The University Of Sheffield.

Electronic & Electrical Engineering.

EEE341 ELECTRICAL POWER SYSTEMS

Credits: 10

Course Description including Aims

1. To provide an insight into the main issues concerning the design and performance of a large power supply network.
2. To develop models and analytical techniques, used to calculate the characteristics and specifications of the main items of equipment involved in the generation, transmission and distribution of electrical power.

Outline Syllabus

Power Systems : important operational features, 3-phase networks, unbalanced systems, power calculations, neutral-to-earth potential. **Synchronous machines and Induction generators** : characteristics and performance, calculation of power flow and power factor. **Power Generation :** brief discussion of different types of conventional power station and renewable sources, characteristics, basic performance calculations. **Power Network :** system scheduling, system response, control of power and VAR flow. **Faults :** fault current levels, per unit calculations, fault impedance, fault MVA, fault limiting, circuit breakers. **Transformers :** 3 phase connectors and types of construction, performance, parallel operation, circuit model, load sharing.

Time Allocation

24 lectures and 12 problem solving classes.

Recommended Previous Courses

EEE101 “Circuits and Signals”, EEE102 “Power Networks”, EEE202 “Electromechanical Energy Conversion”

Assessment

2 hour examination, answer 3 questions from 4

Recommended Books

Weedy, B.M.	*Electric Power Systems 3rd edition*	Wiley
Grainger, J. J. & Stevenson W.D.	*Power Systems Analysis*	McGraw-Hill
Harrison, J.A.	*An Introduction to Electric Power Systems*	Longman
Saadat, H	*Power system analysis*	McGraw-Hill
Guile, A.E. & Paterson, W	*Electrical Power Systems*	Pergamon Press

Shepherd, J., Morton, A.H & Spense, L.F	*Higher Electrical Engineering*	Pitman
Say, M.G	*Alternating current machines*	Pitman

Objectives

By the end of this module successful students will be able to

1. analyse unbalanced three-phase, three and four wire networks.
2. show awareness of various conventional and renewable methods of power generation.
3. calculate the steady state behaviour of synchronous machines and induction generators and recognise their main control features and performance characteristics when connected to a large power network.
4. use equivalent network models to calculate the effects of power and VAR demands on power system performance.
5. use the per-unit-system in power system specification.
6. use the per-unit system in calculating fault levels under balanced three-phase fault conditions.
7. calculate the performance of three phase transformers and their load sharing capacity when connected in parallel.

Detailed Syllabus

1. Introduction and course outline. Revision of typical power system arrangements, main components and important operational features including voltage regulation, frequency control system reliability and efficiency.

2. Revision of 3-phase networks, extension to unbalanced systems.

3-4. Continuation of unbalanced system calculations, measurement of power and calculation of the neutral to earth potential.

5 Types of synchronous machine used in power systems. Development of a circuit model for non salient pole machines (steady-state only).

6-7 Synchronous machine characteristics in a power system (infinite bus-bar system). The effects of excitation control and load changes, steady state power limit.

8-9. The performance of synchronous machines in a power system. Calculation of power flow and power-factor control.

10-11. Introduction to renewable energy. Performance analysis of a wind turbine driven induction generator when connected to an infinite bus-bar system. Calculation and discussion of real and reactive power flow.

12. Discussion (based on a handout) of the types and role of alternative power stations (nuclear, coal/oil, gas turbine, hydroelectric), their characteristics, etc. System scheduling (merit order) and load predictions.

13. Model of a power network, the effects of power and VAR flow.

14-15. Faults on power systems, the need for system protection and types of fault to be detected. Brief discussion of protection scheme principles. Symmetrical 3-phase short-circuit faults, method of calculating system impedance and fault current levels.

16. Development of the per-unit system for power system calculations.

17. Calculations of up to fault impedance for typical network models, calculation of fault MVA and the rating of circuit-breakers.

18. Techniques for limiting fault levels. The use of bus-bar reactances and HV dc links.

19. Principles of circuit breaker operation and rating. The effects of current chopping.
20. Types of circuit breaker (handout), discussion of their relative merits and ratings.
21. Three-phase transformers, types of construction and winding connections and their effects on performance.
22. Continued discussion of transformer performance and the effects of unbalanced load.
23. Parallel operation of transformers, development of a circuit model for load sharing.
24. Calculation of load sharing, the use of per-unit impedances and the conditions for correct operation.

UK-SPEC/IET Learning Outcomes

Outcome Code	Supporting Statement
SM1p/SM1m	Students are given a comprehensive overview of the UK power generation, transmission and distribution and the engineering considerations that led it to develop into a ‘top-down’ system. Transmission and distribution voltages, types of switchgear and transformers used on the UK power system, the need for reactive power control and how this is achieved, are covered in detail together with the reason behind the geographical location of power stations. Assessed by examination.
SM2p	Mathematical models are used extensively in this module. Extensive use is made of complex numbers, phasor analysis, algebraic manipulation and calculus. Assessed by examination.
SM3p/SM3m	General techniques such as the star-delta transformation and Millman’s theorem are applied to the solution of unbalanced 3-phase circuits. The per-unit system is introduced and is extensively used in fault calculations. Assessed by examination.
SM2m	Extension of SM2p. Students are taught how to analyse the performance of synchronous generators and integrate these calculations into a systems model from which they can critically evaluate the operating conditions to satisfy a particular load operating at a desired power-factor.
SM4m	Students are taught the importance of renewable energy and the problems associated with developing this, in particular the transportation of power over long distances to the end user. The future trends for embedded generation and the emergence of smart grids are also discussed. Assessed by examination.
SM5m	When developing the mathematical models (see SM2p and SM2m) assumptions and limitations are cited. Students are given an appreciation of what effect this has on the accuracy of calculation (e.g. Ignoring the effect of resistance when modelling synchronous machines).
EA1p	Models are developed for the analysis of 3-phase balanced faults, modelling the performance of synchronous machines and induction generators and load sharing of parallel connected transformers. Assessed by examination.
EA2p	Analytical methods are extensively employed on this module for analysing the performance of power systems and components. Examples of this are the calculation of fault levels in order to specify the rating of switch gear, the derivation of performance charts for synchronous machines or the measurement of power in unbalanced systems. Assessed by examination.
EA1m	Models are developed for the analysis of 3-phase balanced faults, modelling the performance of synchronous machines and induction generators and load sharing of parallel connected transformers. Assessed by examination.

EA2m	Analytical methods are extensively employed on this module for analysing the performance of power systems and components. Examples of this are the calculation of fault levels in order to specify the rating of switch gear, the derivation of performance charts for synchronous machines or the measurement of power in unbalanced systems. Assessed by examination.
EA3m	Students are introduced to the benefits of using the per-unit system for fault calculations applied to a simple radial power system and comparing the traditional method of referring quantities across transformers with the per-unit method. Students can then select appropriate fault limiting reactors to limit the fault current. Assessed by examination.
EA6m	Students learn the fundamental processes and techniques to solve for fault levels in power systems. With this knowledge students should be capable of solving for fault levels in any unfamiliar layouts and knowing how to limit fault levels at particular points in the network.
ET2p	Students are introduced to the main types of generation used in the UK power system including types of fuels used and prioritisation of generation plant on both practical and economic grounds. The importance of diversity in generation to protect the electricity supply from fuel availability difficulties and cost fluctuations is discussed in detail. Reactive power control and the importance of power-factor correction in relation to tariff structures are covered. Assessed by examination.
ET4p	Students are taught about the problems associated with generation from fossil fuels (eg global warming, security of supply, fuel poverty etc.) and how this is being addressed by a renewable energy portfolio through government directives and international agreements. An overview of alternative types of renewable generation is given, but the main focus is directed at wind turbines. Students are also made aware of the financial incentives that are being made to encourage renewable generation. Assessed by examination.
ET2m	Students are introduced to the main types of generation used in the UK power system including types of fuels used and prioritisation of generation plant on both practical and economic grounds. The importance of diversity in generation to protect the electricity supply from fuel availability difficulties and cost fluctuations is discussed in detail. Reactive power control and the importance of power-factor correction in relation to tariff structures are covered. Assessed by examination.
ET4m	Students are taught about the problems associated with generation from fossil fuels (eg global warming, security of supply, fuel poverty etc.) and how this is being addressed by a renewable energy portfolio through government directives and international agreements. An overview of alternative types of renewable generation is given, but the main focus is directed at wind turbines. Students are also made aware of the financial incentives that are being made to encourage renewable generation. Assessed by examination.
EP2p/EP2m	Students are taught the basic components that comprise a typical power system. The module includes a detailed study of synchronous and induction generators, transformers and alternative types of fault protection equipment. Common materials used in constructing these components, together with those used for overhead lines, underground cables and insulators are also discussed. Assessed by examination.
EP6p	Students are taught the industry standard voltages used in transmission and distribution networks and the statutory prescribed tolerances at the point of supply. Assessed by examination.
EP6m	Students are taught the industry standard voltages used in transmission and distribution networks and the statutory prescribed tolerances at the point of supply. Assessed by examination.

EP9m	Students are made aware of new developments such as the emergence of embedded generation and use of power electronics in the control of fault currents..