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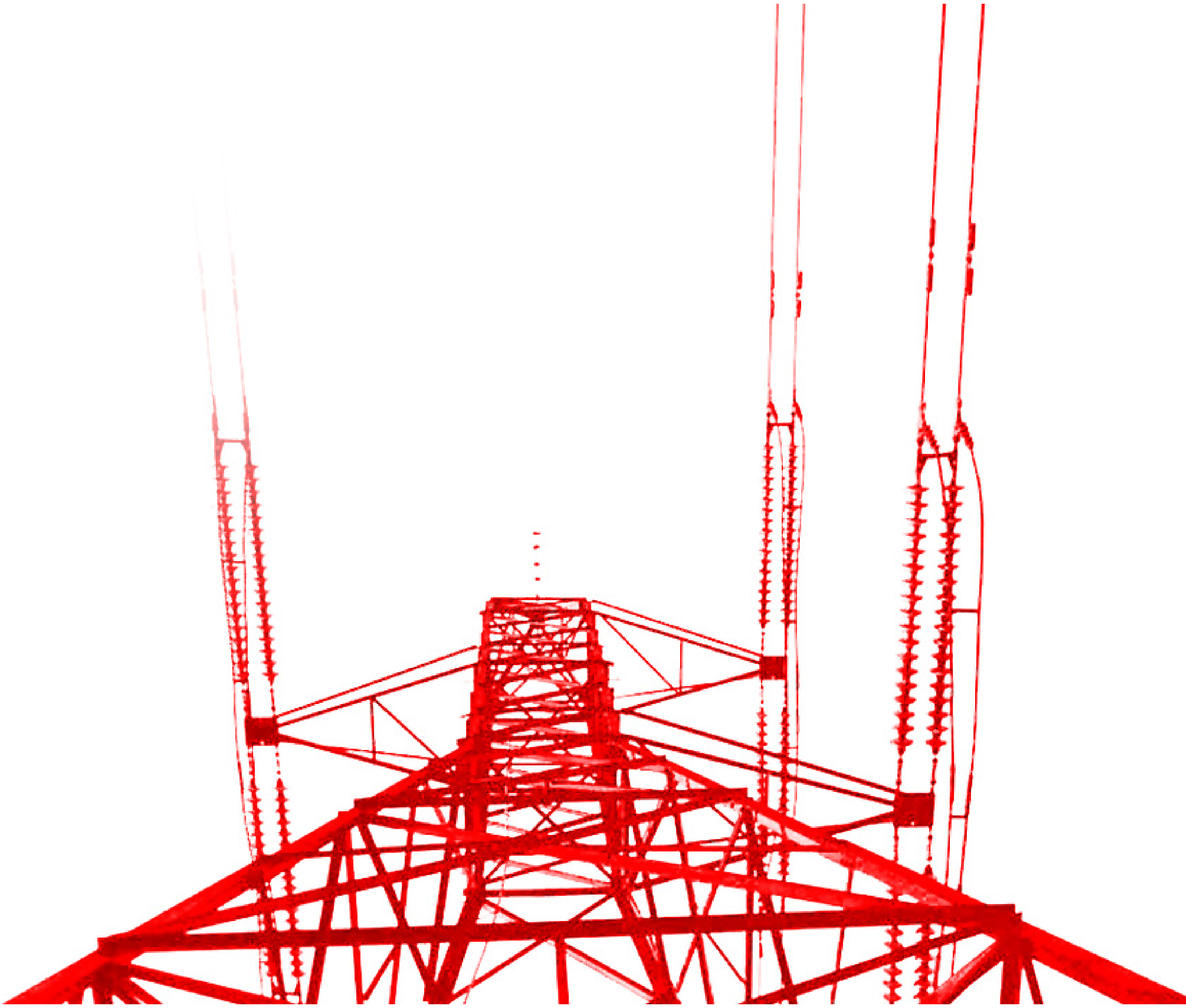
Plataforma española de redes eléctricas



Research Schedule

FUTURED - ELECTRICAL GRID SPANISH PLATFORM

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Chapter 3

INTRODUCTION

Introduction

Research Schedule

FUTURED'S Strategic View thematic groups have analysed the current situation of electrical grids and what electrical grids shall have to be like in 2025 and described the nature of the transition from the former to the latter. Whilst undertaking this task a series of technological insufficiencies and needs was discovered that shall have to be addressed and resolved over the next few years.

In order to do this, a **Research Schedule** has been established, that is to say a specific action plan that enables the actions that have to be performed to achieve it to be identified. The plan includes the short- to medium- and the medium-to long-term actions to be carried out, identifies obstacles and opportunities, and estimates the resources required.

In this plan a series of strategic objectives and projects are identified and grouped into different lines of research based upon four functional areas:

- Control and Operation
- Electrical Grid Planning and Design
- Maintenance and Lifespan Management
- Metering, Efficiency and Management of the Demand

Some topics are included in two functional lines because the proposed projects are approached from different perspectives.

An essential aspect during the preparation of these objectives has been the participation of the manufacturers, technology centres and universities, whose contributions and know-how have enriched this schedule and prevented any loss of contact with the technological advances being made and the expectations being shown.

Scheduling

The outstanding features from the timescale point of view are:

- Projects to be pushed through in the short- to medium-term (horizon of up to 5 years) - Innovative projects which serve to motivate and promote the activities of those involved in the industry.
- Medium- and long-term research plans (in excess of 5 years) - Research plans which serve to guide and advise Government Ministries and Public Authorities. An especially relevant part of these plans shall be the development of new technologies.

Classifying the Projects

The projects have been classified as follows in accordance with their strategic relevance:

1) Priority
2) Significant
3) Complementary Aspects

This classification is individually reflected in each of them in accordance with their importance, with this being represented by the symbols ❶, ❷, or ❸ respectively.

Chapter 4

PRIORITY TECHNOLOGICAL AREAS

1.- Operation and Control

1. Operation and Control

What will the electrical grid of 2025 be like?

In 2025, the operator will probably find him-/herself dealing with an electrical grid that is far more optimised and diverse as far as equipment and technology is concerned, a grid capable of working closer to its limits in a far more efficient manner.

The operator of the future will have to confront stricter quality of service criteria; (the length of time supplies are interrupted will cease to be a quality of service criterion; an uninterrupted service shall be "taken as a given"), which will force far shorter reaction times with respect to the operation and control process.

It will also be a far more open and deregulated electrical grid.

How will the grid of the future be operated?

Hierarchical: the lower levels will be automated to the maximum degree while the upper level will be operated:

- From the office:

  With all the routine tasks (maintenance and breakdowns) being automated and supervised by the operators.

  With systems capable of issuing orders and instructions to the field elements by way of optimisation programmes acting in a closed loop.

- In the field the generalised use of local automatisms establishes a primary action level that reaches as far as the low-voltage distribution hubs of the grid.

- Local operation is managed automatically, with the work area being clearly marked and with access to all the information required in real time.

Absolutely **safe** for people and equipment, with quality of service being guaranteed all the way down the line.

Sustainable coexistence with the environment: Demand Management will produce a less pronounced demand curve, minimise winter peaks and summer troughs, and enable power stations to be operated at their points of maximum energy efficiency.

Generally **transparent** and accessible to new active agents.

Lines of Research

By thoroughly analysing the view provided in the previous paragraphs and comparing it with the situation we find ourselves in today, a series of technical insufficiencies can be observed that technology must help to resolve on a more or less urgent basis.

Those whose development directly affects the installation of elements in the field have been identified using medium- to long-term project lines. Deployments and roll outs on the ground are always complicated and costly, due not only to their volume, but also to their dispersion, which is why if the aim is to incorporate any technology, this has to be done sooner rather than later and in the most standardised way possible.

The following have been identified as **short- and medium-term** lines of research:

1) Advanced Electrical Equipment
2) Communications and Automation

This deployment will also condition other more elaborate lines of research that depend on the capacities of the equipment installed in the field. These have been identified in **medium- and long-term** lines:

3) Detection of faults, replacement and quality of service
4) Distributed energy resources
5) Operation support tools
6) External connection to the control systems

1.1 Advanced Electrical Equipment

OBJECTIVE:

In addition to the incorporation of local functions and automation, the equipment of the future shall have to be capable of predicting and reporting faults in order to anticipate and, therefore, bring the operation task forward. In order to do so, this information shall have to accessed and analysed by the operator in real time.

All the equipment developed shall have to be highly reliable because it will be entrusted with a greater degree of responsibility.

Potential Projects:

1) The improvement, development and unification of electrical equipment accessibility standards
2) The incorporation of power electronics control equipment
3) The development of prediction and self-diagnosis systems

1.1.1 The improvement, development and unification of electrical equipment accessibility standards ❶

The plan is for field equipment to be completely visible, that is to say able to remotely provide any information requested of it and even make parameterisation changes. This is going to entail expanding current standards in order that they meet the required safety and efficiency needs.

Special attention shall be paid to accessibility with respect to Protection Devices, Fault Detectors and Oscilloperturbographs.

1.1.2 The incorporation of power electronics control equipment ❷

The development of power electronics control in the field of high-voltage enables the inclusion of different FACTS devices that control power flows and improve the operation of the system. This type of equipment increases the supply capacity of the current electricity transport networks and makes them more robust.

Another aspect that must be considered are devices for controlling power flows, improving stability and guaranteeing the quality of the energy supplied by the electrical distribution systems. These functions shall be performed in coordination with other devices within the distribution system. Devices based on power electronics will also be installed and managed in the electricity substations and these shall support the operation and control of the entire system. These devices will include protection switches and systems based on static switches.

1.1.3 The development of prediction and self-diagnosis systems ❷

Incorporating the intelligence that the field devices need in order to be able to provide the information required for a prediction system and, where appropriate, for compiling a self-diagnosis report and notifying the control and local operations centre of any malfunction detected.

These devices will enable the level of predictability to be increased with respect to the maintenance process and, in turn, improve the quality of supply levels.

1.2 Communications and Automation

OBJECTIVE:

A number of electrical grid automation needs are foreseen and which current communications are not designed to cope with. Likewise, in this field the adoption of standards and solutions that simplify the mass incorporation of devices into the grid and support the multiplication of agents involved must be strengthened. Security and confidentiality will be key elements in this section.

Potential Projects:

1) Communications solutions for mass automation
2) The standardisation of communication with automation elements protocols

1.1.4 Communications solutions for mass automation ❶

Automation needs are going to force great changes in the field of communications. It will be necessary to handle a huge volume of data in real time, which calls for communications networks that are powerful, reliable and secure.

Special attention shall be paid to information in connection with Protection Devices, Fault Detectors and Oscilloperturbographs. This will be processed in real time together with the remote control data in order to simplify the decision-taking process.

1.1.5 The standardisation of communication with automation elements protocols ❷

In addition to automation, market deregulation and other factors, a generalised form of information exchange with all the agents (market, maintenance, customers, etc.) and with the devices going to make up the operation and control systems will be required.

It shall be necessary to prepare standards for making operation and control information accessible in the most transparent manner possible while at the same time protecting it against intrusion.

In the two aforementioned projects it shall be necessary to include pilot experiments in which the different technologies, architectures and means of communication used to provide automation support are deployed. These pilot tests must prove the scalability of these elements and their capacity for providing mass coverage with respect to the automation of the electricity distribution networks.

1.3 Fault Detection, Replacement and Quality of Service

OBJECTIVE:

To improve the quality of service. In order to achieve this it is first essential to strengthen the degree of control over this quality before carrying out corrective actions.

In order to improve quality of service, it is necessary to locate faults faster so that they can then be isolated. Automatic reinstatement strategies combined with a more efficient management of the work teams will bring us closer to achieving this objective.

Potential Projects:

1) Intelligent fault detection and service reinstatement systems
2) Electronic wavelength quality control and improvement devices
3) WAMS-based wide area protection systems.

1.1.6 Intelligent fault detection and service reinstatement systems ❶

Finding the faults quickly, rectifying them followed by immediate reinstatement are key factors when it comes to improving quality of service. Using the information provided by the local devices developed in line 1.1.1, applications based on knowledge of the topology in real time shall be capable of automatically rectifying and/or isolating any type of fault in the electrical grid.

These fault detection systems shall be intelligent, will identify any irregularities accurately and unequivocally and notify the operation and control centre of them the moment they occur and even predict them in advance.

It shall be important to prove the effectiveness of these developments using real prototypes and field trials.

1.1.7 Electronic wavelength quality control and improvement devices ❸

These must provide the information about the quality of customised service to those customers interested in receiving it in such a way that it might be a factor to bear in mind when negotiating with the supply companies and that these shall be able to offer it as a product.

Suitably designed devices based on power electronics enable disturbances to be mitigated. To help towards their development, the topologies required for each level of voltage and application and the most efficient control techniques must be identified. The traditional devices used for this function must be replaced using far more efficient technologies.

1.1.8 WAMS-based wide area protection systems ❷

From the point of view of the large electrical grids, it is necessary to install WAMS (Wide Area Monitoring Systems) real time phasor metering systems. Experiments in which a series of nodes representative of the grid are selected enable clear conclusions to be obtained regarding the status of the grid in order to anticipate and prevent major incidents.

1.4 Distributed Energy Resources

OBJECTIVE:

The intention is to make the absolute most of the contribution that distributed energy resources can provide to the operation and support of the electricity system and to make it easy for them to form a part thereof.

To study the real possibilities of the microgrids as a case in point and to develop, in turn, a portfolio of new services that these distributed resources can and must provide.

It shall be important not only to include their relationship with the electricity operators, but also that which they have with the Market.

Potential Projects:

1) Demand and microgeneration management
2) Microgrids
3) Developing the technology for the incorporation of new energy services
4) Aggregating Distributed Energy Resources

1.1.9 Demand and microgeneration management ❷

Distributed energy resources (DERs) are a reality and they contribute towards the maintenance of the system by allowing the operation systems to use their resources whenever necessary based on the rules of the market.

The balance between generation and demand will be controlled in real time thanks to the intensive application of the diverse information and communication technologies while new devices will enable this technology to reach any point of consumption.

1.1.10 Microgrids ❸

Microgrid projects that enable the protagonists to operate in an island-like manner, either within their own isolated systems or operating in accordance with the seasonal demands of the major electrical grids. Exploring the advantages and benefits that this can provide to the operation of the system.

1.1.11 Developing the technology for the incorporation of new energy services ❶

Following on from the mass incorporation of distributed generation into the grids, research the appearance of new energy services and how these can be regulated and managed. Once these aspects have been determined, the technologies required to make the system providing the new energy services efficient and reliable must be developed.

1.1.12 Aggregating Distributed Energy Resources ❷

As a case apart of those mentioned above, but serving to highlight their usefulness, projects are planned in which full advantage is taken of the distributed resources in an aggregated manner in order to simplify the interfaces between agents and provide economy of scale. Develop how this aggregation must be implemented so as to make it as effective as possible.

A study of the products and services that can be offered and provided in this environment. How would they benefit the operation and maintenance of the system?

1.5 Operation Support Tools: Online and Simulation Mode Applications, Reliability of the Systems

OBJECTIVE:

Applications are required that help the operator to maintain, in real time, the security of the electrical grid and to rationalise the operation, with the automatic despatch of orders into the field also being considered. A further necessity is simulation environments in which actions can be evaluated without actually having to directly implement them for short-term planning purposes or simply for the training of operators. These are especially scarce and necessary for distribution networks.

On the other hand, the reliability of the control structure must, due to its critical nature, be considered as being the key factor in the development of applications for the control centres.

Potential Project:

1) Online applications for electrical grids
2) Simulation and optimisation tools
3) The reliability of the control structure

1.2.1 Online applications for electrical grids ❶

Applications are increasingly required that help the operator to maintain, in real time, the security of the electrical grid and to rationalise the operation thereof, with the automatic despatch of orders into the field also being considered. Online applications are especially scarce and necessary for distribution networks.

Monitoring grid activity will enable a know-how database to be kept updated which will help in the detection of weak points.

Prediction models enable the operation centre to head off bottlenecks or problems in the grid before they occur.

In the case of transport networks, the intention is to make progress with respect to new generation control systems capable of determining the status of the system and carrying out diagnoses upon it in real time, (and even faster than real time).

1.2.2 Simulation and optimisation tools ❷

Simulation environments are required in which actions can be evaluated without actually having to directly implement them for short-term planning purposes or simply for the training of operators. The information received from the grid itself shall be used to maintain and improve the syntony between the models and reality.

Simulation environments are especially scarce and necessary for distribution networks.

In addition to the aforementioned points there is the objective of obtaining the optimum configuration of the grid, especially that of the distribution network, by using optimisation functions such as: safety and losses and even functions capable of obtaining this configuration automatically.

These include applications in real time that help the operator to run the grid at its optimum point (losses, safety, etc.).

1.2.3 The reliability of the control structure and the characteristics of the systems ❷

The control infrastructure must be 100% reliable, even in the face of catastrophic contingencies. For this reason the ways to achieve this in the most efficient manner possible must be investigated, although not to the extent that the systems are reduced to enclosed and proprietary environments.

Quite the opposite, the systems shall be sufficiently open to guarantee their unfettered growth and enable the inclusion of any type of functionality and/or technology of any supplier whilst retaining the required reliability.

1.6 Connection to the Control Systems, Integration of Applications

OBJECTIVE:

The idea is to explore the added value of relating the control systems (traditionally isolated) with other corporate systems: customers, maintenance, inventory, etc., and to strengthen the use of a single network model for all the areas of the electricity company that can also be used by the operation centre for the correct management of all the tasks and breakdowns.

Potential Projects:

1) Coordinating the operation with the external systems (customers and protections)
2) The handling and interoperability of large databases

1.3.1 Coordinating the operation with the external systems (customers and protections) ❷

Projects that investigate the added value of synchronising the electrical grid control systems with the customers' control systems. Providing the customer with information, controlling the quality of service, responding to complaints, access to quality history logs, help in controlling fraud, reducing losses, etc.

At the same time the idea is to develop interfaces between the operation systems and the protection inventories in order, on the one hand, to make it easier to analyse incidents and coordinate protective measures and, on the other, to improve the operator's knowledge in emergency situations.

1.3.2 The handling and interoperability of large databases ❸

Projects aimed at simplifying the handling of large quantities of information, as is the case of the control systems, and how this interacts with the information generated by other corporate systems.

Encourage the use of a single model of multifunctional network for all the areas of the electricity company that can also be employed by the operation centre for correctly managing all tasks and breakdowns within the electrical grid.

A study into data and tool standards.

2.- Maintenance and Lifespan Management

2. Maintenance and Lifespan Management

What maintenance developments must there be between now and 2025?

The maintenance of the future is seen as being a rational and optimum process that is conveniently centred upon the real and adjusted needs of the installation. The devices deployed will be capable of performing self-diagnoses, the digital technologies of the future will be incorporated and the advanced development of management models and information technologies coupled to the degree to which these will be capable of penetrating the operational fabric of the organisations and will enable assets to function to their maximum potential with a minimum amount of maintenance activity, thereby guaranteeing optimum operability.

The approach adopted for the Maintenance and Lifespan Management Schedule is divided up into three phases. First, incorporate the technologies and tools required and available in accordance with current and projected developments. Second, consolidate the information and maintenance management models once these have been adapted. And third, attempt to achieve the highest possible degree of automation with respect to the maintenance management process.

2.1 Developing the Means that enable Signals to be Digitally Acquired.

Objective:

To have enough means in place for the full integration of digital technology within the electricity installations. For this to be possible it is necessary to have devices and sensors capable of translating the performance of the installations into digital environments that enable decisions to be taken online and more or less in real time. It is also necessary that the signals transmitted by the devices are reliable, strong and comparable from the time of capture through to the time action is taken.

POTENTIAL PROJECTS:

1) Optical and/or digital transformers
2) Intelligent sensors capable of self-diagnosis
3) Capturing the dynamic parameters of the installations (temperature, load, wind speed, etc.)
4) Online monitoring of partial discharges
5) Development and implementation of the IEC 61850 in its entirety

2.1.1 Optical and digital transformers ❷

Signals are currently captured in substations using conventional analogue technology transformers. Market trends, combined with the advances being made by digital technology, indicate that it will not be long before digital transformers are available on the market. This development brings with it a significant improvement in certain areas. It requires less cabling, the security provided by the capturing devices is considerably increased and, furthermore, the efficiency of the substation is raised by the reduction in consumption due to the fact that the losses generated by the new equipment falls to practically zero.

2.1.2 Intelligent sensors capable of self-diagnosis ❷

Knowing the true situation of the equipment in order to be able to determine its status will be transformed into a task the simplicity of which depends on the information that can be extracted from the devices. Therefore, the sensors that provide us with the equipment parameters, its status and with the information that is deemed relevant with respect to the assets will enable us to better manage their working lifespan or even allow the devices to manage themselves via the self-diagnosis capability.

2.1.3 Capturing the dynamic parameters of the installations (temperature, load, wind speed, etc.) ❷

Entering the operational conditions and parameters to which the installations are subjected will enable us to gain a more detailed knowledge of the forces to which they are exposed. This will make it possible to work with a larger amount of data that enables the integration of active information (about the pieces of equipment themselves) and contextual information (about the environment in which they operate), in other words truly relevant information that will prove invaluable when it comes to implementing a correct equipment management procedure.

2.1.4 Methods for capturing and interpreting partial discharges ❷

Most faults and breakdowns that occur in underground power lines occur where the conductors join. Being able to anticipate the problems that occur in these by way of the online monitoring of partial discharges will enable any faults that might occur to be correctly managed and to anticipate and correct defects caused by deficient assembly, installation or components reaching the end of their working life.

2.1.5 Development and implementation of the IEC 61850 in its entirety ❷

The full implementation of emerging protocols with respect to communications between electronic devices will leave the door open to a digital future for the installations. These will make it possible to equip the installations with an efficient Ethernet network that enables the devices that go to make them up to be interconnected and to communicate (interoperate) in an effective manner, thereby simplifying both management and maintenance.

OBSTACLES

The obstacles identified are:

- Lack of development in the market as regards the devices that enable the aforementioned projects to be implemented.
- Market availability of digital devices capable of forming part of the 61850 protocol and performing the process bus functionality.
- Having the data structure required for managing and maintaining the digital control and protection devices organised.
- The formation of profiles adapted to the new communications in substations protocol model.
- Insufficient development of reliable and robust partial discharge detection sensors that are immune to electrical noise.

2.2 Maintenance based on Asset Lifecycle Management

Objective:

The medium-term objective consists of optimum installations maintenance. This implies acting only and when necessary. In other words, at the opportune moment. On occasion it can be observed that programmed maintenance activities are performed that are unnecessary bearing in mind the service life of the asset to be maintained. This leads us to think that we have to move towards maintenance models which determine the most suitable moment for the action to be carried out. Furthermore, it is worth thinking about constructional, material and equipment solutions that pave the way towards a non-maintenance scenario.

1) Reducing maintenance costs via the integral development of SF6 solutions
2) Developing and implementing standardised communications protocols outside the substations.
3) Monitoring the electrical grid and optimised assets management.
4) Maintenance based on asset lifecycle management, reliability and risk reduction.

POTENTIAL PROJECTS:

2.2.1 Reducing maintenance costs via the integral development of SF6 solutions ❷

SF6 enables the programming of maintenance activities that are extremely far apart time wise by making a strong contrast between devices the dielectric materials of which are different, namely oil or air. The penetration of SF6 equipment continues to be partial in the European market, hence the search for and promotion and use of solutions that have achieved a great degree of penetration in other markets, such as Asia (benchmarking), will enable some of the maintenance models or standards of certain devices, such as power transformers, to be changed.

2.2.2 Developing and implementing standardised communications protocols outside the substations ❷

Once the internal communications protocol of the substations (IEC 61850) has been fully developed and contrasted, efforts shall be channelled into extending the communications standardisation possibilities beyond the confines of the substations.

2.2.3 Monitoring the electrical grid and optimised assets management. ❷

In order to be able to take decisions which form part of the optimised assets management process, it will be useful to have access to real operational data with respect to the transport network and to the distribution network. Installations currently exist in the grid that employ different technologies and support materials that have been introduced in accordance with the advances made by the market, price trends as regards materials, and accumulated experience (economies of scale). Although some installations are planned to have a working life of some 40 years, it is a well known fact that there currently are installations with a longer active lifespan, and with a life expectancy that is still to be exactly defined. Monitoring will help to get a more accurate idea of the current status, maintenance requirements and reinvestment policy necessary.

Knowing the true lifespan status of the assets will enable their working life to be more precisely estimated. This will in turn enable a more effective forecast of the investments required to be made, not only due to the most immediate replacement requirements, but also by improving the accuracy of working life estimates which will, therefore, push other programmed investments back in time.

2.2.4 Maintenance based on asset lifecycle management, reliability and risk reduction. ❷

All of the above combined and considered in an efficient management model must lead us to change the current maintenance model. Corrective maintenance will not be abandoned, nor will only predictive or preventive maintenance be carried out. However, in the future there will be more adjustment and programming with respect to the types of maintenance that are necessary in accordance with the lifespan of the asset, its calculated and studied reliability, and the risk that the taking of such decision will imply.

OBSTACLES

The obstacles identified are:

- A lack of development in new power transformer technologies.
- A cultural change in the way installations are maintained.
- The formation of profiles adapted to the new maintenance model.
- The shared creation and populating of a database of the parameters of the installations and events which have an influence on their working lifespan for making a correct estimation.

2.3 Advanced Decision-Taking Systems

Objective:

The concept of the full digital integration of the installations, and the optimised management models makes the development of communications technologies that automate the management and the decision-taking processes in the electricity installations necessary. Bearing in mind that the grid control, manoeuvre and protection elements have to be ordered, unified, standardised and managed by way of an efficient model, the next step will be that of introducing a decision engine that considers the current status of the installation, weighs it up and is capable of anticipating statuses in the near future, resolves the operational conflicts that might arise and has a global vision of the ideal parameters of the system in order to try and incorporate them. It shall have to be capable of processing the information at the same time as implementing an ICT (Information and Communications Technologies) strategy efficiently and independently, which brings us to the threshold of a no-maintenance or a no-management installations scenario.

POTENTIAL PROJECTS:

1) An intelligent decision-taking system in an electrical grid
2) Maintenance models based on the expert systems of intelligent grids

2.3.1 An intelligent decision-taking system in an electrical grid ❸

The introduction of an advanced engine that automates the information gathering and decision-taking process in such as way that enables the most suitable to be chosen at any given time and thereby makes it easier and apply another turn of the screw with respect to managing the working life of the assets and maintenance in general.

2.3.2 Maintenance models based on the expert systems of intelligent grids ❸

Maintenance and, therefore, its management model will, foreseeably, develop in response to the automation of the information technologies. This will mean the emergence of an integral data management process and the correct provision of an engine that makes everything more dynamic and paves the way for an advanced decision-taking process.

3. – Grid Planning and Design

3. Grid Planning and Design

Introduction

Some of the greatest challenges foreseen with respect to maintaining the performance levels of the current electrical grid after 2025 are:

- the difficulty of constructing new installations, especially overhead power lines
- the uncertainty as to the location of the new generating plants
- the integration of a large amount of distributed generation
- increasingly strict environmental restrictions

One of the most relevant subjects as regards the electrical grids of the future is the difficulty of building new infrastructures, above all overhead power lines. This will make it necessary to take full advantage of the existing infrastructures by recurring to improving and expanding the capacity of these instead of constructing new ones.

Another extremely relevant subject is the massive development of distributed generation, which although in some aspects might well provide help to the system is seen by many as representing a challenge. The difficulties thrown into the mix by the huge advances made in distributed generation include the following:

- generally speaking, distributed generation installations are unmanageable
- in many instances they are located in low-consumption areas with scarce grid infrastructure
- in the case of primary renewable energy sources, it is a hit and miss generation scenario
- the protective measures have to be adapted

In order to face up to the aforementioned aspects, given the difficulty of continuing to develop the grid as it has been developed up to now and the need to have a "flexible" grid, a number of possible solutions have been put forward:

- Using special conductors and upping the capacity of the existing infrastructures, thereby enabling the continued use thereof, and high-capacity power lines.

- Using FACTS and other power electronics devices to control the power flows and voltages in the transport and distribution networks, likewise adapting wave quality or limiting the short-circuit bracing rating wherever necessary.
- Creating tools that predict those places where generating plants are going to be installed in the future. Creating tools that help to predict production and demand whilst bearing in mind, among other aspects, renewable energy installations and demand management.
- Installing energy storage facilities connected to the grid with different response times.
- Developing the regulation that enables the management of distributed generation (within its technical limitations).
- Planning distribution networks the performance levels of which are close to those of the transport networks.
- Developing new market mechanisms that penalise/reward in accordance with the losses associated with the point of connection (applicable to generation and/or demand). This can be done, for example, by applying local restrictions or influencing the specific transport and distribution costs of each location.

Lines of Research

By examining the challenges a series of shortfalls can be observed that research shall have to help resolve with a greater or lesser degree of urgency.

Those aspects of a more urgent nature that can be directly tackled here and now have been identified as **short- and medium-term** lines of research:

1) Alternative development of the grid
2) The creation of grid development models
3) Electrical equipment

Those lines of research that represent more far-reaching changes to the grid development model currently in force and which therefore need more time to mature have been identified as **medium- and long-term** projects:

4) Development alternatives regarding the distribution network of the future
5) Development alternatives regarding the transport network of the future

3.1 Alternative Development of the Grid

OBJECTIVE:

The last few years have seen the rejection of new electrical grid infrastructures increase. As a result, procedural deadlines have lengthened (delaying their entry into service), and in some cases it has not been possible to construct the new power lines required. However, the continuing growth of demand and the new generating installations make expanding the grids a necessity.

It is necessary to evaluate, both technically and economically, alternatives for increasing the performance levels of the existing grids whilst at the same time minimising the area of ground they occupy.

Potential Projects:

1) New designs of power lines and substations with less of a socio-environmental impact
2) High-temperature and other special conductors
3) The incorporation and use of FACTS
4) The modelling of new grid components and structures

3.1.1 New designs of lines and substations with less of a socio-environmental impact ❷

This project sets out to evaluate, both technically and economically, the possible alternatives for increasing the performance levels of the existing grids whilst at the same time endeavouring not to increase the current mileage of power lines and, in general, not expanding the area of ground occupied. Both the benefits achieved and the losses incurred are evaluated including, among others: costs incurred, costs avoided, increase or decrease of risks, etc. The performance values evaluated include: increase of voltage, changing the design of the power lines, using FACTS, etc.

The objective of the project is to develop an algorithm and create a computer tool to implement it in order to evaluate the benefits of the different alternatives with respect to the construction of electricity power lines. This tool shall evaluate the alternatives by generating a document that describes them, together with their respective advantages and disadvantages, thereby helping to plan projects which tackle the development of specific alternatives. The demonstration or presentation of one or more specific alternatives could be included within the scope of the project.

3.1.2 High-temperature and other special conductors ❷

Tied in with Project 3.1.1., this project involves the study of special conductors that would increase the capacity, and therefore the performance, of existing power lines. The objective is to evaluate different alternatives of special high-capacity transport conductor by carrying out a series of tests, with special emphasis being placed on superconductor technology.

3.1.3 The incorporation and use of FACTS ❷

The FACTS devices act upon the voltages and currents in the transport system, thereby enabling the power flows to be controlled and increasing their capacity for transporting energy.

Tied in with Project 3.1.1., the objective of this project is to evaluate the different uses to which FACTS could be put in order to enable better use to be made of the existing grid and to provide some sort of proof of this.

3.2 The Creation of Grid Development Models

OBJECTIVE:

The uncertainty when it comes to the siting of the new electricity generating plants, to the growth in demand and to the commissioning of new grid infrastructures represents a challenge when planning the electrical grids of the future. At present, the installation of new electricity generating plants is subject to the whims of the developers as well as to technical requirements. This, combined with the relatively short deadline needed for the construction of these installations results in a great deal of uncertainty with respect to which grid infrastructures are necessary in the medium- and long-term.

It is necessary to reduce this uncertainty in order to prevent an inefficient development and usage of the grid.

Potential Projects:

1) Tools for estimating the siting of generating plants
2) Energy storage systems for favouring the integration of renewables
3) Models for planning and developing grids involving a high degree of uncertainty

3.2.1 Tools for estimating the siting of generating plants ❷

The objective of this project is to develop an algorithm (and implement it using a computer programme) that enables the most probable sitings and characteristics of future generating plants to be estimated in order to be able to better plan the grid required. It will be necessary to bear in mind the characteristics of the different types of generating plant and the traits of the Spanish electricity systems (both mainland and offshore). The idea behind the aforementioned estimation is to reduce uncertainty and thereby make the task of planning the future electricity installations easier.

3.2.2 Energy storage systems for favouring the integration of renewables ❶

The need to reduce dependency on energy generated outside Spain and to reduce the emissions of greenhouse gases has led to a sharp rise in the installation of renewable energy generating plants. These installations possess a number of traits that differentiate them from their conventional counterparts and demand special attention when it comes to integrating them into the electricity system.

In order to simplify the integration of the renewable energy generating plants, this project will carry out a technical and economic evaluation of the energy storage process as a method for maximising the incorporation of renewable generation. The legal aspects will also be taken into account.

3.3 Electrical Equipment

OBJECTIVE:

The growth of the electricity system and of the socio-environmental restrictions, which are becoming increasingly strict, requires equipment capable of producing higher levels of performance. On some occasions it is not viable to replace equipment en masse, and this makes it necessary to design new topologies or incorporate special equipment.

Potential Projects:

1) Dynamic short-circuit current governor
2) Devices for conditioning wave quality
3) Developing the auxiliary elements of superconductor systems
4) Developing and integrating energy storage systems
5) Developing and integrating mobile recharging points

3.3.1 Dynamic short-circuit current governor ❸

The increase of shielding of the transport networks has, in some areas, caused an excessive growth of short-circuit currents, especially in the 220 kV grids of large cities. For a number of installations it is forecast that the maximum value that can be withstood by the devices will be reached in the short- to medium-term. Replacing the equipment affected is not generally seen as being an effective solution as the problem normally affects a great many substations. The other solutions currently being adopted are the deshielding of the grid (opening power lines or dividing one substation into two) or increasing the impedances (with high-impedance transformers or standard reactances). This type of solution makes it difficult for the grid to function adequately on a permanent basis as it restricts the flows of loads or charges, especially in a situation of contingency.

This project sets out to prove whether the performance of the dynamic short-circuit current governors is suitable for solving the problem and which configurations are optimum. This type of device enables the grid to operate shielded on a permanent basis and unshielded (or with greater impedance) during the short circuit. Computer tools will be used to evaluate the different types of device and different installation sitings. A device will then be installed in AT and its performance will be evaluated.

3.3.2 Devices for conditioning wave quality ❸

The growing sensitivity of the equipment that consumers connect to the electrical grid coupled with the growing number potentially disruptive surges within the grid mean that every so often the emission limits of some disturbances can be reached.

Appropriately designed devices based on power electronics enable these disturbances to be mitigated. In order for these to be developed, the topologies required for each level of voltage and application must be identified, as must the most effective control techniques.

3.3.3 Developing the auxiliary elements of superconductor systems (temperature and screening control) ❸

A project aimed at developing the auxiliary elements needed to use superconductivity in the development of technologies based on high-temperature superconductors such as generators, cables, transformers, motors and storage devices, short-circuit current governors, etc.

3.3.4 Developing and integrating energy storage systems ❷

These are more of a distributed energy-related resource, but at the same time are extremely relevant and emerging factors.

Pilot projects that enable their impact upon the way the system operates to be analysed.

3.3.5 Developing and integrating mobile recharging points ❶

The scarcity of oil-based fuels heralds the expansion of electrically driven vehicles. This will cause the composition of the demand curve to change dramatically.

The intention is to carry out projects that consider the impact of this means of transport upon the way electrical grids are planned and run.

3.4 Development Alternatives of the Electrical Grid of the Future

OBJECTIVE:

In the future electrical grids will be faced with the problem caused by the existence of a large amount of distributed generation. In the light of this future situation the grids of the future shall have to be so planned as to be able to not only provide an integrated response to the problem of security, but also a response that is structured in such a way that a problem in one part of the grid does not compromise other parts to such an extent that they can continue to operate with almost total normality.

The objective of this line of research it that of evaluating grid designs that enable the distribution and transport networks to perform the role they will have to play in the future. In order to evaluate the performance of the distribution networks once a greater degree of distributed generation has been integrated, it will be especially important to evaluate flows that are more similar to those of a shielded grid and compare them with the traditional flows of radial grids in which the only thing that exists is demand.

Potential Projects:

1) Microgrids
2) Aggregating distributed generation
3) Using power electronics devices
4) Static switch-based protection devices

3.4.1 Microgrids ❷

The planning of electrical systems has been oriented towards an interconnected structure with the stability of these systems being of prime importance. The installation of distributed generation sources at sites that are relatively close to the points of consumption and the advances made with respect to local control systems might pave the way for an alternative design of the electricity supply system.

The electrical grid can be designed to react to certain contingencies by dividing it up into perfectly planned and studied segments which minimise the possibility of the spread of incidents.

This strategy will enable the creation of independent isolated systems that are stable unto themselves and which would reduce the consequences of a disruption and make the subsequent replacement process easier.

3.4.2 Aggregating distributed generation ❶

The so-called distributed generation, irrespective of whether it is renewable or not, has, up until now, been integrated into the operation of the electricity system. Legislative changes are trying to encourage the participation of these agents in the day-to-day maintenance tasks that ensure the stability and safety of the system, but their effective participation continues to be minimal, hindered in part by their lack of technical capacity and in part by their relatively small size.

An alternative to study as a mechanism for increasing their commitment with respect to safety criteria involves the aggregation of this type of resources. The aggregator is set as being a manner of super agent who brings together individual elements until a critical size is reached in terms of power. He/She then coordinates and represents them, and is ultimately liable for the commitments entered into with the respective electrical grid operators within his/her scope of activity and influence.

3.4.3 Using power electronics devices ❷

The use of power electronics devices will enable the installations of the grid to be used in an optimum manner. Among potential applications are the redirecting of flows, both on a permanent basis and during a contingency, and wave quality.

In a scenario within which a great many power electronics devices exist side-by-side with other pieces of control equipment, it will be necessary to study the interaction between them.

Power electronics must likewise contribute towards improving supply quality control in relation with distributed generation.

3.4.4 Static switch-based protection devices ❷

The installation of intelligent switches and protection devices based on static devices incorporated into the grid's electric equipment enables the system to be controlled and protected. These devices can be controlled in a flexible manner by alleviating the severity of the transients associated with the protection opening and rearming operations, thereby preventing the damage caused to transformers and the rest of the equipment. The selection of the switching technologies and the connection thereof to the medium- and high-voltage levels with a reduced associated size and cost is one of the challenges of this activity.

On the other hand, the growth and shielding of the transport networks, and the proliferation of large power generating and consumption centres has resulted in the critical defect clearance times shortening, reaching, in some cases, values that are on the limit of the possibilities of mechanical switches. As far as future developments of the electricity system are concerned, it might be necessary to install, in some locations, static switches whose performance level and coordination with other pieces of equipment shall have to be evaluated.

3.5 Alternative Development Strategies as regards the Grid of the Future

OBJECTIVE:

With the purpose of being able to cover increases in demand, over the last few years, installations similar to those already in existence have been planned and built. There has been a tendency towards the installations having a greater transport capacity, but technology and transport voltage levels remain where they have always been. The question is whether continuing to expand the grid along the same lines in the future will be sufficient, or will the time come when a conceptual change in the design of the transport network will have to be made.

The objective of this line of research is to evaluate alternative grid development strategies in light of extremely large increases in demand, in other words, within a long-term horizon. Alternative technologies capable of supplying the demand when the value thereof reaches in the order of double that of today are evaluated, bearing in mind not only all the benefits attained, but also the disadvantages involved, including, among others: costs incurred, costs avoided, estimated expiry, increase or decrease of risks, etc. Included among the actions evaluated are: the creation of grids with voltages greater than those of today, the use of installations under direct current, the use of FACTS, etc.

In the result of these projects the type and distribution of the generating plants adopted in the study scenarios will be extremely influential.

Potential Projects:

1) Direct current
2) Extra High Voltage

3.5.1 Direct current ❷

Direct current enables more power to be transported by a line designed to function with alternate current and also enables the flow through that line to be controlled. Both applications might be very useful for making better use of the grid without constructing new power lines.

Likewise, it could be an interesting solution with respect to distribution when it comes to resolving a number of special situations such as is the case of microgrids.

In a scenario in which direct current installations operate side-by-side with power electronics devices and with other control equipment, it is necessary to study the interaction between all of them.

3.5.2 Extra High Voltage ❸

One of the possible solutions for getting more out of the existing layouts is to increase the voltage of the installations. To do this, it might be necessary to plan large hubs operating with very high voltage in the future.

4. – Metering

4. Metering

What will the electrical grid-end consumer relationship be like in 2025?

The consumer of 2025 will most likely be supplied by a far more diversified electrical grid as far as services are concerned, with different agents involved, a grid in which he/she will play a dual role: that of consumer and generator.

The idea behind the grid of the future is to optimise resources on a local scale and manage them by way of a decentralised grid control process. In this sense, the operation of the grid will have a local control centre which will have to manage a series of demanding quality of service criteria.

In addition, the customer will have a number of non-electrical energy service offerings from which to choose, such as the supply of steam, hot water, cold water, etc., meaning that the electrical grid will form part of an energy network in which the different services will exist side-by-side, thereby enabling them all to be optimised.

This would therefore signify the development of an open and deregulated energy market in which consumers can buy and sell their energy, all controlled by a decentralised operations centre with access to real time information with respect to both generation and demand, and it shall be possible to implement demand management strategies and techniques in order to: maintain the reliability/availability of the grid at all times, optimise supply costs and create a market in which pricing is organised in such a way as to enable customers to choose when, how much and how to consume in accordance with the prices in force.

How will demand be metered and managed?

In order to enable the grid to be operated and the demand to be actively managed in real time, it will be necessary to deploy a communications network between the electrical grid operator and the customers. This situation, combined with the creation of the decentralised control of the grid, will speed the development of a metering process that is implemented, in the main, locally and remotely, a system in which the different parameters (levels of power generated/consumed, voltage, frequency and other quality parameters) of the different energy sources and points of consumption will be monitored. This information will feed the system which, together with other information, will optimise the exchange of energy on both a local and a global level.

What opportunities does demand management present?

The current demand management process consists, on the one hand, of an interruptibility system that is used whenever forecast demand exceeds the available generation capacity and, on the other, of an hourly-rate distinction model that rewards the consumption of trough-period energy and penalises peak-period energy consumption. The demand management process of the future will be a dynamic management carried out in real time that optimises not only global, but also local production/generation. The consumer/producer will receive an input in real time (an input that could be the energy price), and he/she will be able to change his/her consumption/production status accordingly. The advantages of this system are:

- The grid becomes more reliable due to the increase of flexibility in supply/demand, which in turn makes the grid easier to manage (less peaks of consumption, faster response to incidents in the grid, etc.).
- The quality and quantity of energy supplied increases. Active management will enable better use to be made of the installation, meaning that it will be possible to transport more energy of a higher quality.
- Reduced costs derived from the incorporation of distributed generation into the overall generation, transport and distribution scenario, thereby enabling electricity prices to fall.
- More efficient markets due to the better use that consumers are making of their energy.
- Minimisation of risks, due to a price-dynamic market and the fact that power available in the grid is safe, reliable and accessible.
- Less environmental impact due to the replacement of traditional polluting generating plants with others of a renewable nature, less polluting, etc.
- Less losses during distribution due to more and better using being made of distributed generation.

Demand management is closely linked with **Energy Efficiency**, with the former seeking out the best way to consume electricity while the latter pursues the reduction of electricity consumption (kWh). This subject has a direct bearing on the sustainable development of energy resources, so necessary in Spain where primary energy intensity is above the European average (EU 25). Therefore, the opportunities here are as follows:

- With the new services unnecessary and expensive transformations of energy are avoided.
- By integrating the distributed generation energy flows and knowing how they will develop and their capacity, the intention is that these operate at their optimum energy efficiency by balancing Consumption against Generation.
- Accurate metering carried out on time helps to prevent maintenance problems and inefficient performance levels and, therefore, unnecessary consumption.

What are the current obstacles and conflicts hindering this venture?

- A lack of standard and open communications protocols that guarantee the interoperability between equipment made by different manufacturers.
- Limitations in the capacity of the communications.
- Lack of adaptation of customers' equipment to energy management process.
- Large investment needed for the mass deployment of the metering and communications technology to reach 100% of customers.
- The customer's perception of saving. Social awareness forms a fundamental part of the demand management process.
- Distributed control development.

- Conflicts of interests among the agents involved.

Lines of Research

4.1 Metering and Control Equipment and Technologies for the Grid-Customer Interface

INTRODUCTION

In the electrical grid of 2025 the role of the consumer will change and he/she will go from being a passive part of the system to actively participating in it by managing the energy he/she both demands and generates. In order to be able to achieve this aim, it is necessary to develop the metering devices we know today and convert them into integrated metering and control devices. The communication systems must also be developed to enable them to handle the growing amounts of information as well as the interconnection between the different systems involved.

OBJECTIVE

The objective is to define, develop and test an interoperable, standards-based energy management system that is capable of managing the energy demand and resending locally generated energy so that customers can reap the real time benefits of energy prices, information regarding the status of the electrical grid, and other opportunities of the market with special focus upon distributed generation and demand participation. The system will be based on a new and open architecture that will support bidirectional communications between all the agents involved and the metering device on the one side, and between the metering device and apparatus (electrical domestic appliances) and distributed generation devices on the other.

Potential Projects:

Short-term projects:

1) Integrated (control and metering) devices for managing demand and distributed generation
2) Establishing the communications system between the metering and control device and the demand management centres
3) Defining the interaction between the metering and control device and the customer's installation

4.1.1 Integrated (control and metering) devices for managing demand and distributed generation ❷

The requirements of the new metering and control devices will be established bearing in mind the increase in the quantity of information to be handled by them (the metering of energy, metering quality of supply parameters, the provision of new services) and the interaction thereof with the control systems upstream as well as with the installations of the customer.

4.1.2 Establishing the communications system between the metering and control device and the demand management centres ❶

Given the amount of information to be transmitted and the high number of devices involved, it is vitally important to define a standard communications protocol that is open, robust and safe in order to simplify interoperability between the devices of different suppliers.

4.1.3 Defining the interaction between the metering and control device and the customer's installation ❶

This project must define how the metering device will interact with the customer's installation, in other words, the way in which the metering and control device will manage the energy generated by the customer in accordance with the information received for the demand management centres and from the instructions pre-established in the device itself.

4.2 Demand Response

INTRODUCTION

This line of action involves an innovative user-level energy management concept that sees the customer actively participating in the new energy market.

The current scenario would be the following: while electricity prices are constantly fluctuating, the end consumers do not generally see these price changes. Deprived of any clear indications as to variations in price, there is no incentive for customers to reduce their consumption during those less frequent periods during which prices are low.

Active demand response, which enables the electric charge to be sensitive to the variation of prices, is essential for ensuring an efficient supply-demand interaction. It alleviates generation and distribution restrictions, reduces the severity of peak period prices (and penalties) and leads to an overall reduction of electricity prices.

Therefore, demand response has to be based on the different markets and sectors, be profitable, and it has to efficiently promote a market of cheap prices.

It is for this reason that this line of action sets out to acquire in-depth knowledge as to which production and consumer sectors and markets are more likely to react and respond to the provision of economic incentives in real time. This is an incentive that, on the other hand, represents the implementation of a great many infrastructures and the acquisition of a lot of knowledge, both of which have to be compensated by the profits that the Demand Management process provide.

OBJECTIVES

- To adapt a bidirectional customer market response in an advanced real time electricity and services model.
- To characterise the demand response by sector/usage in order to create the customised incentive programmes and plans that foster the charges management process.

Potential Projects

Short- and medium-term projects:

1) The flexibility of electricity demand by sector / usage
2) Designing social sensitisation programmes: training/education, the diffusion of results, the advantages of certain services, etc.
3) Demand management programmes

Medium- and long-term projects:

4) Energy storage applications in response to demand
5) Research into energy efficiency

4.2.1 The flexibility of electricity demand by sector / usage ❷

Objectives: The need to change a consumption profile will directly depend on the degree to which the energy needs in question fluctuate. Therefore, the energy needs of a railway transport system will not be subject to much change, whereas the central heating/air-conditioning system of a hotel will. This project will be the first step of section 4.3.2.

- Characterising technologies in order to discover their energy management possibilities
- Characterising and quantifying the response's susceptibility to variations of price.

4.2.2 Designing social sensitisation programmes: training/education, the diffusion of results, the advantages of certain services, etc. ❷

Objectives: Public sensitisation will be a fundamental point with respect to active demand response bearing in mind current energy prices.

- Proposals for mass public social awareness programmes which will consist of not only informative campaigns, but also financial aid schemes in order to encourage customers to adopt the necessary infrastructures
- Identifying educational elements for schools regarding energy costs
- Awareness programmes in the workplace

4.2.3 Demand management programmes ❶

Objectives: The process for determining the reference price needed for managing the demand is influenced by a multitude of factors, such as the price of energy, the local availability of energies (renewables, self-generation, etc.), the technical restrictions, the condition of the grid, degrees of synchronicity, etc. The purpose of this project is that of defining an algorithm that uses all of these parameters to optimise operational capacity.

Defining the strategies of the customer in order to reduce his/her energy bills. A number of strategies are considered in accordance with time frames (long-term by way of a pre-established static discrimination, medium-term via weekly or daily energy cost planning procedures and short-term using price changes in real time) and with the distributed energy resource possibilities available to the customer.

- Different simulation models for each of the strategies: cheap period consumption, reduced consumption in accordance with the status of the grid, with the availability of self-generated energy, etc.).
- The detection of effective strategies that enable manual, semi-automatic and automatic management processes.

4.2.4 Energy storage applications in response to demand ❷

Objectives: Storage technologies will be a key parameter for separating specific energy needs from energy production and in this way bringing more flexibility into the consumption process as a whole.

- Identifying the storage technologies most likely to enable the per sector demand management process to be more flexible.

4.2.5 Research into energy efficiency ❶

Objectives: Energy efficiency research projects will help to reduce CO_2 emissions and encourage a more responsible and sustainable use of energy among consumers in the medium- and long-term.

This section will include projects for reducing the losses of energy in the grids, improving efficiency in installations and buildings, rationalising consumption and improving energy efficiency in general.

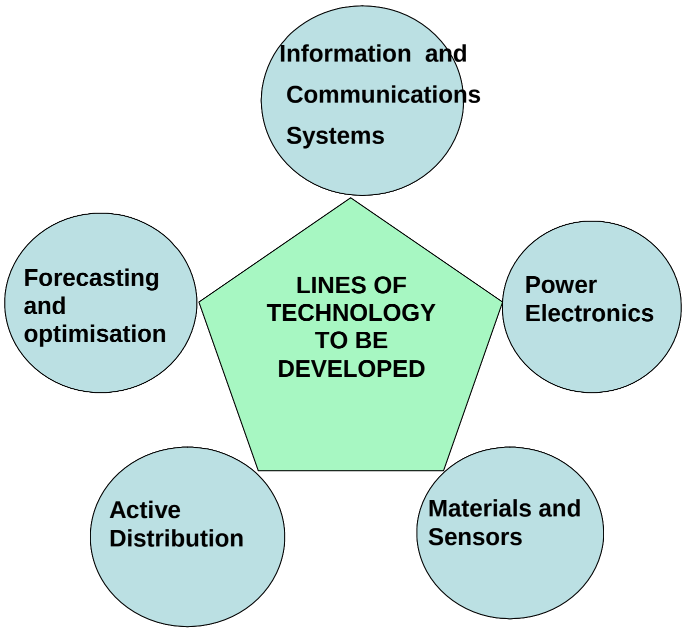
5. – Technological Developments to which Priority must be given in order to achieve the FUTURED Vision

Given the fact that it is a fare more sophisticated grid, FUTURED shall have to incorporate significant technological developments as regards both software and hardware and in the application of new materials.

FUTURED will need to incorporate intelligent elements to an extensive degree. This intelligence will be mainly obtained via development and the application of Information and Communications Technologies (ICTs), as well as advances made as regards forecasting and optimisation capacities.

Together with the technological advances, which could well be jointly referred to as grid software developments, there is the need to develop other technologies that are closer to or related with grid hardware: power electronics —for providing a greater degree of control over the components of the grid— and active distribution —in order to enable the integration and a more efficient use to be made of distributed energy resources—.

Both the development of the aforementioned areas and the advances made with respect to the basic components of the grid must be supported by and, in turn, conducive to innovation involving materials and sensors.



5. Other Technologies to be Prioritised

Information and Communications Technologies (ICTs)

Applying ICTs automates the majority of electrical grid operations, such as metering, billing, transport and distribution. It goes without saying that the current control and automation algorithms installed in the grid's control systems do not provide a response that can be adjusted to the variable conditions that will be present in the electrical grid of 2025. Distributed intelligence, the establishment of standards and the need to respond not only to the capacity of different systems and devices to interoperate, but also to the mass processing of data will be the driving force behind the development of the communications architecture of the future and this, in turn, will determine how this type of systems must be controlled and how they must operate.

In the electrical grid pieces of equipment from different technological eras exist side-by-side, but the installation of a more intelligent supply system —with advanced sensors and communications systems that are both integrated and secure— will characterise a more modern electrical grid that is:

- Always **available and alive**, interconnected and interactive, and inextricably combined with standardised communications to form a complex grid that is capable of exchanging energy and information in real time.
- **Self-reconfigurable**, that is to say that it monitor and corrects itself in real time in order to enable a constant flow of high-quality energy. It is capable of detecting any anomalies and counteracting them, or reconfiguring the flows in order to isolate any defect before it can become an incident.
- **Proactive**, thanks to the distributed intelligence of the devices, which enables the availability of advance information with respect to the maintenance needs or working life management of the devices themselves.
- With an extremely **flexible, robust and sensitive** integrated and controlled supply system capable of responding in real time to the millions of decisions taken by the different agents involved: consumers, suppliers, operators, etc.

Forecasting and optimisation

The new configurations of electrical grids that are more decentralised and flexible and capable of absorbing new energy generation and storage elements will require the development of new analysis models.

These models shall have to cover the functions of a regulated design —system planning, operation and control— and simulate different time frames —long-, medium- and short-term—, by considering not only the institutional and organisational, but also the financial and physical relationships between the agents involved.

Described below are some of the challenges facing the development of these models:

- The size of the systems, with numerous active elements: distributed generation, microgrids, FACTS control elements and interactive demand.

- The capacity to manage and process an extremely large volume of information originating from the grid's increased observation and control capacity and from the agents connected to it.
- The distributed and decentralised logic based on intelligent agents —with local functionality— but integrated with the efficiency and security maintenance processes of the system as a whole.
- The integration of the different energy resources as well as the interaction, dependency and vulnerability of the different supply networks —electricity and gas— and of communications.
- The different forms of modelling and simulation of the agents and of the system linked to the different problems to be solved: designing tariffs and prices, planning investments, simulating markets and interaction with the grids, operation and control, security and stability and monitoring and managing the working life of the installations.

Power electronics

The development of power electronics in the field of low-, medium and high-voltage will enable the components of the grid to be controlled rapidly and accurately.

Power electronics will represent the core of the intermediary phases between the different types of grid (AC/DC) and between the different energy storage and distributed generation elements.

As far as the transmission mechanisms and systems are concerned, the power electronics configurations applied to those inductive couplings with a high switching frequency provide important alternatives to the current systems based on the synchronous environment of the alternate current. Furthermore, different FACTS devices will be developed that are capable of acting like flow controllers and static grid conditioner in order to improve the control of the system and increase the levels of transferred energy.

With respect to distribution levels, power electronics will enable the development of the «active distribution» concept. This will allow the power flows to be controlled, contribute towards maintaining the stability of the grid and ensure the quality of the energy supplied. Different stabilisation and regulation systems will be installed and managed in the electricity substations. The incorporation of intelligent switches and protections based on static switches will also be necessary.

Active distribution

The development of new integration technologies with respect to distributed generation and consumption systems —integrated in local microgrids and macrogrids connected to the ends of the general distribution grid— is fundamental for constructing the infrastructures of the electricity system of the future.

The random nature of the generating systems involving renewable energies and the fact that it is impossible to adapt these to demand development shall be compensated by the new technologies —by way of integration techniques between different energy generating, storage and proportioning systems—. The application of direct electrical energy storage techniques using electrochemical process will represent a veritable revolution within the energy scenario in general, but, despite the spectacular technological advances of the last few years, cost will have to fall dramatically if these are to form a feasible part of our electricity supply systems.

In rural areas efforts shall also have to be made with respect to potential energy storage techniques by way of making the very most of water, wind and solar resources. The integrated generation-impulsion installations —with common devices and systems for the different functions— will generate electricity in an efficient, solid and cheap manner and transfer the energy to the general system in a stable and regulated way.

The advances made with respect to obtaining more efficient systems, such as the micro-CHP systems —combined electrical energy and heat and cold generating elements—, will increase the number of installations in the domestic, tertiary and industrial sectors.

The development of H2 exploitation techniques, as well as the advances being made with other storage techniques —such as compressed air, flywheel drives, enthalpic storage, etc.— shall also have to be prioritised in order to create complementary systems capable of regulating and stabilising a high-quality energy supply.

The application of new technologies in direct current designed for the integration of generating and consumption systems which, by their very nature, generate or use this type of electrical energy —photovoltaic panels, fuel batteries fed using H2, supercondensers, organic batteries, variable speed systems, etc.—, will favour the implementation of distributed generation techniques.

Finally, the development of new elements that enable active demand management will provide an additional distributed resource to help regulate and stabilise the grid.

Materials and sensors

A primary requisite is the development of materials that are, in turn, capable of future development, fine tuning these and installing new conductors that make developing the grid of the future possible. In this respect, nanoscience will be the driving force behind the development of new ceramic, metal and biological elements, etc. This development must prompt innovation with respect to components linked with the respective development of power electronics in the fields of medium- and high-voltage. It is also worth proposing the creation of new conductor materials whose characteristics enable a large density of energy to be distributed with an extremely low loss rate, are of a reduced volume and weight and, of course, cheap and very easy to handle.

The scope of the performance levels of the grids of the future will depend, to a large extent, on the development of high-temperature superconductors. The possibility of transmitting large quantities of energy via compact underground conduits over long distances or distributing this energy in the large towns and cities with minimum losses and drops in voltage will revolutionise the electricity system and increase its reliability and efficiency at the same time as reducing the use of fuel, polluting emissions and the land surface area used.

High-temperature superconductor-based technologies shall be used in generators, cables, transformers, motors and storage devices, as well as in all that equipment that provides the system with greater flexibility (for example, short-circuit current governors).

When these technologies are applied in the «synchronous alternate current environment», the large density of current reached will give rise to a number of electromagnetic fields associated with much higher capacity power lines and grids. This will constitute a key aspect. What is more, it will represent a complementary challenge: the development of auxiliary screening systems that will not hinder the technical-financial viability of applying superconductors.