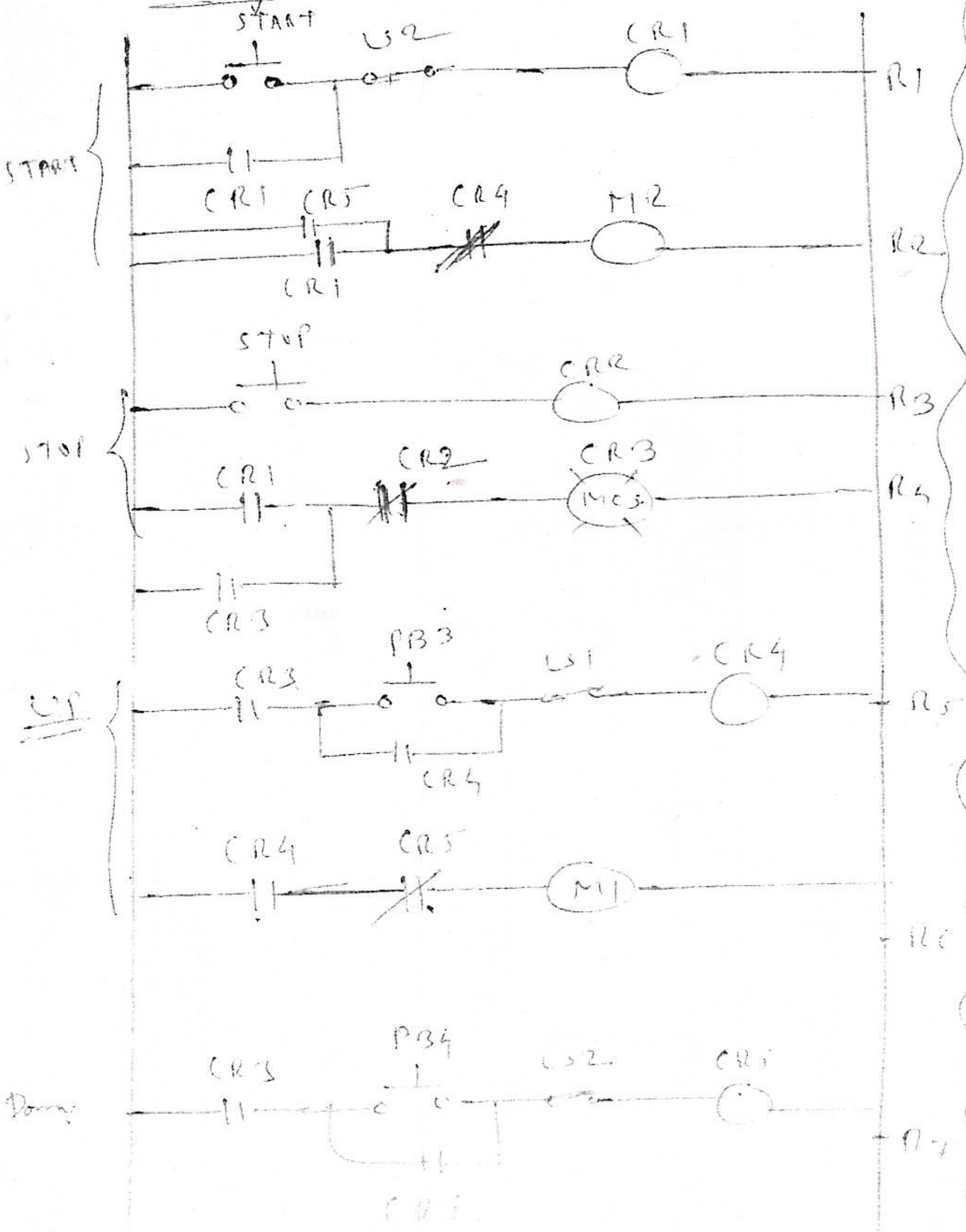
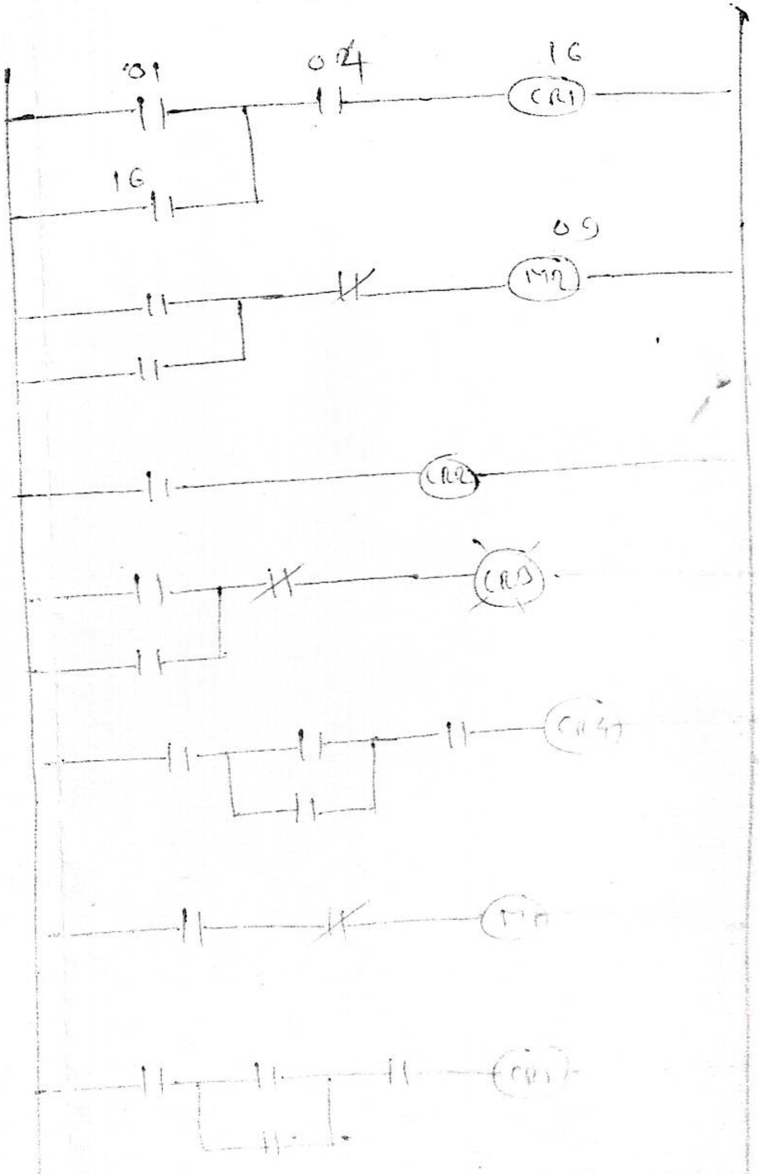
#24 When. Start & stop both are NO types



Physical ladder Diagram.



Program ladder Diagram

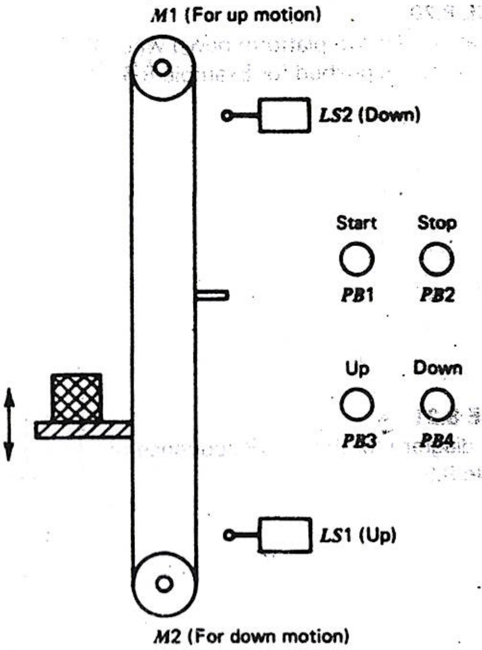


Start 01
Stop 02
LS1 03
LS2 04
PB3 05
PB4 06

M1 - 08
M2 - 09

CR1 16
CR2 17
CR3 18
CR4 19
CR5 20
CR6 21

FIGURE 8.19
Elevator system for Example 8.6.



The following narrative description indicates the required sequence of events for the elevator system.

1. When the START button is pushed, the platform is driven to the down position.
2. When the STOP button is pushed, the platform is halted at whatever position it occupies at that time.
3. When the UP button is pushed, the platform, if it is not in downward motion, is driven to the up position.
4. When the DOWN button is pushed, the platform, if it is not in upward motion, is driven to the down position.

Prepare a ladder diagram to implement this control function.

Solution

Let us prepare a solution by breaking the requirements into individual tasks. For example, the first task is to move the platform to the down position when the START button is pushed.

This task can be done by using the START button to latch a relay, whose contacts also energize *M*2 (the down motor). The relay is released, stopping *M*2, when the *LS*2 limit switch opens. Figure 8.20 shows ladder rungs 1 and 2 that provide these functions. Pushing START energizes *CR*1 if *LS*2 is not open (platform not down). *CR*1 is latched by the contacts across the START button. Another set of *CR*1 contacts starts *M*2 to drive the platform down. When *LS*2 opens, indicating the full down position has been reached, *CR*1 is released and unlatched, and *M*2 stops. These two rungs will operate only when the START button is pushed.

Both start & stop buttons are NO Type

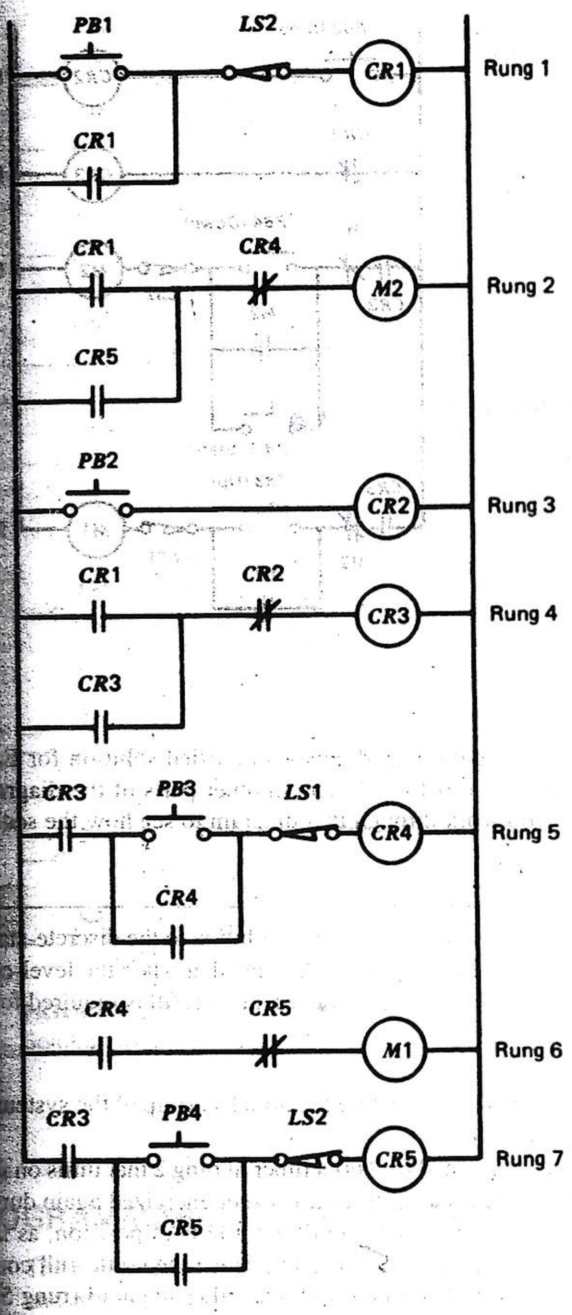
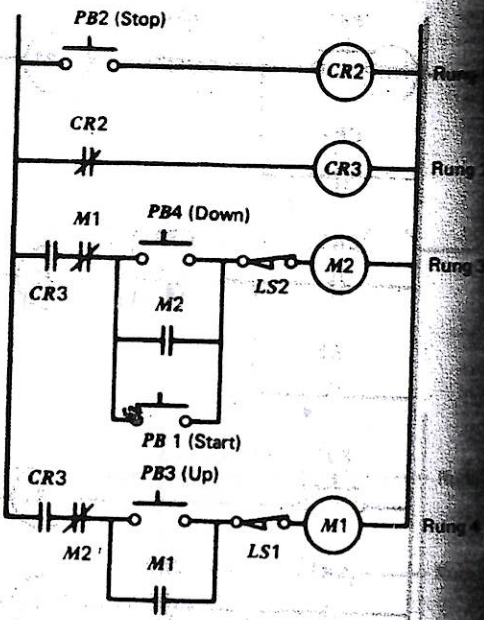


FIGURE 8.22
The complete ladder diagram for Example 8.6.

FIGURE 8.23
A simplified ladder diagram for Example 8.6.



relays can be eliminated. Figure 8.23 shows a simplified solution for Examp[illegible] use the *M*1 and *M*2 designations for contacts in other parts of the diagram, [illegible] control relays. You should work through this diagram to see how the seque[illegible] is satisfied.

EXAMPLE 8.7

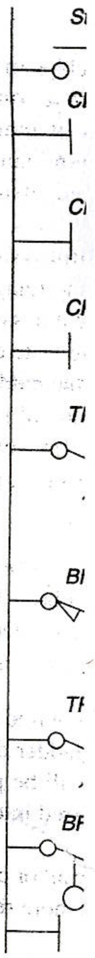
Construct the ladder diagram that will provide a solution to the discrete-state co[illegible] lem defined by Figure 8.5 and Example 8.3. Assume that when the level-contro[illegible] commanded off, the input valve is closed and a 1-min prefill is required for [illegible]

Solution

A START/STOP latch is provided to define the initial start-up of the system. Th[illegible] agram is shown in Figure 8.24.

Initialization is accomplished by a 60-s timer in rung 2 that turns on the le[illegible] system for 1 min following the start button. It is never energized again during [illegible]

Rung 3 drives the conveyor motor until a bottle is in position, as indi[illegible] bottle position switch opening. Rung 5 is used to detect the bottle-full condi[illegible] gizing *CR*2. The contacts of *CR*2 turn on both the valve solenoid (rung 5) and [illegible] control system (rung 6). Note the timer in rung 6 for initialization. Rung 7 is [illegible] detect that the bottle is full and to restart the conveyor until the bottle is move[illegible] sition and the bottle-present switch is opened. Continuous running now occu[illegible] rung 3 and rung 7.



FIGURE
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PROGRAM

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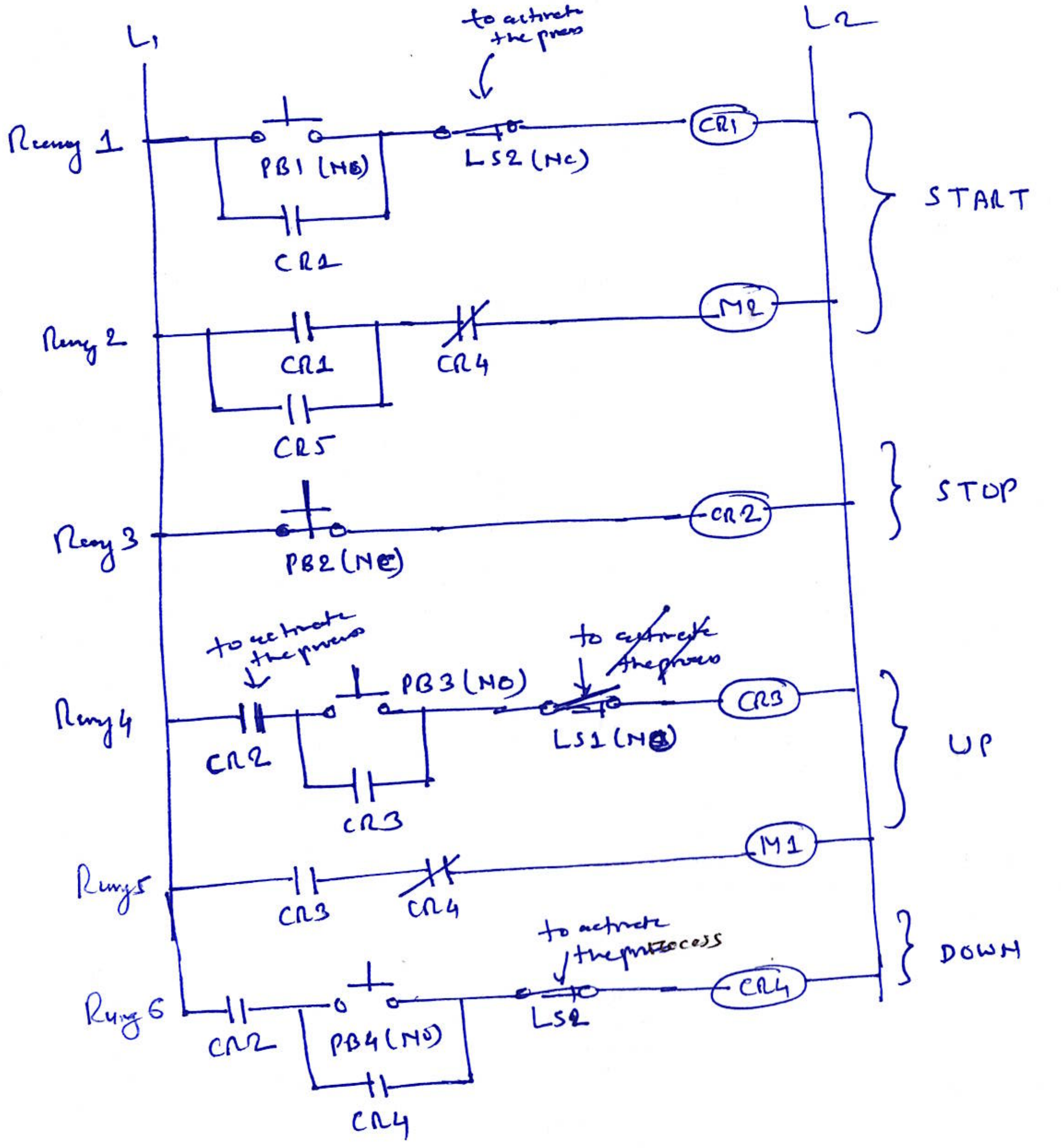
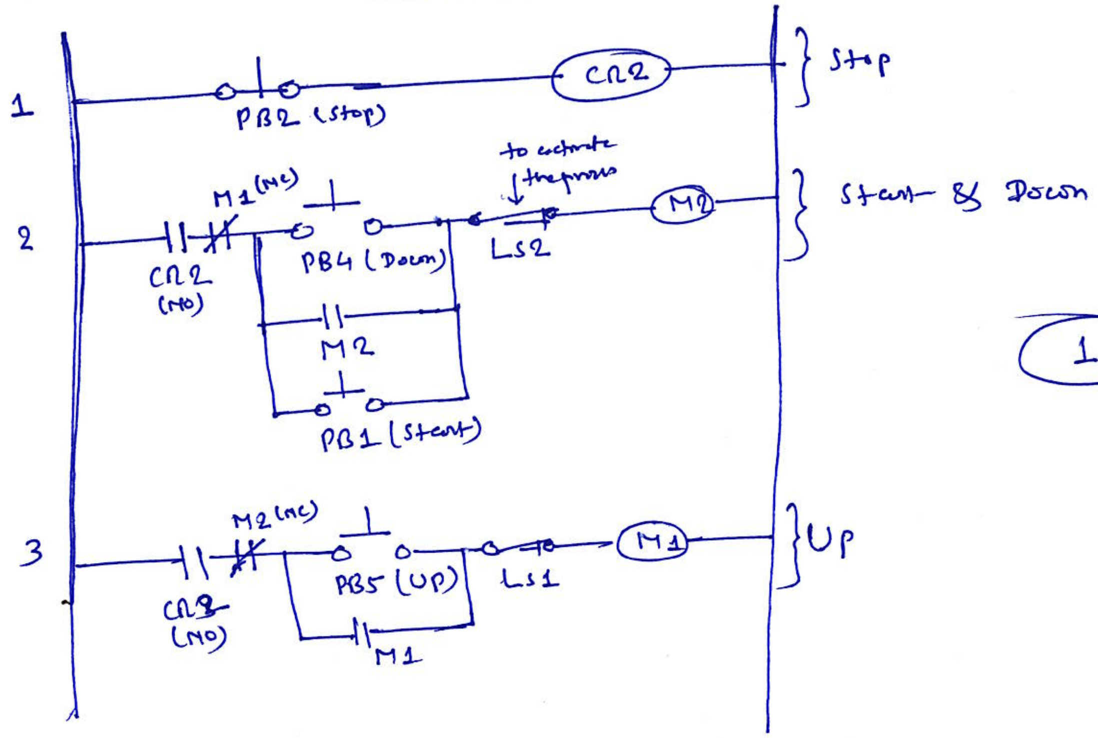
LS2 – NO type ; STOP – NC



23

simplified ladder



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1st IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES-2016)

SF_6 Density-and-Viscosity Sensing in Gas Insulated Switchgear using MEMS Resonator

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***Abstract*—SF_6 based Gas Insulated Switchgear (GIS) are widely used for High Voltage (HV) applications. Due to the environmental impact of SF_6 gas, strict regulations have been laid to monitor their use and to restrict their emission from switchgears. Quartz based resonant density sensor is the best technology commercially available today for SF_6 monitoring. Frequency response of the sensor is a function of both density and viscosity. However, each sensor contains a matched pair of quartz crystals for temperature compensation. The accuracy of the density sensor is limited by the extent of mismatch between the quartz crystals which determines the minimum detectable change in SF_6 density. Calibration makes the sensor gas-specific and dependent on the environmental conditions. We propose a MEMS based resonator for in-situ SF_6 viscosity measurement that can be used as an input to the existing gas density sensor. It will make the matched pair of quartz crystal redundant resulting in more accuracy.**

Keywords*—*Sub-station Automation; Gas Insulated Switchgear; MEMS Resonator; SF_6 Density Sensor; SF_6 Viscosity Sensor

I. INTRODUCTION

Sulfur Hexafluoride (SF_6) is a gaseous dielectric used in Gas Insulated Switchgear (GIS) for High Voltage (HV) power applications. Its dielectric strength is approximately 3 times greater than air which enables design of compact switchgear. [1].The superior insulation and arc-extinction capabilities of SF_6 make it ideal for use in HV switchgear. However, SF_6 is a potent greenhouse gas with a global warming potential of 23, 900 as compared to CO_2 [2]. In 1997, the Kyoto Protocol (Global Warming Treaty) listed SF_6 as one of the six greenhouse gases that should be controlled by reducing emission or eliminating use. SF_6 emissions from electric power systems can be attributed to (i) type and age of SF_6 based GIS and (ii) handling and maintenance procedures practiced by electric utilities. The IEC Standard 62271-203 states that the maximum allowed SF_6 leakage rate shall not exceed 0.5% per year. [3]. SF_6 leakage affects the system performance in two fold ways (i) It causes reduction of insulation strength leading to unreliable switchgear operation (ii) Emission of SF_6 into the atmosphere causes global warming. Hence, real-time monitoring of SF_6 density inside GIS is very critical for reliable switchgear operation.

In the absence of real time monitoring, SF_6 emissions can be prevented by periodic maintenance and gas analysis at regular intervals. For developing countries, SF_6 emission prevention can be a problem, as the know-how is not always available and procedures are not in place to limit SF_6 emissions. Especially in countries where the daily temperature cycle shows extreme values, leakage of SF_6 is more difficult to prevent due to the expansion and contraction of seals. In order to comply with stricter future regulations on SF_6 usage and to improve the reliability of operation, cost-efficient in-situ density sensors are required.

II. REVIEW

Generally, for 245 kV applications and above, GIS tends to be single-phase enclosed and for lower voltage ratings, GIS installations tend to utilize three-phase enclosure designs [4]. Any fault developing inside the enclosure cannot be visually checked by the maintenance personnel. Currently, maintenance personnel monitor SF_6 density by peripherally mounted density transducer as shown in Fig. 1. Two types of SF_6 density transducers are currently commercially available for SF_6 density monitoring. The first type of density transducer measures the pressure and internal SF_6 gas temperature to derive density. The gas temperature is typically recorded where the sensor is installed, which can affect the accuracy of the measurement due to heat flux.

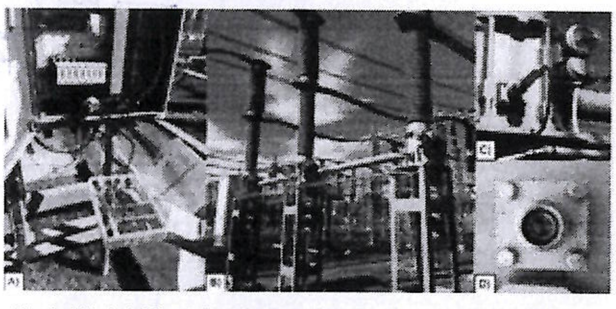

Fig. 1: (A) A 4-20 mA Data Logger Connected to Density Transducer Outputs; (B) 132kV Live Tank SF_6 Circuit Breaker Fitted with Density Transducers; (C) Density Transducer Installed to Spare Fill Valve of White Phase of Circuit Breaker; (D) Self-sealing Spare Fill Valve of the Circuit Breaker

The second type of transducer available uses the quartz oscillating principle to directly measure density. The constant resonant frequency of a quartz oscillator under vacuum is compared with the resonant frequency of identical quartz situated in the sample gas. The difference

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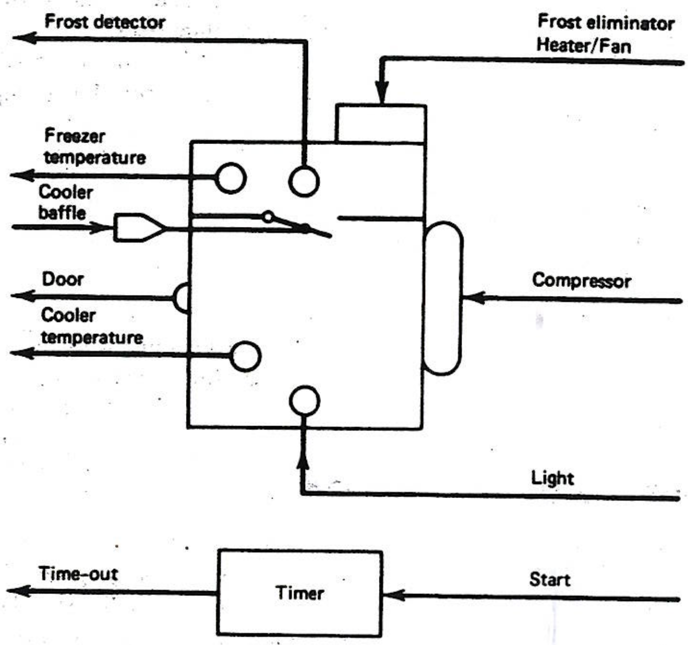

FIGURE 8.2
Refrigerator/freezer system inputs and outputs.

This is a total of 11 two-state variables. In principle, there are $2^{11} = 2$
states or events. Of course, only a few of these are necessary. The event seque

a. If the door is opened, the light is turned on.
b. If the cooler temperature is high and the frost eliminator is off, the c
turned on and the baffle is opened until the cooler temperature is lo
c. If the freezer temperature is high and the frost eliminator is off, the c
is turned on until the temperature is low.
d. If the frost detector is on, the timer is started, the compressor is turne
the frost eliminator heater/fan are turned on until the timer times out.

The events of (a) can occur in parallel with any of the others. The event
(c) can occur in parallel. Event (d) can only be serial with (b) or (c).

8.3.1 Discrete-State Variables

It is important to be able to distinguish between the nature of variables in a dis
system and those in continuous control systems. To define the difference careful
consider an example contrasting a continuous variable situation with a discrete

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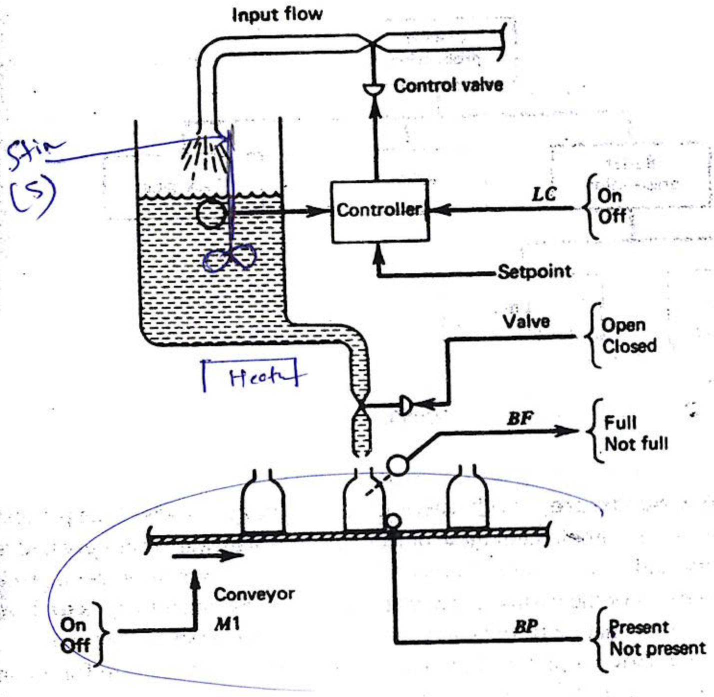

FIGURE 8.5
Composite continuous and discrete control.

of the industry. Often a *global objective* is defined as the end result of the plant. This is then broken down into individual, mostly independent *secondary objectives* to which the actual control is applied.

For example, in a food industry plant, a particular global objective might be to produce crackers. Clearly, this means that the plant takes in raw materials, processes them in specified ways, and outputs packaged and labeled crackers, ready for sale.

The overall objective can be broken down into many secondary objectives. Figure 8.6 suggests some of the secondary objectives that might be involved. There can be further subdivisions into simpler operations. The objectives of the process are formed by the objectives of each independent part of the whole operation. A discrete-state control system then will be applied to each independent part. Thus, in Figure 8.6 the operations within cracker batter preparation can probably be viewed as a stand-alone process.

A process-control specialist typically will not be responsible for the development of the objectives. That is the job of the industry experts. Thus, for crackers, we need experts in food chemistry; for petrochemical industries, we need chemical engineers; for steel production, we need metal specialists; and so on. Nevertheless, it is important for the control system specialist to study the industry and come to an understanding of the products, the process, and the objectives of the process.

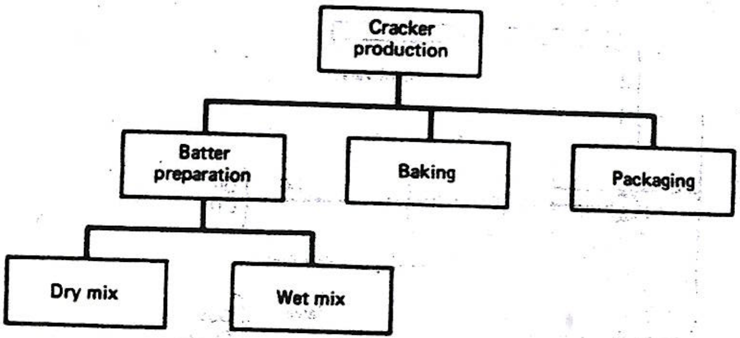

FIGURE 8.6
Objectives and subobjectives of a process.

Process Hardware With determination of the objectives of the process c design of hardware to implement these objectives. This hardware is closely tied to th of the industry, and its design must come from the joint efforts of process, producti control personnel. For the control system specialist, the essential thing is to develo understanding of the nature of the hardware and its characteristics.

Figure 8.7 shows a pictorial representation of process hardware for a convey tem. The objective is to fill boxes moving on two conveyors from a common feed and material-conveyor system. A process-control system specialist may not have b volved in the development of this system. To develop the control system, he or sh study the hardware carefully and understand the characteristics of each element.

In general, the specialist analyzes the hardware by considering how each pa lated to the control system. There are really only two basic categories.

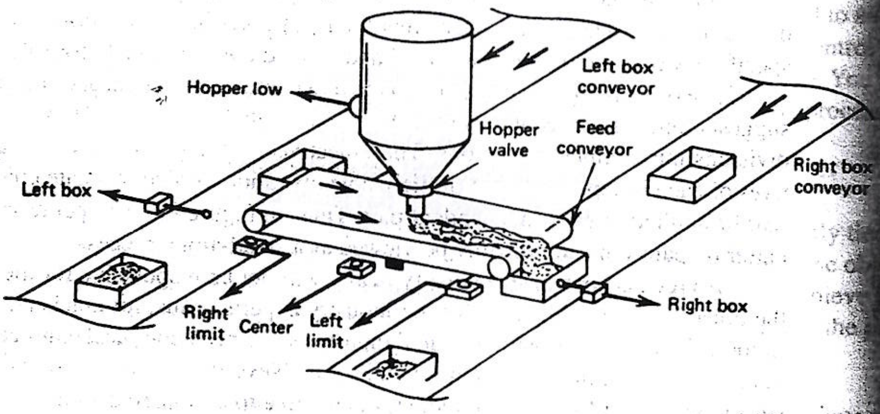

FIGURE 8.7
A discrete-control process.

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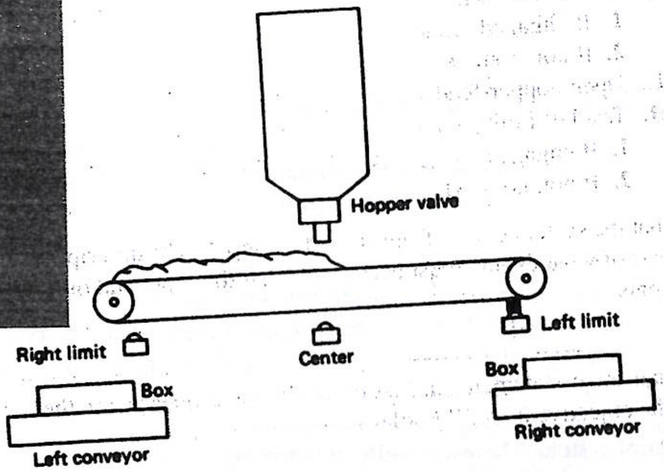
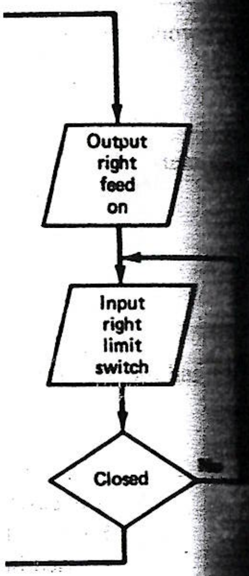


FIGURE 8.8
Completion of the initialization phase of the process shown in Figure 8.7.

Completion of this phase means that the feed conveyor is positioned at the left limit position and the right half of the conveyor has been filled from the feed hopper. The system is in a known configuration, as shown in Figure 8.8.

The running phase is described by a similar set of statements of the sequence of events. For the example of Figure 8.7, this phase might be described as follows:

- **I.** Running
  - **A.** Start right box conveyor
  - **B.** Test right box present switch
    - **1.** If set, go to C
    - **2.** If not, go to B
  - **C.** Start feed-conveyor motor, right motion
  - **D.** Test center switch
    - **1.** If engaged, go to E
    - **2.** If not, go to D
  - **E.** Open hopper-feed valve
  - **F.** Test right limit switch
    - **1.** If engaged, go to G
    - **2.** If not, go to F
  - **G.** Close hopper-feed valve, stop feed conveyor
  - **H.** Start left box conveyor
  - **I.** Test left box present switch
    - **1.** If set, go to J
    - **2.** If not, go to I
  - **J.** Start feed conveyor, left motion



igure 8.11. The time
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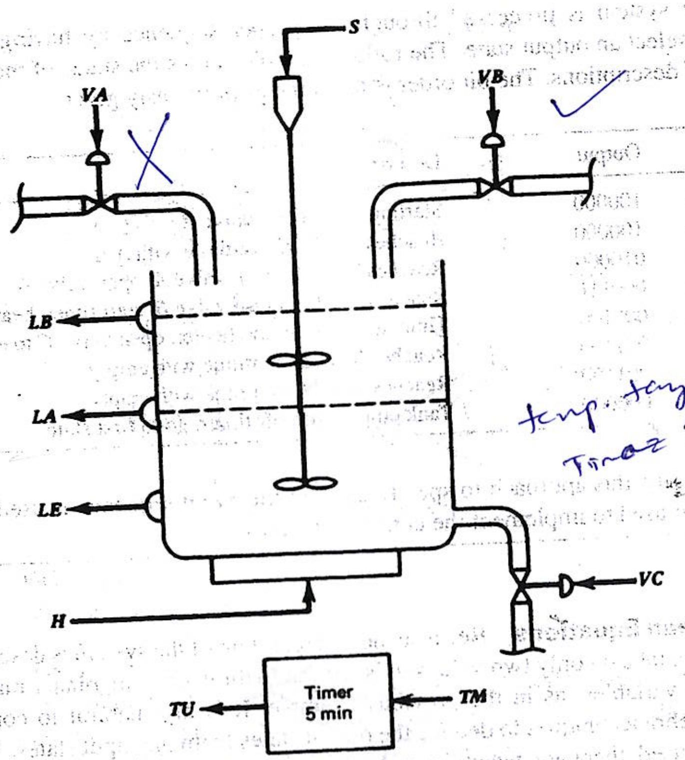

temp. target = 20°C
Timer 30 min.

FIGURE 8.11
Tank process for Example 8.4.

5. Open output valve (*VC*) until the tank is empty (*LE*)
6. Take the timer low (*TM*) and go to step 1.

Solution

To provide the solution, we first form the state variable representation of the system by assignment of binary states. There are four input variables (*LA, LB, LE, TU*) and six output variables (*VA, VB, VC, TM, S, H*).

A discrete state of the system is defined by specifying these variables. Because each variable is a two-state variable, we use a binary representation: true = **1** and false = **0**. Thus, for input, if level *A* has not been reached, then $LA = 0$, and if it has been reached, then $LA = 1$. Also, for output, if valve *C* is to be closed, then we take $VC = 0$, and if it is commanded to be open, then $VC = 1$. Let us take the binary "word" describing the state of the system to be defined by bits in the order

$$(LA)(LB)(LE)(TU)(VA)(VB)(VC)(TM)(S)(H)$$

The sequence of events is now translated into an expression of the discrete state as a binary word per state.

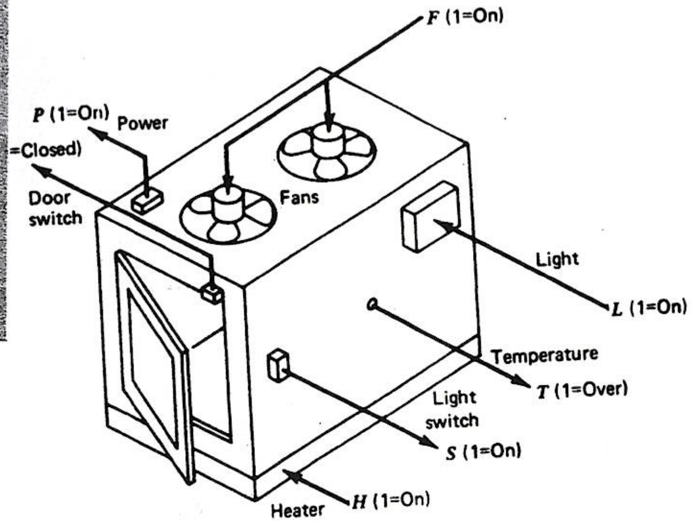

FIGURE 8.12
Oven system for discrete control.

Solution

The solution for problems of this type is developed by simply translating the narrative statements of the events into Boolean equations. In this case, referring to the variables defined in Figure 8.12, you can see that the solution is

Heater: $H = D \cdot \overline{T} \cdot P$
Fans: $F = H + D \cdot T$
Light: $L = \overline{D} + S$

RELAY CONTROLLERS AND LADDER DIAGRAMS

The previous section showed how a discrete-state control system is described in terms of the hardware of the system and the sequence of events through which that hardware is taken. These two elements are now combined to show how the hardware should be driven so that the proper sequence of events can be accomplished. In essence, this amounts to a "program" for the system written with symbols for the hardware.

A special schematic representation of the hardware and its connection has been developed that makes combination of the hardware and event sequence description clear. This schematic is called a *ladder diagram*. It is an outgrowth of early controllers that operated from ac lines and used relays as the primary switching elements.

8.4.1 Background

An industrial control system typically involves electric motors, solenoids, heaters or coolers, and other equipment that is operated from the ac power line. Thus, when a control

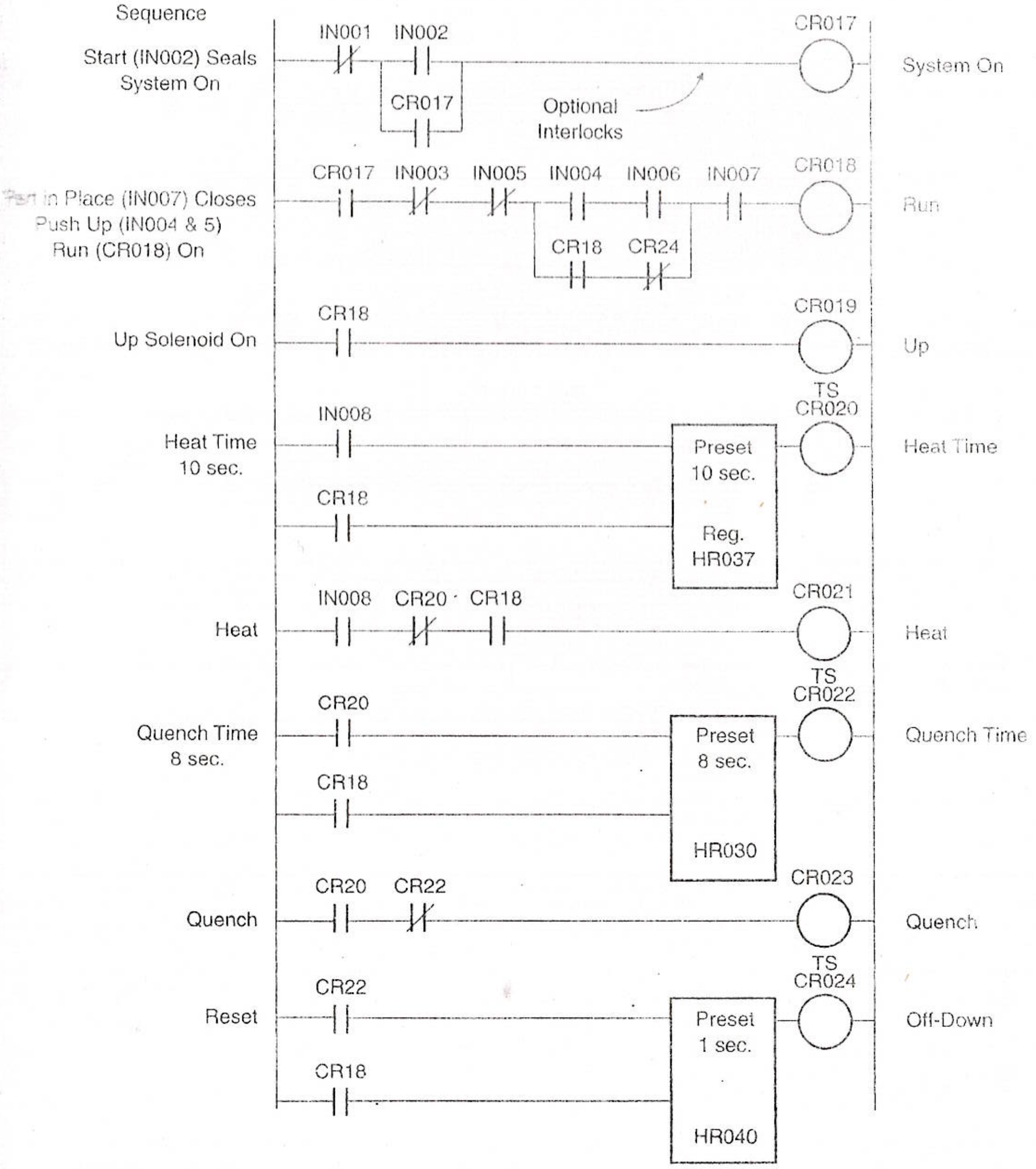

FIGURE 9–15
Heat/Quench Machine Program

5. The part is raised from bottom to top by pneumatic air action. A
supplies this air to a pneumatic elevating cylinder. The lower-limit
be actuated before the part will rise. Lower-limit switch actuation
there is a part on the mandrel and that the mandrel is down. Note
switch opens as the part leaves the bottom position.
6. The mandrel makes contact with a limit switch at the top of the travel.
7. Heat comes on for 10 seconds and goes off.
8. Quench comes on for 8 seconds and goes off.
9. The part returns down by gravity and spring action. The upper-
comes inactivated when the mandrel starts down.
10. The part and mandrel reach the bottom. The down-limit switch is
11. The system should reset.
12. The part is removed.

Some optional features not included in this program are:

- ☐ If you assume the heat generator and both water pumps are on, interlock
added to insure they are running throughout the process.
- ☐ The same ring part could be processed two or more times. We could
ring to be removed after step 12 before resetting takes place.
- ☐ Is proper temperature reached? A thermocouple sensor could be incorp
monitor temperature.
- ☐ Manual controls for setup could be added. These are Up, Heat, and Quench
- ☐ Safety features could be added, such as a safety shield that lowers during
Where does the process restart after interrupted power is restored?
- ☐ Other features as required.

The next step is to assign PLC register or address numbers to the various inputs
outputs.

Inputs		**Outputs**	
0001	Master Shop	0019	Solenoid Valve—Up
0002	Master Start	0021	Heat On Contactor Coil
0003	Left Stop-Up	0023	Quench Spray Water Soleno
0004	Left Start-Down		
0005	Right Stop-Up		**Options**
0006	Right Start-Down	0017	System On Pilot Light
0007	Limit Switch Down	0018	Machine On/Up Pilot Light
0008	Limit Switch Up		

A ladder diagram to carry out the process is then developed, as shown in figure 9–15.

The next step is to draw the connection diagram for the PLC. There are eight input connections and five output connections, three to process actuators and two to pilot lights. The connection diagram is illustrated in figure 9–16.

The final two developmental steps are to program the PLC for the process and make modifications as required.