Marwadi University
Marwadi Chandarana Group

**Syllabus for Diploma Engineering**

**Electrical Engineering**

**Semester – VI**

**Subject Name: Substation Engineering and Power Quality**

**Subject Code: 09EE2602**

**Diploma Branches in which this subject is offered:** Electrical Engineering

**Objective:** This course provides knowledge of Gas Insulated Substation (GIS), earthing in substation and various parameters of power quality like transient, disturbances, harmonics and power factor of the power system. Due to economic impacts on power system, their customers, and suppliers of load equipment power Quality is gaining more attention in recent years.

**Credits Earned:** 5 Credits

**Course Outcomes:** After completion of this course, student will be able

1. To understand basic construction and working of GIS and substation earthing.
2. To analyze various power quality problems and issues.
3. To apply and uses various techniques to mitigate power quality disturbance and transients
4. To apply appropriate techniques to mitigate harmonics in power system.
5. To measure and improve power factor of power network

**Pre-requisite of course:** Basic knowledge of Electrical Machine and Power system

**Teaching and Examination Scheme**

| Teaching Scheme (Hours) | | | Credits | Theory Marks | | | Tutorial/ Practical Marks | | Total Marks |
|---|---|---|---|---|---|---|---|---|---|
| Theory | Tutorial | Practical | | ESE | IA | CSE | Viva | Term work | |
| 4 | 0 | 2 | 5 | 50 | 30 | 20 | 25 | 25 | 150 |

**Contents:**

| Unit | Topics | Contact hours | Weightage (%) |
|---|---|---|---|
| 1 | **Gas Insulated Substations**<br>• Introduction of GIS<br>• Construction and single line diagram of substation<br>• Sulfur Hexafluoride insulated substations<br>• Advantages and Disadvantages of SF6 insulated switchgear.<br>• Control and monitoring of GIS; Gas monitoring, partial discharge, PD monitoring strategies, CB monitoring, local control cabinet. | **07** | **13** |

| | | | |
|---|---|---|---|
| | • Testing of GIS; type tests, routine tests, on-site field tests, measurement of loss and temperature rise<br>• Installation and maintenance of GIS<br>• Application of GIS | | |
| **2** | **Substation Earthing System**<br>• Introduction of electrode and earth mat<br>• Components of substation earthing system<br>• Connections of electrical equipment to station earthing system<br>• Measurement of step potential and touch potential<br>• Earthing grid and earthing resistance<br>• Earth resistance measurement<br>• Integrated earth system | **07** | **13** |
| **3** | **Introduction to Power Quality**<br>• Introduction<br>• Definition of power quality<br>• Power quality progression<br>• Power quality terminology<br>• Power quality issue<br>• Significance of Power Quality<br>• Causes and effect of power quality problems, Transients - Impulsive, Oscillatory, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation<br>• Power Quality measurement devices: Harmonics Analyzers, Transient disturbance analyzers, Power line disturbance analyzer, Flicker meters, Oscilloscopes, True RMS meters.<br>• Numbers of test locations and test duration<br>• Instruments setup, Power quality standards.<br>• IEEE and IEC standard for power quality | **11** | **20** |
| **4** | **Power Frequency Disturbances and Electrical Transients**<br>• Introduction<br>• Common power frequency disturbances; Voltage sag and their sources<br>• Voltage sag, due to starting of induction motor, Estimation of the sag severity<br>• Mitigation of voltage sags<br>• Cures for low frequency disturbances<br>• Voltage tolerance criteria: CBEMA and ITIC curves<br>• Transient system model<br>• Examples of transient models and their response<br>• Power system transient model<br>• Transients types and their sources<br>• Types and causes of transients<br>• Example of transient waveform | **13** | **23** |

| | | | |
|---|---|---|---|
| | • Lightning protection, shielding, line arresters, protection of transformers and cables | | |
| **5** | **Harmonics and Its Mitigation Techniques**<br>• Introduction<br>• Concept of harmonics, harmonics number, odd and even order harmonics, inter harmonics, harmonic phase rotation and phase angle relation<br>• Voltage and current harmonics<br>• Individual and THD<br>• Harmonic signature<br>• Effect of harmonics on power system equipment: motors, transformer, conductors, capacitors, power electronic equipment, cable and lamps<br>• Guidelines for harmonics voltage and current limitation<br>• Harmonic current mitigation techniques: harmonic filter, isolation transformer, reactor | **13** | **23** |
| **6** | **Power Factor**<br>• Introduction<br>• Active and reactive power<br>• Displacement and true power factor<br>• Improvement and correction of power factor<br>• Penalty of power factor<br>• Advantage of power factor correction<br>• Power factor correction devices | **05** | **8** |

**Suggested Theory distribution:**

The suggested theory distribution as per Bloom's taxonomy is as per follows. This distribution serves as guidelines for teachers and students to achieve effective teaching-learning process

| Distribution of Theory for course delivery and evaluation | | | | | |
|---|---|---|---|---|---|
| Remember | Understand | Apply | Analyse | Evaluate | Create |
| 35% | 40% | 13% | 12% | 0% | 0% |

**Suggested List of Experiments:**

| **Sr. No.** | **Unit No.** | **Name of Topics** | **Contact Hours** |
|---|---|---|---|
| 1 | 1 | Draw single line diagram of GIS substation and its components | 2 |
| 2 | 2 | To understand substation earthing system and measure earthing resistance | 4 |
| 3 | 3 | To understand different power quality terminology | 2 |

| | | | |
|---|---|---|---|
| 4 | 3 | To monitor electrical power quality as per IEEE /IEC standard | 2 |
| 5 | 4 | To analyze common causes of voltage sag and swell and their remedies. | 2 |
| 6 | 4 | To measurement of high frequency noise with oscilloscopes having high sampling rates | 2 |
| 7 | 4 | To simulate various causes of electrical system transient such as interruption of fault current in cables followed by transmission line, switching of capacitor banks, switching ON and OFF of large loads using MATLAB | 2 |
| 8 | 5 | To measurement of harmonics using power Analyzer | 2 |
| 9 | 5 | To calculate THD and IHD of non-linear loads using MATLAB | 2 |
| 10 | 5 | To measurement of current harmonics using current probe | 2 |
| 11 | 5 | To understand harmonic distortion limit in agreement with IEEE 519 | 2 |
| 12 | 5 | To simulate passive filter techniques for non-linear load using MATLAB | 2 |
| 13 | 6 | To simulate power factor improvement using static VAR compensators using MATLAB | 2 |

**Instructional Method:**

a. The course delivery method will depend upon the requirement of content and need of students. The teacher in addition to conventional teaching method by black board, may also use any of tools such as demonstration, role play, Quiz, brainstorming, MOOCs etc.

b. The internal evaluation will be done on the basis of continuous evaluation of students in the laboratory and class-room.

c. Practical examination will be conducted at the end of semester for evaluation of performance of students in laboratory.

d. Students will use supplementary resources such as online videos, NPTEL videos, e-courses.

**References:**

1. P.S. Satnam and P.V. Gupta, "*Substation Design and Equipment*", Dhanpat Rai Publication, New Delhi. 2012.
2. C Sankaran, *"Power Quality",*CRC Press, Washington, D.C.2002.
3. Roger C.Dugan, "*Electrical Power System Quality*", Tata Mcgraw Hill Publication. 2nd Edition
4. Francisco C. De La Rosa,*"Harmonics and Power System",* CRC Press, Washington, D.C. 2014.
5. M. H. J. Bollen,*"Understanding Power Quality Problems: Voltage sags and Interruptions",* WileyIEEE Press, 1999
6. S. Chattopadhyay ,M Mitra, S Sengupta,*"Electric Power Quality",* Springer Publication, 2011
7. R. Sastry Vedam & Mulukutla S. Sarma,*"Power Quality: VAR Compensation in power systems"*, CRC press, 2009.

**Supplementary Resources:**

1. https://nptel.ac.in/courses/108/106/108106025/
2. https://www.youtube.com/watch?v=q4_2vS6W16Q
3. https://npti.gov.in/3-months-course-distribution-substation-management-optimal-utilization-components
4. https://nptel.ac.in/courses/108107112/
5. https://nptel.ac.in/courses/108108099/
6. https://electrical-engineering-portal.com/how-to-determine-correct-number-of-earthing-electrodes-strips-plates-and-pipes-part-1
7. https://nptel.ac.in/content/storage2/courses/108105066/PDF/L-16(NKD)(PE)%20((EE)NPTEL)%20.pdf