ENERGY ACADEMY

POWER CABLE COURSES
Introduction
Underground power cables are becoming more and more important for a number of reasons. Firstly, medium- and high-voltage cables are being used more widely due to increased electricity consumption, the fact that overhead lines are being replaced by high-voltage underground cables, and the trend towards offshore wind power generation. Secondly, underground power cables are being developed for higher electric stresses and higher currents. This creates considerable challenges. Thirdly, there is a tendency to push existing underground distribution and transmission power cables to their limits, which is associated with a range of issues. And all this is happening at a time when society increasingly depends on a reliable and efficient energy supply.

The increased use of power cables means that in many urban areas cables now often form a significant portion of the capital invested by network operators.

Furthermore, underground medium- and high-voltage cables have an important influence on matters such as the design, use, maintenance and reliability of the overall energy system.

Reasons enough to learn more about underground power cables!
Course outline
To meet growing demand for training we developed a series of power cable-related courses, consisting of a general three-day course:

- Power cables in general

plus four in-depth supplementary two or three day courses:
- Ageing, quality assurance, testing, diagnostics and failures of power cables
- Ampacity and engineering aspects of power cables
- Asset management, maintenance and remaining life of medium voltage cables
- Asset management, maintenance and remaining life of high and extra high voltage cables

Participants will be able to put their questions to reputed power cable experts, exchange experiences and share practical examples with fellow participants.

For whom?
Anyone involved (or to be involved) with power cables in the course of their daily work. It is recommended that the participants hold at least a Bachelor of Engineering degree or have some prior knowledge of power cables.
COURSE POWER CABLES IN GENERAL

A relatively large number of cables are buried underground. This means that many people will be involved with (underground) power cables professionally, and that associated knowledge is a key requirement. This basic course, Power cables in general, covers all the relevant aspects relating to power cables - not always down to a detailed level (specialized courses are available for this purpose), but especially in a related context. This means the course provides a good overview of all the elements that are of interest, as well as the options available for approaching or solving certain problems.

Subjects

Design parameters
The course deals with the theory that is relevant to cables and its practical implications. We calculate the electrical fields, the capacity, cable losses and also look at subjects such as transmission line models and the skin effect.

Cable manufacture
An overview of the factory. How is a cable manufactured and what are the implications of this in terms of use?

Cable joints and terminations
There are many types of joints and terminations in use, and a great deal of (practical) experience has been gained with them. However, one thing is certain: accessories remain an area of special concern. In this part of the course we cover this area in more detail and we are introduced to the full range of existing technologies. In addition, the vulnerabilities of joints and terminations are addressed.

Materials
The common insulation materials for cables are paper and extruded materials (plastics). The properties of these materials in particular and the influence of these properties on the performance of the cable are discussed.

Types of cable
The cable types currently in use are discussed in relation to the various voltage levels. Additional attention is devoted to the water tightness of cables. Furthermore, additional specialized cable types are discussed, such as submarine cables, HVDC cables and superconducting cables.

Cable installation
The installation of cables itself predetermines many future conditions. In view of the extended life of cables, a detailed study of the installation and everything connected with it, such as special placements, overvoltage, connections, current load, grounding, cross bonding, etc., is called for. The current load is particularly discussed in a coherent context. The ‘Ampacity and engineering aspects of power cables’ course deals with this aspect in detail.

Ageing
The course provides a summary of the ageing mechanisms that apply to cables, joints and terminations, the physical phenomena and the influence of the surroundings and temperature. The causes of faults are also discussed. The course ‘Ageing, quality assurance, testing, diagnostics and failures of power cables’ addresses this theme in further detail.
Testing cables during the production phase
The different types of tests conducted to complete the design and production phases are covered in general. In addition, the course addresses the technical background and the current standards and norms. The course ‘Ageing, quality assurance, testing, diagnostics and failures of power cables’ addresses this theme in further detail.

Testing cables during the operation phase
This section provides a summary of the various tests that can be conducted in the field. The acceptance tests and various forms of diagnostic testing are discussed. This subject matter is subdivided into potentially destructive and completely non-destructive testing and into off-line and on-line testing. We will take a look at the value of all of these tests and the way in which the tests should be applied. This section also provides a general overview of fault localization. The course ‘Ageing, quality assurance, testing, diagnostics and failures of power cables’ addresses this theme in further detail.

Asset management
A number of themes are addressed at a summary level as part of Asset management. On the one hand, the course reviews the possibility of improving the use of cables by thermally monitoring them using temperature sensing fiber optics. On the other hand, the course teaches how the residual life of cable systems can be identified, with due consideration to the available diagnostic technologies. In all instances, the technical, economic and strategic aspects of the available technologies and solutions are briefly discussed. A more detailed treatment of this theme forms part of the courses ‘Asset management, maintenance and remaining life of medium voltage cables’ and ‘Asset management, maintenance and remaining life of high and extra high voltage cables’.

Visit to the KEMA Laboratories
A visit to the KEMA High Power and High Voltage Laboratories is also included.

A few responses from the participants:
- “A very rich concept, with lots of practical experience. Intense.”
- “Excellent course!”
- “I didn’t know there was so much to know about cables.”
- “Trainers with a theoretical background mixed with practical experience is a big advantage.”
COURSE AGEING, QUALITY ASSURANCE, TESTING, DIAGNOSTICS AND FAILURES OF MV AND (E)HV POWER CABLES

What degradation mechanisms or ageing mechanisms affect cables and their accessories? What is the rate of progression of these degradation processes? Do they all result in failure? What methods are available for diagnosing degradation mechanisms? Are these analyses and testing techniques only available in a laboratory or also in the field? And how effective are they? And what is the relationship of all this to safeguarding quality and reliability? Plenty of questions, but not every supplier of analysis and testing

Subjects

Causes of failures
The course will explain how various components can fail and the possible underlying causes. This material will be put in a broad context, looking not only at the purely physical degradation, but also at other reasons, such as the training level of installers, misunderstandings during installation work, defects in type and acceptance tests, etc.

Degradation mechanisms
A number of typical degradation mechanisms are described in this section. An introduction will be provided for the less known intrinsic and thermal breakdowns, while the more relevant degradation mechanisms (degradation of paper insulation due to heating and moisture, the partial discharge and electric tree formation phenomenon, and the water tree phenomenon in cables insulated using extruded materials) will be dealt with extensively.

Testing cables during the production phase
The various types of tests conducted to complete the design and production phases are addressed extensively. This includes pre-qualification testing (for high voltage cables), type tests, and special and routine tests. Furthermore, attention will be devoted to standardization (current standards and norms), certification and the interrelationship with quality systems. This will not just be limited to summarizing the facts; their necessity and effectiveness will also be discussed.

Testing of cables during the operation phase
This section provides an extensive overview of various tests that can be conducted in the field. The acceptance tests and various forms of diagnostic testing are discussed. This subject matter is subdivided into potentially destructive and completely non-destructive testing and into off-line and on-line testing. We will take a look at the value of all of these tests and the way in which the tests should be applied. Fault localization will be addressed as well.

Failure analysis
A failure analysis can help understand the background to a failure as a means of preventing reoccurrence. An explanation is provided of how to conduct a failure analysis and everything involved in such an analysis. Finally, a number of interesting facts are provided.

Preparation
The course Power cables in general is recommended preparation for the in-depth courses, but not a requirement.

Result
This course will provide you with insight into:
- Ageing of power cables and their accessories
- Causes and risk of power cable system failures
- Failure analysis
- Quality assurance measures to increase reliability
- Various testing and diagnostic options and their use
COURSE AMPACITY AND ENGINEERING ASPECTS OF MV AND (E)HV POWER CABLES

With the increasingly widespread use of underground and submarine power cables, proper design and engineering of medium- and high-voltage power cables for distribution and transmission systems is becoming more and more important. An essential topic in the design and engineering of these systems is the ampacity of power cables, which can appear to be surprisingly good over the short term, but surprisingly poor over the long term or at very specific spots (thermal bottlenecks). This course will help you determine the ampacity properly. It will also discuss various topics which play a major role during the design and engineering phase.

Subjects

General framework and existing standards
A general framework will be presented, highlighting topics which play a role in the design and engineering of a new underground distribution or transmission power cable system. Existing standards giving regulations, guidelines etc. will also be discussed.

Cable installation design
There are multiple options for installing (underground) power cables, all with their benefits and drawbacks. Important installation options will be discussed in detail and topics needing consideration will be identified.

Continuous current rating
Due to the variety of situations in the field, the computation of the continuous current carrying capacity of a power cable is fairly complex, despite the existence of an IEC guide in this field. How to handle special situations and identify thermal bottlenecks and how a continuous current rating is actually set up will be discussed in detail.

Dynamic current rating
Dynamics in the loading of underground or submarine power cables or in the power cable environment make it possible to increase the cable loading above the continuous current rating. The ins and outs of this discussion as well as the dynamic calculation of the current rating itself through to on-line dynamic rating systems in control rooms, will be discussed in detail.

Short-circuit behavior
The short-circuit behavior of cables will be discussed. The short-circuit current rating as well as the short-circuit forces will be covered.

Magnetic fields
A high current rating is often accompanied by high magnetic fields. Increasingly, the magnetic fields around a power cable circuit are limited in magnitude due to (inter)national regulations. This makes magnetic field design an important part of this course.

Requirements and specifications of power cables
Design and engineering is often performed in a project environment where project requirements and specifications are put forward as starting points. During the course, important requirements and specifications will be gathered and discussed.

Preparation
The course Power cables in general is recommended preparation for the in-depth courses, but not a requirement.

Result
This course will provide you with:

- Understanding of the different design parameters for medium- and high-voltage power cables
- Insight and methodologies to determine the ampacity as accurately as possible
- Knowledge to make project specific design decisions.
COURSE ASSET MANAGEMENT, MAINTENANCE AND REMAINING LIFE OF POWER CABLES (MV AND (E)HV)

Performing the right maintenance at the right time and, if necessary, replacing components, is essential for making optimal use of your operating resources. This course is designed to demonstrate that with the proper knowledge and with the proper use of tools, it is possible to manage the acquisition of insight into the residual life of power cables.

Subjects

Asset management
Maintenance, diagnostics and replacement are key tools for determining or influencing the remaining life. Sound asset management strategy is indispensable in this respect and can help find a proper balance between cost savings and reliability, for example. Numerous practical cases are dealt with in this course with a focus on ensuring that maintenance on a particular cable type is properly carried out. The supporting process, with reference to international standards such as PAS 55, is also discussed.

Ageing processes
In terms of degradation, many types of defects can be grouped into a number of generally known processes, such as partial discharge, electric tree formation, water trees, etc. These processes largely affect the remaining life.

Diagnostic methods
A number of ageing processes can be made visible by means of diagnostic methods. Partial discharges can be measured and localized using solid PD measurement technologies and the associated analysis methods.

Cable types and accessories
A short overview will be provided of the most common cable types, components and accessories of MV and HV systems.

Types of faults
Many common defects are addressed, often with examples, such as: penetration of moisture in oil joints, degradation of resin joints, carbonization in earthing joints, water trees in an XLPE cable and drying out of PILC cable.

Remaining life of MV cables
The course deals with a method designed to identify the remaining life. What data is required and how can this data be...

Remaining life of HV cables
The remaining life is determined on the basis of a methodology that uses a combination of technical, economic and strategic criteria. This course fuses the method which consists of two steps: the ‘simplified approach’ and the ‘detailed approach’. The simplified approach differentiates situations that are still doubtful. The remaining life is then determined using the detailed approach. The course covers a number of practical cases to which this methodology is applied.

To ensure that course participants will be able to sufficiently master the subject matter, time has been allocated for completing a number of exercises.
Life Extension
Finally, attention is given to extending the lifespan. What actions can be taken to further expend the lifespan? In this respect, a distinction is made between situations where the normal lifespan is achieved and situations where, due to excessive ageing, the lifespan is significantly lower than the expected lifespan.

For whom?
Anyone involved (or to be involved) with power cables in the course of their daily work. It is recommended that the participants hold at least a Bachelor of Engineering degree or have some prior knowledge of power cables.

Result
This course will help you to:
■ Focus on points of reference for efficiently dealing with cables and accessories
■ Determine the right asset management strategy
■ Define the appropriate maintenance activities in cope with degradation mechanisms
■ Estimate the remaining life span in order to determine and justify the correct resulting actions
■ Gather knowledge required to reduce maintenance costs and the number of fault, while increasing the total life

Preparation
The course Power cables in general is recommended preparation for the in-depth courses, but not a requirement.

Result
This course will provide you with:
■ Points of reference for efficiently dealing with cables and accessories
■ Insight into which form of maintenance to apply and when
■ Insight into which maintenance strategy can be best applied
■ Knowledge required to reduce maintenance costs and the number of faults, while increasing the total life
Team of instructors

Fred Steennis
Fred Steennis has M.Sc. and Ph.D. degrees in electrical engineering (subject: water treeing). He has worked at DNV GL since 1982, and is presently service line principal for underground power cables, responsible for the development of different cable tests and cable failure investigations. He is also a part-time professor of power cable network diagnostics at Eindhoven University of Technology, as well as a member of Cigré and active in various other committees.

Frank de Wild
Frank de Wild has an M.Sc. in applied physics from the University of Twente. He is an internationally renowned expert on power cables and a service line principal for underground power cables at DNV GL. HVAC and HVDC cable design and engineering, interconnectors, dynamic rating systems, risk management and quality control are some of his key areas of expertise. He is the Dutch representative in Cigré B1 (High Voltage Cables).

Peter van der Wielen
Peter van der Wielen has an M.Sc. from Eindhoven University of Technology and a PhD for his study on on-line monitoring of PDs in medium voltage power cables. He works as a consultant on power cables at DNV GL and is specialized in power cable diagnostics, remaining life estimations, asset management, smart diagnostics and failure analysis. He is a member of the IEEE Power & Energy Society and both author and reviewer of multiple scientific publications.

Sander Meijer
Sander Meijer has M.Sc. and Ph.D. degrees in electrical engineering (topic: VHF/UHF PD measurements). He worked at the AM Department of TenneT TSO where he was responsible for the life-cycle management of power cable systems. He has been involved in projects covering the complete life cycle of power cable systems, covering land and submarine, HVDC and HVAC cable technology, interconnectors, submarine cables to wind farms and oil and gas platforms and quality control. He is a member of Cigré and active in different Working Groups.

Bernd van Maanen
Bernd van Maanen obtained his MSc degree from Eindhoven University of Technology in 2012. Since then he has been working as a consultant on power cables at DNV GL. He specializes in: power cable diagnostics, power cable consultancy in general, development of new measuring techniques & diagnostic methods and failure analysis.
Practical information

Registration
For the following items, we refer to the registration form:
- Course dates
- Venue details
- Registration fee
- Payment & cancellation conditions
- Accommodation / hotel reservations

To encourage active participation, the number of participants is limited. The course may be cancelled or rescheduled if there are insufficient participants. The registration fee includes course materials, lunches, dinner on the first course day and refreshments. The costs of travel and accommodation are not included. Hotel accommodation can be arranged through us, but payment must be made directly to the hotel.

Language
The courses are available in English and Dutch. The English course material will be a useful reference tool.

For more information and to register please visit: www.dnvgl.com/cable-courses.

DNV GL’s Energy Academy organizes training courses and workshops covering the whole spectrum of the electricity energy supply chains.

Upon request, DNV GL can also develop customized and in-company training courses.

ABOUT DNV GL

DNV GL is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil and gas, power and renewables industries. We also provide certification and supply chain services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter and greener.

In the power and renewables industry DNV GL delivers world-renowned testing and advisory services to the energy value chain including renewables and energy management. Our expertise spans onshore and offshore wind power, solar, conventional generation, transmission and distribution, smart grids, and sustainable energy use, as well as energy markets and regulations.

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