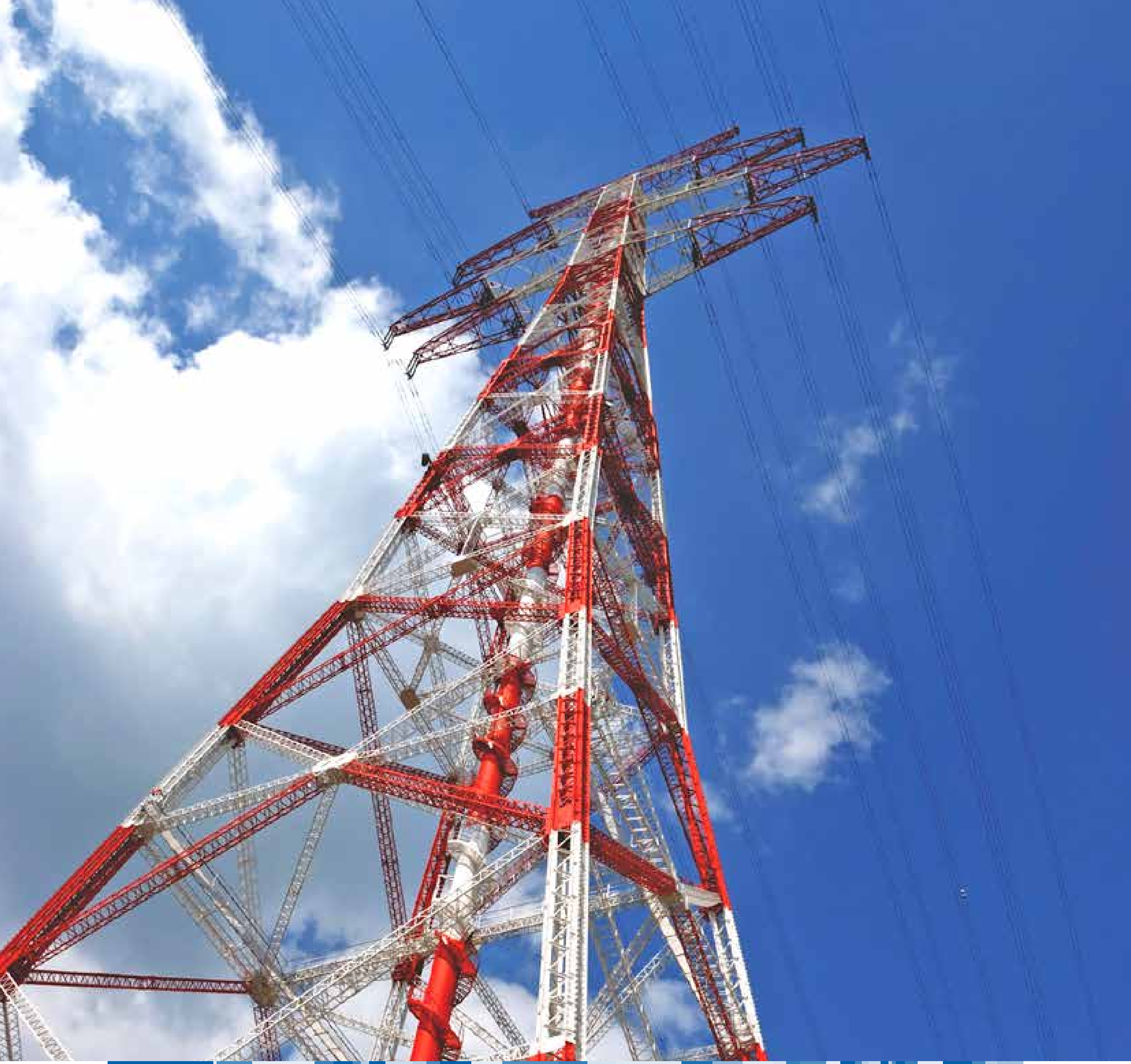
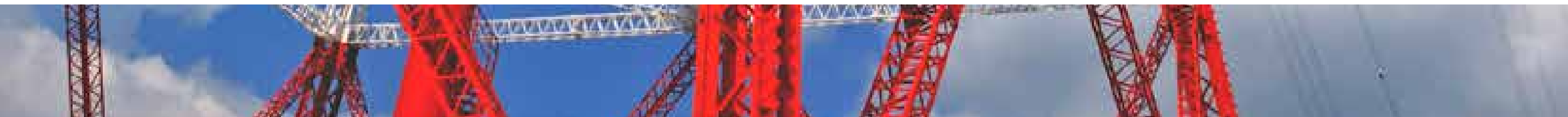


Transmission and distribution



Fact

—

The high current carried in cables results in increased temperatures and this heat bleeds away as lost energy. IEC Standards help in the measuring of that loss.

Table of contents

Meeting global energy needs

With rapidly increasing global population and the industrialization of developing countries, comes soaring demand for energy – particularly electric power. According to the International Energy Agency (IEA), by 2040 global energy needs will have risen by 30%. Transmitting and distributing electric power more efficiently and supplying it from renewable sources are ways of ensuring electricity requirements will continue to be met. More efficient transmission and distribution of electricity will also reduce carbon emissions. Distributed power systems are emerging to complement the uni-directional transmission network, from central power plants to individual households.

Distributed energy resources and smart grids

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Distributed energy resources (DERs) include residential and commercial rooftop solar installations, wind turbines and storage systems that serve a single household or an industrial facility. They can be described as generation sources located near load centres. Typically, they are renewable energy sources and can either be employed individually or their outputs aggregated to serve the main electricity grid.

Smart grids, which can accommodate DERs, are gradually being implemented and connected to existing transmission assets. The European Technology Platform SmartGrids, a European Commission initiative which focuses on research into the technology, has come up with one of the most widely accepted definitions for smart grids: "electricity networks that can intelligently integrate the actions of all users connected to it – generators and consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. Smart grids employ innovative products and services together with intelligent monitoring, control, communication and self-healing technologies".

Key technologies behind a smart grid are sensors that measure the relevant parameters such as temperatures, voltage and current; communications that allow a two way dialogue with a device; control systems that enable a device to be reconfigured remotely; and user-interface and decision support systems that provide an overview of asset status and perform advanced analytics on data to provide information.

DERs and smart grids are expected to improve energy efficiency. They also pose a number of challenges, not least concerning their integration with the conventional grid and the existing transmission and distribution network.

↘ **Fact**

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Distributed energy resources (DERs) include rooftop solar installations.

IEC International Standards pave the way for integration

—

The IEC helps to meet these challenges by issuing International Standards and Technical Specifications (TS), which facilitate the interoperability and integration of the new systems with existing transmission assets. One of the key Standards defining the communication and control interfaces of all DERs with the conventional grid is IEC 61850-7-420, published by IEC Technical Committee (TC) 57: Power systems management and associated information exchange.

This Standard is part of the IEC 61850 series which comprise the core publications applicable to the implementation and interoperability of smart grids. They include IEC 61850-6, which deals with communication in substations relating to intelligent electronic devices and IEC 61850-4, which applies to substation automation systems, for example. Digital substations are one of the constituent parts of smart grids. They require fewer cables and take up less space than conventional substations. They are also easier to maintain due to their standardized interface. The three main functional levels of digital substations are process, bay and station level. Signals are transmitted from the process workstation. The system protection and control processes are performed in the bay level workstation, while the engineering and report activities are produced at station level.

IEC TC 8: Systems aspects of electrical energy supply, aims to improve coordination between the different IEC TCs which prepare Standards in transmission, distribution and use of electrical energy in order to ensure all the necessary system aspects are covered. The TC deals with basic topics relating to DERs such as their interconnection with the grid, as specified in IEC TS 62786. Its Subcommittees (SCs) prepare publications relating to grid integration of renewable

↘ **Fact**

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The demand for electrical power is soaring.

energy as well as to the design and management of decentralized electricity supply systems.

The IEC has also formed a systems committee, IEC SyC Smart energy. It works at a systems level and spans the activities of several IEC TCs in the area of smart grid technologies. SyC Smart energy supports the work of these TCs, by issuing a number of documents which can then be referenced by them. It publishes a Technical Report, IEC TR 63097, which sets out a smart grid standardization roadmap. Its aim is to highlight International Standards which have been specifically designed to support the transition towards smarter energy.

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Smart meters and intelligent switches

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IEC TC 13 prepares Standards in the field of electrical energy measurement and control, for smart metering equipment and systems forming part of smart grids. Smart meters are integrated into metering systems that exchange data with other systems, in support of a range of business processes. Among other things, these devices supply power quality measurement, load management, local generation management, customer information, customer and contract management and other value added functions. IEC TC 13 issues many Standards which have relevance to the smart grid, including the IEC 62052 series on general requirements, tests and test conditions for electricity metering equipment for both alternating and direct current and the IEC 62056 series on electricity metering data exchange. A joint working group, JWG 16, is set up within IEC TC 57, in order to make sure that the smart metering Standards of IEC TC 13 are harmonized with the metering specifications of IEC TC 57. The group's goal is to integrate smart meters into smart gird applications such as distribution automation.

IEC TC 17 publishes Standards on high-voltage switchgear and controlgear as well as their assemblies, together with the associated control and/or power equipment, measuring and signalling equipment. The TC issues key Standards required for the conventional grid, such as the IEC 62271 series on high-voltage switchgear and controlgear. In that series, IEC 62271-3 lays the ground for smart grids. The publication specifies the digital interfaces based on the IEC 61850 series, the core smart grid Standards published by IEC TC 57. Smart grids require intelligent switches equipped with electronic processors and sensors. Embedded intelligence enables smart switches to tackle problems locally, as they occur. This allows them to respond more efficiently to changes in system conditions thereby improving service reliability.

The International Special Committee on Radio Interference (CISPR), issues a guide to the application of CISPR Standards in support of the introduction of smart grids. The guidance document looks at the electromagnetic compatibility of equipment connected to the smart grid – for instance smart meters or grid-connected power converters. CISPR is made up of IEC National Committees and several international organizations, including the International Telecommunication Union (ITU) and the European Broadcasting Union (EBU).

↘ **Fact**

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IEC TC 13 prepares Standards for smart metering equipment and systems forming part of smart grids.

Improving the energy efficiency of existing assets

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While the introduction of these new systems and their integration within the conventional network will generate energy savings, many steps are being taken to improve the energy efficiency of existing transmission assets. They include the use of high efficiency transformers, more efficient overhead conductors, high temperature superconductors and high voltage direct current power transmission systems. The IEC publishes the International Standards that enable these energy-saving technologies to be planned and used in transmission and distribution networks around the world.

Lost in transmission

A power plant produces electrical energy of medium (20 000 V) or low (1 000 V) voltage which is then elevated to high voltage, up to 500 kV, and in some cases ultra high voltage of 750 to 1 000 kV, by a step-up substation. Electrical power is then transmitted across long distances by high-tension power lines. The higher the voltage is, the greater are the levels of power that can be transmitted. A step-down substation converts the high voltage back to medium voltage and electrical power can then be transported by medium voltage lines to feed medium and low voltage transformers, through overhead lines or underground cables. Most users receive low voltage feeds but big power consumers such as factories or hospitals receive medium voltage feeds.

A transformer operating at power close to the assigned value will provide optimum efficiency. Medium and low voltage transformers are of different types and their efficiency may range from 90% to 98%, depending on the amount of power delivered. IEC TC 14 publishes the IEC 60076 Standards which cover all aspects relating to transformers from test methods to loading guides and measuring methods for loss.

Energy loss over long distances

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Transmitting electricity over long distances results in energy losses, from overhead lines and conductors, transformers and power cables. They are due to three different effects:

→ The Joule effect, where energy is lost as heat in the conductor (a copper wire, for instance)

↘ **Fact**

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The longer the distance electricity is transmitted over, the bigger the energy loss.

- Magnetic loss: energy dissipates in metallic parts penetrated by magnetic fields
- The dielectric effect, where energy is absorbed by the insulating material

The Joule effect in overhead lines and power cables accounts for losses of about 2,5% while the losses in transformers range between 1% and 2%, depending on the type and ratings of the transformer. A 1% saving in the electrical energy generated by a 1 000 MW power plant equates to an additional 10 MW available for consumers, which is sufficient to supply between 1 000 and 2 000 more homes.

Heat loss due to the Joule effect

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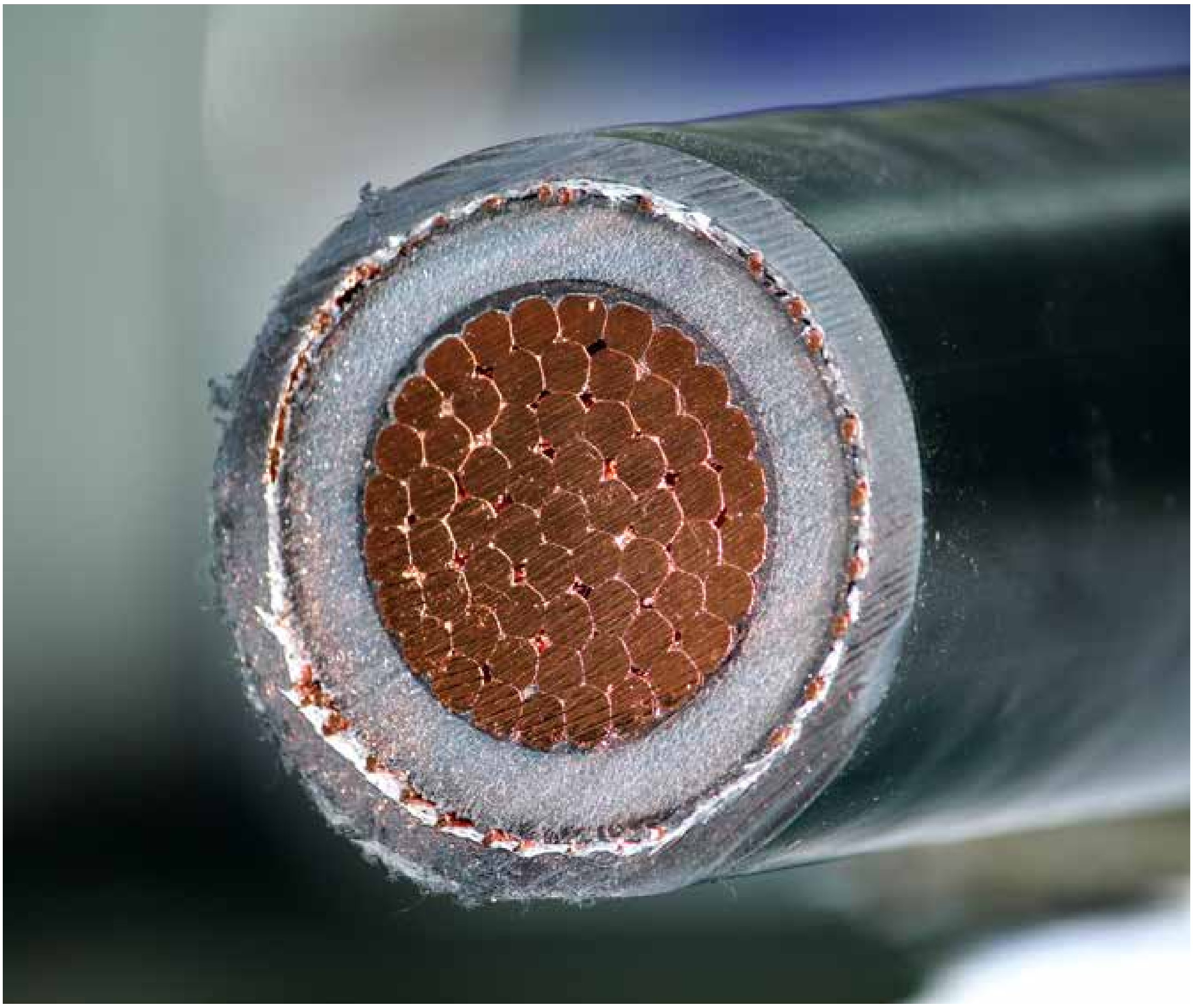
The high current carried in overhead lines and power cables results in increased temperatures, causing energy loss due to the Joule effect. As electrical current passes through a conductor, its temperature rises and this heat then bleeds away as lost energy. This raises design considerations for the long-distance transmission overhead lines and electric cables that deliver energy from the step-down substations to the user.

IEC TC 20 helps to establish Standards for cables rated up to 500 kV. They include IEC 60502 (cables up to 30 kV), IEC 60840 (cables above 30 kV and up to 150 kV) and IEC 62067 (cables above 150 kV and up to 500 kV). It also publishes the IEC 60287 series on the calculation of the current rating of electric cables.

IEC TC 11 prepares Standards on overhead lines. It issues IEC 60652, which tests towers and structures of overhead lines for voltages above 45 kV, as well as IEC 60826, which establishes the design criteria of overhead transmission lines.



↘ **Fact**

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IEC TC 20 publishes the IEC 60287 series of Standards on the calculation of the current rating of power cables.

Standards for improving energy efficiency

More efficient conductors

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The use of specially-designed overhead conductors can increase the current-carrying capacity and decrease the energy losses of overhead lines. These include thermal-resistant aluminium alloy conductors, composite material core conductors and expanded diameter conductors. Their performance has improved thanks to the development of new structures and materials. Conductors with pre-formed annealed (heat-treated) wires and Milliken conductors (stranded conductors comprising an assembly of shaped stranded conductors, lightly insulated from each other) can reduce electrical losses for power cables.

IEC TC 7 publishes Standards which establish the guidelines and specifications for overhead electrical conductors, notably IEC 61089 and IEC 62219, as well as IEC TR 61597 on the calculation methods for standard bare conductors. IEC TC 20 publishes IEC 60228, detailing the requirements of a wide range of conductors of insulated cables, including solid and stranded copper, aluminium and aluminium alloy conductors. IEC TC 55 prepares Standards for wires, including large insulated and covered wires for power transformer industries. It publishes the IEC 60317 series on specifications for enamelled round copper winding wires, for example.

High efficiency transformers

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High efficiency transformers differ from standard ones through their use of high quality magnetic material and selected insulating substances. IEC TC 68 publishes International Standards for the magnetic alloys and steels used in transformers, including the IEC 60404 series on magnetic materials. It also prepares publications on the new soft magnetic materials being used in high efficiency transformers because they are less prone to energy loss.

Insulating substances, or dielectrics, are evolving in line with environmental concerns. Mineral oil, essentially a form of distilled crude oil, is still the most commonly used dielectric for medium and large transformers. Since this type of liquid can generate polluting by-products such as sludge and organic acids, alternative insulating liquids are increasingly being used, especially in distribution transformers.

IEC TC 10 prepares product specifications, test methods as well as maintenance and use guides for liquid and gaseous dielectrics. The TC publishes most of the Standards applicable to insulating liquids, including IEC 61620, which describes a test method for determining the dielectric dissipation in electric liquids.

IEC TC 15 establishes specifications for solid electric insulating materials, including glass and ceramic, paper and press boards, films

© CEphoto, Uwe Aranas/Wikimedia commons

↘ **Fact**

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Conventional substations take up more space than their digital counterparts.

and laminates, mica products, tapes, as well as varnishes and resins. The development of new products or the improvement of current materials requires constant monitoring of existing Standards as well as the publication of new ones. The TC issues the IEC 60371 series on the specifications for insulation based on mica materials, for instance.

IEC TC 112 publishes International Standards that help in measuring the thermal endurance of the insulating material, its electrical strength and its resistance to tracking as well as its dielectric and resistive properties, including the IEC 60243 series on test methods for the electrical strength of insulating materials.

Superconductivity

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Most conductors have some degree of resistance which prevents electricity from flowing effortlessly. Superconductors are materials that offer no resistance to the flow of DC current at extremely low temperatures. The material exhibits minimal losses when subjected to AC currents. Today, superconductivity occurs at 138 K (–135 °C). This is known as high temperature superconductivity (HTS) as the temperature initially used for superconductors was even lower. Typically, liquid nitrogen is used as a coolant, at temperatures ranging from 65 K to 80 K (from –208 °C to –193 °C). IEC TC 90 prepares International Standards relating to superconducting materials and devices, including the IEC 61788 series on superconductivity.

HTS cables generate less energy loss than conventional cables and are also more lightweight and compact. As a result, their installation is easier, faster and takes up less space. Research and commercial projects are looking at using HTS cables for high voltage transmission lines run underground. The potential of HTS cables for the highly efficient transmission of large quantities of electrical power means that they are viewed as a possible replacement for the conventional high voltage cables that form the backbone of a transmission grid and which carry power over long distances. IEC TC 20 publishes IEC 63075, which addresses test methods and requirements for superconducting AC power cable systems and their accessories.

For the time being, HTS cables are only employed over short distances because of the problems implicit in supplying the nitrogen they require for cooling purposes. Research into improved cooling methods is taking place to make it possible to use these cables over long distances.

High voltage direct current

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Power loss in high voltage direct current (HVDC) systems is lower than for the more ubiquitous high voltage alternating current (HVAC) systems over long distances. Direct current transfers active power alone. Losses are therefore lower than with alternating current which also transfers reactive power. HVDC also allows the transfer of power between grids running at different frequencies, making the overall grid system more efficient and more resilient to failure.

HVDC voltage is suitable for extra long-distance transmission schemes above 3 000 km. This is attractive for countries where energy generation is situated at a long distance from end users. Voltage source converter-based HVDC technology has also been used to integrate energy generated by long-distance offshore wind turbines. Connecting small electrical networks to the main grid also becomes feasible.

IEC TC 115 prepares International Standards for HVDC transmission for DC voltage above 100 kV and issues publications dealing with the design aspects, technical requirements, construction and commissioning, reliability and availability, as well as the operation and maintenance of HVDC equipment. This includes extra high voltage DC (EHVDC) transmission at 400 kV, 500 kV and 600 kV, as well as ultra high voltage DC (UHVDC), from 800 kV to 1 100 kV.

IEC TC 20 also publishes an important Standard on HVDC cables, IEC 62895. It concerns cables with extruded insulation and rated voltage up to 320 kV.

IEC TC 42 publishes Standards on high voltage and high current test techniques. The TC is working on publications that deal

with the increased use of DC transmission, as well as UHV in both AC and DC voltages. One example is IEC 62475 which specifies the requirements for test currents and measuring systems for high and low voltage equipment.

Nanotechnologies

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The efficiency of electricity transmission can also be improved through the application of nanotechnologies. Nanoscale transmission wires called quantum wires produce no line loss or resistance when used in a grid, for instance. Examples of nanoscale materials with the potential to significantly impact the transmission of electrical energy in the foreseeable future include, but are not limited to, carbon nanotubes and quantum dots. Carbon nanotubes are a type of fullerene molecule formed when atoms of carbon link together into tubular shapes. They are generally extremely light, strong and resilient, and some are more electrically conductive than steel or copper.

Quantum dots are semiconductor crystals with electrical and optical properties that provide more efficient lighting and solar collection and make them attractive for use in electricity transmission. IEC 113 publishes International Standards in this promising area. They include IEC 62624 on the test methods for measuring the electrical properties of carbon nanotubes.

↘ **Fact**

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Voltage source converter-based HVDC technology has been used to integrate energy generated by offshore wind farms into the transmission system.

Key contribution from the IEC

The emergence of DERs and the introduction of smart grids are changing the way in which electricity is transmitted and distributed. IEC International Standards are paving the way for this transition by helping to integrate these new technologies within the existing network. Moreover, the IEC issues essential publications that help to improve the energy efficiency of existing transmission and distribution assets. Standardizing the use of these energy-saving technologies in the field of transmission and distribution is making a key contribution to the reduction of carbon emissions around the world.

Fact

—

IEC International Standards are helping to integrate new technologies within the existing network.

About the IEC

The IEC, headquartered in Geneva, Switzerland, is the world's leading publisher of international standards for electrical and electronic technologies. It is a global, independent, not-for-profit, membership organization (funded by membership fees and sales). The IEC includes 173 countries that represent 99% of world population and energy generation.

The IEC provides a worldwide, neutral and independent platform where 20 000 experts from the private and public sectors cooperate to develop state-of-the-art, globally relevant IEC International Standards. These form the basis for testing and certification, and support economic development, protecting people and the environment.

IEC work impacts around 20% of global trade (in value) and looks at aspects such as safety, interoperability, performance and other essential requirements for a vast range of technology areas, including energy, manufacturing, transportation, healthcare, homes, buildings or cities.

The IEC administers four conformity assessment systems and provides a standardized approach to the testing and certification of components, products, systems, as well as the competence of persons.

IEC work is essential for safety, quality and risk management. It helps make cities smarter, supports universal energy access and improves energy efficiency of devices and systems. It allows industry to consistently build better products, helps governments ensure long-term viability of infrastructure investments and reassures investors and insurers.

A global network of 173 countries that covers 99% of world population and electricity generation

Offers an affiliate country programme to encourage developing countries to get involved in the IEC free of charge

Develops international standards and runs four conformity assessment systems to verify that electronic and electrical products work safely and as they are intended to

IEC International Standards represent a global consensus of state-of-the-art know-how and expertise

A not-for-profit organization enabling global trade and universal electricity access

Key figures

173
members and affiliates

>200
technical committees

20 000
experts from industry, test and research labs, government, academia and consumer groups

>10 000
international standards published

4
global conformity assessment systems

>1 million
conformity assessment certificates issued

>100
years of expertise

Further information

Please visit the IEC website at www.iec.ch for further information. In the “About the IEC” section, you can contact your local IEC National Committee directly. Alternatively, please contact the IEC Central Office in Geneva, Switzerland or the nearest IEC Regional Centre.

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