Standardization of Fieldbus and Industrial Ethernet

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DOI: 10.12142/ZTECOM.201902008
http://kns.cnki.net/kcms/detail/34.1294.TN.20190529.0953.002.html, published online May 29, 2019
Manuscript received: 2018-01-17

Abstract: Fieldbus and industrial Ethernet standards can guide the specification and coordinate bus optimization. The standards are the basis for the development of fieldbus and industrial Ethernet. In this paper, we review complex standard systems all over the world. We discuss 18 fieldbus standards, including the International Electrotechnical Commission (IEC) 61158, the IEC 61784 standard matched with IEC 61158, the controller and device interface standard IEC 62026 for low voltage distribution and control devices, and the International Organization for Standardization (ISO) 11898 and ISO 11519 standards related to the controller area network (CAN) bus. We also introduce the standards of China, Europe, Japan and America. This paper provides a reference to develop fieldbus and industrial Ethernet products for Chinese enterprises.

Keywords: fieldbus; industrial Ethernet; standard

1 Introduction

Technical standards are a set of established norms about a technical system; they are usually developed and approved by recognized organizations. In today's digital technology era, a standard is more than a product specification; it also guides the development of the relevant high-tech field [1]. The standardization of fieldbus and industrial Ethernet is convenient for users to use products and regulates the market; it also promotes the development and optimization of bus technology.

The International Electrotechnical Commission (IEC) was committed to develop the one and only comprehensive international fieldbus standard and it began to formulate the fieldbus standards in 1985 [2]. However, the development of the fieldbus standards was not smoothly sailing due to the limitations of the industry, the history of geographical development, the driving of commercial interests, as well as the complex economic and social causes. After many years of debating and coordination, the first edition of the fieldbus standard IEC 61158 was published in March 1999 as a technical specification, following which the second edition with eight fieldbuses, the third edition with 10 fieldbuses, and the fourth edition with 18 fieldbuses were published in 2000, 2003 and 2007 respectively. After the fourth edition, new bus technology has no longer been added to IEC 61158; however, the revisions of the fourth edition are continued.

In recent years, Ethernet with unique advantages has gradually been applied into the field of industrial control. The Publicly Available Specifications (PAS) documents based on 11 real-time Ethernets were published in the IEC 61784-2, and IEC 61784 was the "Communication Profile Family" matched with IEC 61158. Furthermore, IEC has developed the IEC 62026 that is control equipment interface standard for low voltage switchgears and control devices.

In addition to the IEC, the International Organization for Standardization (ISO), an international standard-setting body, has developed the standards for the controller area network (CAN) bus. They are ISO 11898 and ISO 11519.

Several countries, such as China, and regions have also developed fieldbus standards to promote the development of fieldbus technology.

At present, the fieldbus and industrial Ethernet are the mainstream technology in industrial control field, which are the key to intelligent manufacturing. Fieldbus and Industrial Ethernet standards are critical; standard formulation marks the fact that fieldbus and industrial Ethernet are moving towards harmonization and maturity and it is also directly related to the economic interests of major manufacturers. It is especially necessary for Chinese enterprises to understand and master the fieldbus and industrial Ethernet international standards and related regional and national standards, if they want to develop products with strong applicability and seize the larger world market.

This paper describes the international, regional and national standards of fieldbus and industrial Ethernet. It reviews the development process, content and standard types of the international standards IEC 61158, IEC 61784 and IEC 62026 in detail, the content of the international standards ISO 11898 and ISO 11519, and the types of Chinese standards corresponding to IEC62026 and IEC 61158. It briefly introduces European,

This work was supported by ZTE Industry-Academia-Research Cooperation Funds under Grant No. 2016ZTE04-08.

Japanese, American and other standards. Finally, the summary of the research significance of fieldbus and industrial Ethernet standards is presented.

2 International Fieldbus Standards

At present, recognized standardization organizations of fieldbus and industrial Ethernet are the IEC and ISO.

2.1 IEC Fieldbus Standards

2.1.1 IEC 61158

In 1985, IEC established the working group IEC/TC65/SC65C/WG6 for drafting fieldbus standards. The Digital Data Communications Subcommittee SC65C of the IEC and the Instrument Society of American (ISA) jointly developed fieldbus international standards called IEC 61158 for industrial control systems [3]. IEC 61158 has released four versions so far, and its long-time development and the number of voting reflect the diversity of the development of fieldbus and industrial Ethernet.

(1) The First Edition of IEC 61158:

The IEC began to develop fieldbus standards in 1985, but the progress had been slow due to inconsistent views from different countries. After years of debating, the first edition of IEC 61158 fieldbus standard (Ed1.0) was finally published as a technical specification in March 1999. The first edition is based on foundation fieldbus (FF). It consists of the Introductory Guide, Physical Layer Specification, Date Link Service Definition, Date Link Protocol Specification, Application Layer Specification, Application Layer Protocol Specification, and System Management.

(2) The Second Edition of IEC 61158:

After the release of IEC 61158 first edition, the major companies rushed to put forward all kinds of suggestions on amendments about the first edition of IEC 61158 specification in order to make their own fieldbuses into international standards. To coordinate, the IEC defined a matrix of protocol modules (called the type) [4], recognized by the parties. The second edition of IEC 61158 Standard (Ed2.0) was released in January 2000, including eight types of fieldbus. The types are shown in **Table 1** [5]. The Ed2.0 consists of the following five parts.

- IEC 61158-2: Fieldbus standard for use in industrial control systems—Part 2: Physical layer specification and service definition
- IEC 61158-3: Digital data communications for measurement and control—Fieldbus for use in industrial control systems—Part 3: Date link service definition
- IEC 61158-4: Digital data communications for measurement and control—Fieldbus for use in industrial control systems—Part 4: Date link protocol specification
- IEC 61158-5: Digital data communications for measurement and control—Fieldbus for use in industrial control systems—Part 5: Application layer service definition
- IEC 61158-6: Digital data communications for measurement and control—Fieldbus for use in industrial control systems—Part 6: Application layer protocol specification.

The new IEC 61158 retained the original IEC technical report as Type 1, and the other buses entered IEC 61158 as a Type 2-Type 8 in accordance with the IEC Technical Report format [6].

(3) The Third Edition of IEC 61158

After the release of IEC 61158 second Edition (Ed2.0), fieldbus and industrial Ethernet technology had developed rapidly. In April 2003, the third Edition (Ed3.0) was officially released. **Table 2** shows the types of IEC 61158 Ed3.0. The title of the third edition of IEC 61158-2 was amended as "IEC 61158-2: Digital Data Communication Systems for Measurement and Control—Fieldbus for Industrial Control Systems—Part 2: Physical Layer Specification" [7]. The titles of IEC 61158-3 to IEC 61158-6 in IEC 61158 version 3 were the same as the corresponding parts of version 2.

In particular, IEC 61158 Ed3.0 was amended by MT9. The MT9 Maintenance group develops amendments to IEC 61158 [8].

▼Table 1. The types of IEC 61158 Ed2.0

Type	Technical name
Type 1	Foundation fieldbus
Type 2	ControlNet
Type 3	ProfiBus
Type 4	P-Net
Type 5	HSE
Type 6	SwiftNet
Type 7	WorldFIP
Type 8	Interbus

HSE: High Speed Ethernet WorldFIP: World Factory Instrument Protocol
P-Net: Process automation net

▼Table 2. The types of IEC 61158 Ed3.0

Type	Technical name
Type 1	Foundation fieldbus
Type 2	ControlNet
Type 3	ProfiBus
Type 4	P-Net
Type 5	HSE
Type 6	SwiftNet
Type 7	WorldFIP
Type 8	Interbus
Type 9	FF H1
Type 10	ProfiNet

FF: Foundation Fieldbus P-Net: Process automation net
HSE: High Speed Ethernet WorldFIP: World Factory Instrument Protocol

(4) The Fourth Edition of IEC 61158

The Fieldbus Maintenance Working Group IEC/SC65C/MT9 and the Realtime Ethernet Working Group WG11 held a joint working group meeting at Phoenix, USA, from December 5 to 9, 2005. A total of 32 technical experts from the world's major industrial companies and bus organizations and related IEC officials attended the meeting. They worked together for drafting IEC 61158 fieldbus (Ed4.0) and IEC61784-2 real-time Ethernet Committee Draft with Vote (CDV) [9].

IEC 61158 Ed4.0 consists of the following six parts under the title "Industrial Communication Networks—Fieldbus Specifications":

- IEC 61158-1: Overview and guidance for the IEC 61158 and IEC 61784 series
- IEC 61158-2: Physical layer specification and service definition
- IEC 61158-3: Data link layer service definition
- IEC 61158-4: Data link layer protocol specification
- IEC 61158-5: Application layer service definition
- IEC 61158-6: Application layer protocol specification.

The 20 fieldbus types of the IEC 61158 Ed4.0 are shown in **Table 3**.

The fieldbus and industrial Ethernet standards basically keep stable after the release of IEC 61158 Ed4.0, and their development and application are onto the track of continuous development.

From the viewpoint of the development of IEC 61158, the IEC eventually have to use a variety of fieldbuses as a standard to meet the requirements of different parties, although its original intention was to develop a standard for a single fieldbus. There are two main reasons. One is the technical reason. There is no best fieldbus that could be used for all the application areas yet; actually, each fieldbus had its own application scope. The other reason is the commercial interest. The bright development prospects of fieldbus have attracted major companies, especially large-scale multinational companies, to invest much in developing their own fieldbus products without taking the related established standards into account. These major companies and bus organizations would then push their own fieldbuses to become the international standards for the purpose of protecting their own investment and interests. They bargained and competed with one another, eventually leading to a variety of buses in IEC 61158.

2.1.2 IEC 61784

The series of IEC 61158 standards are conceptual specifications that do not involve the specific implementation of fieldbus. And there is only fieldbus type number in the IEC 61158 standard, and the specific fieldbus technical name and commercial trade name are not allowed to appear. So IEC/SC65C developed IEC 61784 matched with the IEC 61158 standard, in order to make developers and users easily carry out product design and application selection.

IEC 61784 is the Communication Profile Family (CPF) in continuous and decentralized manufacturing systems related to fieldbus in industrial control systems. IEC 61784 describes a subset of the communication used by a particular fieldbus system. The communication profiles of the different fieldbuses and the bus type of IEC 61158 corresponding to them are shown in this standard. The IEC 61784 standard under the title "Industrial Communication Networks—Profiles" consists of the following parts [10]:

- IEC 61784-1: Profile sets for continuous and discrete manufacturing relative to fieldbus use in industrial control systems
- IEC 61784-2: Additional profiles for ISO/IEC 8802.3 based communication networks in real-time applications
- IEC 61784-3: Profiles for functional safety communications in industrial networks
- IEC 61784-4: Profiles for secure communications in industrial networks
- IEC 61784-5: Installation profiles for communication networks in industrial control systems
- IEC 61784-6: Time sensitive networking profile for industri-

▼**Table 3. The types of IEC 61158 Ed4.0**

Type	Technical name
Type 1	Foundation fieldbus
Type 2	CIP
Type 3	ProfiBus
Type 4	P-Net
Type 5	HSE
Type 6	SwiftNet (be revoked)
Type 7	WorldFIP
Type 8	Interbus
Type 9	FF H1
Type 10	ProfiNet
Type 11	TCnet
Type 12	EtherCAT
Type 13	Ethernet Powerlink
Type 14	EPA
Type 15	Modbus-RTPS
Type 16	SERCOS I, SERCOS II
Type 17	Vnet/IP
Type 18	CC-Link
Type 19	SERCOS III
Type 20	HART

CC-Link: Control & Communication Link
CIP: Common Industrial Protocol
EPA: Ethernet for Plant Automation
EtherCAT: Ethernet for Control Automation Technology
FF: Foundation Fieldbus
HART: Highway Addressable Remote Transducer
HSE: High Speed Ethernet
P-Net: Process automation net
RTPS: Real-time Publish/Subscribe
SERCOS: Serial Real Time Communication Specification
TCnet: Time-Critical Control network
WorldFIP: World Factory Instrument Protocol

al use based on IEEE 802.1 and IEEE 802.3 (The document has not been officially published).

CPF for fieldbuses in IEC 61784-1 [11] are shown in **Table 4** and real-time Ethernet CPF in IEC 61784-2 [10], [11] are shown in **Table 5**.

The above communication profiles provide a detailed description of the interoperability features and options in fieldbus devices, and specify the capabilities and detailed communication function of equipment in the network communication, and give the specific performance indicators of equipment communications. IEC61784-2 communication profiles specify delivery time, number of end nodes, basic network topology, number of switches between end nodes, throughput RTE, RTE broadband, time synchronization accuracy, and redundancy recovery time of real-time Ethernet [12]. These profiles help to correctly describe the consistency of ISO/IEC 8802.3 of the Real-Time Ethernet (RTE) communication network and avoid bias to prevent its understanding and use.

▼Table 4. CPF for fieldbuses in IEC 61784-1

Family	Technology name	The corresponding type in IEC 61158
CPF 1	Foundation fieldbus	Type 1, 9
CPF 2	CIP	Type 2
CPF 3	ProfiBus	Type 3
CPF 4	P-Net	Type 4
CPF 5	WorldFIP	Type 7
CPF 6	Interbus	Type 8
CPF 8	CC-Link	Type 18
CPF 9	HART	Type 20
CPF 16	SERCOS I, SERCOS II	Type 16

CC-Link: Control & Communication Link
CIP: Common Industrial Protocol
FIP: Factory Instrument Protocol
HART: Highway Addressable Remote Transducer
IEC: International Electrotechnical Commission
P-Net: Process automation net
SERCOS: Serial Real Time Communication Specification

▼Table 5. CPF for real-time Ethernet in IEC 61784-2

Family	Technology name	IEC/PAS	The corresponding type in IEC 61158
CPF 2	EtherNet/IP	IEC/PAS62413	Type 5
CPF 3	Profinet	IEC/PAS62411	Type 10
CPF 4	P-Net	IEC/PAS62412	Type 4
CPF 6	Interbus	—	Type 8
CPF 10	VNET/IP	IEC/PAS62405	Type 17
CPF 11	TCnet	IEC/PAS62406	Type 11
CPF 12	EtherCAT	IEC/PAS62407	Type 12
CPF 13	Ethernet powerlink	IEC/PAS62408	Type 13
CPF 14	EPA	IEC/PAS62409	Type 14
CPF 15	Modbus-RTPS	IEC/PAS62030	Type 15
CPF 16	SERCOS III	IEC/PAS62410	Type 19

EPA: Ethernet for Plant Automation
EtherCAT: Ethernet for Control Automation Technology
IEC: International Electrotechnical Commission
IP: Industry Protocol
PAS: Publicly Available Specification
P-Net: Process automation net
RTPS: Real-time Publish/Subscribe
SERCOS: Serial Real Time Communication Specification
TCnet: Time-Critical Control network

2.1.3 IEC 62026

IEC 62026 standards (**Table 6**) developed by IEC/TC17/SC17B/WG3 relate to the fieldbus for low-voltage switchgears and controlgear.

Among these standards, Actuator sensor interface (AS-I) was launched by the German Pepperl and Fuchs; DeviceNet and Smart distributed system (SDS) were respectively launched by the original AB company (Rockwell Automation Company now) and Honeywell in America.

The main contents of the original IEC 62026 are as follows [13]:

- Part 1: General rules. They specify some contents of the special interface standards and some common requirements
- Part 2: AS-I. AS-I is originally the European standard (EN50295), which is particularly suitable for connecting sensors and actuators with switching characteristics
- Part 3: DeviceNet. It is an open communication network based on CAN and it is easy to connect the low voltage switch device to the main control device through DeviceNet. In addition, DeviceNet has become one of European standards EN50325
- Part 4: Lontalk. It is not suitable as a general agreement of device layer and removed later
- Part 5: SDS. It is a CAN-based control network technology introduced in 1993. This network can connect low-voltage electrical appliances and the main control device through a trunk line to achieve data exchange, processing and transmission in automation systems. SDS has also become one of European standards EN50325
- Part 6: Serial multiplex control bus (SMCB). It is used for connection with switching devices, control equipment, sensors, switches, etc.

With the development of technology and the choice of the market, IEC deleted IEC62026-4 and IEC62026-6 in June

▼Table 6. IEC 62026 standards

Standard number	Standard title	Published date	Status
IEC62026-1	Part 1: General rules	2000-07	In force
IEC62026-2	Part 2: Actuator sensor interface (AS-I)	2000-07	In force
IEC62026-3	Part 3: DeviceNet	2000-07	In force
IEC62026-4	Part 4: LonTalk	2000-07	Cancelled
IEC62026-5	Part 5: Smart distributed system (SDS)	2000-07	Cancelled
IEC62026-6	Part 6: Serial multiplex control bus (SMCB)	2001-11	Cancelled
IEC62026-7	Part 7: CompoNet	2010-12	In force

2000, IEC62026 - 5 in 2006; updated IEC62026 - 2and IEC62026-3 in June 2007; and added IEC62026-7 in December 2010.

2.2 ISO Fieldbus Standard

CAN is one of the earliest international fieldbus standards before IEC 61158 and IEC 62026 in the fieldbus field. CAN is approved by Technical Committee ISO/TC22 as international standards for ISO 11898 (communication rate < 1 Mbit/s) and ISO 11519 (communication rate < l25 kbit/s).

2.2.1 ISO 11898

IS0 11898 was a controller area network for high-speed communication developed by Technical Committee ISO/TC22 - Road Vehicles and its subcommittee SC 31-Data Communication in November 1993.

ISO 11898 conforms to the Open System Interconnection (OSI) reference model specified in ISO 7489, and describes the general structure of the CAN in a hierarchical form, including the detailed technical specifications of the CAN physical layer and the data link layer. It specifies the various characteristics of digital information exchange between the electronic control units of road vehicles equipped with CAN at a transmission rate of 125 kb/s to 1 Mb/s.

ISO 11898 consists of the following parts, under the general title "Road Vehicles—Controller area network (CAN)" [14]:

- ISO 11898-1: Data link layer and physical signaling
- ISO 11898-2: High-speed medium access unit
- ISO 11898-3: Low-speed, fault-tolerant, medium-dependent interface
- ISO 11898-4: Time-triggered communication
- ISO 11898-5: High-speed medium access unit with low-power mode
- ISO 11898-6: High-speed medium access unit with selective wake-up functionality.

Specially, CAN Technical Specification Standard 2.0 was released in 1991, included 2.0A and 2.0B. 2.0A describes the CAN message format defined in the CAN specification version 1.2; 2.0B describes both standard and extended message formats.

2.2.2 ISO 11519

The Technical Committee ISO/TC22-Road Vehicles and its subcommittee SC 31-Data Communication also developed ISO 11519, a controller area network for low speed serial data communication. The contents of ISO 11519 include Part 1: General and Definitions; Part 2: Low Speed Controller Area Network (CAN); Part 3: Vehicle Area Network (VAN) [15].

ISO 11519-1 (Part 1) describes the general definition of low-speed serial data communication for road vehicles at a rate of no more than 125 kb/s, stipulates the general structure of the communication network for information transmission between different types of electronic modules on road vehicles and the main contents of the data link layer and the physical layer. ISO 11519-2, 3 (Parts 2 and 3) respectively specify the data link layer and physical layer of the CAN and VAN (communication networks up to 125 kb/s) for road vehicle application and illustrate the general structure of the networks.

In particular, CAN is the physical layer of the IEC 62026-3 DeviceNet and IEC 62026-5 Smart Distribution System, so it is the most important technical basis for IEC 62026.

3 Chinese Fieldbus Standard

The basic principle of standardization of relevant agreements in China is to adopt IEC standards equivalently, and the research of Chinese fieldbus standards corresponding to IEC 62026 and IEC 61158 has achieved some success.

3.1 Chinese Fieldbus Standard Corresponding to IEC 62026

The third meeting of the second National Low Voltage Electrical Apparatus Standardization Technical Committee of China was held in Qingdao, China, September 2001. The fieldbus standard GB/T 18858 corresponding to IEC 62026 was reviewed and adopted at this meeting [16]. It consists of the following three sections:

- GB/T 18858.1—2002: Low-voltage switchgear and controlgear—Device interface (CDI)—Part 1:General rules
- GB/T 18858.2—2002: Low-voltage switchgear and controlgear—Device interface (CDI)—Part 2: Actuator sensor (AS-I)
- GB/T 18858.3—2002: Low-voltage switchgear and controlgear—Device interface (CDI)—Part 3: DeviceNet.

With the development of technology and improvement of IEC 62026, the National Standard Committee of China approved to release the revised GB/T18858.1, GB/T18858.2, GB/T18858.3 in November 2012, followed by the release of the GB/T 18858.7 in June 2014. The revised China Fieldbus Standard GB/T 18858 includes the following sections:

- GB/T 18858.1—2012: Low-voltage switchgear and controlgear—Device interface (CDI)—Part 1:General rules
- GB/T 18858.2—2012: Low-voltage switchgear and controlgear—Device interface (CDI)—Part 2: Actuator sensor (AS-I)
- GB/T 18858.3—2012: Low-voltage switchgear and controlgear—Device interface (CDI)—Part 3: DeviceNet
- GB/T 18858.7—2014: Low-voltage switchgear and controlgear—Device interface (CDI)—Part 7: CompoNet.

3.2 Chinese Fieldbus Standard Corresponding to IEC 61158

3.2.1 Recommended National Standards

In China, recommended standards are a type of standards that is voluntarily adopted by means of economic adjustment in the aspects of production, exchange, use, and so on, also known as voluntary or non-mandatory standards. Any unit has the right to decide whether or not to adopt these standard, and does not bear economic or legal responsibility in violation of such standards. However, once a recommended standard is accepted and adopted, or agreed to be included in an economic contract, the parties have to comply with the technical basis, with legal binding.

Table 7 shows the recommended national fieldbus standards.

3.2.2 Guidance National Standards

The guidance standard refers to the national standard that is voluntarily adopted by the organization (enterprise) in the aspects of production, exchange, use and so on. It is not compulsory and does not have the legal restriction, but only the technical basis for the related parties. **Table 8** shows the guidance national fieldbus standards in China.

As can be seen from the above standards, China has not copied the IEC 61158 international standard. There are two reasons. First, IEC 61158 standards issued separately according to the general, physical layer service definition, protocol specification, data link layer service definition and data link Layer protocol specification, etc. It is very inconvenient to choose from more than 4000 pages of IEC 61158 with 18 kinds of standards when users need to use a standard. Second, performance, application scope, development difficulty and the level of openness vary in 18 kinds of fieldbuses, but generally, we only select buses with the best performance in these buses as national standards instead of using all of them. The methods of selecting Chinese national standards include:

▼Table 7. The recommended national fieldbus standards

Name	National standard number	The title of standard
EPA	GB/T 20171—2006	System structure and communication specification of EPA for industrial measurement and control systems
ProfiBus	GB/T 20540—2006	Fieldbus for measurement and control—digital data communication-Industrial control systems type 3: ProfiBus specification
Modbus	GB/T 19582—2008	Industrial automation network specification based on Modbus Protocol
CC-Link	GB/T 19760—2008	CC-Link control and communication network specification
HART	GB/T 29910—2013	Industrial communication network fieldbus specification type 20: HART
EtherCAT	GB/T 31230—2014	Industrial Ethernet EtherCAT
Profinet-IO	GB/T 25105—2014	Industrial communication network fieldbus specification type 10: Profinet-IO
Profisafe	GB/T 20830—2015	Functional security communication profiles based on ProfiBus-DP and ProfiBus-IO—Profisafe
CC-Link IE	GB/T 33537—2017	Industrial communication network fieldbus specification type 23:CC-Link IE

CC-Link: Control & Communication Link
DP: Decentralized Periphery
EPA: Ethernet for Plant Automation
EtherCAT: Ethernet for Control Automation Technology
HART: Highway Addressable Remote Transducer
IE: Industrial Ethernet
IO: Input Output

▼Table 8. The guidance national fieldbus standards

Name	National standard number	The title of standard
LonWorks	GB/Z 20177—2006	Control network LonWorks technical specification
Profinet	GB/Z 20541—2006	Fieldbus for measurement and control -digital data communication-Industrial control systems type 10: Profinet
ControlNet, EtherNet/IP	GB/Z 26157—2010	Fieldbus for measurement and control -digital data communication-Industrial control systems type 2:ControlNet and EtherNet/IP
Interbus	GB/Z 29619—2013	Fieldbus for measurement and control -digital data communication-Industrial control systems type 8:Interbus
CC-Link safety	GB/Z 29496—2013	Control and communication network CC-Link safety specification

CC: Control & Communication　　IP: Industry Protocol

(1) Some excellent and promising buses with great influence are chosen as the standard of China. These buses need to be truly open. Relevant international organizations need to support and help China´s standardization work so that Chinese enterprises can better develop Fieldbus products. (2) The standard text is in the form of the European Fieldbus standard and a bus corresponds to a text, which is user-friendly.

4 Other Fieldbus Standards

In addition to international standards and Chinese standards, there are some fieldbus standards in Europe, Japan, America and other regions. We select some for a brief introduction here.

4.1 European Fieldbus Standards

(1) EN 50170:

EN 50170 is an open international fieldbus standard. In 1996, the European Committee for Electrotechnical Standardization (CENELEC) issued a non-single European standard EN 50170 containing three incompatible protocols: Volume 1: P-Net; Volume 2: ProfiBus; Volume 3: WorldFIP [17]. P-Net is the Danish standard DSF 21906, ProfiBus is the German standard DIN 19245, and WorldFIP is the French standard FIP.

(2) EN 50254:

EN 50254 was prepared by the Technical Committee CENELEC TC 65CX in 1998, including Volume 1: Introduction; Volume 2: Interbus; Volume 3: ProfiBus-DP Profile; Volume 4: WorldFIP Profile 1. Among them, Interbus is the German national standard DIN 19258.

(3) EN 50295:

EN 50295 was prepared by the Technical Committee CENELEC TC 17B in 1999. The title of EN 50295 is “Low voltage switchgear and controlgear—controller and device interface systems actuator sensor interface AS-i”.

(4) EN 50325:

EN 50325: Industrial communication subsystem based on ISO 11898(CAN) for controller device interfaces includes:

- EN 50325-1-2001: General requirements
- EN 50325-2-2001: DeviceNet
- EN 50325-3-2001: SDS
- EN 50325-4-2003: CANopen
- EN 50325-5-2010: Functional safety communication based on EN 50325-4 (CANopen Safety).

Among them, CANopen is an application layer protocol based on the CAN. In Europe, CANopen is considered to be a leading standard in CAN-based industrial systems.

4.2 Japanese Fieldbus Standards

(1) CC-Link:

Japan Mitsubishi Electric released the CC-Link fieldbus standard in 1996. It was approved by the International Semiconductor Manufacturers as one of the fieldbus standards used in semiconductor manufacturing (SEMI E54.12) in 2001, and was into the IEC61158 standard and ISO15745-5 standard in 2007.

(2) Vnet/IP:

The real-time Ethernet Vnet/IP is a real-time factory network system developed by Yokogawa Corporation in 2004 for process automation. It has become the IEC/PAS 62405 and IEC 61158 standards.

(3) TCnet:

Tcnet is a real-time Ethernet developed by Toshiba Corporation, which is mainly used in Toshiba´s Toshiba 3000 industrial automation control system. And it is widely used in high speed areas such as drive devices and steel rolling. It has become the IEC/PAS 62406 and IEC 61158 international standards.

4.3 American Fieldbus Standards

American National Standards Institute/National Electrical Manufacturers Association (ANSI/NEMA) supported International Society of Automation (ISA)/IEC standards in the same way:

- ISA/IEC 61158-1 General rules
- ISA/IEC 61158-2 Physical layer specification
- ISA/IEC 61158-3 Link layer service definition
- ISA/IEC 61158-4 Link layer specification
- ISA/IEC 61158-5 Application layer service definition
- ISA/IEC 61158-6 Application layer specification
- ISA/IEC 61158-7 Management system
- ISA/IEC 61158-8 Consistency test.

4.4 Other Fieldbus Standards

In addition to the above standardized fieldbuses, there are other fieldbuses, such as Lonworks, Sensoplex 2, Attached Resource Computer Network (ARCNET), and Dupline.

Lonworks—Local Operating Network was published in 1990 [18]. It was developed by Echelon, and jointly advocated by Echelon, Motorola, and Toshiba. Lonworks has become the recognized international standard for construction industry, and was also used as a China's national standard (GB/Z) in 2006.

Sensoplex 2 is a control network designed by TURCK in Germany for heavy industry automation [8]. It has strong anti-jamming capability and is widely used in the world's major automobile factories.

ARCNET is a widely installed local area network (LAN) technology developed by Datapoint in 1977 [20]. The initial application target of the ARCNET network was office automation. However, as the demand for office network systems shifts to Ethernet, ARCNET networks are gaining new applications in real-time control.

Dupline is a field and installation bus designed by Carlo Gavazzi [21]; it offers unique solutions for building automation and other fields.

5 Conclusions

Fieldbus and Industrial Ethernet are the hotspots of automation technology in the 21st century. There are following benefits to understand and master international, national, regional and other related standards of fieldbus and industrial Ethernet. First, tracking the trend of fieldbus and industrial Ethernet technology in the world promotes the application and development of the fieldbus and industrial Ethernet technology in China. Second, it will provides reference to develop fieldbus and industrial Ethernet standards and improve the standard systems in China. Third, it can guide the development of enterprise products in China, make enterprises develop fieldbus products in accordance with the international mainstream fieldbuses and try to take a larger market share in the country and abroad.

Acknowledgment

We would like to extend our heartfelt thanks to LIU Xuan and LI Lei for their assistance in searching relevant information.

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