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Metering, revenue protection, billing and CRM/CIS functions

Working Group

D2.18

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CIGRE WG D2.18

Metering, revenue protection, billing and CRM/CIS functions

Technical Brochure

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SUMMARY

This technical report is about energy measurement assurance, revenue protection, billing as well as customer relationships, which are the fundamental functions of the distribution and commercialization processes of electricity. This report was carried out by the WGD2.18 Working Group, with effect from 2006 to 2009.

The purpose of this Technical Report is to analyze the state of the art and of the practice, standards, recommendations as well as the technological trends in the aforementioned functions, setting guidelines and suggestions related to the application of technologies in the aforementioned fields.

The socio-economic environment of each country and even that of the regions located in the same country varies considerably. For this reason, these environments must be taken into account when applying the technologies cited in this report in order to minimize risks.

KEYWORDS

Metering, Advanced Metering Infrastructure, Automatic Meter Reading, Smart Meter, Smart Metering, Smart Grid, In-home display, Electromechanical Meter, Billing, Revenue Protection, Energy Theft, Demand Response, Home Area Network, Hybrid Meter, Electronic Meter, Prepayment, Energy Theft, Meter Data Management, Radio frequency, Broadband over power line, Power line communication, Advanced Meter System, Broadband over Power line, Residential Consumer, Commercial Consumer, Industrial Consumer, Common Information Model, Customer Information System, Demand Response, Energy Management System, Global System for Mobile Communication™, Home Area Network, Meter Data Management System, Power Line Carrier, Vehicle to Grid, WiMAX, Wi-Fi, Demand side Management, Smart Grid, Advanced Metering System, Outage Management System, Plug-In Hybrid Electric Vehicle.

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1 INTRODUCTION

Metering, billing and more recently revenue protection are basic functions of the electricity supply chain, both in liberalized markets and vertically structured utilities, while billing and CRM/CIS functions have been pulled out in their complete functionality since market is opening. Traditionally, the existing metering, billing and revenue protection functions and systems were taken over and applied as such by the electric utilities. With the restructuring and deregulation of this industry these systems and functions have been adapted to the process needs and to the requirements of the countries specific market or operating rules, based on the experience and the results of pilot projects on new metering and information technologies. Some procedures and technologies have been evolving to become recommendations or “de facto” standards. All of this has lead to the structuring and definition of the information exchange needed among all the involved utility or market processes and participants.

The scope of the WGD2.18 has been to identify the state of the art and of the practice as well as the trends in metering, revenue protection, billing and CRM/CIS functions and systems. The last two functions approached with emphasis in vertically structured utilities. However, exploring the sensitivity level of the two functions for liberalized markets have been also considered. Standards and recommendations that apply are presented.

1.1 Purpose

The purpose of this Technical Brochure is to provide a perspective of the state of the art and of the practice, standards and recommendations, as well as technological trends related to metering, energy loss detection, billing and CRM/CIS systems in the distribution and commercialization processes of electricity. Topics regarding the optimal application of technologies in the aforementioned fields are commented, taking into account the socio-economic environments.

1.2 Scope

The physical scope of this work includes the electricity distribution process; residential, commercial and industrial consumers as well as the operative functions of the electric utility with regard to metering, revenue protection, billing and CRM/CIS.

1.3 Outline

This Technical Brochure is organized as follows: **Section 1**, this Introduction. **Section 2** presents an overview of the evolution of metering technologies, focusing on their current status, technological trends and standards that apply. **Section 3** deals with energy loss problems, particularly non-technical energy losses. The technologies to detect, prevent and fight energy loss are also described. **Section 4** refers to the different schemas to carry out the billing function. **Section 5** deals with CRM/CIS and the importance of opportunity and quality of the customer service functionality as well as the convergence of metering and CRM/CIS. **Section 6** presents the general conclusions of this report. **Section 7** presents a proposal for future works and investigations. Finally **Section 7** presents a list of references.

1.4 Methodology

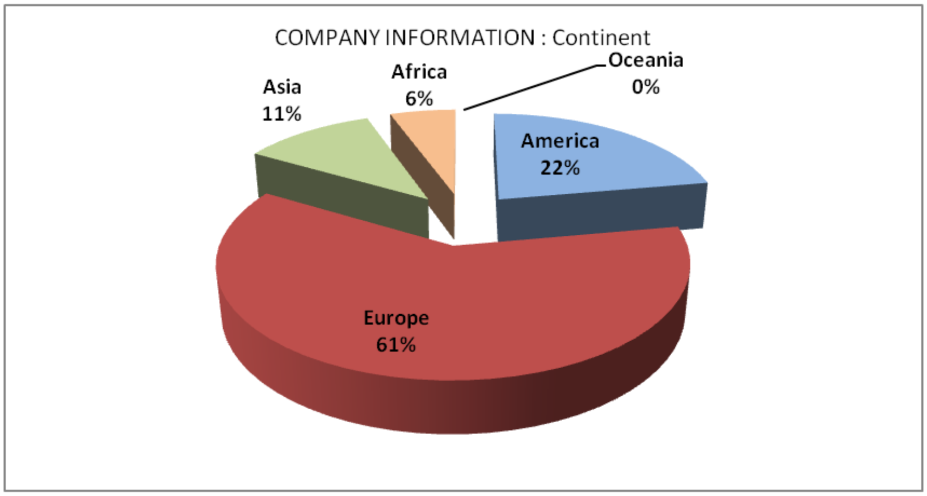
The information related to the topics covered by the WGD2.18 Working Group was gathered through a technical questionnaire and bibliographic investigations.

The technical questionnaire was distributed among the members of our Working Group and the national SC D2 Study Committees Coordinators who, in turn, distributed it among all those people they considered would be interested in collaborating.

The questionnaire asked for:

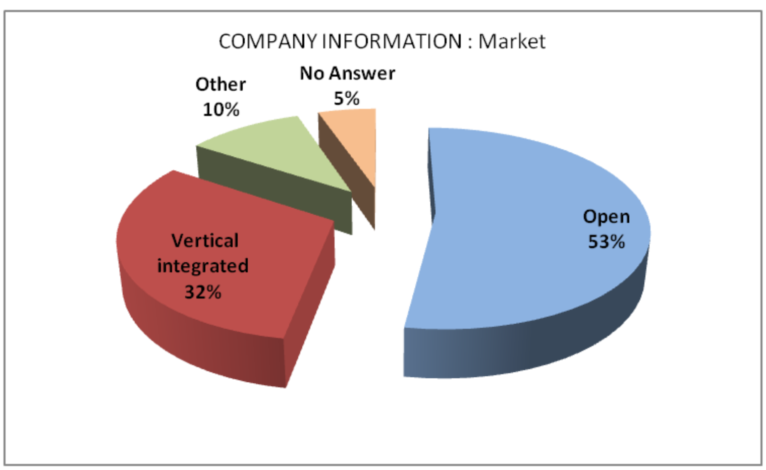
- General information about the respondent's company and the respondent her/himself.
- Main functional requirements for the electric energy metering devices (meters and transducers), to perform both the energy metering function itself as well as the revenue protection function.
- Main physical media characteristics and the communication protocols between the electric energy metering facilities and the electric utility control centers.
- Representative electric energy metering operational systems regarding its functionality (electric variables metered, metering periodicity, etc.), as well as the physical media and communication protocols.
- Main functional requirements for the billing and CRM/CIS systems, related to billing- payment schemes, revenue protection and value-added services.

18 companies answered the technical questionnaire. The information was obtained from specialists who are in charge of metering, revenue protection, billing and CRM/CIS functions in the electric utilities from different countries. The following graph shows the country of origin of these companies.

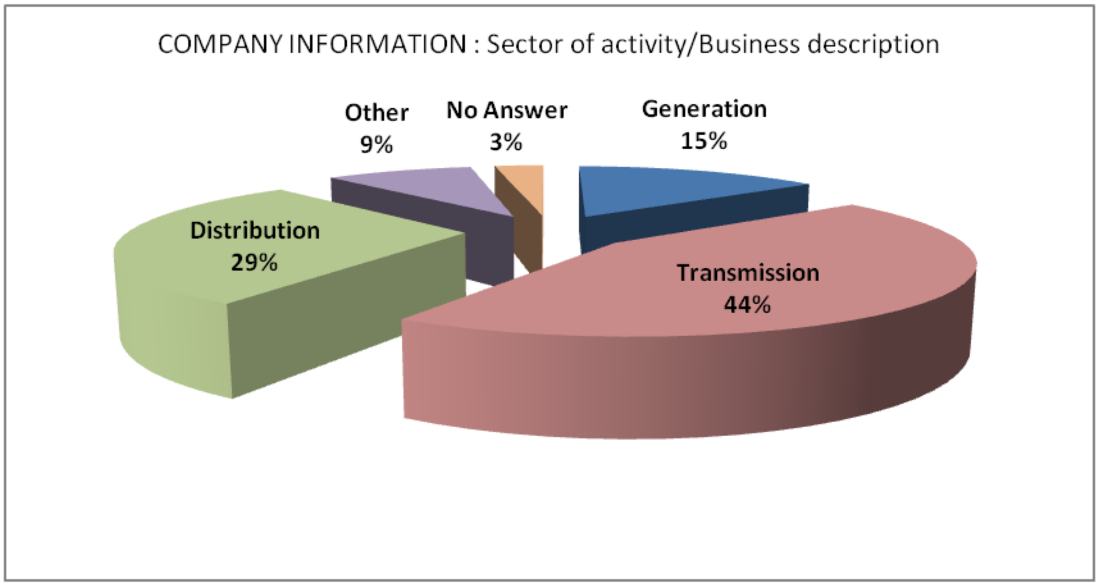


It is important to highlight that the vast majority of responses were obtained from European companies.

The following graph shows the type of market the participating electric utilities belong to.



The core activities supported by each respondent company are:



We supported our bibliographic investigation on many sources, such as:

- **Papers**
  - **Metering**
  - **Revenue protection**
  - **Billing**
  - **CRM/CIS**

- **Magazines**
  - **Electra**
  - **Elektron**
  - **Transmission & Distribution World**
  - **Utility Automation & Engineering T&D**
  - **Electric energy**
  - **Metering International**
  - **Electrical world**
  - **Electric light & power**
  - **Power engineering**

- **Associations, Institutions, etc.**
  - **CIGRE**
  - **EPRI**
  - **AMRA**
  - **IURPA**
  - **IEEE**
  - **IEC**
  - **ANSI**

- **Web sites**

2 METERING

The increasing number of customers and the fact that they have become more demanding about the quality of service, power quality, rates, etc., have encouraged the use of more versatile, accurate, reliable and intelligent metering systems.

That is why nowadays, besides having meters that record the customer's energy consumption for billing purposes, it is necessary to have systems that: a) Facilitate the metering, billing and customer service processes; b) Allow the application of different rates; c) Make possible the implementation of an efficient demand control; d) Include provisions to detect and prevent technical and non-technical energy losses; e) Measure the quality of the electricity supplied; f) Tightly integrate the consumers with the utility process, allowing them to an optimal management of their energy consumption and collaborate with the quality of the energy and of the service; etc.

The technology has lead the energy metering industry to accept the use of advanced electronic meters that incorporate those functional characteristics demanded by the electric utilities and their customers.

The barriers that have traditionally hindered the use of this type of meters, such as price, reliability, etc., have been gradually disappearing.

Likewise, the deregulation of the energy markets has created new opportunities and challenges for the electric utilities and the customers as well. Many metering and information processing schemes have served as a model for vertical markets.

The trading of electricity in an open market requires well-informed participants in order to analyze the market conditions. In vertical markets well informed participants are required to better understand the tariffs and in general, to develop a closer relationship between the company and the customer. They both need to know how much energy is consumed and in what period of time.

Several countries have implemented metering schemes for deregulated environments. England is a good example of how important metering is in this type of environment, where the energy price is set on a half hourly basis; this means opportunities for the market participants since different tariffs at different times of the day can be offered. All this also suggests that the customers must know their load profiles and their energy needs at different times of the day; as a result, the requirements of these metering systems are more stringent than those of the traditional ones.

This section presents the state of the practice of most representative technologies and metering systems in liberalized, deregulated and vertical markets, their capabilities and preceding technologies as well as the technological trends.

2.1 Technologies

The evolution of the metering technologies (Figure 2.1) has its origin in the electromechanical meter, which was introduced in the electric power industry at the end of the 19th century. Nowadays the installed base of this type of meters is still the biggest in the world. This is because of its low cost and robustness, which, until a few years ago, hindered the introduction of the electronic meter into the market, in spite of its superior performance features.

The advances in solid-state electronics have brought down the main barriers, making the electronic meter a strong rival for the electromechanical meter even for residential customers.

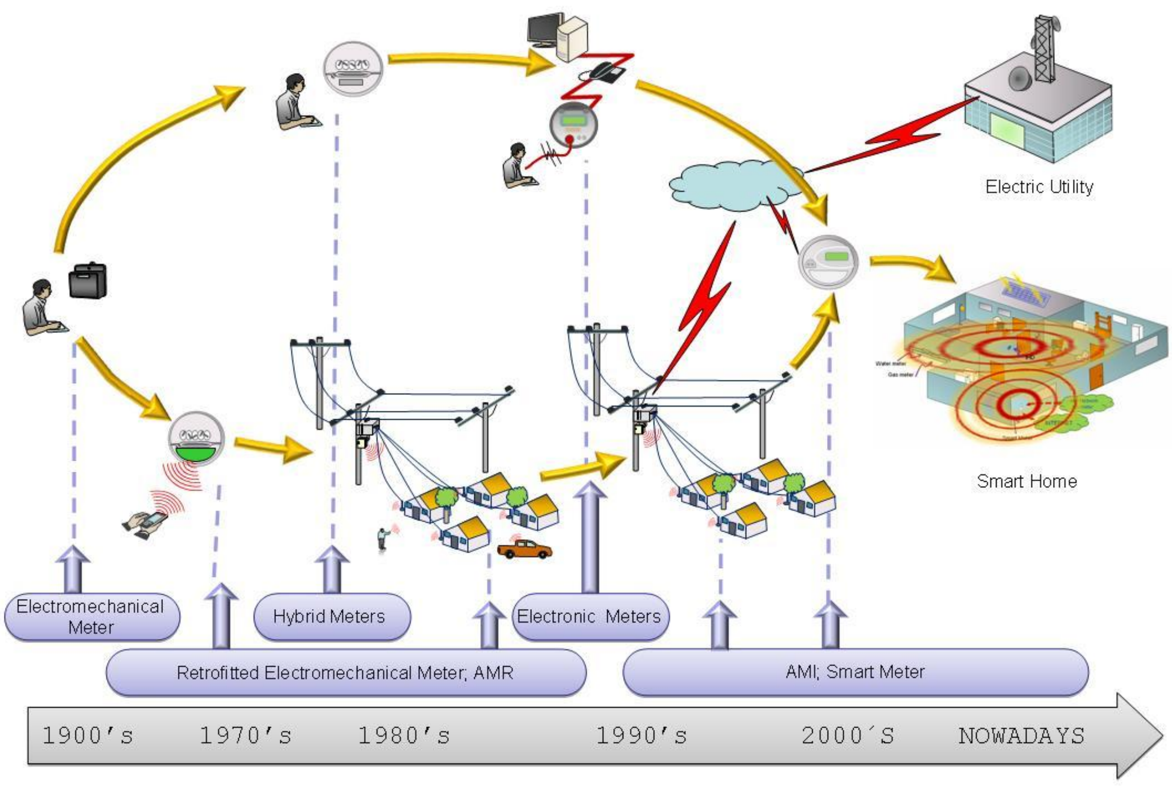


Figure 2.1 Metering technologies evolution.

In the late sixties, the single-phase watt-hour meter was redesigned in order to make it less obvious and less prone to damage. One of the advantages of this redesign was that the new meters were at least one pound lighter than the older ones.

The introduction of AMR devices and electronic registers in the 1970‘s was encouraged by the advances in electronics.

Later, in the mid-1980‘s several manufacturers began to sell hybrid meters with electronic registers mounted on induction-type meters.

Further advances in electronics, in the 90‘s, encouraged the introduction of fully electronic energy meters.

Once the electricity industry accepted the new electronic meters, the production of induction-type poly-phase models dropped. Likewise, when electronic single-phase models became viable and widely accepted, the leading manufacturers cut back the production of the single-phase electromechanical models and some discontinued them.

Besides measuring electricity, solid state meters record many other load and supply parameters such as power factor, maximum demand, reactive power, load profile, power quality and alarms. Some of these meters (smart meters) provide customers and energy suppliers with accurate information on each customer‘s power usage as well as the time of use and the amount to pay according to the applicable tariff.

2.1.2 Automatic Meter Reading (AMR)

The Automatic Meter Reading System (AMR) is a representative scheme of the evolution of energy metering technologies, which was introduced to the electric utility industry by the 1970s.

Initially, the Automated Meter Reading concept was used to describe any meter reading system that allowed the collection of billing information, on a monthly basis, without carrying out manual meter readings. This included a broad range of meter reading technologies, which involve walk-by, mobile, radio and phone-based systems.

Although there is no consensus about what the definition of AMR encompasses, it commonly refers to ―the collection of meter data without physically visiting the meter location. It is typically a drive-by or walk-by system, which provides a monthly meter reading for billing purposes”. There are also other definitions such as ―meter reading through fixed one-way communication network, capable of obtaining daily readings”. This definition is the most commonly accepted (See figure 2.1.2-1).

The main purpose and advantages of installing a mobile or one-way AMR system is that it eliminates operational costs (such as labor, supervision and transportation) and helps reduce claims and insurance costs due to decreased injury and accident rates derived from maintaining a large manual meter reading force. Customers also benefit from AMR deployments since these systems prevent estimated and missed meter readings; reduce billing errors and protect customers' privacy by eliminating the need for on-site meter readings. AMR, however, merely automates existing functionality.

AMR enables the utilities to remotely and automatically collect information from electricity, gas, and/or water meters using diverse communications networks. The utilities can save money since there is no longer the need to carry out physical meter readings and the customers' monthly bills are automated. Fixed-network AMR systems not only collect consumption information, but also allow the utility to collect information over intervals, detect power outages and inform its customers when their service has been restored, even though most of these systems only record and transmit consumption data. The operational cost savings that AMR technology provides is one of its main attractions.

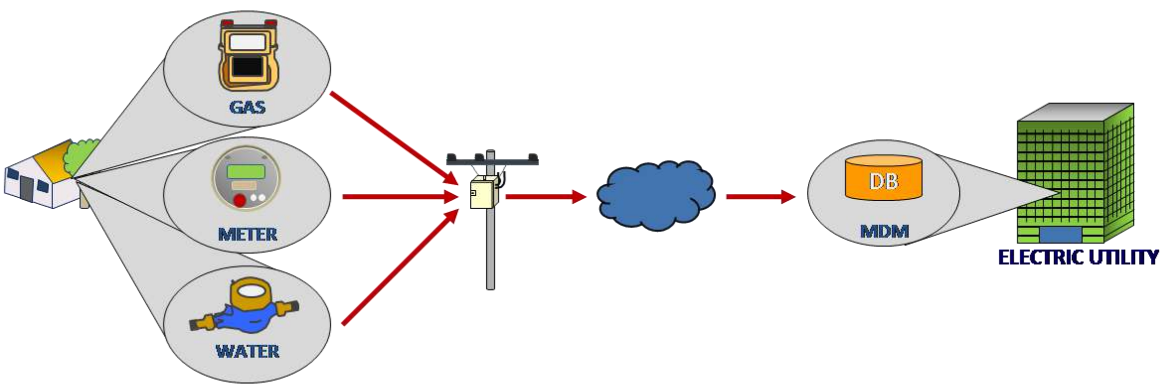


Figure 2.1.2-1 Typical AMR system.

A typical AMR system is made up of the following components:

- Meter.
- Meter interface unit connected to the meter to transmit the information.
- One-way fixed communication network, drive-by or walk-by system, to transfer the data from the Meter interface unit to the utility's offices. There may also be a ―metering or communications concentrator" that collects data

from many nearby meter interface units and transmits it over the fixed communication network to the utility's offices.

- Hand-held terminal units and control computer to collect and manage the information.
- Meter data management (MDM) software to control the AMR system and present the data to the utility's billing and other information systems.

2.1.3 Advanced Metering Infrastructure (AMI)

In some countries, the legislation requires the opportune information exchange between the electric utility and its customers in order to facilitate their consumption management through advanced metering and communication technologies.

Technological advances have enabled the development of systems that can remotely control metering devices and that are able to capture, store and transmit larger amounts of data related to events and alarms such as meter tampering, leak detection, low battery or reverse energy flow.

Unlike AMR, Advanced Metering Infrastructure (AMI) systems collect more detailed and opportune information on energy usage at thoroughly analyzed intervals, as short as data storage can support. AMI systems are able to establish two-way, real-time communication between the utility and the end-use customers, which allows utilities to support time-based pricing programs and offer more alternatives for energy usage. Likewise, AMI systems help decrease energy demand by sending signals to control customer appliances that are directly linked to the systems and real-time pricing signals to customers.

AMI generally refers to AMR systems with the improved capabilities aforementioned.

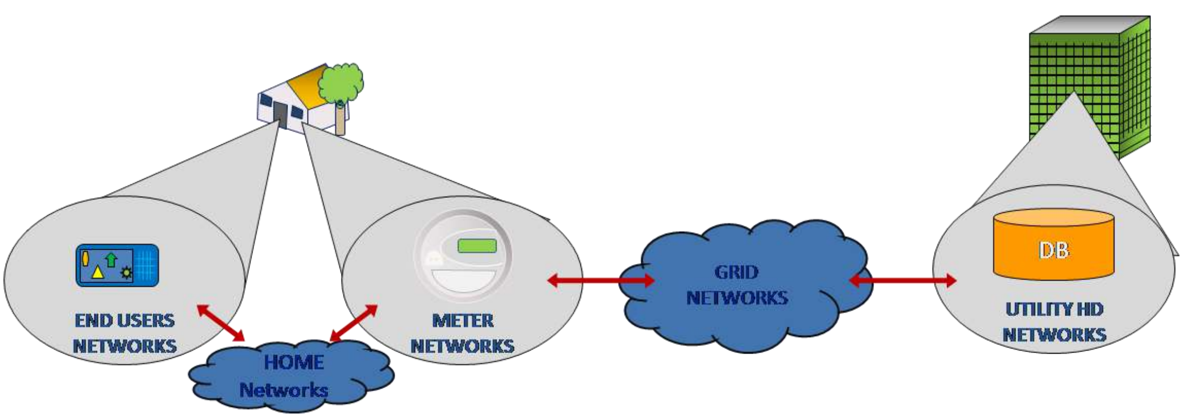


Figure 2.1.3-1 Typical AMI system.

A typical AMI system is made up of the following components (See figure 2.1.3-1):

- Advanced meters.
- Two-way fixed communication network. To transfer the data to/from the advanced meters to/from the utility‘s offices. There may also be a ―metering or communications concentrator” that collects data from many nearby advanced meters and transmits it over the fixed communication network to the utility's offices.
- A meter data management (MDM) application to handle the large volumes of interval data provided by the system.

The AMI network management software is a key component that manages the AMI communications network, schedules and collects meter readings and coordinates routine customers and meter data changes in order to ensure that all meters are read.

AMI is sometimes considered as an advanced form of AMR with a robust Meter Data Management (MDM) that can store huge quantities of information and is supported by smart tools that can obtain utile information from the MDM data. This data can be presented in a pre-defined form, such as load profile, to either, the utility or the customer. AMI systems also support other state-of-the-art services like Demand Response (DR) through which the customer enables the utility to disconnect the service in exceptional circumstances.

MDM is an essential system that captures the customer and social benefits derived from AMI deployments. Besides providing a permanent repository for meter interval data, MDM manages data and interfaces with other system applications such as the company‘s Customer Management and Information Systems (CRM/CIS), billing, outage management, and enterprise asset management applications.

Some benefits of AMI over AMR systems are:

- For the customers.

  - Hourly information to make the energy consumption management easier for the customer, resulting in cost-savings
  - Proactive customer service.

- For the supplier.

  - Reduces customer visits.
  - Provides more efficient tools for energy theft detection.
  - Provides information for consumption forecasting, power cuts

detection and distribution optimization. It also facilitates planning.

- Benefits for the environment.
  - When customers manage their consumption, the combustion that generates CO_2 emissions is prevented.
  - Savings, since it delays or prevents the necessary investment in distribution, transmission and generation.

The critical problem of the AMI systems is that of the communications and the need of interoperability among equipments from different manufacturers. Each meter, regardless of the brand, must be able to communicate the complete collected information in a secure way to the utility's offices or to a communications concentrator from a different manufacturer. To achieve this, the use of a common communication protocol is fundamental.

2.1.4 Smart Metering

The term —Smart Metering” is frequently interchanged with the AMI concept. —Smart Meter” refers to an electrical meter with advanced functional characteristics such as: net metering (the ability to measure energy used by the customer as well as the energy delivered by the customer back to the utility); remote disconnect/reconnect (the ability to remotely cut-off and re-establish service); two-way communications (the ability to both, read the meter and send information to the meter, including programming updates); interface with home area networks (the ability to exchange messages with the customer and to automatically control their electrical appliances consumption); the ability to collect meter readings in multiple categories (e.g., supporting TOU, power outage notification, power quality and tamper monitoring applications).

Electricity deregulation and market driven pricing have urged government regulators around the world to search for means to match consumption with electricity generation. Smart meters have played an important role in pursuing this objective, since, unlike traditional electrical meters, this type of meters allow obtaining timely information on when the energy was consumed. This data is used by price-setting agencies to fix different tariffs based on the time of day and season.

Smart meters do not automatically result in energy savings. They allow the customers to check their hourly electricity consumption profile thus helping them identify periods when they may wish to shift the use of their appliances in order to manage their electricity costs (See figure 2.1.4-1).

―Smart meter” usually refers to an electrical meter; however, this term is also related to the measurement of natural gas and water consumption.

Figure 2.1.4-1 Smart meter.

2.1.5 In-Home Displays

Demand response is a concept that encourages reductions in peak energy demand by providing customers with a real-time view of their energy consumption and utility pricing on a networked in-home display (IHD). This concept allows customers to monitor their household electricity use in real time (See figure 2.1.5-1).

Power utilities are investigating how efficient IHD devices are when it comes to helping customers manage their energy consumption and control costs. These devices could provide the customers with real-time information on their present energy consumption, real-time costs, send/receive messages or alerts to/from their electricity supplier and the possible savings that can be reached by turning off or rescheduling the use of appliances at certain times of the day.

When customers know their load profiles and energy tariffs at different times of the day, they are able to reschedule the usage of major appliances (refrigerators, dishwashers, etc.) in order to use them more efficiently, when the overall electricity usage is lower. This helps utilities meet demand and helps consumers save energy under demand-based pricing plans.

Statistics show that most of the surveyed consumers have high interest in IHDs. Recent studies carried out by the European Union, shows that demand response mechanisms could lead to annual savings of 25 billion Euros, approximately.

Figure 2.1.5-1 In-home display

2.1.6 Smart Grid

The fundamental goal of electric utilities is to operate a ―smart grid". One of the requirements is to have smart metering at both, the meters located at customer premises and at intermediate points in the utility network (grid), such as at transformers, substations, capacitor banks etc. The objective is to thoroughly understand how the utility is operating at any moment, to report power outages and problems in detail and in real-time and to analyze grid performance over time.

The smart grid is considered as a model of a better electricity delivery infrastructure. Smart Grid implementations increase impressively the quantity, quality, and use of information available from advanced sensing, computing, and communications hardware and software.

Effective use of Smart Grid technologies helps utilities:

- Improve grid efficiency and security.
- Better align demand with supply constraints and grid congestion.
- Enable distributed generation (especially from renewable sources).
- Empower customers to manage their consumption and take advantage of pricing and supply alternatives.
- Deal with two of today‘s most crucial business factors: environmental concerns and power delivery restrictions and disturbances.

These technologies are implemented by the electric utilities both to grid operations, including transmission and distribution wires and associated equipment, and to the customer site including meters, customer owned energy technology equipment and appliances, and home area networks (HAN‘s).

Smart Metering has generally been considered as the first step toward a greater utility-customer interaction in early customer-focused Smart Grid projects.

Smart appliances and near-real-time usage displays or messaging allow customers to be part of a wide range of utility programs for conservation, peak demand reduction, load shifting, and carbon footprint reduction. Smart Metering is capable of reducing both customer and utility costs. Smart Metering is capable of reducing both customer and utility costs. It helps customers save money on their electricity bill by reducing overall use and changing their electricity consumption patterns according to different price incentives. It also reduces the utility costs derived from on-site meter reading activities, turn-on/offs, and contact center responses to bill estimations.

Smart Metering will provide other major benefits to the utilities, since it avoids building new transmission and distribution infrastructure by reducing peak-demands and the related capacity constraints and defers the construction of new electricity generation plants. Smart Metering also involves important environmental aspects since it helps reduce greenhouse gas emissions and landscape-damaging (See figure 2.1.6-1).

Smart Grids require the integration of the appropriate applications so that:

- Meters can act as grid nodes, enabling the opportune detection of power outages thus reducing service restoration time.
- Customers' smart appliances and energy technology equipment respond individually to system disturbances and ―on-peak" conditions in order to diminish the potential negative effect of these conditions on customers.
- Transmission and distributions grids can integrate small electricity generation and distributed storage sources such as rooftop photovoltaics, advanced batteries and plug-in hybrid electric vehicles (PHEVs) into the electric grid. Other technologies like thermal storage for cooling or combined heat and power can be also used to reduce peak and overall demand.
- Utilities become less-dependant on less-efficient fossil-fuel power generation contracts.

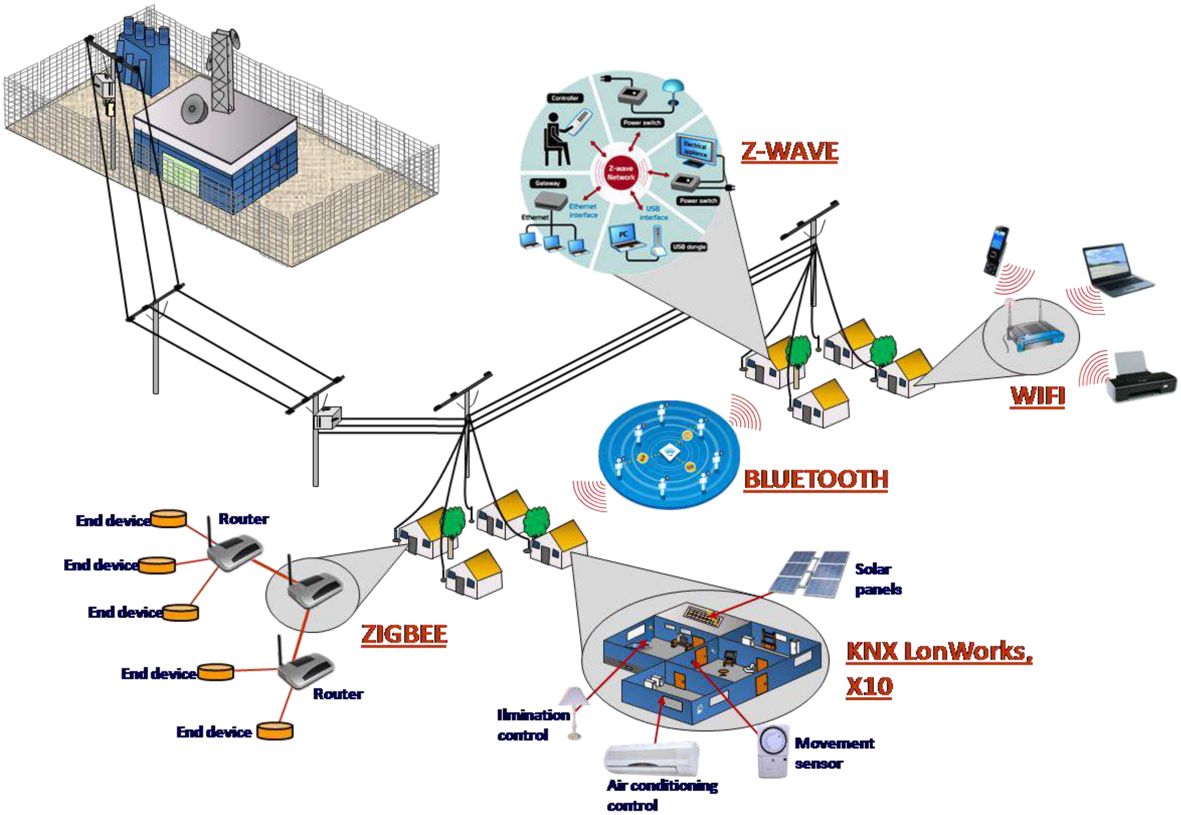


Figure 2.1.6-1 Smart metering in smart grid concept.

2.1.7 Communications

Fixed communications networks are applied by the most advanced metering technology systems. These networks, which are the mainstay of the AMI system, are able to read an advanced meter many times a day and can also send meter data such as power outage and tamper alarms in near real time, from the meter to the utility data center.

Hierarchical systems star and mesh networks are common communication architectures. Data collectors or concentrators are generally used in hierarchical networks as the link between the meter and the operation center. They are installed at the pole distribution level, in substations or on other facilities. There are other systems that use a more flattened architecture that involves peer-to-peer communications to a data concentrator that delivers the data to the operations center over different communication media (telephone, cellular, fiber optic cable, etc.).

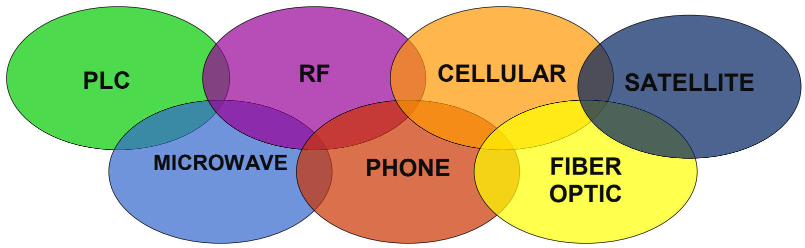


Figure 2.1.7-1 Communications media technologies.

The most common types of communication media used in advanced metering systems are (See figure 2.1.7-1):

- RF (WiMax, Wi-Fi, etc.)
- Power Line Carrier (PLC) and Broadband over Power Line (BPL)
- Cellular GPRS
- Fiber optic cable
- Phone
- Hybrid Systems

RF

Hierarchical point-to-point or peer-to-peer communications are the most common topologies for RF-based AMR systems. Point-to-point systems generally use pole top or tower-based collectors to store and send information back to the data center, while peer-to-peer networks will often use a wireless mesh technology that sends data through other meter endpoints before getting to a collector take out point. In both cases, the wide area network (WAN) portion of the system can use telephone, cellular or other public sources such as satellite, licensed frequencies, fiber or private radio networks or microwave to backhaul the data from the collector to the data center.

DPLC

Power line Carrier is a communication technology that has been widely employed by utilities for many years now. This technology uses utility wiring designed for carrying electrical power to transmit data between points along the utility's transmission and distribution systems. Power line Carrier technology has traditionally been used for relaying, SCADA and distribution automation applications. More recently, Digital Power line Communication (DPLC) has proven to be a cost effective usage of utility power lines for data communications. Other benefits derived from the deployment of PLC include avoiding monthly costs in communications for public networks and extra capital expenses associated with the construction of towers and other RF network infrastructure.

DPLC systems are capable of servicing customers located in urban, suburban and rural areas, since they can operate over long distances regardless of the terrain conditions, topography or vegetation which generally affects the operation of other kind of systems.

BPL

The use of power line communication systems for transmitting high bandwidth (broadband) communications is now possible thanks to the recent advances in DPLC technologies. This new version of DPLC, known as Broadband Power line (BPL), is being employed by the utilities in order to meet the full range of two-way AMI functionality required by today‘s applications. BPL also provides the adequate bandwidth for other applications including Smart Grid technology.

DPLC and BPL are promising emerging technologies that have arisen a growing interest, mainly motivated by the wide availability of power distribution lines, at the same time these technologies are competing with RF technology.

TELEPHONE

Telephone-based AMR systems, which use the customer‘s telephone line, a separate dedicated line or a cellular connection, are suitable for reading small groups of meters geographically scattered, such as large customer meters. Although telephone communications are offered by many AMI systems as the preferable alternative for WAN communications from the collector to the data center, this it is more suitable for large commercial or industrial customers, since it is considered very expensive for residential use.

HYBRID ARCHITECTURES

Nowadays, there is not only one solution for all the applications. The communication problems of the rural electric utilities are different from those of the urban electric utilities or from those located in mountainous regions or in regions with poor wireless or Internet network coverage.

The deployment of a single AMI technology or communications architecture can be costly even when economies of scale and standardization are considered in the analysis. Therefore many utilities are now opting for hybrid systems. In this type of systems, two or more architectures are deployed in portions of their service territory with different geographic and demographic characteristics. Based on the communication needs of a particular environment, hybrid communication systems use mesh, point-to-point RF or BPL architectures in densely populated urban areas and PLC technology in low-density urban or agricultural areas. Utilities are also using BPL, WiMax or Wi-Fi for higher density areas or to add bandwidth for Smart Grid applications. Moreover, larger C&I customers technology can be used for special circumstances or to support special rates.

The success of hybrid systems lies in the incorporation of a MDM system that is capable of interfacing with various network management systems, providing a single integration point with the CRM/CIS platform and other operations applications.

HOME AREA NETWORKS (HAN)

Following the recent energy directives and the green movements, the leading IT companies and telecommunication service providers are seeking to position themselves within standards groups and alliances in order to take advantage of the opportunity that provides the customer oriented energy management, which did not exist until recently.

Smart grid concept and wireless sensor networks technologies integrated with broadband provide more cost-effective in-home energy management systems, revolutionizing management for consumers and energy providers. These technologies lead to efficiency concepts, such as ―Smart Energy” homes, where consumers use smart meters and Home Area Networks (HAN) to directly communicate with their appliances for managing energy.

The main types of HAN communications networks are based on:

- Wi-Fi and low power Wi-Fi
- ZigBee
- IPv6LoWPAN
- KNX LonWorks
- X10
- Z-wave
- ONE-NET
- HomePlug
- Bluetooth

According to studies carried out by consulting companies, in five years there could be more than 20 million home area network worldwide.

2.3 State of the Art and of the Practice

The state of the practice in technology and metering systems architectures are identified in the three main types of consumers: residential, commercial and industrial.

For residential and low power consumption commercial customers, smart meters and electronic meters are being used, with basic functions (registration of consumption, voltage, current and energy theft detection). In some countries AMR systems are widely used. Also, in some countries, in low power consumption residential consumers and in zones with difficult access, have being using intelligent card prepayment meters with automatic disconnect/ reconnect service.

For high consumption commercial and industrial consumers, electronic multifunction meters are being used, with functions like: load profile, four quadrant energy meter, power factor, voltage and current, energy quality and hourly tariffs. This type of meters equipped with communication media, like: Ethernet; optic, serial and modem phone ports; with proprietary, DNP3.0 and MODBUS protocols.

In the State of the Art, the electric utilities are using AMI with smart meters equipped with two-way communication, which firmware can be remotely updated. It has hourly tariff capacity, load profile, interruptions and black outs in the network, meter disconnection, lack/absence of single phase potential, etc.

These systems allow locating, in a quick way, any fault in the network, overloaded transformers, faults on (electrical) lines. It also allows to better plan the distribution network.

The electric utilities that use these systems can offer preferential tariffs to their most important customers, knowing the load profile of each customer in order to keep him/her in a competition-free environment. All this is part of a new concept: Smart Grid. The schemes may vary in each country in accordance to the operative requirements of the market model.

A specification released by the Utility Smart Network Access Port (U-SNAP Alliance), that sets the guidelines for enabling home appliances to communicate with any smart meter, will help grid manufacturers supply low-cost connectors for home appliances. One of the advantages of this specification is that it adapts to a variety of common wireless standards as ZigBee, Z-Wave and Wi-Fi among others. It is soon expected to see thermostats using this new specification.

ZigBee Alliance (an association of companies developing reliable, cost-effective, low-power, wirelessly networked products based on the IEEE-802.15.4 wireless standard) released The ZigBee Smart Energy specification, that is being embraced by the IEC, IETF, HomePlug Power line Alliance, European Smart Metering Industry Group, and was recently chosen as one of the standards to be included in the US Smart Grid Interoperability Framework.

2.4 Standards

The main metering standards in the areas listed below are followed by most all of the leading meter manufacturers.

FUNCIONALITY:

IEEE 1705/ ANSI 12.23: Compliance certification standard.

DATA REPRESENTATION:

IEEE 1377/ ANSI C12.19 - defines a set of flexible data structures ("tables") for use in metering products and a syntax for identifying and describing these structures. It forms the basis for common data structures and provides a common industry "vocabulary" for meter data communications.

COMMUNICATION:

- IEEE 1701/ ANSI C12.18/ IEC 61107 - designed to transport data structures via the infrared optical port currently used in most North American electricity revenue meters.
- IEEE 1702/ ANSI C12.21- protocol specification for telephone modem.
- IEEE 1703/ ANSI C12.22 - supports data network communications at the meter.
- 802.11 (Wi-Fi) - wireless standards that specify an "over-the-air" interface between a wireless client and a base station or access point. The standard applies to wireless LANs and provides 1 or 2 Mbps transmission in the 2.4 GHz band using either frequency hopping spread spectrum (FHSS) or direct sequence spread spectrum (DSSS).
- 802.15.4 (ZIGBEE) - open standard for low power network monitoring and control products based on IEEE 802.15.4.
- 802.16 (Wi-Max) - A family of IEEE standards for wireless broadband access, which provides up to 70 Mbps of shared point-to-multipoint transmission in the 10 to 66GHz frequency bands as far as 37 miles.
- DLMS / COSEM, IEC 61107 2000 - Remote reading communication channels. For remote communication only include optic power, IEC TC 13.
- IEC 62053 – 21 2004 - Electricity metering, IEC TC 13 WG 14.
- IEC 61334 – 4 – 41 - Communication channel.
- IEC 60870-5-102 1996 - Transmission of integrated totals, in and between transmission and distribution stations, IEC TC 57 and ANSI C 12.18 (transmission).
- ANSI C 12 – 23 - Signal stability against noise affects during PLC transmissions.
- GSM / PSTN communication protocols: Multi-channel Flag protocol, AT / DT

and DN.

- ANSI C 12.18, C 12.19 - Pulse transmission (utility tables).
- ANSI C 12.21 (flash) - Two-way communication transmission protocol.
- C 12.24 - Two-way communication through LV power line carrier.
- IEC 481 - Coupling devices for power line carrier systems; CEN TC 294 as EN 1434 – 3 : 1997 (future EN13757 – 2 and 3) - MBUS for metering.
- IEC TC 13 - Electricity metering.
- IEC 62056 series of standards, parts 6 – 42, 6 – 46, 6 – 53, 6 – 61 and 6 – 62 year 2002; CEN TC 294 - Utility metering.
- ANSI C 24.31, 36 - IR interface.
- ANSI C 63.07, 08- Noise stability for communication via LV power line. DMC PLC OBIS code.

<u>HAN are based primarily on the following standards:</u>

- Wi-Fi. Globally defined, widely accepted and widely deployed open standard. Supports Internet connectivity.
- ZigBee. Supports RF and Power line. HAN functionality Advanced Application Layer.
- Bluetooth. Widely deployed. Supports RF.
- Z-wave. Home Automation. Supports RF. With acceptance in Europe.
- ONE-NET. Home Automation. Supports RF.
- HomePlug. Home Automation. Supports RF with Internet connectivity.
- IPv6LoWPAN. IPv6 over Low power Wireless Personal Area Networks. Like ZigBee, it is based on IEC 802.15.4 physical layer.
- KNX. Supports RF and Power line physical layers. widely accepted in Europe. Defines interoperability between devices.
- LonWorks. Large deployments in home automation and AMI areas. Supports Power-line communications. There are devices that provide RF bridge.
- X10. Widely accepted in Home Automation. Supports power-line and RF.

The National Institute of Standards and Technology (NIST), a non-regulatory agency of the U.S. Department of Commerce, involved in standards development and testing done by the private sector and U.S. government agencies identifies the following specifications and standards:

Standard	Title
ANSI/ASHRAE 135-2008/ISO 16484-5 BACnet	A Data Communication Protocol for Building Automation and Control Networks
ANSI C12.1-2008	Performance and safety type tests for revenue meters.
ANSI C12.18/IEEE P1701/MC1218	Protocol and optical interface for measurement devices.
ANSI C12.19/MC1219	Revenue metering End Device Tables.
ANSI C12.20	Revenue metering accuracy specification and type tests.
ANSI C12.21/IEEE P1702/MC1221	Transport of measurement device data over telephone networks.
ANSI/CEA 709.1-B-2002	Control Network Protocol Specification
ANSI/CEA 709.2-A R-2006	Control Network Power Line (PL) Channel Specification
ANSI/CEA 709.3 R-2004	Free-Topology Twisted-Pair Channel Specification
ANSI/CEA-709.4:1999	Fiber-Optic Channel Specification
CEA-852.1:2009	Enhanced Tunneling Device Area Network Protocols Over Internet Protocol Channels
DNP3	Standards-based Interoperability between substation computers, RTUs, IEDs and master stations for the electric utility industry.
IEC 60870-6 / TASE.2	Define the messages sent between control.
IEC 61850 Suite	Define communications within transmission and distribution. substations for automation and protection.
IEC 61968/61970 Suites	Standards to define information exchanged among control center systems using common information models.
IEEE C37.118	Define phasor measurement unit (PMU) performance specifications and communications.
IEEE 1547 Suite	Standards defines physical and electrical interconnections between utility and distributed generation (DG) and storage.
IEEE 1588	Standard for time management and clock synchronization across the Smart Grid for equipment needing consistent time management.
Internet Protocol Suite including, but not limited to :IETF RFC 2460 (IPv6)	IPv6 is new version of the Internet Protocol that provides enhancements to IPv4 and allows a larger address space.
Core Protocol in the Internet Suite, draft-baker-ietf-core-04	Core Protocols in the Internet Suite applicable for Smart Grid.
Multispeak	A specification for application software integration within the utility operations domain; a candidate for use in an Enterprise Service Bus.
OpenADR	The specification defines messages exchanged between utilities and commercial/industrial customers for price-responsive and direct load control.
OPC-UA Industrial	A platform-independent specification for a secure, reliable, high-speed data exchange based on a publish/subscribe mechanism.
Open Geospatial Consortium Geography Markup Language (GML)	A standard for exchange of location-based information addressing geographic data requirements for many Smart Grid applications.
ZigBee/HomePlug Smart Energy Profile 2.0	Home Area Network (HAN) Device Communications and Information Model.
IEC 62351 Parts 1-8	Define information security for power system control operations.
IEEE 1686-2007	Define the functions and features to be provided in substation intelligent electronic devices (IEDs) to accommodate critical infrastructure protection programs.
NERC CIP 002-009	Cover physical and cyber security standards for the bulk power system.
NIST Special Publication (SP) 800-53, NIST SP 800-82	cover cyber security standards and guidelines for federal information systems, including those for the bulk power system.

The Utility Standards Board (USB), a utility industry leader in developing open standards and promoting system interoperability, in coordination with external organizations and international standards bodies, has been focusing on Advanced Meter Infrastructure (AMI) data processing, with a particular emphasis on standardization opportunities for Meter Data Management (MDM) solution interfaces.

With a growing number of utilities rapidly launching AMI initiatives across North America and Europe, there is increasing attention on the enormous data management challenges of MDM.

Although there are currently several MDM solutions available on the market, many organizations like ICE, the GridWise Alliance and the UCA International Users Group have been developing interface standards that impact AMI data management. Still, little progress has been made in establishing actionable integration and interface standards; therefore, the USB expects to speed up the standards development process by focusing primarily on:

- Utility-specific and practical MDM implementation solutions
- An enterprise MDM picture aligned with providing information and functionality for the entire customer service experience
- An MDM architecture that improves efficiency and integrates with the Smart Grid

For 2008, the USB will focus its MDM standardization efforts on four work streams:

- Meter Event Codes
- AMI Headend Data Acquisition
- Outage Detection and Restoration
- Remote Connect Disconnect Functionality

These work streams represent a mix of de facto standards development and functional requirements that can be used to develop standards.

2.5 Trends

Deregulation is one of the most important reasons why metering technologies must evolve at a faster pace in the years to come.

The clear trend is that the AMI systems integrated to the Smart Grid will gradually replace the electromechanical meters. This, in order to reduce the costs of manual meter reading carried out by the electricity supplier; improve billing, customer service and the grid operation and comply with the local regulation which already requires the installation of these systems.

Trends in technology and metering systems architectures are identified in the three main types of consumers: residential, commercial and industrial.

For low consumption residential and commercial consumers, the trend is towards the application of AMI systems, including mesh topology communication. Functions like: automatic demand response (intelligent electric appliances, in-home displays), remote disconnect/ reconnect and metering at pole distribution level are being considered.

It is worth noting that there are nearly 2 billion electric meters worldwide, of which 150 million are in the United States, 300 million in Europe and 350 million in China and a smaller proportion in countries like Canada, Australia and New Zealand. Although smart metering has not yet been implemented in many countries, this technology is a trend that can not be avoided.

Thanks to smart meter and the AMI systems, now it is possible to implant certain functions and to get information that was restricted only for great consumers, due to the relatively high cost of the conventional electronic multifunction meters. Some types of this functions and information refers to: Load profiles, what allows generation prediction according to energy consumption patterns; Energy quality (harmonic distortion, sags, swells, service interruptions, etc.); Communication of precise dynamic tariffs to the consumers, as well of warnings about changes in energy prices; Change of tariffs by the consumers.

Another trend is towards the use of standardized interfaces to share data between high-level functions in the electric utility, such as Outage Management Systems (OMS), Customer Information Systems (CIS) and the AMI systems.

The prepayment employ the infrastructure of AMI systems is another trend; the purchase of credit is remotely done through communication media, like SMS, GPRS and Internet, among others. In this prepayment schema, the consumer interfaz could be the in-home display, the utility web portal or the authorized sales points.

In some cases, legislation also requires domestic load control from the meter, as well as providing the customer with a rate signal. The final customer will be able to manage her/his loads, contribute to reduce costs and pollutant and make the installed capacity of the electricity supplier more efficient.

2.6 Case Studies

<u>**European Union**</u>

The European Commission mandated smart metering at the beginning of 2009 for all electric, gas, water and heat meters, and put mandatory dates on electric metering -- 80 percent by 2020 and 100 percent by 2022. Many European countries have already passed laws with tighter deadlines than those mandated by the EC.

Enel SpA, Italy‘s largest power company, undertook the world‘s largest smart meter deployment. This company has already installed 30 million smart meters across Italy.

These smart meters are fully electronic equipped with integrated bi-directional communications, advanced power measurement and management capabilities, an integrated software-controllable disconnect switch, and an all solid-state design. They communicate over low voltage power line using standards-based power line technology from Echelon Corporation to Echelon data concentrators at which point they communicate via IP to Enel‘s enterprise servers.

The system is able to remotely connect or disconnect the service, collect information about each customer‘s power usage, identify power outages, detect illegal taps, help customers make choices on how much energy they use and remotely change the meters billing plan from credit to prepay as well as from flat-rate to multi-tariff.

Canada

The Ontario Energy Board in Ontario, Canada has strived to define the technology and develop the regulatory framework to encourage smart meters implementation. The objective is to achieve 100% penetration of smart meters this year.

United States

The largest AMI technology implementation project in the United States involved the installation of 10.3 million meters, during a five-year period (2006 – 2011).

Although the adoption of AMI technology is still slow, it is steady and is expected to gain greater importance since this technology offers a wide range of benefits to the utilities, regulators and customers by making the customer connection more intelligent and responsive to system needs. According with the FERC staff report, utilities are planning to install nearly 40 million AMI meters in the next three years. It is expected that AMI meters will replace electromechanical and AMR meters.

The FERC report also predicts that AMI meters will outpace AMR meters in the next three to five years. The California Public Utilities Commission (CPUC) has approved AMI deployments all over the state worth about US$3.5 billion. Likewise, in the next five years utilities will enhance their customer connection by installing about 16.5 million AMI meters.

Pacific Gas and Electric (PG&E San Francisco, California), which has more than 5 million electric and 4 million gas customers, is carrying out its Smart Meter project. The main goals of this project are to help introduce time-of-use rates, demand response features through programs like Critical Peak Pricing, and provide capabilities like opportune outage detection and assessment and remote connect disconnect of electricity service.

CPUC has given San Diego Gas & Electric (SDG&E), a public utility that provides service in San Diego and south Orange County, approval to deploy Smart Meter technology. SDG&E will replace 1.4 million electric meters and retrofit 900,000 gas meters at a cost of about $572 million. Through the implementation of AMI technology, SDG&E will be able to develop a system capable of collecting and storing data from meters on an hourly basis. SDG&E customers will also benefit from new and improved services to manage their energy usage efficiently, enhanced service reliability and new pricing options.

SmartConnect is an AMI deployment project undertaken by Southern California Edison (SCE) that will automate nearly 5.3 million meters. It will allow utilities to enhance customer service, reduce outage response time, offer dynamic pricing structures, demand response and promote energy conservation. Moreover, AMI technology will enable SCE‘s customers to shift energy usage to off-peak periods in order to make consumption more efficient. SCE estimates that this deployment will cost more than $1.5 billion, for the AMI meter installation portion of the SmartConnect program.

United Kingdom

First Utility was the first energy company that brought smart meters to the United Kingdom. Since September 2008, this energy supplier has offered customers smart meters free of charge. It is important to highlight that in 2009, the United Kingdom Department of Energy and Climate Change announced the plan to roll out smart meters to all homes by 2020. The projected cost of fitting approximately 22 million gas and 26 million electricity meters was estimated at £7 billion.

Turkey

Elektromed, one of the leading developers of metering technology in Turkey, has installed more than 1 million prepayment smart electricity, water and gas meters.

Australia

In 2004, the Essential Services Commission of Victoria, Australia (ESC) published the changes to be made to the Electricity Customer Metering Code and the Victorian Electricity Supply Industry Metrology Procedure in order to begin the installation of interval meters for 2.6 million Victorian electricity customers.

The ESC's Final Paper entitled "Mandatory Rollout of Interval Meters for Electricity Customers" suggested the changes to be implemented, including the rollout plan which started in mid 2009 and is expected to be completed by the end of 2013.

In 2009 the Victorian Auditor General reviewed the program and identified significant inadequacies and found that the project governance was inappropriate.

As a consequence, the Victorian Government announced a moratorium on the introduction of time of use tariffs under its smart meter rollout, following concerns about how the new pricing structures could affect the customers. The government announced its decision to postpone the introduction of time of use pricing until further work is done to ensure best practice consumer protections will apply.

In 2006, the Commonwealth issued a Joint Communiqué which committed all governments to the progressive smart metering rollout, starting in 2007.

Netherlands

In 2007, The Dutch government proposed to fit every home in the country with a smart meter by 2013, a part of a national energy reduction plan.

However, this smart meter rollout plan was postponed because there was uncertainty on future developments in smart meters and it was not yet foreseen the possibility to record small-scale energy generation. Privacy concerns also hindered the smart meter deployment.

Nordic countries

In 2003, Northern Europe became the hotspot for Automatic Meter Management (AMM) systems deployment when Sweden announced that it required a system that could provide the utilities with accurate information on energy usage on a monthly basis. As a consequence, leading energy suppliers like Vattenfall, Fortum and E.ON undertook AMM deployment projects in Finland and Sweden. Likewise, by 2004 some of the largest utilities in Denmark announced plans to carry out ambitious deployment projects. Although Norway has taken a cautious position, the Norwegian energy authority (NVE) declared that it would recommend a new legislation requiring the introductions of smart meters by 2013. As of August 2007, almost all of the DISTRIBUTION SYSTEM OPERATORS (DSOs) in Sweden had signed contracts to implement AMM solutions. Contracts for nearly 8 million smart meters are still open in the Nordic region.

China

In 2008, China announced a smart metering project encompassing 170 million meters and an estimated budget equivalent to approximately $10 billion. At the beginning of 2009, the project was expanded to 200 million smart meters, to be completed in three to five years.

New Zealand

In November 2005, Meridian Energy started the installation of smart meters in over 1000 homes. By the end of 2006, about 6,300 smart meters had already been installed as part of a pilot project. The first smart meter rollout for households in Christchurch began in 2007 and there were plans to install over 112,000 smart meters by January 2009.

In June 2009, the Parliamentary Commissioner for the Environment informed that the 150,000 smart meters installed in New Zealand did not include HAN chips at the initial installations, which only meant benefits for the power retailers.

France

Electricité Réseau Distribution France (ERDF) is carrying out a smart metering pilot project that involves 300,000 customers. In June 2008 ERDF awarded the AMM pilot project to a consortium managed by Atos Origin. The goal of this project was to deploy 300k meters and 6k concentrators in two geographic areas. This project, which only affected 1% of LV customers, was only the first stage of the nationwide deployment for 35 million customers in France. One of the key success factors of this project, which testing phase started in March 2010, will be the interoperability of various suppliers‘ equipment. The deployment phase, which entails the replacement of 35 million meters, will start in 2012 and continue through 2017.

Ireland

In 2007, the Green Party Minister for Communications, Energy and Natural Resources, announced that all homes in the Republic of Ireland should be fitted with a smart meter within a five-year period. Smart meters are considered as the key technology that will support the introduction of demand-response rates and facilitate the management of distributed generation and distributed storage like plug-in hybrid electric vehicles. Smart metering systems should also empower the customers to automatically respond to fluctuating electricity prices by, for instance, buying electricity during off-peak times, and selling micro-generated electricity back to the supplier when better rates are available.

Malta

Enemalta Corporation, has been responsible for the installation of smart meters across the country. This roll-out is a major national project that will involve several phases and its main goal is to replace meters at all homes and businesses, so that every meter in Malta will be ―smart" by 2012. This deployment will cost the Ministry of Infrastructure, Technology and Communication in the region about 40 million Euros, which will be completely absorbed by the government. A pilot project is currently in progress with more than 5,000 smart meters already installed.

Mexico

The following pilot projects were deployed by the Federal Commission of Electricity (CFE), the national electric utility:

10k meters with two-way RF communication, at the south of the country in historical buildings.

1,500 meters with two-way RF and GPRS communication, mesh network, remote reconnect/ disconnect, at south of the country (hotels in a tourist zone). This pilot is under a non-technical energy losses reduction program. In the near future, CFE is planning to install 64k of these intelligent meters along the country.

220 meters with netting function, at the north of the country, for low consumption clients with photovoltaic local generation interconnected to the grid. Savings of 50% in client's bills.

90k meters at the south of the country. Two-way DPLC communication. In-home displays. Meters at pole distribution level. Remote reconnect/ disconnect. Low and medium consumption clients. Non-technical energy losses reduction program.

1,000,000 intelligent card prepayment meters installed along the country. Register of Vmax, Vmin, electric service interruption and disconnected meter statistics, abnormal meter functioning. CFE is planning to install 2,000k/year of this type of meters.

At the center of the country CFE provides water meter readings through the metering infrastructure.

CFE is planning to deploy a WiMax communication network at the center of the country, to be used in remote meter reading.

3 REVENUE PROTECTION

There is a great incidence of illegal practices such as deviations and meter tampering and subsequent energy theft in many electric utilities worldwide. Average non-technical energy losses such as energy theft amount up to 15% of the total commercialized energy in some countries.

To cope with this problem, devices and procedures are evolving to help fraud detection. On the other hand, many dishonest consumers are also evolving their illegal practices, and in spite of the technological advances in the metering field, in many situations they have succeeded, as indicated by the very high percentage of energy losses due to frauds.

Up to now, technological developments have focused only on the metering concepts for commercialization purposes. Energy losses can only be inferred from them.

It is a common practice to classify energy losses in technical and non-technical. Technical losses are those that occur in electricity systems as a result of thermal, electrical insulation and magnetic effects in the plant, transmission lines, transformers and capacitor banks that make up the system. *Their origin is the energy transformation principles.*

Non-technical energy losses can be classified as follows:

- Accidental.- Are those that originate in the improper operation of the elements an equipment of the electric circuits, for example: a wrong connection.
- Administrative.- Energy that is not billed for some reason, for example: problems with the billing systems, consumers and public buildings without meters.
- Fraudulent.- Energy stolen by dishonest consumers, that bypass the meters.

It is possible to control technical energy losses by means of automated operating practices and design techniques that allow the proper dimensioning of the elements and equipment of the electric circuits, in such a way that this type of energy losses can be kept within acceptable levels.

Non-technical losses, particularly those occurring as a result of fraud, have become a problem for the electric companies. Although dishonesty can be found at all levels of society, it is surprising that major customers are most likely to engage in fraudulent activities. In most instances where energy is being stolen, tampered service connections and meters have been discovered.

Likewise, these economic losses are reflected on the companies‘ revenue and unfortunately, these costs are passed to customers in the form of higher electricity tariffs as the company must compensate generation, transmission and distribution expenses with energy billing.

Energy theft has also a negative impact on the quality of electricity service as the electric utility has no control over energy demand in transformers located in regions where almost all households and businesses have illegal electricity connections; resulting in more frequent voltage variation and service interruption.

To cope with this problem, some electric utilities have created Departments to investigate and try to recover energy losses. But these Departments work mostly on a limited budget and with few staff, so the results are not as satisfactory as expected.

There are also locking devices that protect meters and peripheral equipment (e.g. instrument transformers) against unauthorized access, such as security rings, padlocks, security seals, etc. Likewise, there have also been some changes in the normativity as regards metering equipment, medium and low-tension grid configuration with the purpose of minimizing the incidence of these kinds of problems. Following are some issues that have been considered to prevent energy theft.

- Location of the metering equipment, always on the boundary of the premises.
- Usage of concentric cable for the connections.
- Replacement of secondary networks by non-isolated cable.
- Usage of antifraud connection boxes.
- Changes in the form of the meter.
- Installation of meters and low voltage grids at the same height of medium voltage.

As a result, in some countries, reading activities are required to be carried out more often in order to detect, report and solve evident frauds, along with billing inspection which is performed previous to the bill issuance, in order to identify important consumption reduction.

The ethical behavior of electric companies' employees is an important issue when it comes to energy losses, as they are also likely to engage in fraudulent activities like alterations to meter readings or meter tampering.

3.1 Technologies

Technological development is not focusing directly on the detection and registration of energy losses, but on adding tools or functions to electronic meters, such as detection of possible meter tampering or registration of lack of potential with which can be inferred whether there has been an illegal activity that affects the meter readings.

For the purpose of this study, the following classification of technologies is considered:

- Mechanical devices that protect the integrity of the metering equipments and their peripherals.
- Electronic devices that make use of the advantages of AMR, AMI, Prepayment, etc.

- Software for analyzing metering, billing and collection information.

3.1.1 Mechanical Devices

The accessories for protecting the equipments from tampering have been the traditional and basic precautionary measures against energy theft. Some of these accessories are the following:

Seals that provide resistance to an intentional attempt to remove the socket type meter; covers that protect the meter connections and cabinets/stopcocks attached to the metering equipment, which have evolved from devices made of lead to padlocks. The last ones include features that impede any attempt of tampering and tamper-evident devices that make unauthorized access easily detected; special folds and sharp edges; slots that easily break the plastic, making the tampering attempt more evident; transparent plastics that show any tampering attempt.

Rings to hold the socket type meters. They have also evolved from the typical metal ring with a protection device for the installation of the corresponding seal to similar rings with two protection accessories, which have improved the security and rings with bolt padlocks. With the last ones it was intended to provide greater mechanical protection to the meter and its base (so the meter could not be removed from the base). This obliged to improve the security mechanisms of the bolts, which are fixed to the rings, by creating mechanical and even electronic combinations.

As the security rings, security padlocks that are fixed to the rectangular bases of the meters were created to provide a greater mechanical security. The development of these security padlocks was influenced by the evolution of the bolt padlocks and has allowed the modification of the aforementioned rectangular bases, which already consider the receptacles for the direct installation of the bolts.

3.1.2 Electronic Devices

The incorporation of electronics has provided important advantages such as:

- Prevention of tampering with the hands of the electromechanical meters.
- Monitoring the lack of potential and keep a logbook/register.
- Registration of energy consumption even when a meter is upside-down.
- Implementation of mechanisms for monitoring the registration of maximum and accumulated demand.
- Access to meters through their communication ports.
- Fitting out of the tool box which is capable of monitoring the operating conditions that allow the correct association of tension-current, tension levels, minimum current, minimum potential factor, and continuous current

components.

All these, combined with the communication advantages and opportune information provided by the AMR and AMI systems as well as the use of specific software for the analysis of event registration and load profiles, allow a strict monitoring in order to determine those customers who are likely to experience anomalies or disconnection from the service.

In particular, load profiles registered in the meters have been exhaustively analyzed in order to study consumption habits that help determine how often anomalies occur in metering registration.

3.1.3 Statistical Analysis

In this respect intelligent tools are being applied for the processing and analysis of metering, billing and collection information through artificial intelligence techniques, inference models and fussy logic techniques in order to determine, with some confidence, those customers that may have any registration or billing problems in their energy consumption.

Likewise, statistical algorithms based on the customer‘s consumption profile such as data mining and the —Rough Sets” technique are applied in some software packages with the aim of analyzing the energy consumption behavior of the customers that are suspicious of fraud. Nevertheless, this method has not yielded the expected results since some reports show that only a 10% of the investigated customers have committed fraud.

3.1.4 Social Aspects

Non-technical energy losses are a result of an inefficient operation of the processes. As regards to the electric utilities and particularly non-technical energy losses, the components are the following: commercialization process, personnel who carry out the activities and energy customers.

The application of any solution must start with the collaboration of all workers. It is fundamental that the personnel is convinced that, when the company is financially strong, their will benefit from it. Therefore, they will support the correct application of the chosen solutions.

To achieve this, several electric utilities have implemented methodologies that emphasize the values, attitudes, knowledge and abilities of the personnel including managers, who must also develop their own leadership styles. —Balance Scorecard”, quality models and other systems are being outlined as the tools that help achieve these goals. All of them start from the fact that the person is the central element in the operation of the company.

Just as the electric utility‘s employees, it is essential to educate the customer about the efficient use of energy. ―Consume only what is necessary” is the result of this customer education, which purpose is to improve the relationship between the customer and the electric utility thus enhancing customer satisfaction.

Some electric utilities have implemented programs to educate customers about energy consumption which are aimed at replacing equipments with energy-efficient appliances and looking, in future, for this attribute in new equipments in order to reduce energy consumption during peak hours.

3.2 State of the Art and of the Practice

The State of the Practice is still the physical inspection of the customer‘s premises and the meter. It is also common in South Africa, India and The United Kingdom, the usage of a prepayment meters to allow the customers to better manage their energy consumption, which has a positive impact on their household expenditure.

The main feature of these meters and even of the most advanced prepayment systems is that the meter itself detects and alert the electricity supplier to any changes in the normal operating conditions: a continuous phase absence, non-authorized meter disconnections, attempts to modify the programming, etc.

The State of the Art is the use of electronic devices or meters with advanced functions combined with data mining software for the analysis of the obtained information. This software is capable to predict, with some certainty, the possibility of energy theft. These programs are either part of the AMR or AMI metering systems or an independent application.

Technologies or methodologies that have yielded good results in some countries do not produce the same results in other countries. This is mostly because of the cultural aspects of each region, the economic situation and the legal system (as regards how the current legislation addresses the severity of energy theft).

3.3 Trends

It is important to recognize that when it comes to revenue protection, each country's legislation, as well as the economic situation of the population plays a relevant role. This issue is closely related to the aforementioned aspects. There are countries where energy theft is a rare issue or where there is not awareness of it, and some others with a high-energy theft incidence.

AMR/AMI systems seems to be a good option to cope with the energy theft problem, as they can offer low-cost meter reading, accurate measurements, as well as elimination of estimations. Thus, it is clear that revenue protection is undergoing an important upgrading. Smart Meters and pre-prepayment systems are also included in this concept. The last ones have yielded satisfactory results in some European and African countries.

The use of equipment and meters that offer remote disconnection and connection from the electricity service will benefit both, the utilities and the customers since they can help prevent energy losses. The objective is to eliminate the direct interaction between the electric utility‘s employees and the customers.

Another trend that seems to be adequate is the separation of the energy measurement from the meter readings. This includes the use of a metering module located on the distribution pole and a module that displays the readings which is installed in the customer premises. Both modules interact using PLC or radiofrequency communication.

3.4 Case Studies

Energy loss has become a major problem for the electric utilities, as a result, several studies have been carried out in order to determine the magnitude of this losses and their impact on the companies‘ revenue and the overall economy.

In Malaysia, an inspection that lasted two months was carried out in areas suspicious of fraud, with results showing that 86% of the electricity was being stolen through meter tampering.

In Soweto, South Africa, a six-month examination of the customers‘ electrical installations was scheduled in order to eliminate illegal taps; approximately 6 tons of cables used in illegal taps were withdrawn.

In Armenia, a study showed that energy losses at residential level derived from ―no-payment”, a common practice in several countries, range between 80 and 90%.

Arizona Public Service Company (APS) carried out a study in order to determine the economic losses derived from meter tampering. The study consisted of testing 550 meters out of a 868,000 total, from which a 35% were on rural and urban zones and 12% on residential and industrial zones. The project lasted two months with the following results: tampered meters rate: 0.72%, possible tampered meters: 1.00%; economic losses in USD: $330,148. The data was extrapolated to the APS capacity and estimations showed that nearly 15,000 meters were tampered and yearly losses were as high as $7,967,279 USD.

Ampla, in Brazil, reduced its energy loss rate from 23.64% to 20.37% in a three year period through the implementation of a metering system installed at the top of the pylon at the same level of the secondary network which was relocated with multiple cable at the same height of the primary network; the metering system is AMI with remote disconnection and connection. All of this was complemented with social programs.

CFE Centro Oriente Distribution Division, in Mexico, managed to reduce the energy losses rate from 11.94% to 8.21% between December 2006 and June 2008, by working on the restructuring and monitoring of the commercialization process, assuring metering equipment, following-up anomalies reports, improving the quality of the billing process, educating the customers about the opportune payment of their electricity bills and by involving operative personnel in the process.

Monitoring is performed through the commercialization process Control Board; its main goal is to provide opportune information on the main events of the process and publish it on the intranet at different levels: clients, work routes; consolidating information by collaborator, Agency, Zone and Division. Data is obtained directly from the CRM/CIS systems, which makes the information reliable and opportune.

4 BILLING

Billing is a fundamental activity of the electricity commercialization process. The opportune collection of the issued invoice, the reduction of non-technical energy losses as well as the customer satisfaction depend, in large extent, on how efficient billing is.

The problems of billing are focused mainly on:

1. The correct measurement of the consumed energy,
2. The obtention of metering parameters (readings) for billing purposes,
3. The data processing and validation, and
4. The issuance, deliver and collection of the invoices.

Once the energy consumed has been accurately measured, the following step is to focus on obtaining the reading. For many utilities, meter reading is a labor-intensive activity; although the use of technologies such as AMR/AMI is increasing, most of the meter reading is still carried out manually on a monthly basis. Any mistake or delay in the reading process has a negative impact on billing, as well as on the utility‘s revenue and the customer‘s satisfaction.

Meter readers are not only responsible for the correct and efficient measurement of the energy consumed, they also play an important role in the detection of energy leaks, service anomalies and safety issues related to the electric supply. For many customers, meter readers are the only utility employees they ever seen therefore, they are the only touch-points that act as the basis of customer opinion.

As meter readers are entry-level utility employees, meter-reading departments generally have high turnover rates, which increases hiring and training costs and ultimately increases the overall cost of meter reading activities.

The constant changes in the industry and the economy have forced companies worldwide to reduce their operating costs. Likewise, regulators, customers and shareholders are urging the utilities to enhance customer service in order to increase customer satisfaction through the efficient management of the company's resources. All this poses a major challenge for the organizations.

There is also a growing need to have opportune access to energy consumption data to support real-time pricing initiatives, load forecasting, demand-side management, load control, competition and customer demand. Status and usage information on an event basis is also needed in order to improve reliability, power quality and to identify outages.

Having an economic and timely access to a large quantity of data has gained importance for the electricity suppliers, as the energy consumption data obtained directly from the metering installation/ at the metering point is not only used for billing purposes, but for the optimization of the entire added value chain: distribution, dynamic tariffs control, marketing, customer relationship management and electricity supply are based on the metering system data. This need for more complete information requires the implementation of advanced metering systems, smart meters and a greater automation.

Other aspect that must be considered is the efficiency of the processing of the information obtained from the meters either manually or automatically; the improvement of the controls and the established validation measures that guarantee the accurate billing of the energy used by the customers.

Once the invoice has been issued, other fundamental factor is to send it opportunely to the customer residence. This activity is costly and, combined with the cost of manual meter reading makes the electricity commercialization process more expensive.

4.1 Technologies

Energy meters, the only direct revenue link between utilities and the customers, have experienced many improvements. Conventional electronic meters are being replaced with advanced electronic meters to make meter reading more accurate and to obtain additional useful information.

Billing and energy auditing accuracy depends directly on the ability to obtain energy meter readings. There is a wide variety of energy meters and metering methods such as manual or semi-automated readings and fully automated readings that incorporate the use of modems, Internet and radio frequencies.

4.1.1 On-Site Billing

Consists of, the obtention of meter readings and the immediate issuance of the invoice at the customer‘s residence. This is carried out through portable hand-held terminals equipped with printers. On-site billing provides tangible benefits like collection recovery, nevertheless, the lack of communications infrastructure in some countries such as India and Malaysia have hindered the implementation of this type of technology.

It is thought that this technology will not be sustainable in the future, because of the advancements in communications that will improve their quality.

4.1.2 Electronic Billing

The advances in communications, the deployment and expansion of the Web, as well as more efficient algorithms and encryptions have made it possible to carry out Internet transactions in a more secure way.

And so, electronic billing was developed, which consists of sending a collection notice via Internet and the possibility of receiving the payment over the same via.

4.1.3 Prepayment

The concept of prepaid metering was first introduced in the United Kingdom before World War II in the form of coin operated gas meters. It was not until the 1980s, when electronic or numeric credit transfer was introduced, that prepaid metering underwent a significant change.

The advances in telecommunications and electronic meters have enabled this type of billing which provides many important advantages both, to the customers and the utilities located in distant, suburban or rural towns where access is costly.

Prepayment offers flexibility to the customers since they do not have to make an accumulated payment for the used energy; instead, they pay upfront according to their financial means.

Prepayment is considered, in some countries, as a way to help low-income customers to manage their energy consumption more easily, decreasing billing and collecting problems and protecting their income.

Prepayment meters can be either smart meters integrated into an AMI system or less expensive meters without real time communication. The ones without real time communication are made up of electronic meters equipped with functions that perform connections and disconnections from electricity supply. These functions interact bidirectionally through tokens that are operated by the meters themselves and points of sale operated by third parties.

The points of sale are connected to the commercial process management systems, which contain information related to the customer registers, readings, eventualities in the electricity supply and prepayment recharge among other parameters.

The metering equipments allow notifying the customer, in advance, when their credit is about to expire so they can buy more credit and load it into the meter.

This system allows generating the necessary statistics for the commercialization process management, optimizing its costs since it avoids sending a meter reader out as well as the customer‘s disconnection and connection from the electricity supply when they have failed to pay their electricity bills. It also allows monitoring the energy consumption in order to detect any anomalies in customers‘ consumption.

According to consulting companies, one of the main key advantages of prepayment is the flexibility in the amount the consumer can choose to top up her/his meter with and when you pay. One of the main key disadvantages of prepayment is running out of energy, especially at odd hours of the day, and taking into account that sale points can be located far away from the customer and that some of them are rarely open late at night.

4.2 State of the Art and of the Practice

The state of the practice is the visual meter reading, frequently using a handheld device; the information storage in every company‘s billing system and its subsequent delivery, either personally or via email.

With the technology advances, energy meters have become a powerful source of information concerning the services offered to the customers. Conventional electromechanical meters are being replaced by electronic meters in order to improve the accuracy of the meter readings and to obtain different types of data, which can be used for billing purposes, electricity analysis and electricity supply quality. Some can even provide additional information on the customer.

In some countries, meter readings are carried out using radio communication, sometimes combined with on-site billing processes, which is the case of India, Malaysia, and the Centro Occidente Division in Mexico.

Concerning the state of the art, meter readings can be obtained via radio or PLC. This information is transmitted to a concentrator or a handheld, and then sent to the central system for billing purposes. This is possible through AMR or AMI systems.

Now that the available technologies are affordable for everyone, the customers have become more demanding regarding the timely issuance and delivery of their electricity bills. As a result, utilities are using electronic media in order to reduce the time gap between meter reading and the delivery of the invoice, speeding up the return of the investment and reducing invoice issuance and delivery costs. Both, customers and utilities benefit from this since customers can receive their invoices and make their payments via e-mail.

4.3 Standards

Many countries around the world are currently testing prepayment systems. Nevertheless, the implementation of this technology has been delayed because customers still do not fully support the use of these systems. Although several groups like the Standard Transfer Specification (STS) association are developing common standards for prepayment metering systems, this technology has only been successfully implemented in South Africa.

In 1997 the STS Association was created to oversee the prepayment metering technology standard. Its main objectives are maintaining the necessary infrastructure, promoting the technology internationally and further developing the standard to meet emerging international demands for additional functionality. The Association ensures inter-operability between system components from different manufacturers by creating a database of test laboratories that ensure correct STS functionality of equipment through the use of encrypted vending keys to manufacturing members of the Association and the consistent use of manufacturer identity codes and meter serial numbers.

The Standard Transfer Specification (STS) is the only globally accepted open standard for prepayment systems, since it ensures inter-operability between system components from different manufacturers of prepayment systems.

STS Association authorizes the implementation of prepayment technology ensuring that the appropriate encryption key management practices are applied to protect the security of the prepayment transactions of utilities that use STS systems. It has been established as a standard for transfer of electricity prepayment tokens since its initial introduction in South Africa in 1993.

STS-compliant meters have found widespread application, starting in South Africa and subsequently in many developed and developing countries. Currently, this type of meters has been installed at over 400 utilities in 30 countries worldwide.

The STS was published as an International Standard by IEC in 2007:

- IEC 62055-41: Electricity metering - payment systems - Part 41: Standard Transfer Specification - Application Layer Protocol for one-way token carrier systems
- IEC 62055-51: Electricity metering - payment systems - Part 51: Standard Transfer Specification - Physical Layer Protocol for one-way numeric and magnetic card token carriers

The IEC has named the STS Association as the Registration Authority for IEC62055-41 (and the upcoming IEC62055-52) responsible for the maintenance of various data entities, companion specifications, etc.

Currently an IEC project team, in liaison with the STS Association, is finalizing the specification (IEC62055-52) for a two-way Virtual Token Carrier to be used in conjunction with IEC62055-41.

Some countries have developed its own standards. China, for example, has the National Standard related to a vending system of prepayment energy meter, which comprises:

Part I, General Principles (GB/T18460.1-2001);
Part II, Management of Medium (GB/T18460.2-2001);
Part III, IC card prepayment energy meter (GB/T18460.3-2001).
This standard applies to sales management of electricity to all kinds of residential areas, stores and business office buildings.

The standard Adopts Germany SIEMENS-SLE4442 logical encrypt card to achieve prepaid electricity selling model, high security, reliable and easy to operate.

4.4 Trends

The improvements in the billing process are directly linked to the existing advances in metering technology.

Some of the advantages of the AMI systems include: almost nule errors on obtained readings; reduction of labor-intensive activities, specifically meter reading activities; automatic report of anomalies; a faster billing process as well as the remote connection and disconnection from the electricity supply.

In order to make the best use of the new metering technologies, remote meter reading should be complemented with electronic payment and delivery of the invoice.

As stated before, this reduces delivery costs and allows the customers to make online payments which increase the company‘s cash flow by reducing substantially the time gap between meter reading and payment.

Yet another option given by AMI systems is the possibility to implement them in pre-payment schemes, as an alternative for the customers that will help them manage their energy consumption, according to their needs.

One mayor trend refers to prepayment based on AMI systems.

Another trend is the AMI based prepayment systems. Payment management is remotely done through communication media, like SMS, GPRS and Internet, among others. This prepayment schema uses the IHD, the points of sale or the utility web based customer portal as an interfaz to the customer.

Regulatory and Ethical Issues associated with Prepaid Meters

Automatic service interruption is one of the reasons that have hindered the implementation of prepayment technology as regulators and lawmakers consider that this feature is opposite to the right of society of having electric service.

In the USA, regulatory rules evolved to protect customers of investor-owned utilities from service interruption. Before terminating service to a customer whose payment is seriously past due, the utility must pursue an array of measures to secure payment. Prepaid electric service with automatic disconnection when the prepayment runs out is incompatible with the protective measures, and as a result only a few thousand customers are being served through prepaid metering in the US, mostly in municipal and cooperative utilities. Where as in UK there are more than 3 million prepaid electricity meters are in use today. ESKOM has installed about 2.6 million keypad type prepaid meters in South Africa from 1995 to 2005.

Widespread concern exists about the growing use of pre-paid water and electricity meters by private companies and governments. The meters are considered efficient and cost-effective for companies, which experience no lost revenue because users are cut off when they use all the credit they have paid for. But the public health impact of prepaid meters, particularly prepaid water meters can be devastating.

In many countries, people have protested against the use of prepaid meters as automatic service disconnection has triggered some negative social issues. For instance, prepaid water meters were declared illegal in the United Kingdom (U.K.) under the U.K. Water Act of 1998 after water cut-offs were linked to increased cases of dysentery and other diseases related to lack of clean water.

In developing countries, ethical issues in use of prepaid electricity meters should not be treated as an injustice to the society at initial stages of development. However, caution may be exercised while choosing areas for deployment of prepaid meters.

4.5 Case Studies

Argentina

Edenor implemented, in Merlo, a pilot project in 4782 low-income customers which was promoted by people from outside the company with an integral marketing program obtaining the following results: energy consumption decreased by 37.4% in 98% of the customers; this is because the customers were educated about the prepayment system which is seen as a tool to adapt energy consumption to their financial means. It was also detected that payments are received everyday throughout the month; payments are very small because of the economic situation of the population.

United Kingdom

In the Midlands region (United Kingdom) the prepayment meter is equipped with magnetic cards. A specification was developed for the use of smart cards with an integrated microprocessor in order to obtain meter readings, improve the security and have several suppliers of cards and meters. The meter data is sent to the central database every time the card is recharged, and in each recharge only the new information that is useful to the company is sent to the meter, such as tariffs, customer information, etc.

Ireland

In Northern Ireland Electricity, a prepayment system was implemented. This system uses a 20-digit number that is manually entered by the customer using a keyboard and a display which can be installed far from the prepayment device.

One of the system's features is that it can reduce the supplied power instead of just disconnecting the customer from the service. The device accepts credit card or prepayment.

Nigeria

According to a recent survey, the rollout of prepayment meters in Nigeria is being delayed because many of these meters have been tampered with.

Asia

Many Asian countries are currently planning to introduce electricity meters across their distribution network, mainly motivated by the success of this technology in South Africa, the inherent problems with the post-paid system and privatization of state held power distribution companies.

More than 40 countries have successfully installed prepaid meters. In the United Kingdom this system has been in use for over 70 years with nearly 3.5 million customers. Likewise, South Africa started its prepaid meter rollout in 1992 and, to date, over 6 million meters have been installed. Following the success of this technology in South Africa, other countries like Sudan, Madagascar, Argentina and New Zealand are announcing their deployment projects.

The Sabah Electricity Sdn Bhd (SESB), Malaysia, has awarded a contract to a local manufacturer to supply 1,080 prepaid meters.

It is worth noting that countries like Thailand, Bangladesh, Singapore, and Iran are showing a growing interest in adopting prepaid system.

In India, the State of West Bengal is planning to introduce the smart card operated prepaid energy meters in remote islands of Sunderbans. Tata Power, India's largest power utility, plans to introduce pre-paid electricity for its customers in Delhi. Tata Steel is also likely to install prepaid electricity meters at its employee township in Jamshedpur.

An on-site reading and billing system that works through portable readers equipped with printers was implemented in Malaysia. It is rough use equipment, made to resist the weather conditions of South Asia. The system is aimed to domestic costumers and is being implemented for industrial customers as well. It's linked to a CIS.

In the west distribution area in India, handhelds are used to obtain readings and for on-site billing. This is complemented with the intense use of information technologies, including GIS, in order to increase revenues of the electricity distribution company. The observed tendency is that the handhelds are used for the manual reading of the meters and for the acquisition of georeferenced data of the costumers and the distribution network.

Mexico

Along the country, CFE has installed 1,000,000 prepayment meters with smart card (RFID), and automatic reconnect/ disconnect service, register of Vmax, Vmin, bad functioning and failure service statistics. CFE have also plans to install 2,000,000 of this type of prepayment meters per year.

In the Centro Occidente Division of the Federal Commission of Electricity, the on-site billing was implemented for medium voltage costumers, which resulted on a 95% customer satisfaction rate. The used technology is undergoing several improvements as it requires a greater level of reliability of the on-field equipment. Nowadays, 3,145 customers are being billed using this method.

5 CRM/CIS

The electricity industry players, who are willing to provide future proof solutions in a competitive market place are benefiting from the fast convergence of metering, billing and CRM/CIS systems and strategies.

Customer Information Systems provide integrated solutions including billing and provisioning capabilities as well as customer support and account management functionality.

Managing customer relationships has always been a challenging task for the utilities. Nevertheless, the technology to drive personalized interactions through knowing and understanding the customers has only recently evolved to meet the demands of the energy industry. Nowadays, CRM has made a great difference in managing customer relationships and stimulating more productive and more satisfying customer relationships.

According to Forrester Research, 25.6 percent of North American utilities have completed a CRM deployment or have a rollout underway. By choosing CRM to address current and future customer relationship needs, forward-looking utility companies are preparing to operate in deregulated energy markets.

It is important to highlight that this report does not cover the functionality of CRM/CIS systems; it just focuses on the convergence of metering and CRM/CIS systems through what it is known as ―Meter Data Management Systems (MDM)”.

5.1 Technologies

Utilities have acknowledged that, in order to compete in the marketplace, they must place the customer at the center of their initiatives. Although CIS helps handle billing, service orders, account management, and to some extent customer care; CRM enhances the customer-focused functionality by helping energy companies develop stronger more profitable customer relationships by understanding customer needs and being able to react to these needs in real time.

An MDM system is required in order to achieve and effective implementation of interfaces between advanced metering technologies and CRM/CIS systems.

MDM technologies are driven by two main factors:

- Open database platforms.
- Scalable, open-architecture systems that manages data from many different metering technologies, vendors and brands.

The most common functions required from MDM systems are:

- Multi-channel support (kWh, kW, kVAR, …)
- Meter asset and data management capabilities
- Distribution Asset Optimization
- Support for Demand Response programs
- Meter Event Processing
- Web based customer portal support
- Validation, Editing, and Estimation (VEE)
- Data Aggregation
- Multi-utility support (gas, electric)
- Support for Different Interval Lengths
- Support for Demand Management Programs and on-demand read capabilities and soft turn-on and shut-off
- Ability to Maintain Meter Reading Schedules
- Support for Regulated and De-regulated Markets
- Outage Management and Restoration Support
- Meter Asset Management Capabilities
- Complex billing capability
- Real-Time Pricing Ability

Besides providing a permanent repository for meter interval data, MDM manages data and interfaces with other system applications such as the company's Customer Information System (CIS), billing, outage management, and enterprise asset management applications. Data stored in the MDM systems can be used to prepare business reports and develop analytical programs.

MDM software applications interface with the AMI network management data collection system and processes; these applications store meter reading and other AMI data for use with CIS, Billing, GIS, distribution automation and other operations applications. Depending on the functional design and the type of billing system being used, the MDM application can be used to calculate the billing determinants and to bill time of use, critical peak pricing, interruptible service and other complex rates. The company's CIS systems is complemented with the MDM application to bill time-differentiated rate structures including the switching functions needed to support retail competition and the associated reconcilement process.

Many AMI essential features depend on the successful collection and manipulation of meter data and alarms within the MDM. In order to achieve the operational efficiencies foreseen through AMI, utilities must be able to efficiently transfer data such as outage management, enterprise asset management and distribution automation from the MDM to their own applications.

5.2 State of the Art and of the Practice

The State of the Practice in CIS systems is databases either developed by the electricity suppliers themselves or by third parties. These databases are autonomous systems which main function is customer billing.

Generally, they are not integrated with other systems and work in a network environment at the supplier company's offices.

In the State of the Art, CIS systems have a greater online interaction with the customer. Each customer can access his/her account, enter meter readings, make payments and check or download demand profiles of his/her consumption on a half hourly basis.

CIS functionality has been enhanced with additional features such as commercial and industrial billing, data warehousing/energy data management, and credit/collection programs. These improvements have enabled interactions over the internet and a more comprehensive management of customer interactions. What is more, it has helped utilities change their focus from account- focused to customer-centric.

CRM solutions use state-of-the-art technologies that integrate information from disparate systems throughout the entire energy enterprise in order to resolve front-office business problems. This creates great benefits such as reduced servicing costs, targeted marketing campaigns, and improved sales. True CRM entails dealing with customers individually or as unique groups, and involves integrating all systems that touch the customer, from billing to the call center to sales and marketing. Although CIS and CRM have several similar features, CRM remains distinct mainly because it:

- Focuses on front-office interactions while integrating with back-office transactions.
- Automates and manages marketing, sales, and service functions.
- Optimizes customer interactions across multiple channels.
- Uses enterprise-wide data for analysis of customer and channel profitability.
- Expands the definition of customer to include prospects.

Companies also have the option to extend and adapt customer information systems in order to provide more customer-centric functionality; however, custom software development is costly and time-consuming.

By combinating the features of CIS with CRM, energy companies can leverage all customer information to achieve a comprehensive and consistent approach to marketing, sales, and service, and enhance current and future technology investments. It is worth noting that, in order to speed up the implementation of this technology, CRM vendors provide extensible frameworks that integrate business processes and data from across the front-and back-office with little or no customization.

To deliver a better customer experience, CRM solutions should complement the foundation that CIS provides by focusing primarily on:

- Deep customer insight.
- Cost-effective customer service.
- Improved employee productivity.
- Precision marketing.

5.3 Standards

NOTE: The following concepts are also applicable to the Metering topic (Chapter 2).

As the implementation of AMI and MDM systems becomes critical for the utilities, the systems need to interface together and with other applications that are being used. In this sense, are very important the interfaz with open data buses or bus enterprise services, like Multispeak and CIM.

The MultiSpeak Initiative and International Electro technical Commission‘s TC 57 Working Group 14 (WG14) have agreed to collaborate on new international integration standards to improve data exchange among electric utilities.

Nowadays, developers that want to use standardized interfaces must choose between specifications determined by MultiSpeak, widely used by electric cooperatives, or Common Information Model (CIM), international standards, mostly used by large utilities. This represents a great challenge for those utilities that need to share data between software applications such as Outage Management Systems (OMS), Customer Information Systems (CIS) and Advanced Metering Infrastructure (AMI) systems.

There have been efforts to create and propose two additions to IEC Standard 61968 for users who wish to implement MultiSpeak interface functionality using CIM objects.

Data exchange among electric utilities is of great importance; therefore, a detailed mapping effort that helps identify and compare the main strengths of each set of standards will be carried out in order to allow utilities and software developers to build better data exchange solutions. *More specific guidance to Common Information Model (CIM) developers who wish to implement MultiSpeak functionality using CIM objects will come from creation of a CIM profile for MultiSpeak 4.0 and for pertinent parts of IEC 61968.*

This collaboration will create and propose two sets of IEC standards:

- ✓ IEC 61968-14-1: Mapping between MultiSpeak 4.0 and IEC 61968, parts 3 through 10.

- ✓ IEC 61968-14-2: A CIM profile for MultiSpeak 4.0, one profile for IEC 61968 parts 3 through10.

Opportunities for standardization in utility customer-facing systems are no exception. This impetus has led the Customer Care Research Consortium (CCRC) to tackle the utility customer service standardization challenge head-on. The CCRC is a forum for 14 of the leading electric and gas utilities to conduct research and provide industry leadership on issues concerning customer strategy across operational, technological, and regulatory dimensions.

Since 2003, the CCRC has spearheaded a number of strategic and tactical initiatives and published a catalog of thought-leading research reports, among others:

- A Day In the Life of a Customer in 2015 (DILO) - A vision of the customer experience in the year 2015 with the advancement of new technologies and AMI.
- Customer Segmentation Strategies - Explored the drivers behind why

companies have elected to perform advanced segmentation studies.

- Customer Service Model 2011 - Examined the strategic implications of how utilities are likely to manage their customers in the future and the impact this will have for utility operations and business models.
- Customer Communication - Evaluated the impact of different communication strategies on customer satisfaction call volumes.
- Customer Service Quality, Regulatory White Paper and Working Group - Highlighted the strategic implications of CSQ standards for utility operations and business models and highlighted successful member strategies during rate cases connected to CSQ standards.

5.4 Trends

CRM/CIS are a fact of 21st century life, there is no doubt of its increasing importance in a competitive, deregulated energy industry.

The Internet is mentioned as one of the major trends in CRM/CIS; transactions are cheaper than a call-centre and it can provide 24-hour-a-day, 7-day-a-week service. The trend is towards customer self-service; a customer can request a call centre to contact them, and ―co-browsing", enabling the customer and call-centre to view identical screens.

Another trend in the coming years is the need for increasing integration of systems right across the utility.

Yet another trend is on the analytical side of the business, which is going to become increasingly more important in the future for measuring the success of the utility and customer satisfaction and providing a base for future strategic planning. Possibilities, particularly for the big energy customers such as industry, will be to combine CRM with energy data management to bring the buying and selling of energy down to periods as short as a quarter-hour, amounting in effect to real-time pricing and metering.

A similar trend in CIS is reorienting the utility from an inward-looking, vertically-integrated organization to one realigned on markets and new processes, and that information and the means to transfer it rapidly into competitive advantage is the key to success in this increasingly competitive environment.

In the future they will also become increasingly web/browser-based for speed, accessibility and functionality such as seamless e-commerce and business-to-business portals, with the use of XML as a data transfer protocol.

It is predicted that in the very near future, in some markets at least it will be possible to order energy, like the stock markets, from virtually anywhere in the world.

CIS systems will have a greater interaction with the customers in order to:

a) Ease the payment process.
b) Reduce the costs for the electric supplier.
c) Stand out from other electric utilities in a **free market.**

When CIS systems are complemented with an AMI system, the services provided to the customers can become highly specialized.

5.5 Case studies

Manila

The Manila Electric Company (Meralco) has undertaken an extensive re-engineering project, during which the computer telephony interface (CTI), the normal call centre function, the billing and the customer information system (CIS) were embedded as modules in the utility's customer management system (CMS).

Meralco implemented the Customer Management System (CMS), an information system capable of managing the billing, customer information and call centre functions. The CMS is an homogeneously integrated system which application software is developed on the same operating platform, operating system (OS/390), database management system and development language. This enables a faster and smoother flow of data and data capture within and among the modules, enhancing operational efficiency and effectiveness.

Other CIS modules in the CMS are service applications, meter reading, payments, field order processing and meter management. The CMS also incorporates management requirements such as process performance, service levels, and information for making decisions in the management information system (MIS) module.

The integration of information systems in Meralco had many benefits.

- There is single entry/capture of data at the point of collection, ensuring data integrity across the organization.
- The integration of billing and the CIS allows meter reading data to be processed immediately. This reduced the customer cycle by at least two days, generating savings on interest cost by recovering payments sooner.
- Improved quality of service and effective customer assistance management through fast, 24x7 response.

Smooth interface and exchange of information across transactional systems, allowing information to flow freely from one system to another. Data and information can be aggregated easily and presented in a format that is useful for management information or decision support

- Online access for customer data calls centre operators, allowing them to address customer needs instantly.
- One-stop customer transaction at any branch or other transaction channel such as the telephone, Internet and third party agents. Customers are able to get all the information they need with regard to their account and perform transactions at any branch office.
- The strengthening of back-end operations, which is a prerequisite for implementing more advanced applications in business intelligence, Internet and industry-specific applications that will be used in a deregulated environment.

United States

In 2009, Austin Energy (Austin, Texas) selected an advanced Customer Care and Billing system to replace an outdated, legacy customer information system and support the city‘s smart grid initiatives.

The City of Austin will roll the solution out to both Austin Energy — the nation‘s ninth largest community-owned electric utility with 388,000 customers — and Austin Water. The application will provide Austin Energy with a complete view of customer data and streamline billing processes to enable more responsive customer service.

Customer Care and Billing will enable Austin Energy to implement innovative energy efficient and demand management programs by providing detailed energy usage data that will allow its customers to make more informed decisions to conserve energy. The application will also help Austin Energy create new rate structures.

6 CONCLUSIONS

METERING

The energy metering industry has been experiencing significant technological developments since the introduction of the Ferraris induction meter at the end of the 19th century.

The change to solid state meters has been encouraged by: government mandates for replacement, as enacted by the governments of India, Iran, Sweden, Netherlands, California and Victoria in Australia, with others on the way; large-scale utility deployments, for example the Telegastore in Italy and many others in the US; and smaller ad-hoc deployments frequently starting with the C&I segment of the meter market and then spreading out to residential meters. The evolution of advanced metering has attracted much attention. Many consider it as a certain technological development that brings numerous benefits. However, there are those who consider that the benefits are so moderate that only government legislation will promote it.

The smart metering industry is so young that it also seems likely that worldwide standards will remain minimal and will have little effect on industry growth. Where standards are employed, they will probably be regional -- not international. So growth will include multiple generations of products, as well as an evolution of interfaces, equipment and services that will gradually converge over the next years.

A major challenge for governments and related entities around the world will be to define standards. Though this effort will likely bear fruit eventually, the only way that the resulting standards will encourage trade worldwide is if they are open and flexible and can serve the needs of many countries.

It now seems inevitable that every First World country will be starting smart metering projects within this decade, and every major city in developing countries will also start such projects.

The drive toward smart metering is a worldwide phenomenon. With the United States now participating in the Kyoto Protocol Replacement effort, it's inevitable that this new protocol will enjoy broad support in the United Nations.

Because electricity generation is a key contributor to carbon emissions, most countries will need to better manage what they generate, and the only way to measure usage is through metering.

Equally important is the fact that smart metering will be a huge new industry worldwide. Deployment rates for smart metering will probably rival the deployment rates for cell phones and the Internet.

Deregulation and in general the restructuring of the world electricity markets are two of the most important reasons why metering technologies must evolve at a faster pace in the years to come.

REVENUE PROTECTION (ENERGY THEFT)

Energy theft and unauthorized use of service, account for approximately 30 percent and up in some countries. In the past, not much was heard about energy theft through the media.

Utilities are cautious by nature and concern about the cost-effectiveness of a diversion program, especially given the low level of write-offs. Furthermore, utilities frequently treat energy theft the same way as distribution system losses, hindering the reduction of these significant losses derived from diverted energy.

Utilities that employ effective methods for fraud detection and prevention can recover anywhere from $4 to $6 for every $1 they invest to recapture stolen or diverted energy – recouping up to an average of $10 to $20 per customer per year.

Technological development is not focusing directly on the detection and registration of energy losses, but on adding tools or functions to electronic meters, such as detection of possible meter tampering or registration of lack of potential with which can be inferred whether there has been an illegal activity that affects the meter readings.

The application of any solution must start with the collaboration of all workers. It is fundamental that the personnel is convinced that, when the company is financially strong, their will benefit from it. Therefore, they will support the correct application of the chosen solutions.

BILLING AND CRM/CIS

The interrelationship among the utility activities such as billing, customer information systems, customer relationship management, payment, collections, revenue assurance, call center, and Web site services, shows the growing cross-departmental thinking and performance required to achieve higher customer satisfaction.

Over the last 10 years, the attitudes and procurement practices related to the utility‘s core billing systems have experienced a profound change, specifically in the deregulated sector. Almost a decade ago the great majority of large utilities were developing their own CISs – large, expensive and disruptive projects, normally in association with important consulting firms, while presently less than a third of utilities use in-house systems, with the majority being acquired off-the-shelf from a growing number of specialty companies or being developed from earlier installations.

Almost half of the larger utilities have implemented any type of CRM system, and most of those companies have recently installed CISs with CRM functions built-in.

While some utilities are only passively involved in major CIS/CRM investments,

practically all are trying to integrate and upgrade their legacy systems in order to allow them to compete until the market stabilizes and the future becomes clearer.
Billing is a fundamental activity of the electricity commercialization process. The opportune collection of the issued invoice, the reduction of non-technical energy losses as well as the customer satisfaction depend, in large extent, on how efficient billing is.

The accuracy in Billing and Energy auditing directly depends on the ability to obtain energy meter readings. There are several energy meters and reading methods. They vary from manual or semi-automated to fully automated reading methods that incorporate the use of modems, Internet and radio-frequencies.

Once the energy consumed has been accurately measured, the following step is to focus on obtaining the reading. For many utilities, meter reading is a labor-intensive activity; although the use of technologies such as AMR/AMI is increasing, most of the meter reading is still carried out manually on a monthly basis. Any mistake or delay in the reading process has a negative impact on billing, as well as on the utility‘s revenue and the customer‘s satisfaction.

7 PROPOSED FUTURE WORKS

The smart grid concept offers a great opportunity for future works, particularly in the smart metering field. Some topics for future investigations include:

Demand side energy management systems.- Demand management is a tool for energy efficiency optimization through the implementation of management technologies and the improvements of power consumption patterns. To reach this goals, energy management systems (EMS) have been developed and applied to residential, commercial and industrial consumers, taking the name of HEMS, BEMS and FEMS, respectively (See figure 7-1).

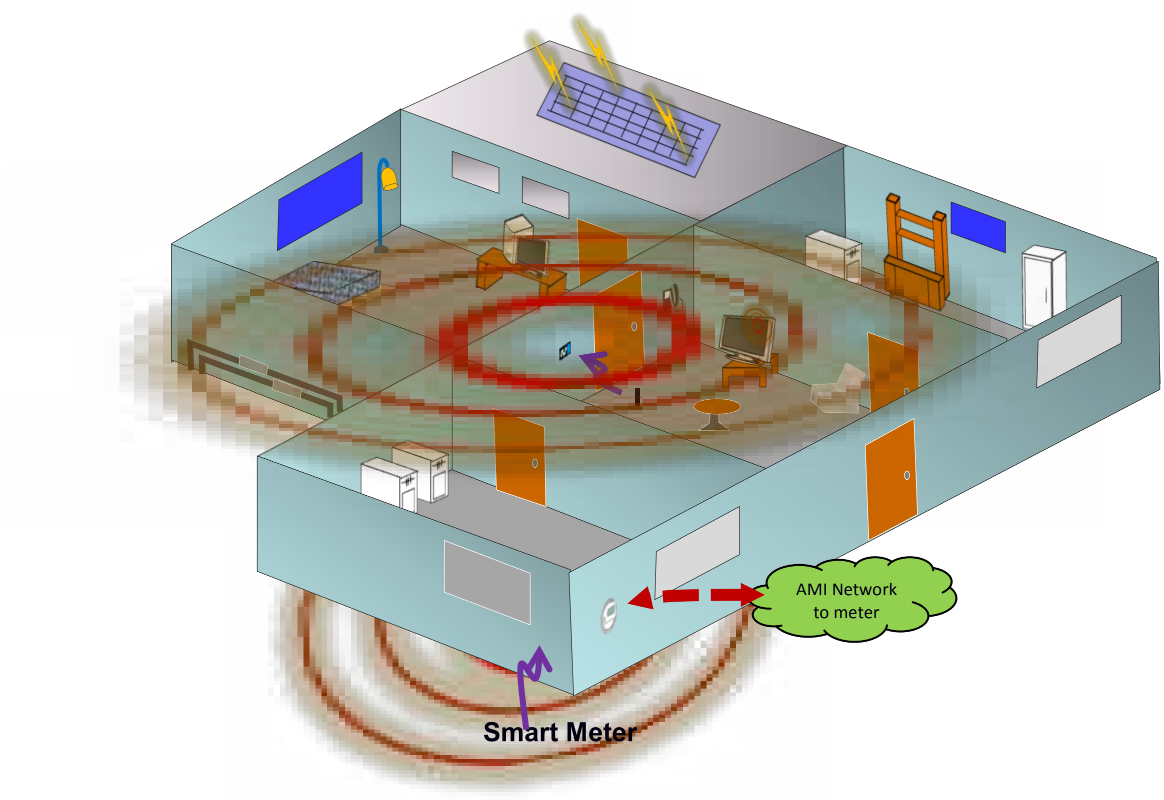


Figure 7-1 Energy management systems (EMS). HEMS.

Vehicle-to-Grid (V2G).- The grid could operate more reliably if the power stored in electric vehicles could be used as a backup to balance out fluctuations in supply and demand. One of the research opportunities in this field refers to the vehicle battery administration to pull in power to recharge the battery and to send electricity out to the home, the microgrid or the grid (See figure 7-2).

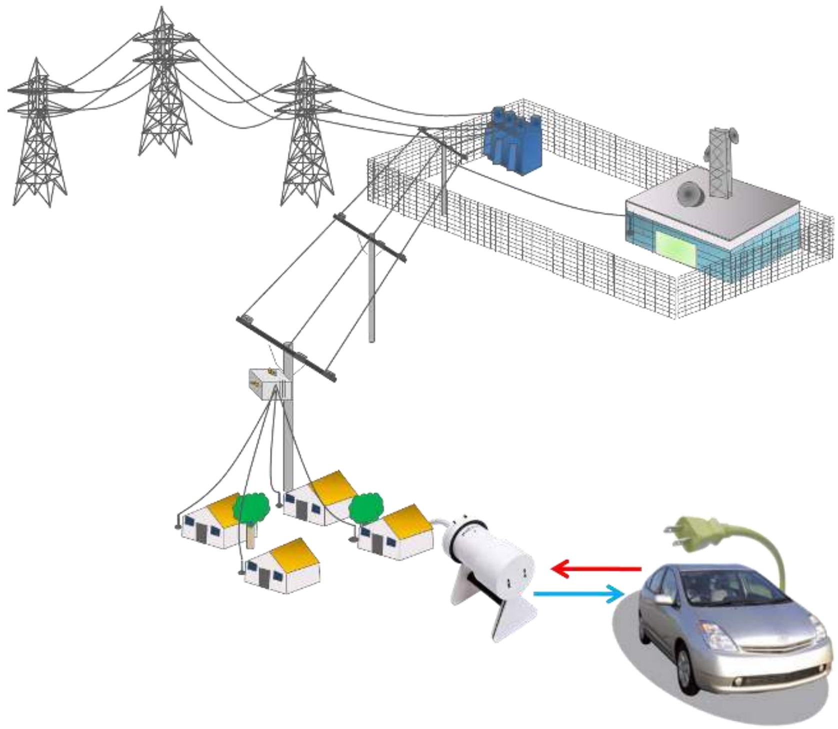


Figure 7-2 Vehicle-to-Grid (V2G).

Outage management.- AMI systems have exceptional information storage capabilities thus giving utilities the flexibility to retrieve the AMI's information when needed. An interesting opportunity lies in the fact of exploding this information to investigate a myriad of power delivery situations (See figure 7-3).

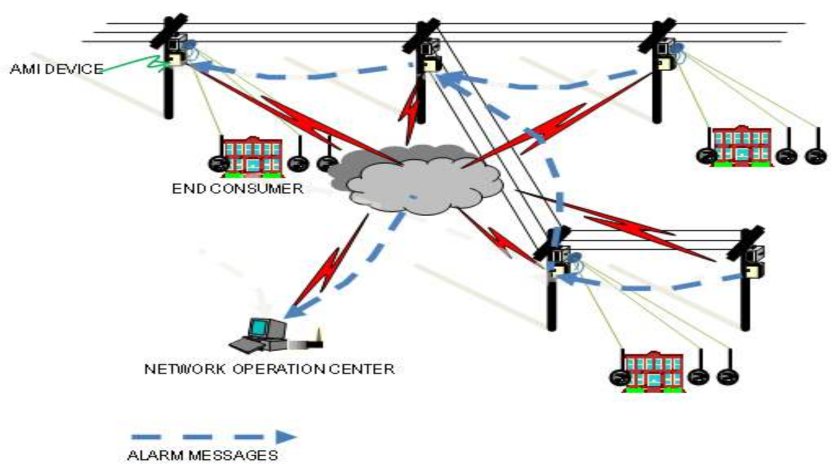


Figure 7-3 Outage management through AMI systems.

Data exchange among high level utility functions.- A lot of work is pending with regard to sharing data between high level utility functions such as Outage Management Systems (OMS), Customer Information Systems (CIS) and Advanced Metering Infrastructure (AMI) systems through open enterprise data buses, like CIM and MultiSpeak.

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9 ACRONYMS

AMR	Automated Meter Reading
AMI	Advanced Metering Infrastructure
AMS	Advanced Meter System
MDMS	Meter Data Management System
MDM	Meter Data Management
AMM	Automatic Meter Management
EMS	Energy Management System
PLC	Power Line Carrier
DPLC	Digital Power Line Carrier
BPL	Broadband over Power line
CIM	Common Information Model
CIS	Customer Information System
CRM	Customer Relationship Management
DR	Demand Response
GMS	Global System for Mobile Communication™
HAN	Home Area Network
V2G	Vehicle to Grid
WiMAX	Worldwide Interoperability for Microwave Access
Wi-Fi	Wireless Fidelity
DSM	Demand side Management
SG	Smart Grid
AMS	advanced metering system
OMS	Outage Management System
PHEV	Plug-in Hybrid Electric Vehicle