GUJARAT TECHNOLOGICAL UNIVERSITY, AHMEDABAD, GUJARAT

Course Curriculum

SAFETY INSTRUMENTATED SYSTEMS AND SAFETY INTEGRATED LEVEL (Code: 3331701)

Diploma Programme in which this course is offered	Semester in which offered
Instrumentation and Control Engineering	3rd semester

1. RATIONALE

In the present industrial scenario, to avoid industrial accidents and hazards, many inbuilt checks and controls are provided by having "Safety Instrumented Systems". It is therefore desirable that a diploma engineer should be able to identify, classify and maintain the different 'Safety Instrumentated System's as well 'Safety Integrated Levels' applied to Safety Instrumented Systems. They are required to implement the planned safety Process Instrumentation maintenance schedules universally followed by the instrumentation and process industries. Therefore, this course has been designed to take care of this need, to make the students 'work ready'.

2. COMPETENCY ('Programme Outcome' according to NBA Terminology)

The course content should be taught and implemented with the aim to develop different types of skills so that students are able to acquire following competency:

- **Maintain the different types of "safety Instrumentated systems" as well as "safety integrated levels" associated with them in Process Instrumentation Application**

3. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	ESE	PA	ESE	PA	150
3	0	2	5	70	30	20	30	

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

4. COURSE DEATAIL

UNIT	MAJOR LEARNING OUTCOMES **('Course Outcomes' in Cognitive Domain according to NBA terminology)**	Topics/subtopics
UNIT-1 INSTRUMENTATION SAFETY IN PROCESS APPLICATIONS	1a.Classify the various types of zones with respect to hazard and safety of process in instrumentation and control 1b.Compare the specific Zones in Process Instrumentation	1.1 With guiding standard of IEC 61421.10 and IEC 60079.10 for Types of Zones of Processes in NFPA 497/API 500: Non-Hazardous Area, Division 2 or Zone 2 area, Division 1 or Zone 1 area, Zone 0 area
		a. Dust zones: Zone 20, Zone 21, Zone 22
		b. Gas / Vapour groups : Gas Group, Gas Group IIA, Gas Group IIB, Gas Group IIC
		c. Equipment Protection Level (EPL): Level - I (mines), II (gas) , III (dust) Equipment category: Category 1, Category 2, Category 3
		d. Common Materials within Associated Class and Group Ratings · Class I Areas: Group A: Acetylene / Group B: Hydrogen / Group C: Propane and Ethylene / Group D: Benzene, Butane, Methane and Propane · Class II Areas: Group E: Metal Dust / Group F: Carbon and Charcoal / Group G: Flour, Starch, Wood and Plastic · Class III Areas: NO GROUP: Cotton and Sawdust
		f. ANSI/NFPA areas description (Class I- Div. 1, Class I- Div. 2, Class II- Div. 1, Class II- Div. 2, Class III-Div. 1, Class III- Div. 2)

		g. Temperature classification: USA°C Type T1 - 450 , T2 – 300, T2A - 280, T2B – 260, T2C – 230, T2D – 215, T3 – 200, T3A - 180, T3B - 165, T3C - 160, T4 - 135, T4A – 120, T5 – 100, T6 – 85
		h. Type of protection: Ex Code d-Flameproof ,e- Increased Safety ,o- Oil Filled ,q-Sand/Powder/Quartz Filled ,m-Encapsulated ,p-Pressurised/purged ,i- Intrinsically safe ,n- Non Incendive ,s- Special
	1c. List out different system included in 1.2 in reference of safety instrumented system with application	1.2 Safety Instrumented Systems include: Equipment protection system, Emergency shutdown system, Safety critical system, Interlock (engineering)
	1d. Describe reliability regimes	1.3 Reliability regimes: regimes for life-critical systems, Fail-operational systems, Fail-safe systems, Fail-secure systems, Fail-Passive systems, Fault-tolerant systems 1.4 Software engineering for life-critical systems
UNIT-2 SAFETY INSTRUMENTED SYSTEM	2a.Define Safety Instrumentation Systems (terms)	2.1 safety instrumentation systems terms : Hazard and operability studies (HAZOP), failure modes, effects, and criticality analysis (FMECA), probability of failure on demand (PFD), failure mode and effects analysis (FMEA), SFF Safe Failure Fraction , , Safety Instrumented Function) SIF , Process Hazards Analysis PHA, , Process Hazards Analysis (PHA), Hardware Fault Tolerance , HIPPS (High Integrity Process Pressure System)

	2b.Describe safety life cycle	Safety Life Cycle: Concepts (safety acronyms), Safety Life Cycle, Safety Instrumented Function (SIF), Safety Requirement Specification(SRS)
UNIT-3 SAFETY INTEGRATED LEVEL(SIL)	3a.Define Risk with reference to safety integrated system.	3.1. Each SIF is assigned a Safety Integrity Level (SIL) during SIL analysis - risk assessment: i. SIL 0/none – lowest risk ii. SIL 1 – 95% of the SIFs iii. SIL 2 – 5% of SIFs iv. SIL 3 – < 1% (not likely in refineries, but possible in off-shore platforms or nuclear) v. SIL 4 – highest risk (only seen in nuclear industry) vi. RISK = Hazard Frequency X Hazard Consequence Event
	3b.Describe safety integrated level SIL-0 to SIL-4	
Unit– 4 SIF (Safety Instrumented Function) and SFF (Safe Failure Fraction) in Field , Utility and Safety Instrumentation Maintenance	4a. Compare SIF and SIS	4.1 SFF (Safe Failure Fraction)
	4b. Compare SIF and SIL	4.2 SIF (Safety Instrumented Function) i. Hazard, Mode of operation, Detection, Decision, Action, Safety integrity level (SIL), Safe state, Response time, Proof-test interval, Safety instrumented system (SIS), Spurious trip rate,
	4c. Define the terms of SIF	
Unit – 5 Operation, maintenance, testing, reporting and management of Protection System Maintenance Program (PSMP)	5a. Describe the working of various types of reports required for maintenance management.	5.1 Reports / Records i. Safety Instrument bin card ii. Safety Instrument log book iii. Safety Instrument Maintenance indent book(physical, human resource) iv. Safety Instrument complaint book
	5b. Define the terms context to Protection System Maintenance Program (PSMP)	5.2 Protection System Maintenance Program (PSMP) Terms : Verification ,Monitoring ,Testing, Physical Inspection , Calibration , Upkeep , Restoration i. Monitoring by Analysis of Fault Records ii. Performance-Based
	5c. List types of Protection System Maintenance Program PSMP - 5.2.1 to 5.2.7	
	5d. Describe the working of various types of PSMP 5.2.1 to 5.2.7 maintenance management	

	5e. Compare each other (PSMP – 5.2.1 to 5.2.7	Maintenance Process iii. Maximum Allowable Verification Intervals iv. Time Based versus Condition Based Maintenance
	5f. Identify maintenance activity and tasks in Time Based Maintenance.	
		v. Condition Based Maintenance (CBM) Programs vi. Time Based Maintenance (TBM) Programs vii. Overlapping the Verification of Segments of the Protection System
	5g. Describe Self-Monitoring Capabilities and Limitations of the system components	5.3 Self-Monitoring Capabilities and Limitations
	5h. Notify the Protection System failures as report and action	5.4 Notification of Protection System Failures

5. SUGGESTED SPECIFICATION TABLE WITH HOURS and MARKS (THEORY)

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total
I	Instrumentation Safety in Process Applications	5	3	2	2	7
II	safety instrumented systems (SIS)	10	4	5	5	14
III	safety integrated level (SIL)	10	4	5	5	14
IV	SIF (Safety Instrumented Function) and SFF (Safe Failure Fraction) in field, utility and Safety Instrumentation Maintenance	5	3	2	2	7
	Critical, Safety,	5	4	5	5	14

V	Protective Instrumented System					
VI	Operation, maintenance, testing reporting and management of Protection System Maintenance Program (PSMP)	7	4	5	5	14
Total		**42**	**22**	**24**	**24**	**70**

Legends: R = Remember; U = Understand; A = Apply and above levels (Bloom's revised taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

4. SUGGESTED LIST OF EXERCISES/PRACTICALS

The practical/exercises should be properly designed and implemented with an attempt to develop different types of practical skills (**Course Outcomes in psychomotor and affective domain)** so that students are able to acquire the competencies (Programme Outcomes). Following is the list of practical exercises for guidance.

Note: Here only course outcomes in psychomotor domain are listed as practical/exercises. However, if these practical/exercises are completed appropriately, they would also lead to development of **Programme Outcomes/Course Outcomes in *affective domain*** as given in a common list at the beginning of curriculum document for this programme. Faculty should refer to that common list and should ensure that students also acquire those Programme Outcomes/Course Outcomes related to affective domain.

S. No.	**Unit No.**	**Practical Exercise ('Course Outcomes' in Psychomotor Domain according to NBA terminology)**	**Approx Hours Required**
1.	I	Identify the Instrumentation Safety in Process Applications continuous process from a textile industry.	02
2.	I	Identify the Instrumentation Safety in Process Applications continuous process from a chemical industry	02

3.	I	Prepare a daily maintenance schedule for a given safety instrumented systems in a textile process.	02
4.	I	Draw a control loop for a safety instrumented systems operated in a textile process.	02
5.	I	Draw a control loop for a safety instrumented systems operated in a chemical process boiler plant.	02
6.	I	Prepare a half-yearly maintenance schedule of activities for safety integrated level (SIL) 1 instrument used in a given chemical process.	02
7.	I	Prepare a list of activities for a yearly shut down maintenance for SIF (Safety Instrumented Function) schedule for a given chemical process.	02
8.	I	Maintain the indicating instruments for SIF (Safety Instrumented Function) in a given process.	02
9.	II	Maintain the Protective Instrumented System controlling instruments for a given chemical process boiler plant.	02
10.	II	Maintain the Protective Instrumented System recording instruments for a given process in a boiler.	02
11.	III	Maintain the Protective Instrumented System final control elements/instruments for a given textile dyeing process.	02
12.	IV	Test the performance of the final control	02

		elements/instruments of Protective Instrumented System for a given chemical process	
13.	V	Log the maintenance activity carried out for a given process in hard as well enter the data in computerized maintenance management software in appropriate log. Field.	02
14.	V	Carry out maintenance activity with Antivirus / Authorization/ Password for a given computerized maintenance management software.	02
Total		**28**	

7. SUGGESTED LIST OF STUDENT ACTIVITIES

i. Students may be given exercises based on various instrumentation devices and components to maintain related to above topics.

ii. Students may be asked to collect photographs using internet which is relevant to field application of various topics and have to prepare learning materials using it.

iii. Teachers guided self learning activities, Course/library/internet/lab based mini projects, industrial visit etc.

iv. Students activities like: course/ topic based seminars, Internet based assignments.

8. SPECIAL INSTRUCTIONAL STRATEGIES (if any)

i. Visits to Industries

ii. Bring small instrumentation components to the class when teaching

iii. Internet based home assignments

iv. Mini project

9. SUGGESTED LEARNING RESOURCES

A) List of Books S.No.	Author	Title of Books	Publication/Year
1	ld Goettsche.	ISA | Maintenance of Instruments and Systems,	2nd Edition Maintenance of Instruments and Systems, 2nd Edition ld Goettsche.ISA
2	Lindley R. Higgins, R. Keith Mobley, Darrin Wikoff	Maintenance Engineering Handbook,	Seventh Edition
3	W G Andrew	Applied Instrumentation to Process Industries	Vol. 1 to 4 Gulf Publication
4	Jones E. B.	Instrument Technology,	Vol - I, II, Hollywell
5	Williams M. Goble	Control system safety evaluation and reliability	ISA
6	Alan McMillan,	*Electrical Installations in Hazardous Areas*,	Butterworth-Heineman 1998
7	Harry Cheddie , William M. Goble	Safety Instrumented Systems Verification: Practical Probabilistic Calculation	ISA

B) List of Major Equipment/ Instrument with Broad Specifications

i. Instrument Maintenance Shop Tools

a) Dead weight tester / Comparison Guage,
b) Temp. Controlled Bath,
c) Temp. Controlled Oven,
d) Assorted Pneumatic and Hydraulic tubing/ piping tools,
e) Pneumatic Calibrator, Electronic Calibrator ,
f) Thermo Couple Calibrator, Indicator puller,
g) Impulse line bending and flaring tools, Allenkey set,
h) Open and Ring fix Spanner set,
i) Adjustable pipe wrench and Spanner,
j) Screw Driver set,
k) Digital Multimeters with True RMS 41/2 Digit,
l) Clip on meters,
m) Assorted Electrical Insulated Tools set ,
n) Soldering / Desoldering Station,

o) Drilling M/c ,
p) Mini Compressor,
q) Mechanical Vice,
r) Megger / insulation tester
s) Fibre Optic assorted tools – Splicer, Alignment tool , cutter , Splitting Tools, All assorted Magnetic tools,
t) All maintenance Consumables viz., Isopropyl Alcohol, Silicon Oil, Sprays ,CTC Thermic Fluids, Silicon Grease, Graphite based Grease, Clove Oil, Chart recorder Inks – Red/ Blue/ Black

ii. Standards Equipment Room

a) high precision dead weight tester (customs design)
b) high precision voltmeter
c) general purpose oscilloscope
d) stabilized power supply (high precision-high and low voltage)
e) high precision weighing balance
f) precision resistance thermometers
g) one set of glass thermometers (-5 to +250°C)
h) precision variable resistance (Decade box)
i) whetstone bridge
j) high precision barometer
k) high precision dew point hygrometer
l) standard platinum resistance
m) precision current source
n) flat bed recorder
o) standard thermocouples

iii. **Pneumatic 'Shop'**

a) precision pressure regulator
b) pneumatic test rig for controllers (depending on manufacturer)
c) set of precision gages
d) low pressure/vacuum calibration system
e) pneumatic calibration unit
f) digital pressure calibrator (300 mbar)
g) digital pressure calibrator (1.6 bar)
h) digital pressure calibrator (10 bar)
i) high pressure test kit (200 bar)
j) portable low pressure pump
k) portable calibrator
l) pneumatic calibrator- electro
m) pneumatic calibrator
n) absolute pressure unit

iv. **Electronic 'Shop'**

a) portable temperature indicator (6½ digits)
b) portable multivolt meter (6½ digits)
c) whetstone bridge
d) variable resistance (decade box)
e) analogic voltmeter multi-function
f) logic analyzer
g) electronic voltmeter
h) digit al counter frequency meter
i) universal impedance measuring bridge
j) adjustable and portable power supply (high + low voltage)
k) function generator
l) programmable pulse generator
m) general purpose oscillator
n) transistometer
o) stroboscopic tachometer
p) calibration set for vibration monitor
q) digital circuit tester
r) milli-ohm meter (in 0.001 ohm steps)
s) high resistance meter (500 kohms)
t) PT 100 simulator
u) flat bed recorder (dual bed)
v) portable tachometer
w) XY recorder (dual bed)
x) set of standard resistors (10 000 to 1 000 ohm)
y) set of standard platinum resistances
z) test oscilloscope microprocessor (to be kept in the control room, for integrated control systems)
aa) digital oscilloscope with memory
bb) low-voltage megger (50 Volts)
cc) high-voltage megger (500 Volts)
dd) earth fault detector
ee) specific 'manufacturers' calibrator
ff) cold junction reference
gg) computer peripherals.

v. **Special test-benches**

a) control valve
b) hydraulic (portable type)
c) temperature, pressure , flow , level & analytical instrumentation

vi. **Standard Test-Benches**

a) light duty
b) pneumatic
c) electronic
d) DCS and PLC
e) analyzer (general duty)
f) analyzer (specific duty)

vii. **Test Equipment**

a) set of precision pressure gages
b) low-pressure calibration unit (including vacuum)
c) set of digital pressure calibrators (300 mb to 10 bar)
d) pneumatic portable calibration unit (0.2 to 1 bar)
e) portable temperature indicator (TC simulator)
f) one or two electronic digital accurate voltmeters
g) variable resistance (decade box)
h) portable oscilloscope (general purpose)
i) PT 100 simulator calibrator
j) portable tachometer
k) manufacturer's' calibrator(s)
l) portable pulse and function generator
m) portable variable power supply (amps/volts).
n) -standard Voltage/frequency Sources

C. List of Software/Learning Websites

a) http://confirm.pbbiblogs.com/2009/11/28/8-types-of-maintenance-a-comparison/
b) www.maintenancephoenix.com/.../8-steps-to-success-in-maintenance-
c) www.reliabilityweb.com/.../Maintenance%20Scheduling%20101.pdf
d) Maintenance Event Builder (MEB). Soft ware
e) www.clicksoftware.com/service_schedule
f) www.mainpac.com/ Maintenance Software
g) http://www.mainpac.com.au/ Preventive Maintenance Software
h) www.clicksoftware.com/service_schedule SOFTWARE
i) Predictive maintenance software module of DCS, safety instrumentation preventive maintenance software.

- www.mainpac.com/ Maintenance Software
- http://en.wikipedia.org/wiki/Electrical_equipment_in_hazardous_areas
- http://en.wikipedia.org/wiki/Safety_instrumented_system
- http://en.wikipedia.org/wiki/Safety_critical_system
- http://en.wikipedia.org/wiki/Fail-safe

- http://en.wikipedia.org/wiki/Fail-secure
- http://en.wikipedia.org/wiki/Fault-tolerant_system
- Center for Chemical Process Safety book, Guidelines for Safe and Reliable Instrumented Protective Systems
- http://www.mpri.lsu.edu/workshop/Safety%20Instrumented%20Systems%20Angela%20Summers.ppt
- http://www.processengr.com/ppt_presentations/safety_instrumented_systems.pdf
- https://www.jlab.org/accel/ssg/safety/Understanding_sil.pdf
- http://www2.emersonprocess.com/siteadmincenter/PM%20DeltaV%20Documents/Articles/ControlMagazine/The-Safety-Instrumented-Function-An-S-Word-Worth-Knowing.pdf
- http://www.google.co.in/url?sa=tandrct=jand q=safety%20instrumented%20systems%20pptandsource=webandcd=3and cad=rjaandved=0CD0QFjACandurl=http%3A%2F%2Fwww.c-ad.bnl.gov%2FESSHQ%2FASW2009%2FPresentations%2FEtkin%2C%2520Asher%2520Tuesday%25208-18-09.pptxand ei=-NlfUf65GMPirAeR94CoBAand usg=AFQjCNFicYjLjSmRHXfjoXZTIhwQogfovgand bvm=bv.44770516,d.bmk
- http://www.cyber.st.dhs.gov/pcs/
- http://www.amazon.com/Safety-Instrumented-Systems-Verification-Probabilistic/dp/155617909X#reader_B0092WVBH8
- http://www.isa.org/Template.cfm?Section=books3and template=Ecommerce/FileDisplay.cfmandProductID=7915and file=ACFE503.pdf
- http://www.iec.ch/functionalsafety/
- www.siracertification.com
- http://www.hima-sella.co.uk/data/pp/pp054/docs/61508_overview_sira.pdf
- http://www.iamechatronics.com/notes/78-lessons-in-instrumentation/482-safety-instrumented-functions-and-systems
- http://www.nerc.com/docs/standards/sar/PSMT_Supplementary_Reference_Draft1_2009July23.pdf
- NERC/SPCTF/Relay_Maintenance_Tech_Ref_approved_by_PC.pdf

10. COURSE CURRICULUM DEVELOPMENT COMMITTEE

Faculty Members from Polytechnic

- **Prof. R.R. Manchiganti**, HOD IC Engineering, Govt. Polytechnic Gandhinagar

- **Prof. N.B. Mehta,** Lecturer IC Engineering, Government Polytechnic, Ahmedabad
- **Prof. H.P. Patel,** Lecturer IC Engineering, Government Polytechnic, Ahmedabad

Faculty Member from NITTTR Bhopal

- **Dr. Joshua Earnest**, Professor, Department of Electrical and Electronics Engineering
- **Dr. Shashikant Gupta**, Professor and Coordinator for State of Gujarat.