King Fahd University Petroleum & Minerals
Electrical Engineering Department

EE 499 Power Quality and Harmonics in **Electrical Power Systems**

Course Handout for FE 499 Term 051-2005

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Textbook: Voltage Quality in Electrical Power Systems, By J. Shlabbach 1st edition
Reference Book: Electrical Power Systems Quality, By: R. C. Dugan et. al., 2002, 2nd edition, McGraw Hill
Instructor Notes & Handouts complements course materials.

Tentative Materials to Be Covered:

- Introduction
- What is Power Quality?
- Power Quality -- Voltage Quality
- Why Are We Concerned About Power Quality?
- Power Quality Terms
- The technical impact of problems on various load equipment
- The principles of harmonics , applied Harmonics
- Harmonics filtering
- Voltage Sags and Interruptions
- Benchmarking power quality and standards
- **Power Quality Monitoring**
    - Monitoring Considerations
    - Historical Perspective of Power Quality Measuring Instruments
    - Power Quality Measurement Equipment
    - Assessment of Power Quality Measurement Data
- Transient overvoltages due to lightning and switching
- Power Quality issues in Distribution Systems, voltage imbalance, Sags & Swells
- Practical Experiments using PQA

NOTE: Syllabus material may be presented out of the textbook. The instructor reserves the right to relax or cut some of the topics.

Grading Policies:

Homework quizzes, class performance, course folder, and attendance: 15 %
Exam: 15%
Experiments: 15%
Term Project: 35 %
Final Exam: 20 %

Tentative Exam Dates: Exam one: October 2005 **Or as will be Announce by Instructor**.

The instructor will not tighten these requirements; however, he reserves the right to relax them.

Personal Information: Given Verbally,
Guidelines:

Makeup exams and late homework will only be permitted for officially excused absence. Students are expected to attend, participate in all course activities, and to give oral presentation of their project and submit a full project term paper on due date.
- Students are required to attend all BI-weekly briefing meetings for term project progress
-It is expected from each student to be able to learn independent studying habits, self reliance, and to be creative, analytical, able to develop and comprehends course materials with little help and assistant.

Term Projects:

Each student may work in one of the following project list below. Each student separately should prepare a brief

proposal within 2-weeks, which must be approved by instructor, submit a final project report (soft and hard copies), and each student should be able to present his work at the final presentation.

Details of the project will be submitted in the first BI-Weekly meeting with course instructor, the student should arrange meetings with instructor.

Another alternative of Term project: any student have his own idea on a related topic can submit a term project preliminary proposal in the Third week, proposals should give a brief description of the project. Instructor will give suggestion, changing, refusals, of the topic, or go ahead within fourth week, proposals should contain statement of objectives, and methodology, and references, etc ... Should be briefly mentioned NOT MORE THAN (5) five PAGES (typed) PLEASE.

Each term project report should at least consist of:

- Abstract
- Introduction
- Literature review or theory
- Statement of the problem or objectives
- Data, Schematics, and diagrams
- Program, method of analysis
- Calculations and results
- Conclusions
- References used

Term project typed report will be due in: November 28, 2005

Presentations: Each student MUST present his work-using power point, and it can be 30 slides or more if needed, but all should present in 15-minute time.

Tentative presentation date: December 3, 2005

***A* folder with notes, graded homework, quizzes, exams, and any *extra* work, neatly organized must be submitted to the instructor on due date of the term project submission.**

No matter how it is emphasized that term project is a vehicle for you to show how could you apply topics learned and expand on them to make something useful, you will always treasure?

Suggested term paper projects list

By: Dr. M- H. Shwehdi, for EE 499, term 051

1- USE of EDSA-PQ module to in Design and calculate voltage, current harmonics of a practical system, also design and select filters to reduce any high harmonics.

2- Conduct Complete Survey for all Power Quality available and used standards for Transmission, Distribution and industrial Systems.

3- Measurements methods of voltage dips and short interruptions occurring in industrial Installations with real case studies if possible.

4- Flicker Meter, functional and design specifications as well as operation.

5-The Impact of Voltage sags on Industrial Plant loads.

6- Voltage sags in Industrial Systems
7- Protecting Distribution Circuits: Overhead shield wire versus Lightning Surge Arresters

8- How to Control Transient over voltages on T. L, causes, methods, and application on case study.
9- Voltage Imbalance in distribution systems of 13.8-69 KV, causes, effects, remedies, and mitigation

10- Voltage Sag problem on Distribution Systems, defining problem, causes, effect, measurements, reducing or mitigation of the problem, with a case study application

11- Causes, effect, and Strategies, Remedies and modren means to analyze and reduce Voltage Fluctuations in distribution systems.

12-Use of EDSA or Similar Package to study and analyze a Power System (5-6 Bus systems), conduct all analysis, i.e. load flow, short circuit, protection coordination, harmonic, and imbalance voltage determination and mitigation.

Example of a good project:

Singapore is currently the home to many high technology industries such as wafer fabrication & petrol chemical industries whose operations are very critically dependent on the power supply.
The quality of the power supply has become a very important issue for power utilities and their users. On one hand, the rapidly increasing use of electronic equipment such as computers, digital controls and sensitive equipment has increased the susceptibility of electrical consumers to supply disturbances. On the other, the application of high-energy efficiency power electronic drives and equipment with advance control features has in turn increased the level of disturbances that might affect consumer equipment.

A recent study by the Electric Power Research Institute, EPRI estimated that power quality problems account for about US$15-24 billion in annual losses in the United States. Voltage dips, transients & momentary and complete outages are the major causes of power quality problems. Others include current and voltage distortions caused by harmonics as the result of the abundant use of non-linear loads. In Singapore, we are becoming increasingly aware of the power quality problems, and it is very important for us to understand the causes of these problems and learn the ways of mitigating or preventing them. A practical course and study in power quality is becoming an area of high demand.

To meet this demand, we have developed a Module on "Fundamentals of Power Quality" with guidance & assistance from our UK Specialist, Dr. Jovica V. Milanovic under the British Council Higher Education Links Programme. This Module is aimed at teaching our students the various technical and economic issues concerning power quality as well as the various methods used in mitigating or solving power quality problems.

Besides learning the various topics like voltage sags, interruptions, transient over-voltages, harmonics, filters and common earthing problems, students will be taught the methodology of power quality monitoring, survey, characterization and analysis of voltage sags. Students are also expected to learn the impact of these problems on equipment and the strategies of the utility and end-user for improving power quality.

The Module on "Fundamentals of Power Quality" satisfies the growing needs of industries for Power Quality Education. It also integrates well with the other Electrical Modules offered by the Electrical Engineering Division, School of Engineering in the Diploma course.

TANGIBLE/INTANGIBLE BENEFITS

Students will have the opportunity to learn about the causes of Power Quality problems and their impact; the various monitoring and analysis strategies; and the available methods & devices used to mitigate or eliminate the problems.

Students and staff will be able to carry out research & development work by undertaking specific projects related to Power Quality.

Students and staff can work together with other Higher Educational institution on joint projects (eg Hadeed, Saddaf Al-Razi, and KACST).

Staff can now provide expertise in the area of Power Quality and practical training courses to industries.

Example of LABORATORY EQUIPMENT:

The Power Quality Training Laboratory is equipped with the following equipment. They are:

Three-phase AC Programmable Power Source.
California Instrument Model 3001 ix

- Single-phase AC Power Source/Analyser.
  Agilent Technology Model 6813B
- Fluke Electrical Power Standard.
  Models 6100A and 6101A.
- Shunt Active Power Filter.
  Nokian Capacitors MaxSine Type 25A-3L
- Single and Three-phase Dynamic Sag Compensators.
  DynaCom (SP Systems) Model SS40025 and SS4926
- Power Quality Meters.
  Fluke 43B and Siemen Model Access 9500
- 5 HP Motor Brake System.

DEMONSTRATION PROJECTS

Projects to demonstrate the causes, effects, measurement, analysis, and mitigation of power quality problems are:
(a) Harmonics generated by non-linear loads (eg. Electronic dimmer, PCs, domestic appliances and variable speed drives).
(b) Effects of harmonics on:

- Tripping sensitivity of protection relays eg. IDMTL;
- Measuring accuracy of different types of ammeters;
- Recording accuracy of single and three-phase kWh meters; and
- Motor/inverter drive system fed by long cables.

(c) Mitigation of harmonics using active harmonic filter.
(d) Equipment/device sensitivity to voltage sags. These include:

- Variable Speed Drives;
- PLC;
- PCs; and
- Electromagnetic contactors and relays.

(e) Mitigation techniques of voltage sags by:

- Sag compensator;
- Ferroresonant constant voltage transformer; and
- Electromagnet contactor and relay fitted with DC operating coils..

(f) Measurement and analysis of harmonics, inrush current, transient over-voltage and voltage sag by portable power quality meters.

(g) Software simulation of load-flow, short-circuit analysis, pre and post fault voltage sag analysis, harmonic distortions and filters using the EDSA program.