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| **Radiocommunication Study Groups** |  |
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| Smart grid power management systems |

# 1 Introduction

Smart grid communication technologies have fast become a fundamental tool with which many utilities are building their smart grids.

Over recent years, administrations and national commissions overseeing electric power generation distribution and consumption have made commitments to improve efficiency, conservation, security and reliability as part of their efforts to reduce the 40% of the world’s greenhouse gases produced by electric power generation[[1]](#footnote-1). Smart grid systems are a key enabling technology in this respect. Secure communications form a key component of smart grid, and underpin some of the largest and most advanced smart grid deployments in development today.

High-capacity, two-way communication networks with embedded sensing can be installed on existing electric, water, and gas distribution networks to transform them into interactive, automated, self-healing smart grids. These smart grids are monitored by a 24 × 7 network management system and analytic software platforms that enhance and modernize the efficiency, reliability, and security of electric distribution networks. Electric distribution wires touch every single critical juncture point that an electric smart grid must monitor and control and power Smart Grid devices that monitor and control electric, water, and gas distribution. Using secure, reliable, standards-based communication systems is a natural and economical extension of the existing electric distribution infrastructure, one that is sure to access every desired segment of today’s grid.

Smart grid systems reduce distribution infrastructure, operating, and maintenance costs by optimizing grid operations. This optimization also reduces the amount of needed electric generation, which in turn lowers generation-related green house gas (“GHG”) emissions. These particular savings emanate from efficient grid operations, including distribution automation and real-time system optimization. Smart Grid systems also enable grooming in alternative energy sources, such as photovoltaic and wind power, and managing the large and variable loads, for example, electric transportation applications like Electric Vehicles (EVs).

# 2 Smart grid features and characteristics

The fundamental method of operating the electric distribution grid has not changed significantly in the past 100 years. Customer complaints are most often the only source information about a local electrical outage. Most utilities do have reliable data reflecting local operational inefficiencies or vulnerabilities, so problems may continue for years after they develop due to inadequate or nonexistent automated monitoring and control capabilities. The digital sensing, monitoring and control technologies that are widely deployed in telecommunication networks, traffic systems and automobiles have not been similarly applied to utility distribution. Today’s communication technologies will provide needed visibility, control, and security for the smart grids of the 21st century.

A smart grid provides this information overlay and control infrastructure, creating an integrated communication and sensing network. The smart grid network provides both the utility and the customer with increased control over the use of electricity, water and gas. Furthermore, the network enables utility distribution grids to operate more efficiently than ever before. This communication capacity makes possible key benefits including:

• reduction in product “lost” during distribution;

• increases in efficiency, reducing the amount of energy actually needed to serve a given amount of demand;

• remote detection of equipment problems to extend the life of such equipment and avoid outages or repair them more quickly;

• controlling end-user consumption during peak times;

• enabling end users to control their consumption all the time;

• integrating the wide spread use of renewable energy distributed energy resources (like roof-top solar panels and plug-in electric vehicles).

Recent United States legislation[[2]](#footnote-2) characterizes smart grid as consisting of these elements:

1) increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid;

2) dynamic optimization of grid operations and resources, with full cyber-security;

3) deployment and integration of distributed resources and generation, including renewable resources;

4) development and incorporation of demand response, demand-side resources, and energy‑efficiency resources;

5) deployment of “smart” technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation;

6) integration of “smart” appliances and consumer devices;

7) deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning;

8) provision to consumers of timely information and control options;

9) development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid;

10) identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

The Electric Power Research Institute (EPRI)[[3]](#footnote-3) defines smart grid as a power system that can incorporate millions of sensors all connected through an advanced communication and data acquisition system. Such a system will provide real-time analysis by a distributed computing system that will enable predictive rather than reactive responses to blink-of-the-eye disruptions and is designed to support both a changing generation mix in a carbon constrained world, and more effective participation by consumers in managing their use of electricity[[4]](#footnote-4).

The Modern Grid Initiative sponsored by the U.S. Department of Energy (DOE)[[5]](#footnote-5) has a similar definition.

The critical nature of communications is also emphasized by EPRI in its plan to reduce U.S. carbon emissions where it identifies “Deployment of smart distribution grids and communications infrastructures to enable widespread end-use efficiency technology deployment, distributed generation, and plug-in hybrid electric vehicles” as one of four strategic technology challenges to be met to enable its overall plan[[6]](#footnote-6).

The European Commission ***Strategic Research Agenda*** recognizes that the communications system is a key element of active grids and the management of dispersed generation[[7]](#footnote-7), and identifies the following characteristics of smart grid:

1) flexible: fulfilling customers’ needs whilst responding to the changes and challenges ahead;

2) accessible: granting connection access to all network users, particularly for renewable power sources and high efficiency local generation with zero or low carbon emissions;

3) reliable: assuring and improving security and quality of supply, consistent with the demands of the digital age with resilience to hazards and uncertainties;

4) economic: providing best value through innovation, efficient energy management and “level playing field” competition and regulation[[8]](#footnote-8).

It further describes how the system can “efficiently link power sources with consumer demands, allowing both to decide how best to operate in real time. The level of control required to achieve this is much greater than in current distribution systems. It includes power flow assessment, voltage control and protection require cost-competitive technologies as well as new communication systems with more sensors and actuators than presently in the distribution system”[[9]](#footnote-9).

The May 2007 **European Strategic Energy Technology Plan** (SET-PLAN) also identifies System control and data exchange via ICT systems as one of the main technologies for the deployment of the smart grid[[10]](#footnote-10):

 “improving the ability to monitor and control areas of our networks not considered before will lead to improved deployment of RES [renewable energy sources] and real‑time optimization and operation of our networks in a more secure and safer way … Integration of large amounts of intermittent renewables will require increased data exchange (for instance intercompany data exchange among the generation to supply value chain to comply with deregulation requirements) and intelligent control systems in order to deliver the desired reliability with dedicated “platforms” managing the transmission of information among the different electricity system players (e.g. according to the UK model). This in turn will deliver the ability to react in real‑time for trading, fault prevention, asset management, residential and industrial generation control, demand side participation (e.g. frequency control from white goods appliances, integration of carbon credit schemes, etc), demand response management, energy data management, automated metering infrastructure where smart meters will offer tailored tariffs, flexible contract and value added services. The application of intelligent, highly distributed control strategies will enhance reliability and quality of service and provide self-healing capabilities at the distribution level including local black-start capabilities.”

As these policy pronouncements all make clear, smart grid is far more than advanced meters in homes and the remote monitoring and transmission of energy usage data via an advanced meter infrastructure (AMI). It is a network of sensors and devices providing real time analysis and control of the use of electricity throughout the distribution area, including on the grid itself[[11]](#footnote-11).

## 2.1 What is automated meter reading (AMR)?

Automated meter reading (AMR) refers to the technology used for automating collection of water and energy (electricity or gas) consumption data for the purposes of real-time billing and consumption analysis. At a specified time, the AMR system gathers real-time data and transfers the information gathered to the central databases, through networking technology, for billing, troubleshooting and analysing.

The primary benefit of AMR is that it provides more frequent, accurate, and precise measurement of water, electricity or gas consumption, saves utility providers the expense of periodic trips to each physical location to read a meter, and provides readings free of human errors in transcription.

AMR technologies include handheld, mobile and network technologies based on telephony platforms (wired and wireless), radio frequency (RF) or power line transmission.

## 2.2 How does automated meter reading (AMR) work?

AMR operations are simple on the surface but rather complex underneath. Initially, the meter must be read by the meter interface. Then the same interface translates the data into digital information to facilitate transmission. A code is then added to the meter data reading so that the data can be attributed to the correct subscriber. Once the data is encoded, the data is then read by a data collection unit, either a mobile handheld unit or a wireless gateway, operated by the utility personnel. During this time, a digital transfer from the meter interface to a device that the meter reader controls takes the data, whereby, the data collected is downloaded in the office. Data can also be automatically transmitted to the database through automatic data transmission protocols.

## 2.3 Difference between automated meter reading (AMR) and advanced metering infrastructure (AMI)

The advent of AMR came about in the early 1990s as an automated way to collect basic meter-reading data. Whereas, the term and technology behind advanced metering infrastructure (AMI) began showing itself around 2005, evolving from the foundations of AMR. The two terms, AMR and AMI, are used interchangeably even though the actual meaning or definition is slightly different. All AMI systems contain AMR functionality, although it is not the core of its purpose, but all AMR systems are not AMI systems.

AMR likely includes all one-way systems, drive-by and walk-by systems, phone-based dial-up systems, handheld reading entry devices and touch-based systems. These systems tend to be collection only, without means for broadcasting command or control messages. In addition, data from AMR systems is typically gathered only monthly or, at most, daily. AMI is typically more automated and allows real-time, on-demand interrogations with metering endpoints. The meters in an AMI system are often referred to as smart meters, since they often can use collected data based on programmed logic.

## 2.4 Typical configuration

AMR

The configuration of an AMR system generally begins at the meter and includes a meter reading interface device, a data collection device, and the mobile application software, which calculates the billing information to the client. For an AMR system, the meter reading interface device is a radio device which reads the data off of the meter. It is in close proximity to the meter and is generally mounted on a wall near the meter. The information that is read with the meter interface unit is transmitted over to a data collection point. Some data collection devices use radio frequencies in close proximity, such as walk-by or drive-by devices, which are mobile data collection devices that can read the data off the meter interface unit at short distances. Other data collection devices come in the form of a wireless gateway. Once the data is collected, the mobile application software analyses the data and the information is stored and information for billing is also processed for the consumer.

AMI

The configuration of an AMI system includes the aspects of AMR within its infrastructure, but also implements automated two-way communication for real-time, on-demand data access at the metering endpoints. There is two-way communication between the meter interface unit and the base application software. This communication may be transported using one or more of several available media. In this case, the information collected from the meter is analysed and consumption of the utility is assessed. For AMI, there are two major ways in which the control portion of the system operates. Firstly, the radio signal from the meter to the device can be controlled, similar to that of a thermostat, where the utility consumption level would be assessed at a certain threshold. Secondly, there would be communication back from the meter to the utility and then to the device to be controlled via the internet.

Currently, there are a wide variety of standard technologies being used in AMI applications, which include cellular modems, dial-up modems, power-line telecommunications, as well as the more common radio technologies, for example, IEEE 802.11 (Wi-Fi), IEEE 802.15 (Bluetooth and ZigBee), and IEEE 802.16 (WiMAX).

A typical configuration for AMR and AMI is shown in Fig. 1.

Figure 1

Automated meter reading and advanced metering infrastructure

[no figure attached]

## 2.5 Smart metering as a required component for a metering infrastructure in Europe

On 12 March 2009 the European Commission set out a standardization mandate M/441 to the European Standards Organization CEN, CENELEC and ETSI to develop one standard[[12]](#footnote-12).

The description of the mandated work is:

 “CEN, CENELEC and ETSI are requested to develop:

1) A European Standard comprising a software and hardware open architecture for utility meters that support secure bidirectional communication upstream and downstream through standardized interfaces and data exchange formats and allows advanced information and management and control systems for consumers and service suppliers. The architecture must be scalable to support from the simplest to the most complex applications. Furthermore, the architecture must consider current relevant communication media and be adaptable for future communication media. The communication standard of the open architecture must allow the secure interfacing for data exchanges with the protected metrological block.

2) European standards containing harmonized solutions for additional functionalities within an interoperable framework using where needed the above-mentioned open architecture for communication protocols. These solutions must be standardized to achieve full interoperability. Solutions meant to be installed in living quarters should be silent, non‑intrusive and safe.

3) The standards to be developed must be performance-based and permit innovation in the protocols that enable remote reading of utility and advanced information and management services for consumers and suppliers. In particular, the standards shall permit fully integrated instruments, modular and multi-part solutions. Standards developed under this mandate and M/374 should not conflict with each other and other standards and any overlaps should be indicated.

 CEN, CENELEC and ETSI should take into account international, European and national standard that have already been developed or are under development.”

As one goal the customer should have an indication of his current and thus adjust his consumption (intelligent metering).

The ESO are requested to provide a progress report by the end of October 2010.

CENELEC (Comité Européen de Normalisation Electrotechnique) is the European Committee for Electrotechnical Standardization and is responsible for European Standardization in the area of electrical engineering. ETSI (European Telecommunications Standards Institute) is responsible for European Standardization in the area of telecommunications whereas CEN (Comité Européen de Normalisation) the European Committee for Standardization tasks are in the other technical areas.

Additionally CEN, CENELEC and ETSI will invite ANEC (European Association for the Coordination of Consumer Representation in Standardisation, www.anec.org), ECOS (European Environmental Citizens Organisation for Standardisation, www.ecostandard.org), NORMAPME (European Office of Crafts, Trades and Small and Medium sized Enterprises for Standardisation, [www.normapme.com/](http://www.normapme.com/)) and the Open Meter Project (European Consortium, [www.openmeter.com/](http://www.openmeter.com/)) to take part in the standardization work.

The ESOs are guided through a high level steering and coordination forum SM-CG (smart metering coordination group). Two ad hoc groups, one which deals with ‘communication’ (architecture of standardization parts) and the other one dealing with ‘additional functionalities’ (catalogue of additional features in the sectors of gas, electricity, water and heating), were established. The Council of European Energy Regulators (CEER) is represented by currently five members from Austria, France, Germany, Italy and the United Kingdom.

ETSI signed a memorandum of Understanding with the Smart Metering Industry Group and CENELEC cooperates with ESMIG[[13]](#footnote-13).

# 3 Smart grid communication network technologies

Various types of communication networks may be used in smart grid implementation. Such communication networks, however, need to providesufficient capacity for basic and advanced smart grid applications that exist today as well as those that will be available in the near future.

Assessing communications needs of various smart grid applications requires an understanding of 1) the “control loop” timeline of the application[[14]](#footnote-14), 2) the amount of data that needs to be transferred at any particular time, 3) the number and location of devices with which communications must be maintained, and 4) the overall communication capacity of the proposed communication system. An application’s timeline and tolerance for latency in transferring and analysing data or control signals is critical to determining appropriate communications capability.

For example, the gathering of metering data for daily meter collection can tolerate a latency period of many hours (and even a period of several days in the case of monthly billing). But real-time, control-oriented applications such as voltage control, integration of distributed generation resources, and distribution switching require latency periods of no more than two seconds[[15]](#footnote-15).

Contemporaneous consideration must also be given to the consistency or predictability of a particular application’s activity. For example, a utility generally can schedule the collection of metering data and gradually perform such collection throughout the day or night in order to smooth out any data peaks. Many of the applications with the most stringent latency needs (e.g. outage alerts, system control applications), however, occur randomly and their activity therefore cannot be scheduled. A utility’s full analysis of its communication needs will therefore address all such application timelines, latency tolerances, and application predictability, including consideration of simultaneous activity from multiple applications.

The fundamental characteristic of a smart grid is its integrated communication and sensing network, which allows proactive management of the energy input sources as well as consumer demand. This communication capacity can and often will, be enabled by various technologies; however they all present different challenges and limitations.

One solution uses communication **via power lines**. This solution requires only the addition of communication/sensing devices overlaid on the existing electric distribution infrastructure.

Testing has shown PLC based ‘Smart Meter’ solutions to be sufficient for monthly readings or non-critical daily device communications.[[16]](#footnote-16)

An attractive alternative are the various wireless Smart Grid solutions being developed worldwide and applied in Europe. Ranging from point-to-multipoint solutions (e.g. cellular radio or satellite) through RF mesh solutions, and including hybrid deployments of both architectures[[17]](#footnote-17).

In Europe, ETSI TC M2M (Technical Committee Machine to Machine)[[18]](#footnote-18) is developing the response on European Mandate M/441. Smart meters as a device within smart grids are understood a part of broader machinery telecommunications. The deliverables contain a functional architecture on M2M[[19]](#footnote-19), use cases for smart metering[[20]](#footnote-20) and the technical report on ETSI M2M plans and deliverables for the EU Smart Meter Mandate M/441[[21]](#footnote-21).

The functional architecture decompose the architecture into M2M core, M2M access network and in the customers properties (e.g. houses, flats, etc.) installed M2M devices. The M2M devices got access to the access network directly or via an M2M area network and an M2M gateway.

Figure 1

Draft ETSI TR 102 691V0.4.1 (2010-02)



The M2M area network may use technologies such as IEEE 802.15 (Bluetooth and ZigBee), etc. or local networks such as PLC, M-BUS, Wireless M-BUS and KNX[[22]](#footnote-22). The M2M access network is based on existing access networks. Examples of access networks may include: xDSL, HFC, PLC, satellite, GERAN, UTRAN, eUTRAN, W-LAN and WiMAX. DSL technologies may include sharing an Internet access from the telecommunication premises of a subscriber.

Access to the smart meter with mobile networks (e.g. GSM/GRPS) may be assumed as one of the first deployed solutions. Those technologies are well introduced in the markets and the network operators can use their experiences in traditional markets.

PLC or the various wireless alternatives to cellular can offer economic efficiencies when their deployment is practical.

[Others: To be developed]

While all the different types of smart grid telecommunication technologies listed above can be used in specific circumstances, in some cases, especially where population densities and grid architecture dictate, Non-GPRS based smart grids may enable utilities to achieve the performance and cost profiles that allow for mass deployment and the full exploitation of the smart grid concept

# 4 Smart grid benefits

## 4.1 Reducing overall electricity demand through system optimization

Existing local electric distribution systems are designed to deliver energy and send it in one direction, but lack the intelligence to optimize the delivery. As a result, energy utilities must build enough generating capacity to meet peak energy demand, even though such peaks occur only on a few days per year and the average demand is much lower. Practically, this means that during days when demand is expected to be higher than average, the utility companies will restart occasionally used, less-efficient and more expensive generators.

In addition, utilities have limited information about the actual conditions on the distribution grid. The use of highly distributed sensors and two-way communications made possible with smart grid enables utility companies effectively to manage those peak loads and optimize their systems: studies show that by more tightly controlling voltage, utilities can reduce overall energy usage by 2 to 3%[[23]](#footnote-23). Additional savings can be realized by taking action to reduce line losses and reducing unnecessarily high voltage levels that serve only to inflate the amount of generation (and customer bills) needed to support a given level of demand. The EU, the U.S. Congress[[24]](#footnote-24), the International Energy Administration[[25]](#footnote-25) and many researchers and utilities believe that smart grid is an essential technology to improve the reliability and reduce the environmental impact of electric consumption. The EPRI has estimated that smart grid-enabled electrical distribution could reduce electrical energy consumption by 5% to 10% and carbon dioxide emissions by 13% to 25%[[26]](#footnote-26).

## 4.2 Integrating renewable and distributed energy resources

Rising energy costs and ever-greater environmental sensitivity mean that more and more individuals and companies are taking it upon themselves to generate their own electricity from renewable energy sources, such as wind or solar. Government incentives are often used to subsidize the deployment of these technologies, whether at a micro-generation level (i.e. an individual household) or as part of a larger commercial development. Unfortunately, the existing energy distribution network, which was never designed to accept ***input*** from the edge of the network, but merely to send power ***out*** to the edges, has difficulty in accommodating distributed generation patterns.

As a result it is often difficult, expensive, or even impossible to connect distributed renewable energy sources to the grid. Furthermore, even where renewable energy is fed back into the grid, the present distribution grids around the world have no way of anticipating or reacting to this backflow of electricity. Because these systems must be kept in balance and electricity is not easily stored, and because distribution systems and equipment are designed with the assumption that only the utility will determine when and where to send electricity, renewable and distributed resources put strain on the grid[[27]](#footnote-27).

Smart grid changes that. By communicating back to the control centre how much energy is required and how much is being input from the edges, the main generating capacity can be balanced to meet demand. Because smart grid enables this to happen in real time, utility companies can avoid the question of how unpredictable renewable energy sources are. They can compensate for fluctuations in renewable supply by system optimization, demand response and the integration of distributed electric storage such as plug-in hybrid vehicles, making the wide-scale use of distributed generation from micro and large-scale renewable sources a practical possibility. The recent report for the California Energy Commission on the Value of Distribution Automation, prepared by Energy and Environmental Economics, Inc. (E3), and EPRI Solutions, Inc., stated that the value of such distributed electric storage capable of being managed in real time (such as a battery or plug-in vehicles) would be increased by nearly 90% over a similar asset that is not connected by a smart grid[[28]](#footnote-28).

## 4.3 Providing a resilient network

PLT technology uses the electric distribution lines to sense events on the grid, allowing network operators to gather real-time intelligence on the status of their network. This enables providers of critical national infrastructure both to prevent outages before they occur and quickly pinpoint the site of an incident when one does occur. Smart grid does this by a series of software tools that gather and analyse data from sensors distributed throughout the electric distribution network to indicate where performance is suffering. Distribution companies can maximize their maintenance programmes to prevent breakages, and quickly dispatch engineers to the scene of an incident, independent of consumer feedback. In recent years, highly publicized blackouts in North American and European networks have made electricity network security a political question, and with an aging network the number of outages, and associated disruptions to end users, are only going to increase. Smart grid will provide a real tool in this constant battle for control. For example, PLT has been successfully used in Texas and Colorado to identify grid issues, eliminate outages, reduce outage times, and eliminate customer-impacting events and associated customer complaints[[29]](#footnote-29).

# 5 Smart grid in North America

In the United States and Canada, government agencies have recognized the real-time, high-capacity capabilities of a smart grid will enable utilities and end users to access the full economic and environmental benefits from renewable, especially distributed renewable, resources[[30]](#footnote-30). Similarly, these capabilities are expected to unleash the potential benefits of dynamic rate structures and demand response applications that require the ability to interact with many thousands of devices in real time[[31]](#footnote-31).

U.S. and Canadian authorities already acknowledge a fully integrated communication network as an integral part of a smart grid. For instance, the U.S. Department of Energy-sponsored modern grid initiative identified that “the implementation of integrated communications is a foundational need [of a smart grid], required by the other key technologies and essential to the modern power grid …”[[32]](#footnote-32)

The Department goes on to say that “[h]igh-speed, fully integrated, two-way communications technologies will allow much-needed real-time information and power exchange”[[33]](#footnote-33).

Similar emphasis on advanced communications functionality has been put forth by state authorities[[34]](#footnote-34) and other industry stakeholders. For example, the Ontario Smart Grid Forum recently stated that “communications technology is at the core of the smart grid. [Such technology] brings the data generated by meters, sensors, voltage controllers, mobile work units and a host of other devices on the grid to the computer systems and other equipment necessary to turn this data into actionable information”[[35]](#footnote-35).

# 6 Smart grid in Europe

Extensive European expertise and resources have been devoted to understanding and promoting smart grids as a solution to the challenges that Europe faces in terms of climate change and energy efficiency, including all of the following initiatives:

**• January 2008, Fiona Hall MEP Report “Action plan for energy efficiency: realizing the potential”**[[36]](#footnote-36)Report recognizes the importance of information and communication technologies to help generate additional productivity gains beyond the EU’s 20% target and considers that “*certain technologies such as smart grid technology … should … be the subject of effective policy recommendations*”.

**• June 2008, European Parliament (first reading) on the Directive on common rules for the internal market in electricity**[[37]](#footnote-37)advocates that“*pricing formulas, combined with the introduction of* ***smart metres and grids****, shall promote energy efficiency behaviour and the lowest possible costs for household customers, in particular households suffering energy poverty.”*

**•** The **Smart Grid European Technology Platform**[[38]](#footnote-38)works to “formulate and promote a vision for the development of European electricity networks looking towards 2020”, and in particular looks at how advanced ICT can help electricity networks become flexible, accessible, reliable and economic in line with changing European needs.

**•** The **Address project**[[39]](#footnote-39)(Active distribution networks with full integration of demand and distributed energy resources) is an EU-funded project which aims to deliver a comprehensive commercial and technical framework for the development of “active demand” in the smart grids of the future. ADDRESS combines 25 partners from 11 European countries spanning the entire electricity supply chain. PLT is a significant component of the projects underway pursuant to Address[[40]](#footnote-40).

## 6.1 European activities in some Member States[[41]](#footnote-41)

### 6.1.1 The European Industrial Initiative on electricity grids

The European Industrial Initiative on electricity grids[[42]](#footnote-42) is launched by the European Commission within the European Strategic Energy Technology (SET) Plan.

The SET-Plan was proposed by the European Commission’s General Directorates for Energy and for Research on 22 November 2007 with the aim to accelerate the availability of new energy technologies and to create a long term EU framework for energy technology development. The SET-Plan brings together the coordination of the European Commission, the research capacities of the major European institutes and universities, the engagement of European industry and the commitment of the Member States. One of two challenges addressed by the SET-Plan is mobilizing additional financial resources, for research and related infrastructures, industrial-scale demonstration and market replication projects. In the SET-Plan communication, the Commission informed about the increased budgets of the Seventh Framework Programme of the European Communities (2007-2013), as well as the Intelligent Energy Europe Programme.

The average annual budget dedicated to energy research (EC and Euratom) will be €886 million, compared to €574 million in the previous programmes[[43]](#footnote-43). The average annual budget dedicated to the Intelligent Energy Europe Programme will be €100 million, doubling previous values.

To engage the European industry, the European Commission proposed to launch in spring 2009 six European Industrial Initiatives (EII) in the areas of wind; solar; bio-energy; CO2 capture, transport and storage; electricity grids and nuclear fission. EIIs are devoted to strengthen energy research and innovation, to accelerate deployment of technologies and to progress beyond business-as-usual approach. EIIs bring together appropriate resources and actors in industrial sectors, in which sharing of risks, public-private partnerships and financing at European level gives additional value.

The EII on electricity grids is expected to focus on the development of the smart electricity system, including storage, and on the creation of a European Centre to implement a research programme for the European transmission network[[44]](#footnote-44), with the final objective to enable a single, smart European electricity grid able to accommodate the massive integration of renewable and decentralized energy sources[[45]](#footnote-45). As for other European Industrial Initiatives, EII on electricity grids shall have measurable objectives in terms of cost reduction or improved performance.

### 6.1.2 National technology platform – smart grids Germany

“E-Energy: ICT-based Energy System of the Future[[46]](#footnote-46)“is a new support and funding priority and part of the technology policy of the Federal Government. Just like the terms “E-Commerce” or “E‑Government”, the abbreviation “E-Energy” stands for the comprehensive digital interconnection and computer-based control and monitoring of the entire energy supply system.

It was decided that the electricity sector would be the first area addressed by the project, as the challenges with regard to real-time interaction and computer intelligence are particularly high due to electricity's limited ability to be stored. The primary goal of E-Energy is to create E-Energy model regions that demonstrate how the tremendous potential for optimization presented by information and communication technologies (ICT) can best be tapped to achieve greater efficiency, supply security and environmental compatibility (cornerstones of energy and climate policy) in power supply, and how, in turn, new jobs and markets can be developed. What is particularly innovative about this project is that integrative ICT system concepts, which optimize the efficiency, supply security and environmental compatibility of the entire electricity supply system all along the chain - from generation and transport to distribution and consumption - are developed and tested in real-time in regional E-Energy model projects.

To force the pace on the innovative development needed and to broaden the impact of the results, the E-Energy programme focused on the following three aspects:

1) creation of an E-Energy marketplace that facilitates electronic legal transactions and business dealings between all market participants;

2) digital interconnection and computerization of the technical systems and components, and the process control and maintenance activities based on these systems and components, such that the largely independent monitoring, analysis, control and regulation of the overall technical system is ensured;

3) online linking of the electronic energy marketplace and overall technical system so that real-time digital interaction of business and technology operations is guaranteed.

An E-Energy technology competition was held and six model projects were declared the winners. They each pursue an integral system approach, covering all energy-relevant economic activities both at market and technical operating levels.

The programme will run for a 4-year term and mobilizes, together with the equity capital of the participating companies, some €140 million for the development of six E-Energy model regions:

• eTelligence, model region of Cuxhaven

**Subject**: Intelligence for energy, markets and power grids

**•** E-DeMa, Ruhr area model region

**Subject:** Decentralized integrated energy systems on the way towards the E-Energy marketplace of the future

**•** MeRegio

**Subject**: Minimum Emission Region

**•** Mannheim model city

**Subject:** Model city of Mannheim in the model region of Rhein-Neckar

**•** RegModHarz

**Subject**: Regenerative model region of Harz

**•** Smart Watts, model region Aachen

**Subject:** Greater efficiency and consumer benefit with the Internet of Energy

Besides the project coordinators, others like vendors of electrical equipment, system integrators, service providers, research institutes and universities are involved.

By 2012, the selected model regions are to develop their promising proposals up to the stage at which they are ready for market launching and to test their marketability in everyday application.

# 7 Smart grid in Brazil

## 7.1 Introduction

The Ministry of Mines and Energy has promoted studies on technologies that could be used for the Smart Grid concept. These studies were motivated by the necessity to reduce the technical and non-technical losses and to improve the performance of the whole system in order to provide more reliability, resilience, security, etc. Recently, a study group supported by the Brazilian Ministry raised problems of the current power system and presented technologies and solutions that may reduce the losses and improve the performance of these power systems. These studies took into account the economic aspects as well, mainly the cost that would be acceptable for the installation over 45 million meters in the country.

## 7.2 Brazilian power sector

Currently Brazil has over 114 GW of power capacity and over 67 million of costumer use. As shown in Fig. 1, it can be seen that the power capacity in Brazil is provided mainly by hydroelectric and thermoelectric plants that make up 94% of the total generation capacity.

Figure 1

Brazilian



The average consumption in Brazil is 68 GW with peaks over 70 GW. Recently, the electric sector informed that it is foreseen that the consumption will increase around 60%, what demands energy efficiency for the electric system.

As a first step of this process, the Ministry considers as priority the reduction of technical and non-technical losses of power systems. The technical losses in transmission system and distribution system are 5% and 7%, respectively. Additionally, the non-technical losses, such as non authorized energy taps in distribution systems add up to 7%.

With these numbers, one can foresee huge challenges for Brazil in developing a power system that would increase efficiency and reduce losses.

## 7.3 Brazilian smart grid study group

In order to understand the Smart Grid concept, in May 2010 the Ministry of Mines and Energy created a study group composed of members of the electric and telecommunications sectors. One of the aims of this group is to evaluate the applicability of this concept in the Brazilian Power Grid in order to increase the efficiency of the system.

In mid-March 2011, a report was presented to the Minister of Mines and Energy on the state of art of this technology. This report contains information on the concepts of the Smart Grid, as well as technical information on economic, billing and telecommunication issues.

In the part on telecommunications, the study took into account the technologies and resources available in Brazil and what kind of technologies used in other countries could be applied in Brazil. As an initial strategy, the Brazilian Government has special interest in Advanced Metering Infrastructure deployment.

As part of this study, in October 2010, a technical group visited the United States of America to gather information on Smart Grid issues. In general, it was detected that almost all telecommunication technologies deployed as support for Smart Grid functionalities could be applied for Brazil’s purposes.

## 7.4 Telecommunication issues

It was seen that several kinds of telecommunication technologies can be applied for the same purpose. For example, both Zig-Bee and Mesh Grid can be used for reading end-users’ energy consumption meters. For Backhaul, WiMax, GPRS, 3G, 4G etc. may all be used. Each solution depends on technical aspects like available spectrum, propagation, throughput etc.

Currently there is uncertainty about the backhaul throughput needed by the Smart Grid applications. Certainly, this information is strategic for Smart Grid projects in order to choose the proper solution and requirements for spectrum resources like bandwidth, limits of harmful interference to other services, power limits and propagation aspects. So far, there have not been any studies on system requirements for telecommunication system that could be applied for Smart Grid.

We are concerned of electric field measurement techniques in the use of Power Line Carrier (PLC) in LF band in Smart Grid applications. Recently, some companies in Brazil have demonstrated interest on certification of PLC equipment with carries around 80 kHz with 20 kHz of band for Smart Metering. The emissions around this frequency are limited by regulation and the electric field limit is presented for measures taken at 300 m from the source.

## 7.5 Technical data

It is essential to raise data about backhaul throughput, latency, resilience, reliability etc., which would be considered suitable for Smart Grid in order to plan the necessary resources of infrastructure and spectrum and to avoid obsolescence and waste of resources.

## 7.6 LF measurements

Additionally, for enforcement purposes, in order to avoid the cumbersome procedures for electric field measurements in urban areas, taking into account rigorous regulation, it is recognized that other procedures such as power measurement would be less cumbersome than spectrum analyzer connected to LF antenna.

## 7.7 Conlusion

Due to the strategic nature of Smart Grid implementation in developing countries, we request contributions from other administrations on technical data and LF measurements as discussed above.

# 8 Data rates, bandwidths, frequency bands and spectrum requirements needed to support the needs of power grid management systems

## 8.1 AMI/AMR frequencies

The following is an example list of bands used for AMR/AMI in some parts of the world.

Table 1

AMR/AMI frequencies

|  |
| --- |
| Frequency (MHz) |
| 220-222 |
| 450-470 |
| {869} |
| 902-928 |
| 1 427-1 432 |
| 2 400-2 483.5 |
| 3 600-3 650 |
| 5 150-5 250 |
| 5 725-5 850 |

## 8.2 Middle mile

Where there are numerous collector points, it may be more efficient to use a point-to-multipoint architecture to link them to the backhaul network. This can be referred to as the middle mile. Some example characteristics of middle mile are as shown in Table 2.

Table 2

Middle mile

|  |  |
| --- | --- |
| Frequency band(MHz) | 1 800-1 830 |
| Architecture | Point-to-point/point-to-multipoint |
| Modulation | QPSK/16-QAM/64 QAM[1] |
| Channel spacing (MHz) | 3.5 MHz/5 MHz |
| Maximum Rx antenna gain (dBi) | Base: 11 dBi |
| Feeder/multiplexer loss (minimum) (dB) | 1 dB |
| Antenna type (Tx and Rx) | Base: Omni/sectoral Terminal: flat panel |
| Maximum Tx output power (dBW) | 2 Watts in any 1 MHz |
| e.i.r.p. (maximum) (dBW) | +55 dBW per RF channel |
| Receiver noise figure (dB) | 3 |
| Note [1]: Adaptive |

## 8.3 Backhaul

Wireless backhaul can make use of any fixed point-to-point frequency band.

# 9 Interference considerations associated with the implementation of wired and wireless data transmission technologies used for the support of power grid management systems

[TBD]

# 10 Impact of widespread deployment of wired and wireless networks used for power grid management systems on spectrum availability

[TBD]

# 11 The ITU-T Focus Group on smart grid

ITU-T Focus Group on Smart Grid (FG Smart) was established further to ITU-T TSAG agreement at its meeting in Geneva, 8-11 February 2010 followed by ITU-T study groups and membership consultation.

The Focus Group was formed to, from the standardization view points and within the competences of ITU-T:

• identify potential impacts on standards development;

• investigate future ITU-T study items and related actions;

• familiarize ITU-T and standardization communities with emerging attributes of smart grid;

• encourage collaboration between ITU-T and smart grid communities.

The Focus Group collaborates with worldwide smart grid communities (e.g. research institutes, forums, academia) including other SDOs and consortia.

These are the findings of the Focus Group: [TBD]

The full report of the Focus Group is available here: [TBD]

# 12 Conclusion

High-capacity, two-way communication networks employing wireless, PLT, or other telecommunications technologies that couple sensors and smart meters can transform existing electric distribution networks into smart grids. These interactive networks can be monitored and controlled to enhance the efficiency, reliability, and security of electric distribution networks.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. The European Commission Smart Grid Vision and Strategy Report similarly states “Smart grids is a necessary response to the environmental, social and political demands placed on energy supply.” (EUR 22040 - European Technology Platform Smart Grids – Vision and Strategy for Europe’s Electricity Networks of the Future (“EC Smart Grid Vision Report” at 7 European Commission, 2006, available at <http://www.smartgrids.eu/documents/vision.pdf>)). [↑](#footnote-ref-1)
2. The Energy Independence and Security Act of 2007 (Public Law 110-140). [↑](#footnote-ref-2)
3. <http://my.epri.com/portal/server.pt>? [↑](#footnote-ref-3)
4. *See* Michael W. Howard, Ph.D., P.E., Senior Vice President, R&D Group, Electric Power Research Institute, *Facilitating the Transition to a Smart Electric Grid*, Testimony Before the U.S. House of Representatives Energy and Commerce Subcommittee on Energy and Air Quality (3 May 2007). [↑](#footnote-ref-4)
5. The DOE Sponsored Modern Grid Initiative identifies a Modern or Smart Grid as having five components, Integrated Communications, Sensing and Measurement, Advanced Components, Advanced Control Methods and Improved Interfaces and Decision Support. It states “[o]f these five key technology areas, the implementation of integrated communications is a foundational need, required by the other key technologies and essential to the modern power grid.” and that “[h]igh-speed, fully integrated, two-way communications technologies will allow much-needed real-time information and power exchange.” A Systems View of the Modern Grid at B1-2 and B-1. [↑](#footnote-ref-5)
6. The Power to Reduce CO2 Emissions, The Full Portfolio at 3-1 August 2007, EPRI. [↑](#footnote-ref-6)
7. EUR 22580 – Strategic Research Agenda for Europe’s Electricity Networks of the Future (EC Strategic Research Agenda) at 62, European Commission, 2007. [↑](#footnote-ref-7)
8. EC Strategic Research Agenda at 15. [↑](#footnote-ref-8)
9. EC Smart Grid Vision Report at 27. [↑](#footnote-ref-9)
10. European Strategic Energy Technology Plan (SET-PLAN) Annex 1 at 6 May 2007. The other technologies are wind and intermittent renewables, storage and demand side management and smart metering. Each of these technologies also requires a communications component. [↑](#footnote-ref-10)
11. The New York Public Service Commission recently stated that “it is essential that deployment of communication facilities for [advanced metering infrastructure] does not result in stranded facilities that are not capable of being expanded for broader smart grid applications. Therefore, AMI systems must be designed to meet future requirements of the smart grid, and particular must contain communications systems that are scalable and expandable to accommodate sensors in multiple locations throughout the grid.” Order adopting minimum functional requirements for advanced metering infrastructure systems and initiating an inquiry into benefit-cost methodologies at 18, New York Public Service Commission (13 Feb. 2009). [↑](#footnote-ref-11)
12. The text can be obtained at <http://ec.europa.eu/enterprise/standards_policy/mandates/database/> by typing the mandate number into “other search” folder. [↑](#footnote-ref-12)
13. <http://www.esmig.eu/newsstor/esmig> or <http://www.etsi.org/website/newsandevents/200905_esmig.asp>. [↑](#footnote-ref-13)
14. The control loop timeline refers to the overall length of time to make a decision and initiate action relevant to a particular control application. For instance, a control decision that needs to be made with real-time information every 30 seconds cannot utilize a communications link that takes 60 seconds to transfer the related data. [↑](#footnote-ref-14)
15. For example, distributed protection systems use multiple isolating switches and relays that disconnect power from a section of the electric distribution system in the event of a failure or short circuit. Such disconnection helps reduce the size and impact of any resulting outage, prevent widespread damage to the system, and minimize public safety hazards. In order to make control decisions, these systems rely on widely dispersed devices that access information about real-time conditions at other devices connected to the distribution grid. Distributed protection systems respond to events of only several milliseconds in duration and must communicate information just as quickly in order to perform their functions effectively. [↑](#footnote-ref-15)
16. ESB Networks, Smart Meter Project, 11 November 2010 – <http://www.cer.ie> [↑](#footnote-ref-16)
17. ibid [↑](#footnote-ref-17)
18. <http://portal.etsi.org/portal/server.pt/community/M2M>. [↑](#footnote-ref-18)
19. Draft ETSI TS 102 690 V<0.1.2> (2010-01) Work item Number DTS/M2M-00002. [↑](#footnote-ref-19)
20. Draft ETSI TR 102 691V0.4.1 (2010-02) Work item Number DTS/M2M-00003. [↑](#footnote-ref-20)
21. ETSI TR 102 xxx V<0.0.1> (<2010-03>) Work item Number DTR/M2M-00009. [↑](#footnote-ref-21)
22. KNX is an open standard ISO/IEC 14543 (also known as EN 50090). M-Bus (or Meter-Bus) is the European standard EN 13757 series for remote reading meters. [↑](#footnote-ref-22)
23. California Energy Commission on the Value of Distribution Automation, California Energy Commission Public Interest Energy Research Final Project Report at 89 (Apr. 2007) (CEC Report). [↑](#footnote-ref-23)
24. For example, recent U.S. federal legislation, the Energy Independence and Security Act of 2007 (Public Law 110-140), sets out as the policy of the United States the implementation of smart grid systems to modernize the electric grid, and requires both the federal and state governments and regulators to take specific actions to support the implementation of a smart grid. [↑](#footnote-ref-24)
25. International Energy Agency, Energy Technology Prospectives, 2008 at 179. [↑](#footnote-ref-25)
26. See Electricity Sector Framework for the Future: Achieving the 21st Century Transformation at 42, Electric Power Research Institute, (Aug. 2003) (“EPRI Report”), available at: <http://www.globalregulatorynetwork.org/PDFs/ESFF_volume1.pdf>. [↑](#footnote-ref-26)
27. See, e.g., Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids, Part 1: Technical Analysis, at p.14 (May, 2007), available at: <http://www.ferc.gov/about/com-mem/wellinghoff/5-24-07-technical-analy-wellinghoff.pdf> (“System components such as transformers may impose additional constraints on the delivery limit because they may not be designed to sustain a constant high loading [from electric vehicles] without a period of lower load conditions during which the equipment can cool down.”) [↑](#footnote-ref-27)
28. California Energy Commission on the Value of Distribution Automation, California Energy Commission Public Interest Energy Research Final Project Report at 95 (Apr. 2007) (CEC Report). [↑](#footnote-ref-28)
29. See Xcel Energy SmartGridCity™ Update: Project Status and Early Benefits, at 11-15, 7 July 2009, Commissioners' Information Meeting, available at <http://www.dora.state.co.us/puc/presentations/InformationMeetings/09M-247ALL-CIMs.htm>. Similarly, “through the broadband-over-power-line network, [Oncor Electric Delivery] is able to monitor its electric delivery system, obtaining a steady stream of data that can be analysed for potential problems. Once a problem is pinpointed, Oncor dispatches operations personnel to investigate the irregularity before it can become an outage or other service issue. Issues are often resolved before consumers even realize that there was a problem.” See “Oncor Reaches National Milestone,” (Sept 19, 2007), available at <http://oncor.com/news/newsrel/detail.aspx?prid=1094>. [↑](#footnote-ref-29)
30. In late 2008, the California Air Resources Board (CARB) stated that “a ‘smart’ and interactive grid and communication infrastructure would allow the two-way flow of energy and data needed for widespread deployment of distributed renewable generation resources, plug-in hybrids or electric vehicles, and end‑use efficiency devices. Smart grids can accommodate increasing amounts of distributed generation resources located near points of consumption, which reduce overall electricity system losses and corresponding GHG emissions. Such a system would allow distributed generation to become mainstream, … would support the use of plug-in electric vehicles as an energy storage device … [and] would in turn allow grid operators more flexibility in responding to fluctuations on the generation side, which can help alleviate the current difficulties with integrating intermittent resources such as wind.” California Air Resources Board Scoping Plan, Appendix Vol. I at C-96, 97, CARB (Dec. 2008). [↑](#footnote-ref-30)
31. See e.g. Enabling Tomorrow’s Electricity System – Report of the Ontario Smart Grid Forum, Ontario Smart Grid Forum (February, 2009) which cautions “initiatives on conservation, renewable generation and smart meters begin the move towards a new electricity system, but their full promise will not be realized without the advanced technologies that make the smart grid possible.” [↑](#footnote-ref-31)
32. *See* A Systems View of the Modern Grid at B1-2 and B1-11, Integrated Communications, conducted by the National Energy Technology Laboratory for the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability (Feb. 2007). Such integrated communications will “[connect] components to open architecture for real-time information and control, allowing every part of the grid to both “talk” and “listen”. The smart grid: An Introduction at 29, U.S. Department of Energy (2008). [↑](#footnote-ref-32)
33. *Id.* [↑](#footnote-ref-33)
34. “Modernizing the electric grid with additional two-way communications, sensors and control technologies, key components of a smart grid, can lead to substantial benefits for consumers.” California PUC Decision Establishing Commission Processes for Review of Projects and Investments by Investor-Owned Utilities Seeking Recovery Act Funding at 3 (10 Sept. 2009), available at: <http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/106992.pdf>. *See also,* California Energy Commission on the Value of Distribution Automation, California Energy Commission Public Interest Energy Research Final Project Report at 51 (Apr. 2007), available at: <http://www.energy.ca.gov/2007publications/CEC-100-2007-008/CEC-100-2007-008-CTF.PDF>. “[C]ommunications is a foundation for virtually all the applications and consists of high speed two-way communications throughout the distribution system and to individual customers.”) [↑](#footnote-ref-34)
35. *See* Enabling Tomorrow’s Electricity System – Report of the Ontario Smart Grid Forum at 34, Ontario Smart Grid Forum (Feb. 2009). The Report also states that “the communication systems that the utilities are developing for smart meters will not be adequate to support full smart grid development. The communications needs associated with the collection of meter data are different from those of grid operations. Additional bandwidth and redundant service will be needed for grid operations because of the quantity of operational data, the speed required to use it and its criticality.” *Id*. at 35. [↑](#footnote-ref-35)
36. <http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+REPORT+A6-2008-0003+0+DOC+PDF+V0//EN&language=EN>. [↑](#footnote-ref-36)
37. <http://www.europarl.europa.eu/sides/getDoc.do?type=TA&language=EN&reference=P6-TA-2008-0294>. [↑](#footnote-ref-37)
38. <http://www.smartgrids.eu/>. [↑](#footnote-ref-38)
39. <http://cordis.europa.eu/fetch?CALLER=ENERGY_NEWS&ACTION=D&DOC=1&CAT=NEWS&QUERY=011bae3744bf:2435:2d5957f8&RCN=29756>. [↑](#footnote-ref-39)
40. See “Iberdrola, EDP Announce Big Smart Grid Expansions at EUTC Event,” Smart Grid Today, 9 November 2009 (“Iberdrola is using PLC to connect its smart meters while EDP is using a mix of PLC and wireless”). [↑](#footnote-ref-40)
41. Source for whole paragraph: European Regulators’ Group for Electricity and Gas Position Paper on Smart Grids - Ref: E09-EQS-30-04, Annex III
[http://www.energy-regulators.eu/portal/page/portal/EER\_HOME/EER\_CONSULT/CLOSED PUBLIC CONSULTATIONS/ELECTRICITY/Smart Grids/CD](http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_CONSULT/CLOSED%20PUBLIC%20CONSULTATIONS/ELECTRICITY/Smart%20Grids/CD) [http://www.energy-regulators.eu/portal/page/portal/EER\_HOME/ EER\_CONSULT/CLOSED %20PUBLIC %20CONSULTATIONS/ELECTRICITY/Smart%20Grids/CD](http://www.energy-regulators.eu/portal/page/portal/EER_HOME/%20EER_CONSULT/CLOSED%20%20PUBLIC%20%20CONSULTATIONS/ELECTRICITY/Smart%20Grids/CD). [↑](#footnote-ref-41)
42. References: European Commission, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions “A European strategic energy technology plan (SET-Plan) - Towards a low carbon future”, COM(2007) 723 final, 22 November 2007 European Commission, “Energy for the Future of Europe: The Strategic Energy Technology (SET) Plan”, MEMO/08/657, 28 October 2008. [↑](#footnote-ref-42)
43. European Commission, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions “A European strategic energy technology plan (SET-Plan) - Towards a low carbon future”, COM(2007) 723 final, 22 November 2007. [↑](#footnote-ref-43)
44. The proposal to constitute a European Centre for Electricity Networks came from the 6FP RELIANCE project, in which eight European transmission system operators participated. [↑](#footnote-ref-44)
45. European Commission, “Energy for the Future of Europe: The Strategic Energy.
Technology (SET) Plan”, MEMO/08/657, 28 October 2008. [↑](#footnote-ref-45)
46. http://www.e-energy.de/en/. [↑](#footnote-ref-46)