Special Report – Technical Theme 1

NETWORK COMPONENTS

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Session 1 is organized into 2 days:

- the plenary session will be an opportunity to examine the essential themes relative to network and substation components.
- the so-called "beta" session will emphasize two different themes:
    - the diagnosis and monitoring of the equipment for which many articles have been proposed and will be discussed during a round table
    - a second special roundtable during which the articles proposing technical innovations of interest will be presented more specifically.

The special report presented in the following deals with the reports submitted to discussion during the plenary session. It is based on two preferential themes and seven different chapters:

Theme 1: equipment design

- cable design
- substations equipment design
- overhead lines design
- electrotechnical materials
- lightning arresters

Theme 2 : Diagnosis and preventive maintenance

- maintenance of the network and substation equipment

Theme 3 : environmental issues

- Environmental aspects of substations and switchgear

THEME 1 : EQUIPMENT DESIGN

Cable design

Article 1.1 (Belgium) describes the work carried out in Belgium to reduce the cost of links at 36 kV
Cables insulated with polyethylene have been available for more than 20 years and since then, manufacturing specifications have not changed, in particular concerning the thickness of the insulation. The Belgian company wished to redefine its requirements and, in particular, change from a constructive specification to a functional specification. The result is a new cable with thinner insulation (gain of 2.2 mm, a reduced metal shield (still unsuited to the short-circuit current) and an outer sheath that is reduced in conformity with the IEC standards. The interfaces within existing cables have been tested. The results of the tests are favorable and several hundred km of cable has been laid. Even if all the longevity tests have not been run, and although we have little experience return, users are confident and would like to see this product incorporated into the IEC standards.

Article 1.2 (France) describes a similar development for French MV cables.
The French MV cable has been around for more than 20 years and the return on experience is excellent. In particular, some of the tightness questions have been resolved and the tests have been sized so as to test out the performance in this area. Progress had been made in the manufacturing techniques using synthetic insulation (quality of materials, methods of extrusion) and optimization was possible. The first development retained was to reduce the thickness of the insulation from 5.5mm to 4.5mm.
The compatibility of this cable with existing cables has been investigated. It also benefits from the progress made in the technologies now available for connecting accessories. The new cable, called the 2000 cable, has been procured since March 2000 for sections of 150 and 240 mm^2. This product is liable to be beneficial to the burying of MV networks.

Question 1
what elements of design or return on experience enable you to affirm that the developments implemented on this cable do not affect the reliability of the system?

Article 1.3 (Sweden) presents the continuous link installed in GOTLAND.
The electrical system on the island of GOTLAND only uses wind-generated production. A DC link ensures connection to the mainland. It was requested that this link should offer particularly high-performance so that wind generated production does not interfere with customer use, inducing particularly severe demands on the link control and design. Performance and testing are outlined below.

Article 1.4 (The Netherlands) deals with the subjects of standardization, qualification and diagnosis, the key elements in the control of a cable distribution system.

The optimization of a cable distribution system is based on the method of qualification, the diagnostic system, the monitoring of the thermal properties of the cable and on standardization. The philosophy outlined in the present article looks at the advantage of monitoring the manufacturing process rather than running tests on the finished product, and considers the traceability of the components used. There is no doubt that the characterization of the materials involves tests that are very representative of functional performance levels. These characterization tests may use new diagnosis techniques that are adapted to the components. Accordingly, infrared spectroscopy is represented. As far as the diagnostic is concerned, several tools are described, more particularly the measurements of partial discharges carried out after a life duration, or a given number of faults. The monitoring of thermal constraints using dedicated sensors permits optimal cable loading. A humidity detector conveying information by optical fiber is a means of identifying mechanical injury. The article suggests inserting some of the provisions as tested into cable standardization.

Equipment design

Article 1.5 (France) deals with a new neutral reactance. It refers to the description of the various types of MV neutral management. Insulated neutral, non-distributed solidly earthed neutral, neutral earthed by a resistor, by impedance, by a composition of a resistor and impedance and by a compensation coil. The neutral management system currently used at EDF is described here, followed by the system toward which the company is now turning. It includes an impedance variable in steps and a control and test system. The expected functional objectives are defined in terms of quality in particular, and the progress made with the project is stipulated.

Article 1.6 (Belgium) explains the effect of fast transient states on transformer insulation.
The tests habitually used to do not cover all the constraints affecting the transformers in their environment, and in particular for the fast transient overvoltages. The purpose of the article is to present a simplified simulation model, describe the results of equipment behavior modeling when affected by such constraints, and to compare the results with full-scale tests. These tests are also a way of simulating of the accelerated aging process, by injecting high frequency pulses and monitoring aging by detection of partial discharges.

Article 1.7 (The Netherlands) indicates the specific increase in the performance of a switch converted into a circuit-breaker.
The insertion of a circuit-breaker into an underground network group reduces the cut-off time when a fault occurs. To install a device like this, without generating a high cost, a solution based on the combination of a switch and a vacuum in circuit-breaker can be associated with a protection system. Suitable locks avoid any false maneuvering. The three-pole switch ensures a visible cut-off and isolates the forward side of the circuit in the event of tripping on a fault. The standards used as a reference are indicated below. So far, and several feeders have been equipped with this device.

Article 1.8 (Germany) presents a family of vacuum switches with global applications based on standard components.
The design of new products must always allow a compromise between customer expectations: diversity of products, adaptation to specific needs, short availability time, low cost, and manufacturer objectives: production standardization, modularity and small numbers of subassemblies.
The range of switches presented here focuses on these objectives, based on a vacuum switch operated by a magnetic system, a solution that minimizes the number of components. The

elements governing the size of the switch are essentially, the short circuit current, governing the size of the contact, the dielectric strength which governs the length of the bulb, and the forces applied to the actuator whose size depends on the short-circuit current. This equipment has been applied to a variety of uses and has proved the advantage of this approach.

Article 1.9 (Germany) deals with the design of an MV circuit-breaker specially designed for industrial purposes (in a lignite mine).
The particularly difficult operating conditions of equipment in the industrial environment, for instance in mines, call for very stringent design and test methods. The article proposes an approach that includes the special provisions available at all the life stages of the cable. During the design and production test phase, the partial discharge is measured and mechanical and electrical testing is performed with inspection of the control. Vibration tests are particularly important. A special test is carried out during the installation and new partial discharge measurements are made. Maintenance during operation must be minimized, more particularly by the use of suitable lubricants. Gas emissions must be controlled. At life end, the materials are separated and recovered. A process of this type guarantees the performance and the environmental quality of the installation.

Article 1.10 (Sweden) presents a new circuit-breaker isolating switch concept that reduces costs and improves reliability while being adapted to the renewal of a primary substation.
An innovative solution for the reconfiguration of a primary substation using a high voltage circuit-breaker isolating switch instead of traditional separate circuit-breakers and isolating switches is described. This solution reduces the dimensions and thereby facilitates the operations for the renewal of the existing inventories. It reduces the number of pieces of equipment used, thus reducing the total cost. The solution does not reduce overall reliability. To do this, the functional characteristics of the circuit-breaker have been adapted to guarantee cut-off and permit mechanical and electrical locking. The circuit-breaker developed in this project has also been equipped with a service monitoring system.

Question 2
Controlled cost and improved reliability of the two lines of progress developed in particular in the articles presented here. Will the presented solutions be capable of achieving the objectives expected by the distributors? What are the constraints preventing suppliers from going further in boosting performance and cutting costs?

Article 1.11 (France) presents a new concept for MV/LV substations.
The transformer with built-in cut-off and protection is a development of the traditional transformer. It can be placed in an MV/LV substation without external protection. This new equipment opens the way to a simplified MV/LV substation including a cut-off passage without a transformer protection cell. In this way, there is no need for an MV cell in the substation, meaning a gain in space and costs. It is also proposed to go further than this development, and to connect the transformer directly to the cable, without a cut-off passage. The predicted reliability levels lead to cut-off forecast times similar to those currently reported. This simplification in the scheme goes hand in hand with a significant cost reduction of approximately 25% but with a definite change in the operating mode.

Article 1.12 (Belgium) deals with the design of secondary substations to resist internal arcing.
Resistance to an internal arc is a definite safety factor. When a circuit-breaker is installed in limited and confined spaces there is a problem because the space available in the substation will not always allow gas expansion compatible with the desired pressure levels. The article presents different studies on the configuration of cabin substations with proposed solutions to limit these overpressures with the use of the buffer volumes. A modeling tool is used for simulating pressure variations. The results can be adapted to substations installed inside buildings. Constructive recommendations are also available.

Article 1.13 (Spain) deals with the development of MV/LV substations.
In order to reduce the losses, spanish companies have decided to structure their networks with shorter LV outgoings and limited power MV/LV transformers unit. This has caused increased interest in secondary compact MV/LV substations that can be used on a turnkey basis. Three solutions are presented: an indoor solution, an outdoor solution and a solution for burying. In all 3 cases, the surface area taken up is much smaller compared with traditional solutions. To decrease size even more, the insertion of the transformer protection into the system is considered desirable. Special measures are taken to reinforce product safety: internal arc testing, elaborate protection of the transformer

(fuses and circuit-breaker, oil leak detector, oil temperature detector). A remote control system can facilitate the operation of the equipment.

Question 3
the design with respect to the substation and not the equipment permits higher performance, but gives rise to new questions: will these orientations satisfy distributors and suppliers?

Article 1.14 (Belgium) covers the approach initiated in an article of CIRED 99 for the standardizing of the man-machine interface of network cut-off equipment. Faced by a variety of models, well beyond the understood demands of the standardization of line diagrams, we can imagine that it would be possible to standardize the signaling of basic maneuvering operations. Indeed, accidents often come from a lack of attention or concentration. The use of drawings and pictograms schematizing the steps of a procedure would facilitate understanding by the personnel. It would be a source of improved safety for them.

Overhead lines design

Article 1.15 (Spain) describes how the use of high temperature conductors could significantly improve the capacity of an equipment. The induced question is generally that of controlling the lengthening of the conductor, and therefore the sagging of the line. Obviously, only solutions that can be established from towers in place are interesting for upgrading an equipment. The use of composite conductors (a core with peripheral conductors), having a core with an almost zero linear dilatation coefficient is one solution. A number of solutions are presented. At high temperature, the core governs the lengthening. At low temperature, the conductor in its entirety takes up the voltage. In addition, the electrical resistance of conductors like this is low. Gain can be of up to 70%.

Article 1.16 (Iran) analyzes the performance of composite material insulators, coming to the conclusion that their level is comparable to that of glass or porcelain insulators on the basis of similar constructive specifications. The gain in weight is approximately 20%. The three main manufacturing techniques of these insulators are described. They are insulators intended for 15, 20 or 63 kV networks. Electrical and mechanical testing on the manufactured products is described. An overall saving is expected with the use of these products.

Article 1.18 (Brazil) -presents a type of LV distribution network suitable for dense and low organization urbanization areas with narrow roads, small and numerous where overhead networks are difficult to install because of the short protection distances. Nevertheless, power has to be distributed with use of a system that is not beneficial to fraud. The solution proposed by the article is as follows: MV networks with 2 or 4 conductors, secondary networks with 4 conductors, overhead lines formerly using uninsulated conductors, now replaced by preassembled conductors. A new approach consisted in installing an underground network at the surface, following the profile of the road. The network is placed in steel tubing, thus avoiding current theft. The network is built without a maneuvering point from transformer to meter. Each cable is powered by a dedicated transformer. This solution contributes to the social development of electrification in highly populated areas.

Article 1.19 (Austria) presents a 20 kV protected overhead line technology.
The use of conductors isolated by a coat of 20 kV synthetic materials was tested in Austria. This solution offers a number of advantages by facilitating the routing of lines through wooded areas, improving transmission capacity, enhancing safety but also decreasing costs. Indeed, pruning can be reduced, and it has been possible to reduce distances between conductors, having a beneficial effect on the cost of the equipment, but also on indemnification paid to residents under the lines. Experience has shown better resistance to snow, the absence of faults on contact with branches and advantageous behavior in the event of arcing. Arc propagation is reduced. Experiments since 1994 are proving to be positive.

Question 4
are the solutions presented liable to restore interest in overhead lines in terms of supply safety and economy, or is underground progress, under the impulse for aesthetics, an inevitable next step?

Electrotechnical materials

Article 1.20 (USA) presents a special polymer for purifying transformer oil.

The regenerating of transformer oil is an essential operation to combat the degradation of the insulator due to the oxidization of the product. Longer equipment life is a saving factor. Composite cements have been used in the USA for 20 years as insulation, to replace porcelain. Because of their composition, composites have excellent absorption faculties. These absorption properties are put to good use to purify transformer oil. The method is easier to use than traditional methods that involving heating and centrifugation. Ideally, it would be necessary to be able to construct the tank with these composite materials.

Article 1.21 (USA) presents a fiber designed to reinforce the high temperature strength of insulating paper.
Paper is cheap and efficient insulation. However, overheating causes degradation in it. Progress already made in the 50's has made it possible to increase operating temperatures from 5 to 110°. Very costly products allow operation at 220°. Other products based on cellulose offer good behavior under heat, but cannot be used alongside conventional liquid dielectric. The addition of synthetic fiber to the paper boosts performance. Many tests have been performed to select the best combinations. Aging tests make it possible to measure the advantage of the solution. The gain is in a ratio of 3 to 5. A product like this will allow transformers to operate at a higher temperature or permit higher temperature temporary overloading.

Question 5
what is the expected progress in terms of electrotechnical materials to achieve the posted objectives: improved reliability, reduced costs? Is there any short-term progress to be expected? In what area? Are some of the products announced at the previous CIRED now industrializable?

THEME 2 : MAINTENANCE OF THE NETWORK AND SUBSTATION EQUIPMENT

The border between diagnostic and maintenance is often difficult to identify. Some of the articles examined during the "beta" session will also deal with maintenance, even if the round table focuses on diagnostic.

Maintenance is generally presented as being essential to reduced investment costs. The methods of optimized maintenance through reliability are described abundantly in several articles.

Article 1.22 (Sweden) proposes a new design of substation maintenance.
The proposed maintenance system aims at establishing a link between the equipment to be maintained and the organization in place to ensure maintenance. The substation alarm management device sends e-mail over a TCP IP (Internet or Intranet) network toward the control center. This information feeds a database, but can also supply data directly to the maintenance teams. A Web-camera is associated with the device providing visual assistance to the operator during his intervention, or for surveillance. The system can be combined with local acquisition tools monitoring faults concerning temperature, leakage and vibration. A system like this could result in a development of the equipment guarantee contract.

Article 1.23 (France) presents a project to optimize overhead line maintenance.
Based on the observation that the challenge raised by the life duration of networks built 50 years ago is considerable, the article proposes a study of optimized equipment maintenance with a variety of expected results: better resistance to climatic ups and downs, better knowledge of the equipment, optimized investments into renewal, longer life duration, maintained skill and overall economy. This presupposes the identification of defective components and an evaluation of the residual life of each element. Obviously, the information will need to be established according to each equipment technology used over the years.

Article 1.24 (USA) describes an expert maintenance-aid system applied to a primary substation equipped with old SF6 equipment whose maintenance cost was considered to be prohibitive. A system like this offers many advantages: orienting maintenance toward equipment that requires it, cutting costs, improving reliability, and lengthening the life duration of the components. The system monitors the fundamental parameters: operating time, pressure, temperature, current on transient operating conditions. An expert system analyzes the information and supplies a diagnosis associated with an emergency. An example of how to set up a diagnosis is given. The expert system, better than simple information recording, permits rapid detection of phenomena that operating personnel would not identify.

Article 1.25 (Belgium) outlines a maintenance control system.
In a context where competition is increasingly keen, the advantages offered by maintenance are increasing, generally driven by a quest for lower costs and the presentation of a structured maintenance program to the controlling authority. The proposed approach consists in improving the conventional periodic maintenance approach, replacing it by maintenance based on the gathering of reported events and analysis of them, through expertise rules. The new maintenance design means breaking the equipment down into subassemblies, analyzing the failure mode of each subassembly and defining the maintenance plan for each subassembly thus obtained. The method has been applied to overhead lines and primary substations. Studies have made it possible to plot the failure curve as a function of time while identifying the surveillance zone and the maintenance zone. The method has been used and demonstrated its efficiency. The results in figures are encouraging, even if they are yet to be confirmed.

Article 1.26 (The Netherlands) describes the conditions for accepting transmission and distribution network components.
The conditions for the technical validation of the distribution equipment represent a particularly important challenge because of the immobilized capital. Validation must be based on 3 different standpoints: economic, technical and strategic. Technical aspects include three domains: dielectric strength, thermal strength, mechanical strength and performance expressed as a failure level. Their evaluation calls for the identification of failure modes, the definition of their criticality, the understanding of the failure mechanism, the determination of the diagnosis modes (inspection, sampling, diagnosis, surveillance), then the analysis of the results. The strategic aspects cover the adaptation of the product to regulatory requirements and specific aspects of the network. Economic aspects concern the evaluation of the complete cost: investment, maintenance, operation, cost of failure, etc. and make it possible to establish the optimum age for replacement. Overall analysis of a product like this guarantees the optimization of the investment and maintenance cycle.

Three articles concerning cables emphasize these partial discharge measurement methods.

Article 1.27 (Czech Repbulic) explains the importance of gathering all the information relative to the life of a medium voltage underground equipment to understand the reliability level. Every aspect of information must be taken into consideration, for instance, cable characteristics and environment, criticality, behavior and use of cable in electrical system, all the measurements and the surveillance performed. Statistical analyses are a means of predetermining the equipment reliability level. Steps have been taken to make measurements on cables, in particular after faults and repairs. The most significant tests are measurements of partial discharge giving a good image of cable quality except for aggression affecting the outer envelope. For the ends, thermovision has proved to be effective. The studies performed demonstrate the reliability gap between the impregnated paper cables and synthetic insulation cables.

Article 1.28 (The Netherlands) shows how the conditional maintenance of the cables represents a tool for the management of network assets. It goes over some of the points covered by the previous article.
Maintenance based on observed performance rather the utilization time is a source of savings for the distribution system. The article presents the implementation of this conditional maintenance. Initially it is determined by the history of the cable and the evaluation of the place it takes up in the distribution system. Diagnostic by partial discharge at 0.1 Hz is specified for paper cables and for synthetic insulation cables. The method will permit the localizing of weak points in cable sections of up to 4 km and even 10 km in length, by combining several measurements together. For cables with synthetic insulation, dielectric spectroscopy is a way of localizing watertrees. Measurement of the loss factor variation at 0.1 Hz and of the capacitance gives an idea of the deterioration level. This is indicative of the fact that conditional maintenance of cables is now technically possible.

Article 1.29 (The Netherlands) describes more specifically a conditional maintenance approach on cables, based on the use of partial discharge measurement.
The diagnosis of partial discharges is presented as a preferential tool for the identification of the modes dominating cable failure. Half of the causes are external rather than electrical. The article describes how, from analysis of the result, it is possible to identify failures concerning cables or accessories, localized or distributed failures, etc. Testing after installation can help to detect potential faults. The distribution of interpretation assistance tools can help with reaching the right decision.

Article 1.30 (U.K.) deals with the optimization of maintenance on an oil type MV circuit-breaker.
The method described, tested on MV oil circuit-breakers, can be extended to other components in the network. It will optimize the life cycle. First, a close tie has been identified between the quality of the oil and the operating conditions of the circuit-breaker. Optimizing conditional maintenance therefore naturally depends on the state of the oil. Tests relative to low quality have therefore been defined: in particular, two new tests, chromatography to separate the oxidization products and analyze the solid residues. A test and inspection program has been defined: the planning of diagnosis, oil testing and internal examination of the circuit-breaker, determination of the time before the next inspection according to the reports obtained. The application of these arrangements has demonstrated that the average time between two maintenance operations is getting longer. Several cases of maintenance requiring more frequent attention have been identified. This conditional maintenance type generates more than tangible gains.

Article 1.31 (Austria) explains that network maintenance can be organized in several ways: depending on the observed events, in compliance with time intervals between each maintenance operation or by carrying out maintenance as a function of the behavior of the equipment since the last maintenance operation. Maintenance can be based on different methods: inspection, performance testing, diagnostic techniques. The article analyzes the nature of the information gathered by using each of these methods. More particularly, it details the advantage of diagnosing specific magnitudes like temperatures, vibration, partial discharge and describes the associated methods of measurement: thermography, spectrometry, vibration analysis, dilatometry. Diagnostic can be carried out in service and combined with a data processing system of the expert system type, which can supply continuous information about the state of the equipment.

Question 6
can there be returns on experience regarding the technical and economic advantage of such optimized maintenance systems? Are they liable to restart intelligent surveillance of the equipment?

Lightning arresters design

Article 1.32 (France) deals with acknowledgment of environmental respect in lightning arrester design.
Manufactures consider today that compliance with environmental requirements is a major challenge. It is even desirable to anticipate regulations. Detailed analysis of the process of manufacturing a lightning arrester shows that considerable gains on component reject factors during manufacturing could be possible. These gains, around 30% for all the materials, contribute to limiting the rejects but also reduce production costs, demonstrating that the objectives of cost reduction and environmental friendliness are not necessarily incompatible. In addition, greater product removal capability, incorporated at the design stage, favors proper elimination at life end.

Article 1.33 (U.K.) deals with the capability of zinc oxide varistors to evacuate energy.
Energy evacuation capability is defined as the maximum energy that a varistor can evacuate before destruction. This value is related to the heating caused by the circulation of current, causing a break in the semiconductor, or the scale of the mechanical stress when an electric pulse is conducted. The purpose of the test is to determine the number of current conduction cycles the lightning arrester can withstand. An infrared imagery system is used to monitor the temperature. The test reveals that performance is related to the correct distribution of calorific energy through the entire semiconductor, and therefore to the consistency of the material. In the event of repetitive solicitations, the varistor offers higher performance than for a single pulse. Other methods, like an acoustic microscope, can be used for filling out these investigations.

Article 1.34 (Germany) shows the advantage of lightning arresters used on MV cable screens.
The grounding of cable screens at both ends avoids dielectric stresses but increases losses by current circulating to ground, up to 10% more, depending on the cable-laying method. These supplementary losses can be avoided by grounding one end only. If, at the other end, a lightning arrester is installed between the screen and the ground, the screen/ground voltage will be limited to the residual voltage of the lightning arrester, thus protecting the cable envelope. The assigned voltage of the lightning arrester depends on the screen potential

increase, due to the short-circuiting current. The economic justification of the device will be acquired for 500 m cable lengths used at more than 30% load.

Article 1.35 (Finland) investigates the performance and life duration of the polymers used in lightning arresters when they are exposed to current pulses.
A series of lightning arresters from different manufacturers has been selected. The goal was to submit these lightning arresters to current constraints in a wet atmosphere, increasing the diffusion of humidity inside them. Out of 20 tested units, 12 were dstroyed, and the article describes the failure mode. It goes on to compare similar tests run previously without a damp environment. The appearance of considerable losses originated more from breakdown than from simple humidity. Lightning arresters using epoxy tubes reinforced with glass fiber offer better performance.

Question 7
do lightning arresters offer performance adapted to user expectations? Will the evolution of the performance be likely to modify the current market?

THEME 3 - ENVIRONMENTAL ASPECTS OF SUBSTATIONS AND SWITCHGEAR

Article 1.36 (France) relates to the dilemma of how to use a greenhouse effect gas while complying with environmental requirements.
SF6 used in circuit-breakers offers high electrical performance: stability, dielectric capability, maintained performance at high temperature. It was used for constructing low cost, low weight, reliable products offering reduced maintenance. Requirements in terms of the environmental have prompted SF6 users to examine the process for the use of its product in its detail and confines rules of construction, use and management of life end. Stringent management is a way of checking the volumes emitted at every stage of the process. Furthermore, an overall "écobilan" study was carried out on 3 pieces of equipment: an air insulated switch, a switch insulated in SF6 and a vacuum bulb. The environmental impact of each of the products was analyzed on the basis of 10 criteria.

Article 1.37 (Italy) describes HV/MV substations using a new low price equipment that is environmentally friendly.
The need to strengthen the network to deal with load increases at minimum cost has spurred ENEL to revise the design of its reinforcement primary substations. The proposed solution replaces the traditional substation with redundancy by a simplified substation with a single transformer, backed up by adjacent substations and associated with 25% automation of the secondary substations. The primary simplified substation takes up little space and can therefore be placed near the supply lines more easily. Ideally, it would be placed amid a preexisting MV cable bundle. Ten simplified HV schemes were presented. The cut-off equipment used in these substations consists of very compact air / SF6 hybrid equipment. A 24 kV compact model has also been developed whereby a complete busbar could be placed in a container. This type of equipment must correspond to the new environmental requirements encountered.

Article 1.38 (Russia) takes a look at the requirements to be taken into consideration so that the overhead distribution equipment can obtain urban area acceptance. It is proposed to make them attractive by giving them extreme and surprising aesthetic characteristics while complying with a number of constraints: small footprint, short distances between conductors, encouraging the use of specific technologies such as polymer insulation, metal towers. The reduction of the electromagnetic fields is obtained by limiting the current admitted into the line.

Question 8
how are environmental expectations changing with respect to equipment? Are requirements becoming more demanding or not? Are the themes dealt with changing? In what area is it necessary to anticipate developments?