The University Of Sheffield.

Electronic & Electrical Engineering.

EEE301 POWER SYSTEMS ENGINEERING

Credits: 10

Course Description including Aims

1. To develop and demonstrate the use of system models for unsymmetrical fault analysis and load flow studies.
2. To study the dynamic stability of power systems.
3. To study power system components, and basic techniques for power system protection.

Outline Syllabus

Fault analysis: symmetrical components, sequence impedances and voltage drops, positive, negative and zero sequence circuits and networks, asymmetrical faults on power systems. **Protection**: measurement of symmetrical components for protection, differential protection.
Transmission/distribution system parameters: overhead lines, resistance, inductance, capacitance, underground cable, capacitance. **Power flow control**, **Power System Stability**: steady-state and dynamic stability, swing equation, critical fault clearance time. Load flow analysis: direct and iterative methods.

Time Allocation

24 lectures plus 12 hours of additional support material.

Recommended Previous Courses

EEE117 "Electrical Circuits and Networks", EEE223 "Energy Management and Conversion", EEE341 "Electrical Power Systems"

Assessment

2 Hour Examination.

Recommended Books

Grainger J.J. & Stevenson W.D.	Power Systems Analysis	McGraw-Hill
Guile, A.E.	Electric Power Systems (vol. I & II)	Oliver and Boyd
Waddicor, H	Principles of Electrical Power Transmission	Chapman and Hall
Weedy, B.M	Electric Power Systems (3rd ed.)	Wiley

Objectives

By the end of the unit a successful student will be able to

1. analyse normal and abnormal conditions of operation of power systems.
2. calculate transmission line parameters for use in load flow, fault current magnitude estimation and power system stability analyses.
3. describe the operation of power systems.
4. demonstrate knowledge of time and current graded protection methods and equipment.
5. show awareness of the issues involved with embedded power generation

Detailed Syllabus

1. Review of course content.

   Recap of second-year work, notably per-unit systems symmetrical fault calculations, line diagrams, short-circuit MVA.

2. Theory of symmetrical components.

   Operator ‘a’.

   Definition of +ve, -ve and zero sequence components.

3. Sequence impedances and voltage drops.

   Sequence networks.

   Unsymmetrical faults.

   Line-Earth fault.

4. Zero sequence circuits for transformers and generators.

   Power system zero sequence networks.

   Calculation of sequence currents and fault currents.

   Examples.

5-8. Relation of positive, negative and zero sequence line reactances to self and mutual reactances.

   Two phase fault

   Two phase-to-Earth fault.

   Series faults (optional).

   Relative severity of different fault types.

9. Sequence reactances of lines/cables, transformers, alternators (qualitative treatment).
10. Symmetrical component filter networks/protection schemes.
11. Transmission line parameters.

    Resistance.

    Inductance - due to internal and external flux.

    Single-phase, 2-wire line.

    Single-phase, bundled conductor line.

    Bundled conductors.

12. Inductance, 3-phase, equilaterally spaced line.
    Unsymmetrically spaced 3-phase lines.
    Transportation.
    Zero sequence reactance of 3-phase line.
13. Capacitance of overhead lines.
    Single-phase, 2-wire line.
    3-phase, equilaterally spaced line.
14. 3-phase, asymmetrically spaced line.
15. Underground cables.
    Belted and screened types.
    Stress and capacitance.
16. Control of voltage, power and reactive power flow in power system.
    Generation and absorption of reactive power.
17. Tap charging transformers.
18. Power system stability.
    Steady-state stability limit.
    Transient stability.
19. The Swing equation.
20. Equal area criteria of stability.
    Machine connected to infinite bus.
21. Two machine system.
22. Solution of swing equation by step-by-step method.
    Critical fault clearance time.
23. Load flow analysis, direct and iterative methods.
24. Review of course.
    Revision examples.

UK-SPEC/IET Learning Outcomes

Outcome Code	Supporting Statement
SM1p	The main ideas introduced in EEE341 are revised and built on in this module. Unbalanced faults, system stability and strategies for protection are all introduced. Assessed by examination.
SM2p	Students require a good competence in mathematical skills to be able to apply the concepts used in most areas of this module. Assessed by examination.
SM3p/SM3m	An understanding of inertia and angular momentum are fundamental to analysing the transient behaviour of synchronous machines under fault and switching conditions. Assessed by examination.
SM1m	The symmetrical component system is used extensively in the calculation of unbalanced faults. Electric and magnetic field theory is the basis for calculating the impedance of overhead lines etc. Historical and likely future developments of the UK grid are discussed throughout the course. Assessed by examination.

SM2m	Extensive use of Gauss's law and Ampere's law (line and surface integration) are made in analysing the inductance and capacitance of overhead lines. Different layouts of conductor bundles are discussed and students assess the effect of this on overall line capacitance/inductance. Assessed by examination.
SM4m	Developing technologies (e.g. solid state relays, FACTS, FADS and smartgrids) are introduced as part of the lecture course.
SM5m	An approximate numerical technique is used for the solution of the swing equation in the time domain. Assessed by examination.
EA1p/EA1m	Analytical methods are extensively in the application of electrical network theory to predicting aspects of power system performance such as the calculation of fault current levels and transmission losses. Assessed by examination.
EA2p	The performance of sub-systems such as synchronous machines and components such as switchgear is modelled and described analytically. Assessed by examination.
EA3p/EA3m	Students are taught an iterative technique for calculating the load angle of a synchronous machine operating under transient conditions with respect to time and they use this to determine suitable fault clearance times for circuit breakers. Assessed by examination.
EA4p/EA4m	The interdependence of systems is taught throughout this course, for example time and current grading of protection systems. Assessed by examination.
EA2m	The performance of sub-systems such as synchronous machines and components such as switchgear is modelled and described analytically. Assessed by examination.
EP2m/EP2p	Equipment and materials used in power systems are reviewed with particular emphasis being paid to the various types of protection relays commonly used in the UK power system. Assessed by examination.