TECHNOLOGICAL BREAKTHROUGH FOR REAL TIME SMART METERING VIA POWER LINE COMMUNICATION (PLC)

EANDIS TESTS INNOVATIVE PLC CONCEPT IN 2850 FLEMISH HOMES (BELGIUM)

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ABSTRACT

Eandis, the largest grid company in Flanders (Belgium) operating for seven Distribution System Operators (DSO), developed and tested a PLC filtering method that considerably improves data communication via LV networks in the upper Cenelec Band A frequency range. Next to the PLC filtering, the Eandis concept also uses multiple gateways to connect the PLC segments to broadband Internet.

INTRODUCTION

For the above described concept Eandis was granted a patent which is published under reference WO 2009/000869 A1 'Distributor Powerline Communication System'. To confirm the performance gain achieved in real life it was decided to conduct a field trial or 'Proof of Concept' (PoC).

In this Proof of Concept the grid companies Eandis and Infrax are collaborating closely. Between April and June 2010 Eandis installed about 3 000 smart electricity meters and 1400 smart gas meters in 2850 homes near Mechelen (in Flanders). Infrax has a similar pilot project with 300 meters, spread over its operational area in Flanders.

In the Infrax area data communication goes via the broadband network for cable tv. In the Eandis area the smart meters use Power Line Communication: sending and receiving information via the low voltage network.

The aim of the Eandis and Infrax Proof of Concept is to verify the quality of the technology used and its impact on the business case.

In this article we will focus on the real life performance of the new Eandis PLC concept in terms of the promised near real time operation thanks to faster meter response and wider bandwidth actually available for each individual meter.

NEED FOR SMART GRID FUNCTIONALITIES IN SMART METERS

The need for smart grid functionalities in smart meters is rising sharply: the number of photovoltaic electricity production units on residential and business premises is exploding, plug-in (Hybrid) Electric Vehicles are expected to appear in volume on the roads the coming years, micro-CHP's (Combined Heat & Power) are leaving the drawing boards ….

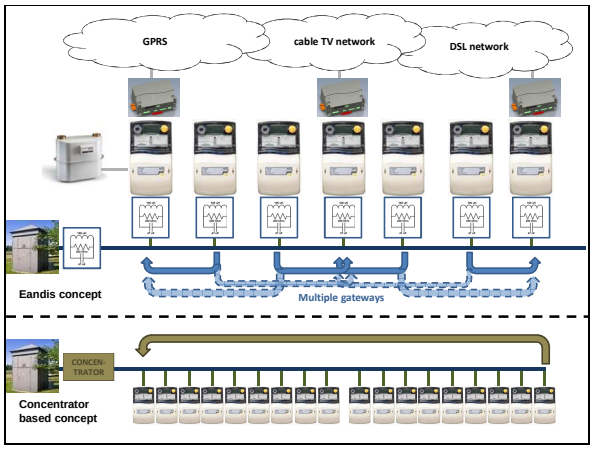
Distribution System Operators (DSO) are indeed worried that all these evolutions will put the stability of supply and the quality of service in danger. Furthermore, it is expected that most of the future developments for alternative energy production (and energy storage) will eventually lead to more energy traffic between local production sites and end users, leading to an increased risk of overloads during peak periods and unsteady voltage levels.

Studies predict that in 2020, as required by the European objectives, locally installed power generation will represent over 50% of the peak load on Flemish LV and MV networks. Given the lower reliability and availability of these sources, the possibility to control loads will become crucial to assure grid stability and to avoid expensive and less eco-friendly peak power generation.

The Eandis concept of advanced smart meters offers the possibility to control peak loads in two ways thanks to the improved real time performance: commands can be send to the smart meters in near real time and the great majority of the addressed meter groups will respond within seconds. Response to the commands will happen by either switching off the second independent LV outputs of the meters or by passing on the commands and information to the smart appliances in the houses and buildings via Cenelec band C powerline, wireless or via any other interface that will be standardized for building - and appliance automation. This interface will also be useful to connect in-home displays to inform customers about their energy use and even to offer interactivity and other information such as planned maintenance outages.

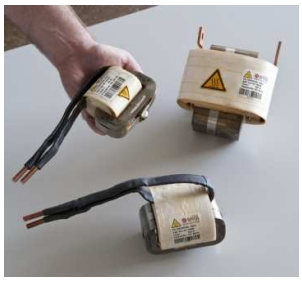
THE EANDIS SMART METER COMMUNICATION CONCEPT

Eandis introduces two innovations in the power line communication: PLC filtering and multiple gateways. The Eandis concept is based on Cenelec band A powerline communication but differs in various aspects from the traditional concentrator based approach.



Caption figure 1:
Eandis communication concept

All connections to the LV cable are filtered, even the outlet of the LV substation, and all meters can choose to connect to at least two gateways on each PLC segment.



Caption figure 2:
Left and under: 63A and 120A filters for smart meters, right above: 300A filter for LV-substation outlets

PLC filtering concept

Traditional Power Line Communication (PLC) has insufficient reliability. This is mainly due to sensitivity to 'noise' created by all kinds of electrical equipment in the homes connected to the grid. With the Eandis concept the noise generated in customers' installations is prevented from entering the LV networks by using a filter. In fact a reduction of over 20 dB in noise levels is observed on real networks by using the patented Eandis filtering concept.

The typical low impedance loads in the building installations and on the LV side of the distribution transformer are suppressing the powerline signals on the LV network. This can be avoided by adding filters with a 200 Ohm impedance in series with the power carrying wires in every connection on the upper half of the Cenelec A band. The filters guarantee an increased impedance on the powerline frequencies so that PLC modems can inject higher signal levels with another increase in the signal-to-noise ratio while introducing negligible impact on the mains voltage itself.

The same filters, but with a 300 A current rating, are also installed in the LV substations on every cable leaving the substation to suppress noise that is passed on from the MV side of the power transformers to the LV side whilst increasing the very low impedance of the transformer's secondary for PLC-signals. Furthermore, these filters isolate PLC signals on the different outlets so that gateways using the same frequencies on different PLC segments do not interfere. Also, PLC-signals tend to leak through the transformers, which causes inter-network interference. The filters in the LV-substation greatly reduce the levels of these leaked signals, and hence improve the signal to noise ratio even further.

Multiple gateway concept

Because the single concentrators installed in LV substations are replaced by at least two gateways on each branch of the network, the average distance between the meters and their selected gateway will be up to 4 times shorter (cfr. Figure 1). We expect this to improve the powerline communication quality dramatically since the use of 'repeating' meters will be almost unnecessary.

By installing multiple gateways, at least two on every PLC segment, each using a different frequency in the upper half of Cenelec band A. By using multiple gateways the single point of failure of the concentrator is avoided.

The available bandwidth in one PLC channel is shared by a far smaller number of meters and every meter can choose the gateway with the highest PLC signal level. Should the quality of the connection between a meter and its gateway deteriorate, the meter can switch to an alternative gateway avoiding loss of control of this meter.

The gateways will use existing broadband modems in the customer's premise. Spare gateways can be connected to available broadband modems and can be taken into operation via remote control to replace gateways that have for some reason gone out of operation. Half of the gateways will be connected to cable modems and the other half to xDSL modems. This offers redundancy against outages of single provider networks. The use of future 3G or later IP networks is easily possible.

New developments

Basically, gateways are bridging routers without much

intelligence: they simply pass data packets between the broadband IP connection over ethernet and the PLC segment. They have some buffering capacity to enable asynchronous operation between broadband and PLC. The MAC layer of the gateways has to take care of the meter registration process on the PLC segment and its communication quality. Algorithms to efficiently operate powerline communication were developed by Eandis. The final objective is to base all communication, even with respect to slave meters, on one protocol (probably DLMS). This avoids protocol conversions which are prone to error and difficult to maintain.

Thanks to all these improvements in communication reliability more efficient modulations can be considered, for example simple QPSK modulation with speeds up to 9.6 kbps. Simple error detection will suffice as it is inefficient to use bandwidth for error correcting codes if the risk of losing data due to transmission errors is low. Implementing retransmission of these data packets is more efficient.

The bandwidth between 50 and 95 kHz is cleaned with filters. Six channels are available, with the best channels located at the centre of this frequency range. S-FSK is used as modulation technique.

THREE KEY BENEFITS OF THE EANDIS COMMUNICATION CONCEPT

With the Eandis concept it is possible to read out almost every meter within a 15 minute period after the measured interval. Consequently, the electricity and gas markets can be provided with near real time information. This offers the following three key benefits.

1. Improved load prediction to enable a better balance between generated power and demand: less online backup power needed and less balancing cost for retailers. Without this feature ever more spare capacity will be necessary to remedy the expected decrease in reliable power generation due to the increase of 'unpredictable' local generation.

2. Pre-payment functionality: with the Eandis near real time concept the fast and reliable upload of credit to the meters is guaranteed. Meters should be able to work with Euros, keeping the indicated credit accurate without intervention of central systems.

3. Power quality measurements: measurement of minimum and maximum values of currents and voltages in each 15 minute interval with alarms generated when certain limits are exceeded. Possibility to record current or voltage waveforms in short intervals on operator demand to enable remote diagnosis of power quality issues like harmonics.

NEW OPPORTUNITIES

Apart from the unique filtered PLC concept with multiple gateways, several other functionalities seem to be vital to the integration of smart meters in a future advanced smart grid environment.

Smart meters with at least two independently measured and switchable LV outputs are recommended in order to be able to offer innovative energy services, such as:

- Managing time of use for electrical heating and hot water
- Measurement and switching of locally generated power: solar, combined heat and power micro-generation (micro CHP)
- Load control for non-smart appliances like refrigerators, heaters …
- Load control for electric cars
- Multi-tariff applications (time of use).

Phase switching for single phase meters to be able to dynamically balance network load over the three phases and to be able to remotely solve power quality problems such as over- or under-voltage.

Possibility to group meters and to quickly send group commands to these meters which might be especially useful in case of emergency.

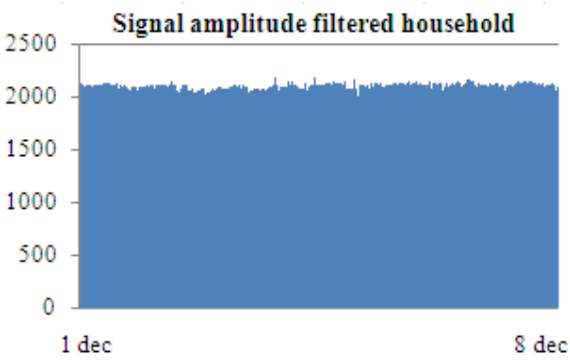
Opportunity to upgrade gas meters to static meters at the introduction of smart meters.

RESULTS PROOF OF CONCEPT

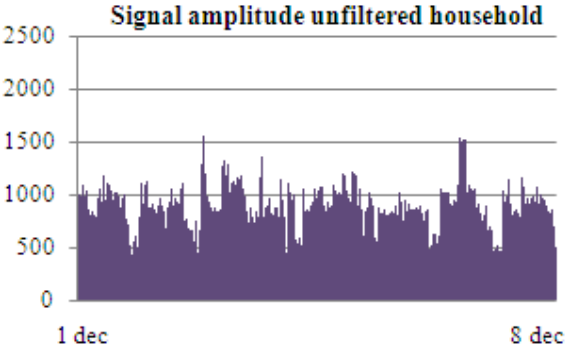
PLC filtering concept

Signal levels are measured by each operational PLC modem connecting a smart meter. A comparison between a filtered and unfiltered network was made.

The filtered network shows a significant improved signal strength. (cfr. Figure 3 and Figure 4) The mean signal strength of the filtered network is more than double with respect to the unfiltered network. Additionally the variation through time of the filtered network is much lower in comparison with the unfiltered network.

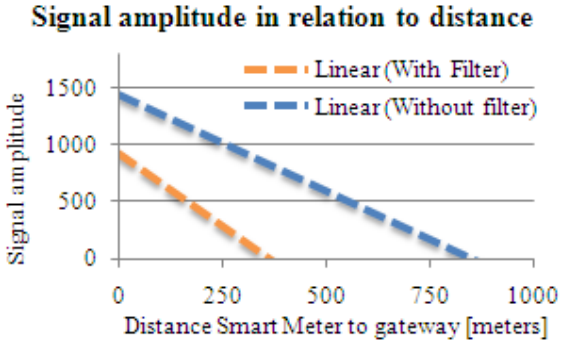


Caption figure 3:
Signal amplitude of the PLC signal over a period of 1 week on a filtered network.



Caption figure 4:
Signal amplitude of the PLC signal over a period of 1 week on an unfiltered network.

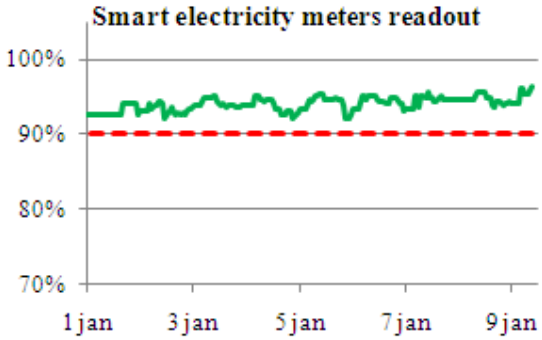
This filtering effect was verified over a large number of PLC modems. The signal amplitude has been interpolated in relation to the communication distance of the smart meter. (cfr. Figure 5) The PLC signal on the unfiltered network can be detected to distances of 350 meters. Filtering reduces successfully the dissipation of the PLC signal, thus enabling communication paths up to 850 meters, doubling the range of PLC communication.



Caption figure 5:
Interpolated signal strength of PLC communication in relation to the distance between transmitter and receiver.

Smart Meter Functionalities

The increased communication quality leads to an increased bandwidth for reading out smart meters. In a group of LV transformers including 600 meters, the ratio of electricity meters that were read out successfully during the last 4 hours is shown in Figure 6.
At least 92% of the electricity meters and sometimes over 96% of the meters have successfully reported their 15-minute consumption data to the central management system. The target was set at 90%.



Caption figure 6:
Hourly monitoring of the ratio of electricity meters that were successfully read out during the last 4 hours.

Further improving the readout percentage of the smart meters is done by means of firmware upgrades. These upgrades introduce new features and increases the communication quality even further. For example the PLC communication speed was increased by 60% since the installation of the smart meter.
The firmware upgrades are an automated process and are ongoing. The firmware size is as large as 196 kb and pushes the powerline communication to its limits. At the moment of writing a success rate of 82% is achieved, successfully proving the performance gain that can be achieved with the Eandis concept.