The Fieldbus Standards: History and Structures

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This paper gives a short introduction to the history of development of fieldbuses and their standards in IEC and CENELEC in the area of industrial automation. It demonstrates the structure of the actual IEC 61158 standard with 18 different fieldbus systems and its relation to the European standards EN 50170, EN 50254 and EN 50325. The paper gives an introduction to the new IEC 61784 actually under vote. It give a short introduction how to use these profiles for reference and implementation of devices connected to these fieldbuses.

1 Introduction

Already in the early 1970s the first Field-buses are installed and used. However the standardisation work did not start until the mid 1980s. The basic idea behind a standard is, that it establishes a specification in a very rigid and formal way, ruling out the possibility of quick changes. This attaches a notion of reliability and stability to the specification, which in turn secures the trust of the customers and, consequently, also the market position [1,2]. Furthermore, in many countries standards have a legally binding position, which means that when a standard can be applied (e.g., in connection with a public tender), it *has* to be applied. Hence a standardized system gains a competitive edge over its non-standardized rivals.

It is therefore no wonder that a race for standardization was launched. Now this was quite easy on a national level, and most of today's relevant fieldbus systems soon became national standards. Troubles started when international solutions were sought. This caused heavy turbulences and opened a battlefield for politics that gradually left the ground of technical discussion [3,4]. Tab. 1 shows the timeline of these "fieldbus wars".

1986 - 1990	The claims are staked	Selection of various national standards, German PROFIBUS and French FIP are the main candidates
1990 - 1994	German-French fieldbus war	Attempt of a general specification based on WorldFIP and the Interoperable System Project (ISP)
1995 - 1998	Standardization locked in stalemate	Development of the "American" Foundation Fieldbus (FF) in response to the European approach and formation of the CENELEC standards comprising several fieldbus systems in one standard. Deadlock of the international standard through obstructive minorities.
1999 - 2000	The compromise	The eight type specification becomes a standard.
2000 - 2002	Amendments to reach maturity for the market	The standard is enhanced by more types and the necessary profiles are specified in IEC 61784.

Tab. 1: Fieldbus standardization time line from the viewpoint of IEC 61158.

2 The German-French fieldbus war

In the second half of the 1980s, at the beginning of the IEC efforts in the technical committee TC65C, the development of fieldbus systems was mainly a European endeavor, thrust forward by research projects that had still a strongly academic background as well as many proprietary developments. The most promising results were the French FIP and the German PROFIBUS. Both were soon standardized on the respective national level and finally proposed to the IEC for international standardization. Unfortunately, the approaches of the two systems were completely different. PROFIBUS was based on a, distributed control idea and in its original form supported an object-oriented vertical communication according to the client-server model in the spirit of the MAP/MMS specification. FIP, on the other hand, was designed with a central, but strictly real-time capable control scheme and with the newly developed producer-consumer or publisher-subscriber model for horizontal communication.

Different as they were, the two systems were suited for complementary application areas. Evidently, a universal fieldbus had to combine the benefits of both, and an expert group came up with a new proposal [5]. In a extension of FIP towards WorldFIP, the functionality of the client-server model was added. On the other side, the ISP (Interoperable System Project) attempted to demonstrate how PROFIBUS could be enhanced with the publisher-subscriber communication model. The ISP was abandoned in 1994 before reaching a mature state because of strategic reasons [6].

In the meantime, the leading role in the standardization efforts on IEC level had been taken not by the Europeans, but by the work of the committee SP 50 of the Instrumentations Society of America (ISA), who had been much more efficient during the late 1980s and exerted an important influence on the layer structure of the standard as we have it today [7,8]. Still, by the mid 1990s, the IEC committee had not produced any substantial outcome for more than eight years. The only exception was the definition of the Physical Layer, which was adopted as IEC 61158-2 standard already in 1993. This part is the one that has since been used very successfully mainly in the process automation area. On top of the physical layer, however, the standardization drafts became more and more comprehensive and overloaded with all kinds of communication and control principles imported from the different systems. In the Data Link Layer specification, for example, three different types of tokens were introduced: The "scheduler token" determines which station controls the timing on the bus, with the "delegated token" another station can temporarily gain control over the bus, and the "circulated token" is being passed from station to station for bus access. The problem with these all-inclusive approach was that a full implementation of the standard was too expensive, whereas a partial implementation would have resulted in incompatible and not interoperable devices.

This work was done outside the IEC committees within the ISA, and for some time, the IEC work seemed to doze off.

Following the failure to find an acceptable draft for a universal fieldbus, the Europeans feared that it might be impossible to get their national standards into an international one. By that time, the standardization issue had ceased to be a merely technical question. Fieldbus systems had already made their way into the market, much effort and enormous amounts of money had been invested in the development of protocols and devices, and there were already many installations. Nobody could afford to abandon a successful fieldbus, hence it was – from an economical point of view – impossible to start from scratch and create a unified but new standard which was incompatible to the existing national ones. Within CENELEC, the national committees found after lengthy discussions a remarkable and unprecedented compromise: All national standards under consideration were simply compiled "as is" to European standards [9]. Every part of such a multi-part standard is a copy of the respective national standard, which means that every part is a fully functioning system.

To make the CENELEC collection easier to handle, the various fieldbus systems were bundled according to their primary application areas. EN 50170 contains "General purpose field communication systems", EN 50254 "High efficiency communication subsystems for small data packages", and EN 50325 comprises different solution based on the CAN technology. In the later phases of the European standardization process, the British national committee played the part of an advocate of the American companies and submitted also FF, DeviceNet, and ControlNet for inclusion in the European standards. Tab. 2 shows a compilation of all these standards, as well as their relation to the new IEC standard. For the sake of completeness, it should be noted that a comparable, though much less disputed standardization process took place also for bus systems used in machine construction

CENELEC standards part	Contained in IEC standard	Brand name
EN 50170-1 (Jul. 1996)	IS 61158 Type 4	P-Net
EN 50170-2 (Jul. 1996)	IS 61158 Type 1/3/10	PROFIBUS
EN 50170-3 (Jul. 1996)	IS 61158 Type 1/7	WorldFIP
EN 50170-A1 (Apr. 2000)	IS 61158 Type 1/9	Foundation Fieldbus
EN 50170-A2 (Apr. 2000)	IS 61158 Type 1/3	PROFIBUS-PA
EN 50170-A3 (Aug. 2000)	IS 61158 Type 2	ControlNet
EN 50254-2 (Oct. 1998)	IS 61158 Type 8	INTERBUS
EN 50254-3 (Oct. 1998)	(IS 61158 Type 3)	PROFIBUS-DP (Monomaster)
EN 50254-4 (Oct. 1998)	(IS 61158 Type 7)	WorldFIP (FIPIO)
EN 50325-2 (Jan. 2000)	IS 62026-3 (2000)	DeviceNet
EN 50325-3 (Apr. 2000)	IS 62026-5 (2000)	SDS
EN 50325-4 (under vote)		CANOpen
EN 50295-2 (Dec. 1998)	IS 62026-2 (2000)	AS-Interface

Tab. 2: Contents of the CENELEC fieldbus standards. The dates given in brackets are the dates of ratification by the CENELEC Technical Board

3 The international fieldbus war

In 1995, after long years of struggles between German and French experts to combine the FIP and PROFIBUS approaches, several mainly American companies decided to no longer watch the endless discussions. With the end of the ISP project, they began the definition of a new fieldbus optimized for the process industry: the Foundation Fieldbus (FF).

(dealt with by ISO) as well as building automation (in CEN and more recently in ISO).

While the Europeans were busy standardizing their national fieldbus systems and sort of neglected what happened in IEC, the Fieldbus Foundation prepared their own specification. This definition was modeled after the bus access scheme of FIP and the application layer protocol of PROFIBUS-FMS. The FF specification naturally influenced the work in the IEC committee, and consequently the new draft evolved into a mixture of FF and WorldFIP. When this draft was put to vote in 1996, the actual fieldbus war started, and the *casus belli* was that PROFIBUS was no longer represented in the draft. Given the strict European standardization rules where international (i.e., IEC) standards supersede opposing CENELEC standards, the PROFIBUS proponents feared that FF might gain a competitive advantage and "their" fieldbus might lose ground. Consequently, the countries where PROFIBUS had a dominant position managed to organize an obstructive minority that prohibited the adoption of the standard by a narrow margin. The fact that the IEC voting rules make is easier to cast positive votes (negative votes have to be justified technically) was no hindrance, as there were still inconsistencies and flaws in the draft that could serve as a fig-leaf. However, the FF empire (as it was seen by the PROFIBUS supporters) struck back with legal tricks to save the standard. They launched an appeal to cancel negative votes that had not sufficient technical justification, which would have turned the voting result upside down. They even proposed that the members (i.e., the respective national mirror committees) should decide about the (non-)acceptance of the incriminated votes – a procedure which is not in conformance with the IEC rules and caused substantial exasperation. In the course of subsequent voting processes, things grew worse: countries voting – both in favor and against – that had never cast a vote before; votes not being counted because they were received on a different than the designated fax at the IEC and thus considered late; rumors about presidents of national committees who high-handedly changed the conclusions of the committee experts, and finally the substantial pressure exerted by leading companies on the national committees. By and large, the obstruction of the standard remained unchanged, and the standardization process had degenerated to an economical and political battle, which was apt to severely damage the reputation of standardization as a whole.

4 The compromise

On the 15th of June 1999, the "Committee of Action" of the IEC decided to go a completely new way to break the stalemate. One month later, on the 16th of July, the representatives of the main contenders in the debate (Fieldbus Foundation, Fisher Rosemount, ControlNet International, Rockwell Automation, PROFIBUS user organization, and Siemens) signed a "Memorandum of Understanding", which was intended to put an end to the fieldbus war. The Solomonic resolution was to create a large and comprehensive IEC 61158 standard accommodating all fieldbus systems [10]. However, other than CENELEC, where complete specification had been copied into the standard, the IEC decided to retain the original layer structure of the draft with physical, data link, and application layer, each separated into a services and protocols part (Tab. 3). The individual fieldbus system specifications had to be adapted to so-called "types" to fit into this modular structure. In a great effort and under substantial time pressure the draft was compiled, submitted for vote, and released as a standard on December 31st, 2000.

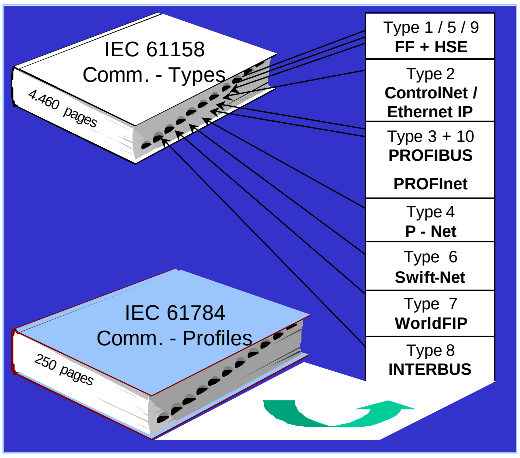

Fig. 1Construction of IEC 61158 and IEC 61784 (Source: PROFIBUS International)

It was evident that the collection of fieldbus specifications in the IEC 61158 standard is useless for any implementation. It needs a manual for the practical use showing which parts can be compiled

Standards part	Contents	Contents and meaning
IEC 61158-1	Introduction	Only Technical Report
IEC 61158-2	PhL: Physical Layer	8 Types of data transmission
IEC 61158-3	DLL: Data Link Layer Services	8 Types
IEC 61158-4	DLL: Data Link Layer Protocols	8 Types
IEC 61158-5	AL: Application Layer Services	10 Types
IEC 61158-6	AL: Application Layer Protocols	10 Types
IEC 61158-7	Network Management	Must be completely revised
IEC 61158-8	Conformance Testing	Work has been cancelled

Tab. 3: Structure of IEC 61158, fieldbus for industrial control systems

to a functioning system and how this can be accomplished. This guideline was compiled later on as IEC 61784 as a definition of so-called “profiles”. At the same time, the specifications of IEC 61158 have been corrected and amended. The drafts of these documents are currently under vote and can be expected to be put into operation by the end of this year. These profiles show that the international fieldbus today consists of seven different main profiles that in turn can be subdivided (see Tab. 4). All important fieldbus systems from industrial and building automation are listed here, and the world’s biggest automation companies are represented with their developments.

FF consists of three profiles. The H1 bus is used in process automation, whereas HSE is planned as an Ethernet backbone and for industrial automation. The H2 is a remainder of the old draft. It allows for a migration of the WorldFIP solution towards FF, but in the profile description it is explicitly noted that there are no products available. The Danish Fieldbus P-Net was taken over like all definitions and variants of WorldFIP and INTERBUS. In the latter case, also the extensions for the tunneling of TCP/IP traffic have been foreseen in the standard. A newcomer in the Fieldbus arena is Swiftnet, which is widely used in airplane construction (Boeing).

Let us have a closer look at the PROFIBUS solution: The former EN50170 Part 2 was included in IEC 61158 Type 3. The former Application Layer PROFIBUS-FMS is not presented anymore and replaced by the “User Layer” of EN50170-2. This configuration, known in the market as

IEC 61784 Profile	**IEC 61158 Protocols**			**CENELEC**	**Brand names**
	Phy	**DLL**	**AL**		
CPF-1/1	Type 1	Type 1	Type 9	EN 50170-A1 (Apr. 2000)	Foundation Fieldbus (H1)
CPF-1/2	Ethernet	TCP/UDP/IP	Type 5	-	Foundation Fieldbus (HSE)
CPF-1/3	Type 1	Type 1	Type 9	EN 50170-A1 (Apr. 2000)	Foundation Fieldbus (H2)
CPF-2/1	Type 2	Type 2	Type 2	EN 50170-A3 (Aug. 2000)	ControlNet
CPF-2/2	Ethernet	TCP/UDP/IP	Type 2	-	EtherNet/IP
CPF-3/1	Type 3	Type 3	Type 3	EN 50254-3 (Oct.1998)	PROFIBUS-DP
CPF-3/2	Type 1	Type 3	Type 3	EN 50170-A2 (Oct.1998)	PROFIBUS-PA
CPF-3/3	Ethernet	TCP/UDP/IP	Type 10	-	PROFInet
CPF-4/1	Type 4	Type 4	Type 4	EN 50170-1 (Jul. 1996)	P-Net RS-485
CPF-4/1	Type 4	Type 4	Type 4	EN 50170-1 (Jul. 1996)	P-Net RS-232
CPF-5/1	Type 1	Type 7	Type 7	EN 50170-3 (Jul. 1996)	WorldFIP (MPS,MCS)
CPF-5/2	Type 1	Type 7	Type 7	EN 50170-3 (Jul. 1996)	WorldFIP (MPS,MCS,SubMMS)
CPF-5/3	Type 1	Type 7	Type 7	EN 50170-3 (Jul. 1996)	WorldFIP (MPS)
CPF-6/1	Type 8	Type 8	Type 8	EN 50254-2 (Oct. 1998)	INTERBUS
CPF-6/2	Type 8	Type 8	Type 8	EN 50254-2 (under vote)	INTERBUS TCP/IP
CPF-6/3	Type 8	Type 8	Type 8	EN 50254-2 (under vote)	INTERBUS Subset
CPF-7/1	Type 6	Type 6	-	-	Swiftnet transport
CPF-7/2	Type 6	Type 6	Type 6	-	Swiftnet full stack

Tab. 4: Profiles and protocols according to IEC 61784 and IEC 61158

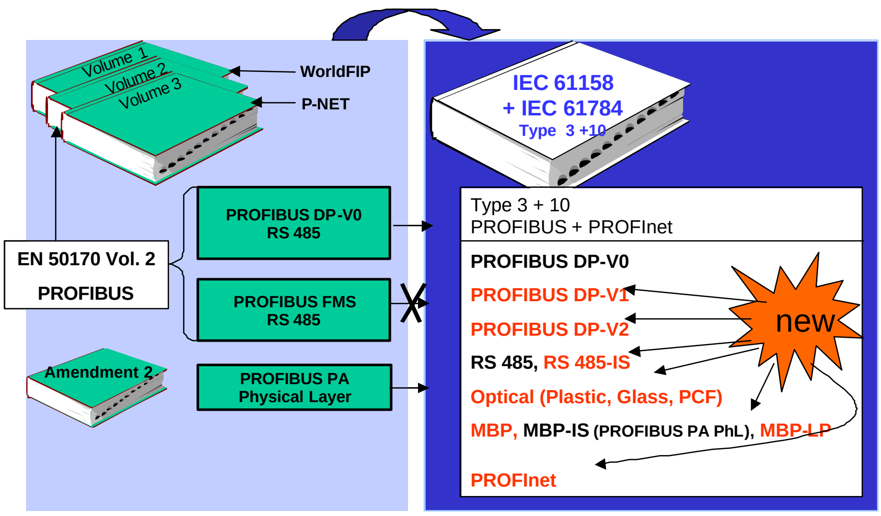

Fig. 2 Example of PROFIBUS for the construction of IEC61158 based on EN50170 (Source: PROFIBUS International)

PROFIBUS-DP, is used as Profile 3/1. The additions for parameterization, before this standardization only PROFIBUS Guidelines, were added in IEC61158. Therefore there exist now six different device profiles in IEC61158: DP Master Class 1 as typical controller, DP Master Class 2 as engineering tool and DP Slave devices. All these 3 types of devices exist as a basic version (DP-V0) with cyclic data only and an extended Version (DP-V1) with additions for acyclic communication.

The Amendment 2 of EN50170, the PROFIBUS-PA, was included as Profile 3/2 in IEC 61784. To complete the standard, the PROFInet specification is included as type 10 in IEC61158 and makes profile 3/3 of IEC 61784.

The correct designation of a IEC Fieldbus profile is shown for the example of PROFIBUS-DP: *Compliance to IEC 61784 Ed.1:2002 CPF 3/1.*

Low-level fieldbus systems for simple I/Os such as the ones based on CAN or the AS-Interface are not part of IEC 61158, it is planned to combine them in IEC 62026.

5 Summary and Outlook

In the next years the European standards will be withdrawn and replaced by the presented international standards. It is now up to the market to decide, which of them will be used and gain large acceptance in the market. It is not up to the standardization bodies to decide.

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