GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3172415

Semester – VII
Subject Name: Power Electronics for Power System Applications

Type of course: Professional Elective Course

Prerequisite:
1. 311005 – Basic Electrical Engineering
2. 3132407- Electrical Machine and Application
3. 3142404 – Basic Power System Engineering
4. 3152407- Power Processing Circuit- I
5. 3162413 -Power Processing Circuit - II

Rationale: As the society develops, automation and intelligence are becoming the inevitable tendency of power system, and power electronics is an essential technology for modern science. Advanced power electronics can strengthen and optimize power system to ensure the stability and safety of operation and improve the power quality better. Accelerating power electronics is an important path to constructing the strong smart grid and accelerating the development of power system. FACTS is the acronym for Flexible AC Transmission Systems and refers to a group of resources used to overcome certain limitations in the static and dynamic transmission capacity of electrical networks. The main purpose of these systems is to supply the network as quickly as possible with inductive or capacitive reactive power that is adapted to its requirements, while also improving transmission quality and the efficiency of the power transmission system. FACTS Devices course is designed to provide in-depth knowledge to provide actual hardware solution of the FACTS.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Course Contents	Total Hrs
1.	Introduction: Problems of AC transmission systems – Power flow in parallel paths and meshed system – Factors limiting loading capability – Stability consideration – Concepts of power quality – Introduction to IEEE/IEC and other standards related to power quality – Power flow control of an AC transmission line – Basic types of FACTS controllers – Advantages of FACTS technology.	5
2.	Shunt Series & Compensation Introduction – Concepts of Series & Shunt Compensation – Comparison – Methods of VAR generation – Shunt Compensation Methods – TCR –TSC – Fixed capacitor TCR – STATCOM – Series compensation methods – GCSC – Comparison of TCR and GCSC – TSSC – TCSC – SSSC – Modes of Operation – Voltage Regulator and Phase Angle Regulator (PAR) – Multifunctional FACTS controllers like UPFC and IPFC – basic operating principles and characteristics – Applications.	8

3.	HVDC Introduction – Various possible HVDC configurations – Unipolar and bipolar links–Components of HVDC system like converter, transformer, smoothing reactor, harmonic filter – Control of HVDC system – Rectifier and inverter characteristics –Mode of stabilization – Current control – Voltage control – Modern HVDC system	**8**
4.	Renewable Energy Source Interface Introduction – Interconnection of Renewable Energy Source to utility grid – Energy storage systems to utility grid & their interconnection – Photovoltaic array interconnection – Wind and small hydro connection.	**8**
5.	Optimizing Utility with Power Electronics Systems Introduction – Need for improved utility interface – Improved single phase utility interface – Interface for a bidirectional power flow – Improved three phase utility interfaces	**8**
6.	Static Relay Introduction – Classification – Basic components – Directional static over-current relay - Static differential relay – Static distance relay	**8**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks (%)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
10	**35**	**20**	**20**	**10**	**05**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create andabove Levels (Revised Bloom's Taxonomy)

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

Reference Books:

1. N.G. Hingorani and L. Guygi, "Understanding FACTS Devices", IEEE Press Publications, 2000
2. K. R. Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International (P) Ltd. Publishers.
3. Y. H. Song and Allan T. Johns, "Flexible AC Transmission Systems (FACTS)" Institution of Electrical Engineers Press, London, 1999
4. N.G. Hingorani and L. Guygi, Concepts and Technology of Flexible AC Transmission System, IEEE Press New York, 2000 ISBN –078033 4588
5. T.J.E. Miller, "Static Reactive Power Compensation", John Wiley & Sons, New York, 1982.
6. Ned Mohan, Undeland & Robbins, "Power Electronics: Converters, Applications and Design", Wiley Publications.

Course Outcome:

The theory should be taught and practical should be carried out in such a manner that students are able to acquire different learning outcomes in cognitive, psychomotor, and affective domain to demonstrate

following course outcomes.

Sr. No.	CO statement After learning the course, the students will be able to	Marks % weightage
CO-1	Distinguish various power quality issues and how are they mitigated by various FACTS Devices.	20
CO-2	Select proper controller for the specific application based on system requirements.	30
CO-3	Interpret the control circuits of Shunt Controllers SVC & STATCOM for various functions viz. Transient stability Enhancement, voltage instability prevention and power oscillation damping.	30
CO-4	Detect the Power and control circuits of Series Controllers GCSC, TSSC and TCSC	20

List of Experiments:

1. To Study or simulate of reactive power compensation with TCR in open loop or Compensation with TCR in close loop system.
2. To Study or simulate of reactive power compensation with TSC in open loop or Compensation with TCR in close loop system.
3. To Measurement of voltage, current, active power, reactive power and THD of source current with 5th and 7thharmonic tuned filter connected in the system.
4. To perform or simulate Transient performance evaluation of DVR.
5. To understand Compensation of reactive power with STATCOM operating in open loop or closed loop.
6. To Study the Effect of Different Type of Loadings on Transmission Line Compensation using Shunt Compensator in Closed Loop or Open Loop.
7. To Study the Effect of Different Type of Loadings on Transmission Line Compensation using Series Compensator in Closed Loop or Open Loop.
8. To Study the Effect of Different Type of Loadings on Transmission Line Compensation using Shunt-Series Compensator.
9. To study principle and different types of static relays.
10. To study interconnection of renewable energy sources and energy storage system to utility grid.
11. To study and simulate concept and application of power converter of HVDC transmission.
12. To study and simulate about the use of FACTS controller for custom power.
13. To study and simulate SSSC for Power oscillation damping.
14. To study and simulate 3-ϕ harmonic filter used on a 12 pulse AC-DC converter.
15. To study working and principle of UPSC and IPFC.

Design based Problems (DP)/Open Ended Problem:

1. Analyze the performance of transmission line using passive reactive power compensation.
2. Analyze the performance of compensated transmission line using a FACTS device.
3. Compare the control schemes of the GCSC, TSSC and TCSC.
4. Analyze the Real and reactive power control of UPFC.
5. Analyze the power quality issues using power quality conditioners.

Major Equipment:

1. Single Phase Thyristor Controlled Reactor
2. Single Phase Thyristor Switched Capacitor
3. Three Phase Thyristor Controlled Reactor
4. Three Phase Thyristor Switched Capacitor
5. Tuned Harmonic Passive Filter
6. Dynamic Voltage Regulator (DVR)
7. HVDC Trainer with 6 pulse converter
8. Instantaneous VAR Compensator (STATCOM)
9. Shunt Active Power Filter (SAPF)
10. VSC based FACTS Controller (STATCOM, SSSC and UPFC) with Transmission Line and Different Loading
11. Other Equipment : System voltage 120V, 50 Hz, three-phase provided through 415:120 V three-phase transformer ϖ Transmission line with three PI sections are constructed
12. Three load banks (i) R load; (ii) R-L load and (iii) R-C load are provided for experimenting their effect on transmission line.
13. Four stage load banks for experimenting variation of loading on transmission line. ϖ Maximum loading is up to 1 kVA.
14. Three multi parameter energy meters are provided at sending end, receiving end and load end of the transmission line.
15. Numbers of MCBs are provided for connecting and disconnecting different compensators.
16. FACTS controller with shunt compensator (STATCOM), series compensator (SSSC) and shunt-series compensation (UPFC operation) is provided.
17. 1 kVA IGBT based VSC with filter as shunt compensator.
18. 1 kVA IGBT based VSC with filter and series injection transformer as series compensator.
19. Control circuit designed using Synchronous Reference Frame (SRF) based control algorithms.
20. Control algorithm are developed using ST Microelectronics ARM Cortex M4 microcontroller.
21. Intermediate stage test point observations using two Digital to Analogue Converter (DACs)
22. AC/DC voltages and currents sensing circuit and DC link voltmeter is provided.

List of Open-Source Software/learning website:

1. https://nptel.ac.in/courses/108/107/108107114/
2. https://onlinecourses-archive.nptel.ac.in/noc18_ee44/preview
3. https://sites.google.com/a/vgecg.ac.in/powerelectronics/academic/semester_viii/peaps
4. https://drive.google.com/drive/u/0/folders/1ciHR4wcwnOHCthwrhxMUhsdLvt3rLR4A
5. https://drive.google.com/drive/u/0/folders/1PMH2Hx6ZSsoAKGB11OzvPioPn65sXpi3
6. https://drive.google.com/drive/u/0/folders/1uKMvMXGRroGwXbA9xRwqIsNUT02gXZdV
7. https://drive.google.com/drive/u/0/folders/1OoyosOUN8YHfyMliAh2OaqopEMcYjD-I
8. https://new.abb.com/facts
9. https://new.siemens.com/global/en/products/energy/high-voltage/facts.html

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the website of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on

the first slide. The best three works should submit to GTU.