RELIABILITY AND DEPENDABILITY MANAGEMENT FOR DOMESTIC ELECTRICITY METERS

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INTRODUCTION
For the last 10 years, practically all new purchased and installed domestic kWh-meters in Denmark have been static or electronic meters. To gain information of the operational characteristics of the meter population after this sudden shift in technology, from the classic electromechanical meters to electronic, a systematic collection of service experiences with electronic meters has been established. Based on this a revised quality assurance system is under development.

QUALITY ASSURANCE OF kWh METERS

Metering of active electrical energy in the domestic sector is legal metrology i.e. measurements upon which exchange of money are based. According to national (Danish) legal requirements a satisfactory quality assurance system for the meters in service must be in operation for such measurements. The system shall be devised by the responsible meter operator and acknowledged by the legal authority.

Existing system

Measurement of active electrical energy is the responsibility of the grid companies. They operate a quality assurance system for domestic meters in service which is based either on replacement of the meter after a service-time of 14 years or on sample-tests after 10 years in service. The latter method is the most used. The grid companies have arranged to pool their meters in order to maximise the number of the individual meter types in the population, from which the samples are drawn. The sampling tests are in accordance with ISO, Ref (3) or Ref (4), and based upon the error of the meter at rated current and at 5 % rated current.

Correlation with life expectancy

The above mentioned system has been in operation for a length of time, and works quite satisfactory. Even though its primary aim has been to secure the metrological quality of the meters in service, it has actually also proven itself as an effective mean to secure a gradual out phasing of old meter-types as they reach the end of their service life. The success of this system, however, relies on the fact, that all meters are based on the same electromechanical principle: They are all Ferraris meters, a mature technology, the only relevant ageing process of which is connected with the mechanical wear in the bearings.

ELECTRONIC METERS

The new generations of meters, based upon electronic and digital solutions can be expected to have different service characteristics than the electromechanical meters. As a consequence, the operational routines including the quality assurance system need to be revised as electronic meters begin to comprise a significant part of the meter population.

Metrological characteristics

Whereas all electromechanical kWh meters work after the same principle, the term "electronic meter" covers several generic very different principles; they may be based upon Hall sensors, on logarithmic amplifiers or fully microprocessor based etc. A priori it can thus not be expected, that the long-term behaviour is identical through all types. As that they do not contain moving parts, except maybe for an electromechanical counter, it is common for all, that no wear can be expected. They do however all have analogue components, resistive voltage dividers etc. which may drift over time, and the individual parts of electronic constructions may certainly show ageing effects, but this can to a large extend be foreseen and counteracted at the design state. It could thus be expected, that electronic meters have metrological characteristics, i.e. error-curves, which are much more stable over time, than the electromechanical. Initial measurements seem to support this assumption.

Reliability.

An electronic meter consists of a large number of individual parts, fault in which lead to malfunction of the meter. The probability for this to happen can be evaluated at the design stage. It is in practice influenced by the manufacturing process and by the specific environment in which the meter is operating and is not easy to predict accurately. Domestic kWh meters today are mass-produced constructions of controlled high quality, but they are on a very price sensitive market. It must thus be expected, that a certain number of meters will fail in service, and that the proportion which fails is higher than for electromechanical meters, which is a mature technology.
Working with the service characteristics of meters, it could then seem to be justified to expect the reliability to be a more relevant property for the long-term behaviour than a slow change in the metrological characteristics for the average of the population.

Generations

Domestic electronic meters have been on the marked for over 10 years now. When a new technology is introduced, the first generations tend to have different characteristics than the later, especially concerning reliability. Teething-troubles can be expected for the first generation etc. As the technology grows older, becomes more mature, new types will be introduced, and existing solutions will be optimised in the manufacturing process etc. This may not necessarily imply a higher reliability of the individual types, but most often, the reliability for the technology as such will improve.

In general must be anticipated that the electronic meters in service now and put into service in the years to follow, comprise a rather inhomogeneous population with quantitatively different long term characteristics.

Development of the Population of Meters in Service

The average rate of replacement of meters in Denmark is approximately 2 % per year. The total population of domestic meters is 2.8 million. It is fair to assume, that all new meters are electronic from 1995 and onwards, which gives a population in the area of 400,000 electronic meters in service today. It is worth to note, that even though all new meters are electronic, at the present rate, 50 % of the meter population will still be electromechanical in 2015. There seem to be reason to believe, however, that the exchange rate will raise considerable due to a wish for the introduction of remote reading of domestic meters. Through this, meters will be replaced even if their service-life has not expired, and the composition of the population of meters in service will change more rapidly.

![Population of electronic meters](image)

**Figure 1. Population of electronic meters**

Electronic meters from more than 15 different manufacturers are in service today. As can be seen on fig. 1, the majority (85% of the population) is however from only 5 different manufacturers. Never the less, the number of different types in operation may expected to be high and the differences in operational behaviour accordingly.

**Quality Assurance of Electronic kWh Meters**

A quality assurance system for electronic meters should focus on the availability of (correct) measurement of the electrical energy at the consumer/customer. This imply a meter which works, and which works with satisfactory metrological properties i.e. error of measurement in accordance with the prescribed class.

Sample tests of the meter population, or a simple fixed-time based system will deal satisfactory with the latter requirement, provided that the rate of change in the metrological characteristics with time is known.

The former, i.e. the individual meters which suddenly stop due to an internal fault, is more difficult to deal with. If sudden errors are rare, it is possible to deal with the individual events in turns, independently of the quality assurance system. This has been the case with the electromechanical meters.

If sudden errors are frequent and statistically a threat to the availability of correct metering of the population, the quality assurance system needs to deal with that.

**Systematic Collection of Data and Establishment of the eLS Database**

As the demand for systematic knowledge of the operational properties and long-term behaviour of electronic meters became evident, it was decided to establish a national database, the eLS database, and launch a system for collection of operational experiences with the electronic meters to the database. A pilot project was established, and the system developed within this. During 2004 the system has been introduced to the majority of the grid companies, and it will go into normal operation during 2005.

**System**

The system is based upon a standardised report-form filled out manually by the operator, as the individual meter is replaced, repaired or just inspected. The information recorded identifies the meter, its type, serial number, the primary fault i.e. meter stopped, display not readable, mechanical damage etc. and which functional unit has failed. The philosophy for error classification is based on IEC TR 62059-11 Ref. [2]

The information from the report-sheets is transferred to the eLS database over the internet by the grid company. The eLS database is located and maintained by DEFU. It contains for each event, information which identifies the meter in question, down to its Serial number, the history of the meter, its reading(s), description of the fault and its primary and secondary causes and more.
Other means of information

The information which is gathered in this way may, for the individual events, be supplied with additional information which could be based upon a more thorough investigation of the faulty meter. Also information of changes of the error-curve with time in service may be added. This information can be obtained from the existing quality assurance system, sample tests after 10 years in service, as long as this is still in operation.

Administration of the eLS database

The data in the database are regarded as confidential. The grid companies who supply information to the database have access to their own data, and to their own data compared to the other grid companies in anonymous form. The service performance of the individual types is compared to each other using statistical tools, and the grid companies have in principle access to these data. The manufacturer may also have access to the data, but only data from their own meters compared to the average of the other meters in service (again in anonymous form).

RESULT THIS FAR

The number of events reported to the eLS database today is of course limited; the majority of the meters in service, (85 %), are after all still electromechanical and few electronic meters have been in service for more than 10 years. It is thus not possible to draw specific conclusions on individual types of meters yet. If all types of electronic meters are pooled together and treated as one, it is however possible to extract some information. There may be no physical justification for a pooling of all the meters, as their only common characteristic is, that they all are “non-electromechanical”, but it serves to illustrate the potential of the database and some of the principles used in the treatment of data. Electronic meters installed in 1996 can be taken as an example:

Their total number is 121,000. In the analysis of the service performance we have excluded faults occurring in the first service-year, as these clearly are of different types and origins than later faults. During the following seven years all in all 90 of the meters have failed.

Fig 2 shows a Weibull plot of the Unreliability function F(t) of the population i.e. the part of the population which will have failed at a given time. After e.g. 9 years 1 % of the meters will have failed. The slope β of the curve is of particular interest, as it informs of the failure rate for the meters i.e. the probability for a fault in a meter the next small moment, at a given time, provided it has not already failed. A β = 1 indicates that the rate is constant. That is in fact the case in fig 2.

![Weibull plot of the 1996 population of meters: Unreliability function F(t) in function of years in service](image)

The expectations with electronic constructions, are a β value below 1 at the very start of the service life for a given product (burn-in problems), a value close to 1 during the majority of the service life, and a value larger the 1 in the end, corresponding to a rise in the fail-rate and indicating the end of the practical service life.

![Slope for different populations.](image)

For all the populations, Weibull plots of the unreliability gives values of β as shown in the figure 3. It must of course be emphasised, that the statistical background is limited, and that different types with different characteristics are pooled, but the indication of a failure rate which after so relatively few years in service is all ready increasing is somewhat remarkably. An other valuable information already obtained with these relatively limited set of data is the actual value for F(t), the unreliability. As sufficient amount of data arrives to deduce the service characteristics of the various specific types, their characteristics can be compared to the average value, indicating more and less reliable types.
USE of eLS

eLS shall serve as a source of information of the service performance of the different types of meters in service. In this it can be used by the grid companies when they plan to purchase new meters, and in their operational planning. Besides this, the information in the database shall be used to establish a quality assurance system which is tuned to the characteristics of the electronic meter.

QUALITY ASSURANCE OF METERING

The availability of (correct) metering of electrical energy at the end-customer depends of a meter, which works and which measure the energy correctly i.e. within the prescribed accuracy limits.

The change with time of the error-curve of the meters can be deduced from the (sample) test after 10 years, which most companies use for electronic meter also. Up to now these results seem to confirm, that the measurement error for electronic meters remains stable over years. But this needs of course to be stated more general, also considering that the first generations of electronic meters may have other long-term properties than the following.

If the period can be extended beyond 10 years is thus not clear yet. The present limited experience indicates however no causes for a shortening of that period.

If the probability of a fatal fault in the meter is low, it may be sufficient to concentrate on the accuracy of the non-faulty meters. If the probability is high, then the complete population may need to be changed. This situation can not be dealt with by the simple fixed-time tests but needs the information which can be extracted from the eLS database.

One promising way to work with the reliability of the meters is through Dependability Management, focusing on a given availability for (correct) measurement of energy, and not a fixed-time control system.

DEPENDABILITY MANAGEMENT

Dependability management Ref [1] offers the possibility of defining the quality level for domestic metering as a value for the availability of correct metering.

The availability of correct metering is a function of the probability for the meter working correctly and the replacement/repair performance of the meter, should that not be the case.

The Availability (A) can be calculated from two parameters, the Mean up-time (MUT) during which the meter is ready to perform its function and the Mean down time (MDT), the time necessary to discover the fault and replace the equipment. Ref[1]:

\[ A = \frac{MUT}{MUT + MDT} \]

MUT depends on the failure rate of the meter, and can thus be derived from the eLS-database. MDT depends of the repair or rather the exchange rate of defective meters. The main parameter in this quantity is the time elapsing from the meter develops a (fatal) error to the error is detected. A faulty meter will normally be detected through the reading of the meter, in comparison with the normal consumption. At present the meters are read annually, and a period of more than one year can easily pass until a fault is discovered and reacted upon.

Trade-off between meter reliability and service performance. One particular interesting feature of dependability management is the possibility for the meter operator to make tradeoffs between meter reliability, which could depend on meter age or price and the service performance of the organisation i.e. how rapidly can a faulty meter be detected and replaced. The time-critical part of the latter is the time to discover the fault. If a direct communication link to the meters is available, this time can be shortened radical. Remote reading of the meters may offer such a link.

Remote reading of meters Remote reading of domestic meters will be introduced by Danish grid companies in the coming years. More that 20 % of all meters are for example planned to be read remotely within the next 5 years. The reason behind these decisions may have nothing to do with the quality assurance question, but through this, the MDT may be brought considerable down. Through remote metering it will be possible to detect a faulty meter instantaneously, if the meter itself can identify an error. Most electronic meters have a self-check facility which makes this the case. The information needs only to be based through the same communication canal as the metering values.

Even though a self-check facility is not available in the meter, remote reading of the meters will shorten down the time to discover a faulty meter considerably; normally meters will be read once a month, and with relatively simple SW routines, it should be possible to discover a faulty meter after a little more than one month.

Legal considerations. As the quality level of metering is a legal parameter, the legal authorities need of course to accept such a system. In fact, the legal authorities need to fix the value for the availability of correct metering. The parameters for this could for example be based upon the quality level defined by the present sample test system.

CONCLUSION

The shift to a new technology for such a vital component as the electricity meter has prompted the investigation of operational routines and quality assurance for the new meters. Information of the service characteristics of the new types of meters are collected systematically through a new set of routines, and the information compiled in a central database, eLS.

This database contains only limited amount of data yet and it is not possible to draw far-reaching conclusions. Not unexpectedly it appears, that electronic meters in general
show a good stability in their metrological data, but that their reliability performance needs to be studied carefully. Even though it is still early days for a picture of a quality assurance system adapted to the characteristics of the changing meter population, interesting perspective can be drawn. The philosophy in Dependability management, in combination with remote reading of the domestic meters, offers interesting new perspective for quality assurance of the meters in operation, with a freedom in operational choice for the grid companies.

References


