A General Review on DLMS/COSEM and IEC 60870-5 Smart Grid Standards

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***Abstract* – DLMS/COSEM and IEC 60870-5 standards, are the most widely accepted standards for smart grid industries at Europe and large sections of the world. It is the trend for the observable future. This paper reviews these standards, and an effort is being made to present the material from an innovative point of view. There are various accurate and clear papers describing the standards, and these works are referenced herein. Most of the relevant articles are from professional journals and less from academic journals. This paper –gives explanation to the objective of these standards. Moreover, it explains why these standards successfully obtaining that objective. The paper reviews the standards in a way that enables the reader to access them, and provides technical means for people who wish to start implementing them. Professionals from various disciplines: metering and equipment industry and any proffesional who wishes to test the level of adaptation of a purchased equipment.**

Index Terms--*AMI – Advanced Metering Infrastructure. Tech – technology. DMZ – De Militarized Zone. SCADA- Supervisory Control and Data Acquisition.*

I. Introduction

DLMS/COSEM is a standard intended for unification of the interaction of revenue meters (not only electric) to a remote metering center. IEC 60870-5 is a standard for supervisory control and data acquisition *(SCADA)* **control and monitoring** equipment of **electric networks**. The official objective of these standards is to regulate this equipment market. Effectively they **enable** the successful construction of a smart grid. The following two figures demonstrate why this is so. Fig 1 shows a heuristic layer structure of the

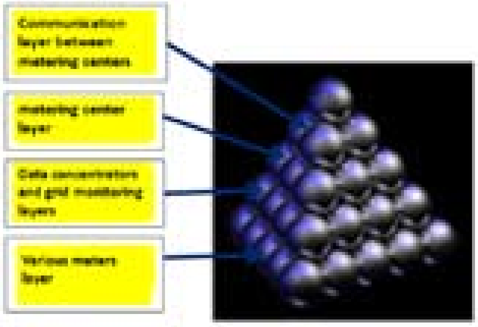

Fig 1: a pyramidal construction of the smart grid through technological layers

smart grid. If the revenue meters layer, or the conduction infrastructure monitoring and control layer, equipment consists of multiple technologies, let's say N technologies, then the technological integration and assimilation effort is at order $O(N)$. Most of the construction effort shall be invested at the multiple technological layers, and there shall remain no resources to construct the further hierarchal layers. The integration effort is affected by many parameters: financial budget, technical integration (comm. etc.), maintenance effort, failure rates, diagnostics effort and ease of implementation. One method of reducing the effort is to unify the technology through standardization and regulation as displayed in Fig 2. Another method is through automation of testing and other tasks. The unification takes a bundle of technological equipment and turns them into a single technological cluster. By that the various integration efforts are reduced to $O(1)$ or being on the safe side mostly $O(log(N))$, meaning usually bundling into a few sub clusters is succeeded, forming a tree as seen in Fig 2. If for example 20 equipment types are being used at the smart grid, with an average bundling success of log_{10}, it means that approximately *1.3* equipment integration effort is required, namely 130%, rather than 20 equipment integration effort.

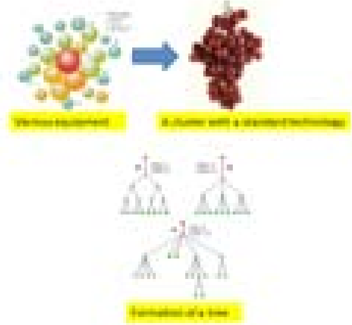

Fig 2: (a) heuristic view of bundling of various technologies and instruments into a single cluster of unified technology. (b) formation of a tree through *physically* or *technologically* clustering of several instruments into a single technology.

Other goals obtained by the two above standards are: (a) prevention of collapse of the smart grid structure through reduction of complexity and partition of load/effort to sub nodes of the tree. (b) minimization of dependency over a specific manufacturer or test equipment. The equipment is not identical, allowing each manufacturer to install its own cutting edge technology. (c) minimization of integration time due to usage of robust technology. After the explanation of why are the standards required a discussion on why are these specific standards successful at obtaining that task is presented. Not all standards succeed to remain for so many years. DLMS/COSEM and IEC 60870-5 support: (a) *standard communication*, of the high level layer (=DLMS), and *low level multi-protocol* support- The entire range of protocols and communication methods at the industry is supported by DLMS/COSEM: Ethernet, GSM/GPRS, Wi-Fi, ZigBee and PLC. At PLC various communication standards declared by relevant organizations are covered. DLMS/COSEM and IEC 60870-5 are high-level protocols, i.e. they do not replace any of the low level protocols. Additionally DLMS/COSEM adopts every new meaningful low level protocol. (b) *Standard data structure*-In order to obtain equipment plug & play ability, it is insufficient to obtain standard communication. The entire revenue meter or grid equipment data structure *as reflected* to the remote software is standard. Inside implementation may be different, As reflected to the outside is standard. That's the most important highlight of these standards. The result is a multi-equipment software capable of remote/proxy communication. Unification in every meter and network equipment.

II. Structure and layers of the two standards

[1] is a good reference to current smart grid standardization effort in Europe (IEC) . . The standards lists, that this work provides, are of what are considered as a complete set. Tables 1 to 3 list these standards and standard literature:

Table 1: list of DLMS/COSEM standards

IEC standards
IEC 62056-21: Direct local data exchange (3d edition of IEC 61107) describes how to use COSEM over a local port (optical or current loop) [5]
IEC 62056-42: Physical layer services and procedures for connection-oriented asynchronous data exchange [6]
IEC 62056-46: Data link layer using HDLC protocol [7]
IEC 62056-47: COSEM transport layers for Ipv4 networks [8]
IEC 62056-53: COSEM Application layer [9]
IEC 62056-61: Object identification system (OBIS) [10]
IEC 62056-62: Interface classes [11]

Table 2: list of IEC 67850-5 standards

IEC standards
IEC 60870-5-1 Transmission Frame Formats [12]
IEC 60870-5-2 Data Link Transmission Services [13]
IEC 60870-5-3 General Structure of Application Data [14]
IEC 60870-5-4 Definition and Coding of Information Elements
IEC 60870-5-5 Basic Application Functions [15]
IEC 60870-5-6 Guidelines for conformance testing for IEC 60870-5 companion standards. [16]
Companion standards
IEC 60870-5-101 Transmission Protocols, companion standard especially for basic telecontrol tasks [17]
IEC 60870-5-102 Companion standard for the transmission of integrated totals in electric power systems (this standard is not widely used) [18]
IEC 60870-5-103 Transmission Protocols, Companion standard for the informative interface of protection equipment [19]
IEC 60870-5-104 Transmission Protocols, Network access for IEC 60870-5-101 using standard transport profiles [20]

The DLMS User Association has also published four books. Fig 3 shows the books front covers for identification:

Table 3 lists the books, their description and mapping to standards:

Table 3: **list of DLMS/COSEM known *colored* books**

Book color	DLMS UA Books contents	Mapping to standard id
Blue	the Blue Book describes the COSEM meter object model and the object identification system	IEC 62056-61 OBIS code IEC 62056-62 interface class
Green	the Green book describes the architecture and protocols to transport the model	IEC 62056-53 Application layer IEC 62056-47 Ipv4 IEC 62056-46 HDLC IEC 62056-42 physical IEC 62056-21 local data exchange
Yellow	the Yellow book describes the conformance testing process	none
White	the White book holds the Glossary of DLMS/COSEM terms	none

The DLMS/COSEM is constructed of the following logical layers:

1. *DLMS layer*– **this is a Device Language Message Specification. A layer that accesses the COSEM objects, to construct and transport the messages.**
2. *COSEM layer*– **Companion Specification for Energy Metering. This is an object model that implements revenue and smart meter various registers and functions, such as: tariff, load profile, max demand, energy registers, etc..**
3. *Communication protocol layer*– **this layer translates the DLMS messages into a specific communication protocol.**

The object model is now discussed: the contents. In order to comprehend the DLMS/COSEM standard it is recommended to focus into the blue book. The smart meter functionality is unified as Fig 4 indicates, by the interface classes object model:

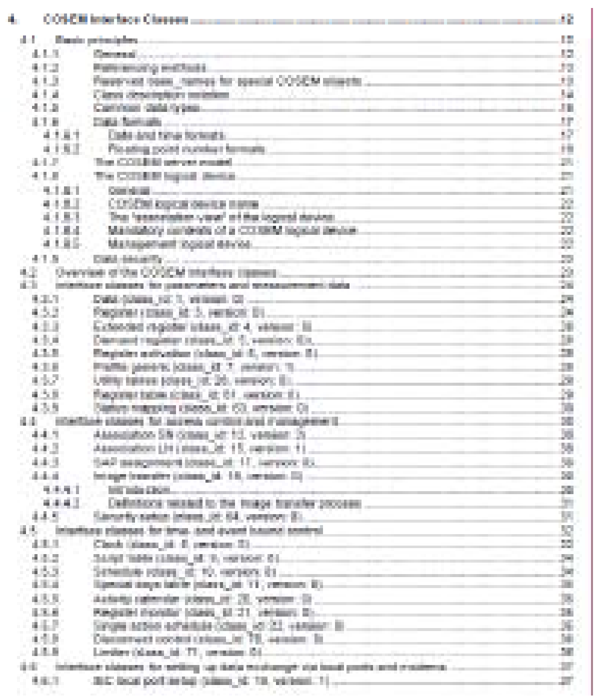

Fig 4: an excerpt of DLMS/COSEM blue book exposing the interface classes standardization. The rows are the classes

Tariff, daylight saving time, max demand, self-reads and all other smart meter functionalities are unified at the interface classes. Therefore all meters are identical *as reflected* to the outside. Inside implementation may be different, and a specific manufacturer may add functionality, but the structure of the matching interface class should be standard. For IEC 60870-5 there are *state transition diagrams and object models*.

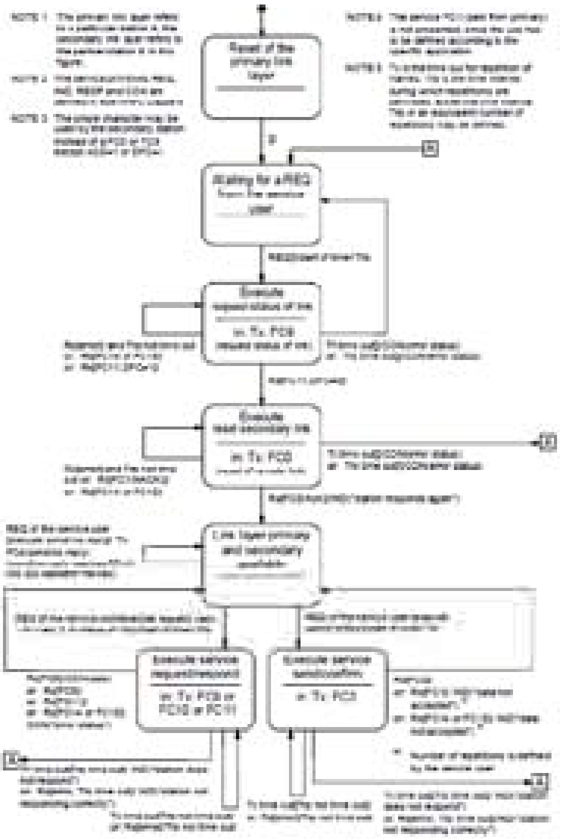

Fig 5: Excerpt of protocol IEC 60870-5-101 state transition diagram [17].

III. The layers are not inter-connected to assure easy addition of new functionality to the standard. Support of existing communication protocols and novel feautures

Next a list of a few novel functions and trends at DLMS/COSEM activity are presented.

A. Event notification

Initially DLMS/COSEM protocol supported the meter only as a client, i.e. passive, and the AMI software as server. Smart grid demands an ability from the side of the meter to notify on occurrence of events. Eventually the DLMS standard has adopted function event notification possibly which were borrowed from TCP/IP. This feature enables through periodic time slot to the meter to alert the AMI software to sample it for an event that occurred in the meter.

B. Information security, encryption and decryption.

The roles of information security are [1]: (a) *Authentication*– which is assurance that the entity accessing the equipment is legitimate and entitled to get access. (b) *Data integrity*– which is Assurance to an entity, which was transferred by data, has not been altered or corrupted. (c) *confidentiality*– this is the assurance that the information to the entity is secure and no other entity may access it.

There are two major options for maintaining information security: (a) *encryption/decryption* in cellular modems *outside* the standard protocols. There are commercial successful products capable of delivering *80Mbit/sec*. these products cost at the range of 50-500$. Information security does not include only encryption/decryption but also structures such as De Militarized Zone (DMZ) and firewall. It is a discipline by its own right and not the specific subject of this paper. (b) information security *inside* the DLMS/COSEM standard- There is no single encryption/decryption standard yet. Under IECEE organization TC13 is the committee responsible of definition of security requirements. For a further concise outline of the requirements the reader is referred to [1].

C. DLMS: Multi-protocol and ongoing protocols adaptation

As been discussed above, DLMS/COSEM supports all kinds of communication available at the smart grid industry. New protocols which were adopted by major organizations, are on-going adopted by the standard as low level layers, in order to guarantee standard dominancy. PLC G3 is such an example. ZigBee is another. A major issue at a meter certification is that the standard supports all its communication options.

IV. Adaptation of the new standard – howto

A. Certification

A trustable product operating according to DLMS standard must be certified by the *DLMS organization*. That is the only way to assure that all the standard was obtained. A certified product carries the DLMS logo which is shown in Fig 6-a. The certification procedure includes successful passing of tests performed by the *Conformance Test Tool (CTT).* Initiation of a certification includes accessing DLMS org. and recently KEMA laboratories. A meter passing the CTT, will possibly have fewer bugs, because it was tested with a standard test software, and that is potentially saving integration and meter approval procedure time.

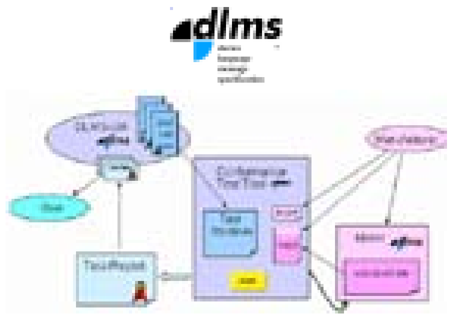

Fig 6: (a) DLMS/COSEM certification logo.(b) block diagram of the DLMS Conformance Test Tool (CTT).

B. Training and documentation

The following training options are available:

A company purchasing the DLMS UA privilege, receives an access to the books. The two standards DLMS and IEC 60870-5 may be purchased from IECEE web-store. Training is available by registering to DLMS UA. KEMA lab offers a two days professional course [3]. Besides the web is full of material on both standards.

C. DLMS/COSEM: Co-processors, open source code and diagnostic platforms

A meter manufacturer that wishes to adapt his equipment to the standard does not have to and should not develop everything from scratch. There is open source code developed by companies such as Gurux and icube, which their logo is shown at Fig 7 bellow. That code is capable of running over standard processors and co-processors.

Fig. 7: logos of DLMS/COSEM open source code companies.

The two above companies provide drivers, and diagnostics environments. There are companies which produce such products for purchase such as KalkiTech[2]. As for test equipment, there are professional test environment products such as KEMA, which provide, protocol analyzer for both standards. KEMA and other companies provide a test writing environment, a specialized environment for field tests, and finally emulators of clients and server. The DLMS CTT may also be considered as a kind of test environment. Fig 8 shows an example for a protocol analyzer[4].

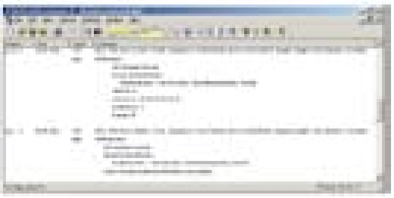

Fig 8: KEMA DLMS protocol analyzer

V. state of standardization in israel

Smart grid standard committees, has approved IEC 60870-5-102,103,103. A request is being voted for the approval of additional of the rest of IEC 60870-5 standards. As for DLMS/COSEM the entire standard is being scheduled to work on in 2013 smart meters committee. Israel Electric Company organization, the prime electricity manufacturing and grid -company has adopted DLMS/COSEM as a mandatory requirement for future meter tenders. Reasoning: over the years a number of metering protocols (proprietary or seemingly standard) have come to be existent in IECo metering system These are namely IEC 1107, ANSI, the PACT (fast LS) from specific meter manufacturers. The Meter Reading is available after reading and conversion the manufacturer proprietary format into user readable format (IECo). These protocols and meters software have been modified by the manufacturers to meet the unique requirements of the IECo from a functional point of view, especially with regard to Israeli D.S.T, special days, and unique load survey requirements .The biggest drawback with the current system is the large resources and efforts being made by individual metering companies, the system integrators, the software implementers and the IECo in maintaining of communication protocols, drivers, adapters, converters, and application solutions. IECo has adopted the DLMS / COSEM IEC 62056 as the standard for metering and will use it for next /future purchases.

VI. IEC 60870-5: outline and structure

Besides generic issues common to DLMS/COSEM standard, the current paper did not expand discussion on the standard. Two issues are discussed further herein: (a) it's a standard for power systems control, monitoring and protection. The standard structure is again an object model of the functions and specific information objects required by such an equipment. (b) The standard is adopted by key equipment manufacturers, so it's available at market.

VII. Conclusion

This paper reviewed aspects in the DLMS/COSEM and IEC 60870-5 standards. these standards are included at IEC smart grid roadmap. The rest of the world including India, China, Australia and New-Zealand as well as sections of the Middle East, has joined in using these standard. Open Meter project, has adopted the standard as well. In this paper it was shown that the standards are nearly mandatory in order to enable the smart grid construction. This paper has also shown why are the standards, successful at implementing their objective? It is the issue of minimizing dependency on a single product, manufacturer. That lies on the interest of the manufacturers, because there's no other choice to succeed in smart grid integration, and because the standards still enable the insertion of specific manufacturer cutting edge technology. The proof of standards success is that Open Meter project which is constructed of six leading manufacturers and of KEMA laboratories, adopted the standard. Since there are about 200 equipment types which are certified according to DLMS, and leading grid equipment manufacturers adopt the IEC 60870-5 standard. The paper has shown the structure of the standards: DLMS, COSEM, and communication layers. The paper also provided tools for organizations who wish to adopt the standards, whether they are manufacturers, utility companies, and smart grid integration companies. The tools are certification, becoming a member of DLMS UA, test tools, DLMS/COSEM of-the-shelf or open source code software to embed at standard processors, standards documentation, and training.

References:

[1] G. Kmethy,"Getting there: smart metering standardization in Europe", *Metering International*, issue 3,2012. DLMS UA.

[2] DLMS – COSEM (IEC 62056) source products and solutions manual, KalkiTech.

[3] "DLMS/COSEM Training course brochure", DNV KEMA academy.

[4] "test suit for smart meters", DNV KEMA.

[5] IEC 62056-21: Electricity metering - data exchange for meter reading, tariff and load control – Part 21: Direct local data exchange.

[6] IEC 62056-42: Electricity metering - data exchange for meter reading, tariff and load control – Part 42: Physical layer services and procedures for connection-oriented asynchronous data exchange.

[7] IEC 62056-46: Electricity metering - data exchange for meter reading, tariff and load control – Part 46: Data link layer using HDLC protocol.

[8] IEC 62056-47: Electricity metering - data exchange for meter reading, tariff and load control – Part 47: COSEM transport layers for Ipv4 networks.

[9] IEC 62056-53: Electricity metering - data exchange for meter reading, tariff and load control – Part 53: COSEM Application layer.

[10] IEC 62056-61: Electricity metering - data exchange for meter reading, tariff and load control – Part 61: Object identification system (OBIS).

[11] IEC 62056-62: Electricity metering - data exchange for meter reading, tariff and load control – Part 62: Interface classes.

[12] IEC 60870-5-1: telecontrol equipment and systems. Part 5: Transmission protocols – section one: Transmission Frame Formats.

[13] IEC 60870-5-2: telecontrol equipment and systems. Part 5: Transmission protocols – section two: Data Link Transmission Services.

[14] IEC 60870-5-3: telecontrol equipment and systems. Part 5: Transmission protocols – section three: General Structure of Application Data.

[15] IEC 60870-5-5: telecontrol equipment and systems. Part 5: Transmission protocols – section five: Basic Application Functions.

[16] IEC 60870-5-6: telecontrol equipment and systems. Part 5: Transmission protocols – section 6: Guidelines for conformance testing for IEC 60870-5 companion standards.

The companion standards:

[17] IEC 60870-5-101: telecontrol equipment and systems. Part 5-101: Transmission Protocols, companion standard for basic telecontrol tasks.
[18] IEC 60870-5-102: telecontrol equipment and systems. Part 5-102: Companion standard for the transmission of integrated totals in electric power systems
[19] IEC 60870-5-103: telecontrol equipment and systems. Part 5-103: Transmission Protocols, Companion standard for the informative interface of protection equipment.
[20] IEC 60870-5-104: telecontrol equipment and systems. Part 5-104: Transmission Protocols, Network access for IEC 60870-5-101 using standard transport profiles.

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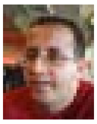

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