SYLLABUS

EE5374 - 001 Power System Protective Relaying
Fall 2002
Lecture: 9:00 – 11:20 AM, Friday
Laboratory: 3 Persons a Team, 3 Hours a Week
ROOM 313, WOOLF HALL

Instructor:
Wei-Jen Lee, Ph.D., PE
Professor of the Electrical Engineering

Office:
ENGINEERING ANNEX, RM 204

Office Hours:
9:00 AM – 11:30 AM, TUESDAY & THURSDAY
(OTHER TIME BY APPOINTMENT)

Phone:
(817) 272-5046

Mailbox:
UTA BOX 19048, Arlington, TX 76019

Email:
lee@exchange.uta.edu or wjlee@ieee.org

Instructor WWW site:
http://www-ee.uta.edu/

Course WWW site:
http://www-ee.uta.edu/

Required Textbook(s):

Final Examination:
9:00AM – 11:30 AM, December 7, 2002

Teaching Assistant:
TBA

Office and Office Hour of Teaching Assistant:
TBA

Contact Information of Teaching Assistant:
TBA
Course Description:
Fundamental understanding of symmetrical components, applications of symmetrical components in system protection, philosophy of power system protection, various protective relay systems, and the special considerations in applying the microprocessor based relays are covered. Experiments utilizing the Power System Simulation Laboratory and relay testing equipment are required.

Course Learning Goals/Objectives:
The goal of this course is to give students a good understanding of the function and applications of the protective relays. This course emphasizes the symmetrical components, applications of symmetrical components in system protection, philosophy of power system protection, various protective relay systems, and the special considerations in applying the microprocessor based relays.
Power system protection is essential to the reliability and security of the power system. Learning the materials in this course is an important step toward a rewarding career as a power engineer.

Attendance and Drop Policy:
The general format of the class will be a formal lecture and hand-on experiments to develop the ideas and knowledge required for the understanding the function and applications of protective relay system. Since this is your education, you will be required to participate by:

- Being aware of class procedures as set forth in this syllabus,
- Attending all the lectures and labs,
- Reading all assigned materials prior to the lecture,
- Working the assigned homework problems,
- Being aware of the course calendar, particularly examination times and dates

The grade of W will be assigned only if the conditions imposed by the University are met. The grade of X will be assigned only if the student has encountered circumstances beyond his or her control and the student’s previous actions have not created these circumstances. The assignment of this incomplete grade will be made at the decision of the instructor after consideration of the facts as presented in a written request from the student. See the Registrar’s Bulletin or the University Calendar in the front part of the UTA catalog for drop dates.

Tentative Lecture Schedule*:

Chapter One Introduction and General Philosophies
- Introduction and Definition
- Typical Protective Relays and Relay Systems
- Typical Power Circuit Breakers
- Nomenclature and Device Numbers
- Typical Relay and Circuit Breaker Connections
- Basic Objectives of System Protection
- Factors Affecting the Protecting System
- Classification of Relays
- Protective Relay Performance
- Principles of Relay Application
- Information for Application

Chapter Two Fundamental Units: Per Unit and Percent Values
- Introduction
- Per Unit and Percent Definitions
- Advantages of Per Unit and Percent
- General Relations Between Circuit Quantities
- Base Quantities
- Per Unit and Percent Impedance Relations
- Per Unit and Percent Impedance of Transformer Units
- Changing Per Unit (Percent) Quantities to Different Bases

Chapter Three Phasor and Polarity
- Introduction
- Phasors
- Circuit and Phasor Diagram for a Balanced Three-Phase Power System
- Phasor and Phase Rotation
- Polarity
- Application of Polarity for Phase-Fault Directional Sensing
- Directional Sensing for Ground Faults: Voltage Polarization
- Directional Sensing for Ground Faults: Current Polarization
- Other Directional Sensing Connections

**Homework 1:** 2.4, 2.5, 3.2, 3.3, 3.4  
**Due:** September 13, 2002

**Chapter Four** Symmetrical Components: A Review  
- Introduction and Background  
- Positive-Sequence Set  
- Nomenclature Convenience  
- Negative-Sequence Set  
- Zero-Sequence Set  
- General Equations  
- Sequence Impedance  
- Positive Sequence Sources  
- Sequence Networks  
- Shunt Unbalance Sequence Network Interconnections  
- Series and Simultaneous Unbalances

**Chapter Five** Relay Input Sources  
- Introduction  
- Equivalent Circuits of Current and Voltage Transformers  
- Current Transformers for Protection Applications  
- Current Transformer Performance on a Symmetrical AC Component  
- Secondary Burdens During Faults  
- CT Selection and Performance Evaluation for Phase Faults  
- Performance Evaluation for Ground Relays  
- Effect of De-energized CTs on Performance  
- Flux Summation Current Transformer  
- Current Transformer Performance on a DC Component  
- Current Transformer Performance Evaluation  
- Voltage Transformers for Protective Applications

**Homework 2:** 4.2, 4.3, 5.1, 5.3, 5.5  
**Due:** September 27, 2002

**Chapter Six** Protection Fundamentals and Basic Design Principles  
- Introduction  
- The Differential Principle  
- Overcurrent-Distance Protection and the Basic Protection Problem  
- Back-up Protection: Remote Versus Local  
- Basic Design Principles  
- Ground Distance Relays  
- Solid-State Microprocessor Relays

**Chapter Seven** System Grounding Principles  
- Introduction  
- Ungrounded Systems  
- Transient Overvoltages  
- Ground-Detection Methods for Ungrounded Systems
High Impedance Grounding Systems
System Grounding for Mine or Other Hazardous Type Applications
Low Impedance Grounding
Solid (Effective) Grounding
Ferroresonance in Three-Phase Power Systems
Safety Grounding

Homework 3: 7.2, 7.3, 7.5
Due: October 11, 2002

Midterm Exam: October 18, 2002

Chapter Eight Generator Protection: Utility and Non-Utility Owned
• Introduction and Potential Problems
• Generator Connections and Typical Protection
• Stator Phase-Fault Protection for All Sizes Generators
• Unit Transformer Phase Fault Differential Protection (87TG)
• Phase Fault Back-up Protection (51V or 21)
• Negative Sequence Current Back-up Protection
• Stator Ground Fault Protection
• Multiple Generator Units Connected Directly to a Transformer: Grounding and Protection
• Field Ground Protection (64)
• Generator Off-Line Protection
• Reduced or Lost Excitation Protection (40)
• Generator Protection for System Disturbances and Operational Hazards
• Synchronous Condenser Protection
• Generator-Tripping Systems

Chapter Nine Transformer, Reactor, and Shunt Capacitor Protection
• Transformers
• Factor Affecting Differential Protection
• Magnetizing Inrush
• Transformer Differential Relay Characteristics
• Application and Connection of Transformer Differential Relays
• Load-Tap Changing Transformers
• Application of Auxiliaries for Current Balancing
• Parallel CTs in Differential Circuits
• Special Connections for Transformer Differential Relays
• Differential Protection for Three-Phase Banks of Single-Phase Transformer Units
• Ground Differential Protection for Transformers
• Equipment for Transfer Trip Systems
• Mechanical Faults Detection for Transformers
• Grounding Transformer Protection
• Ground Differential Protection with Directional Relays
• Protection for Regulating Transformers
• Transformer Overcurrent Protection
• Transformer Overload-Through-Fault-Withstand Standards
• Transformer Thermal Protection
• Overvoltage on Transformers
• Reactors
• Capacitors

Homework 4: 8.1, 8.3, 9.3, 9.5, 9.7
Due: November 1, 2002

Chapter Ten Bus Protection
• Introduction: Typical Bus Arrangements
• Single Breaker – Single Bus
• Single Buses Connected with Bus Tie
• Main and Transfer Buses with Single Breaker
• Single Breaker – Double Bus
• Double Breaker – Double Bus
• Ring Bus
• Breaker-and-a-Half Bus
• Transformer – Bus Combination
• Differential Protection for Buses
• Other Bus Differential Systems
• Ground-Fault Bus

Chapter Eleven  Motor Protection
• Introduction
• Potential Motor Hazards
• Motor Characteristics Involved in Protection
• Induction Motor Equivalent Circuit
• General Motor Protection
• Phase-Fault Protection
• Differential Protection
• Ground-Fault Protection
• Thermal and Locked-Rotor Protection
• Locked-Rotor Protection for Large Motors
• System Unbalance and Motors
• Unbalance and Phase Rotation Protection
• Undervoltage Protection
• Bus Transfer and Reclosing
• Repetitive Start and Jogging Protection
• Multifunction Microprocessor Motor Protection Units
• Synchronous Motor Protection

Homework 5:  10.1, 11.3, 11.5, 11.6
Due: November 15, 2002

Chapter Twelve  Line Protection
• Classification of Lines and Feeders
• Line Classification for Protection
• Techniques and Equipment for Line Protection
• Coordination Fundamentals and General Setting Criteria
• Distribution Feeder, Radial Line Protection, and Coordination
• IPP, DSG, and Other Sources Connected to Distribution Lines
• Instantaneous Trip Application for a Loop System
• Short-Line Applications
• Network and Spot Network Systems
• Distance Protection for Phase Faults
• Distance Relay Applications for Tapped and Multiterminal Lines
• Voltage Sources for Distance Relays
• Distance Relay Applications in Systems Protected by Inverse-Time-Overcurrent Relays
• Ground-Fault Protection for Lines
• Distance Protection for Ground Faults and Direction Overcurrent Comparison
• Fault Resistance and Relaying
• Directional Sensing for Ground-Overcurrent Relays
• Polarizing Problems with Autotransformers
• Voltage Polarization Limitations
• Dual Polarization for Ground Relaying
• Ground Directional Sensing with Negative Sequence
• Mutual Coupling and Ground Relaying
• Ground Distance Relay with Mutual Induction
• Long EHV Series-Compensated Line Protection
• Back-up, Remote, Local, and Breaker Failure

Homework 6: 12.1, 12.4, 12.8, 12.9
Due: November 29, 2002

Chapter Thirteen  Pilot Protection (Time permit)
• Introduction
• Pilot System Classifications
• Protection Channel Classifications
• Directional Comparison Blocking Pilot Systems
• Directional Comparison Unblocking Pilot Systems
• Directional Comparison Overreaching Transfer Trip Pilot Systems
• Directional Comparison Underreaching Transfer Trip Pilot Systems
• Phase Comparison: Pilot Wire Relaying – Wire Line Channels
• Phase Comparison: Audiotone or Fiber-Optic Channels
• Segregated Phase Comparison Pilot Systems
• Single-Pole-Selective-Pole Pilot Systems
• Directional Wave Comparison Systems
• Transfer Trip Systems
• Communication Channels for Protection

Chapter Fourteen  Stability, Reclosing, and Load Shedding (Time permit)
• Introduction
• Electric Power and Power Transmission
• Steady State Operation and Stability
• Transient Operation and Stability
• System Swing and Protection
• Out-of-Step Detection by Distance Relay
• Automatic Line Reclosing
• Distribution Feeder Reclosing
• Subtransmission and Transmission Line Reclosing
• Reclosing on Lines with Transformers or Reactors
• Automatic Synchronizing
• Frequency Relaying for Load Shedding (Load Shaving)
• Frequency Relaying for Industrial Systems

* The schedule and the course contents will be adjusted as necessary.

Specific Course Requirements w/ Descriptions:
HOMEWORKS: are due at the end of the class on the day the assignment is due. All work presented must meet professional standards regarding materials and format. Homework will be checked as to effort and number of problems presented. The homework grade is based on ten (10) points per problem per assignment. Since it is faculty’s strongly belief that a student’s success is directly proportional to success with homework, it is imperative that the homework be done.
It is the expressed policy of the faculty of the department to take decisive action involving any incidence relating to academic dishonesty. The instructor of this course will strictly enforce this policy!

LATE HOMEWORK ASSIGNMENTS: Homework must be turned in at the end of the class period on the day the assignment is due. No late homework will be accepted after the solution is posted in the copy center or web site. There will be a 25% grade reduction for each class period late.
MAKE UP OF MISSED EXAMINATION: There will be no make up of a missed examination. All missed examination points will be reassigned to the point value of the next examination.

MAKE UP OF MISSED FINAL EXAMINATION: There will be no make up of a missed examination. If the missing of the final examination is unexcused, the student will receive the course grade computed with a Final Exam. Score of zero. If the student has an excused absence from the final examination, there are two options: 1) the student may elect to receive the course grade earned with the final counted as a zero, or 2) the student may elect to receive the grade of X and make arrangements to complete the course by taking the final examination. If the student elects the second option, it is the responsibility of the student to make necessary arrangement with the instructor to complete the course.

CONSIDERATION OF RE-GRADING REQUEST: It is the student’s responsibility to keep up with various grades assigned to their work by the instructor. If there is any question concerning the assigned grade, the instructor will accept a formal request to examine the grading in question if such a request is presented to the instructor within one-week following the returning of the material in question from the instructor. The entire original work in question must be submitted to the instructor. The instructor reserves the rights to re-grade the entire materials.

Course Evaluation & Final Grade:

<table>
<thead>
<tr>
<th>#</th>
<th>ITEM</th>
<th>POINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HOMEWORK</td>
<td>20.00</td>
</tr>
<tr>
<td>2</td>
<td>MIDTERM EXAMINATION</td>
<td>20.00</td>
</tr>
<tr>
<td>3</td>
<td>FINAL EXAMINATION</td>
<td>30.00</td>
</tr>
<tr>
<td>4</td>
<td>LABORATORY</td>
<td>10.00</td>
</tr>
<tr>
<td>5</td>
<td>PROJECTS</td>
<td>20.00</td>
</tr>
<tr>
<td></td>
<td>TOTAL COURSE POINTS</td>
<td>100.00</td>
</tr>
</tbody>
</table>

STUDENT COURSE AVERAGE | FINAL LETTER GRADE
-----------------------|---------------------
90.0 - 100.0           | A
80.0 - 89.9            | B
70.0 - 79.9            | C
60.0 - 69.9            | D
0.0 - 59.9             | F

Student Evaluation of Teaching
Students will be asked to complete instructor/course evaluation forms at the end of the semester.

Americans with Disabilities Act:
The University of Texas at Arlington is on record as being committed to both the spirit and letter of federal equal opportunity legislation; reference Public Law 93112—The Rehabilitation Act of 1973 as amended. With the passage of new federal legislation entitled Americans with Disabilities Act – (ADA), pursuant to section 504 of The Rehabilitation Act, there is renewed focus on providing this population with the same opportunities enjoyed by all citizens.

As a faculty member, I am required by law to provide “reasonable accommodation” to students with disabilities, so as not to discriminate on the basis of that disability. Student responsibility primarily rests with informing faculty at the beginning of the semester and in providing authorized documentation through designated administrative channels.

If you require an accommodation based on disability, I would like to meet with you in the privacy of my office, during the first week of the semester, to make sure you are properly accommodated.
\textbf{Academic Dishonesty}  

It is the philosophy of The University of Texas at Arlington that academic dishonesty is a completely unacceptable mode of conduct and will not be tolerated in any form. All persons involved in academic dishonesty will be disciplined in accordance with University regulations and procedures. Discipline may include suspension or expulsion from the University.

“Scholastic dishonesty includes but is not limited to cheating, plagiarism, collusion, the submission for credit of any work or materials that are attributable in whole or in part to another person, taking an examination for another person, any act designed to give unfair advantage to a student or the attempt to commit such acts.” (Regents’ Rules and Regulations, Part One, Chapter VI, Section 3, Subsection 3.2, Subdivision 3.22).

********** ANY CHEATING WILL RESULT IN SEVERE PENALTIES **********