Program Name : **Electrical Engineering Program Group**

Program Code : **EE/EP/EU**

Semester : **Sixth**

Course Title : **Power System Operation and Control (Elective-II)**

Course Code : **22632**

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 control strategies/mechanisms, and methods to ensure power system stability. They should also be aware of load flow studies and load dispatch. Hence, this course is designed to develop awareness about these concepts in diploma pass outs so that they may ensure power system stability. 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 the power system network for stability and load dispatch.**

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 real and reactive power flow in power system network.
b) Interpret the functioning of Automatic Generation control.
c) Interpret development of Load flow studies.
d) Apply different techniques to maintain stability of power system.
e) Interpret factors involved in Load dispatch.

4. TEACHING AND EXAMINATION SCHEME

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

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

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

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

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the

course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

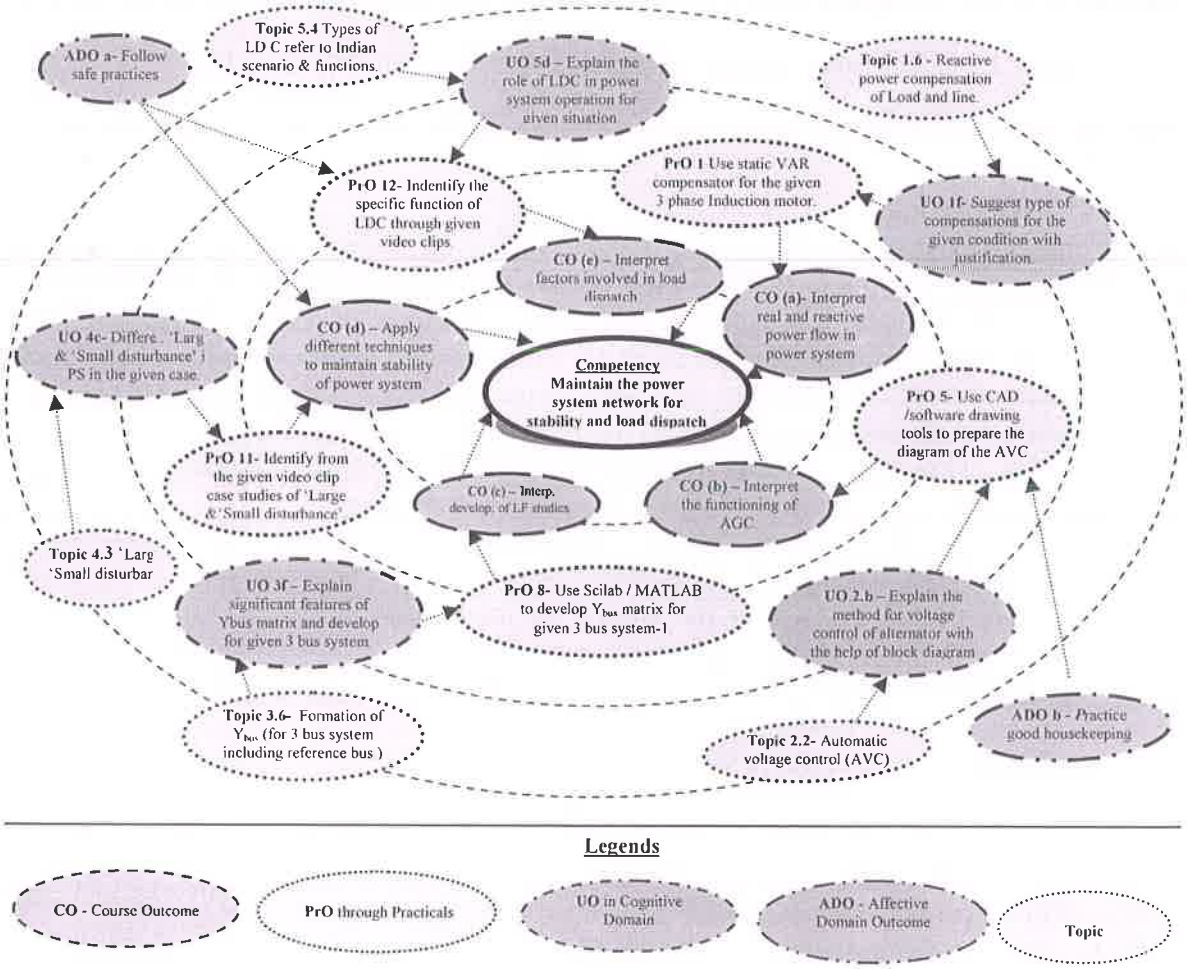

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

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

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Use static VAR compensator for the given three phase Induction motor.	I	02*
2	Identify the different voltage controls of H.V. substation with respect to the given video clip with justifications.	I	02
3	Identify the different frequency controls of a power plant with respect to the given video clip with justifications.	I	02
4	Identify different components of Turbo generator control with respect to the given video clip/ animation/chart with justifications.	II	02
5	Use CAD /software drawing tools to prepare the schematic diagram of the Automatic Voltage Control (AVC) for the given condition.	II	02£
6	Use CAD /software drawing tools to prepare the schematic diagram of the Automatic Load Frequency Control (ALFC) for the given condition.	II	02£

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
7	Use CAD /software drawing tools to prepare the schematic diagram of the Automatic Generation Control (AGC) for the given condition.	II	02£
8	Use Scilab / MATLAB to develop Y_{bus} matrix for given 3- bus system-1.	III	02#
9	Use Scilab / MATLAB to develop Y_{bus} matrix for given 3- bus system-2.	III	02#
10	During the maintenance outages, determine the effect on SLFE for given power system using relevant software.	III	02*
11	Identify from the given video clip case studies of 'Large disturbance' and 'Small disturbance'.	IV	02*
12	Identify the specific function of Load dispatch center through given video clips.	V	02*
13	Identify specific reasons for Load shedding adopted by DISCOM in specific area from given video clip (case-1).	V	02$
14	Identify specific reasons for Load shedding adopted by DISCOM in specific area from given video clip (case-2).	V	02$
	Total		**28**

Legend: £- Minimum two ; # -Minimum one; $- Minimum one

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 10 or more practical need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

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

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

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

a) Follow safety practices.
b) Practice good housekeeping.
c) Practice energy conservation.
d) Work as a leader/a team member.
e) Follow ethical Practices.

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

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

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Induction motor (3phase /1 phase,3kW)	1
2	Ammeters MI Type: AC/ DC 0-5-10Amp (3 in number)	1
3	Voltmeter MI Type: AC/DC, 0-150/300V, 0-250/500V(1 in number)	1
4	Wattmeter: Single phase, single element 2.5/5Amp, 200/400V, (2 in number)	1
5	Dimmer: 3-phase, 5kVA	1
6	Star- delta starter :3phase,3kW	1
7	Load bank: Inductive bank, 3-phase, 5kW, 415V	1
8	Capacitor bank, 3-phase, 5kW, 415V	1
9	Knife switch :10Amp	1
10	Chart relevant to practical	4
11	Electrical –CAD or equivalent software	5,6
12	Software –Scilab / MATLAB or other open sources.	7,8,9
13	Internet facility	2 to 13
14	Videos relevant to different practical	2,3,4,10, 11,12,13

8. UNDERPINNING THEORY COMPONENTS

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

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit-I Real And Reactive Power Flow	1a. Interpret the impact of real and reactive power imbalance for the given data. 1b. Explain the adverse effect of real power imbalance in the given situation for the power system. 1c. Explain the effect of the given condition of the frequency on the specified side in the power system. 1d. Explain the causes for imbalance of reactive power flow in the given situation for the power system. 1e. Explain the effect of the given condition of the voltage on the specified side in the power system 1f. Suggest type of compensations for	1.1 Concept of power flow and real power balance and reactive power balance and its adverse impact. 1.2 Relation between Real power balance and frequency of the system (derivation) 1.3 Need of constant frequency control, adverse impact of variation in frequency on consumers and supply agencies. 1.4 Relation between reactive power balance and voltage of the system (derivation) 1.5 Effect of change in voltage on consumers and supply agencies. 1.6 Reactive power compensation for

	the reactive power under given condition with justification.	Load and line.
Unit– II Automatic Generation Control	2a. Explain the specified method used for speed control of the given turbo-generator using schematic diagram. 2b. Explain the specified method for voltage control of given alternator using block diagram. 2c. Explain with sketches the application of Load-frequency control for the given type of control area. 2d. Describe the functioning of the Automatic Load Frequency Control using the block diagram for the given type of generator. 2e. Draw the block diagram of Automatic Generation Control (AGC) for the specified generating system.	2.1 Schematic diagram of Turbo generator speed control (Turbine speed governing system) and its functioning. 2.2 Automatic voltage control (AVC) 2.3 Load frequency control (single area case) 2.4 Schematic diagram of The Automatic Load Frequency Control (ALFC) and its functioning. 2.5 Schematic diagram of The Automatic Generation Control (AGC) and its functioning.
Unit-III Load flow studies	3a. Identify the significance of Load flow analysis for the given power system. 3b. Categorize the data required for Load flow studies for the given power system. 3c. Develop the Static Load Flow Equation (SLFE) for a simple two bus system. 3d. Interpret the Characteristics' of the given SLFE for specified power system.. 3e. Identify the information obtained from the given Load flow study. 3f. Identify significant features of the given Y_{bus} matrix and develop for given 3 bus system.	3.1 Concept of Load flow studies and its need. 3.2 Data required for Load flow studies. 3.3 Static load flow equation (SLFE) for simple two bus system and definition of parameters (only equation). 3.4 Characteristics' of SLFE. 3.5 Information obtained from Load Flow Studies 3.6 Formation of Y_{bus} (for 3 bus system including reference bus).
Unit –IV Power system stability	4a. Explain the specified type of Stability of given power system. 4b. Explain the adverse effects of instability of given power system on consumers and on power utility companies. 4c. Differentiate 'Large disturbance' and 'Small disturbance' in the given power system in specified case. 4d. Identify the type of power system stability condition for the given	4.1 Illustration of terms: Power system stability, overall stability, Stability limit and Instability. 4.2 Adverse effects of instability of power system. 4.3 'Large disturbance' and 'Small disturbance' 4.4 Classification of Stability: i) Steady state stability ii) Transient state stability iii) Dynamic stability 4.5 Stability studies with the help of

	power system. 4e. Explain the different stability condition of the given power system with the help of power angle diagram. 4f. Describe the specified method of improving Steady state stability condition of the given power system. 4g. Explain specified method of improving Transient State Stability condition for the given power system.	power angle diagram (Steady state stability and Transient state stability 4.6 Methods of improving Steady state stability condition. 4.7 Methods of improving Transient State Stability condition (Conventional and New techniques).
Unit-V Load dispatch	5a. Explain the idea of Load dispatch in the given power system. 5b. Explain impact of specified factors on the Load forecasting of the given power system. 5c. Explain impact of the specified factors on Load shedding in power system operation. 5d. Explain the role of Load Dispatch Center in power system operation for the given situation.	5.1 Concept of Load dispatch. 5.2 Load forecasting i) Significance of forecasting. ii) Use of load curve. iii) Environmental and social factors in load forecasting. 5.3 Load shedding and its governing factors 5.4 Types of Load Dispatch Centre refer to Indian scenario and their functions.

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

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Real And Reactive Power Flow	10	02	04	04	10
II	Automatic Generation Control	08	04	08	00	12
III	Load flow studies	10	02	08	08	18
IV	Power system stability	12	04	04	08	16
V	Load dispatch	08	04	06	04	14
Total		48	**16**	**30**	**24**	**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 any two of the 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 the information about impact of variation in frequency –case study.
b) Collect the information about impact of variation in voltage –case study.
c) Create awareness of Load shedding and its importance among students.
d) Carry out internet survey to collect information related LDCs and their locations with Indian scenario.
e) Write report on power failure in nearby area.
f) Prepare case study on recent Major power failure in India / world.
g) Prepare a report on impact of Wind/Solar farms on Power system operation.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Use Flash/Animations to explain working of Real power balance and its relation with frequency.
g) Use Flash/Animations to explain working stability of power system.
h) Pre-guided visits to Load dispatch / HV substations centers in which the students will observe functioning of LDC.

12. SUGGESTED MICRO-PROJECTS

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

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

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

a) **Indian National grid and Regional grid:** Collect information and prepare charts with significant details.
b) **Major power failure:** Collect information about power failure in / outside India.
c) **Load dispatch center**: Prepare technical presentation on details of functioning of RLDCs.

d) **Social impact on Load forecasting**: Collect information about nearby social activities which affect Load forecasting.
e) **Environmental impact on Load forecasting**: Collect information about changes in environment which affect Load forecasting.
f) **Load shedding:** Collect information about strategy adopted in specific area.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Modern Power System Analysis	Nagrath, I. J. Kothari, D. P.	McGraw Hill Education, New Delhi 2003 ISBN-0-07-049489-4
2	Electric Power Systems (Analysis ,Stability and Protection)	Gangadhar, K. A.	Khanna Publishers, Delhi. India, 2006. ISBN 9788174090041
3	Elements of Power System; Analysis e-book	Stevenson, William	McGraw-Hill Book Company, New York, 2014 (4th addition) ISBN: 9780070612785
4	Power System Analysis, operation and control	Chakrabarty, Abh ijit	PHI Learning, New Delhi, New Delhi, 2010 ISBN: 788120340152
5	Electrical Power System	Wadhava, C. L.	New Academic Science, UK, 2017 ISBN: 9781781831014
6	An introduction to Reactive Power Control and Voltage Stability in Power Transmission Systems –	Chakrabarti, D P A Kothari, A K Mukhopadhyay, Abhinandan De	PHI Learning, New Delhi, 2015 ISBN: 9788120340503
7	Power Generation Operation and Control	A. J. Wood, B. F. Woolenberg,	John Wiley and Sons, UK ISBN:978-0-471-79055-6

14. SOFTWARE/LEARNING WEBSITES

a) https://mahatransco.in/information/details/load_despatch
b) ieee.org/houston/files/2018/04/Fundamentals-oF-Turbine-Generator-Speed-Control.pdf
c) https://www.electrical4u.com/power-system-stability/
d) https://mahatransco.in/information/details/load_despatch
e) http://nptel.ac.in/courses/108101040/
f) http://www.electrical-engineering-portal.com/
g) http://nptel.iitm.ac.in/courses.php
h) https://www.youtube.com/watch?v=ouWOhk1INjo