



TECHNICAL WHITE PAPER

INTRINSICALLY SAFE FIELDBUS IN HAZARDOUS AREAS

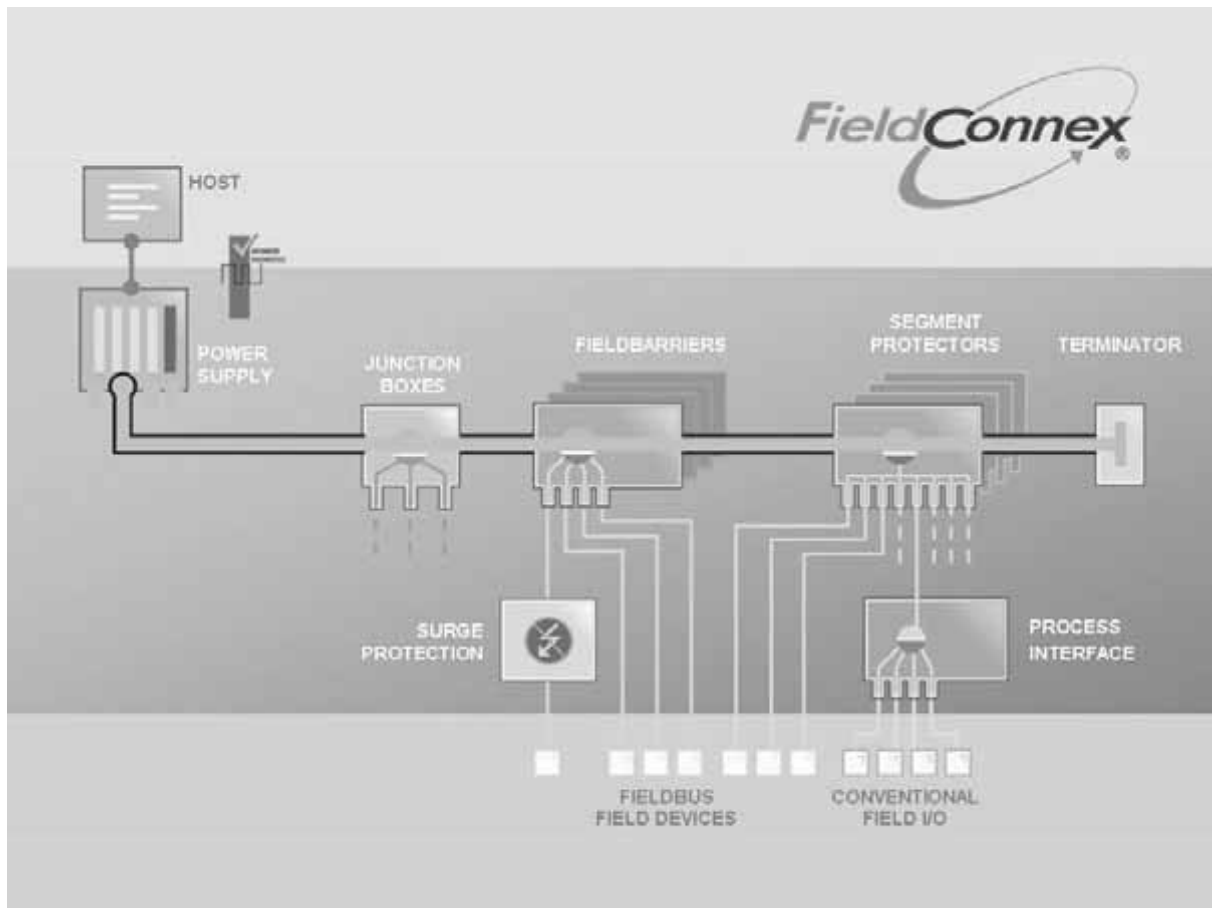
Decision Guidance for Intrinsically Safe Fieldbus Solutions

Currently different solutions are available for intrinsically safe fieldbus like Entity, FISCO or High-Power Trunk and recently announced redundant FISCO and DART concepts. This paper chronologically accounts the history of all intrinsically safe explosion protection concepts for fieldbus and gives an outlook on DART and the redundant FISCO concepts. The paper then goes on to compare all methods one-on-one with a practical view on their merits and drawbacks. This paper is directed at technical decision makers involved in planning fieldbus topologies for the hazardous area in search of solutions.

Prepared by:

Armin Beck
Product Portfolio Manager – Fieldbus Infrastructure

Andreas Hennecke
Product Marketing Manager – Fieldbus Infrastructure



Pepperl+Fuchs is the proven market leader for innovative and highly available components for your fieldbus according to IEC 61158-2. With quality components to fit your process automation system and demands in the field our highly reliable and energy-efficient design allows you to focus on the task at hand. Knowing that your fieldbus is running.

The High-Power Trunk Concept with Entity or FISCO devices: Connect the maximum number of devices to the same fieldbus trunk; and at the same time make use of maximum cable lengths. This concept utilizes standard power supplies such as the easy to install and configuration free Power Hub. Segment Protectors and FieldBarriers are installed close to field devices and limit the energy at the spur. You are free to work on field devices without hot work permit.

Advanced Diagnostics: Take control of your fieldbus installation. This latest innovation brings transparency to fieldbus. Speed up commissioning with automated documentation. Measure fieldbus performance and detect changes in the control room before they become critical to your plants operation.

You can rely on products built to serve your every need in fieldbus for process automation. You can gain from the experience of knowledgeable engineers to create your fieldbus solution. You can be at ease with products and solutions from Pepperl+Fuchs.

Table of Contents

1	Introduction	2
2	Entity	2
	2.1 Description	2
	2.2 Appraisal	2
3	FISCO – Fieldbus Intrinsically Safe Concept	3
	3.1 Description	3
	3.2 Appraisal	3
4	Redundant FISCO	4
	4.1 Description	4
	4.2 Appraisal	4
5	The High-Power Trunk Concept	5
	5.1 Description	5
	5.2 Appraisal	5
6	DART – Dynamic Arc Recognition and Termination	6
	6.1 Description	6
	6.2 Appraisal	6
7	Technical Comparison	7
	7.1 General performance of the intrinsically safe fieldbus solutions.....	7
	7.2 Comparison based on real-life application requirements	7
8	Conclusion	9
9	References	9

1 Introduction

Process production plants are heterogeneous and complex in many respects: field devices of very different types are mounted alongside conventional motors and simple digital sensors. Sites place requirements for long cable lengths distributed across buildings and floors, with installation in safe and explosion-hazardous areas with their stringent safety regulations. In short, a typical plant layout consists of practically any type of application, and this has to be taken into consideration when designing and installing fieldbus systems.

Limiting the amount of energy in a hazardous area with intrinsically safe isolating barriers has been around since the 1960's, and these circuits are easily validated by comparing the safety parameters of the power source, with those of the supplied apparatus and the connecting cable. However, a fieldbus is traditionally a network with trunk-and-spur topology where each device is connected to a home run cable via distribution interfaces. To validate the overall intrinsic safety it is required to compile all field devices' and cables' safety parameters, and match them against the power source. In the beginning this effort and the very low amount of energy initially available prohibited application of fieldbus in hazardous areas.

Today the market is able to look back on a respectable and rapid development of intrinsically safe fieldbus implementation. This paper provides an overview on how this technology has improved to the point where today it is meeting the technical requirements of modern process plants. It considers technical specifications and output relevant to segment layout and design and compares individual solutions. Latest developments are described, which will provide further enhancements to the process industry.

2 Entity

2.1 Description

The Entity model as defined by IEC 60079-11 [5] is a method of validating an installation of intrinsically safe and associated apparatus through the use of intrinsically safe parameters. In addition to the devices' parameters the cable capacitance and inductance is assumed as being concentrated and has to be considered as well. Simplifications for Fieldbus were not considered within this specification and planners had no other

option than to accept the complex and time consuming calculation efforts to validate an installation.

The first initiative to broadly define standardized IS parameters for fieldbus was started by the release of the FOUNDATION fieldbus FF-816 Physical Layer Profile [2]. Based on the conservative Entity model this document recommended safety parameters of $U_o = 24\text{ V}$, $I_o = 250\text{ mA}$ and $P_o = 1.2\text{ W}$ for power supplies used for gas group IIC (group A,B) applications. Developing Entity compliant fieldbus products by observing these values got much easier, however the maximum available power of 1.2 W continued to be a limitation, preventing reasonable use.

Gases of group IIB (group C) need more energy to ignite. In an attempt to overcome the 1.2 W limitation one manufacturer introduced a IIB Entity power supply. Wiring blocks further limited the energy for IIC Entity field devices. Wiring had to be located in a IIB location even for IIC applications.

2.2 Appraisal

Applying the Entity model to fieldbus in practical applications is rather rare, there are only a few power supplies conforming to the Entity model available today. Typically they provide 10...12 V and 70...100 mA which is just enough to operate 2...3 field devices per segment (gas group IIC). In the end Entity:

- Provides power for segments with up to 3 instruments
- Requires a significant calculation effort to validate intrinsic safety
- IIB solution offers more power, however not suitable where many applications require group IIC

From a market point of view the limitations prevented the conservative customer base from really adopting intrinsically safe fieldbus when it was evaluated for use in hazardous areas. This restraint was intensified by the high initial cost of intrinsically safe technology in general. The very nature of the electrical design including double (Ex ib) or triple (Ex ia) redundant circuits for current limitation and constant voltage together with galvanic isolations were invoking a high effort with a direct influence on the customer's expense. Compared to the expense of using traditional protection methods such as Ex e and Ex d and non-incendive field wiring the technology was not competitive at all.

3 FISCO – Fieldbus Intrinsically Safe Concept

3.1 Description

Utilizing fieldbus in general for plant instrumentation became globally more and more popular in the early 1990s. For fieldbus in hazardous area applications however a feasible solution was still missing.

Fast adoption of fieldbus technology in factory automation caused a desire to reevaluate the application of fieldbus in process automation as an alternative to 4...20 mA interface technology. Preliminary experiments conducted by the Physikalisch Technische Bundesanstalt (PTB), Germany showed that long cable lengths connected to a power source did not significantly increase the incendivity of a spark. Under the premise to recheck the conservative approach of Entity with concentrated cable inductances and capacitances and with the objective to simplify system calculations and to allow more power in the field, PTB ascertained experimentally new IS parameters for fieldbus with the following objectives:

- Increase available power
- Standardize the installation parameters and limits
- Simplify system calculations and documentation

The results of this study were published as a report by PTB in 1994 [1]. Two years later Pepperl+Fuchs introduced the first power supply compatible with the report's requirements (Figure 1).

Analog to Entity one manufacturer decided to provide a IIB FISCO solution. This approach effectively offered more energy to the field enabling longer trunk lengths and more field devices. Entity field devices are interfaced using special "add-on couplers". The fieldbus installation had to be located in a IIB location. Further special active wiring interfaces were required to take fieldbus spurs into a IIC environment.

FISCO prescribes that only one power supply is permitted per fieldbus segment and that all other devices are power drains with measures in place preventing unintentional power feedback to the cable. For the first time a standard placed actual restrictions on cable and electric apparatus with regards to parasitic capacity and induc-

tance. Instruments and power supplies require certification through a notified body. Cables are documented through a declaration by the manufacturer.

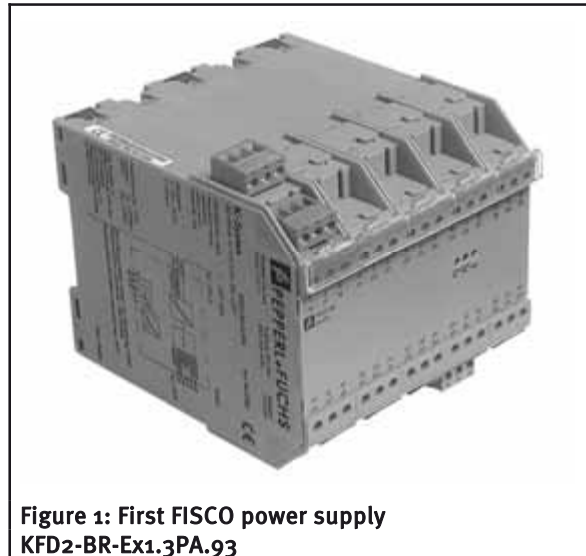


Figure 1: First FISCO power supply KFD2-BR-Ex1.3PA.93

FISCO validation of intrinsic safety is limited to the documentation of FISCO compliance of all hardware involved. Later the FISCO report turned into the technical specification IEC TS60079-27 and adopted in the year 2005 as standard IEC 60079-27 [3].

3.2 Appraisal

FISCO offers the easiest method for validation of explosion protection, which explains its popularity. It shifted the bulk of the responsibility for sound electric design from the planner and operator of process plants to equipment manufacturers. FISCO improved the available IS power. Under real-life conditions it is suitable for small applications with very short cable lengths and 4...8 devices per segment depending on the gas group it is used in. (See Table 3: Values calculated for Real-Life application on page 8).

In spite of the improvements offered by FISCO a real breakthrough of intrinsically safe fieldbus failed to appear. This was due to the fact that the expected savings in installation cost and effort could not be realized, even if FISCO allows practically the operation of twice as many field instruments when compared to Entity. Further other disadvantages moved to the foreground which haven't changed with the introduction of FISCO:

- No power supply redundancy. Power supply as single point of failure

- Very little flexibility in segment design because mix of devices for safe and hazardous areas on one segment is not permitted
- Operation of more field devices but still marginal compared to 32 possible devices as defined in the fieldbus standard IEC 61158-2 [4].
- Need of special “add-on” devices for simultaneous use of FISCO and Entity field devices.

4 Redundant FISCO

4.1 Description

The demand for high availability for many process applications lead to the concept of redundant FISCO power supplies. To achieve redundancy of power supplies for a FISCO segment it must be ensured that only one power supply is active at any time. For redundant FISCO two intrinsically safe power supplies are managed by two arbitration modules. The arbitration module ensure that only one power supply is switched onto the fieldbus segment at any given time. They monitor the voltage output level of each supply, and in the event the voltage level of a supply falling below a specific level the switch over is initiated between the two interacting arbitration modules.

In the case of a redundancy switch over the switch of the active arbitration module opens and after a finite period of time the other one closes. (See Figure 2). For a short period of time the fieldbus loses power and the segment voltage drops. As a rule of thumb, 100 μ s is permissible as maximum glitch time to avoid field devices resetting due to a power loss. However the redundancy transfer will have a significant influence on the communications by destroying telegrams with very high probability due to the power drop.

The FISCO standard IEC 60079-27 permits only one power supply per electric circuit [3]. This is ensured by the arbitration modules, which will require certification by a notified body. Timing is critical and the hardware must be carefully tested to ensure explosion protection during redundancy transfer.

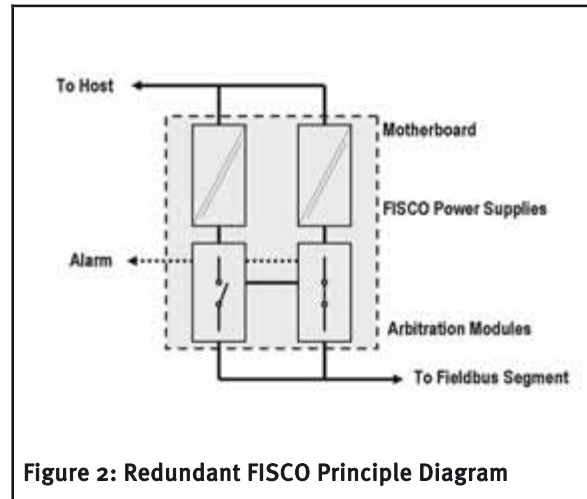


Figure 2: Redundant FISCO Principle Diagram

4.2 Appraisal

Compared to FISCO with single power supplies four electronic modules are required to provide redundancy. This requires about 3 times more cabinet space for the same number of field devices and the same cable lengths. Redundant FISCO can be classified as an interim solution for applications with the same requirements as FISCO and a need for higher plant availability. Redundant FISCO compares to standard FISCO as follows:

- Not certified yet, test methods are needed to verify functionality and intrinsic safety of power supplies and arbitration modules
- Same limitations with regards to cable length and number of devices as FISCO
- An extension to the current FISCO standard may be required for general acceptance
- High probability of communication errors during redundancy transfer
- Arbitration modules require extra power which is drawn from the segment putting further constraints on cable length and number of devices
- Significantly more cabinet space required
- Higher capital cost

5 The High-Power Trunk Concept

5.1 Description

The High-Power Trunk Concept (HPTC) was introduced in 2002. It removed the limitations with regards to segment length and number of devices. Fieldbus in hazardous area applications was more commonly accepted afterwards. HPTC was developed and introduced by Pepperl+Fuchs (See Figure 3).

The principle idea of the HPTC is to deliver energy on the fieldbus trunk not limited for explosion protection close into the hazardous area. Within the hazardous area it is distributed via energy-limiting wiring interfaces to its final destination, the field instrument. The trunk is installed utilizing increased safety methods (Ex e) and is therefore protected from mechanical damage and effects such as unintentional disconnect or corrosion etc.

Compared to all other intrinsically safe installation methods standard power supplies can be applied for the HPTC, which are much simpler by design and available at a low price. For Zone 1/0 (DIV 1) applications the wiring interface, typically called FieldBarrier is used and acts as distribu-

tion interface providing four galvanically isolated outputs certified Ex ia IIC'. Each output acts as independent FISCO or Entity power supply. Up to four FieldBarriers may be operated on one segment, allowing up to 16 IS field devices and an overall maximum cable length of 1900 m.

The HPTC enables higher availability of the fieldbus segment as the power supplies may be operated in redundant configuration. Connected in parallel both power supplies share the load current. In the event of a power supply failure the other supply takes over immediately without any interruption. Additionally the life expectancy of the power supplies is longer in redundant configuration due to the shared lower continuous provided current which is half of the actual load current.

5.2 Appraisal

The introduction of the HPTC caused the breakthrough and general acceptance of fieldbus in process automation. It is the enabling technology for fieldbus in hazardous areas, because it satisfies the need for long trunk cables while at the same time allowing a large number of devices per segment. The desired cost reduction in engineering, installation, check-out and commissioning are achieved.

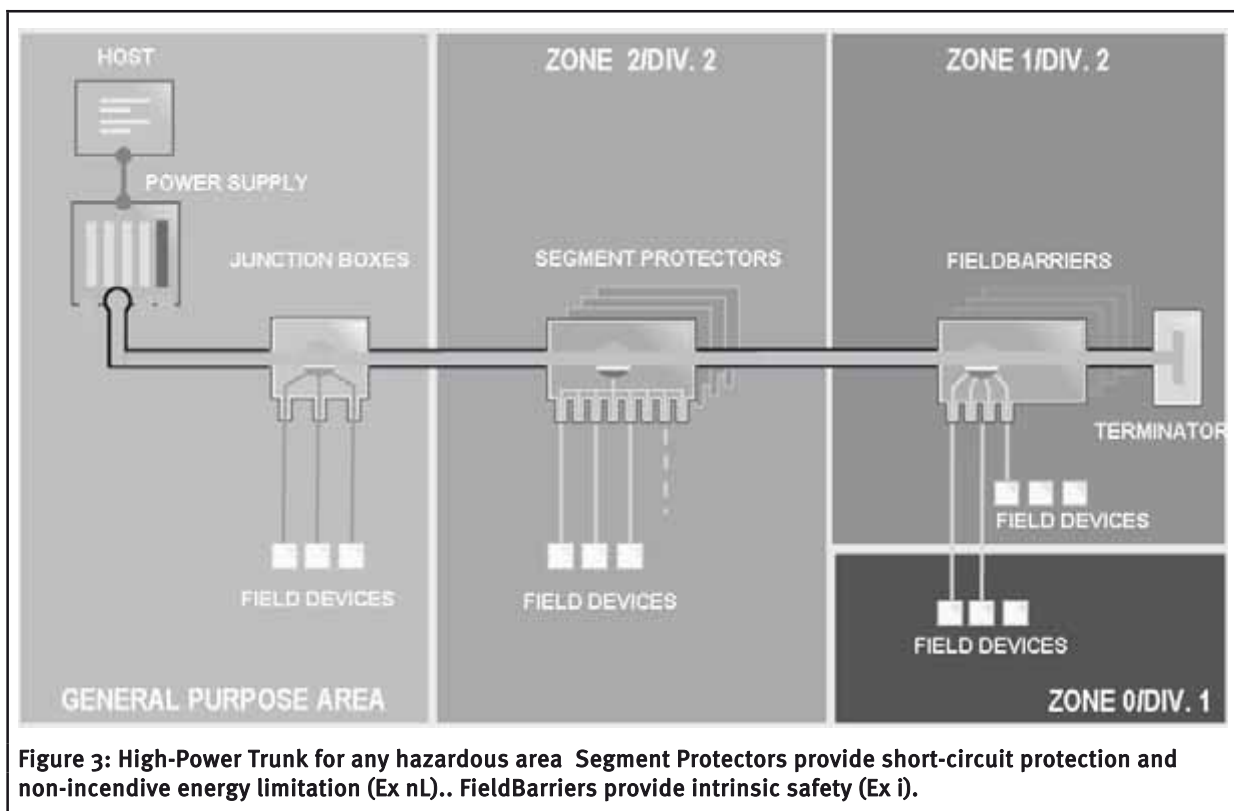


Figure 3: High-Power Trunk for any hazardous area Segment Protectors provide short-circuit protection and non-incendive energy limitation (Ex nL).. FieldBarriers provide intrinsic safety (Ex i).

The same topology can be used for all areas: non-hazardous, Zone 2 and intrinsically safe Zone 1, 0 applications. Attributes enabled by the HPTC are:

- Highest possible overall cable length and at the same time largest number of field devices per segment
- Live work on field devices allowed without hot work permit
- 4 times less valuable cabinet space required with standard power supplies compared to FISCO compliant supplies
- Easiest validation of intrinsic safety once per spur with no calculation required
- Mix and match of FISCO and Entity compliant devices on one segment
- Redundancy of the power supplies
- Integrated physical layer diagnostics for long-term monitoring

6 DART – Dynamic Arc Recognition and Termination

6.1 Description

According to IEC 60079-11 [5] an electric circuit is considered intrinsically safe if it can be guaranteed that “electrical energy within the apparatus and of interconnecting wiring exposed to the potentially explosive atmosphere is restricted to a level below that which can cause ignition by either sparking or heating effects”. Currently intrinsically safe system designs rely primarily on the continuous limitation of the available power. Dynamic Arc Recognition and Termination (DART) technology eliminates this restricting factor through a totally new approach to energy limitation:

When a spark occurs it gradually heats up. It remains non-incendive during its initial phase reaching incendive temperatures during the critical phase (Figure 4).

DART detects the characteristic electric behavior of a spark, more specifically the sharp current change di/dt , see Figure 4. DART safely limits the energy within the first 5...10 micro seconds of a spark being detected (Figure 5), which is during the initial phase of the spark, and therefore a spark is extinguished before it becomes incendive

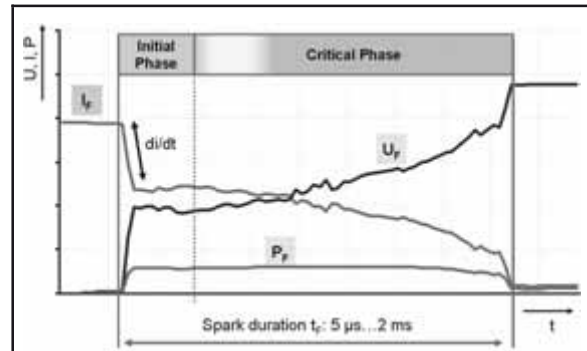


Figure 4: Typical electric behavior of a spark. Current, voltage and power shown over time.

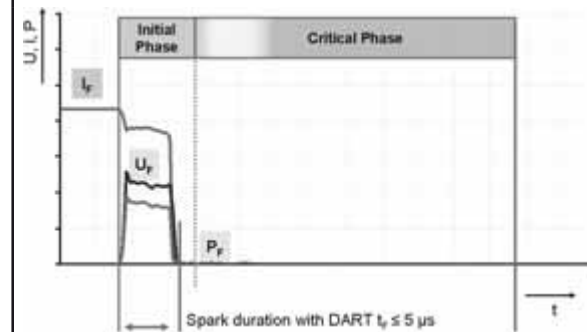


Figure 5: An electric spark terminated by DART before it becomes incendive.

Verification of intrinsic safety of DART power supplies and Segment Protectors is possible according to existing standards using modified testing methods. These new methods for testing of dynamically acting power supplies are currently being introduced to the standard. Validation of intrinsic safety will utilize the same mechanisms currently used to verify FISCO applications.

With DART all HPTC characteristics such as amount of available power, redundancy, diagnostics and support of FISCO/Entity devices remain enabled. Additionally the trunk is now intrinsically safe allowing maintenance along the trunk under operation without hot work permit.

6.2 Appraisal

DART represents the next, though revolutionary step from the High-Power Trunk concept. DART fieldbus allows up to 1000 m cable length and up to 24 devices per segment. In summary:

- Intrinsically safe protection of the entire segment including the trunk
- Support of Power supply redundancy
- Connection of any FISCO and Entity-compliant device, same as HPTC
- Continuous Advanced Physical Layer diagnostics.

7 Technical Comparison

As a summary the following table gives a brief overview of the basic merits and drawbacks of the four intrinsically safe fieldbus solutions introduced in this paper:

7.1 General performance of the intrinsically safe fieldbus solutions

	Entity	FISCO (redundant)	High-Power Trunk	DART
Available Power	–	0	+	+
Validation of Explosion Protection	–	+	+	+
Power Supply Redundancy	–	– (+*)	+	+
Long term Physical Layer Diagnostics	–	–	+	+
Segment Design Mix	–	–	+	+
Cabinet Space Requirement	–	– (–)	+	+
Power Supply Initial Cost	–	–	0	0
Trunk Live Working	+	+	–	+

* currently not certified

7.2 Comparison based on real-life application requirements

As basis for the case study the following values and limits are taken into consideration:

- The average current is derived from values found in datasheets of ordinary instruments such as Rosemount 8800C Flow meter, ABB pressure transmitter 265DC and Emerson Temperature Transmitter 848T.
- IEC 61158-2 defines 9 V as the minimum voltage level an instrument needs for proper operation. Adding a safety margin of 10% is usually demanded by specifications as reserve. This results in a minimum field device voltage level of 10 V.
- In order to allow future extensions of one or two instruments and to avoid overuse of the power supplies a current reserve of 20 % is factored in.
- Distribution units protect the trunk from spur shorts. A short additionally loads the trunk with 20 mA in the event. Distribution units contain electronics and consume approximately 5 mA per unit.
- An AWG 18 fieldbus cable operated at a temperature of 50°C has a resistor value of 50 ohms per km.

Parameter	Value
Instrument average current consumption	20 mA
Minimum available voltage available to instrument	10 V
Current reserve for future extensions per segment	20%
Power supply load reserve for short-circuit condition	20 mA
Current consumption per wiring interface, where used	5 mA
Cable specification	AWG 18, 50 Ω/km

The comparison shown in Table 3 illustrates the significant differences in actual available cable length, number of field instruments for each method described in this paper. Primarily the voltage level is the constraint for the maximum achievable cable length, while the current value is the constraint for the number of field instruments that can be operated.

Calculation basis is the voltage level a power supply provides under load which is typically 10...20 % less than the maximum voltage available at no load. The effectively available current describes the current available for the field instruments. It is calculated by the 20 % current reserve, the subtraction of 20 mA short circuit

current and 5 mA multiplied by the number of distribution units in use.

From the performance indicator values listed in Table 3 the conclusion can be drawn that the High-Power Trunk concept enables the longest cable runs while at same time allowing for a satisfactory number of field devices. DART however has the potential to become the alternative once it has been generally accepted, as it provides a completely intrinsically safe solution with the same amount of power for the same number of devices and cable length.

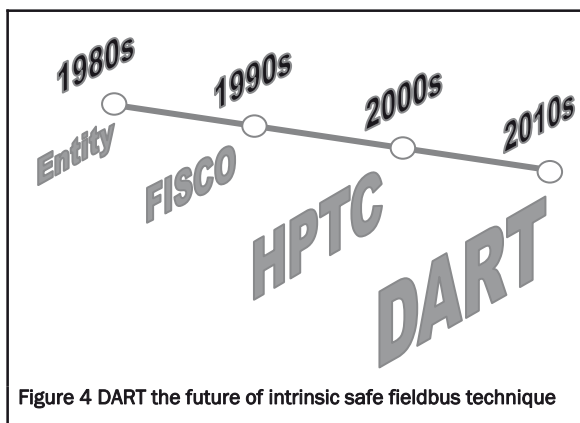
Table 3: Values calculated for Real-Life application

Performance indicator	Entity		FISCO		High-Power Trunk	DART
	IIC	IIB	IIC	IIB		
Maximum output voltage	10.9 V	18,65 V	14 V	14.8 V	30 V	24 V
Output voltage under load	10.6 V	17 V	12.4 V	13.1 V	28.5 V	22 V
Maximum output current	100 mA	350 mA	120 mA	265 mA	500 mA	360 mA
Effectively available current	55 mA	255 mA	66 mA	177 mA	360 mA	248 mA
Real-life trunk length (theoretic trunk length)	180 m (1900 m)	700 m (1900 m)	570 m (1000 m)	290 m (1900 m)	670 m (1900 m)	670 m (1000 m)
Real-life spur length (theoretic spur length)	30 m (120 m)	60 m (120 m)	60 m (60 m)	60 m (60 m)	100 m (120 m)	100 m (120m)
Max. Number of field devices	2	8	4	8	12	12

8 Conclusion

Beginning with a historic review how the intrinsically safe technology developed and how the High-Power Trunk has lead to the wide adoption of fieldbus technology this paper provides valuable decision making criteria where FISCO and comparable solutions such as the HPTC have their merits and drawbacks. Of all existing techniques the High-Power Trunk concept offers most benefits to users when a fieldbus installation implements intrinsically safe field device.

For the future, DART with a total power rating of 8 watts per segment offers more than 4 times the amount of intrinsically safe energy than with FISCO and 3 times more field devices. This improvement will have the biggest influence on the success of fieldbus compared to any other previous improvements. This time we can really speak about the “next generation” of intrinsic safety.



As a logical progression to the High-Power Trunk Concept, DART meets the demand for an intrinsically safety trunk line while providing higher levels of available power. It is the next milestone and the logical next chapter in the story of “Intrinsically Safe Fieldbus in the Hazardous Area”.

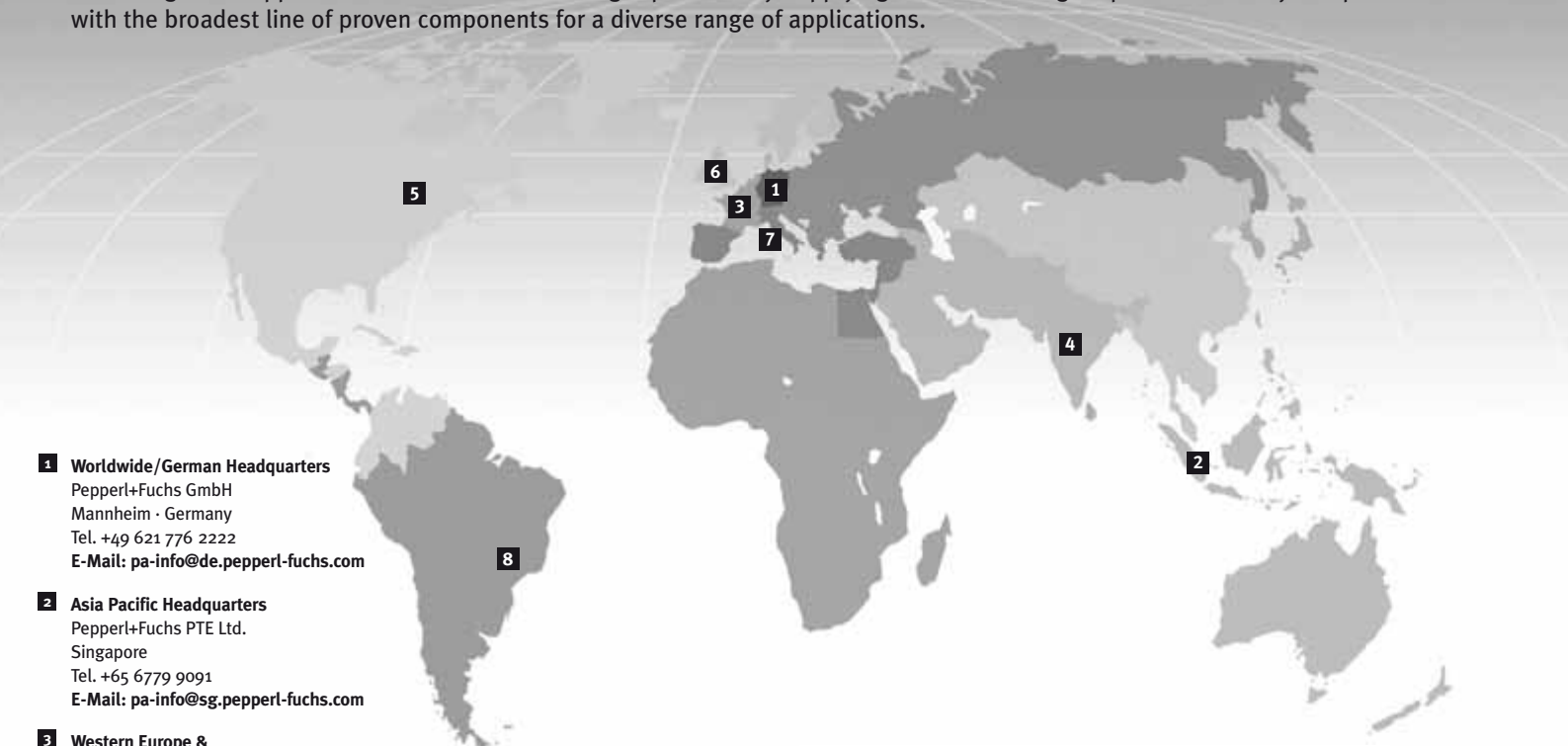
9 References

- [1] PTB report PTB-W-53e : „Investigations into Intrinsic Safety of field bus systems”, Physikalisch Technische Bundesanstalt, Braunschweig August 1994
- [2] FF-816: FOUNDATION™ Specification „31.25 kbit/s Physical Layer Profile”, Fieldbus Foundation Revision 1.0, May 1996
- [3] IEC 60079-27: International standard „Apparatus for explosive gas atmospheres – FISCO/FNICO”, International Electrotechnical Commission, First Edition 2005-04
- [4] IEC 61158-2: International standard „Digital data communication for measurement and control – Fieldbus for use in industrial control systems – Part 2: Physical Layer specification”, International Electrotechnical Commission, Fourth edition 2007-12
- [5] IEC 60079-11: International standard „Explosive atmospheres – Equipment protection by intrinsic safety “i” “,International Electrotechnical Commission, Fifth edition 2006-07
- [6] 5'th PCIC Europe: „DART – The New Dimension of Intrinsic Safety”, Petroleum & Chemical Industry Committee, Weimar Germany June 2008-

PROCESS AUTOMATION – PROTECTING YOUR PROCESS



For over a half century, Pepperl+Fuchs has been continually providing new concepts for the world of process automation. Our company sets standards in quality and innovative technology. We develop, produce and distribute electronic interface modules, Human-Machine Interfaces and hazardous location protection equipment on a global scale, meeting the most demanding needs of industry. Resulting from our world-wide presence and our high flexibility in production and customer service, we are able to individually offer complete solutions – wherever and whenever you need us. We are the recognized experts in our technologies – Pepperl+Fuchs has earned a strong reputation by supplying the world's largest process industry companies with the broadest line of proven components for a diverse range of applications.



1 Worldwide/German Headquarters

Pepperl+Fuchs GmbH
Mannheim · Germany
Tel. +49 621 776 2222
E-Mail: pa-info@de.pepperl-fuchs.com

2 Asia Pacific Headquarters

Pepperl+Fuchs PTE Ltd.
Singapore
Tel. +65 6779 9091
E-Mail: pa-info@sg.pepperl-fuchs.com

**3 Western Europe &
Africa Headquarters**

Pepperl+Fuchs N.V.
Schoten/Antwerp · Belgium
Tel. +32 3 6442500
E-Mail: pa-info@be.pepperl-fuchs.com

4 Middle East/India Headquarters

Pepperl+Fuchs (India) Pvt. LTD
Bangalore · India
Tel. +91 80 28378030
E-Mail: pa-info@in.pepperl-fuchs.com

5 North/Central America Headquarters

Pepperl+Fuchs Inc.
Twinsburg · Ohio · USA
Tel. +1 330 486 0002
E-Mail: pa-info@us.pepperl-fuchs.com

6 Northern Europe Headquarters

Pepperl+Fuchs GB Ltd.
Oldham · England
Tel. +44 161 6336431
E-Mail: pa-info@gb.pepperl-fuchs.com

7 Southern/Eastern Europe Headquarters

Pepperl+Fuchs Elcon srl
Sulbiate · Italy
Tel. +39 039 62921
E-Mail: pa-info@it.pepperl-fuchs.com

8 Southern America Headquarters

Pepperl+Fuchs Ltda.
São Bernado do Campo · SP · Brazil
Tel. +55 11 4339 9935
E-Mail: pa-info@br.pepperl-fuchs.com

www.pepperl-fuchs.com

 **PEPPERL+FUCHS**
PROTECTING YOUR PROCESS