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European Community Announces Major Cable Developments

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In 1991, CIGRÉ (Conseil International des Grands Réseaux Électriques) stated that in developing extra-high-voltage (EHV) cables with extruded insulation up to 400 kV, a principal factor was the effect the new materials and strict quality control at all stages of production had in electrical stress evolution. Subsequent development has been possible because of the European cable industry's extensive testing, manufacturing regimes and decades of in-service experience of lower-voltage cables designed with similar insulation. This development practice will continue and is expected to play an important role in the improvement and fine-tuning of IEC 62067 (International Electrotechnical Commission) to optimize the reliability of EHV cable systems.

European cable manufacturers acknowledge and value the utility in-service experience of cable systems, which together with testing and engineering experience, and the use of proven materials and compounds for cables and accessories, are the foundations of European expertise. For example, the first 225-kV extruded cable installed in France in 1969 is still in operation with an excellent service record. More recently, 400-kV cables with extruded insulation were installed at French nuclear plants in 1985 and are still in service. Following these installations, large 400-kV underground cable systems with extruded insulation were installed in Germany and Denmark. Further major projects are planned or are under construction.

Technical Advantages of EHV Cable Systems

The quality improvement of solid dielectric materials, manufacturing processes and installation techniques are all leading to an increase in the operating voltage of cable systems. Service performance confirms the reliability of EHV XLPE-insulated cable systems. Currently, economic XLPE cable systems are operating at voltages up to 400 kV, offering transmission-system operators circuits that have transfer capacities in excess of 1000 MVA.

Because the soil temperature at the depth at which cable systems are buried is relatively constant — varying by ±5°C (41°F) throughout the year — the calculated operational continuous current ratings can match the actual cable capacity. The large thermal capacity and thermal time constants of cable systems, which depend on the circuit load cycle, permit the use of transient or short-term peak loading without exceeding the cable's thermal design limits and without incurring irreparable damage to the cable insulation. Moreover, temperature monitoring throughout the cable route is now available via a fiber-optic cable incorporated into the cable during manufacturing. This provides system operators with real-time data to determine all circuit-loading decisions for optimum circuit use.

The new technologies incorporated in the design and insulating materials now used in cables continue to improve the reliability above the average value of 0.072 cable faults per 100-circuit km per annum (0.115 cable faults per 100-circuit miles per annum). Also, under normal circumstances, cables do not experience faults as a result of adverse climatic conditions, such as wind, ice, snow and fog.

Increased insulation efficiency has reduced the overall dimensions and weight of the cable; hence, these reductions result in the ability to increase each drum length by approximately 25%. This reduces freight costs and, more importantly, the number of joints required per circuit.

In addition to cable development, installation techniques have improved. Wider adoption of direct laying and use of ploughing and mole techniques has significantly reduced the additional costs associated with installing cable systems.

The continual development of the manufacturing processes used for cables and their accessories, coupled with the availability of more efficient installation methods, has resulted in reduced costs and more cost-effective underground cable systems. Often, once lifetime costs are evaluated, cable systems are economically advantageous.

Environmental Advantages of EHV Cable Systems

Environmental regulation, electric utility deregulation and public opinion affect the planning and refurbishment of transmission systems and distribution networks. At present, cables with extruded insulation are increasingly replacing conventional fluid-filled cables. The reduction in size and the use of fewer natural resources means that they produce more recyclable materials and less scrap at the end of their useful life.

Cable systems have many environmental advantages when compared to overhead lines at all levels of system voltage:

- The installation of a cable system is more aesthetic because it has no permanent, visible impact on the landscape, making these systems are acceptable to local communities.
- Public opinion remains skeptical of electric and magnetic fields, but no adverse effects on health have been established. However, cable systems have no external electric fields, and can be designed to comply with national and international limits on magnetic field levels.
- In general, cable systems provide improved levels of protection to contractors and the general public because they are buried. Statistics show there are fewer electrocutions from accidental contact and flashovers with cable systems than overhead lines.
- Network security is maintained once the cable system has been installed, as experience confirms that they are not as vulnerable as overhead lines circuits to sabotage, theft of materials or illegal abstraction of energy.

Because cable systems incur fewer electrical losses per MVA power transfer than overhead lines, the required generation capacity required and greenhouse gas emissions are reduced. This issue satisfies the expectations of the current environmental legislation and regulatory moves within the European community.

Large European Cable Projects

- **Metropolitan Power Project in Copenhagen, Denmark**

  The NESA project in Copenhagen was part of the utility's major scheme to modernize and update the Danish city's EHV network by eliminating the majority of the existing overhead transmission lines from densely populated areas. The cable project was split into two sections. The southern route, comprising of a 22-km (13.7-mile) cable link, was commissioned in 1997. The shorter northern route consisted of a 12-km (7.5-mile) cable link and was commissioned in 1999. In total, cable manufacturers delivered approximately 104 km (64.6 miles) of 400-kV, 1600-mm^2 (2.5 $inches^2$) single-core, XLPE-insulated cable having a lead sheath and PE outer sheath for the two cable links and circuit terminations. The cable, manufactured in 880-m (2880-ft) lengths and weighing around 45 tons, was delivered to the site on 5-m (16-ft) diameter drums. A total of 114 cable joints, 24 GIS terminations and 12 outdoor terminations were installed in this two-stage project that provides the EHV system with circuits rated at 1000 MVA.

  As this project was the first of its kind in the world, an intensive prequalification development program was undertaken to verify that the 400-kV XLPE, prefabricated joints and GIS, and outdoor terminations satisfied international standards.

- **BEWAG 400-kV Cables in Berlin, Germany**

  In 1996, the Berlin utility BEWAG, following the successful completion of the prequalification testing of 400-kV XLPE-insulated cable, ordered two 400-kV, XLPE-insulated cables for installation in a 6.3-km (3.92-mile)-long tunnel in the center of the German capital city. The air-ventilated tunnel, constructed at a depth varying from 25 m to 35 m (82 ft to 114 ft) below ground level, has an internal diameter of 3 m (9.8 ft). The 1600-mm^2 segmented copper-cored cable has a transmission capacity of 1100 MVA per circuit. These two cable circuits form part of a diagonal 400-kV link between the existing transmission systems on the east and west boundaries of Berlin and were commissioned in December 1998.

  BEWAG awarded a second 400-kV XLPE-insulated cable contract in late 1998 for the supply and installation of two 5.4-km (3.4-mile) cables in an underground tunnel. This contract was completed and commissioned in July 2000.

- **Red Eléctrica de España (REE) Barajas Project in Madrid, Spain**

  AENA, the Spanish Airport Authority, is extending the Madrid Barajas International Airport with the planned construction of two new runways. Because the existing 400-kV transmission lines operated by REE were erected on the airport's boundary would have been an obstruction to incoming aircraft, they had to be dismantled. Sections of both circuits will be replaced by underground cables installed in a tunnel.

Each 12-km circuit will consist of three 400-kV, single-core, XLPE-insulated cables with 2500-mm^2 (3.9 $inches^2$) segmented copper conductors delivered to site in 850-m (2780-ft) lengths. To ensure each circuit has a winter maximum transfer capacity of 1700 MVA, a special forced ventilation system will be installed in the tunnel. This project was commissioned on schedule and energised in February 2004

- **The ELTRA Jutland Project**

  The installation of a 400-kV connection between Aalborg (North Jutland) and Århus, an existing EHV substation in Trige, completed the ring for Jutland's EHV transmission system. The 400-kV circuit comprises overhead line and underground cable sections. The three 400-kV cable sections have a total route length of 14 km (8.7 miles) and have been designed according to the principle of equivalent short-time ratings of the cable and overhead line. This project was the first of 400-kV cables to be directly buried in agricultural land and nature reserves. Special attention was given to the design of transition compounds, the aesthetic design to minimize the visual impact and the use of composite insulators for the terminations. This 400-kV circuit was commissioned in August 2004.

- **The National Grid Company (NGC) Elstree Project**

  NGC has planned a 1600-MVA bulk power transmission circuit via a 400-kV XLPE-insulated cable system to supply the increasing demand for energy in London's metropolis. The cable will be installed in a 20-km (12.4-mile)-long tunnel having an internal diameter of 3 m positioned 30 m (98 ft) below ground level, a depth that avoids existing obstructions and giving the tunnel a straight-line profile. The tunnel will be equipped with a forced-air-ventilation system to increase the maximum power rating of the circuit.

The cable will be manufactured, handled and delivered to site in 1000-m (3270-ft) lengths. This section length was designed to reduce the number of joints required. The cable outer sheath will have an extruded flame-retardant layer to prevent the development of fire in the tunnel. On-site testing and commissioning are scheduled for mid-2005.

Continuing Efforts

Continuous development of solid insulation materials, use of premolded cable accessories and improved cable-installation methods have all contributed to a reduction in the overall cost of installing EHV cable systems. Although the environmental advantages of cable systems compared to overhead lines are difficult to quantify, they are subject to public exposure and debate in the environmental impact statements that are now incorporated into the planning applications for all major transmission system projects. Utilities are finding the negotiation of new rights-of-way for overhead transmission lines increasingly difficult. Often there are no alternatives to upgrading existing overhead lines but increasing conductor size, increasing the number of circuits per tower, or increasing the voltage to comply with system requirements. In many instances, circuit undergrounding becomes the only acceptable and realistic alternative.

European cable manufacturers have made great strides in their efforts to reduce the cost of cable systems, but there are further opportunities for rationalization and economies within the industry. These will materialize if the institutions responsible for international standards applicable to the cable business address the standardization of the complete cable system rather than the present practice of producing separate standards for cables and accessories.

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