Program Name : **Electronics Engineering Programme Group**

Program Code : **DE/EJ/ET/EN/EX/EQ**

Semester : **Fifth**

Course Title : **Control Systems and PLC**

Course Code : **22531**

1. RATIONALE

A control system is a discipline that applies automatic control theory to design systems in such a way as to achieve a desired control of operation of the system. Control engineering has an essential role in a wide range of control systems. It seeks to understand physical systems, using mathematical modeling, in terms of inputs, outputs and various components with different behaviors. This course will facilitate students to use the different control systems used in various range of applications from simple home heating controller using a thermostat to a large Industrial control systems which are used for controlling processes or machines. The course introduces Control system and PLC which is adapted for the control of manufacturing processes.

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 electronic automated systems in process and manufacturing industries.**

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. Identify different types of control systems.
b. Determine the stability of the control system.
c. Test the performance of various types of controllers.
d. Maintain various components of PLC based process control system.
e. Maintain PLC based process control systems.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory						Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	-	2	6	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.

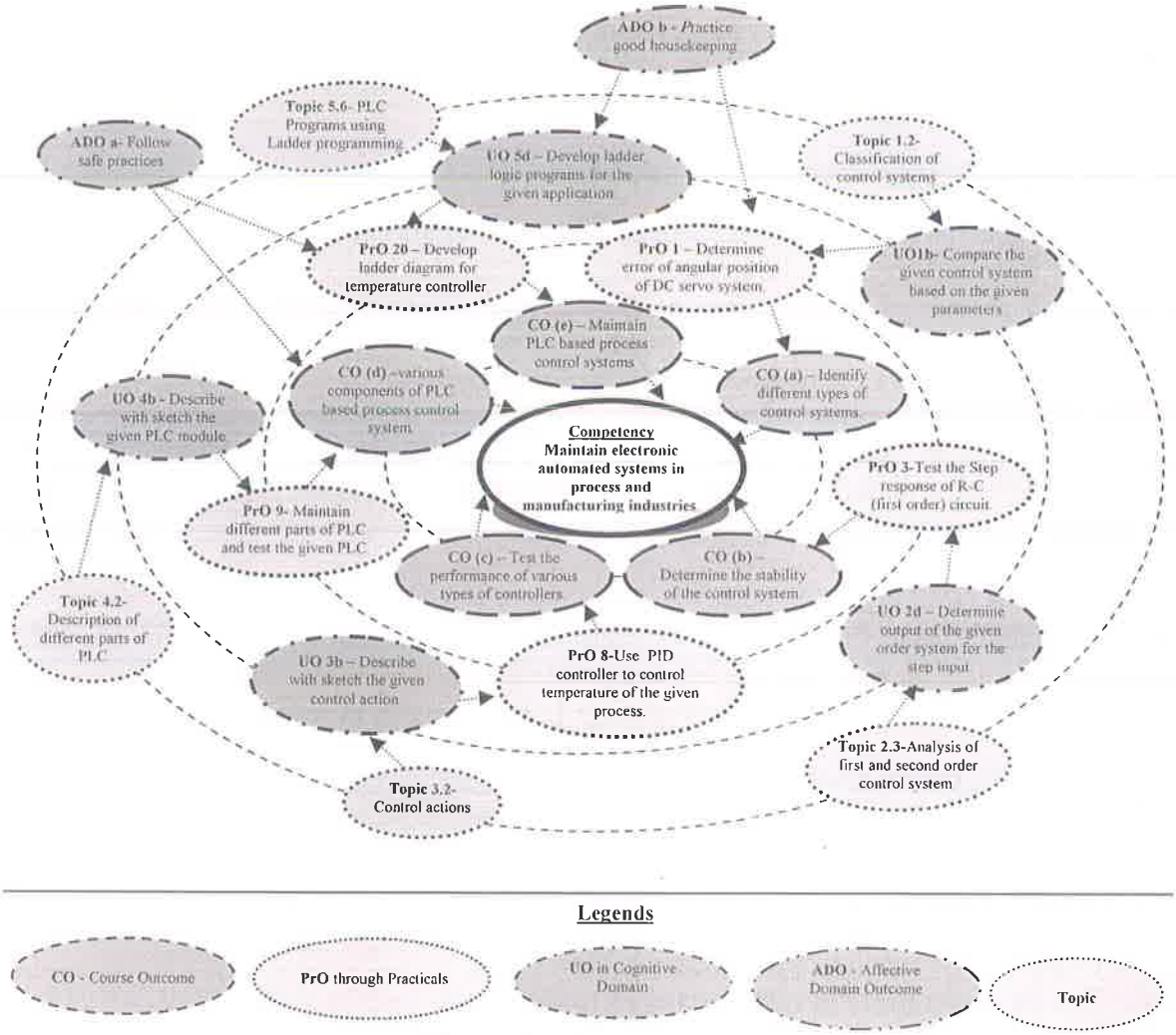

Figure 1 - Course Map

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	Use potentiometer as error detector.	I	02*
2	Determine error of angular position of DC servo system.	I	02
3	Test the Step response of R-C (first order) circuit.	II	02*
4	Test the Step response of R-L-C (second order) circuit.	II	02
5	Test the functionality of temperature control with on-off controller.	III	02*
6	Use PI controller to control temperature of the given process.	III	02
7	Use PD controller to control temperature of the given process.	III	02
8	Use PID controller to control temperature of the given process.	III	02*
9	Identify and test different parts of PLC .	IV	02*
10	Develop ladder diagram to test the functionality of the logic gates.	V	02
11	Develop ladder diagram to test Demorgan's theorem.	V	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
12	Develop the ladder diagram for Adder and Subtractor by using PLC.	V	02
13	Develop ladder diagram for ON and OFF control of lamp using timer and counter.	V	02
14	Develop ladder diagram for traffic light Control system.	V	02
15	Develop ladder diagram for stepper motor control.	V	02*
16	Develop ladder diagram for temperature controller.	V	02*
	Total		**32**

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 %
a.	Preparation of experimental set up	20
b.	Setting and operation	20
c.	Safety measures	10
d.	Observations and Recording	10
e.	Interpretation of result and Conclusion	20
f.	Answer to sample questions	10
g.	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
- 'Organising Level' in 2nd year
- 'Characterising Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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	Cathode ray oscilloscope: Dual trace 50Mhz	03,04
2	Multimeter 3 1/2: AC/DC,0-200V	01 ,02,06 to 08
3	DC position trainer kit	02
4	Potentiometer trainer kit	01
5	RC kit	03
6	RLC kit	04
7	ON-OFF controller kit	05
8	PID controller trainer kit	06 to 08
9	PLC trainer kit (20 digital I/O points and 2 analog I/O channels)	09 to 16
10	Desktop PC	10 to 16
11	Simulation Software: Picosoft,Scilab, Matlab, Prosim, PSpice, LabVIEW, Electronics Workbench, Win pro ladder	01 to 16

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 Basics of control system	1a. Explain with sketches the working of the given type of control systems. 1b. Compare the given control systems based on the given parameters. 1c. Derive transfer function of the given electrical circuits. 1d. Use block diagram reduction rules to determine optimize transfer function of the given system.	1.1 **Control system:** Basics of control system block diagram and practical examples 1.2 **Classification of control systems:** Open loop and closed loop systems- block diagram, practical example and comparison, Linear and non -linear systems, Time varying and Time In-varying systems- practical example and comparison servo system - 1.3 **Transfer function:** Close loop and open loop system RC, LC and RLC circuits-Differential equations and transfer functions and analysis using Laplace transform 1.4 **Block diagram reduction technique:** Need, reduction rules,
Unit– II Time domain stability analysis	2a. Compare the parameter of given standard test inputs. 2b. Identify poles, zeros, type and order for the given transfer function. 2c. Sketch pole zero plot for the given transfer function. 2d. Determine output of the given order system for the step input.	2.1 **Time Response:** Transient and steady state response. 2.2 **Standard test inputs:** Step, ramp, parabolic, impulse and their corresponding Laplace transform 2.3 **Analysis of first and second order control system:** i. **Poles and zeros** - S-plane representation Order of system (0, 1, 2)- standard equations, examples and numerical problems ii. **First order system**-Analysis for unit step input, concept of time constant

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	2e. Calculate time response specifications of the given transfer function. 2f. Calculate error constants of the given type of control system. 2g. Determine stability of the given control system using Routh's stability criteria.	iii. **Second order system-** Analysis for unit step input (no derivation), concept, definition and effect of damping iv. **Time response specifications** (no derivations) - Tp, Ts, Tr, Td, Mp, Ess, numerical problems 2.4 **Steady state analysis**: Type 0, 1, 2 systems- steady state error and error constants, numerical problems 2.5 **Stability:** Concept of stability, root locations in S-plane and analysis- stable system, unstable system, critically stable systems, conditionally stable system, relative stability 2.6 **Routh's stability criterion:** Steps and procedures to find stability by Routh's stability criteria,
Unit –III Process controllers	3a. Explain with sketch the given process control system. 3b. Describe with sketch the given control action. 3c. Compare different electronic controllers on the basis of the given parameters. 3d. Sketch the response of the given controller with respect to error.	3.1 **Process Control System**: Block diagram, functions of each block 3.2 **Control actions:** i **Discontinuous mode-** ON-OFF controllers- equation, neutral zone ii **Continuous modes:** Proportional Controller - offset, proportional band. Proportional, Integral and Derivative controllers -o/p equation, response, characteristics, 3.3 **Composite controllers**: PI, PD, PID controllers- o/p equation,response
Unit-IV Fundamentals of PLC	4a. Explain with sketch PLC based automation system. 4b. Describe with sketch the given PLC module. 4c. Identify different devices interfaced with PLC. 4d. Explain the steps for PLC installation.	4.1 **PLC**-Block diagram, classification, (fixed and modular PLCs), need and benefits of PLC in automation 4.2 **Description of different parts of PLC**: CPU –function, scanning cycle, speed of execution, Power supply- block diagram and function of each block Memory – function and organization of ROM and RAM Input and output modules- function, different input and output devices of PLC (only name and their uses). 4.3 **PLC Installation**
Unit-V PLC hardware and programming	5a. Identify and describe the given module of PLC. 5b. Describe the given addressing of PLC. 5c. Use instruction set to perform the given operation. 5d. Develop ladder logic programs for the given	5.1 **Discrete input modules:** Block diagram, specifications of AC input modules and DC input module. Sinking and sourcing concept in DC input modules 5.2 **Discrete output modules:** Block diagram description, specifications of AC output module and DC output modules 5.3 **Analog input and output modules:** Block diagram, specifications

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	application.	5.4 **I/O addressing of PLC**: Addressing data files, format of logical address, different addressing types 5.5 **PLC Instruction set**: Relay instructions, timer and counter instructions, data movement instructions, logical and comparison instructions 5.6 **PLC Programs** using Ladder programming language.

***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 FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Basics of Control System	10	02	04	06	12
II	Time domain stability analysis	16	04	04	08	16
III	Process Controllers	08	02	04	04	10
IV	Fundamentals of PLC	12	04	04	06	14
V	PLC Hardware and Programming	18	04	06	08	18
Total		64	**16**	**22**	**32**	**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. Prepare manuals based on practical performed in laboratory.
b. Follow the safety precautions.
c. Give seminar on relevant topic.
d. Library / Internet survey regarding different data books and manuals.
e. Prepare power point presentation on PLC.
f. Undertake a market survey of different manufacturer of PLC.

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 control system.
g. Use open source simulation software modules to perform different applications using PLC.

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 are 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 are given here. Similar micro-projects could be added by the concerned faculty:

a. Simulate and test the performance of 1st order RC and 2nd order RLC Circuit using simulation software.
b. Prepare a chart to show the error constants of type 0, 1 and 2 systems for different standard test inputs.
c. Simulate and test the performance of PI, PD, and PID-control action using simulation software.
d. Prepare a chart to show characteristics of control actions with respect to error.
e. Prepare a report on the basis of PLC data sheets of various manufacturers.
f. Develop/Test a ladder diagram for controlling washing machine operations.(Wash cycle-inlet valve should open for 10 sec. Motor starts running after 10sec. Running time for motor is 20sec. After that motors stops. Then outlet valve opens and water is drained out. Same operations are repeated for rinse cycle. Spin cycle- Motor runs at high speed for 20 sec and outlet valve remains open for the whole period of spin cycle.)
g. Develop/Test a ladder diagram for automatic cold drink bottle filling system.(When sensor senses a bottle, after 3 sec outlet valve of the container containing cold drink will open . It will be open for 10 sec and then the valve will be closed. The bottle will be moved forward automatically. The process should stop after filling of 25 bottles.)
h. Develop/Test a ladder diagram for Interlock Control circuit. (The entry/exit of the parking lot is a single lane passage. By controlling the indicators only one car should pass through the entry/exit so as to prevent car accidents between entering and leaving cars.)

i. Develop/Test a ladder diagram for product mass packaging. (When the photoelectric sensor detects specified number of products, robotic arm will begin to pack up. When the action is completed, robotic arm and counter will be reset.)
j. Develop/Test a ladder diagram for 24 hour clock operated by 3 counters.
k. Develop/Test a ladder diagram for sequential delay output i.e starting 3 motors sequentially. (Example- Start the oil pump motor when the start button is pressed. Main motor will be started after 10 sec delay and then the auxiliary motor after 5 sec delay. Also stop all the motors immediately when stop button is pressed.)
l. Develop/Test a ladder diagram for performing Pulse-Width modulation by changing the set value in the timer.
m. Develop/Test a ladder diagram for Artificial Fish pond water level monitoring system. (Feeding /Draining water immediately when the water level of the artificial fish pond is not at the normal level. Also enabling the alarm and alarm lamp when the water is above or below the normal level.)
n. Develop/Test a ladder diagram for Automatic Door Control system. (When someone enters the door should open automatically and if no one enters for about 10sec, door should close automatically. Also if someone enters the sensing field during door closing process, closing action should stop immediately.)
o. Develop/Test a ladder diagram for Automatic Coffee Making system. (When a coin is inserted paper cup should come out from the outlet. At the same time coffee pours in the mixing container. After 2 sec hot water pours in. After 60 sec readymade coffee will come out from coffee outlet.)
p. Develop/Test a ladder diagram for automatic control of a machine which is required to direct 6 objects along one path for packaging in a box and then 12 objects along another path for packaging in another box. A deflector plate might be controlled by a photocell sensor gives an output every time an object passes it.

13. SUGGESTED LEARNING RESOURCES

S. No.	Author	Title of Book	Publication
1	Process control instrumentation Technology	Johnson, C. D.	Prentice Hall, 8th edition, United States of America,2014 ISBN: 978-0131194571
2	Intro. To Programmable logic control	Dunning, Gary	Cenage Learning, United States of America,2005 ISBN: 9781401884260
3	Control System Engineering	Nagrath, J.J. ; Gopal, M.	Anshan Publishers (2008) ISBN: 9781848290037
4	Modern control Engineering	Ogata, K.	PHI , 5th Edition, NEW DELHI,2010 ISBN: 978812034010
5	Programmable logic controllers and industrial automation an introduction	Mitra, Madhuchhanda ; Gupta, Samarjit Sen	Penram,1st Edition, Mumbai, 2007 ISBN: 9788187972174
6	Programmable logic controllers	Petruzella, F.D.	Tata- McGraw Hill, 3rd Edition, 2010 ISBN: 9780071067386

14. SOFTWARE/LEARNING WEBSITES

a. www.scilab.org

b. www.openplc.fossee.in
c. www.github.com/FOSSEE/OpenPLC
d. www.youtube.com /plc
e. www.dreamtechpress.com /ebooks
f. www.nptelvideos.com/control_systems/
g. www.in.mathworks.com/solutions/control-systems.html?s_tid=srchtitle
h. www.edx.org/course?subject=Engineering&course=all&language=English
i. www.plcs.net
j. www.ab.rockwellautomation.com › Allen-Bradley
k. www.plc-training-rslogix-simulator.soft32.com/free-download/


MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION