Program Name : **Diploma in Instrumentation / Instrumentation and Control**

Program Code : **IS / IC**

Semester : **Sixth**

Course Title : **Distributed Control System**

Course Code : **22645**

1. RATIONALE

Nowadays, process industries are being automated by advanced instrumentation devices/ systems to measure and control various process variables like temperature, pressure, flow and liquid level. In today's competitive production environment, process industries demand a totally integrated control and optimization solution that can increase productivity, reliability, and quality while minimizing cost. Distributed Control System (DCS) is designed to meet these customers' needs. The distributed architecture of DCS reduces impact from loss of system components and ensures production continuity. Instrumentation technologists should therefore be able to maintain DCS for automation and this course has been designed to fulfill that purpose.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain Distributed Control Systems.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a) Select the relevant DCS system for given process.
b) Maintain the hardware of given DCS system
c) Configure software for modern automation and communication systems.
d) Interpret displays, alarm and database for the given application
e) Use relevant network protocol for given DCS applications.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory							Practical				
				Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
L	T	P			Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	2	5	3	70	28	30*	00	100	40	25#	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit, **ESE** -End Semester Examination; **PA** - Progressive Assessment*

5. **COURSE MAP** (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels

of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

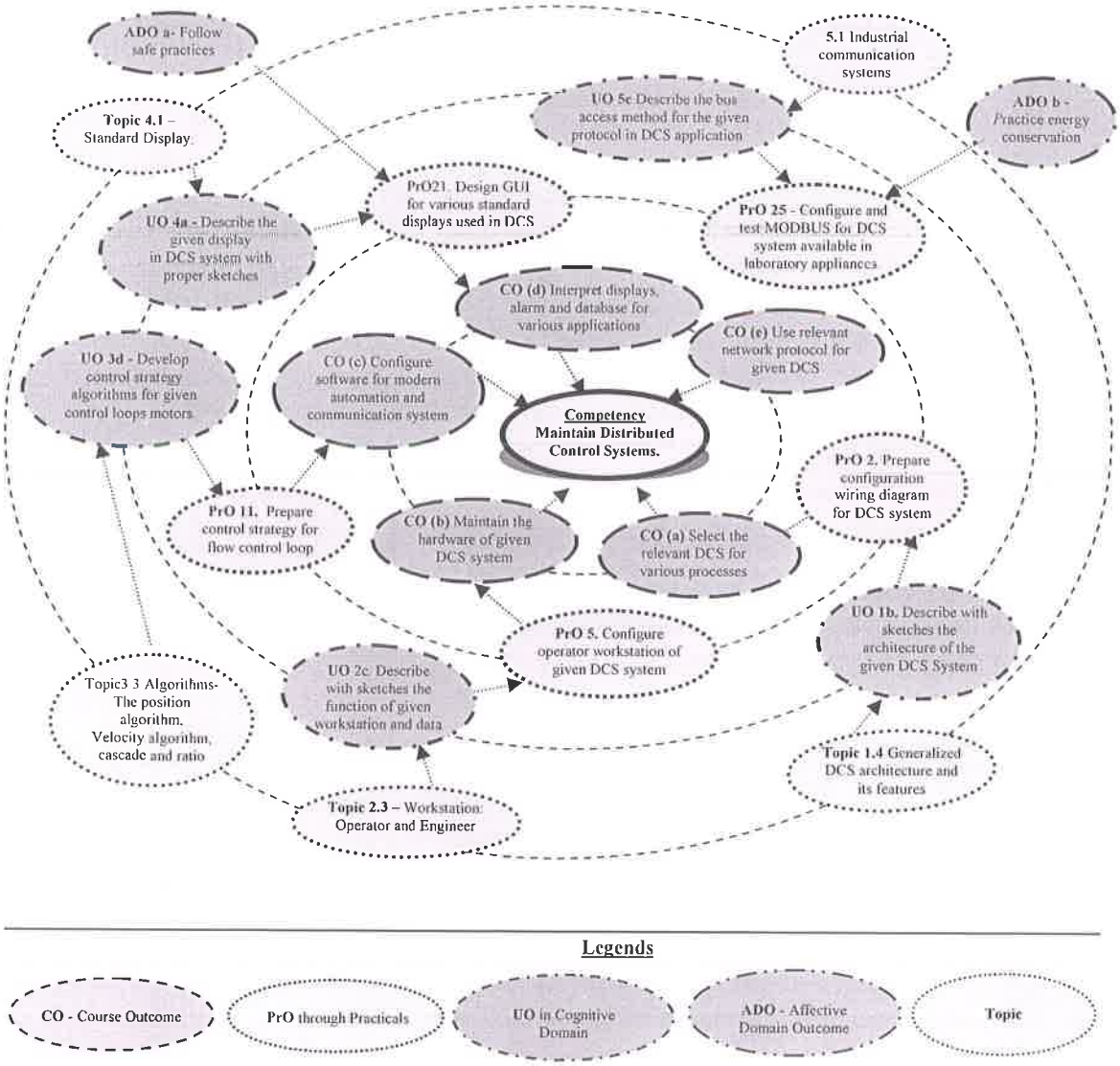

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals' in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Prepare URS (User requirement specification) and FRS (Functional requirement specification) for any small Automation project.	I	02
2	Prepare configuration wiring diagram for DCS system available in laboratory	I	02*
3	Interface the given IO devices with relevant IO module for the given DCS system	II	02*
4	Interface the communication modules with relevant communication protocol for the given DCS system to get the required result.	II	02
5	Configure operator workstation of given DCS system	II	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
6	Configure engineering workstation of given DCS system	II	02
7	Configure the DCS software available in laboratory.	III	02*
8	Prepare control strategy for level control loop	III	02*
9	Prepare control strategy for temperature control loop	III	02
10	Prepare control strategy for pressure control loop	III	02
11	Prepare control strategy for flow control loop	III	02
12	Design control modules using FBD for level control loop.	III	02
13	Design control modules using FBD for temperature control loop.	III	02*
14	Design control modules using FBD for pressure control loop.	III	02
15	Design control modules using FBD for flow control loop.	III	02
16	Develop SFC algorithm for level control loop.	III	02
17	Develop SFC algorithm for temperature control loop.	III	02
18	Develop SFC algorithm for pressure control loop.	III	02*
19	Develop SFC algorithm for flow control loop.	III	02
20	Design graphical user interface for given process on DCS system.	IV	02*
21	Design GUI for various standard displays used in DCS system.	IV	02*
22	Design GUI for various user-defined display displays used in DCS system	IV	02*
23	Design GUI for any two alarms points for given process.	IV	02
24	Interpret the data from log report for given process.	IV	02*
25	Configure and test PROFIBUS for DCS system available in laboratory	V	02
26	Configure and test FIELDBUS for DCS system available in laboratory	V	02*
	Total		**52**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals' marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S.No.	Performance Indicators	Weightage in %
1	Preparation of experimental set up	20
2	Setting and operation	20
3	Safety measures	10
4	Observations and Recording	10
5	Interpretation of result and Conclusion	20
6	Answer to sample questions	10
7	Submission of report in time	10
Total		**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a) Follow safety practices.
b) Practice good housekeeping.

c) Practice energy conservation.
d) Work as a leader/a team member.
e) Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organisation Level' in 2nd year
- 'Characterisation Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTSREQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	**Computer system;** Operating System: Windows 10 or higher **Memory:** minimum of 8 GB RAM, Processor Speed: minimum of Intel Core i5 or equivalent, Hard Drive: 320 GB or larger, DVD Drive: DVD +/- RW Dual Layer Burner or Mac Super Drive, Wireless: Any card that supports 802.11 g/n protocols and WPA2 Enterprise, Ethernet: 10/100/1000 (gigabit), Monitor (Desktop): 19" Monitor or larger	2-27
2	**Profibus PA starter KIT;** Profibus enable controller, devices, cable, connector, power supply.	26
3	**Modbus Trainer Kit;** Modbus enable controller/ PC, Modbus Enable device, Modbus cable, Power Supply	25
4	**Fieldbus Trainer Kit;** Controller with Ethernet enable module, Host computer and OPC server, Stratix 8000 switch, linking device, Power conditioner, Field devices, 24V DC power supply, Network terminator	27
5	**IO Devices:** Switches, Lamps, Relays, Potentiometers, Proximity sensor, DC motor, Fans, Solenoid Valve, Pneumatic valve etc.	3
6	Standard DCS system of reputed brand (such as DeltaV, Experion, Simatic PCS 7, Centum VP) with analog and digital IO modules, power supply module, communication module, controller module with compatible software	2-27
7	Level trainer kit: Level transmitter, Pneumatic control valve, compressor, motor, pneumatic tubes, water tank	8,12,16
8	Temperature trainer kit: Temperature transmitter, Pneumatic control valve, compressor, motor, pneumatic tubes, water tank, heater	9,13,17
9	Pressure trainer kit: Pressure transmitter, Pneumatic control valve, compressor, motor, pneumatic tubes, water tank	9,14,18
10	Flow trainer kit: Flow transmitter, Pneumatic control valve, compressor, motor, pneumatic tubes, water tank	11,15,19

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Overview of distributed control system (DCS)	1a. Explain the given terminologies related to automation. 1b. Describe with sketches the architecture of the given DCS system 1c. Explain with sketches the functions of the given DCS hierarchical levels. 1d. Select the relevant DCS for the given application	1.1 Concept of PLC, SCADA and DCS. Direct Digital control, centralized computer system, Distributed control. 1.2 Hierarchical Control in automation: Hierarchical computer system for a large manufacturing process, overall task, detail task listing, lower level computer task, higher level computer task 1.3 Generalized DCS architecture and its features. 1.4 DCS brands: Delta V, Experion, Simatic PCS 7 – architecture, features, specifications
Unit– II DCS Hardware	2a. Classify the given input and output modules 2b. Explain with sketches the working of the given controller module. 2c. Describe with sketches the function of given workstation and data highway. 2d. Describe the routine maintenance of the given DCS	2.1 Input and output module: Local, Remote, rack mounted, Controller Module, Power supply module, Communication Module 2.2 Workstation: Operator and Engineer 2.3 Data Highway and local IO bus, Redundancy in the DCS 2.4 Maintenance considerations- Reliability, availability, Single loop integrity, backup systems and Fault tolerant systems.
Unit– III DCS software programming	3a. Configure the given DCS system 3b. Explain the given programming languages of DCS system. 3c. Describe the given algorithm for DCS system. 3d. Develop control strategy algorithms for the given control loops. 3e. Develop the program for given application using FBD. 3f. Develop the program for the given application using SFC.	3.1 Operating system configuration, controller function configuration, Algorithm libraries, 3.2 Process control programming: Types of program, Features of process control programs, 3.3 The executive program, Programming language for process control, 3.4 Algorithms- The position algorithm, Velocity algorithm, cascade and ratio control, Feed-forward control, Feed-back control 3.5 Functional Block Diagram programming for basic process control loops, Sequential Flow Chart programming for basic process control loops.
Unit– IV DCS Displays, Alarms And Database	4a. Describe with sketches the given display of a DCS system 4b. Explain with sketches the working of the alarm management system in the	4.1 **Standard Display**: Overview display, unit or area Overview display, Group display, Graphics display, trend display, Loop display. 4.2 **User-defined display**: Plant mimic display, area mimic display, Group

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	given type of DCS. 4c. Describe with sketches the given types of logs and their reports in the specified DCS system. 4d. Justify the need of security at different levels of DCS	mimic diagram and batch control system diagram. 4.3 Alarm reporting, types of Alarm generated and acceptance of alarms 4.4 The different types of logs and report that can be configured on DCS system, Data history use in logs, reports and trend display 4.5 The need for different security levels to various operating parameters configuration (Operator, Engineer and supervisor).
Unit-V Network protocol in DCS	5a. Explain with sketches the given communication protocol in the specified DCS 5b. Compare between the given two protocols based on the specified criteria 5c. Describe the bus access method for the given protocol in DCS 5d. Describe the selection criteria for protocol for the given application	5.1 Industrial communication systems: Management system – MAP/TOP protocol. 5.2 **Field buses**- fieldbus standardization, bus access method, other features, acceptance 5.3 **MODBUS** - bus access method, application services, transmission modes, function, acceptance. 5.4 **PROFIBUS**- bus access method, data link services, application services, and acceptance. 5.5 Smart transmitters-Rackbus: Bus access method, transmitter, gateways, availability 5.6 **FIPBUS** - bus access method, other features, acceptance

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'

9. SUGGESTED SPECIFICATION TABLE FORQUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Overview of distributed control system (DCS)	08	02	02	04	08
II	DCS Hardware	10	-	06	08	14
III	DCS software programming	10	02	04	10	16
IV	DCS displays, alarms and database	10	02	06	06	14
V	Network protocol in DCS	10	04	02	12	18
Total		**48**	**10**	**20**	**40**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual*

distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Compare any three DCS brands based on various parameters.
b) Read an operating manual of available DCS and prepare report.
c) Prepare power point presentation on maintenance of DCS system
d) Read the safety precautions to be followed for installation of DCS system.
e) List different library objects available in DCS software
f) Download animated videos from the internet for any theory topic and make presentation on it.
g) Visit nearby automation industry and prepare a list of various IO devices.
h) Identify various components of Modbus network.
i) Identify various components of Profibus network.
j) Identify various components of Fieldbus network.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Use Flash/Animations to explain working of DCS.
g) Use open source simulation softwaremodules to perform different applications using DCS.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project is group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects is given here. Similar micro-projects could be added by the concerned faculty:

a) Create HMI screen and tag database for bottle filling plant.
b) Create HMI screen and tag database for traffic control system.
c) Create HMI screen and tag database for any batch process.
d) Create HMI screen and tag database for elevator control.
e) Create HMI screen and tag database packaging process.
f) Develop SFC for bottle filling plant
g) Develop SFC for traffic control system
h) Develop SFC for any batch process
i) Develop SFC for elevator control
j) Develop SFC for packaging process.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Instrument Engineers' Handbook, Volume 3:	Bela G. Liptak, Halit Eren	CRC Press, 2016; ISBN 9781439863435
2	Industrial Process Automation Systems: Design and Implementation	Mehta, B.R.; Reddy, Y. Jaganmohan	Butterworth-Heinemann, 2014; ISBN, 9780128010983
3	Industrial Instrumentation & Control	Singh, S. K.	McGraw-Hill Education, New Delhi, 2009; ISBN 9780070262225
4	Distributed Computer Control Systems in Industrial Automation	Bhatkar , Vijay P.	Routledge, 2017; ISBN 9781351454698

14. SOFTWARE/LEARNING WEBSITES

a) www.ourinstrumentation.com
b) http://coep.vlab.co.in/index.php?sub=33&brch=93&sim=425&cnt=571
c) http://coep.vlab.co.in/?sub=33&brch=93&sim=440&cnt=575
d) www.profibus.com
e) https://w3.siemens.com/mcms/topics/en/simatic/pages/default.aspx
f) http://www2.emersonprocess.com/en-US/documentation/Pages/DocSearch.aspx
g) www.profibus.com/uploads/media/PROFIBUS_Planning_8012_V10_Aug09.pdf
h) https://www.youtube.com/watch?v=ZoAwTxZieHowww.fieldbus.org/
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