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GLOSSARY AND ACRONYMS

AMR	Automated Meter Reading
AT	Access and Terminals
CEPCA	Consumer Electronics Powerline Communication Alliance
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
DEG	Distributed Energy Generation
DEMS	Distributed Energy Management System
DSL	Digital Subscriber Line
DVD	Digital Versatile Disc
EIB	European Installation Bus
EIBA	EIB Association
ETSI	European Telecommunications Standards Institute
GSM	Global System for Mobile Communications
GPRS	General Packet Radio Service
HTML	Hyper Text Markup Language
HVAC	Heating, Ventilation, Air Conditioning
ICT	Information and Communication Technologies
IP	Internet Protocol
ISDN	Integrated Services Digital Network
LON	Local Operating Network
LV	Low Voltage
LVHE	Low Voltage Head End
MV	Medium Voltage
MVHE	Medium Voltage Head End
MVM	Medium Voltage Modem
NTU	Network Termination Unit
NV	Network Variables
PC	Personal Computer
PLC	Power Line Communication
POTS	Plain Old Telephone Service
RES	Renewable Energy Sources
RPT	Low Voltage Repeater
SNVT	Standard Network Variables Types
TCP	Transmission Control Protocol
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System

USA	United States of America
WLAN	Wireless Local Area Network

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1 PURPOSE

This document has been produced within the IST OPERA project by WP4. The purpose of this deliverable is to serve as a reference for Smart Home services in combination with Power Line Communication (PLC) access networks. The intention of this document is to analyse the current situation and to identify potential for a power line based approach to Smart Home services. Due to the fact that Smart Home means a broad range of services and technological approaches the document will focus on the relevant topics in context of broadband PLC seen from the strategic point of view of a PLC provider (e.g., a utility).

2 INTRODUCTION

The idea of smart home services is not new: since many years several services are offered. The first movers were the manufacturers of home-installation equipment who formed associations for standardisation and joint projects. Nevertheless smart home services could not achieve a satisfying market penetration until now. The reasons are multifaceted: The first steps were more or less a kind of a technical basic co-ordination between many manufactures to provide compatible solutions.

The initial situation in the near future seems to be influenced by a growing demand for broadband Internet access on the one hand and by the availability of a new generation of broadband PLC technology for utilities on the other hand. This combination leads to new chances for smart home services.

3 EXECUTIVE SUMMARY

The document presents firstly the current situation of Smart Home services, their application fields, solutions for residential user as well as solutions for power utilities. Here the main focus is on the control of distributed energy consumers and generation with PLC.

Chapter 5 presents the technical aspects regarding Smart Home services focussing on utility services. On the one hand a overview of the technical infrastructure and the main user equipment and terminals. On the second hand, all information regarding standard conformance, the telecom network, quality and reliability considerations.

In chapter 6 a pilot project is introduced that was realised within the framework of this document. It is a matter of one specific Smart Home solution for utilities: the monitoring of a residential cogeneration unit over PLC.

Finally, in chapter 7 the business implications in terms of competitive aspects with other technologies, customer target groups, service packaging and pricing considerations are presented.

Afterwards a future outlook about Smart Home services is given concerning applications, markets, technology and regulatory aspects.

4 Smart Home Services

4.1 State of the Art

Rising requirements regarding comfort, security and energy and resources efficiency as well as the rapid development of information and communication technologies (ICT) lead to a multitude of electronic devices within buildings and apartments. Buildings that use electronic networking technologies to integrate these various devices and appliances so that an entire home can be controlled centrally – or remotely – as a single machine are called Smart Homes.

The driving force of the development of Smart Home to a mass market is the Internet and mobile devices with audio, video and image data. According to several studies Smart Homes will be a booming market for handcraft, building and ICT industries within the next 5 to 10 years [PRAG00], [ENQU01]. Today, there are several products for nearly every area of application on the market. The challenge for the future will be the integration and central control of all products within the Smart Home. A market research of [SHFO05] see the Ethernet standard as most promising to use for Smart Home applications. Furthermore they see PLC as the second networking technology behind WLAN (wireless local area network) for the use within homes. The applications with the best potential in short term will be security and energy saving. Consumers are mainly open-minded about Smart Home services as shown in Figure 1.

Several pilot projects have been initiated worldwide in the last years. Most of them are prototypes for single application fields with varying proprietary technologies. Probably the most famous is the home of Bill Gates at the Lake of Washington. Regarding industrial pilots the iHome of Cisco in London, UK, is a Smart Home concept to control comfort and heating appliances based on Internet technologies and applications [CISC05]. The FutureLife home in Switzerland [FULI05] is a project which analyses the impact on the all-day life within a Smart Home. This house uses several bus systems and PLC technology as well. In Germany there are several prototypes, too. The project SmartHOME of the “Universität der Bundeswehr München” in Neubiberg mainly focuses on heating, ventilation and air conditioning [UBWM05]. The inHaus in Duisburg of the Fraunhofer IMS is a concept in the field of product-oriented innovations for a networked life which includes a residential home, a workshop, a networked car and a networked garden. The main research goal is the reduction of energy saving due to an intelligent house [INHA05].

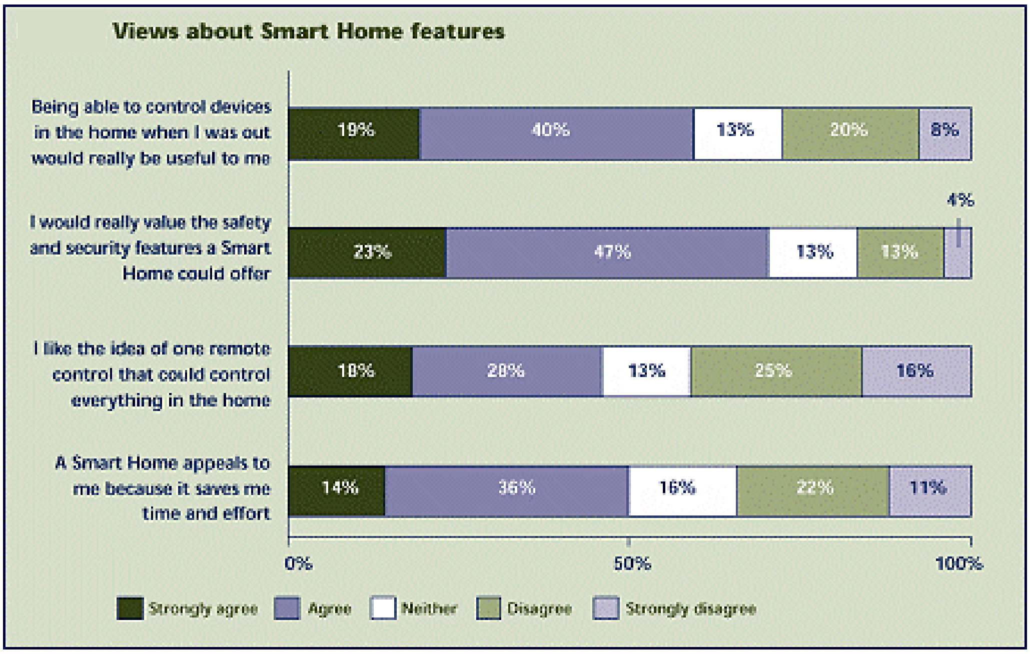


Figure 1: Consumer views about Smart Home features [PRAG00]

4.2 Service Objectives & Application Fields

The service objectives of Smart Homes are

- an easy use,
- a high functionality through integrated connection of the devices and
- the connection to the Internet to offer new services.

Smart Home services offer a broad range of applications which are already realised or possible future opportunities. So a suitable structure is necessary to give an overview. In [BRET01] a simple and theoretical classification is chosen: Control, Entertainment and Computer. Control includes the control of all household appliances by the use of bus systems like EIB or LON (compare chapter 5.3). Entertainment ranges from television (TV), hi-fi system, DVD (digital versatile disc) and video-tape recorder and other multimedia applications. Computer contains the personal computer (PC) and peripheral devices inclusive the connection to the Internet and other communication networks within the house.

Other authors use more often a practical approach and divide into end user application fields [BASI02]. This is what is preferred in this document, too. First of all a differentiation between solutions for residential and business customers and solutions for utilities is useful with regard to the focus of distributed energy generation and consumption of this document. Additional this approach is advisable due to the background that PLC uses the infrastructure of energy companies and PLC providers are often utilities or rather there subsidiaries which want to gain synergies with Smart Home for there core business.

An important goal of Smart Home is to improve the user's comfort and security along with a reduced overall energy consumption. The following chapter should give a short overview about these most important services which can be offered with PLC technology. Solutions for residential and business customers include supplementary to comfort, security and energy saving mainly entertainment, e-shopping and home care. There is no differentiation done between commercial and residential applications.

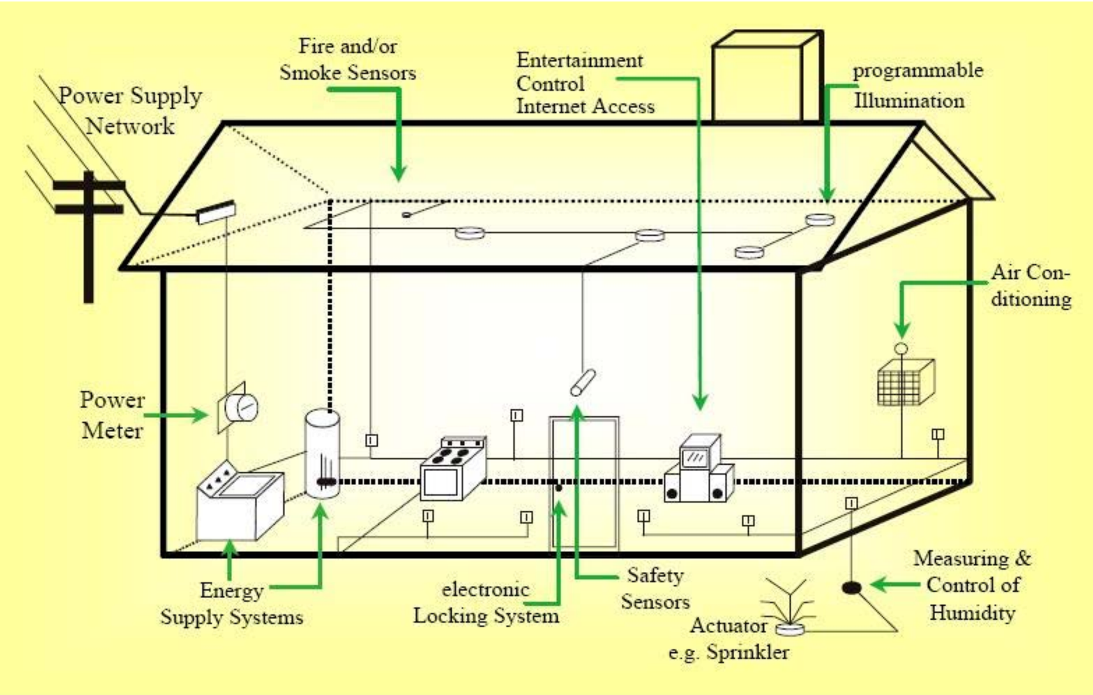


Figure 2: Application fields of Smart Home services over PLC [DOST00]

The market for residential energy services is negligible today, but is likely to grow dramatically over the next few years. The strongest driver for change is deregulation in the energy industry, which is already happening today in the Nordic countries, UK, and California, and will soon happen in the rest of the European Union and USA. Utilities are looking for new ways to create revenue when prices-and margins-are falling, but are also seeking ways to ensure customer loyalty. At the same time new entrants from highly competitive industries, such as the retail and banking industries, see an opportunity to leverage consumer relations and brand on a huge new market.

In chapter 4.4 solutions for utilities are evaluated. Here services are focused which are placed in the customers' houses and supplementary deal with utility processes. These services include at least ripple control, monitoring of distributed energy generation (DEG) and more visionary load management. Automated meter reading (AMR) over PLC is excluded and covered in [OP_D41].

For an energy company Smart Home services for utilities are from higher interest with regards to their core business. In particular, DEG comes to the fore within the next 10 to 20 years. In this chapter the focus is on the evaluation of DEG services. Other points are mentioned for reasons of completeness and show additional business cases which should be analysed separately.

4.3 Solutions for Residential Customers

4.3.1 Security

Security services are already a relatively mature market and there are a number of realised systems today. Traditional security covers measures and installations to protect against damage and malfunction. However, there is a shift towards bundled integrated systems which provide a more flexible platform, thereby enabling new and more advanced services. This offers service providers new business models to enter this market.

Conventional alarm systems include electrical contacts to detect open windows and doors, glass breakage detectors, motion detectors and video surveillance to observe in- and outdoor areas. Furthermore sensors and measuring systems like smoke and fire sensor, water sensors or gas leakage detection belong to modern security systems. They detect changes within the house which could be dangerous for person and building [IVAN02, BASI02]. Figure 3 shows modern security system with the use of PLC technology.

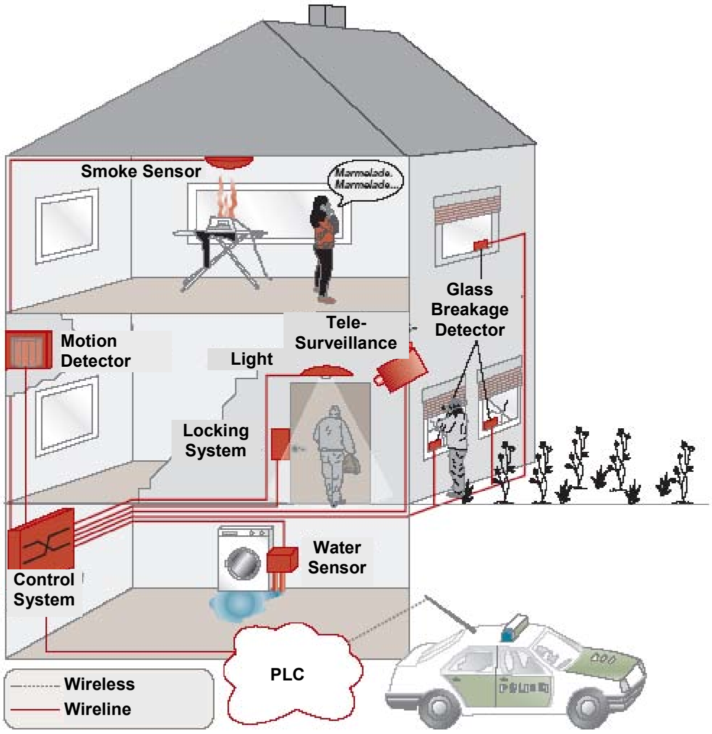


Figure 3: Security system with PLC technology

Previous security systems are mostly self contained communication networks with respects to high security standards. The integration of security systems into the Smart Home (and the connection to the Internet) offers possibilities for value-added services but could minimise the security standards due to possible hacker attacks from the Internet [BRET01].

Value-added services could be for example:

- the use of access devices, such as a standard Internet browser or a mobile phone
- the use of motion detectors and window contacts for the intelligent regulation of Heating, Ventilation, Air Conditioning (HVAC) and lighting
- to observe the building with a web cam from any place

- central control of lighting and roller blinds to simulate presence during holiday trips
- to use HVAC indoor air quality measures for fire warning and gas leakage detection
- to communicate with security, police or fire brigade in times of danger and send detailed data about the problem
- to inform craftsmen automatically in cases of e.g. water leakage damages

The primary business opportunity for service providers is to integrate security systems with current core services, and to offer a broader range of security services. Players from the utility industries will be able to integrate these services with current offerings such as Internet access and 24-hours-emergency-service for electricity problems. Given that these services will utilise the same infrastructure as core offerings, there will be significant opportunities for operational efficiencies.

4.3.2 Comfort

4.3.2.1 Home Automation

Home automation is likely to be the slowest application to emerge. The key drivers for this application segment will be ease of use and the penetration of network enabled devices. Whilst current home automation starter kits are relatively inexpensive, the complexity of the interface and the sophistication of the programming language is likely to limit this market to the technology enthusiast in the near term. Furthermore, whilst it is relatively inexpensive to build intelligence into devices at the point of manufacture, retrofitting intelligence is relatively expensive at this point in time. The primary needs for consumers are convenience, saving time and fun [SHFO05].

Today, most household appliances are whether intelligent nor network compatible. Possible appliances within the comfort area are lamps, sockets, garages, sprinkler, jalousie, white goods (refrigerator, washing machine, microwave oven etc.), brown goods (consumer electronics, PC, TV etc.), heating, ventilation and air conditioning [BRET01]. There are overlaps in the application areas for all of the aforementioned appliances.

The aim of home automation is to connect all devices with each other. That allows to monitor, control and optimise all appliances from everywhere or rather from one single device (e.g. TV, PC, refrigerator). In addition the control of residential installation could proceed automatically which results in a significant increases of comfort for end users (e.g. when waking up roller blinds and windows will be opened and coffee will be cooked, when leaving the house windows will be closed, electronic appliances will be shut down and the washing machine will be started automatically when the electricity price is low). Lots of possible scenarios are mentioned in [SMHO05]. In this area miscellaneous field tests are carried out since years but still there are diverse communication protocols and technologies within the appliances. Therefor the use of gateways and central control units are essential to obtain an integrated Smart Home [BASI02].

The primary business opportunity for service providers will be to bundle home automation services with the aforementioned homeowner services. Whilst the ability to automate the home is unlikely to be compelling to most consumers from a stand-alone perspective, they could be very interesting when combined with services which have a clear consumer benefit [SHFO05].

4.3.2.2 Entertainment

The entertainment area recently became more and more important. Considerable prospects arising through increasing intelligent devices, digitalisation of media and easy data exchange between devices. At this stage in lots of homes personal computers are used for entertainment terms and connected with TV and audio systems. The difference between Home Automation is the significant higher bandwidth demand. Entertainment devices are consumer electronics such as PC, audio system, TV, DVD-player, paddle and mobile appliances (e.g. digital camera, mobile phone).

To connect these devices together offers lots of opportunities, as for example to play movies on TV which are stored on the PC or downloaded from the Internet (video on demand), to play centrally stored or on demand music in different rooms where persons are, to personalise music profiles for special rooms, to use the TV as control surface and so on. To provide full entertainment comfort the Smart Home must be connected to the Internet and the service provider must offer a sufficient bandwidth rate.

4.3.2.3 Home Care

A considerable opportunity exists to provide the home care market with smart services. Key drivers of this segment are the ageing population in developed countries around the world, the breakdown of the extended family combined with the increased geographical mobility of the workforce and the increasing costs for elderly care.

Through comprehensive (medical) care at home more lifetime within the own house and therefor a higher life quality is possible [ERKE99]. The initial applications in this segment are likely to be to provide "peace of mind" to relatives of elderly and disabled people through security and monitoring services, and to offer communication services such as user friendly home shopping and video telephony [SHFO05].

The household and the elderly could be monitored by video surveillance and body sensor. So medical data (e.g. pulse, blood pressure) could be analysed and in case of emergency transferred to the nearest hospital. The ambulance could provide a better medical care through the received data and early notification. Other possible scenarios are reminders, convenient household appliances and fail-safe devices such as automatic door opener, automatic shut down of devices after usage, a reminder about taking medicine, stopping a bath from overflowing, locating misplaced eyeglasses or keys and so on.

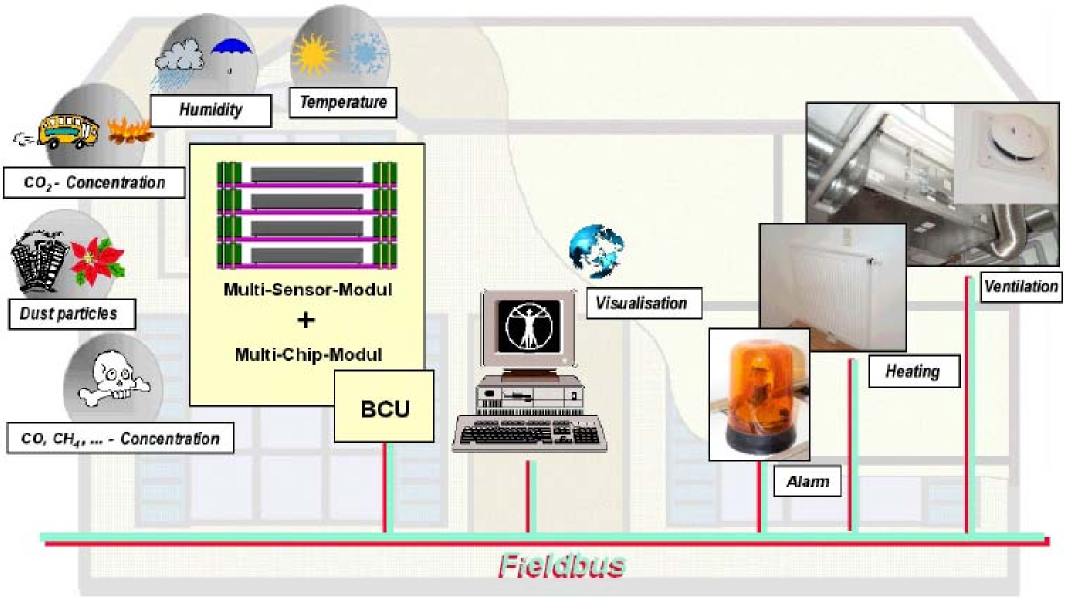
At an estimated consumer cost of 20,000 US$ for such a system [VENK03] installing these smart home technologies would be a less expensive option than placing a senior citizen into residential care. The home care segment represents a large and relatively untapped market for service providers and there is a clear benefit for the consumer (both the elderly and their relatives).

4.3.3 Energy Saving

Energy saving is an important issue within Smart Home because of the increasing number of electronic devices the energy consumption rises. Through intelligent control of all devices and appliances within the household the energy consumption could be reduced up to 25 % [SCHA01].

A core element of this strategy is the automated control of installations within the building (lighting, blinders, HVAC) depending on environmental data. This improves the user's comfort and security along with a reduced overall energy consumption. Depending on presence of residents in the room temperature, carbon dioxide (CO_2) concentration, humidity and light intensity could be regulated optimally. Heating or ventilation could be shut down if windows will be opened or rather solar radiation will be high enough. The blinders could be closed if solar radiation is to strong or rain is to heavy and so on.

In Munich in the SmartHOME Lab on the University Campus [UBWM05] a decentralised HVAC system has been installed in a single-family-type living house. Figure 4 shows the measurement system which comprises of a network of a large variety of specialised indoor and outdoor sensors and actuators and a multi-bus communication and data storing infrastructure. The lead tasks for this system is to maintain a healthy climate and an optimised objective thermal comfort. [IVAN02]



BCU: Bus coupling unit

Figure 4: HVAC system in the SmartHOME Lab, Munich [IVAN02]

4.4 Solutions for Utilities

4.4.1 Ripple Control

Ripple control is used for applications such as tariff switching of meters (main and night tariff), control of municipal lighting equipment, connection and disconnection of load groups and power plants and individual controls (e.g. night-storage heater). With PLC technology these applications are possible based on TCP/IP. Therefore bi-directional communication between appliances and utilities are realisable. Rivalry technologies are the traditional audio frequency ripple control and the new radio ripple control [EFRS05].

Even if traditional audio frequency ripple control becomes more and more expensive due to more often faults, maintenance and outages it is doubtful that ripple control over PLC is competitive against audio ripple control. For ripple control over PLC every device need to have a TCP/IP based receiver which nowadays is expensive.

Additional audio ripple control is managed centrally by transmitting the signal though a long-wave antenna which covers an area of about 500 km. So it is possible to control appliances beyond the PLC covered area from a central located control room. A big disadvantage of audio frequency and radio ripple control is the unidirectional communication which makes it unlikely to use these technologies for the control of virtual power plants. Ripple control over PLC offers bi-directional communication due to TCP/IP.

Ripple control applications within the Smart Home area could be the tariff switching of meter, control of appliances such as night-storage heaters, connection and disconnection of load groups (e.g. refrigerator) and power plants (e.g. micro combined heat and power).

4.4.2 Energy / Load Management

Traditional load management within the residential area is done particularly through the control of night-storage heaters with ripple control up to now. Within the context of future energy supply and an increasing importance of virtual power plants an intelligent load management becomes necessary. It is not sufficient enough to control the power supply regarding the load demand, future energy management systems will need to manage the load demand regarding the supplied power to become efficient. Through optimised load management storage demand could be minimised, peak loads reduced as well as the supply of control energy shortened. Smart Home services over PLC offer a broad range of possible applications to do load management both centrally by the utility and locally by the consumer.

Consumer Group	Consumption / TWh	
Iron industry	23.9	
Chemical and mineral oil industry	56.3	
Other industries	160.8	
Transport	15.5	
Public consumers	40.0	246.0 LV grid level
Agriculture	7.0	
Private Households	131.0	
Trade and commerce	68.0	
Total	502.5	

Table 1: Domestic Energy Consumption per Consumer Group in Germany 2001 [BMWA05a]

Controllable loads can help to operate the grid. The fact that about 50% of the total consumption of electricity in Germany takes place in the low voltage (LV) grid (see Table 1) demonstrates a high potential for load management with Smart Home services.

To realise an intelligent load management different actions have to be taken. Not only technical actions like intelligent appliances which could be connected or disconnected but also soft actions are necessary. They include dynamic electricity rates and sensitisation of customers regarding the use of modern information and communication technology as well as the need for environmentally sound energy consumption.

Test with real time load dependent electricity rates were done in a field test in the city of Eckernförde in North Germany with approximately 1000 randomly selected households. Dynamic electricity prices were related to the high of the grid load. The actual price was shown with feedback systems through different coloured lights. So the customer was continuously informed about the electricity price and could decide whether to consume electricity or not. The test has shown that it is possible to achieve changes in the customers' behaviour and to shift loads from peak periods to off-peak periods. Additional electricity savings up to 12% were possible [ENSH97].

Load shifting through	User behaviour		Technical actions	
	Within a day	About at least on day	Within a day	About at least on day
Refrigerator	--	--	+	O
Freezer	--	--	++	O
Washing machine, tumble-dryer	+	O	O/-	-
Dishwasher	+	O	++	O
Electrical water heating	O	-	+	-
Storage heater and heat pump	-	--	++	-
Miscellaneous consumers	O/+	O	O	-

++ very good (> 75 %) + good (25 % to 75 %) O moderate (5 % to 25 %) - low (up to 5 %) -- none

Table 2: Estimation of load shifting possibilities through user behaviour and technical actions [QUAS99]

Based on different studies, summarised in [QUAS00], estimations were done to evaluate which appliances within the Smart Home are useful to shift loads. Table 2 shows the appliances that are applicable for load management. It was differentiated between load shifting within a day and the potential to shift the load to at least one other day through users' behaviour and through intelligence within the devices (technical actions).

Load management through technical actions as well as users' behaviour is interesting for future Smart Home applications. Figure 5 summarised both and quantifies the estimations of Table 2.

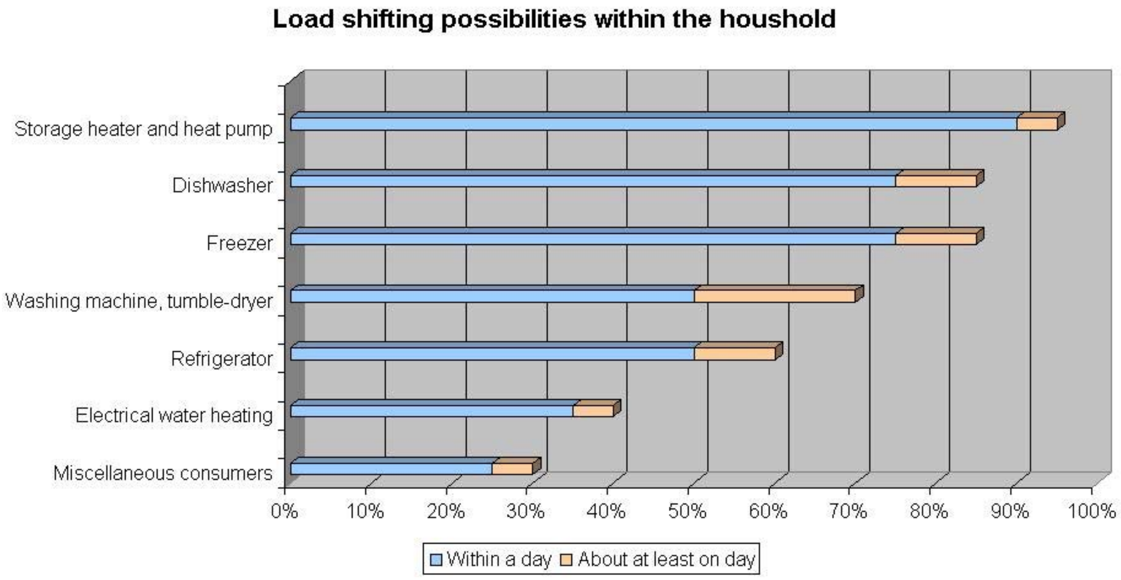


Figure 5: Quantification of load shifting possibilities with residential appliances

Already today storage heaters are used for temporal shifting. This shifting possibility exists in future for storage heaters and heat pumps, too. High potential is seen for freezers, refrigerators and dishwashers. Even if there is seen the potential for washing machines and dryers not as good to do load shifting through technical actions it is probably the same like dishwashers. These appliances need the intelligence to notice if they are filled with laundry or dishes and then operate them in off-peak periods when electricity prices are low.

Especially for freezers and refrigerators high potential is seen. They could shut off during peak usage times in order to lessen usage spikes. During this period, food inside the refrigerator or freezer would not become perceptibly warmer due to improved isolation. The consumer would save costs by less electricity consumption in high price periods.

In total there is a high load shifting potential by Smart Homes. To realise this potential residential appliances with integrated intelligence have to be installed and dynamic electricity tariffs must be adopted. Major Japanese companies like Sony, Pioneer and Mitsubishi Electric are working together in the Consumer Electronics Powerline Communication Alliance (CEPCA) to provide a new generation of household appliances with implemented PLC technology. The aim is that every appliance within the Smart Home could communicate with each other over PLC due to integrated modems. So if the appliance (refrigerator etc.) is plugged into the socket it gets power and can communicate at the same time without an extra modem.

Economically it is not meaningful that utilities control these appliances centrally due to its huge number. This would result in a big central data base and high communication needs. Rather they have to control themselves locally. The future scenario could include a central control unit within the Smart Home which knows the current electricity price and then requests preferred home appliances to shut off during peak loads. So Smart Homes could manage their loads by themselves.

The economic benefit for the electric company by having balanced load profiles would be enormous. More detailed schedules of power demand would increase the efficiency of energy generation, especially with distributed energy generation, and reduce the need to supply expensive control energy. Because the infrastructure for intelligent and efficient load management is not given yet this subject matter will not be followed up in this document.

4.4.3 Distributed Energy Generation

Due to deregulation and liberalisation of the energy market, meagre resources and new technologies the future energy supply will change rapidly. Distributed energy generation will increase based on renewable energy sources (RES) and fossil sources in combination with cogeneration (combined heat and power – CHP). The reorganisation of the electricity power industry will lead to an unbundling of generation, transmission, distribution and supply. Until 2010 – 2030 central electricity generation will still dominate but RES and DEG will have a significant part of the future electricity production in the LV and medium voltage (MV) grid (see Figure 6).

Especial micro CHP will play a major role in the future energy generation and within the Smart Home. CHP is characterised through a higher energy efficiency factor than conventional separate generation of heat and electricity. Due to the higher energy efficiency factor they can displace conventional heating technology.

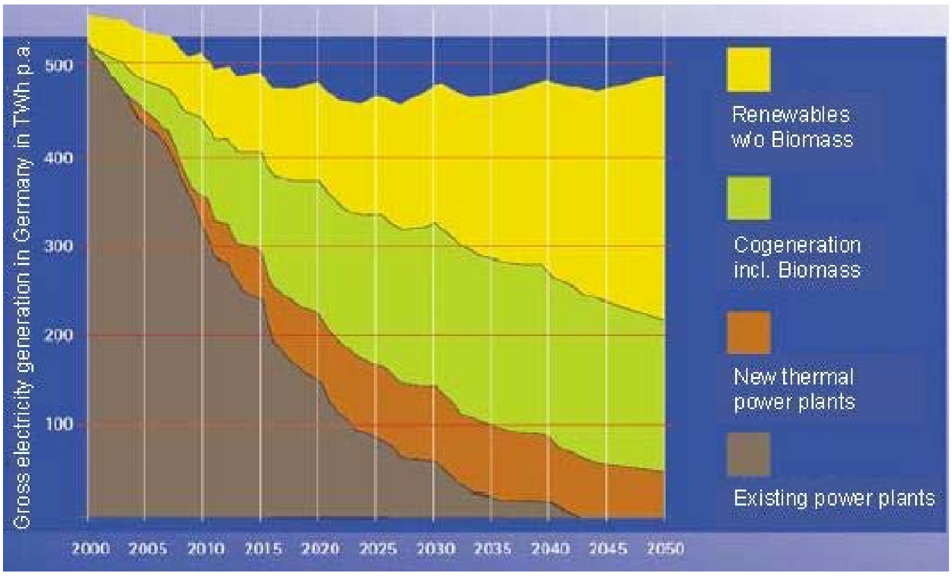


Figure 6: Electricity Generation in Germany until 2050 [WUPP02]

At the same time the increase of DEG will come along with an increase of modern information technology in terms of integrated communication and local intelligence. This will be necessary to control the electricity generation and the electricity gird due to a rising number of (small) power plants and bi-directional electricity flow. So a lot of kW units in a defined area will be added up to a virtual MW unit. The generation of DEG will be optimised and controlled with variable supply tariffs with the help of communication technologies. Basis of a technical and economic optimal integration of DEG is the intelligent Distributed Energy Management System (DEMS). The access network (LV grid) is becoming an active network. It will consist of a number of different generation, consumer and storage units. Therefor a bi-directional communication between generation, storage, consumption and DEMS is required for prognosis, schedule and optimisation of electricity loads within the power grid.

DEG within the Smart Home supply electricity when there is a heat demand (CHP) or primary energy is available (e.g. photovoltaic). In addition they generate and deliver the maximum of possible electricity because of the state-aided supply compensation. This DEG will be forecasted and planned into the daily electricity demand. Therefor it is essential to be connected to every DEG unit within the operating area to collect all required data over a period of time. With this experience values it is possible to forecast and plan DEG units with regards to the type of day and the weather. This will be based on a complex program which collects the data, creates a forecast and then compare the actual data with the planed data to improve the forecast in real-time. If there are, as forecasted, a huge number of such CHP units in an operation area a quite precise forecast about produced electricity through micro CHP within the Smart Home will be available.

To realise the described scenario of the integration of DEG an increased usage of ICT will be necessary. The change to distributed generation will lead to a growing together of the energy and communication grid. PLC gives here a very good opportunity because the energy grid could be used and there is no need for a new communication infrastructure. Powerful information systems and data bases will play an important role to collect, store and analyse the high data amount for monitoring, forecasting, billing and other applications. The communication will be based on TCP/IP and standardised Internet protocols such as HTML (Hyper Text Markup Language).

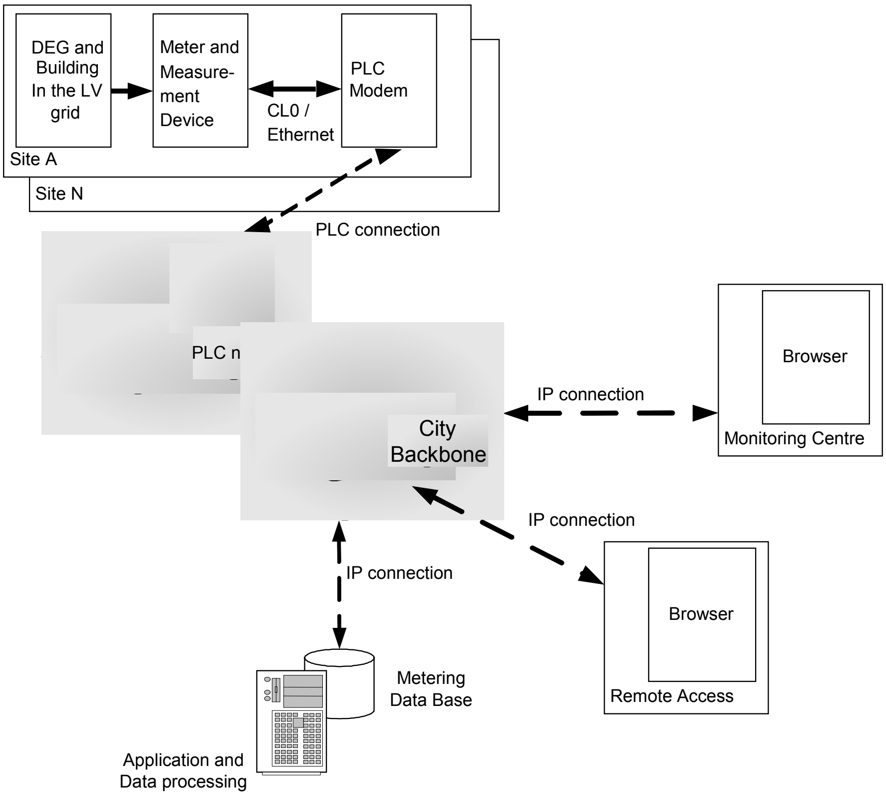


Figure 7: Model of an ICT system for the integration of DEG

5 Technical Aspects

5.1 Technical Infrastructure Description

The following chapter is giving a brief overview of the PLC access network and its components. In addition special requirements and configuration for Smart Home application will be investigated and described.

Deriving from the different working voltage used on the grids, the PLC access network can be separated into two domains. One is the medium voltage; the other is the low voltage domain. For the MV PLC access system two modem types are used. The following figure shows the general architecture of a PLC access system and the division between medium and low voltage. One possible setup for a PLC access system consists out of both parts medium and low voltage. The other setup is just using the low voltage network for the PLC access system.

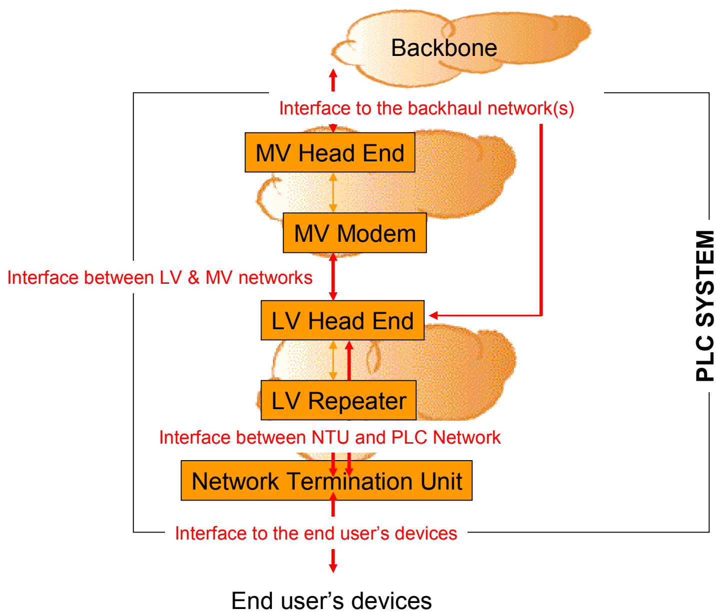


Figure 8: General PLC access architecture

The access network consists of different devices:

- Medium voltage head end (MVHE): The MVHE is the gateway between backbone and the PLC access system; it is transferring the data traffic from Ethernet to PLC and vice versa.
- Medium voltage modem (MVM): The medium voltage modem is the counterpart of the medium voltage head end. It is one part of the connection between the medium and low voltage domain and therefore terminating the medium voltage PLC system.
- Low voltage head end (LVHE): This device is transferring the data from the backbone to the low voltage grid and vice versa. The LVHE is connected to either the backbone or a medium voltage modem which is establishing the backbone connection over the medium voltage

- Low voltage repeater (RPT): Installed in street cabinets or near the house service connection the low voltage repeater is repeating the PLC signal between LVHE and NTU. The number of RPTs between a HE and a NTU can vary.
- Network termination unit (NTU): The NTU is terminating the PLC access network at the customer's site and provides the necessary interfaces for the customer's premises equipment.

The medium voltage PLC system is organised in a ring or chain structure where the MVHE is feeding up to 8 transformer stations. The following figure shows the corresponding setups:

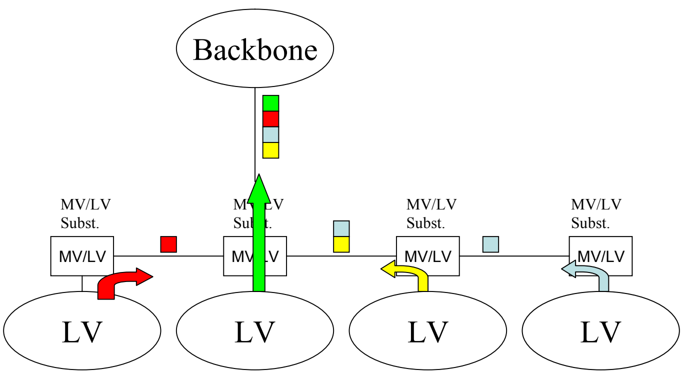


Figure 9: Medium Voltage Chain

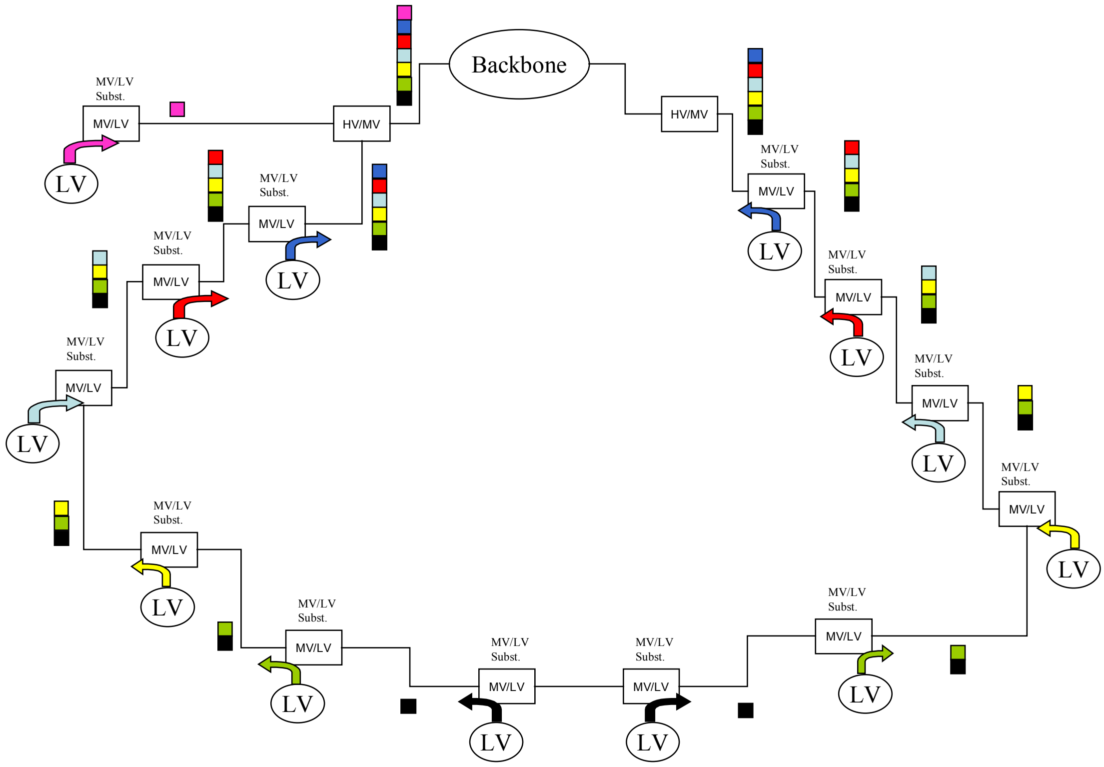


Figure 10: Medium Voltage Ring

The low voltage PLC access network is organised in a cell structure, e.g. each LVHE is feeding several RPT and NTUs. The common installation point of the LVHE is the transformer station where the PLC signal is coupled to every cable. Once the PLC cell is established the installation of further NTUs is easy to realise. The following figure shows an average setup of a low voltage PLC cell.

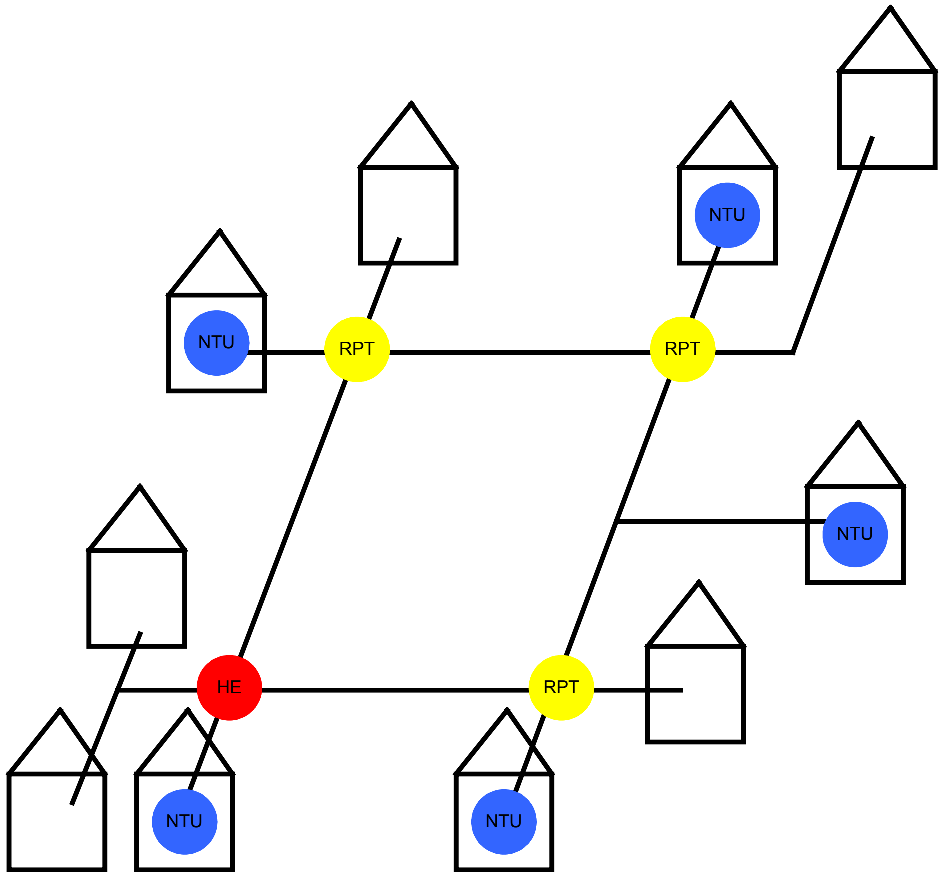


Figure 11: Low voltage PLC access network example

Figure 11: Low voltage PLC access network example shows the cell character of the PLC access network. This circumstance is very useful for applications like ripple control and load management since the deployment of such services can use the already existing infrastructure.

How can the PLC access systems are used for distributed applications. Currently different models of usage are possible and will be discussed in this chapter.

One possible solution is that the PLC access is a substitute for other network technologies being used for remote access. Automatic meter reading is done via GSM modem or an ordinary POTS/ISDN modem. Using an already deployed PLC access network is cheaper and easier to operate and maintain. The functionality is the same; the remote unit (meter or other device) will be polled and the information is normally gathered on the workstation the corresponding application is running on. This kind of poll and store mechanism is widely used.

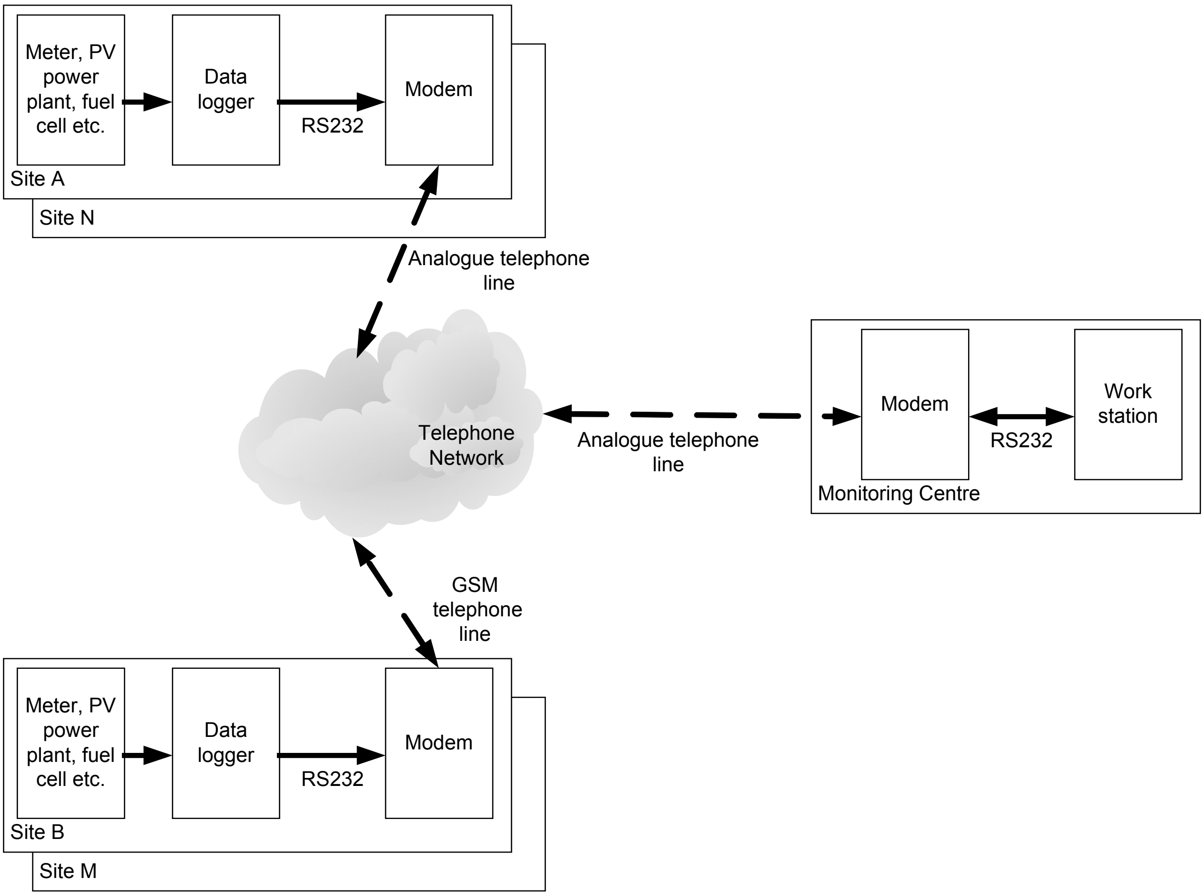


Figure 12: Current situation

Another solution is using the PLC access network for tunnelling RS232 connection between two remote locations for control purposes. Figure 13: PLC substitution of telephone network shows the setup of this usage and Chapter 5.2 On-Site Equipment explains the equipment.

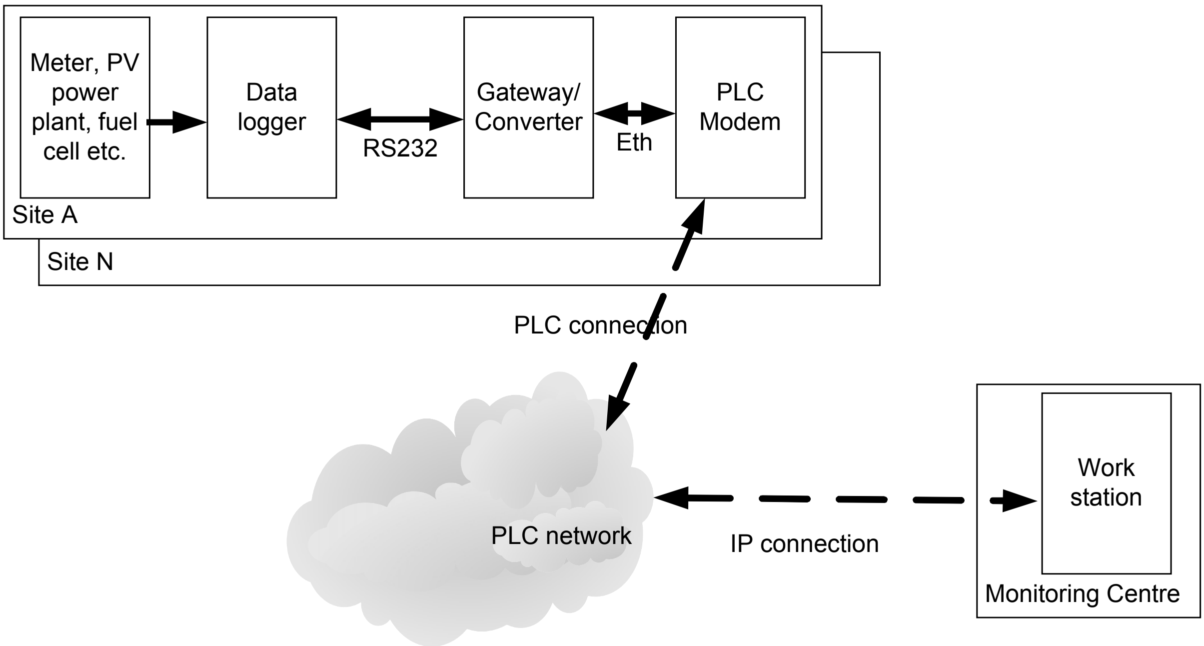


Figure 13: PLC substitution of telephone network

Both above introduced solutions are based on already existing technologies and mechanism. PLC is just a substitution for other transmission technologies.

PLC is an always-on technology, this means that the connection is existing and has not to be established every time a communication process is wanted. Due to this fact some enhanced models of remote control and data logging are imaginable but yet not implemented. The Figure 14: Enhanced ARM and Monitoring system shows the conceptual approach to this scenario.

The main improvement in this scenario is the fact that all kind of data is stored and processed centralised. The central application server is dealing with all requirements for the different use cases. AMR can be realised as well as monitoring of photovoltaic power plants and substation remote control.

This concept has several advantages:

- Scalability: The flexible infrastructure allows the setup of a solution which is managing and monitoring all different kinds of application. Large scale deployments can be handled as well as smaller constellations.
- Flexibility: The centralized processing of the data allows easy implementation of new processes and application.
- User Friendliness: On the user's site no special application is required, only a browser is needed to get access to the personalised data. Central administration of the access rights and different authorisation levels ensure, that the system can be used for customers as well as for engineers and service personnel.

The main challenge to realise this solution is the implementation of the central application server. In particular different data formats have to be implemented.

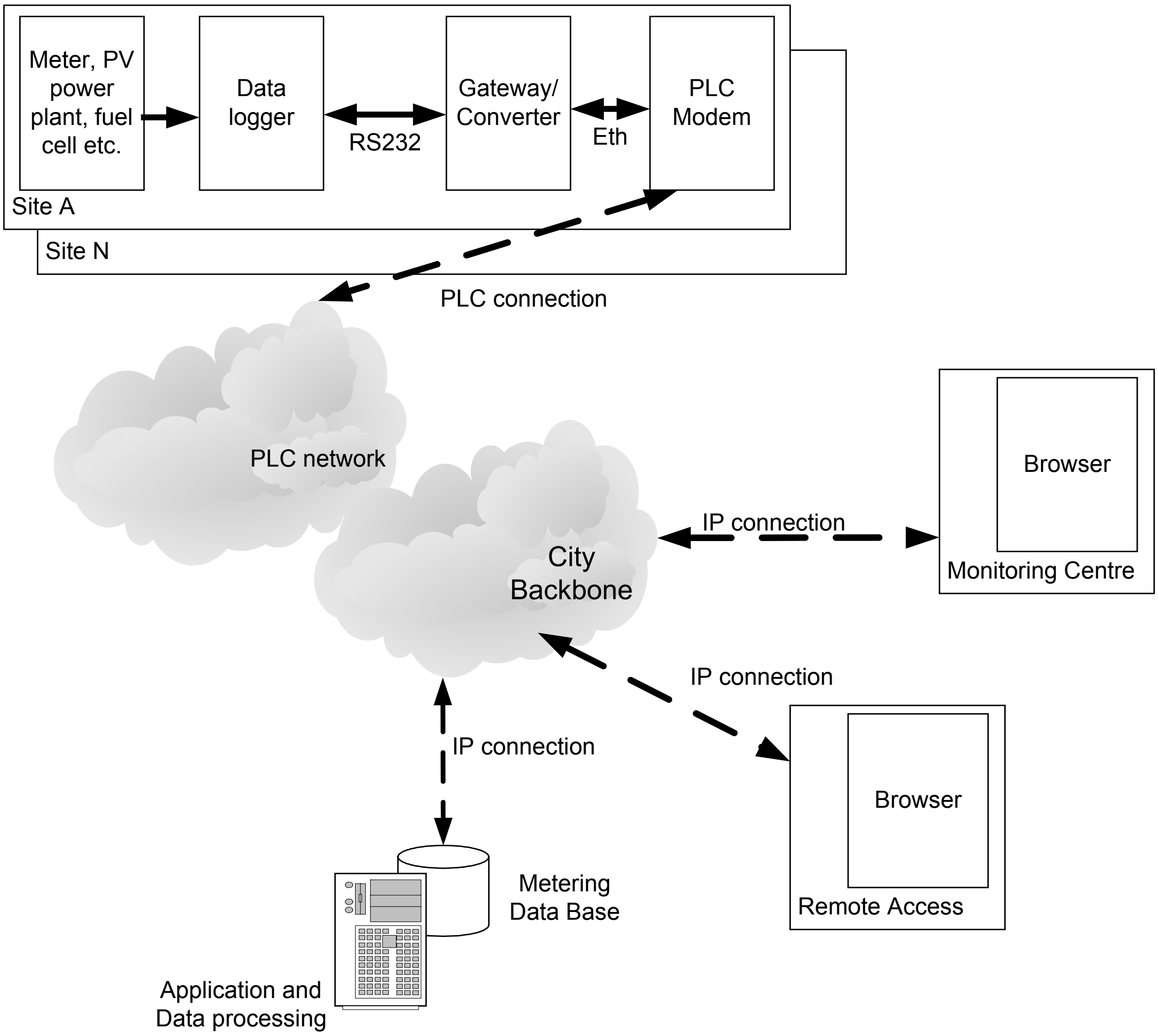


Figure 14: Enhanced ARM and Monitoring system

5.2 On-Site Equipment

On-Site Equipment is the equipment, which is realising the connection to a data network. Beside the PLC modem which is terminating the PLC connection other technical equipment is needed to connect the meter or data logger to the telecommunication network. Due to the fact that a least an interface conversion is needed we take a look at two possible solutions:

The Tibbo DS100 is a RS232 to Ethernet converter with a small functional range. It can only be used to realise a remote access over an IP network. In this case we can speak about an emulation which allows a range extension of the RS232 connection. The setup of this scenario is depicted in Figure 15: Virtual RS232 connection over PLC. From the functional point of view this scenario is predestined to allow remote access over an interface which is not designed for remote access. The application which use used to access the data loggers has been designed to use the RS232 interface. This setup already eases the control of distributed data logging. Units that normally could only be readout during a site visit can now be readout remotely.

The application which is used for the readout and the data management remains the same.

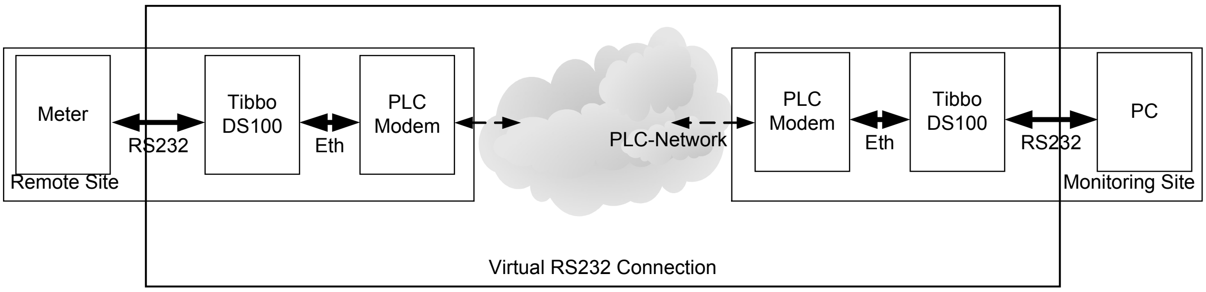


Figure 15: Virtual RS232 connection over PLC

The second on-site equipment we take a closer look at is the ABB-DM2100. This unit has the ability to process different kinds of interfaces like CL, RS232 and RS485. To control all the functionality an application for the gateway control is needed instead of a “normal” metering or monitoring application. This scenario is more specialised which means that the ABB gateway can handle only electricity meters, but for these meters the AMR 2100 applications provides more features like:

- Automatic meter reading in definable intervals
- Storage of metering data in a relational database

- Processing of data

But it is a proprietary solution which has just a little number of direct intervention possibilities. The setup of this scenario is depicted in the following figure.

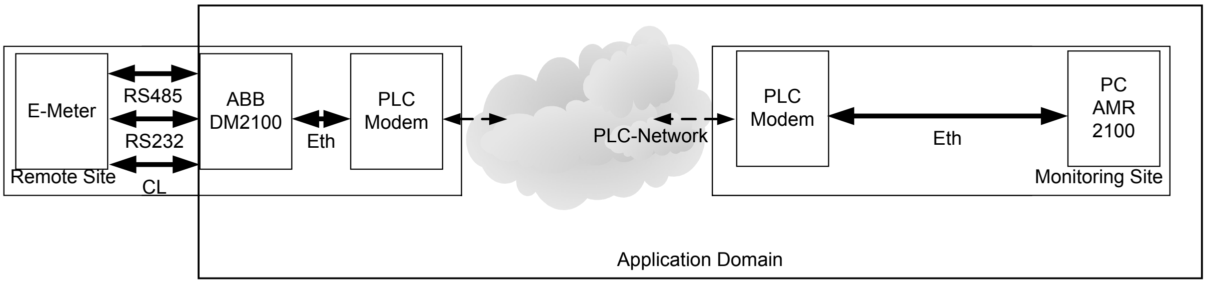


Figure 16: Application Domain with ABB DM2100 gateway

Both introduced solutions give an impression of what is relevant for the choosing of the on-site equipment. The solution which is using the Tibbo converters is a simple emulation with no intelligence, it is just extending the range of access. But it is a flexible solution in terms of the device which can be connected to the RS232 interface and the operated application.

The ABB gateway solution is flexible concerning the possible interfaces for connecting to the gateway, but limited for electricity meters. The AMR 2100 application which is needed to operate the gateway is powerful but can not be changed or extended since the solutions is proprietary.

5.3 Standard conformance

5.3.1 EIB

The European Installation Bus (EIB) is a standard (EN50090) which defines how sensors and actors can be connected to a network for home automation. This is the main application which is including the control of lights and jalousie as well as heating installation and air conditioning monitoring and control. Remote access and control of all connected entities is also included.

EIB is a serial bus using a twisted pair connection for data transmission and power supply (24 V). For communication defined datagram is used. The medium access is like Ethernet free for every network entity. Every sender gets a acknowledge for the datagram. In case of collisions a retransmit of the datagram which did not reach the receiver is initiated. The whole system is using 9600 baud for communication.

For addressing purposes EIB is divided into 15 areas including 15 lines with a maximum of 256 devices. The addressing is done in the following way; 3.5.123 is addressing the device number 123 which is connected to line 5 in area 3.

Programming of the system components is done by using the EIB-Tool-Software. This software is provided by EIBA the EIB association which is also granting interoperability of different manufacturer's components.

5.3.2 LON

LON (Local Operating Network) is a bus used primarily in facility automation. Echelon, a USA based company developed this system around 1990.

The core design of LON is the decentralized automation in a rather flat hierarchy. The devices, called nodes, communicate by using a bus. Several types of devices are pooled under the nodes concept; sensors, actors and controllers are building the LON network. The speciality about LON is that locally required information is processed locally which avoids traffic on the bus.

The processing is done in the microprocessor called Neuron. The used communication protocol is called LonTalk. This protocol is defining layer 2-7 of the OSI layer model. For the physical layer different transceivers are available.

The node is logically seen communicating using NV (Network Variables). To enable communication between the nodes of different manufacturers SNVT (Standard

Network Variables Types) have been defined by the LonMark Association. The data transfer is organised in so called bindings and controlled by the Neuron.

A big advantage of LON is the openness of the system which is allowing to use different manufacturer's devices in one application. But this is also the major disadvantage because it is based on the bindings which have to be licensed by Echelon.

5.4 Telecom Network

5.4.1 Bandwidth

The bandwidth requirements strongly depends on the application which should be realised using the PLC access network. Also the number of connected units plays a role and should be concerned during the design process.

To give a feeling about the bandwidth requirements we take a look at the following scenario:

In dense populated areas one PLC cell is covering 300 households; ergo 300 electricity meters can be automatically polled. The typical time a polling event takes is 12 seconds and needs a bandwidth of 10 kbit/s. The following table shows for different polling intervals the resulting concurrent polls and required bandwidth.

Polling Interval	Concurrent Polls per PLC cell	Bandwidth per cell
60 min	1	10 kbit/s
30min	2	20 kbit/s
15 min	4	40 kbit/s
5min	12	120 kbit/s

Table 3: Polling intervals

5.4.2 Security

CENELEC's "Smarthouse Phase II" is describing the security requirements in an appropriate way: *"A smart house system needs to be trusted by the inhabitants, users and owners of both the home and the system. The purpose of security of the system is to provide trust in the system. This type of security is denoted Information and Communication Technology security or in short ICT security. Since many components of a smart house system will be in operation 24 hours a day continuously and automatically exchanging information to the outside world, ICT security is necessary in order to keep the integrity of the system. A well implemented security solution implies for example that only authorized users and processes have access to the system and information stored on the system or is communicated to and from the system, and that only authorized users are able to use and modify the system. The purpose of this section is to help the system designer to select and install an appropriate set of security mechanisms for a smart house system."*

For the services this white paper is focused on the following requirements derive:

- Access authorisation for the connected devices has to be realised. Remote access and remote control should only be possible for authorised persons, to prevent malicious use.
- The integrity of the transmitted data has to be granted. Nobody should be able to corrupt the data.
- The database of the systems has to be protected. The raw data has to be stored in its original format before further processing takes place.

5.5 Quality / Reliability Considerations

The requirements on the quality of the connection depend on the service or application which is using the PLC access network. Some applications like real time station monitoring have strict timing and bandwidth requirements, which have to be met, otherwise the required security can not be granted. The exact requirements depend on the application and the data which has to be transmitted for this application.

Other non real time applications like AMR are not as critical concerning reliability. Temporary outages do not endanger the data collection process as long as the process is implemented accordingly.

A general requirement is a reliability of 99,9% of the overall system.

6 Pilot Project: Monitoring of a residential µ-CHP in Mannheim

The target object is a residential home in Mannheim that is owned by a medical doctor and includes 3 flats and a medical practise. The installed DEG system is the µ-CHP "Dachs HKA G 5.5" with gas engine from the company SenerTec. The µ-CHP supplies 12.5 kW_{th} thermal and 5.5 kW_{el} electric power. Gas is supplied by MVV Energie. The generated heat is consumed in the building. The generated electricity is first consumed in the building, surplus electricity is inducted in the LV grid and has to be refunded by the MVV Energie. Today the MVV Energie only knows at the end of the year how much electricity was supplied into the MVV Energie grid during that year. Within the framework of Smart Home a pilot project was initiated to monitor this DEG unit over PLC and provide additional services like AMR.

The following equipment is installed at the customer' premise:

- Two Elster A1500 electronic electricity meters with CL0 interface
- A retrofittable low frequency pulser to measure gas consumption
- PLC modem with Ethernet interface
- Tibbo DS100 Ethernet-to-RS232 gateway
- RS232-to-CL0 converter.

The Elster A1500 is an electronic three-phase meter that measures electricity in both directions. The meter has a gauged load profile for billing data that can store energy or power values as well as pulse inputs to measure the gas consumption. Furthermore there is a separate load profile for power quality measurements of network parameters. One A1500 meter is installed at the transfer point to the MVV Energie LV grid and measures received and supplied electricity. The other A1500 meter measures the generated electricity of the µ-CHP which is fed into the in-house grid. The gas impulse transmitter is connected with one A1500 meter. This meters additionally counts the gas consumption. The A1500 meters are read out over a CL0 interface. Originally it was planed to connect these meters directly to a PLC modem with CL0 interface. But this modem is not available until the beginning of 2006 and therefore additional communication equipment was required. The meters are connected to the PLC modem with Ethernet interface over a RS232-to-CL0 converter and Ethernet-to-RS232 gateway. Because PLC is used as transmission technology the meters are always online and a real-time monitoring can be done.

At the MVV Energie the meters are read out with a laptop that is connected to the Internet via UMTS (Universal Mobile Telecommunications System). A virtual serial port is emulated on the laptop and establishes the connection to the DS100 gateway over the Internet and PLC network. For applications on the computer this looks and feels like a “virtual serial cable”. With the vendors specific software Elster *alphaSET* the measured values of the meters are read out over this “virtual serial cable”. Figure 17 illustrates the installations of this pilot project.

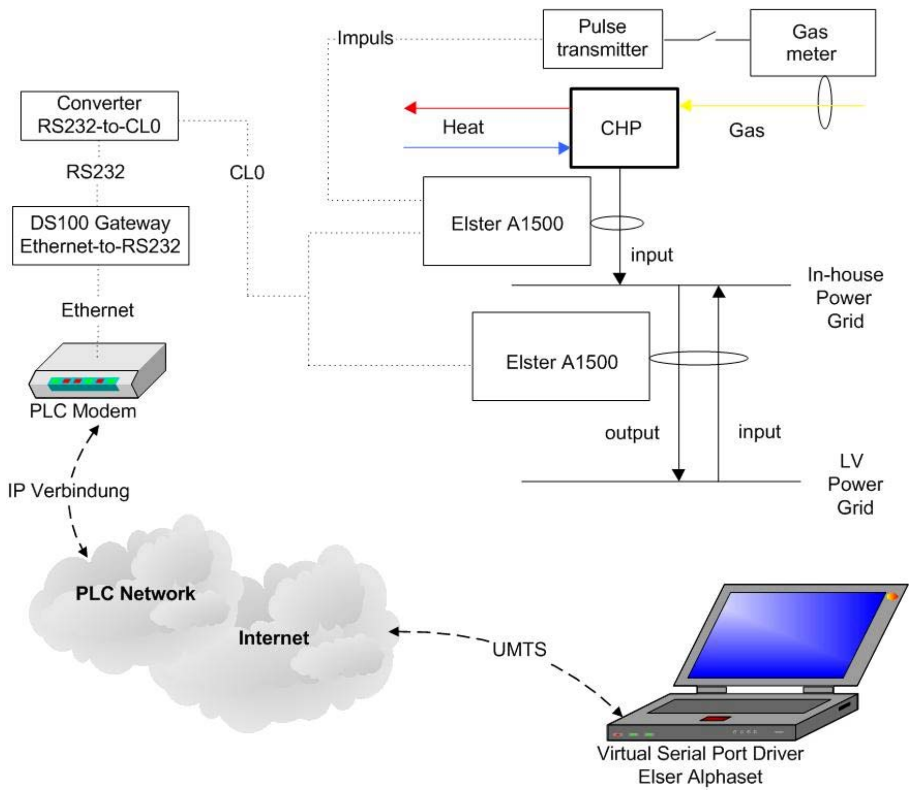


Figure 17: Pilot installation to monitor a µ-CHP unit in Mannheim

The realised monitoring over PLC is a step forward to the intelligent integration of DEG. With this installation it is possible to:

- create schedules of real power per day differentiated in generated power, delivered power to the LV grid, received power from the LV grid and consumed power in the building
- create energy profiles per day differentiated in generated, delivered, received and consumed energy
- create load profiles of generated thermal power to draw conclusions about generated electrical power
- and analyse the performance of reactive power, voltage and frequency which is especially interesting if a high number DEG units are installed within LV grid cell at a transformer substation.

The measured values are recorded every 10 minutes. Figure 18 shows an exemplary load profile of the residential home in Mannheim.

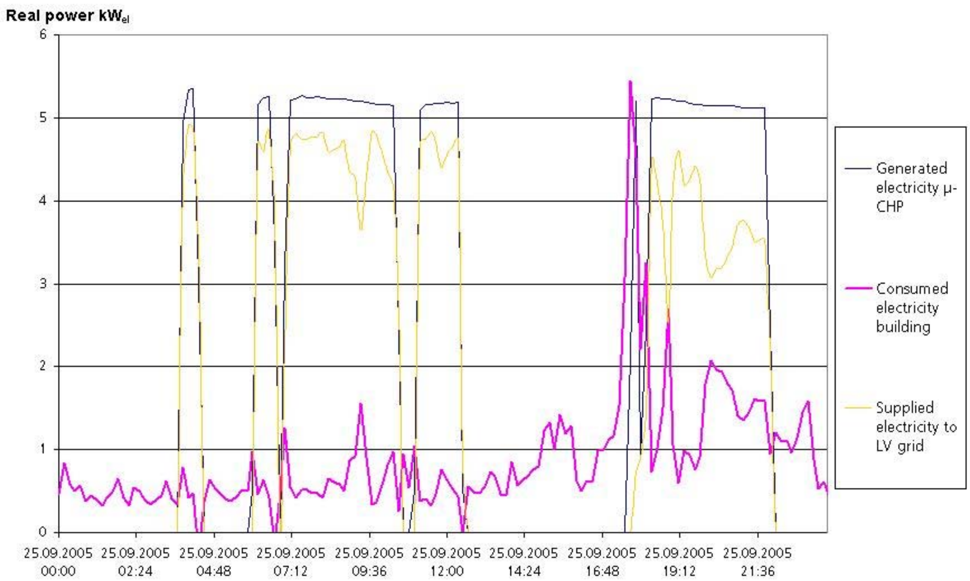


Figure 18: Load profile of the residential home – generated, delivered and consumed real power

Furthermore it is planed to extend this installation to an enhanced monitoring and AMR solution like described in chapter 5.1. Then an application server will read the meters automatically over the PLC network and will store the data in a database. The DEG units will be monitored with a web portal that has access to the database over an IP network. Customised queries of selected DEG units within defined time periods can be done. In addition synergies can be gained through using this solution for AMR purposes as well. The billing system of the MVV Energie will read the billing values from the database and will process them. So the customer can be charged automated and the MVV improve their operational efficiency. Furthermore these data can be used to improve the forecast quality of DEG and therefore to integrate them in the future energy generation. Load profiles of thermal and electrical power for residential homes and DEG units will be available.

7 Business Implications - Services

7.1 Comparison with conventional utility solutions

The business implications for core business related applications are very clear. On one hand there is the possibility to use the infrastructure of third parties on the other side the already implemented PLC infrastructure is used for realisation. Using this infrastructure to substitute or emulate direct connections eases the use of remote controlled applications.

Using the PLC infrastructure has several advantages:

- Lower operational costs because of an already existing system

The usage of the own grid and infrastructure is in most cases easier and cheaper than using third parties transmission capabilities. The PLC network will already exist and has just to be extended with the needed technical devices.

- Larger part of the value chain is generated by utilities

If a third party's transmission capabilities are used for monitoring issues a major part of the service is dependent from outsourced functionality. Taking this fact into account the usage of an existing infrastructure is logically consistent. Using the operated PLC access networks lower also the operational costs compared to exclusively used transmission paths like analogue telephone lines or GSM channels.

- Synergy effects by using PLC for different kinds of services

PLC can be seen as a lorry carrying different types of traffic. In this context every additional service is just an additional packet transported by an already existing infrastructure. Therefore every core business related service like the ones considered in this document. The possible control of the transmission technology allows in case of problems to identify whether the transmission or the facility is broken down.

- Direct control for crucial business processes

The whole process is performed by one company which implicates that all information are already available. In case of problems direct interventions can be taken without the drawbacks of distributed information and responsibilities.

7.2 Customer Target Categories

Three customer target categories are thinkable:

1. The metering department of the utility which is running the facilities itself.
2. Companies which are operating a grid of decentralised energy generating devices.
3. End customers owning a fuel cell or any other decentralised energy generating solution.

All customers have in common, that they need a monitoring solution for their decentralised energy generating facilities. The first and second category is on the operating side which needs detailed information and the possibility to remotely control the facility.

While the end customer who is defined as third category is more interested in the monitoring of the fuel cell and its parameters to be able to crosscheck the balance or bill provided by the utility.

7.3 Service Packaging

Services for utilities which are mentioned in the previous chapters are not services that, as far as our knowledge and news is concerned, are being directly offered to the end user. The monitoring of DEG is a service which will be necessary to operate the electricity grid in the future and will improve the processes of an utility. The same applies to ripple control or load management over PLC.

Broadband PLC is an optimal solution to monitor several DEG units within an operating area and offers considerable advantages against competitive technologies. Once a broadband PLC access for a residential home is putted into operation several services could be bundled. Most obvious is to bundle AMR systems with the monitoring of DEG because nearly the same data will be collected. More detailed information about AMR systems over PLC see [OP_D41]. This allows to gain synergies for the utility company and makes their processes more efficient which accompanies with cost reductions. Furthermore it is possible to operate a load management system over PLC in the Smart Home. So defined load groups could be shut off in peak load times which increases the energy provisioning efficiency, too. In combination with a flexible tariff structure the customers could participate at the equipment costs.

Nevertheless new services are available for residential customers. The measured data could be sold as individual analyses (load profiles) about generated and consumed energy to the customers. Thereof additional services are thinkable like to offer consulting solutions to improve the energy efficiency of these Smart Homes or to change personal energy consume behaviour. The generated energy through DEG units could be charged automated every month unlike today where once a year the customer bills it to the utility company.

Most reasonable is to bundle these utility services which are located in private homes with an Internet access for the home owners. So they can use a cheap and reliable broadband Internet connection and the energy utility can improve their own operation efficiency. Especially PLC offers here unique advantages against competitive technologies like General Packet Radio Service (GPRS) (no broadband Internet possible) or Digital Subscriber Line (DSL) (additional hardware necessary to connect different rooms) and free capacities can be used optimised.

Traditional Smart Home services for residential customers like described in chapter 4.3 can also be offered in different packages. Here has to be kept in mind that significant infrastructure costs are necessary to install smart security, home automation or energy saving systems. These infrastructure investments have to be undertaken by the PLC Smart Home service providers and offered in a kind of "contracting" agreement to lower entry barriers. In addition value-added services can be offered like a 24-hours-hotline that cares about the customer's premises during holiday time or makes sure that security concerns are met. In this case utility companies could gain synergies for example with pooling of their traditional emergency hotline (for electricity, gas, etc.) and such a Smart Home hotline. This will be a real benefit for customers and obtain new revenue streams.

Important is the structure of the utility or rather the PLC provider and how they are diversified. The possibilities of packaging services have to be identified more clearly regarding the kind of utilities than the services provided. On the contrary, electric utilities are not the same kind all over the world; some of them are integrated vertically (transport or distribution and generation or supply) and some of them are integrated horizontally (transport, distribution, generation or supply, and other non electric sector activity); some of them have a multiservice approach, and others focus their efforts on the provision of energy; some of them have regional focus, and others a national one. Thereof it has to be analysed which services suit to the core business and could be offered. Another important point is the question if the PLC provider is the utility company, belongs to the utility or does not belong to the utility. Under aspects of these different points the variation possibilities of services packaging have to be reviewed in each individual case.

7.4 Pricing Consideration

Smart Home solutions for utilities are not services that are being directly charged to the end user. Meter reading is an activity necessary to get the money owed by the customer to the company, and is something the electricity company has to live with. Monitoring of DEG, ripple control and load management are services which increase the operation efficiency and can only charged indirectly to the customers. Thus it makes no sense to speak directly of pricing considerations. So there is interest in getting to know the details about the cost structure of such services, the cost savings through such services and specifically the cost differentiation of PLC regarding competitive technologies.

We want to dwell on the introduced pilot project of the monitoring of µ-CHP in Mannheim. To realise such a solution infrastructure cost, installation costs and communication costs are thereby incurred. Infrastructure cost include the cost for electricity meters, gas impulse transmitter, PLC modem and possible additional communication equipment like in our case an Ethernet-to-serial gateway and a serial-to-current loop converter. In future developments the cost for additional communication equipment could be saved because these devices are integrated within a PLC modem.

Installation costs include consequentially the installation of these devices in the customers building. In addition we add the costs for an one-time installation of application server and data base to collect and prepare the measured data. These costs will be shared on the amount of installed monitoring units.

The third cost pool are the communication costs. They are divided into the on-site communication from the meters to the PLC network and the central communication from the application server to the PLC network, city backbone or Internet. On-site the electricity meters are connected via PLC and the communication costs depends on the monthly rate of the PLC provider. The data volume for meter reading is about 50 kB per day which is about 1.5 MB per month. This data volume should be included in the monthly rate. The communication costs of the application server can be disregarded because this server should be always online, manage several tasks and collects the data of huge amount of meters.

More difficult is the differentiation with cost savings through this solution. The main aim was to get to know the data of such DEG units. The utility wants to know at which point in time they produce and supply energy to the LV grid. The combination of monitoring and AMR permits cost reductions through synergies. The manual metering on site can be saved on. The second point is country specific. In Germany the electricity meters in the customer premises belong to the utility company. The customer has to rent these meters for a yearly charge. The meters now will be used for monitoring activities which offer higher value services. The yearly meter charge is the possibility to compensate additional costs. Therefore the additional costs can be referred to the customer over the meter charge.

Other cost savings are more difficult to separate. Under the aspect of a huge number of DEG units within an operating area there are several aspects to be considered. The improvement of the forecast of electricity generated by DEG lead to less usage of control energy. Control energy is energy that is purchased short term if supplied electricity within a control area is too less. Therefore control energy is very expensive and less usage of such control energy will lead to significant cost reductions. Another point is the avoidance or rather to postpone investments for the electricity grid. For example transformer substations that have lots of DEG units connected must not be upsized for higher electricity demand because a big part of this demand will be covered by DEG units in the LV grid. Thus less electricity will be distributed from the MV to the LV grid over the transformer. These mentioned cost savings are pretty difficult to quantify but have to be taken into consideration.

Smart Home solutions like security or home automation services have to be taken into account under a different point of view. They represent a new business case which can directly be offered and charged to the customers. For the success of such solutions it is important to subsidise the infrastructure equipment. So the market entry barriers will be lowered and more customers will be attracted. With a minimum contract duration the customer will be bounded to the provider and pay the initial costs back with monthly charges. A study of Booz Allen Hamilton has shown that achievable monthly charges for security services could be up to 25 € per month, for home automation and energy saving services up to 40 € per month.

8 Future Outlook

8.1 Future Applications

Future applications could be the monitoring of transformer substations and the LV distribution grid. Thereby possible faults can be recognised earlier, investments in infrastructure could be putted into the future or rather be avoided. This will increase the operational efficiency of grid operators which will be more and more important in a deregulated energy market. Furthermore load management in combination with flexible tariff structures and shorter billing periods will emerge. To realise this scenario the employment of intelligent devices and communication technologies will be essential. Broadband PLC offers here an unique possibility to provide these demands within the electricity grid. For further developments, the meters and monitoring devices could have an integrated broadband PLC chipset that use the connection to the LV grid to transfer the information to the network operator.

The same applies to solutions for residential customers within a Smart Home. If appliances such as refrigerator, washing machine, dishwasher, security systems and so on have an integrated PLC chipset the PLC network could act as a distribution network in the building and not like today as a access network to the building. Additional hardware like modems could be saved and the data transmission could be done simultaneously with the power supply. Nevertheless the Smart Home field is in its beginnings and several other applications will be available which are not mentioned in this document.

8.2 Markets

The Smart Home market is a growth market which is waiting in the starting blocks. Due to growing broadband Internet, digitalisation of the everyday life and new technologies Smart Home services will penetrate the market. The focus of such applications will be on new and renovated buildings. Especially services which aim security matters will be in the first row due to an increasing demand for safety.

Furthermore energy saving becomes more and more important due to increasing prices and short resources.

Narrow energy resources come along with an increase of DEG and RES and more efficiency in the electricity sector. Load management can gain strong market share if the necessary framework will be created. The electricity network will be operated under a stronger use of ICT. A notably part of the ICT will be operated in the residential buildings. The tasks of utility companies and PLC providers will be to develop this market under the use of PLC technology.

8.3 Technology

The next steps for further developments are

- IP based protocols and mechanism:

The convergence towards the IP protocol can be observed in all categories of telecommunications. Therefore the development of IP based protocols is a consequential step towards convergence.

- New interfaces for data loggers and meters:

The ongoing convergence trend will also commence on the physical layer. The respecting interfaces like Ethernet will be implemented. This will allow to directly connect meters, data loggers and other facilities to the telecommunication network without the need for converters.

- New web server based concepts:

As already described in chapter 5.1 Figure 14: Enhanced ARM and Monitoring system new web based applications will be developed. These solutions have the big advantage of scalability and open interfaces towards other web applications. The flexibility and openness of such system will allow the monitoring of heterogeneous networks.

8.4 Regulatory Aspects

Until now there is no common approach in the field of regulation for smart home applications. This is a result of the broad range of different services and players in that market. Therefore no concrete “Standard” has been developed yet. Even the Term “home Gateway” is not defined yet.

Different standardisation bodies are currently working on draft documents for a description of the smart home environment. As an example the input of the European Telecommunications Standards Institute (ETSI) NGN@home working group can be taken which is a part of the ETSI technical body AT (Access and Terminals).

CENELEC is also providing a document describing the requirements of smart home solutions (CENELEC SMARTHOUSE PHASE II Code of Practice).

Some open points in terms of regulation are:

- Standard interfaces
- Internetworking between different transmission technologies
- Standard APIs for applications
- Technological platform or framework

This work is in progress but may take some more time to be finished. Therefore a standard which is covering all aspects of smart home application is not foreseeable yet.

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