CZECH METROLOGY INSTITUTE

# On an alternative approach to the architecture of measuring instruments in legal metrology

Dr. Pavel Klenovský, Czech Metrology Institute (CMI)

Currently, many aspects of digitalization and its impact on legal metrology are studied in metrology community. Various benefits are identified in the first place, arising problems associated with cyber security remain usually in the background. The elevated focus on digitalization in legal metrology can be dated back to the time after the turn of the century when electrical energy utility companies started using the remote transfer of data from electricity meters and their analysis to manage the load in the network and save up consumption of energy. Meters with embedded software and the functionality of a bidirectional transfer of data with external networks started to be called smart meters, especially those used by utilities: electricity meters, gasmeters, thermal energy meters and watermeters. All those measuring instruments are accumulating data for some period of time after, based on them, the customers are invoiced for the consumption of the media. There are different situations in legal metrology, e.g. in direct sales to the public where the transaction has to be closed on spot (e.g. weighing instruments in shops). This article concentrates on smart meters only.

For a long time, at a frustration of some energy specialists, no definition of a smart meter or a smart metering system has been given in legislation. Eventually, in the recast EU Electricity Directive ((further referred to as ED) there is the following definition:

*(23) 'smart metering system' means an electronic system that is capable of measuring electricity fed into the grid or electricity consumed from the grid, providing more information than a conventional meter, and that is capable of transmitting and receiving data for information, monitoring and control purposes, using a form of electronic communication;*

High expectations have developed with time as regards utility meters, especially electricity meters, as to their potential to reduce energy consumption - probably the best hopes to this respect have been harboured in the European Union (EU) which has decided to support this aim by legislation. The basic underlying idea has been that if customers are supplied with up-to-date data on their energy consumption and offered incentives to save up energy (a dynamic contract) they will duly cooperate in achieving savings. Whether this is a realistic assumption is still to be seen – as it happens, the first to rise were the energy bills to their annoyance. On the other hand, predictions are that the consumption of electrical energy will only rise (electromobility, digital infrastructure etc.) – an economy aiming at de-carbonization is an economy transferring to electrical energy so that saving measures cannot be underestimated.

Anyhow, the EU Electricity Directive (2009/72/EC) was first published in 2009 as a part of the 3rd Energy Package. Among others, it has required the Member States (MS) to launch a massive installation of interoperable smart metering systems (without giving a precise definition) – a roll-out – within their territories to cover 80% of customers by 2020 (Annex I.2). No implementation rules were given. This provision was subject to a Cost-Benefit-Analysis (CBA) – some countries (the UK, Sweden, Finland) immediately started with a massive roll-out achieving the target, some other have submitted a negative CBA (Belgium, CR). The basic aim of the legislation in this respect was to motivate consumers to play an active role in energy savings by providing extensive information by communication networks about their electricity

consumption which smart meters would enable. As the open source information (Internet) in recent years might indicate the involvement of consumers as measured by the number of dynamic contracts has not reached sufficiently high levels – instead, complaints about higher energy bills without any benefits have abounded. There are other reasons for a widespread use of smart meters as well: erroneous on-spot taking of readings (inclusive self-readings) and handling of measured data, unreliable mechanical counters that in the past resulted in considerable damages to consumers and to litigation.

Then in 2012 European Commission (COM) published COM recommendation 2012/148/EU on preparations for the roll-out of smart metering systems which lays down in general terms all the proposed functionalities of a smart measuring system (art. 42) inclusive standardized consumer interfaces, advanced tariffications etc. This was followed by the so-called CEP (Clean Energy for all Europeans Package) which also includes a substantial recast of the Electricity Directive 2009/72/EC – EU Directive 2019/944 to become effective on January 1st, 2021. The requirements on the functionalities have been taken over from the COM recommendation (art. 20 of the Directive).

It has to be pointed out here that one of the key attributes of a smart metering system (of which a smart meter is a core part) is the ability to enable some kind of a remote access to the measurement data to the final consumer. This is stipulated in the corresponding provision 20 (a) of ED:

*(a) the smart metering systems shall accurately measure actual electricity consumption and shall be capable of providing to final customers information on actual time of use. Validated historical consumption data shall be made easily and securely available and visualised to final customers on request and at no additional cost. Non-validated near real-time consumption data shall also be made easily and securely available to final customers at no additional cost, through a standardised interface or through remote access, in order to support automated energy efficiency programmes, demand response and other services;*

At the same time, electricity meters have been regulated by the **Measuring Instruments Directive (MID) 2014/32/EU.** This EU Directive covers 10 kinds of measuring instruments being typically regulated around the globe, among them also electricity meters (unfortunately, only active ones) – Annex MI-003. The Directive is a recast of an older directive – 2004/22/EC with minor changes of non-technical character only. Obviously, it reflects the technology state-of-the-art sometimes in 2004. Under the current COM approach to legislation the directive was basically restricted to protection of consumers and SMEs where electricity tariffs were totally independent of reactive power so that covering only the active part was deemed sufficient at that time. Among others, there is the following provision in the directive:

**The Measuring Instrument Directive (MID), Annex I, 10.5:**

*Whether or not a measuring instrument intended for utility measurement purposes can be remotely read it shall in any case be fitted with a* ***metrologically controlled display accessible without tools to the consumer****.* ***The reading of this display is the measurement result that serves as the basis for the price to pay.***

Firstly, it has to be pointed out that if this provision is written today it would surely require a validated remote access for the customer (not only a non-validated as in ED), the display played this role in the past.

Implementation of the EU metrology directives is a subject of proceedings of the European Commission Working Group on Measuring Instruments (COM WG MI) organized by COM DG GROW. In preparation for the COM WG MI meeting in 2019 one of the MS Ministries of Economy sent in an analysis of the situation in the country after a massive roll-out finished in 2018 – among others, it has been pointed out that this 1st generation of meters does not comply with the requirements under art. 20 of the recast Electricity Directive starting with point a) (e.g. a limited memory space of rolled-out meters does not allow to retain all the hourly data on consumption between billings for consumers to be able to analyse them). Putting now the MID limitations aside, a roll-out of the 2nd generation of smart meters compliant with these functionalities should now be launched just after the roll-out of the 1st generation has been completed. As the associated costs will be transferred to consumers already partially dissatisfied it is the situation which should have been avoided if the hearts and minds of consumers are to be won. Controversies have been rising whether electricity meters complying with the energy legislation can fulfil also the above-mentioned MID requirement.

The last developments in the energy sector aimed at achieving energy savings and flatting-out energy demand by motivating consumers to play an active part in the process have indicated that the main motivation factor is a provision of near-real time data on consumption by smart meters (15-30-60 minutes). The experience from the Member States with a high roll-out of meters can be summarized as follows:

- There is a non-alignment between Electricity Directive and the directive on measuring instruments MID which covers also electricity meters concerning information provided by meters for the sake of consumer protection.
- It has appeared that rolled-out meters have technical parameters not enabling them to provide all the hourly data on consumption between consecutive billings to consumers.
- Some consumers started to criticize the roll-out as they could not see any benefits while energy bills went up.
- The uptake of dynamic contracts for energy delivery currently at 10% is still relatively low.

One of the agenda points of the mentioned COM WG MI meeting was devoted to discussion whether especially the highlighted parts present a severe obstacle to a roll-out of smart electricity meters as required by ED – especially the first sentence does not arguably permit even a creative interpretation to be in compliance with it. As a first comment, it has to be pointed out that MID should have been revised already as a follow-up to the 3rd Energy Package after 2009, especially after the COM recommendation with proposed functionalities was published in 2012. Recital 59 of MID states that, to take into account the technical developments, amendments to instrument-specific annexes are delegated to COM. Unfortunately, in this case the problem mentioned above lies in Annex I “Essential Requirements” so that the delegation under Art. 290 of TFEU cannot be used here. There are other strong arguments for a major revision of MID, on the other hand, any such legislative change would require at least 4 – 6 years to be finalized so that faster solutions have to be considered very seriously as well.

In parallel with these developments, due to the fact that remote transfer of data is a main attribute of smart meters, WELMEC WG 7 responsible for software in measuring instruments has struggled to prepare guidance for validation of SW for these telecommunications for the purposes of certification under MID – WELMEC Guide 7.2. For communications there are a couple of requirements here, among those basic ones especially P4/U4 being mandatory:

***P4/U4: Influence via communication interfaces***

*Commands input via communication interfaces of the instrument shall not inadmissibly influence the legally relevant software, device-specific parameters and measurement data.*

P4/U4 is about what communication interfaces are used and **what commands** can measuring instruments accept so as the measurement data used for billing are not corrupted.

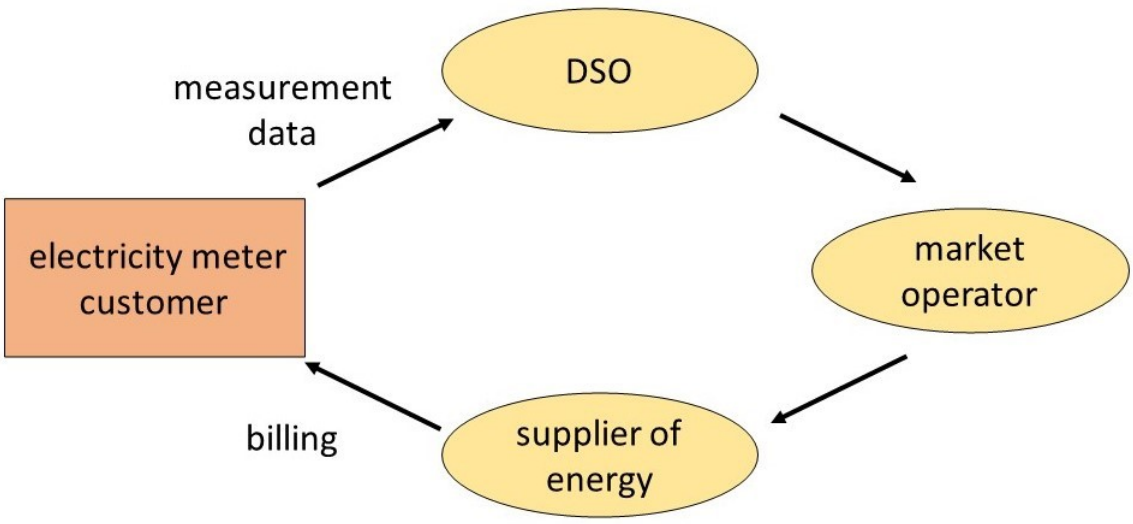
Additionally, there are optional requirements for so called Extension T: "Transmission of Measurement Data via Communication Networks", among those is a demanding requirement T6:

***T6: Receiving, verification and handling of transmitted measurement data***
*There shall be legally relevant software for receiving, verifying and handling transmitted measurement data.*

In the sub-group of WG7 „New technologies" a discussion was opened in 2019 what position to take towards this unresolved aspect of smart-metering in relation to telecommunication. After a decision by the COM that details of smart-metering are to be laid down by Member States themselves WG 7 has decided to abandon this matter.

As it has been demonstrated during discussions between CMI and distribution system operators (DSOs) in the Czech Republic that it is totally unrealistic in the energy distribution system after the horizontal unbundling to submit to any validations/certifications various SW applications used by different bodies along the route from the customer meter down to the billing as exemplified by Picture 1 (in a simplified way):

**Picture 1**

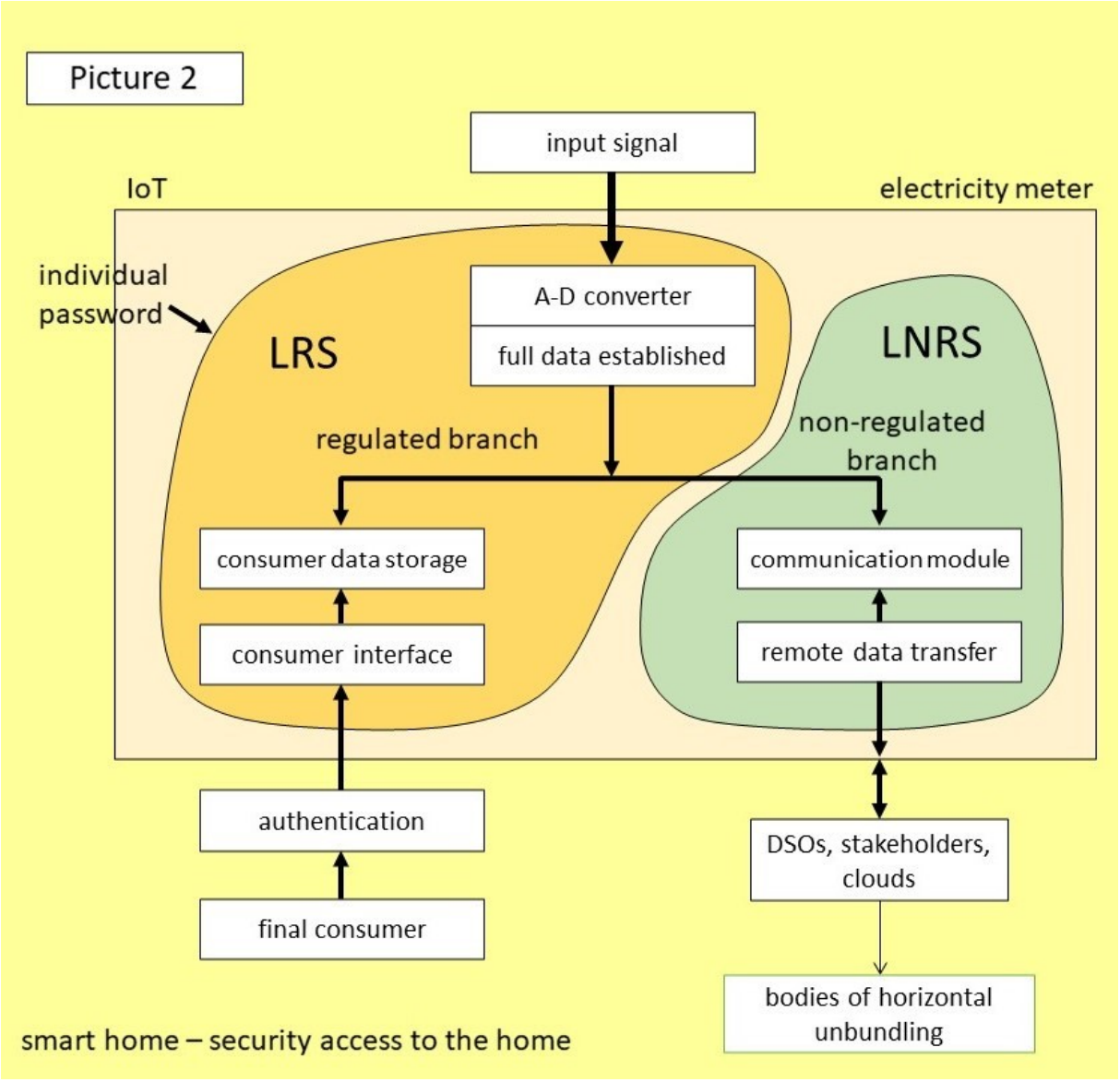



Such certification efforts would be standing in the way of fast and unpredictable innovations in such SW applications. Therefore, we are confronted here with a rather frustrating fact that the most important functionality of a smart metering system cannot be certified. This is surely not an ideal situation: as a communication platform in smart electricity meters so called DLMS/COSEM (EN 13757-1) is often used - CMI software engineers have found that the display with the consumed energy can be remotely switched off using this software which is obviously a hard violation of MID requirements (and not exactly supporting confidence of consumers). On a direct question to the corresponding user association the response was that

this aspect has not been covered in the development of this software - DLMS does not guarantee a compliance of this SW application with MID. It clearly demonstrates that to get those communication channels under independent regulatory control is in fact impossible.

As to measuring instruments in general we are now facing a problem that in times of fast technical innovations due to digitalization the regulation has been often critically trailing back behind those developments thus impeding innovations - and it is unrealistic to assume that the situation in future will be any better. A possible solution to this fundamental problem might be a decoupling of the necessary regulated part of the measuring instrument for the sake of consumer protection from a non-regulated part open to free handling of the measurement data supporting innovations. It will be a responsibility of those processing those data to adopt necessary cybersecurity measures so that these data can get back to the consumer as a part of the billing in an uncorrupted way – and the consumer could independently check via his/her dedicated interface what the original data stored for this purpose in the meter were.

In case of electricity meters, the novel architecture is illustrated on Picture 2:



Immediately after the full measured data are established in the meter they are to be stored in a special consumer data storage. The detailed structure of this storage facility is beyond the scope of this article, however the main principles might be dependent on the requirements of national tariffications and of dynamic contracts taking into account that we deal here with 3-phase 4-quadrant active/reactive meters (measuring in both directions of energy flow – consumption or delivery of energy):

- it should exceed in coverage the billing period (e.g. the last 1+1/4 year if the billing period is 1 year);
- to store customer consumption data for a reasonable time in order to allow the customer and any third party designated by the consumer to consult and retrieve data on past consumption;
- data on consumption and delivery of active and reactive energy in all 3 phases as tariffication requires (every 15 minutes ?);
- data on 15/30/60 minutes of metering intervals in all 3 phases as tariffication requires.

The detailed structure of the data for electricity meters should be an important work item for WELMEC WG 11, possibly it could be even a matter of an applied research project under the EU research programme EMP. Currently, tariffication systems are different in the Member States which should ideally be overcome by EU legislation to achieve very much needed harmonization – this would facilitate the work on the structure of the data storage. The information in the data storage will be remotely available to the consumer only (or to a third party designated by the consumer) by way of a PC, a tablet or a smart phone, playing here the role of a display, in a similar way as citizens would access e.g. their bank accounts.

Various communication technologies can be used in the regulatory part to transfer the data to the customer by way of the customer interface (Bluetooth etc.), however the most systematic option is clearly a connection to the Internet and to design the meter as an IoT (Internet of Things). It is given by the fact that consumers are either business or citizens in homes: all the businesses are now using wired or Wi-Fi connection to the Internet and with the development of the concept of smart homes the same will be sooner or later applicable here as well. Meters would therefore become here a part of the common internal infrastructure covered by the local cybersecurity measures (by a Virtual Private Network – VPN with a firewall) which is important as connections to the public internet are most prone to attacks. Under these circumstances, the electricity meter as an IoT would not result in any additional costs as a VPN server would already be available (and VPN SW is now free of charge up to 1 GB of data/month) in smart homes. In ordinary homes without the internet the additional costs might be individually accepted or the consumer would have to rely on the display of the meter as before (otherwise, the display could be abandoned). However, there is a strong drive in the EU towards smart metering “at any costs” so that it can be expected that ICT specialists will find solutions here as well – anyhow, such work is in WELMEC WG 7 already ongoing.

Such a split of the architecture into regulatory and non-regulatory branches would require a separation of the SW into a legally relevant part (LRS) and legally non-relevant part (LNRS) as shown in Picture 2. Currently, this is not common in electricity meters with typically embedded SW but it can help to implement this idea of separation in other functionalities and can prevent negative effects of communication systems on the measurement data. The access to LRS can be individually password-protected to enhance the cybersecurity (no hacker can get a control over the whole batch of meters of the same type in the field).

As to authentication of the access to consumer data even more robust alternative way can now be considered. It is the access and authentication used by banks to get access to individual citizen´s bank accounts. Due to the importance for general public, it is also supported by special EU legislation: Directive (EU) 2015/2366 (Payment Service Directive 2) and corresponding Resolution (EU) 2018/389. Protection against fraudulent transactions is, in a simplified way, based on the notion of "Strong Customer Authentication" *(an authentication based on the use of two or more elements categorised as knowledge (something only the user knows), possession (something only the user possesses) and inherence (something the user is) that are independent, in that the breach of one does not compromise the reliability of the others, and is designed in such a way as to protect the confidentiality of the authentication data).* It is not necessary to go into any details here – at first look, such an access seems to be too robust in application to data in meters and thus potentially expensive. On the other hand, banks would offer this infrastructure for public purposes which is this case here free of charge – the bank identity (BID) is now the most commonly and widespread used method to identification of persons and to an access to on-line services, most people consider it to be user friendly enough. In that way, the raw measurement data just after their generation in the meter would be made available, using the existing free-of-charge cyber security infrastructure, to final customers.

In conclusion, let us return to the disputed provision of MID, Annex I, 10.5 on "…*metrologically controlled display accessible without tools to the consumer".* The interpretation of what constitutes an access without tools for the consumer very much depends on his/her point of view – arguably, a majority of people would consider their current access to a bank account, bringing a number of benefits, as not requiring any (special) additional tools and in the same way they can access their consumption data in the electricity meter where a tablet or a smart phone can play a role of a display. And those who would consider it really (unacceptable) additional tools might keep using the display in a traditional way or can designate a third party acting on their behalf to get the access (e.g. older, retired people to their children). It could therefore be argued that electricity meters designed in the way described above would comply with the MID requirement under scrutiny and at the same time would be fit for full implementation of the energy efficiency legislation. The proposed architecture would provide ample room for innovations as no regulation would stand in the way to use the measurement data for any possible other applications than consumer protection. And final consumers could any time check what their consumption is via the special interface – to employ a similar system to get access to bank accounts might mitigate the risk of complaints by citizens that user interfaces of smart meters are too complex, not user friendly. However, the development towards wide spread use of smart metering is inevitable, even in countries with a negative CBA like CR there is a plan to use exclusively smart metering by 2027 anywhere where the annual consumption exceeds 6 MWh. Furthermore, the ED encourages MS with a negative CBA to deploy smart metering systems which should allow consumers to benefit from the installation of a smart meter, upon request and under fair and reasonable conditions, and should provide them with all the relevant information. It is also in line with pressure on building renovations supported by EU legislation (smart homes). It remains to be seen what the impact on the price of such a meter might be – in modern households with VPNs it will be basically just the cost of the data storage (which is, however, required by the energy efficiency legislation anyhow). The last but not least, the article 20 (Functionalities of smart metering systems) of the recast ED states at (a) that *near real-time consumption data shall **also** be made easily and securely available to final customers at no additional cost, through a standardised interface or through*

*remote access, in order to support automated energy efficiency programmes, demand response and other services*. The proposal aims at facilitating to achieve this goal in as close a way to the MID provisions as possible.

The discussed topic is associated with legal metrology concepts in general – as any regulation is always slow in response to technological developments it would be wise if legal metrology in future confines itself to minimal arrangements necessary for effective consumer protection not to stand in the way of innovations. It is applicable not only to electricity meters but to utility meters in general and to other categories of legally controlled measuring instruments like weighing instruments etc.