EEP201 Fundamentals of Power System Earthing

This module is currently under revision.

・・ Electrode resistance, potential gradient areas of common types of electrodes.

・・ Multiple electrodes.

・・ Stratified grounds.

・・ Electric shock, calculation of step and touch potentials.

・・ Introduction to substation earthing: ground potential rise, connection of services, grid and mesh potentials.

・・ Measurement of soil resistivity and electrode resistance.

・・ Earthing of transmission lines: tower foot resistance, current division between ground and aerial earth wires, division of earth currents at substations.

・・ Earth current distribution on faulted lines.

・・ Distribution systems: MEN, SWER, safety during faults.

・・ Flow of lightning currents to ground.

EEP202 Thermal Ratings and Heat Transfer

A limiting condition on electrical plant is the maximum allowable temperature above which unacceptable deterioration of operating conditions may occur. This depends on how much heat is generated by the electrical losses and how well it is dissipated. In order to take best advantage of the known operating conditions and achieve a high utilisation of the plant it is important to understand its thermal behaviour under conditions of variable and continuous loading. The aim of this module is to review the basic heat transfer mechanisms, develop equations to model their behaviour, and introduce the approaches used to determine how to size transformers, overhead lines and underground cables to avoid overheating.

EEP203 Condition Monitoring

This course will give an overview of the monitoring of the condition of high voltage plant (mainly switchgear and power transformers) with an emphasis in the ageing and degradation of the electrical insulation materials.

The fundamentals of the electrical insulation affecting the Power Systems Equipment will be explained. This will cover the insulation structures based on solid, liquid and gas insulating materials commonly used in the manufacturing of high voltage plant.

High Voltage testing and the main partial discharge diagnostic techniques will be presented to provide an overview on the existing tools to assess the state of the electrical insulation before and after the installation of the High Voltage equipment. Special consideration will be given to modern partial discharge measurements in the most important substation plant assets as switchgear and transformers. The lecture will be supported with practical demonstrations of various partial discharge detection techniques.

A discussion will be carried out on the different approaches to the maintenance planning and condition monitoring of the substation plant. In order to properly identify the parameters to be monitored, a review of the functions and failure mechanisms of switchgear and transformers will be discussed.

Finally an overview of the different condition monitoring techniques applied to High Voltage plant will be presented.

EEP204 Power System Load Flow Analysis

Load flow analysis is the basic tool for power system analysis in the power industry and serves to give an understanding of power system performance. Knowledge of power system performance is essential before more advanced power system analysis study is carried out. This module aims to give students a basic knowledge of power system performance/operation through the development of an understanding of the theory and use of load flow analysis in Distribution and Transmission systems. The module recognises that load flow analysis forms the basis of other power system analysis studies, e.g. fault study analysis, transient stability and system harmonic analysis.

EEP205 Power System Fault Calculations

The power system fault calculations module provides the necessary basis for assessing fault current levels in any electrical power network. In order to achieve this every plant item in the network is modelled from its own characteristics. Fault calculations are determined from the solution of appropriate networks obtained from these plant model building blocks. Different fault types have their own methodology in deriving the sequence currents and voltages occurring in the power system from which the phase currents and voltages can be determined.

Fault analysis is important in any network involving power frequency and voltage. The theoretical analysis and determination of fault current values is needed to develop, maintain and operate these networks. In design it is important that primary plant is specified and rated so that present and future development of the networks is allowed for and that secondary systems are capable of measuring, monitoring and protecting for the magnitudes of faults encountered. Ongoing assessment of fault scenarios is required in the life of the plant to calculate and ensure that operational and maintenance procedures keep plant and equipment within the limits of their ratings.

Recommended (but not essential) Prior Study: EEP204

EEP206 Project Management

Currently unavailable.

EEP209 Power System Harmonics

It is the aim of this unit to equip students with the skills to maintain acceptable electricity supply quality (from a harmonics perspective) on power systems.

・・ Generation of harmonics: converters, arc furnaces, SVC, inverters, electronic control.

・・ System response characteristics: resonance conditions, effect of load, typical system responses.

・・ Effects of harmonics: motors, generators, power cables, capacitors, electronic equipment, metering, relaying, telephone interference.

・・ Reactive power compensation and harmonic control: converter power factor, reactive power compensation, control of harmonic currents.

・・ Measurement of harmonics.

・・ Recommended practices including AS2279.

Recommended (but not essential) Prior Study: EEP205

EEP210 Abnormal System Voltages

・・ Supply quality standards: review of criteria, statutory requirements, emergency and short term limits.

・・ 50 Hz voltage: cause of voltage deviations, voltages during faults, motor starting.

・・ Negative phase sequence voltages: AS1359 requirements, voltage unbalance studies, modelling, measurement.

・・ Voltage Transients and flicker: AS2279 requirements, disturbing loads, remedial measures, transient disturbances and power system plant.

・・ Power system transient analysis: ATP studies.

Recommended (but not essential) Prior Study: EEP205

EEP211 Basic Power System Protection

Power system protection is the 'invisible' side of the process of generating, transmitting and distributing electrical power. Protection relays, in the words of the Westinghouse Corporation, are the 'silent sentinels' of the power system, being called upon to operate only when something goes wrong on that power system. The most common event seen by protection equipment involves failure of insulation, but other types of events e.g. mechanical failure, thermal overload or overvoltage, can also cause the operation of protection systems.

Protection equipment then initiates remedial action, quickly isolating that part of the system where the problem lies, and thereby moving the system and its components back inside the permissible 'technical envelope'. As a result of this action, plant damage, risk to the public and power utility personnel, and the economic impact on both the utility and the consumer, are minimized.

This unit aims to give you a sound appreciation of protection philosophy, protection relay characteristics, relay setting principles, protection system design and current transformer specification.

Recommended (but not essential) Prior Study: EEP205

EEP212 Advanced Power System Protection

Protection of today's sophisticated Electricity Generation, Transmission and Distribution Systems is necessary to maximise safety for the public and electricity industry employees alike, to disconnect faulted plant from the system, and to maintain quality of supply to customers. Reliability of these protection schemes is important to ensure damage to the power system is minimised, faulted plant is disconnected, system stability is maintained, security is optimised, and to ensure unfaulted plant is not inadvertently tripped from service. Especially with respect to HV and EHV electricity transmission systems, the modern trend is for these to be operated closer and closer to their limits of performance. This requires the associated protection systems to be coordinated, to be fast operating, to be secure and to be reliable. The provision of these conflicting requirements is fundamental to the National Electricity Rules. These rules mandate performance of protection systems to prevent constraint of inter and intra regional power flows and to maintain power system stability. EEP212 provides a comprehensive understanding of the sophisticated protection systems used to protect high voltage transmission and distribution systems. EEP212 also provides a comprehensive reference for the protection of rotating plant, including synchronous generators and large induction motors. EEP212 covers the application of modern micro-processor based relay technology, as well as covering the application of older electronic and electromechanical relays, this latter group being the majority of devices still in service. EEP212 is designed to provide students with an advanced understanding of the full range of protection equipment, except for distance protection which is covered under module EEP241 – “Distance Protection”.

This module will assist both those whose day to day work involves them in the application of protection design and also those in less directly associated areas of transmission system design. This information is necessary for:

- Planning engineers, to identify the difficulties in providing protection for various power system configurations under review.
- Maintenance engineers, to ensure that system protection is not compromised as plant is removed from service during maintenance.
- Circuitry design engineers, to ensure that protective schemes are implemented in a manner to provide optimum performance.
- Protection application engineers, to identify protection implications and to ensure protection scheme design and relay setting principles provide the necessary levels of speed, security, reliability and safety.

Recommended Prior Study: EEP211

EEP213 Statistics

Some students might wonder at the inclusion of a Statistics module in a postgraduate engineering course. However, engineering problem-solving can benefit from the application of techniques using probability models and statistical data analysis whenever unpredictable variability of outcomes should be taken into account. For example, the extraction of electronic signals from random noise is an area where statistical tools are widely used. Other examples include where data are collected from the operation of systems, field or administrative records, or customer surveys that require statistical analysis.

Traditionally, unpredictability in future loads has been dealt with in engineering by incorporating factors of safety. However, it is recognised that these lead to expensive over-design, and the use of probability models for assessing risk is being widely proposed. Studies of reliability and maintenance planning, as well as initial system design, can make use of statistical techniques to improve economic performance. Asset management in the unpredictable customer, economic and physical environment is taking a more important place in power system management and leading to more emphasis on statistical techniques in risk management.

Quality improvement is another area where even quite simple statistical techniques have become important. This is becoming more important in the power industry as increasing emphasis is being placed on power quality. By the end of this module you should be aware of many areas where you already make use of statistical ideas in some way, and perhaps have some improved strategies for dealing with these.

・・ The role of statistics in electricity supply engineering.

・・ Strategies for collecting and recording valid data from which statistical inferences can be made; use of operational and inventory data.

・・ Graphical and numerical techniques to summarise data using statistical or spreadsheet packages.

・・ Review of probability concepts, random variables, probability distributions.

・・ Specific distributions used in system and component reliability studies.

EEP215 Reliability

With increasing pressure to ensure maximum value for each reinforcement dollar, electricity utilities are becoming increasingly interested in using reliability assessment as part of their planning, design and operation. This unit, therefore, is aimed at practising engineers who are interested in acquiring basic concepts, methods and techniques in reliability assessment of power systems, together with practical project examples designed to enable you to use and appreciate the application.

It also introduces the principles and concepts in engineering reliability and leads to system modelling with the emphasis on power systems. It examines a practical implementation of reliability techniques to transmission/sub-transmission systems (termed ‘Reliability Assessment Planning’) and the application of reliability to distribution systems.

・・ Basic reliability concepts.

・・ Reliability analysis methods.

・・ Reliability methods.

・・ Application of important distributions.

・・ Failure rate, repair time and mean time failure.

・・ Reliability of series, parallel and complex systems.

・・ Discrete Markov Chains.

・・ Continuous Markov processes.

・・ Frequency and duration in reliability.

・・ Application of Markov Chain in the reliability evaluation of repairable systems.

・・Application of reliability evaluation in power distribution systems, inclusion of cost estimation.
・・Reliability assessment in subtransmission system planning, including non-constant transition rate considerations.
・・Study of single and double contingencies with switching to restore supply.
・・Inclusion of maintenance in system modelling.
・・Probability and frequency of loss of load.
・・Unsupplied energy and average load at risk.
・・Maximum load at risk.
・・Average outage duration.
・・Hours of Loss of load.

Recommended Prior Study: EEP213

EEP216 Overhead Line Design - Electrical

Transmission lines form part of the transport network that carries electrical energy from generating sources to its ultimate users. This course deals with the electrical design of high voltage transmission lines in which conductors operating at 66kV and above are carried on any type of supporting structure. The principles can equally well be applied down to 415V transmission. The course will cover the complete step-by-step processes of transmission line electrical design, starting from the design criteria, to ensure that all of the following requirements are met:

- preserving public safety in all aspects of the intended line operation,
- meeting defined levels of line operating performance and reliability under all expected operating and environmental conditions, and
- providing safe working access for those who have to operate/maintain any part of the line equipment during its service life.

To undertake this module, you should have a good grasp of electrical transmission technology and the level of design computation needed, and a working knowledge of power system engineering. There is no specific pre-requisite module that needs to be completed before undertaking this module.

There is a single assignment associated with this module, which is the electrical design of a complete transmission line from defined requirements — based upon real conditions and requiring detailed design using conductor and hardware information provided. To help you tackle the assignment, all the design steps are introduced progressively through course notes with worked examples. There is a typical line design worked out at the end of the course notes, showing all the data selection and calculation processes that will have to be applied in the course assignment and in real design work.

・・ Electrical design of transmission lines with ratings of 33kV to 500kV.

・・ Economic conductor size.

・・ Characteristics of conductors.

・・ Standard and new technology insulators: power frequency, impulse and switching flashover voltage, pollution and creepage, wet and dry flashover, mechanical characteristics.

・・ Feasible structure types.

・・ Tower footing resistance and counterpoise.

・・ Insulation co-ordination methodology: determination of overvoltage withstand, design for required outage.

・・ Determination of RI using state of the art methods.

・・ Design to ensure that electrostatic and electromagnetic fields do not exceed NH & MRC guidelines.

Recommended (but not essential) Prior Studies: EEP201, EEP203, EEP210

EEP217 Overhead Line Design - Mechanical

Overhead lines are the most common type of electrical equipment found in power systems. An overhead power line provides the means of conveying electrical power from a source to a load centre using conductors or cables supported on structures (including foundations) by insulators and line hardware.

Typical distribution voltages in Australia are at 33 kV, 11 kV and 415/240 volts, commonly referred to as low voltage. Typical transmission voltages in Australia and New Zealand are; 66 kV, 110/132 kV, 220 kV, 275 kV, 330 kV and 500 kV.

The module will step the student through the Overhead line design process; in particular how the electrical, mechanical and structural aspects of design are combined to produce a sound engineering system which is suitable for construction and long term operation.

・・ Conductor selection.

・・ Catenary theory.

・・ Sag-tension-temperature calculations.

・・ Requirements for survey data.

・・ Statutory and enterprise requirements for line layout: clearances, mechanical loading, safety criteria.

・・ Definition of loading conditions, structure capacities, layout clearances.

・・ Applied mechanics of strung conductors.

・・ Determination of everyday tensions from allowable stress or tension/mass ratio.

・ ・ Determination of vibration protection.
・ ・ Transmission line estimating techniques.
・ ・ Selection of structure type based on optimum capitalised costs.
・ ・ Line layout.

EEP218 Introduction to Automated System Control and Supervisory Systems (SCADA)

The module covers the basic principles of the SCADA systems and SCADA equipment found in the electric power transmission and distribution substations and control centres. Engineering staff engaged in the design and construction of the substations are often required to provide SCADA systems or to liaise with those responsible for providing substation and system control facilities. The continuing integration of substation secondary systems necessitates a wider understanding of the basic functions of SCADA and communications systems.

The course will cover the basic principles of the SCADA systems as applied to the Electricity Transmission and Distribution industry.

・ ・ SCADA fundamentals and protocols.
・ ・ SCADA equipment: master station, remote terminal units.
・ ・ Transmission SCADA systems, distribution automation systems, distribution control systems, PC software applications.
・ ・ Alarm philosophy and control principles: definition of system displays, data logging, database point processing and attributes, master station configuration.
・ ・ Specification of MMI: identification of system functional requirements.
・ ・ Computer system platforms: computer technology fundamentals, computer hardware - processors, peripherals, display, user interfaces.
・ ・ Communication system principles, communications bearer fundamentals, data networks and protocols.
・ ・ Data communications and I/O capacities and types, I/O processing. Application of SCADA systems to transmission and distribution systems.
・ ・ Cost/benefits of alternative schemes.

EEP219 High Voltage Substation Equipment: Power Transformers and Reactive Power Plant

This module covers the basic principles of transformer design, construction and testing found in electric power transmission and distribution substations. Power distribution and large industrial companies are involved in the construction and maintenance of substations with transformers being an integral component. Staff managing or purchasing these critical assets require an understanding of transformer design and performance characteristics. This module is aimed at introducing you to the basic concepts of transformer design and testing criteria required for a transmission or distribution system.

- • Principles of power transformer design from distribution transformers to EHV transformers: ratings, windings, core structure and materials, insulation and cooling methods, insulation and lifetime.
- • Leakage and magnetising reactance.
- • Losses, harmonics and inrush currents.
- • Short circuit forces.
- • Tests to measure: ratio, losses, impedance, phasing, temperature rise, accuracy and traceability of tests, interpretation of test reports.
- • Surge phenomena in windings, RSG and impulse testing of power transformers, interpretation of test results.
- • Oil cooling systems.
- • Fire protection.
- • Tap changers and associated controls.
- • Analysis of transformer failure modes.
- • In-phase and quad-boost regulators.
- • Series and shunt reactors.
- • Reactors for harmonic filters.
- • SVCs: design considerations, equipment characteristics and equipment characteristics.

Recommended (but not essential) Prior Study: EEP203

EEP220 Distribution Planning

This course on distribution planning covers a broad range of topics. These topics are grouped into five sections. The five sections have been ordered to give you a logical sequence to work through the planning process as a Planning Engineer or a person who would like to understand the planning process. The course includes both theoretical and practical exercises based on actual planning studies and experiences.

It is the primary intension of this course to provide a student with the material and examples to conduct a simple planning project. From the initial understanding of the Network and the parameters to which the planning study is bound, to following a planning process to identifying a network limitation, the course will assist students in considering options to address this Network limitation and their use of technical and economic analysis to support the preferred option. Students should be able to then present a recommended option to address the limitation in the form of a report to a Manager or Supervisor for approval. This area in the course will be covered in a case study which will be used as an assignment for final assessment.

This course will also introduce additional information which will provide the students with a broader knowledge of areas of planning such as Low Voltage and Reliability Planning Guidelines. The notes have been formatted to assist students with Planning Investigation with minimum supervision and obtaining a satisfactory solution to a Network Limitation

・・ Identify data and techniques used in load forecasting.
・・ Examine typical distribution network problems and identify performance limitations based on standards.
・・ Relate network problems to different configurations and the effects on customers.
・・ Study network reinforcement options on a simulation package.
・・ Options include regulators, series and shunt capacitors and reconductoring.
・・ Consider the above options to address a realistic network problem assessing line losses and voltage results.
・・ Analyse network reliability and assess the impact of ties, switches and various network configurations.
・・ Compare alternatives based on economic and technical considerations.
・・ Prepare a logical case which recommends one option in the form of a report.

Recommended (but not essential) Prior Study: EEP205

EEP222 Maintenance of Electricity Supply Systems

With increasing pressure to ensure maximum value for each reinforcement dollar, electricity utilities are becoming increasingly interested in using reliability assessment as part of their planning, design and operation. This unit, therefore, is aimed at practising engineers who are interested in acquiring basic concepts, methods and techniques in reliability assessment of power systems, together with practical project examples designed to enable you to use and appreciate the application.

It also introduces the principles and concepts in engineering reliability and leads to system modelling with the emphasis on power systems. It examines a practical implementation of reliability techniques to transmission/sub-transmission systems (termed ‘Reliability Assessment Planning’) and the application of reliability to distribution systems.

・・ Establishment of maintenance policies: review of failure rates, emergency spares, identification of maintenance liabilities, identification of critical success factors to minimise life cycle costs, approval and dissemination of policy, policy review.
・・ Maintenance planning: identification of constraints, review of existing maintenance programs, establishment of plans for periodic actions, documentation of procedures, design of reporting procedures.

・・ Data recording and analysis: registers of defects, design of data collection and reporting systems, preparation of control charts, computer systems, data base development.
・・ Maintenance Operations: identification of refurbishment needs, resource evaluations, design of work procedures, impact of Acts and regulations, identification of staff training needs, supervision, auditing of work practices.
・・ Maintenance program evaluation: assessment against KPI, modification of programs to account for continuing defects and failures or to reflect changing technologies.

EEP224 Underground Cable Engineering

This module gives an overview of underground high voltage cables and is intended for those who are new to Underground Cable Engineering or those who have some experience with underground cables and wish to expand and consolidate that knowledge. It covers basic principles on underground power cables, their construction and manufacture, as well as design, installation and management of cable systems for power networks.

Aspects of underground cable engineering from cable design through to its management after installation will be considered in the course. This includes highlights in their historical development that underlie modern practice. How cables have evolved to their modern designs is a fascinating story that has evolved over last 130 years. Today, underground high voltage cables are made up of many discrete components, including conductor, insulation, metal sheath or screen wires and oversheath/jacket. Each of these is a result of the engineering development to solve problems of cable failures or to improve designs that give more reliable cables at lower costs. A description of cable construction and these components as well theory used in cable design is covered.

There are also challenges associated with the design and installation of cable systems. Cables are buried in the ground and an understanding of how it interacts with this complex environment is important. Topics discussed include cable rating, sheath voltages, bonding theory and earthing of cable sheaths and electromagnetic fields. The specification, manufacture and testing of a cable is also introduced. Standards form an important part of this as well as in other aspects of underground cable engineering and the relevant standards are introduced as appropriate. Also the cable installation requires special considerations to ensure it is carefully installed and with a minimum disruption to the environment. These aspects are covered in a section that looks at the practical design, installation and testing of a specific project and brings together theory considered in previous sections. As high voltage cables were developed to satisfy growing power demands, so were jointing and terminating techniques. High electrical stresses occur at cable ends where they are joined or terminated and these must be controlled to avoid cable failure and ensure reliable service.

Finally when the cable is installed its reliable service depends on attention to details such as safety, ratings, ageing, the role of diagnostics and maintenance of the cable system. High voltage cable failure means extensive blackouts. Rapid fault location is thus important and a discussion on this concludes the course.

・・ A look at the conducting and insulating materials used in modern cable design and factors the lead to their development.

・・ The electrical characteristics that describe the performance of insulated cables and a short qualitative look at the background theory.

・・ An examination of aspects of cable systems design: ・・ Different types of cable ratings

・・ Earthing, induced voltages and bonding of cable sheaths

・・ Electromagnetic fields around underground cables

・・ Characteristics and measurement of soil thermal parameters.

・・ An overview of manufacture, testing and standards for insulated cables

・・ Some notes on cable accessories

・・ A study of the underground cable circuit planning, design and installation: ・・ Concept design/feasibility studies and cost estimates

・・ Details design, permits and approvals

・・ Civil and electrical construction and testing

・・ Considerations in the management of an underground cable installation: ・・ Important aspects of safety

・・ Considerations of ratings including the importance of a knowledge of the cable environment

・・ Factors that affect cable ageing of different types of cables

・・ A look at maintenance practices, monitoring systems and diagnostics.

・・ A brief look at fault location

Recommended (but not essential) Prior Study: EEP202, EEP212

EEP241 Distance Protection

Protection of the power system is necessary to disconnect faulted plant from the system, to minimise disruption of supply to customers and to maximise safety for the public and electricity industry employees alike.

The modern trend is for power systems to be operated closer and closer to their limits of performance. This requires protection, especially on the high voltage system, to be fast operating, to be secure and to be reliable. These are conflicting requirements which, nevertheless must be met. High speed operation is necessary to prevent power system instability from occurring. Reliability is important to ensure faulted plant is disconnected, and security must be maintained to ensure unfaulted plant is not inadvertently tripped from service.

Furthermore, for economic reasons, augmentation of the power system is often delayed for as long as possible and is then done in the most cost effective way. This leads to complex operating arrangements with multiple feeders sharing the same easements (mutual coupling), with teed feeders, with large capacitor banks for reactive power support, and with many other complications.

・・ Current transformers: transient performance, saturation factors and effects on distance relay performance.

・・ Voltage transformers: transient performance and effects on distance relay performance.

・・ Distance protection: select a suitable relay characteristic based on an understanding of relay comparator operation (amplitude and phase angle comparators), implement non-switched distance protection schemes, implement switched distance protection schemes (including allowance for various starter characteristics), allow for the effects of mutual coupling with other feeders, design protection schemes and set relays for teed feeder systems and also for bridged or paralleled feeder configurations, allow for the effects of arc and/or fault resistance, ensure that load encroachment does not cause inadvertent tripping, ensure healthy phase fault currents do not degrade distance relay performance,

develop a grading plan to ensure coordination with protection relays (including IDMT relays) elsewhere on the power system, understand relay functions such as switch-onto-fault logic, VT supervision, memory, power swing blocking and healthy phase polarising. ・・ Protection signalling: direct, series, permissive (overreaching and underreaching), distance acceleration and blocking intertripping.

Recommended (but not essential) Prior Study: EEP211

EEP244 Circuit Breakers - Switchgear

This course provides an understanding of the principles behind the operation of circuit breakers for transmission and distribution of electric power. It does as well familiarise the student with the different types of switchgear elements and assemblies to be found in a substation switchyard as disconnectors, earth-switches, GIS, Metalclad switchgear, etc.The mechanisms of current interruption through the extinction of an electric arc at current zero are explained. The different technologies used in circuit breakers (oil, air, SF6 and vacuum) are described.After you are introduced to the switching technology, the course emphasizes the importance of the specific switching conditions and network interaction for fault current interruption and load switching. The stresses produced in both the breaker and the network during breaker operation are analysed. The course provides the tools to estimate the transient recovery voltage (TRV) when clearing a short-circuit fault.The hardest circuit breaker duties are not limited only to interrupt high currents. Frequent switching of low currents to energize and de-energize capacitor and reactor banks might provoke intolerable transients in the system. The course provides formulas to calculate these transients and discuss the mitigation methods available.The last chapter focuses on the testing and condition monitoring of switchgear to check that the switchgear will have the capability to handle network stresses, insulation levels, mechanical forces and ambient conditions. The main tests contemplated in the standards are described. The needs for condition monitoring to guarantee the long-term behaviour of the switchgear are discussed and an overview of the monitoring tools currently available is given.

・・ Basic switching theory for the main circuit breaker types: SF6, Vacuum, GIS, minimum oil, airbreak (11kV), bulk oil; characteristics and applications for these types at various voltage levels.

・・ Circuit-breaking principles: interruption of load current, small inductive current, short-line faults and out-of-phase switching.

・・ TRV and ITRV concepts.

・・ Direct and synthetic testing.

・・ Technical specifications of circuit breakers: operating voltage; impulse withstand; rated current; interrupting capacity; switching duties; operating mechanisms - single or 3 pole; clearing time; environment.

・・ Selection of circuit breakers: analysis of tenders on a whole of life basis.

・・ Circuit breaker failures: failure modes for different types; catastrophic failures; category of failure - design, operating or maintenance cause; reliability.

・・ Circuit breaker testing and condition monitoring.

・・ Circuit breaker maintenance and refurbishment.

・・ Emerging circuit breaker technology.

Recommended (but not essential) Prior Study: EEP210

EEP245 Introduction to Substation Design

This course covers the major decisions required in the design of a high voltage transmission substation, focusing on those substations which use conventional outdoor equipment. Many of the same principles apply to the emerging use of various forms of gas-insulated and modular switchgear – especially in developing economic layouts and taking advantage of the facilities now available in secondary systems. The emphasis in this module, however, will be on developing economic network substations using separate switchgear, current transformers, voltage transformers and busbars in outdoor configurations. Many people in different technical disciplines will contribute to the final design, and this course cannot cover them all. As described in the title "Introduction to Substation Design", only the following basic topics will be covered:

•Substation site selection and substation plant configuration

•Electrical Layouts, arrangements and configurations

•Civil Design and Environmental Considerations

•Insulation coordination

•Earthing and Earth Grid Testing

•Lightning protection

•Project management and construction

•Circuitry and secondary systems

•Testing and commissioning

•Estimating

・・ Preparation of design/site options: standard layouts (outdoor, indoor, GIS, package, single bus, 11/2 CB et) - cost, site, reliability lead time and communication factors; estimating procedures.

・・ Comparison of design/site options; whole of life cost comparison including capital and operatic costs; environmental and public issues.

・・ Identification of design parameters: voltages, ratings, protection, metering, SCADA, communication, operational - preparation of one-line diagram and general arrangement; design scope; review with other parties.