IARE
INSTITUTE OF AERONAUTICAL ENGINEERING

Outcome Based Education (OBE) Manual
IARE - R18

Department of
Electrical and Electronics Engineering

(M.Tech – Electrical Power Systems)

Contents

OVERVIEW

Outcome Based Education (OBE) is an educational model that forms the base of a quality education system. There is no single specified style of teaching or assessment in OBE. All educational activities carried out in OBE should help the students to achieve the set goals. The faculty may adapt the role of instructor, trainer, facilitator, and/or mentor, based on the outcomes targeted.

OBE enhances the traditional methods and focuses on what the Institute provides to students. It shows the success by making or demonstrating outcomes using statements "able to do" in favour of students.OBE provides clear standards for observable and measurable outcomes.

National Board of Accreditation (NBA) is an authorised body for the accreditation of higher education institutions in India. NBA is also a full member of the Washington Accord. NBA accredited programmes and not the institutions.

Higher Education Institutions are classified into two categories by NBA

Tier – 1: Institutions consists of all IITs, NITs, Central Universities, State Universities and Autonomous Institutions. Tier - 1 institutions can also claim the benefits as per the Washington Accord.

Tier - 2 Institutions consists of affiliated colleges of universities.

What is Outcome Based Education (OBE)?

Institutions adopting OBE try to bring changes to the curriculum by dynamically adapting to the requirements of the different stakeholders like Students, Parents, Industry Personnel and Recruiters. OBE is all about feedback and outcomes.

Four levels of outcomes from OBE are:

1. Program Educational Objectives (PEOs)
2. Program Outcomes (POs)
3. Course Outcomes (COs)

Why OBE?

1. International recognition and global employment opportunities.
2. More employable and innovative graduates with professional and soft skills, social responsibility and ethics.
3. Better visibility and reputation of the technical institution among stakeholders.
4. Improving the commitment and involvement of all the stakeholders.
5. Enabling graduates to excel in their profession and accomplish greater heights in their careers.
6. Preparing graduates for the leadership positions and challenging them and making them aware of the opportunities in the technology development.

Benefits of OBE

Clarity: The focus on outcome creates a clear expectation of what needs to be accomplished by the end of the course.
Flexibility: With a clear sense of what needs to be accomplished, instructors will be able to structure their lessons around the students' needs.
Comparison: OBE can be compared across the individual, class, batch, program and institute levels.
Involvement: Students are expected to do their own learning. Increased student's involvement allows them to feel responsible for their own learning, and they should learn more through this individual learning.

- Teaching will become a far more creative and innovative career
- Faculty members will no longer feel the pressure of having to be the "source of all knowledge".
- Faculty members shape the thinking and vision of students towards a course.

India, OBE and Accreditation:

From 13 June 2014, India has become the permanent signatory member of the Washington Accord. Implementation of OBE in higher technical education also started in India. The National Assessment and Accreditation Council (NAAC) and National Board of Accreditation (NBA) are the autonomous bodies for promoting global quality standards for technical education in India. NBA has started accrediting only the programs running with OBE from 2013.

The National Board of Accreditation mandates establishing a culture of outcome-based education in institutions that offer Engineering, Pharmacy, Management program. Reports of outcome analysis help to find gaps and carryout continuous improvements in the education system of an Institute, which is very essential.

1 Vision, Mission, Quality Policy, Philosophy & Core Values

1.1 Vision and Mission of the Institution

Vision

To bring forth professionally competent and socially sensible engineers, capable of working across cultures meeting the global standards ethically.

Mission

To provide students with an extensive and exceptional education that prepares them to excel in their profession, guided by dynamic intellectual community and be able to face the technically complex world with creative leadership qualities.

Further, be instrumental in emanating new knowledge through innovative research that emboldens entrepreneurship and economic development for the benefit of wide spread community.

Quality Policy

Our policy is to nurture and build diligent and dedicated community of engineers providing a professional and unprejudiced environment, thus justifying the purpose of teaching and satisfying the stake holders.

A team of well qualified and experienced professionals ensure quality education with its practical application in all areas of the Institute.

Philosophy

The essence of learning lies in pursuing the truth that liberates one from the darkness of ignorance and Institute of Aeronautical Engineering firmly believes that education is for liberation.

Contained therein is the notion that engineering education includes all fields of science that plays a pivotal role in the development of world-wide community contributing to the progress of civilization. This institute, adhering to the above understanding, is committed to the development of science and technology in congruence with the natural environs. It lays great emphasis on intensive research and education that blends professional skills and high moral standards with a sense of individuality and humanity. We thus promote ties with local communities and encourage transnational interactions in order to be socially accountable. This accelerates the process of transfiguring the students into complete human beings making the learning process relevant to life, instilling in them a sense of courtesy and responsibility.

Core Values

Excellence: All activities are conducted according to the highest international standards.

Integrity: Adheres to the principles of honesty, trustworthiness, reliability, transparency and accountability.

Inclusiveness: To show respect for ethics, cultural and religious diversity and freedom of thought.

Social Responsibility: Promotes community engagement, environmental sustainability, and global citizenship. It also promotes awareness of, and support for, the needs and challenges of the local and global communities.

Innovation: Supports creative activities that approach challenges and issues from multiple perspetives in order to find solutions and advance knowledge.

1.2 Vision and Mission of the Department

Vision of the Department

To produce comprehensively trained, socially responsible, innovative electrical engineers and researchers of high quality who can contribute for the nation and global development.

Mission of the Department

To provide academic environment with a strong theoretical foundation, practical engineering skills, experience in interpersonal communication and teamwork along with emphasis on ethics, professional conduct and critical thinking.

Further, the graduates will be trained to have successful engagement in research and development and entrepreneurship.

2 Program Educational Objectives (PEOs)

Program Educational Objectives (PEOs) should be defined by the Head of the Department in consultation with the faculty members. PEOs are a promise by the department to the aspiring students about what they will achieve once they join the programme. PEO assessment is not made compulsory by NBA as it is quite difficult to measure in Indian context. NBA assessors usually do not ask for PEO assessment. PEOs are about professional and career accomplishment after 4 to 5 years of graduation. PEOs can be written from different perspectives like Career, Technical Competency and Behaviour. While writing the PEOs do not use the technical terms as it will be read by prospective students who wants to join the programme. Three to five PEOs are recommended.

The PEOs are defined with input from all program constituents and describe the expected accomplishments of graduates during the first several years following graduation:

PEO 1: Success in Electrical Power Systems

Impart engineering knowledge in specific and re-equip with latest technologies to analyze, synthesize the problems in power system and multidisciplinary sectors.

PEO 2 Industrial awareness and research

Design, develop innovative products and services in the field of electrical power systems with the latest technology and toolset.

PEO 3 Successful employment and professional ethics

Inculcate research attitude and life-long learning for a successful career.

PEO 4 Being a leader professional and societal environment

Attain intellectual leadership skills to cater the needs of power industry, academia, society and environment.

The department of Electrical and Electronics Engineering periodically reviews these objectivesand as part of this review process, encourages comments from all interested parties including current students, alumni, prospective students, faculty, teaching assistants and members of related professional organizations, and colleagues from other educational institutions.

2.1 Mapping of program educational objectives to program outcomes :

The following Figure 1 shows the correlation between the PEOs and the POs

PEO-I	PEO-II	PEO-III	PEO-IV
PO: 1, 2, 3, 4, 5, 6	**PO:** 1, 2, 3, 4, 5, 6	**PO:** 1, 2, 3,4, 5, 6	**PO:** 1,2,3,4,5,6

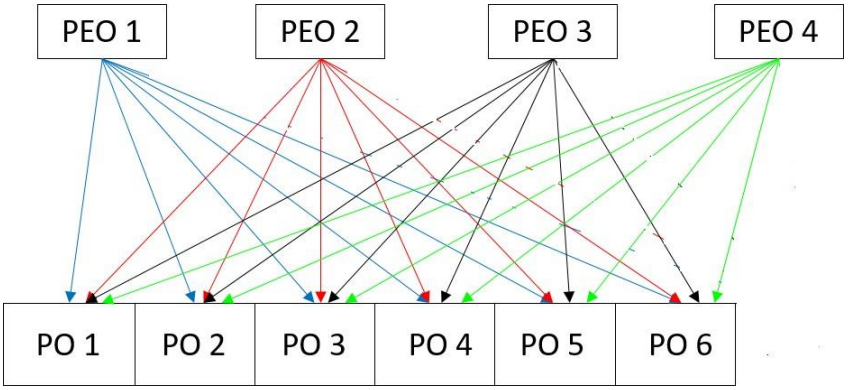


FIGURE 1: Correlation between the PEOs and the POs

3 Program Outcomes (POs)

A Program Learning Outcome is broad in scope and be able to do at the end of the programme. POs are to be in line with the graduate attributes as specified in the Washington Accord. POs are to be specific, measurable and achievable. NBA has defined 3 POs and department has defined 3 more and totally 6 POs are followed for the course. In the syllabus book given to students, there should beclear mention of course objectives and course outcomes along with CO-PO course articulation matrixfor all the courses.

M. Tech (EPS) - PROGRAM OUTCOMES (PO's)	
A graduate of the Electrical and Electronics Engineering Program will demonstrate:	
PO1	An ability to independently carry out research/investigation and development work to solve practical problems.

PO2	Write and present a substantial technical report / document
PO3	Student should be able to demonstrate a degree of mastery over Electrical Power System in designing and analyzing real-life engineering problems and to provide strategic solutions ethically.
PO4	Identify, formulate and solve complex problems on modern-day issues of Power Systems using advanced technologies with a global perspective and envisage advanced research in thrust areas.
PO5	Model and apply appropriate techniques and modern tools on contemporary issues in multidisciplinary environment.
PO6	Engage in life-long learning for continuing education in doctoral level studies and professional development.

4 Relation between the Program Educational Objectives and the POs

Broad relationship between the program objectives and the program outcomes is given in the following Table below:

PEO's→ ↓ PO's		**(1) Success in Electrical Power Systems**	**(2) Industrial awareness and research**	**(3) Being a leader professional and societal environment**	**(4) Being a leader professional and societal environment**
PO1	An ability to independently carry out research / investigation and development work to solve practical problems	3	3	3	3
PO2	Write and present a substantial technical report / document..	2	2	3	3
PO3	Student should be able to demonstrate a degree of mastery over Electrical Power System in designing and analyzing real-life engineering problems and to provide strategic solutions ethically..	2	3	2	3

PO4	Identify, formulate, and solve complex problems on modern-day issues of Power Systems using advanced technologies with a global perspective and envisage advanced research in thrust areas.	2	3	2	3
PO5	Model and apply appropriate techniques and modern tools on contemporary issues in multidisciplinary environment.	2	2	2	2
PO6	Engage in life-long learning for continuing education in doctoral level studies and professional development.	3	3	3	3

Relationship between Program Outcomes and Program Educational Objectives

Key: 3 = High; 2 = Medium; 1= Low

- The assessment process of POs can be direct or indirect.
- The direct assessment will be done through interim assessment by conducting continuous internal exam and semester end exams.
- The indirect assessment on the other hand could be done through student's programme exit questionnaire, alumni survey and employment survey.

5 Blooms Taxonomy

Bloom's taxonomy is considered as the global language for education. Bloom's Taxonomy is frequently used by teachers in writing the course outcomes as it provides a readymade structure and list of action verbs. The stages ascend in complexity and what they demand of students. First students need to simply remember information provided to them — but reciting something doesn't demonstrate having learned it, only memorization. With understanding comes the ability to explain the ideas and concepts to others. The students are then challenged to apply the information and use it in new ways, helping to gain a deeper understanding of previously covered material and demonstrating it moving forward. Questioning information is a vital part of learning, and both analysis and evaluation do just this. Analysing asks a student to examine the information in a new way, and evaluation demands the student appraise the material in a way that lets them defend or argue against it as they determine. The final step in the revised taxonomy is creating, which entails a developing new product or point ofview. How does this learned information impact your world? How can it be used to impact not just your education but the way you interact with your surroundings? By utilizing Bloom's Taxonomy, students are not going to forget the information as soon as the class ends - rather, they retain and apply

the information as they continue to grow as a student and in their careers, staying one step ahead of the competition.

5.1 Incorporating Critical Thinking Skills into Course Outcome Statements

Many faculty members choose to incorporate words that reflect critical or higher-order thinking into their learning outcome statements. Bloom (1956) developed a taxonomy outlining the different types of thinking skills people use in the learning process. Bloom argued that people use different levels of thinking skills to process different types of information and situations. Some of these are basic cognitive skills (such as memorization) while others are complex skills (such as creating new ways to apply information). These skills are often referred to as critical thinking skills or higher-order thinking skills.

Bloom proposed the following taxonomy of thinking skills. All levels of Bloom's taxonomy of thinking skills can be incorporated into expected learning outcome statements. Recently, Anderson and Krathwohl (2001) adapted Bloom's model to include language that is oriented towards the language used in expected learning outcome statements. A summary of Anderson and Krathwohl's revised version of Bloom's taxonomy of critical thinking is provided in Figure 3.

FIGURE 2: Revised version of Bloom's taxonomy

5.2 Definitions of the different levels of thinking skills in Bloom's taxonomy:

1. **Remember** –recalling relevant terminology, specific facts, or different procedures related to information and/or course topics. At this level, a student can remember something, but may not really understand it.
2. **Understand** –the ability to grasp the meaning of information (facts, definitions, concepts, etc.) that has been presented.
3. **Apply** –being able to use previously learned information in different situations or in problem solving.
4. **Analyze** –the ability to break information down into its component parts. Analysis also refers to the process of examining information in order to make conclusions regarding cause and effect, interpreting motives, making inferences, or finding evidence to support statements/arguments.
5. **Evaluate** –being able to judge the value of information and/or sources of information based on personal values or opinions.

6. **Create** –the ability to creatively or uniquely apply prior knowledge and/or skills to produce new and original thoughts, ideas, processes, etc. At this level, students are involved in creating their own thoughts and ideas.

5.3 List of Action Words Related to Critical Thinking Skills

Here is a list of action words that can be used when creating the expected student learning outcomes related to critical thinking skills in a course. These terms are organized according to the different levels of higher-order thinking skills contained in Anderson and Krathwohl's (2001) revised version of Bloom's taxonomy.

Here is the revised Bloom's document with action verbs, which we frequently refer to while writing COs for our courses.

The cognitive process dimensions- categories:

Lower Order of Thinking (LOT)			Higher Order of Thinking (HOT)		
Remember	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Interpreting Illustrating Classifying Summarizing Inferring (concluding) comparing explaining	Recognizing (identifying) Recalling (retrieving)	Executing Implementing	Differentiating Organizing Attributing	Checking (coordinating, detecting, testing, monitoring) Critiquing (judging)	Planning Generating Producing (constructing)

The Knowledge Dimension			
Concrete Knowledge→Abstract knowledge			
Factual	**Conceptual**	**Procedural**	**Metacognitive**
• Knowledge of terminologies • Knowledge of specific details and elements	• Knowledge of classifications and categories • Knowledge of principles and generalizations • Knowledge of theories, models and structures	• Knowledge of subject specific skills and algorithms • Knowledge of subject specific techniques and methods • Knowledge of criteria for determining when to use appropriate procedures	• Strategic Knowledge • Knowledge about cognitive task, including appropriate contextual and conditional Knowledge • Self- Knowledge

Action Verbs for Course Outcomes

Lower Order of Thinking (LOT)				Higher Order of Thinking (HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Bloom's Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas.	Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solution.
Verbs	• Choose • Define • Find • How • Label • List • Match • Extend	• Classify • Compare • Contrast • Demonstrate • Explain • Illustrate • Infer • Interpret	• Apply • Build • Choose • Construct • Develop • Interview • Make use of • Model	• Analyze • Assume • Categorize • Classify • Compare • Discover • Dissect • Distinguish	• Agree • Appraise • Assess • Award • Choose • Criticize • Decide • Deduct • Importance	• Adapt • Build • Solve • Choose • Combine • Invent • Compile • Compose • Construct

Action Verbs for Course Outcomes

Lower Order of Thinking (LOT)				Higher Order of Thinking (HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Verbs	• Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	• Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with	• Organize • Plan • Select • Solve • Utilize • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize • Identify	• Divide • Examine • Function • Inference • Inspect • List Motive • Simplify • Survey • Take part in • Test for Theme • Conclusion • Contrast	• Defend • Determine • Disprove • Estimate • Evaluate • Influence • Interpret • Judge • Justify Mark • Measure • Opinion • Perceive • Prioritize • Prove • Criteria • Criticize • Compare • Conclude	• Create • Design • Develop • Estimate • Formulate • Happen • Imagine • Improve • Make up • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution

6 Guidelines for writing Course Outcome Statements:

Well-written course outcomes involve the following parts:

1. Action verb
2. Subject content
3. Level of achievement as per BTL
4. Modes of performing task (if applicable)

6.1 Course Outcomes (COs)

A Course Outcome is a formal statement of what students are expected to learn in a course. When creating Course Outcomes remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning. Course learning outcome statements refer to specific knowledge, practical skills, areas of professional development, attitudes, higher-order thinking skills, etc. that faculty members expect students to develop, learn, or master during a course.

A well-formulated set of Course Outcomes will describe what a faculty member hopes to successfully accomplish in offering their particular course(s) to prospective students, or what specific skills, competencies, and knowledge the faculty member believes that students will have attained once the course is completed. The learning outcomes need to be concise descriptions of what learning is expected to take place by course completion.

6.2 Developing Course Outcomes

When creating course outcomes consider the following guidelines as you develop them either individually or as part of a multi-section group:

- Limit the course outcomes to 8-12 statements for the entire course [more detailed outcomes can be developed for individual units, assignments, chapters, etc. if the instructor(s) wish (es)].
- Focus on overarching knowledge and/or skills rather than small or trivial details
- Focus on knowledge and skills that are central to the course topic and/or discipline.
- Create statements that have a student focus rather than an instructor centric approach (basic e.g., “upon completion of this course students will be able to list the names of the 28 states and 8 union territories” versus “one objective of this course is to teach the names of the 28 states and 8 union territories”).
- Focus on the learning that results from the course rather than describing activities or lessons that are in the course.
- Incorporate and/or reflect the institutional and departmental missions.
- Include various ways for students to show success (outlining, describing, modelling, depicting, etc.) rather than using a single statement such as “at the end of the course, students will know _____“as the stem for each expected outcome statement.

When developing learning outcomes, here are the core questions to ask yourself:

- What do we want students in the course to learn?

- What do we want the students to be able to do?
- Are the outcomes observable, measurable and are they able to be performed by the students?

Course outcome statements on the course level describe:

- What faculty members want students to know at the end of the course AND
- What faculty members want students to be able to do at the end of the course?

Course outcomes have three major characteristics

- They specify an action by the students/learners that is observable
- They specify an action by the students/learners that is measurable
- They specify an action that is done by the students/learners rather than the faculty members

Effectively developed expected learning outcome statements should possess all three of these characteristics. When this is done, the expected learning outcomes for a course are designed so that they can be assessed. When stating expected learning outcomes, it is important to use verbs that describe exactly what the student(s) / learner(s) will be able to do upon completion of the course.

6.3 Relationship of Course Outcome to Program Outcome

The Course Outcomes need to link to the Program Outcomes.

Learning outcomes formula:

STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE

For example, you can use the following template to help you write an appropriate course level learning outcome.

"Upon completion of this course students will be able to (knowledge, concept, rule or skill you expect them to acquire) by (how will they apply the knowledge or skill/how will you assess the learning)."

6.4 Characteristics of Effective Course Outcomes

Well written course outcomes:

- Describe what you want your students to learn in your course.
- Are aligned with program goals and objectives.
- Tell how you will know an instructional goal has been achieved.
- Use action words that specify definite, observable behaviours.
- Are assessable through one or more indicators (papers, quizzes, projects, presentations, journals, portfolios, etc.)
- Are realistic and achievable.
- Use simple language

6.5 Examples of Effective Course Outcomes

After successful completion of the course, Students will be able to:

- Critically review the methodology of a research study published in a scholarly sociology journal.
- Design a Web site using HTML and JavaScript.
- Describe and present the contributions of women to American history.

- Recognize the works of major Renaissance artists.
- Facilitate a group to achieve agreed-upon goals.
- Determine and apply the appropriate statistical procedures to analyze the results of simple experiments.
- Develop an individual learning plan for a child with a learning disability.
- Produce a strategic plan for a small manufacturing business.
- Analyse a character's motivation and portray that character before an audience.
- Differentiate among five major approaches to literary analysis
- List the major ethical issues one must consider when planning a human-subjects study.
- Locate and critically evaluate information on current political issues on the Web.
- List and describe the functions of the major components of the human nervous system.
- Correctly classify rock samples found in...
- Conduct a systems analysis of a group interaction.
- Demonstrate active listening skills when interviewing clients.
- Apply social psychological principles to suggest solutions to contemporary social problems.

A more detailed model for stating learning objectives requires that objectives have three parts: a condition, an observable behaviour, and a standard. The table below provides three examples.

S No	Condition	Observable Behaviour	Standard
1	Given a list of drugs	the student will be able to classify each item as amphetamine or barbiturate	with at least 70% accuracy
2	Immediately following a fifteen-minute discussion on a topic.	the student will be able to summarize in writing the major issues being discussed.	mentioning at least three of the five major topics.
3	Given an algebraic equation with one unknown.	the student will be able to correctly solve a simple linear equation	within a period of five minutes.

The following examples describe a course outcome that is not measurable as written, an explanation for why the course outcome is not considered measurable, and a suggested edit that improves the course outcome

Original course outcome	Evaluation of language used in this course outcome	Improved course outcome
Explore in depth the literature on an aspect of teaching strategies.	Exploration is not a measurable activity but the quality of the product of exploration would be measurable with a suitable rubric.	Upon completion of this course the students will be able to: write a paper based on an in-depth exploration of the literature on an aspect of teaching strategies.

Examples that are TOO general and VERY HARD to measure. . .

- . . . will appreciate the benefits of learning a foreign language.

- . . . will be able to access resources at the Institute library.
- . . . will develop problem-solving skills.
- . . . will have more confidence in their knowledge of the subject matter. Examples that are still general and HARD to measure. . .
- . . . will value knowing a second language as a communication tool.
- . . . will develop and apply effective problem-solving skills that will enable one to adequately navigate through the proper resources within the institute library.
- . . . will demonstrate the ability to resolve problems that occur in the field.
- . . . will demonstrate critical thinking skills, such as problem solving as it relates to social issues.

Examples that are SPECIFIC and relatively EASY to measure. . .

- . . . will be able to read and demonstrate good comprehension of text in areas of the student's interest or professional field.
- . . . will demonstrate the ability to apply basic research methods in psychology, including research design, data analysis, and interpretation.
- . . . will be able to identify environmental problems, evaluate problem-solving strategies, and develop science-based solutions.
- . . . will demonstrate the ability to evaluate, integrate, and apply appropriate information from various sources to create cohesive, persuasive arguments, and to propose design concepts.

An Introspection - Examine Your Own Course Outcomes

- If you have written statements of broad course goals, take a look at them. If you do not have a written list of course goals, reflect on your course and list the four to six most important student outcomes you want your course to produce.
- Look over your list and check the one most important student outcome. If you could only achieve one outcome, which one would it be?
- Look for your outcome on the list of key competencies or outcomes society is asking us to produce. Is it there? If not, is the reason a compelling one?
- Check each of your other "most important" outcomes against the list of outcomes. How many are on the list of key competencies?
- Take stock. What can you learn from this exercise about what you are trying to accomplish as a teacher? How clear and how important are your statements of outcomes for your use and for your students'? Are they very specifically worded to avoid misunderstanding? Are they supporting important needs on the part of the students?

Write Your Course Outcomes!

One of the first steps you take in identifying the expected learning outcomes for your course is identifying the purpose of teaching the course. By clarifying and specifying the purpose of the course, you will be able to discover the main topics or themes related to students' learning. Once discovered, these themes will help you to outline the expected learning outcomes for the course. Ask yourself:

- What role does this course play within the program?
- How is the course unique or different from other courses?
- Why should/do students take this course? What essential knowledge or skills should they gain from this experience?

- What knowledge or skills from this course will students need to have mastered to perform well in future classes or jobs?
- Why is this course important for students to take?

6.6 CO-PO Course Articulation Matrix (CAM) Mapping

Course Articulation Matrix shows the educational relationship (Level of Learning achieved) between course outcomes and program outcomes for a course. This matrix strongly indicates whether the students are able to achieve the course learning objectives. The matrix can be used for any course and is a good way to evaluate a course syllabus.

The Table 1 gives information about the action verbs used in the POs and the nature of POs, stating whether the POs are technical or non-technical. You need to understand the intention of each POs and the Bloom's level to which each of these action verbs in the POs correlates to. Once you have understood the POs then you can write the COs for a course and see to what extent each of those CO's correlate with the POs.

TABLE 7: Process for mapping the values for CO-PO Matrix

Type	POs	Action Verb(s) in POs	Bloom's level(s) for POs	Bloom's level(s) for COs
Technical	PO1	Apply	L3	Bloom's L1 to L4 for theory courses. Bloom's L1 to L5 for laboratory courses. Bloom's L1 to L6 for project work, experiential learning
	PO2	Build	L6	
		Discover	L4	
	PO3	Analyze	L4	
		Choose	L5	
	PO4	Illustrate	L2	
		Build	L6	
	PO5	Explain	L2	
		Develop	L3	
	PO6	Develop	L3	
		Solve	L6	

At the end, the POs can be calculated using various descriptors that you may define. The mapping of CO towards a PO is evaluated using descriptors such as High, Medium, Low etc. . .

Observations:

1. The first five POs are purely of technical in nature, while the other POs are non-technical.
2. For the theory courses, while writing the COs, you need to restrict yourself between Blooms Level 1 to Level 4. Again, if it is a programming course, restrict yourself between Blooms Level 1 to Level 3 but for the other courses, you can go up to Blooms Level 4.
3. For the laboratory courses, while composing COs, you need to restrict yourself between Blooms Level 1 to Level 5.
4. Only for Mini-project and Main project, you may extend up to Blooms Level 6 while composing COs.

5. For a given course, the course in-charge has to involve all the other Professors who teach that course and ask them to come up with the CO-PO mapping. The course in-charge has to take the average value of all of these CO-PO mappings and finalize the values or the course in-charge can go with what the majority of the faculty members prefer for. Ensure that none of the Professors who are handling the particular course discuss with each other while marking the CO-PO values.
6. If you want to match your COs with non-technical POs, then correlate the action verbs used in the course COs with the thumb rule given in the table and map the values. (Applies only for mapping COs to non-technical POs).

6.7 Tips for Assigning the values while mapping COs to POs.

1. Select action verbs for a CO from different Bloom's levels based on the importance of the particular CO for the given course.
2. Stick on to single action verbs while composing COs but you may go for multiple action verbs if the need arises.
3. You need to justify for marking of the values in CO-PO articulation matrix. Use a combination of words found in the COs, POs and your course syllabus for writing the justification. Restrict yourself to one or two lines.
4. Values to CO-PO (technical POs in particular) matrix can be assigned by
   (a) Judging the importance of the particular CO in relation to the POs. If the CO matches strongly with a particular PO criterion then assign 3, if it matches moderately then assign 2 or if the match is low then assign 1 else mark with " - " symbol.
   (b) If an action verb used in a CO is repeated at multiple Bloom's levels, then you need to judge which Bloom's level is the best fit for that action verb.

6.8 Method for Articulation

1. Identify the key competencies of POs to each CO and make a corresponding mapping table with assigning ✓ mark at the corresponding cell. One observation to be noted is that the first five POs are purely of technical in nature, while the other POs are non-technical.
2. Justify each CO - PO mapping with a justification statement and recognize the number of vital features mentioned in the justification statement that are matching with the given Key Attributes for Assessing Program Outcomes. Use a combination of words found in the COs, POs and your course syllabus for writing the justification.
3. Make a table with number of key competencies for CO – PO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Make a table with percentage of key competencies for CO – PO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, Course Articulation Matrix (CO - PO Mapping) is prepared with COs and POs on the scale of 0 to 3, 0 being no correlation (marked with " - "), 1 being the low/slight correlation, 2 being medium/moderate correlation and 3 being substantial/high correlation based on the following strategy

0–0 ≦ C ≦ 5% - No correlation. 1 – 5 < C ≦

40% - Low / Slight.2 – 40% < C < 60% -

Moderate

3 – 60% ≦ C < 100% - Substantial / High

7 Key Competencies for Assessing Program Outcomes:

PO Number	PO Statement / Key Competencies Features (KCF)	No.of KCF(s)
PO 1	An ability to independently carry out research/investigation and development work to solve practical problems 1. Independence and Self-direction in solving practical problems 2. Scope definition and deliverables by referring related literature 3. Work breakdown structure including resource identification, schedule and implementation	**4**
PO 2	An ability to write and present a substantial technical report / document. 1. Students should demonstrate the ability to communicate effectively in writing / orally. The following parameter should be available in the technical report as well as presentations of the students: 2. Clarity (Writing) 3. Grammar/Punctuation (Writing) 4. References (Writing) 5. Less than 10 % plagiarism (Writing) 6. Speaking Style and Body language (Oral) 7. Subject Matter (Oral)	**7**
PO 3	Student should be able to demonstrate a degree of mastery over Electrical Power System in designing and analyzing real-life engineering problems and to provide strategic solutions ethically. 1. Analysis and synthesis of systematic procedure to examine modern power system, protection renewable energy sources through practical ideas. 2. Assess, inspect, survey and analyze energy flow in environmental aspects. 3. Adapt in-depth knowledge in Power system and related areas to control and manage the power generation and utilization to improve the safety and societal needs 4. Adopt the engineering professional code and conduct. 5. Explore ideas to carry out research / investigation independently to solve practical problems through continuing education. 6. Evolve into green energy and assess results to satisfy cultural, ethical and environmental needs.	**7**

	7. Potential contribution of clean and renewable energy for rural development	
PO 4	Identify, formulate and solve complex problems on modern-day issues of Power Systems using advanced technologies with a global perspective and envisage advanced research in thrust areas. 1. Analyze the operational control and protection of electrical power system using advanced level computing techniques. 2. Assess the interconnected power system using emerging engineering field like Cyber Security, Optimization Techniques, Machine learning, Data science etc. 3. Formulate reliability, efficiency and compliant operation of electrical power systems. 4. Compose and familiarize the safety, legal and health norms in electrical system.	**4**
PO 5	Model and apply appropriate techniques and modern tools on contemporary issues in multidisciplinary environment. 1. Choose explicit software and programming tools for electrical systems. 2. Adapt emerging area resources and literature search for theory as well as laboratories. 3. Construct model, algorithm, program for operation and control of modern electrical Power Systems through Artificial intelligence and optimization techniques. 4. Identify protocols/techniques to work in various environments Interpretation of results in related domain 5. Create interdisciplinary environment through solution of power system related problem /prototype development/implementation/hands-on -training in AI using MATLAB, PSCAD etc.	**5**
PO 6	Engage in life-long learning for continuing education in doctoral level studies and professional development. 1. Excel in Project management and research orientation / Ph.D/ Academia 2. Strengthen in advanced / emerging concepts 3. Personal continuing education efforts through literature, courses 4. Ongoing learning – stays up with industry trends/ new technology 5. Continued personal development in all aspects of life.	**5**

8 Program Outcomes Attained through course modules:

Courses offered in Electrical and Electronics Engineering Curriculum (R18) and POs attained through course modules for I, II, III, IV semesters.

S No	Course Code	Course Title	Key Competenties of POs with weightage					
			Independence in solving practical problems	Technical Presentation Skills	Mastery over Electrical Power System	Development of Solutions	Contemporary issues in multidisciplinary environment.	Life Long Learning
1	BCSB30	Waste To Energy	0	0	0	2	2	3
2	BCSB31	Research Methodology & IPR	2.7	2	1	1	1	2
3	BCSB32	English For Research Paper Writing	0	3	0	0	0	3
4	BCSB33	Disaster Management	0	0	0	2	2	3
5	BPSB01	Modern Power System Analysis	1.4	2	3	3	0	2
6	BPSB02	Economic Operation of Power Systems	1.2	2	1.8	1.2	0	2
7	BPSB03	HVDC Transmission	1	2	1	2.2	0	2
8	BPSB07	Reactive Power Compensation and Management	1.5	0	2.3	2.5	1	2
9	BPSB09	Power System Computational Laboratory	3	0	3	3	2	3
10	BPSB10	Internet Of Things Laboratory	2.2	1	2	1.2	3	3
11	BPSB11	Digital Protection of Power System	1	2	1.8	1.5	0	2
12	BPSB12	Power System Dynamics	2	2	1.3	0	1.5	2
13	BPSB15	Industrial Load Modelling and Control	2.3	1.5	1.8	2	0	0
14	BPSB16	Ai Techniques in Power Systems	1.7	0	3	3	1.7	1.7
15	BPSB19	Artificial Intelligence Laboratory	2	1	2	1.8	3	2.3
16	BPSB20	Power Systems Laboratory	2	2	2	3	3	3
17	BPSB21	Mini Project with Seminar	3	3	3	3	3	3
18	BPSB23	Flexible Ac Transmission Systems	2.5	0	3	3	0	1.5
19	BPSB40	Phase – I Dissertation	3	2	3	3	3	3
20	BPSB41	Phase - II Dissertation	2.3	3	2.2	2.7	3	3
Mean			2.05	2.04	2.19	2.28	2.25	2.45
Number of courses mapped with each PO			17	14	17	18	13	19

9 Methods for measuring Learning Outcomes and Value Addition:

There are many different ways to assess student learning. In this section, we present the different types of assessment approaches available and the different frame works to interpret the results.

i) Continuous Internal Assessment (CIA)
ii) Alternate Assessment Tools (AAT)
iii) Semester end examination (SEE)
iv) Laboratory and project work
v) Course exit survey
vi) Program exit survey
vii) Alumni survey
viii) Employer survey
ix) Course expert committee
x) Program Assessment and Quality Improvement Committee (PAQIC)
xi) Department Advisory Board (DAB)
xii) Faculty meetings
xiii) Professional societies

The above assessment indicators are detailed below.

9.1 Continuous Internal Assessment (CIA)

Two Continuous Internal Examinations (CIEs) are conducted for all courses by the department. All students must participate in this evaluation process. These evaluations are critically reviewed by HOD and senior faculty and the essence is communicated to the faculty concerned to analyze, improve and practice so as to improve the performance of the student.

9.2 Alternate Assessment Tools (AAT)

This AAT enables faculty to design own assessment patterns during the CIA. The AAT converts the classroom into an effective learning center. The AAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video etc. The AAT chosen for this course is given in table.

9.3 Semester End Examination (SEE)

The semester end examination is conducted for all the courses in the department. Before the Semester end examinations course reviews are conducted, feedback taken from students and remedial measures will be taken up such that the student gets benefited before going for end exams. The positive and negative comments made by the students about the course are recorded and submitted to the departmental advisory board (DAB) and to the principal for taking necessary actions to better the course for subsequent semesters.

9.4 Laboratory and Project Works

The laboratory work is continuously monitored and assessed to suit the present demands of the industry. Students are advised and guided to do project works giving solutions to research / industrial problems to the extent possible by the capabilities and limitations of the student. The results of the assessment of the individual projects and laboratory work can easily be conflated in order to provide the

students with periodic reviews of their overall progress and to produce terminal marks and grading.

9.5 Course Exit Surveys

Students are encouraged to fill-out a brief survey on the fulfillment of course objectives. The data is reviewed by the concerned course faculty and the results are kept open for the entire faculty. Based on this, alterations or changes to the course objectives are undertaken by thorough discussions in faculty and DAB meetings.

9.6 Programme Exit Survey

The programme exist questionnaire form is to be filled by all the students leaving the institution. The questionnaire is designed in such a way to gather information from the students regarding the program educational objectives, solicit about program experiences, carrier choices, as well as any suggestions and comments for the improvement of the program. The opinions expressed in exit interview forms are reviewed by the DAB for implementation purposes.

9.7 Alumni Survey

The survey asks former students of the department about the status of their employment and further education, perceptions of institutional emphasis, estimated gains in knowledge and skills, involvement a sunder graduate student, and continuing involvement with Institute of Aeronautical Engineering. This survey is administered every three years. The data obtained will be analyzed and used in continuous improvement.

9.8 Employer Survey

The main purpose of this employer questionnaire is to know employer's views about the skills they require of employees compared to the skills actually possessed by them. The purpose e is also to identify gaps in technical and vocational skills, need for required training practices to fill these gaps and criteria for hiring new employees. These employer surveys are reviewed by the College Academic Council (CAC) to affect the present curriculum to suit the requirement so the employer.

9.9 Course Expert Committee

The course expert team is responsible in exercising the central domain of expertise in developing and renewing the curriculum and assessing its quality and effectiveness to the highest of professional standards. Inform the Academic Committee the 'day-to-day' matters as are relevant to the offered courses. This committee will consider the student and staff feedback on the efficient and effective development of the relevant courses. The committee also review the course full stack content developed by the respective course coordinator.

9.10 Programme Assessment and Quality Improvement Committee (PAQIC)

PAQIC Monitors the achievements of Program Outcomes (POs) and Program Educational Objectives (PEOs). It will evaluate the program effectiveness and proposes the necessary changes. It also prepares the periodic reports on program activities, progress, status or other special reports for management. It also motives the faculty and students towards attending workshops, developing projects, working models, paper publications and engaging in research activities.

9.11 Department Advisory Board (DAB)

Departmental Advisory Board plays an important role in the development of the department. Department level Advisory Board will be established for providing guidance and direction for qualitative

growth of the department. The Board interacts and maintains liaison with key stakeholders. DAB will Monitor the progress of the program and develop or recommend the new or revised goals and objectives for the program. Also, the DAB will review and analyze the gaps between curriculum and Industry requirement and gives necessary feedback or advices to be taken to improve the curriculum.

9.12 Faculty Meetings

The DAB meets bi-annually for every academic year to review the strategic planning and modification of PEOs. Faculty meetings are conducted at least once in fortnight for ensuring the implementation of DAB's suggestions and guidelines. All these proceedings are recorded and kept for the availability of all faculties.

9.13 Professional Societies

The importance of professional societies like IEEE, IETE, ISTE, IE (I) etc., are explained to the students and they are encouraged to become members of the above to carry out their continuous search for knowledge. Student and faculty chapters of the above societies are constituted for a better technical and entrepreneurial environment. These professional societies promote excellence in instruction, research, public service and practice.

10 CO - Assessment processes and tools:

Course outcomes are evaluated based on two approaches namely direct and indirect assessment methods. The direct assessment methods are based on the Continuous Internal Assessment (CIA) and Semester End Examination (SEE) whereas the indirect assessment methods are based on the course end survey and program exit survey provided by the students, Alumni and Employer. The weightage in CO attainment of Direct and Indirect assessments are illustrated in Table.

Assessment Method	Assessment Tool	Weightage in CO attainment
Direct Assessment	Continuous Internal Assessment (CIE & AAT)	80%
	Semester End Examination	
Indirect Assessment	Course End Survey	20%

10.1 Direct Assessment:

Direct assessment methods are based on the student's knowledge and performance in the various assessments and examinations. These assessment methods provide evidence that a student has command over a specific course, content, or skill, or that the students work demonstrates a specific quality such as creativity, analysis, or synthesis.

The various direct assessment tools used to assess the impact of delivery of course content is listed in Table.

- Continuous internal examination, semester end examinations, AAT (includes assignment, 5 minutes videos, seminars etc.) are used for CO calculation.
- The attainment values are calculated for individual courses and are formulated and summed for assessing the POs.
- Performance in AAT is indicative of the student's communication skills.

S No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core / Elective	Continuous Internal Examination	Twice in a semester	25	Answer script
		Alternative Assessment Tools (AAT)	Twice in a semester	5	Video / Quiz / assignment
		Semester End Examination	Once in a semester	70	Answer script
2	Laboratory	Conduction of experiment	Once in a week	4	Work sheets
		Observation	Once in a week	4	Work sheets
		Result	Once in a week	4	Work sheets
		Record	Once in a week	4	Work sheets
		Viva	Once in a week	4	Work sheets
		Internal laboratory assessment	Once in a semester	10	Answer script
		Semester End Examination	Once in a semester	70	Answer script
3	Project Work	Presentation	Twice in a semester	30	Presentation
		Semester End Examination	Once in a semester	70	Thesis report
4	Comprehensive Examination	Written examination (objective type)	Once in a semester	50	Online assessment
		Oral examination	Once in a Semester	50	Viva

10.2 Indirect Assessment:

Course End Survey - In this survey, questionnaires are prepared based on the level of understanding of the course and the questions are mapped to Course Outcomes. The tools and processes used in indirect assessment are shown in Table.

TABLE 12: Tools used in Indirect assessment

Tools	Process	Frequency
Course end survey	• Taken for every course at the end of the semester • Gives an overall view that helps to assess the extent of coverage/ compliance of COs • Helps the faculty to improve upon the various teaching methodologies	Once in a semester

Direct Tools: (Measurable in terms of marks and w.r.t. CO) Assessment done by faculty at department level

Indirect Tools: (Non measurable (surveys) in terms of marks and w.r.t. CO) Assessment done at institute level.

11 PO- Assessment tools and Processes

The institute has the following methods for assessing attainment of POs.

1. Direct method
2. Indirect method

The attainment levels of course outcomes help in computing the PO based upon the mapping done.

TABLE 13: Attainment of PO

	Assessment	Tools	Weight
POs Attainment	Direct Assessment	CO attainment of courses	80%
	Indirect Assessment	Student exit survey	20%
		Alumni survey	
		Employer survey	

The CO values of both theory and laboratory courses with appropriate weightage as per CO-PO mapping, as per Program Articulation Matrix are considered for calculation of direct attainment of PO/PSOs.

11.1 PO Direct Attainment is calculated using the following rubric:

PO Direct Attainment = (Strength of CO-PO)*CO attainment / Sum of CO-PO strength.

The below figure represents the evaluation process of POs/PSOs attainment through course outcome attainment.

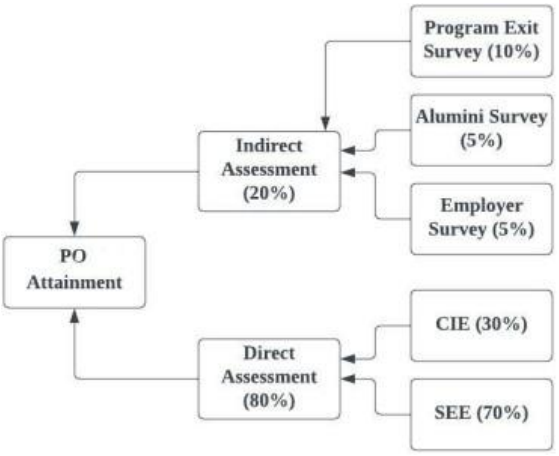


FIGURE 3: The evaluation process of PO attainment through course outcome attainment

12 Course Description:

The "Course Description" provides general information regarding the topics and content addressed in the course. A sample course description is given in Appendix – A for the reference.

The "Course Description" contains the following contents:

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Content delivery / Instructional methodologies
- Evaluation Methodology
- Course Objectives
- Course Outcomes
- Program Outcomes
- How Program Outcomes are assessed
- Mapping of each CO with PO(s)
- Justification for CO – PO mapping- direct
- Total count of key competencies for CO – PO mapping
- Percentage of key competencies for CO – PO
- Course articulation matrix (PO mapping)
- Assessment methodology-direct
- Assessment methodology-indirect
- Syllabus
- List of Text Books / References / Websites
- Course Plan

Appendix A

Sample Course Description

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

COURSE DESCRIPTION

Branch	**Electrical and Electronics Engineering (EPS)**				
Course Title	**Embedded wireless sensor networks**				
Course Code	BPSB01				
Program	M.Tech				
Semester	I				
Course Type	Professional Core				
Regulation	IARE- R18				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	0	3	-	-
Course Coordinator	Dr. M. Pala Prasad Reddy, Associate Professor, EEE				

I COURSE PRE-REQUISITES

Level	Course Code	Semester	Prerequisites	Credits
UG	AEE011	V	Transmission And Distribution System	4
UG	AEE012	VI	Power system analysis	4

II COURSE OVERVIEW:

Power system analysis deals formation impedance and admittance matrices for power system network, finding different electrical parameters for various buses in power system, study fault analysis and represent power system using per unit system, understand steady state and transient stability of power system

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Embedded Wireless sensor Networks	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PowerPoint Presentation	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	✓	Others				

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into FIVE modules and each module carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with ”either” or ”choice” will be drawn from each module. Each question carries 14 marks. There could be a maximum of two sub divisions in a question. The expected percentage of cognitive level of the questions is broadly based on the criteria given in below Table.

Percentage of Cognitive Level	Blooms Taxonomy Level
20%	Remember
20%	Understand
20%	Apply
40%	Analyze

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks, with 20 marks for continuous internal examination(CIE) and 10 marks for Alternative Assessment Tool (AAT).

Component		Marks	Total Marks
CIA	Continuous Internal Examination – 1 (Mid-term)	10	30
	Continuous Internal Examination – 2 (Mid-term)	10	
	AAT-1	5	
	AAT-2	5	
SEE	Semester End Examination (SEE)	70	70
Total Marks			100

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 8^{th} and 16^{th} week of the semester re- spectively for 10 marks each of 2 hours duration consisting of five descriptive type questionsout of which four questions have to be answered.

Alternative Assessment Tool (AAT)

This AAT enables faculty to design own assessment patterns during the CIA. The AAT con-verts the classroom into an effective learning center. The AAT may include tutorial hours/- classes, seminars, assignments, term paper, open ended experiments, METE (Modeling andExperimental Tools in Engineering), five minutes video, MOOCs etc. The AAT chosen forthis course is given in table.

Concept Video	Tech-talk	Complex Problem Solving
40%	40%	20%

VI COURSE OBJECTIVES:

The students will try to learn:

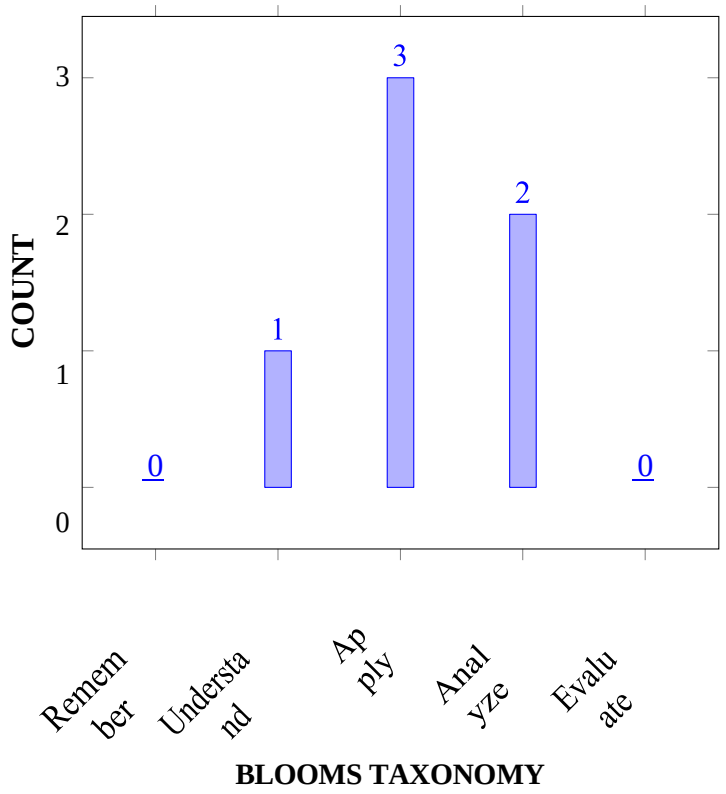
I	Explain the basic components and restructuring of power systems.
II	Understand power flow analysis using various methods.
III	Describe fault analysis for balanced and unbalanced faults.
IV	Describe power system security concepts and study the methods to rank the contingencies.
V	Explain the need of state estimation and study simple algorithms for state estimation.

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Utilize** the representation of basic components and single line diagram of power system for understanding the restructuring of system
CO 2	**Examine** the optimal power flow solution using FACTS devices to solve power flow analysis problems using various methods.
CO 3	**Analyse** the new bus voltages contingency by adding/removal of lines for illustrating the various techniques for contingency evaluation and analysis.
CO 4	**Evaluate** the operating states and security monitoring of power systems to describe its contingency analysis.
CO 5	**Understand** the importance of power flow analysis in planning and operation of power systems.
CO 6	**Apply** the various algorithms for state estimation to estimate different components and states of power systems.

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

M. Tech (EPS) - PROGRAM OUTCOMES (PO's)	
A graduate of the Electrical and Electronics Engineering Program will demonstrate:	
PO1	An ability to independently carry out research/investigation and development work to solve practical problems.
PO2	Write and present a substantial technical report / document
PO3	Student should be able to demonstrate a degree of mastery over Electrical Power System in designing and analyzing real-life engineering problems and to provide strategic solutions ethically.
PO4	Identify, formulate and solve complex problems on modern-day issues of Power Systems using advanced technologies with a global perspective and envisage advanced research in thrust areas.
PO5	Model and apply appropriate techniques and modern tools on contemporary issues in multidisciplinary environment.
PO6	Engage in life-long learning for continuing education in doctoral level studies and professional development.

IX HOW PROGRAM OUTCOMES ARE ASSESSED:

PROGRAM OUTCOMES		Strength	Proficiency Assessed by
PO1	An ability to independently carry out research/investigation and development work to solve practical problems.	3	SEE / CIE / AAT
PO 3	Student should be able to demonstrate a degree of mastery over Electrical Power System in designing and analyzing real-life engineering problems and to provide strategic solutions ethically.	3	SEE / CIE / AAT
PO 4	Identify, formulate and solve complex problems on modern-day issues of Power Systems using advanced technologies with a global perspective and envisage advanced research in thrust areas.	3	SEE / CIE / AAT
PO 6	Engage in life-long learning for continuing education in doctoral level studies and professional development.	2	SEE / CIE / AAT

X MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	-	✓	✓		✓
CO 2	✓	-	✓	✓		✓
CO 3	✓		✓	✓		✓
CO 4	✓	-	✓	✓	-	✓
CO 5	✓	-	✓	✓		✓
CO 6	✓	-	✓	✓		✓

XI JUSTIFICATIONS FOR CO – PO/ PSO MAPPING -DIRECT :

Course Outcomes	PO'S PSO'S	Justification for mapping (Students will be able to)	No. of Key competencies matched.
CO1	PO 3	**understand** the concept of wireless sensor networks in **real time** systems with characteristic requirements involved in **demonstrating** of sensor nodes in real time scenario. **Analyze and design** innovative products by **Using of creativity** to **establish innovative solutions**	5

	PO 4	**understand** the concepts of embedded real time systems for real time embedded applications by**Managing** the design process and evaluate out-comes and **interpreting** of results and **Validation**	4
	PO 6	**Illustrate** the concepts **knowledge** of embedded real time systems for real time embedded applications by using **strengthen** in embedded and advanced engineering areas by **Working** with all levels of people in team	2
CO2	PO 3	**Demonstrate** energy consumption of sensor nodes by understanding embedded applications in real timescenario by **Analyzing and design innovative products Apply the complex engineering problems and their system components** by design and programming of sensor nodes in embedded systems **forsolution development**	5
	PO 4	**Make use of** time constrained embedded systems using the concepts of **engineering** fundamentals to the solution of problem formulation and abstraction to establish innovative solutions for **Interpretation of results and Validation**	4
	PO 6	Improve the life span of wireless sensor networks by **Strengthen** in embedded and advanced engineeringarea and time constrained embedded systems using the concepts of **engineering fundamentals** to the solution of **problem formulation** and **abstraction** to establish innovative solutions.	4
CO 3	PO 3	**Contrast** the design process and evaluation out- comes for Knowledge, understanding and demonstrations of embedded applications in real time scenario for **designing** of large scale wireless sensor networks for **Solution development** or experimentation / Implementation in **Interpretation** of results and Validation	4
Course Outcomes	**PO'S PSO'S**	**Justification for mapping (Students will be able to)**	**No. of Key competencies matched.**

	PO 4	**Experimental Design** for large scale wireless sensor networks by **undertakes research** and **development projects** in the field of Embedded Systems time constrained application as a member of a small group to meet design specifications.	3
	PO 6	**Build** time constrained embedded systems using the concepts of **engineering fundamentals to the solution of problem formulation and abstraction to establish innovative solutions** using RTOS (Real Time Operating System) rapid **design** and its programming	5
CO4	PO 3	**Problem formulation and abstraction** by **Identifying** engineering problems solution development and **implementation** in various applications of embedded wireless sensor networks.	4
	PO 4	**Apply** the skills and knowledge needed to serve as a professional engineer skil ful at **designing** embedded systems by **Interpreting** algorithms of wireless sensor networks for target area coverage to improve the performance of wireless sensor networks.	3
	PO 6	**Recognize** the need to engage in **lifelong learning** through continuing education and research to **improve** the performance of wireless sensor networks.	3
CO5	PO 3	**Knowledge** understanding and demonstrations of embedded applications in real time scenario by **Examine** the architecture of multicore embedded systems in **Analyze** and **design** innovative products like wireless video systems.	4
	PO 4	**Apply** the skills and knowledge needed to serve asa professional engineer skilful by learning the **architecture** of multicore embedded systems in signal processing applications by **Under** take research and **development** projects in the field of Embedded Systems.	4
	PO 6	**Using creativity** to establish innovative solutions by **Apply** the principles and architecture of multi- core embedded systems to establish **Solution development** or experimentation / Implementation	4

CO 6	PO 3	**Demonstrate problem formulation and abstraction** in sensor networks for inter vehicle communication system in **Embedded systems.**	3
	PO 4	**Apply** the skills and knowledge needed to serve as a professional engineer skilful at **designing** embedded systems for effective use in inter vehicle communication networks to **Enhance** the safety of moving vehicles.	3
	PO 6	**Knowledge, understanding** and demonstrations of embedded applications in real time scenario for inter vehicle communication networks by **applying the principles and methodology of** inter vehicle communication system by **Experimental design** of communication networks.	5

XII TOTAL COUNT OF KEY COMPETENCIES FOR CO – PO MAPPING:

COURSE OUTCOMES	**PROGRAM OUTCOMES**					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
	6	6	9	10	7	8
CO 1	-	-	5	4	-	2
CO 2	-	-	5	4	-	4
CO 3	-	-	4	3	-	5
CO 4	-	-	4	3	-	3
CO 5	-	-	4	4	-	4
CO 6	-	-	3	3	-	5

XIII PERCENTAGE OF KEY COMPETENCIES FOR CO – PO:

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
	6	6	9	10	7	8
CO 1	-	-	55.5	40	-	25
CO 2	-	-	55.5	40	-	50
CO 3	-	-	44	30	-	62.5
CO 4	-	-	44	30	-	37.5
CO 5	-	-	44	30	-	50
CO 6	-	-	33	30	-	62.5

XIV COURSE ARTICULATION MATRIX (PO MAPPING):

CO'S and PO'S and CO'S and PSO'S on the scale of 0 to 3, 0 being no correlation, 1 beingthe low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	2	2	-	1
CO 2	3	-	2	2	-	2
CO 3	3	-	2	1	-	3
CO 4	3	-	2	1	-	1
CO 5	3	-	2	1	-	2
CO 6	3	-	1	1	-	3
TOTAL	**18**	-	**11**	**8**	-	**12**
AVERAGE	**3**	-	**2**	**1.3**	-	**2**

XV ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XVI SYLLABUS:

I. SYLLABUS

UNIT-I	PLANNING AND OPERATIONAL STUDIES OF POWER SYSTEMS
Need for system planning and operational studies, basic components of a power system, introduction to restructuring, single line diagram, per phase and per UNIT analysis, generator, transformer, transmission line and load representation for different power system studies, primitive network, construction of Y-bus using inspection and singular transformation methods, Z-bus.	
UNIT-II	**POWER FLOW ANALYSIS**
Importance of power flow analysis in planning and operation of power systems, statement of power flow problem, classification of buses, development of power flow model in complex variables form, iterative solution using Gauss-Seidel method, Q-limit check for voltage controlled buses, power flow model in polar form, iterative solution using Newton-Raphson method, decoupled and fast decoupled power flow solutions, DC power flow solution, power flow solution using FACTS devices, optimal power flow solution	
UNIT-III	**SHORTCIRCUITANALYSIS**
Balanced faults: Importance of short circuit analysis, assumptions in fault analysis, analysis using Thevenin‟s theorem, Z-bus building algorithm, fault analysis using Z-bus, computations of short circuit capacity, post fault voltage and currents. Unbalanced faults: Introduction to symmetrical components, sequence impedances, sequence circuits of synchronous machine, transformer and transmission lines, sequence networks analysis of single line to ground, line to line and double line to ground faults using Thevenin‟s theorem and Z-bus matrix.	
UNIT-IV	**CONTINGENCY ANALYSIS**
Contingency Evaluation: Operating states of a power system, concept of security monitoring, techniques for contingency evaluation, Importance of contingency analysis, addition / removal of one line, construction of a column of bus impedance matrix from the bus admittance matrix, calculation of new bus voltages due to addition / removal of one line, calculation of new bus voltages due to addition / removal of two lines	
UNIT-V	**STATE ESTIMATION**
Power system state estimation, maximum likelihood weighted least squares estimation, matrix formulation, state estimation of AC network, state estimation by orthogonal decomposition, detection and identification of bad measurements, estimation of quantities not being measured, network observability and pseudo measurements	

TEXTBOOKS

1. 1. K Umarao, “Computer Techniques and Models in Power Systems”, I K International Pvt. Ltd.
2. 2. HadiSaadat, “Power System Analysis”, TMH, 2nd Edition, 2003.
3. 3. Grainger and Stevenson, “Power System Analysis”, Tata McGraw-Hill, 3rd Edition, 2011.
4. 4. J Duncan Glover and M S Sarma., THOMPSON, “Power System Analysis and Design”, 3rd Edition ,2006., 2011.

REFERENCE BOOKS:

1. 1. J J Grainger, W D Stevenson, “Power system analysis”, McGraw Hill, 1st Edition, 2003.
2. 2. A R Bergen & Vijay Vittal, “Power System Analysis”, Pearson, 2nd Edition,2000.

XVII COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

S.No	Topics to be covered	CO’s	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Pro- gram Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
1	Need for system planning and operational studies	CO1	T1:1.1
2	Basic components of a power system	CO1	T1:1.2
3	Introduction to power system restructuring.	CO1	T1:1.3
4	Single line diagram of power system network.	CO1	T1:1.4
5	Per phase and per UNIT analysis	CO1	T1:1.5
6	Generator, transformer, transmission line and load representation for different power system studies	CO1	T1:1.6
7	Primitive network	CO1	T1:2.1
8	Construction of Y-bus using inspection and singular transformation methods	CO1	T1:2.2
9	Construction of Z-bus	CO2	T1:2.3
10	Importance of power flow analysis in planning and operation of power systems, statement of power flow problem	CO2	T1:2.4
11	Classification of buses	CO2	T1:2.5
12	Need for system planning and operational studies	CO2	T1:2.6

13	Basic components of a power system	CO2	T1:2.7
14	Development of power flow model in complex variables form	CO2	T1:2.8
15	Iterative solution using Gauss-Seidel method	CO2	T1:2.9
16	Q-limit check for voltage controlled buses, power flow	CO2	T1:2.10
17	model in polar form	CO2	T1:3.1
18	Iterative solution using Newton-Raphson method	CO3	T1:4.5
19	Decoupled and fast decoupled power flow solutions	CO3	T1: 4.6
20	DC power flow solution	CO2	T1:4.7
21	Power flow solution using FACTS devices	CO3	T1:4.8
22	Optimal power flow solution	CO3	T1:4.9
23	Importance of short circuit analysis, assumptions in fault analysis	CO3	T1:5.1
24	Analysis using Thevenin‟s theorem	CO3	T1:5.2
25	Z-bus building algorithm, fault analysis using Z-bus	CO3	T1:5.3,
26	Computations of short circuit capacity, post fault voltage and currents.	CO3	T1:5.5,
27	Introduction to symmetrical components, sequence impedances	CO3	T1: 5.6
28	An Introduction to the Concept of Cooperating Objects and Sensor Networks- Cooperating objects and wireless sensor networks	CO4	T1: 5.7.1
29	An Introduction to the Concept of Cooperating Objects and Sensor Networks- Embedded WiSeNts	CO4	T1:5.7.2
30	Programming models- Requirements	CO4	T1:5.7.3,
31	Programming models- State of the art	CO4	T1:5.7.4,
32	System architectures: node internals- Data-centric and service-centric approach, Operating systems, Virtual machines	CO5	T1:5.5.1
33	Sequence networks analysis of single line to ground, line to line and double line to ground faults using Thevenin‟s theorem and Z-bus matrix.	CO5	T1:5.5.2
34	Operating states of a power system, concept of security monitoring	CO5	T1:5.6
35	Techniques for contingency evaluation, Importance of contingency analysis,	CO5	T1:5.7
36	Addition / removal of one line, construction of a column of bus impedance matrix from the bus admittance matrix	CO5	T1:5.8
37	Calculation of new bus voltages due to addition / removal of one line	CO6	T1:5.9,
38	Calculation of new bus voltages due to addition / removal of two lines	CO6	T1:5.10,
39	Power system state estimation, maximum likelihood weighted least squares estimation	CO6	T1:5.11,

40	Matrix formulation, state estimation of AC network	CO6	T1:5.12
41	State estimation by orthogonal decomposition	CO6	T1:5.13,
42	Detection and identification of bad measurements	CO6	T1:5.14,
43	Estimation of quantities not being measured	CO6	T1:3.1, 5.6, 5.7
44	Network observability and pseudo measurements	CO6	T1:3.2, 5.6, 5.7
45	Sequence networks analysis of single line to ground, line to line and double line to ground faults using Thevenin‟s theorem and Z-bus matrix.	CO6	T1:3.3,
DISCUSSION OF QUESTION BANK			
1	Unit – I: PLANNING AND OPERATIONAL STUDIES OF POWER SYSTEMS	CO1	T1:1.1-1.6
2	Unit– II: POWER FLOW ANALYSIS	CO2	T1:2.1-2.5
3	Unit – III: SHORT CIRCUIT ANALYSIS	CO3, CO4	T1:4.1-4.5,
4	Unit – IV: CONTINGENCY ANALYSIS	CO5	T1:5.7-5.4
5	Unit – V: STATE ESTIMATION	CO6	T1:5.1-5.14
14	Development of power flow model in complex variables form	CO2	T1:2.8
15	Iterative solution using Gauss-Seidel method	CO2	T1:2.9
16	Q-limit check for voltage controlled buses, power flow	CO2	T1:2.10
17	model in polar form	CO2	T1:3.1
18	Iterative solution using Newton-Raphson method	CO3	T1:4.5
19	Decoupled and fast decoupled power flow solutions	CO3	T1: 4.6
20	DC power flow solution	CO2	T1:4.7
21	Power flow solution using FACTS devices	CO3	T1:4.8
22	Optimal power flow solution	CO3	T1:4.9
23	Importance of short circuit analysis, assumptions in fault analysis	CO3	T1:5.1
24	Analysis using Thevenin‟s theorem	CO3	T1:5.2
25	Z-bus building algorithm, fault analysis using Z-bus	CO3	T1:5.3,
26	Computations of short circuit capacity, post fault voltage and currents.	CO3	T1:5.5,
27	Introduction to symmetrical components, sequence impedances	CO3	, 5.6
28	An Introduction to the Concept of Cooperating Objects and Sensor Networks- Cooperating objects and wireless sensor networks	CO4	T1: 5.7.1

29	An Introduction to the Concept of Cooperating Objectsand Sensor Networks- Embedded WiSeNts	CO4	T1:5.7.2
30	Programming models- Requirements	CO4	T1:5.7.3,
31	Programming models- State of the art	CO4	T1:5.7.4,
32	System architectures: node internals- Data-centric and service-centric approach, Operating systems, Virtual ma-chines	CO5	T1:5.5.1
33	Sequence networks analysis of single line to ground, line to line and double line to ground faults using Thevenin‟s theorem and Z-bus matrix.	CO5	T1:5.5.2
34	Operating states of a power system, concept of security monitoring	CO5	T1:5.6
35	Techniques for contingency evaluation, Importance of contingency analysis,	CO5	T1:5.7
36	Addition / removal of one line, construction of a column of bus impedance matrix from the bus admittance matrix	CO5	T1:5.8
37	Calculation of new bus voltages due to addition / removal of one line	CO6	T1:5.9,
38	Calculation of new bus voltages due to addition / removal of two lines	CO6	T1:5.10,
39	Power system state estimation, maximum likelihood weighted least squares estimation	CO6	T1:5.11,
40	Matrix formulation, state estimation of AC network	CO6	T1:5.12
41	State estimation by orthogonal decomposition	CO6	T1:5.13,
42	Detection and identification of bad measurements	CO6	T1:5.14,
43	Estimation of quantities not being measured	CO6	T1:3.1, 5.6, 5.7
44	Network observability and pseudo measurements	CO6	T1:3.2, 5.6, 5.7
45	Sequence networks analysis of single line to ground, line to line and double line to ground faults using Thevenin‟s theorem and Z-bus matrix.	CO6	T1:3.3,
DISCUSSION OF QUESTION BANK			
1	Unit – I: PLANNING AND OPERATIONAL STUDIES OF POWER SYSTEMS	CO1	T1:1.1-1.6
2	Unit– II: POWER FLOW ANALYSIS	CO2	T1:2.1-2.5

3	Unit – III: SHORT CIRCUIT ANALYSIS	CO3, CO4	T1:4.1-4.5,
4	Unit – IV: CONTINGENCY ANALYSIS	CO5	T1:5.7-5.4
5	Unit – V: STATE ESTIMATION	CO6	T1:5.1-5.14

Signature of Course Coordinator **HOD, EEE**
Dr. M. Pala Prasad Reddy