Program Name : Electrical Engineering Program Group

Program Code : EE/EP/EU

Semester : Fifth

Course Title : Power System Analysis (Elective)

Course Code : 22529

1. RATIONALE

The diploma engineers working in power sector, while undertaking major activities related to transmission and distribution systems they should be able to interpret significance of the activities assigned to them. For example, they should be aware of active and reactive power flow and methods to analyze performance of power system. They should also be able to represent power system components in circuit form and analysiswith the concept of 'Generalize Circuit'. They should adopt per-unit system calculations for power system analysis.Hence, this course is designed to enable diploma pass outs to handle different activities in power system sector with appropriate power flow perceptive. Thus this course is important for diploma electrical engineers who wish to work in power generation, transmission and distribution companies.

2. COMPETENCY

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

- **Maintain powersystem networks within power flow strategies.**

3. COURSE OUTCOMES (COs)

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

a. Interpret circuits for various components ofthe power system.
b. Calculate line parameters for different types of transmission lines.
c. Use generalised circuit calculations for transmission line performance.
d. Estimate the power at sending and receiving ends of transmission line.
e. Ensureperformance of transmission lines by graphical analysis.

4. TEACHING AND EXAMINATION SCHEME

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

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

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

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

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

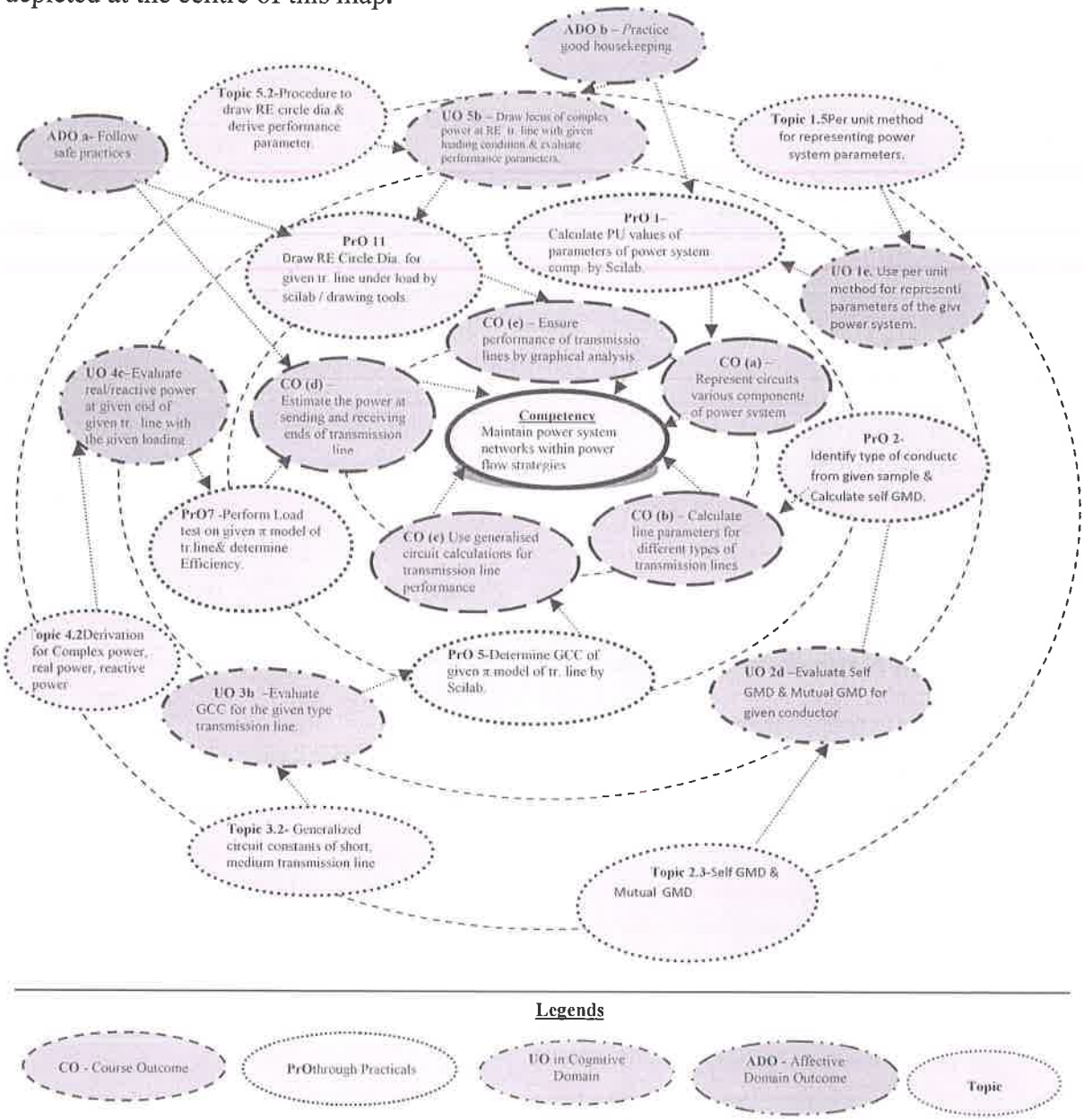

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

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

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Calculate per unit values of parameters of power system components for given power system by using Scilab.	I	02*
2	Identify type of conductor from given sample of line conductors and Calculate self GMD.	II	04*
3	Perform OC and SC Test and evaluate Generalized circuit constant	III	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	of given π model of transmission line.		
4	Perform OC and SC Test and evaluate Generalized circuit constant of given T model of transmission line.	III	02*
5	Determine Generalized circuit constant of given π model of transmission line by using Scilab.	III	02*
6	Determine Generalized circuit constant of given T model of transmission line by using Scilab	III	02
7	Perform Load test on given π model of transmission line and determine the Efficiency.	IV	02*
8	Perform Load test on given T model of transmission line and determine the efficiency.	IV	02
9	Evaluate Receiving end complex power by using Scilab for given transmission line under load condition	IV	02*
10	Evaluate Sending end complex power by using Scilab for given transmission line under given condition	IV	02*
11	Draw Receiving end Circle Diagram for given transmission line under load condition by using scilab / drawing tools.	V	02*
12	Draw Sending end Circle Diagram for given transmission line under given condition by using scilab / drawing tools.	V	02
13	Observe the effect of reactive power consumption by single phase split phase Induction motor connecting capacitor bank (REC).	V	02*
14	Observe the videos on reactive power compensation Equipmentsand prepare informative report.(part-1)	V	02
15	Observe the videos on reactive power compensation Equipments and prepare informative report. .(part-2)	V	02
	Total		**32**

Note

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

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

S.No.	Performance Indicators	Weightage in %
a.	Preparation of experimental set up	20
b.	Setting, collection of data and operation	20
c.	Safety measures	10
d.	Observations and Recording	10
e.	Interpretation of result and Conclusion	20
f.	Answer to sample questions	10
g.	Submission of report in time	10
Total		**100**

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

a. Follow safety practices.
b. Practice good housekeeping.
c. Practice energy conservation.
d. Demonstrate working as a leader/a team member.
e. Maintain tools and equipment.
f. Follow ethical Practices.

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

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year
- 'CharacterisingLevel' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTSREQUIRED

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

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Open source software Scilab 5.5.2 (any other suitable software)	1, 5,6, 9,10,11,12
2	Sample of transmission line conductors	2
3	Simulation π model of transmission line or trainer kit	3,7
4	Simulation T model of transmission line or trainer kit.	4,8
5	AC ammeter 2.5A, 5A	3,4,7,8,13
6	AC voltmeter 30V, 300V	3,4,7,8,13
7	Single Phase Wattmeter –Lpf 2.5A,300 V and unity pf 5A ,75/300V	3,4,7,8,13
8	Single Phase Auto transformer 0-250 V,10A	3,4
9	Lamp Bank 1KW, 230 V, 5A	7,8
10	Single phase split phase induction motor 1HP (Any other Suitable Motor)	13
11	Capacitor Bank	13
12	LCD projector, PC Arrangement with audio system.	14,2
13	Videos on reactive power compensation equipments.	14

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopicsshould betaught and assessed in order to develop UOs for achieving the COs to attain the identified competency.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit– I Representation of power system.	1a. Explain the specified aspects of the given power system. 1b. Describe role of power system engineer for analysing the given power system. 1c. Draw the Equivalent circuit of the given power system components. 1d. Develop impedance diagram and reactance diagram from the given single line diagram of power system. 1e. Use per unit method for representing parameters of the given power system.	1.1 Aspects of power system analysis: 1.2 Role of power system engineer. 1.3 Equivalent Circuit representation of the System components-Alternator, Transformer, Load, Transmission line: Short, Medium and long. 1.4 Representation of power system by single line diagram, impedance diagram and reactance diagram. 1.5 Per unit method for representing power system parameters.
Unit– II Composition of Transmission Line	2a. Develop composition of the given transmission line 2b. Describe the impact of given parameter in transmission line performance. 2c. Calculate inductance of the given single phase line with given configuration. 2d. Evaluate Self GMD andMutual GMD for given conductor configuration. 2e. Develop the equation for inductance/capacitance of given transmission line 2f. Estimate the inductance/capacitance of three phase line for the given conductor arrangement.	2.1 Transmission line composition – resistance, inductance, capacitance and conductance and their significance. 2.2 Inductance-Single phase line composed of solid conductors and bundled conductors. 2.3 Self GMD and Mutual GMD 2.4 Inductance of three phase line (single circuit) composed of solid conductors with symmetrical and asymmetrical spacing. 2.5 Capacitance of single phase line composed of solid Conductors and Duplex bundled conductors. 2.6 Capacitance of three phase line (single circuit) with symmetrical and asymmetrical spacing. 2.7 Effect of earth field on transmission line capacitance.
Unit-III Generalized circuit representation	3a. Apply concept of generalized circuit for the given type transmission line. 3b. Evaluate the generalized circuit constants for the given type transmission line. 3c. Develop resultant generalized network of the given type combination of networks. 3d. Describe the benefits of generalised circuit representation of the given type of transmission line.	3.1 Generalized Circuit – Concept 3.2 Generalized circuit constants of short, mediumtransmission line. 3.3 Generalized circuit constants of two networks connected in series 3.4 Generalized circuit constants of two networks connected in parallel. 3.5 Advantages of Generalized circuit representation

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit –IV Power flow	4a. Describe the concept of complex power with reference to the given power system. 4b. Develop the expression for complex power at given end of given transmission line. 4c. Evaluate real/reactive power at given end of given transmission line forthe given loading condition. 4d. Develop the condition for maximum real power flow of given end of the given transmission line.	4.1 Complex Power ($S=V I^{*}$), Real Power and reactive Power. 4.2 Derivation for Complex power, real power, reactive power for receiving end of the tr. line using GCE. 4.3 Derivation for Complex power, real power, reactive power for sending end of the tr. line using GCE. 4.4 Condition for maximum powerat receiving end of transmission line. 4.5 Condition for maximum power at sending end of transmission line.
Unit-V Line performance by graphical analysis	5a. Describe the locus of complex power flowing through transmission line at both end 5b. Draw locus of complex power at receiving end transmission line with given loading conditionand evaluate performance parameters. 5c. Draw locus of complex power at Sending end transmission line with given condition and evaluate performance parameters. 5d. Identify the relevant reactive power compensating equipment for the given power system condition. 5e. Determine ratings of reactive power compensating equipment for given transmission line data.	5.1 Graphical method for Transmission line performance analysis- Receiving end circle diagramand Sending end circle diagram 5.2 Procedure to draw Receiving end circle diagram and derive performance parameter. 5.3 Procedure to draw Sending end circle diagram and derive performance parameter. 5.4 Reactive power compensation-Necessityand types ofequipments 5.5 Rating of equipment using receiving end circle diagram. 5.6 Advantages of graphical analysis

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

9. SUGGESTED SPECIFICATION TABLE FORQUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Representation of power system	07	00	04	04	08
II	Composition of Transmission Line	16	04	06	06	16
III	Generalized circuit representation	09	04	06	08	18
IV	Power flow	07	02	06	08	16

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
V	Line performance by graphical analysis	09	02	04	06	12
Total		**48**	**12**	**26**	**32**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

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

a. Collect specifications of different reactive power compensation equipment used in electrical power system through market survey/visit and write a technical report.
b. Visit 400/220/132/66/33kV substation and take the help of sub-station in-charge to understandvarious transmission line systems and write a technical report.
c. Collect data of different types of conductors used for different types of transmission lines through internet/ industrial visit.
d. Write all the safety precautionswhich are to be taken while working with distribution & transmission lines.
e. Collect information regarding maintenance of transmission lines. through internet/ industrial visit.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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

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

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are

group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

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

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

a. **Reactive Power compensation scheme**: Collect the information and Prepare comparative chart.
b. **Case study on power flow:** Performance analysis by analytical and graphical method for given loading condition.
c. **Representation in Generalized circuit:**Represent the given transmission line in generalized circuit and evaluate constants.
d. **Information collection**: Collect information of existing EHV transmission line and prepare report.
e. **Development of circuit model of Transmission line:** Evaluate line parameters from given design of transmission line and represent circuit model.

13. SUGGESTED LEARNING RESOURCES:

S. No.	Title of Book	Author	Publication
1	Principles of Power System	Mehta V. K ; Mehta Rohit.	S.Chand and Co., New Delhi. ISBN: 978-81-2192-496-2.
2	Modern Power System Analysis	NagrathI. J. Kothari D. P.	McGraw HillEducation, New Delhi 2003.ISBN-0-07-049489-4
3	Elements of Power System Analysis e-book	Stevenson William	McGraw-Hill Book Company, New York, 2014(4th addition) ISBN 10: 0070612781 / ISBN 13: 9780070612785
4	Electrical Power System	WadhavaC. L.	New age international publishers ISBN: 13-978-1-4987-7757-5-(EPUB)
5	Power System Protection and Switchgear	Badri Ram Vishwakarma D. N.	McGraw-Hill, New Delhi. ISBN : 978-07-107774-X
6	Power system Analysis and Design	Gupta B.R.	S. Chand and Co. Ltd., New Delhi Edition: 6 Year: 2011 ISBN: 81-219-2238-0

14. SOFTWARE/LEARNING WEBSITES

a. Lecture series on power system https://nptel.ac.in
b. Lecture series on power system https://www.youtube.com/watch?v=fBmtdr_gRBk
c. https://circuitglobe.com/power-system.html
d. https://www.electrical4u.com/power-system