Course Code **E03**

Title **HVDC cable technology and testing**

Background

HVCD technology is becoming more and more important in the transmission field. Cable technology is pretty new and also performances tests are not completely standardized. It is therefore useful to be continuously updated both on the evolution of the technology and on the standardization to be able to properly design or procure the suitable systems.

Objectives

The course is aimed at providing basic knowledge on HVDC cable manufacturing, design parameters, system implementation and testing technology. The course allows a comprehensive overview for any engineer who need to master the technology from the end user point of view.

Addressed to

Basic design engineer, procurement officers

Duration **5 full days**

Program

1st day General parts

a. HV power cables in general
- Design parameters
- Material
- Ageing
- Testing during the production
- PD test (LFPD, HFPD)
- Testing during the operation

b. Quality assurance, testing, Failures of HV power cables
- Causes and risk of power cable system failures
- Failure analysis(Degradation mechanisms, process)
- Quality assurance measures to increase reliability

2nd day General parts

c. Asset management, Remaining life of HV power cables
- Asset management
- Determining the remaining lifespan
- Life extension

3rd day HVDC technology

a. HVDC Partial discharge measurement technology
- Principle
- Device
- Measuring Method
- Evaluation

b. HVDC 16. Electrical tests after installation
- DC voltage test of the oversheath
- High Voltage test of insulation Evaluation
- DC-voltage test with simultaneous PD-measurement

4th day HVDC technology

a. Introduction to the HVDC systems
- Reasons for the use of DC transmission
- Type of HVDC technology: lcc (Line commutated Converters) , VSC (voltage source converter)
- Typical layout of the LCC and VSC converter station
- Typical HVDC link configurations
- AC/DC conversion principles for LCC converters (12-pulse type) and VSC converters (multi-level type)
- LCC vs VSC (pros and cons)
-

b. HVDC cable system
- Background of the basic cable system design
- Industrial best practice, existing and future
- Present HVDC Technology solutions (Mass Impregnated insulation technology, Polymeric insulation technology)
- Ongoing and future development
- Laboratory experience to open the doors to realization of real projects
- Major considerations for choosing cable design (conductor, insulation, metallic sheath, armour, optic cable for diagnostic purposes)
- Typical aspects leading to a potential breakdown (for MI and Extruded insulation system): Possible causes & defects, Scenarios, Location
- Typical causes of failures and defects (for MI and Extruded insulation system)
- Typical approach for fault analysis (analytical and testing methods)

5th day HVDC testing technology

- Overview of HVDC laboratory of CESI in Mannheim

a. Test Facilities required to develop HVDC Cable System
- Building requirements
  - Size, Foundations , Shielding, Facilities
- Hardware requirements
  - DC Generator
  - Heating equipment
  - Impulse generator
  - Useful extensions (MV power supply, AC transformer etc.)
- Software requirements
- Human resources
  - Educated staff (test engineers)
  - Workshop

b. Testing of HVDC cable systems with extruded cables
- Set-up of the cable loops
- Test items according to CIGRÉ and clients instructions
  - * CIGRÈ TR for HVDC cables tests on extruded cables
  - * TSO specification – case study
- Load cycles and no-load cycles
- Polarity reversal tests
- Superimposed impulse tests
- Logistics management (deliveries, external suppliers, waste management)

Course Code E4

Title **HVDC Transmission systems technology and application**

Background

HVCD systems are becoming more and more important in any interconnection between different electrical systems. Moreover his innovative technology allows more transmission capacity. The different technology choices must be carefully evaluated since the conceptual studies. A clear understanding of the differences between usual AC application and DC , the maturity stage of the component and the future perspective must be known by any manager in charge of the network development.

Objectives

The course provides an outline of HVDC systems technology, with the reason for its application. It deals with the main technical issues associated to this technology and it is addressed mainly to the conceptual design of such systems.

Addressed to

Electrical engineers involved in the basic design of interconnection based on HVDC system

Duration

5 full days

Program

1st Day:

INTRODUCTION TO THE HVDC SYSTEMS

- Reasons for the use of the Direct Current transmission
    - Advantages and disadvantages of DC
    - Break-even distance
- Type of HVDC technology (LCC, VSC)
- Description of the link configurations (bipolar, monopolar,…)
- Description of the typical arrangement of a converter station (LCC and VSC)
- General presentation of the HVDC links in the world
- Simple comparison of converter station, transmission line and cable costs
-

2nd Day:

AC/DC CONVERSION PRINCIPLES

- AC/DC conversion principles for LCC converters
    - Single and multi-phase converter bridge arrangements
    - Three Phase Graetz Bridge
    - Different HVDC arrangements (bipolar, multiterminal, back to back, etc.)
    - Overlap angle, extinction angle
    - Development of basic dc network equations
- AC/DC conversion principles for VSC converters

Description of the main characteristics of the semiconductor power devices used in HVDC systems

3rd Day:

INTERACTION WITH THE AC NETWORK

- Reactive power requirements
  - Passive and active means for supply of reactive power
  - Co-ordination of reactive power sources
  - Active filters
- AC harmonics requirements and AC filters basic characteristics
- DC harmonics requirements and DC filters basic characteristics
- Interaction with nearby generators
- Short circuit ratio: converter interactions with strong and weak ac systems

4th Day:

REQUIREMENTS FOR AN HVDC LINK

- Lay-out and main components
- Environmental Feasibility study: the Desk Top Study
- Seismic requirements
- Reliability and availability performances
- Losses performance
- Environmental performances (radio interference, electric and magnetic fields, audible noise)

5th Day:

CONTROL AND PROTECTION SYSTEMS

- Basic introduction to thyristor and IGBT technology
- Control overview
  - Co-ordination of inverter and rectifier
  - Characteristics
  - Current control, extinction angle control, voltage
  - control, current error control
  - Voltage dependent current order limits
  - Firing control, phase-locking and bypass pair
  - Operation
  - Higher order controls
  - Controller changes (step changes in controller reference settings)
- Electro-magnetic Digital Simulation (PSCAD-EMTDC)
- Redundancy in control system
- Duplication in protection system
- Control performances and disturbances
- Interaction with nearby generators (Sub-Synchronous Torsional Interaction)
- Reactive power control strategies
- Protection zones and protections
  - AC side faults
  - Detection of and response to commutation failures
  - Clearing of DC line faults
  - Differential protection
  - Measurement of converter quantities (firing and extinction angles, DC voltage, DC current transformer, power, etc.)
- Remote control and telecommunications
- Advanced HVDC Controls
  - Dynamic Control Features
  - Timing and Synchronization
  - Stability Analysis of HVDC Systems
  - Supplementary Controls

Code Course

E12

Title

Power system studies and performance checks

Background

Any transmission or distribution network must be modeled to analyze the power flows and to evaluate how to reinforce it in case of load increase and the real level of short circuit current any circuit breaker installed must withstand.

Objectives

The course provides an exhaustive description of the needs and procedure for power system performance analysis, limited to the ones represented by phasor quantities in terms of static and dynamic performance, but not in terms of instantaneous values that are typical of electromagnetic transient analysis.
The course makes use of well know commercial SW tools for power system analysis, namely PSS-E by Siemens-PTI and Power Factory by DigSilent and others. Note that just an outline of the procedure for the analysis of Temporary Overvoltages (TOV) is given within this course, since TOV's have to be simulated by means of electromagnetic transient models representing the instantaneous values of quantities (voltage and current) in the time domain, which are out of the scope of this course. Another course (namely "Electromagnetic Transients and procedure for Insulation Co-ordination") deals with TOV analysis by applying electromagnetic transient models.

Addressed to

Engineers involved in the power system performance analysis

Duration

5 full days

Program

FIRST DAY – Outline of power systems studies – Load Flow

- Outline of power system studies
  - Transmission system planning activity
  - Transmission system preliminary design
  - Power system operational planning
  - Needs for network performance checks by simulation
  - Introduction to power system simulation tools with phasor models
- Load Flow
  - Load flow analysis for network development planning and preliminary design
  - Load flow analysis for operational planning
  - Load flow as input for other studies

SECOND DAY – Short circuit - Reliability

- Short Circuit
  - Sources of fault currents
  - Fault types and fault duration
  - The purpose of fault evaluation
  - Short circuit current computation
  - Short-circuit current computation as per International Standards
  - Fault currents and circuit breakers selection and assessment
  - Fault current and relaying in HV and EHV networks

- Reliability as part of adequacy in system planning
    - Reliability criteria and indexes
    - Monte Carlo approach for the evaluation of the static reliability indexes

THIRD DAY – Stability and Long Term Dynamics

- General considerations on transient behaviour and stability of an electric power system
- Stability against large perturbations: first swing and transient stability
- Stability against small perturbation (Steady-state stability)
- Long-term stability
-

FOURTH DAY – Reactive power planning – Outline of TOV analysis – Voltage quality assessment

- Reactive Power Planning
    - Reactive power compensation devices:
        - Shunt capacitor banks
        - Shunt reactors
        - Synchronous compensators
        - Static Var Compensators (SVC)
        - Optimum Reactive Power Flow (OPFR) for network development planning
        - Optimum Reactive Power Flow (OPFR) for operational planning
- Temporary Overvoltages: Outline of the methodology for TOV analysis
- Voltage quality assessment: Harmonic disturbance, Unbalance, Flicker
    - Standard and practice with respect to voltage characteristics
    - Harmonic phenomena
    - Unbalance
    - Flicker and rapid voltage changes

FIFTH DAY – Examples and in-class practice of newtwork studies

- Examples of power system studies made by SW tools, with critical analysis of the outcomes
- In- class practice of power system studies by applying SW tools

Course Code **E14**

Title **Electromagnetic Transients and procedure for Insulation Co-ordination**

Background

Electromagnetic transients that affect all transmission systems are originated by internal events, i.e. faults and switching operations, and by external events, i.e. lightning strokes hitting overhead lines.
EMTs are of interest mainly for the insulation co-ordination of the transmission system in the basic design of the network and in the specification of the basic characteristics of equipment and machinery (transformers), but they can even affect the system planning, mainly when unacceptable temporary overvoltages are expected and they have to be avoided by provisions that can even impinge on the development of the network.

Objectives

The course provides an exhaustive description of the electromagnetic transients (EMT) in transmission systems and an outline of the insulation co-ordination of substation and lines.
Furthermore, the course a comprehensive knowledge of the behavior of the system in all its performance aspects (load-flow, short circuit, electromechanical transients, harmonics, control) which is the basis for understanding any EMT phenomenon.

Addressed to

Engineers specializing in insulation coordination activities

Duration **5 full days**

Program

FIRST DAY – EMTs generals - EMTs originated by lightning

- Introduction to Electromagnetic transients in transmission systems
- Physic and mathematical aspects related to the analysis of electromagnetic transients
- Lightning phenomenon: statistics of occurrence and of stroke current parameters
- Electromagnetic transients originated by lightning strokes
    - Back-flashover of overhead lines
    - Shielding failure of overhead lines

SECOND DAY - EMTs originated by internal events

- Fault application
- Fault clearing
- Line energization
- Single-pole-reclosing
- Three-phase reclosing
- Load rejection
- Load rejection following fault clearing
- Transformer energization
- Switching (opening) of magnetizing currents

-
- Operation of disconnecting switch in open air station
- Restrike of circuit breaker in opening of no load line
- Restrike of circuit breaker in opening of shunt capacitor banks
- Operation of disconnecting switch in open air station
- Very fast front overvoltages inside GIS (SF6) station
    - Operation of disconnecting switch
    - Internal fault

THIRD DAY – EMT SIMULATION TOOLS AND MODELING OF ELECTRICAL COMPONENTS

- Electromagnetic transients simulation tools: ATP, ATPDRAW
- Modelling of electrical components for EMT simulation
    - Passive elements
    - Network equivalents
    - Synchronous machines and their AVR
    - Overhead lines and cables
    - Transformers with saturation and hysteresis
    - Surge arresters
    - Circuit breakers

FOURTH DAY – Simulation of EMTs

- Simulation of electromagnetic transients originated by lightning strokes
    - Lightning performance of station
- Simulation of electromagnetic transients originated by internal events:
    - Switching (slow front) overvoltages
    - Temporary overvoltages
    - Very fast front overvoltages

FIFTH DAY – Outline of Insulation Co-ordination procedure and examples of application

- Insulation co-ordination performance criteria
- Reference Standards and documentation
- Procedure for:
    - selection of insulation withstand of substation and line equipment
    - selection and location of protective devices (surge arresters)
- Examples of application

Course Code **E17**

Title **FACTS technology and application**

Background

Objectives

The course provides an outline of FACTS technology, with the reason for its application. It deals with the main technical issues associated to this technology and it is addressed mainly to the conceptual design of such systems.

Addressed to

Engineer

Duration

4 days

Program

FIRST DAY - AC SYSTEMS AND SELECTION STRATEGIES FOR FACTS DEVICES

- Basic FACTS definition
- Power Systems
- Transmission Systems
- Economic Considerations
- AC OHTL's: Series Compensation and high Surge Impedance Loading (SIL)
- DC Transmission
- Fix and controlled reactive power compensation
- Typical Reactive Power Compensation (RPC) application field
- Practical Examples

SECOND DAY – FACTS CLASSIFICATION: SCHEMES AND TECHNOLOGY

- Generalities
- Static Var Compensator (SVC)
- Thyristor Controlled Series Compensator (TCSC)
- Static Synchronous Compensator (STATCOM)
- Static Synchronous Series Compensator (SSSC)
- Unified Power Flow Controller (UPFC)
- Phase Shifting Transformer (PST, TCPST)

THIRD DAY - FACTS SPECIFICATION

- Main characteristic and performance requirements
- Guidelines examples for a Specification
- Standards and other reference documents

FOURTH DAY - FACTS MODELING AND STUDYING

- Modeling principle
- Load flow and Dynamic Study
- Practical Examples

Course Code

M01

Title

Condition Based Maintenance – Basis & Best Practice

Background

Modern maintenance practice is gradually moving from time based operation to the dynamic evaluation of the real behavior and condition of the equipment, aimed at optimizing maintenance cost and effectiveness.

Objectives

The course provides a basic introduction and understanding of condition based maintenance and it covers all major CBM methodologies available for the implementation of CBM in electrical plants. An overview of maintenance strategies and practices is presented. An understanding of component failures, consequences, and criticality of such failures is also included.
The course gives a basic introduction of the practical implementation of CBM via the design of a Smart CMMS System.
The course is addressed to:

- Identify strategies and best practices in maintaining plant and equipment using CBM or other maintenance methodologies;
- Implement CBM to help increase plant availability;
- Choose the right CBM techniques and technology ;
- Choose the right Condition Monitoring actions indicators and thresholds, and frequencies, and scopes of application depending on the criticality and residual life or the equipment;
- Potentially extend the residual life of critical equipment through CBM and CMMS.

Furthermore the course explains how all the above concepts can be integrated into a web based computerized system, and how these systems can improve the asset management of the company.

Addressed to

Maintenance responsible

Duration

3 full days

Program

FIRST DAY - MAINTENANCE PRACTICES

- Definitions
- Classification of Maintenance Strategies
- Corrective, Time Based, Condition Based & Risk Based Maintenance (CBM - RBM)
- The Elusive P-F Interval
- Reactive and Proactive Monitoring Tasks
- The Bathtub Curve;
- Mean Time Between Failure (MTBF) - Pros and Cons

-

- CBM Methodologies for the selection of the best Maintenance Strategy
- Equipment Criticality: Failure Modes, Effects and Criticality Analysis (FMECA)
- Reliability Centered Maintenance (RCM)
- Plant Maintenance Optimization

SECOND DAY - CONDITION BASED MAINTENANCE APPLICATION

- Condition Monitoring (CM) Procedures
    - Selecting the best CM Technique for assets using RCM/PMO
    - CM tasks Indicators and Thresholds
    - A Simple Case of CBM Selection - The Deep Fryer
    - Pros and Cons in implementing a CM program
    - Tutorial - The Power Transformer
- Asset Management Methodologies - PASS55

THIRD DAY - CBM BEST PRACTICE

- Asset Management & CBM: Basis for a Smart Computerized Maintenance Management System (S-CMMS)
- Need for CBM Implementation inside the S-CMMS of a FRACAS (Failure Reporting, Analysis and Corrective Action System)
    - Logical Architecture
    - Structure of the System
    - Workflow of a S-CMMS
    - Introduction of CBM inside the S-CMMS
    - Tutorial - The Power Transformer

Course Code **E53**

Title **Integration of Non-Programmable Renewable Energy Sources in the Electric Power System**

Background

Renewable power generation, mainly photovoltaic or wind farms, are not likely to be programmed and required a suitable network management to exploit all the source potential.

Objectives

The course provides an exhaustive description of what happen in and established electric power system when a significant volume of non-programmable energy sources are connected to the electric power systems, to either the transmission network and the distribution one.
A set of power system performance analyses through simulation tools has to be carried out in order to assess the impact of RES. The basics for such kind of simulations are dealt with in another course, namely "Power system studies and performance checks", but here the modeling of RES generation are explained. Furthermore, the typical provisions in order to compensate the unpredictable variations of such sources are shown.
The course makes use of well know commercial SW tools for power system analysis, such as PSS-E by Siemens-PTI and Power Factory by DigSilent. For the power quality analysis, besides the above mentioned tool, even tools for electromagnetic transient analysis, such as ATP, are applied.

Addressed to

Electric network operators

Duration **5 full days**

Program

1st day Generals on the impact of non-programmable RES on the electric power system

- RES and their characteristics
  - Wind generation
  - Photovoltaic (PV) generation
- Outline of the impact of RES on power system performance
  - System wide impact
  - Network and local impacts
  - Market impact
  - Regulatory issues
  - Hints at environmental impacts
- Feasibility assessment of a RES deployment plan
  - Reserve criterion and balancing capability
  - Network connection – static performance analysis
  - System reliability analysis
  - Market analysis and cost assessment
  - Dynamic performance analysis

2nd day Detailed assessment of RES impact on static and dynamic behavior of the electric power systems – part 1

- Maximum gradients in the variation of RES generation
- Risk associated to RES generation curtailments
- Network congestion caused by RES generation
- Risk of over-generation
- Impact on power market mechanisms
- Load following and reserve
- Optimal dispatch and multiple load-flows
- Selection of the set of Characteristics Days to be analyzed

3rd day Detailed assessment of RES impact on static and dynamic behavior of the electric power systems – part 2

- Change in the inertia of the power system and consequent risk of large frequency deviations
- Risk in voltage profile and impact on reactive power management
- Risk of over-frequency and under-frequency
- Stability of RES power plants and network response to major fault events
- Fault through capability
- Provisions and mitigation measures facing the impact of RES
- Power system reliability with high RES penetration
- Monte Carlo approach

4th day Generals about Power Quality and relevant RES performance
- Harmonics
- Flicker and rapid voltage changes
- Voltage dips
- Unbalance
- Telephonic Interference
- Digital simulation for power quality impact assessment
- Field measurements and monitoring systems

5th day RES compliance to Grid Codes requirements
- Normal operating conditions
- Withstanding Voltage drops – Fault ride through capability
- Frequency regulation and active power control
- Voltage regulation and reactive power control
- Power Quality limits and requirements

Course Code M04

Title **MV cable joint. Theory and applications**

Background Distribution networks are increasing the utilization of cables, mainly in urban area. Joint are usually the weakest point of the cable system, due to the necessity to have skilled and trained operators.

Objectives To familiarize with the main MV joint technology and the mounting techniques

Addressed to Workers in the maintenance team and supervision responsible

Duration 3 full days

Program

1st day Cables system

- Basic classification of cables
- Basic manufacturing technology of cables
- Insulating material XLPE , HTPE, EPR, Impregnated paper
- Semi conductive shields
- basic of electrical calculations
- Identification according CENELEC HD 361

2nd day Cables system

- Electrical field in cable systems
- Thermal stress
- Temperature limits
- Cable earthing
- Mechanical characteristics
- Problems in cable laydown
- Fire behavior
- Cable accessories
- electrical field control
- Cable termination technology
- Available joints

3rd day Practical exercise in cable jointing

- Tools for cable preparation and joint mounting
- technique of preparation
- in field mounting environmental condition
- heat shrink, cold shrink
- testing

Course Code M08

Title **Electrical system and protections**

Background Distribution networks are widely used also in industrial factories, beyond the usual distribution network operated by utilities. Protection rules knowledge is fundamental to maintain the network fully operating.

Objectives To familiarize with the calculation of the short circuit currents and the protection relais

Addressed to Engineers operating in the maintenance of industrial or electrical distribution networks

Duration 3 full days

Program

1st day Electrical systems

- Basic definition of electrical system and its main parameters
- Basic components of a distribution network
- Design criteria of the main system parameters
- ground and earthing systems
- Typical faults in distribution networks
- Component tripping

2nd day Cables system

- Electrical field in cable systems
- Thermal stress
- Temperature limits
- Cable earthing
- Mechanical characteristics
- Problems in cable laydown
- Fire behavior
- Cable accessories
- electrical field control
- Cable termination technology
- Available joints

3rd day Practical exercise in cable jointing

- Tools and calculation criteria
- technique of preparation
- in field mounting environmental condition
- heat shrink, cold shrink
- testing

Course Code M09

Title **Distribution substation and verification of the earthing system**

Background Safe operation or maintenance in an electrical substation ban be met when a suitable earthing system has been duly design and periodically measures.

Objectives To familiarize with operation and maintenance of the MV and LV distribution substation

Addressed to Engineers operating in the maintenance of industrial or electrical distribution networks

Duration 3 full days

Program

1st day Electrical networks

- Basic layout of the electrical substation. Design rules according standards EN 61936-1
- Basic specification of the civil structures
- functional characteristics of the main components
  - MV-LV transformers
  - MV Switchboards
  - LV switchboards
  - Voltage and current transformers
  - Substation automation
  - protections

2nd day Earthing system and substation operations

- Earthing system
  - Basic requirements according standard EN 50522
  - basic design of the earthing systems
  - basic erection of the earthing systems

- Substation operation and maintenance
  - single line diagrams
  - protection devices operations
  - typical commands and operations
  - typical maintenance procedures

3rd day Verification of the earthing system
- Safety requirements
- Earth potential rise- Step voltage and touch voltage
- Soil electrical resistivity
- Method of measurement

Course Code M14

Title **Electrical equipment for potentially explosive atmosphere**

Background European directive ATEX and the IECEX certification scheme are covering the main and essential health and safety requirements any equipment must comply with in order to be sold and used in a potentially explosive environment.

Objectives To familiarize with and educated selection of equipment to be used in electrical power plants or, in general, where the directive can be applied.

Addressed to Engineers operating in the maintenance of industrial or electrical power plant and procurement officers

Duration 2 full days

Program

1st day ATEX directive

- Basic requirement included in the directive
- scope , application range, CE marking
- main features of the protection against explosion hazards
  - EX equipments
  - Gas classification
  - Temperature classes
  - Protection modes
  - Protection level
  - marking

2nd day Equipment and protection modes

- Basics of classification of hazardous areas
  - Definitions and processes to be used for area classification
  - Application of the standard EN 60079-10
  - Application of the standard EN 61241-10
- Manufacturing techniques and testing procedure for Electrical apparatus in explosive gas atmospheres
  - Enclosure explosion proof (Ex-d)
  - Intrinsic safety (Ex-i)
  - Electrical equipment for zone 0
- Installation procedures of electrical equipment in hazardous area
  - Selection according to zones
  - Protection from dangerous sparking
  - Emergency switch-off
  - type of protection “e” – Increased safety
  - type of protection “i” – Intrinsic safety
  - Electrical installations inspection and maintenance according IEC 60079

Course Code E47

Title **Design of electrical headlines for distribution network**

Background International and local standards continuously update and it is necessary to align the personnel skill. Starting from theoretical topics the course gives practical example how to design the electrical line applying the international calculation rules.

Objectives To familiarize with the main design practice and standards of the overhead lines in Medium voltage lines

Addressed to Electrical designer and maintenance responsible

Duration 3 full days

Program

1st day poles and steel structures

- Basic design rules and calculation of structures
- Forces, stress and strain
- Basic elements of the overhead lines structures
- basic of electrical calculations

2nd day using standard CENELEC 50341-1

- Calculation of the limit states
- Classification of actions
- Characteristic values
- Partial factor method and design formula
- Construction material- steel, wood, concrete
- Protection against corrosion and environmental
- Foundation
- Actions on lines- wind, loads, temperature effects, short circuit current effects

3rd day using standard CENELEC 50341-1

- Electrical requirements
- Insulation and air clearance
- Coordination of conductor positions and electrical stresses
- Electric and magnetic effects
- Earthing systems
- Corona effect