Session Eleven:
The Application of Intrinsic Safety to Fieldbus Systems

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Fieldbus Background

There are a significant number of types of Fieldbus but this note concentrates on the systems designed in accordance with IEC61158-2, which in process control are predominantly Foundation Fieldbus and Profibus. Fieldbus systems usually comprise a source of power, host, terminators and a number of field devices interconnected as shown in Figure 1.

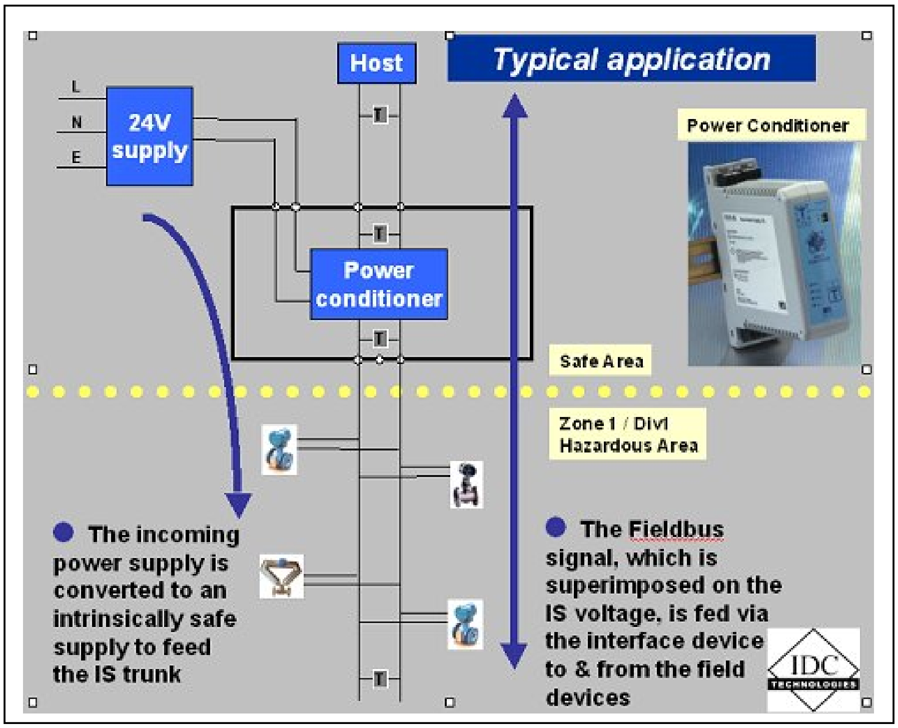

Figure 1

Typical Application

Fieldbus field devices require a minimum of 9V to operate. They continuously consume a direct current, usually of the order of 20mA with an alternating signal current of 10mA superimposed upon that current when the device is active. Since intrinsic safety is of necessity a low current technique, then devices which consume low standing currents are preferable and some recent devices consume only a few milliamps. Conventional

Fieldbus systems are restricted to 32 devices per system. However this is very rarely approached because of the power required, the time it takes to address such a system and the implied system reliability. An average of about eight devices is common with twelve devices being not unusual.

Early intrinsically safe Fieldbus installations used a resistive limited shunt diode safety barrier but this restricted the available current and voltage and imposed a safety earth on the system, which caused some operational difficulties. In addition the safety documentation was complex because of the number of devices in the system. The Fieldbus Intrinsically Safe Concept [FISCO] was developed to alleviate these problems. However there is no reason why the conventional system rules should not be applied to Fieldbus systems if this approach is preferred.

FISCO Installation

The experimental work on which FISCO is based was carried out by PTB [The German certification organisation] and the initial proposal derived from the report on that work

Power-supplies and Power-supply Characteristics: Increased power was made available by using constant current power supplies instead of the usual resistive limited supplies. It has been known that additional power could be safely derived by using constant current techniques for many years but it is only comparatively recently that semiconductor series limitation has become internationally acceptable. Even now it is regarded with suspicion and only permitted for “ib” [Zone 1] circuits. Almost all existing intrinsically safe system theory is based on resistive limited circuits and consequently constant current supplies are not commonly used except in Fieldbus circuits. An annex of the system standard discusses the techniques for combining constant current and resistive limited sources of power and is 74 pages of detailed Germanic logic. This is in itself sufficient to discourage the use of constant current supplies in non-Fieldbus applications. The FISCO standard defines the acceptable voltages and currents and how the power supply can be used in FISCO systems. The increase in available current over that from a resistive limited power source varies with the voltage but at 18V is approximately a factor of two. The power available if a IIC [hydrogen] system is required is restrictive, but where a IIB [ethylene] system is acceptable the available current increases by a factor of two and is considerably less restrictive

The use of “three port” galvanic isolation enables the Fieldbus circuits to operate as balanced circuits and removes the difficult problem of interacting earth faults

A FISCO power supply when used in the conventional manner illustrated in Figure 1 has to deliver direct currents from a low impedance [1Ω] and present a high impedance at the signal frequencies [100kΩ]. This complicates the power supply and tends to interact with the safety requirements. The useable power from an intrinsically safe power supply is always significantly lower than the safety description because of tolerances in the safety components and the voltage drop across them. The more useable power supplies also reshape and boost the received signal.

Other Devices*:* The design of the remainder of Fieldbus devices is governed by the need to be compatible with the power supply output. In particular they must be IIC certified and be capable of dealing with the 5,32 w available from the IIB power supply. Their permissible effective input parameters are restricted to 5nF and 10μH so that they can be added to a FISCO system without further consideration.

The requirements of the terminators are closely and simply defined so that they cannot cause a problem.

The usual “simple apparatus” requirements apply, with the additional limitation on capacitance and inductance to 5nF and 10μH.

System Design

A major difference in the FISCO approach from that of conventional systems is the treatment of cable capacitance and inductance. The PTB research demonstrated that under the permitted voltage and current conditions and provided that the cable parameters were within certain limits the adding cable tended to make the circuit safer. Consequently the FISCO standard requires that cables have parameters between the following limits; loop resistance 15 to 150 Ω/km, loop inductance 0,4 to 1,0 mH/km and capacitance 45 to 200 nF/km and then no further consideration of cable parameters is necessary. Conventional instrument cable is always within these limits and hence the need to document cable lengths and calculate capacitance and inductance is removed. There is a cable length restriction in IIC systems to 1 km but this is because of the absence of supporting experimental evidence rather than belief that it is unsafe to exceed 1km. In practice trunk lengths in IIC systems are usually restricted by voltage drop in the cable resistance. IIB systems are permitted a 5km cable length and hence there is no problem if the less sensitive gas group is acceptable. [Fieldbus trunks are usually limited to 1,8 km for operational reasons.] There is a restriction on spur lengths to 60m because they are unterminated extensions and because of restricted experimental evidence. This is not usually a problem but can affect the location of junction boxes.

When the specified cable and equipment is used a system can be created without further consideration of the safety aspects. The gas group of the system is determined by the power supply and the temperature classification of each apparatus by the certification of that apparatus. The required documentation is a list of the equipment used in the system and their apparatus certification. The format used is not critical.

Practical Consideration

The principal restriction on a FISCO “ib system” is the limitation imposed by the permitted current and voltage, which restricts the number of devices which can be connected and the length of bus which can be utilised. The possible interconnections are infinite and it is difficult to choose a truly representative sample.

Available power supplies have different combinations of voltage and current and different field devices require different continuous levels of current. The two diagrams illustrate the simple arithmetic necessary to ensure operability and assume a trunk resistance of 50 Ω/km and a device current consumption of 20mA. A more optimistic result can be achieved by using a thicker cable and reducing the current consumption per device but the values used are not unrepresentative.

The illustrated results of five devices on a 600m trunk in IIC and twelve devices on a 300m trunk in IIB are not unrepresentative of what can be readily achieved. The available trunk length can be increased by reducing the number of devices.

FNICO and "ic"

The Fieldbus Non Incendive Concept [FNICO] was established as a technique for using the FISCO approach in Zone 2 with larger currents. The "non incendive" concept or in IEC terms the "energy limited" [nL] concept will be replaced by the "ic" concept in future standards and the latest FISCO standard which is at the CDV stage carries this through.

Theoretically it could be possible to relax the requirements in several sectors but in practice the major change is the considerable increase in permissible current caused by the change in safety factor from 1,5 to unity. Changes in the remainder of the requirements were kept to a minimum so as to maintain a uniform approach to system design and utilisation. The majority of field devices used in "ic" circuits will be certified "ia IIC T4" because the manufacturers find it more economic to manufacture a single device useable in all circumstances. To the user this has advantages from a spares stockholding viewpoint. The other advantages of the "ic" concept discussed in the previous paper are equally applicable to FISCO systems. In particular, temperature classification in normal operation makes life simpler.

The documentation required is just a simple spread sheet list of the equipment

From a practical viewpoint the increased current makes it possible to interconnect more devices. For example the number of 20 mA devices that can be connected in an IIC atmosphere is increased from five to nine. The practical limitation in "ic IIB" circumstances is nearly always the available length of trunk and this problem can be overcome by the use of a thicker trunk cable.

In practice it is almost impossible to create a Zone2 IIC location except in a very confined space. Where hydrogen is the risk the concentration has to be in excess of 10% before the ignition energy of the mixture exceeds that of IIB gases and because of the extreme mobility of hydrogen this is unlikely. Consequently almost all freely ventilated Zone2 locations could be designated IIB which would make the use of "ic IIB" the norm and life much easier.

The Exe and Exi Combination

The frequently used solution to overcoming the trunk length limitation is to use an increased safety [Exe] trunk and then convert to intrinsically safe spurs at a field mounted hub. This allows the power supply to operate at higher voltages [24V] and higher currents [2A] and consequently longer trunks and more devices become possible. There are a number of variations on this theme so it is difficult to generalise but the increased trunk lengths necessary on some installations are achievable. Care should be taken to question the more extreme claims as they frequently require the rewriting of Ohm's law. [2A flowing in a 1km cable with a resistance of 50Ω requires 100V and cannot be derived from a 24Vsupply].

The alternative solution to meeting the requirement for a long trunk length is to use a FISCO power supply as a repeater, if necessary mounting the supply in a Zone 2. However this does require a 24V supply to be available at the location of the repeater.

The Exe technique is of German origin and was devised as a "safe by design" technique for high power electrical equipment to overcome an aversion to the flameproof technique. There are some difficulties to applying the technique to light current systems but with some ingenuity this can be done. It helps if you have a tame German technician to make the ad hoc decisions and maintain the equipment in the pristine conditions necessary to ensure its safety. Fortunately the majority of the trunks and the converting hubs are in Zone 2 locations and hence the risk is reduced to an acceptable level.

A typical system is as illustrated in Figure 2, and comprises a power supply, an Exe trunk, Fieldbus barriers and Exi spurs leading to the field devices. The Fieldbus barrier converts the Exe power into an isolated Exi signal allowing the usual advantages of intrinsic safety [such as 'live maintenance'] to be applied to the spurs and to parts of the barrier enclosure. The barrier enclosure requires careful design and is usually bought as part of the complete system.

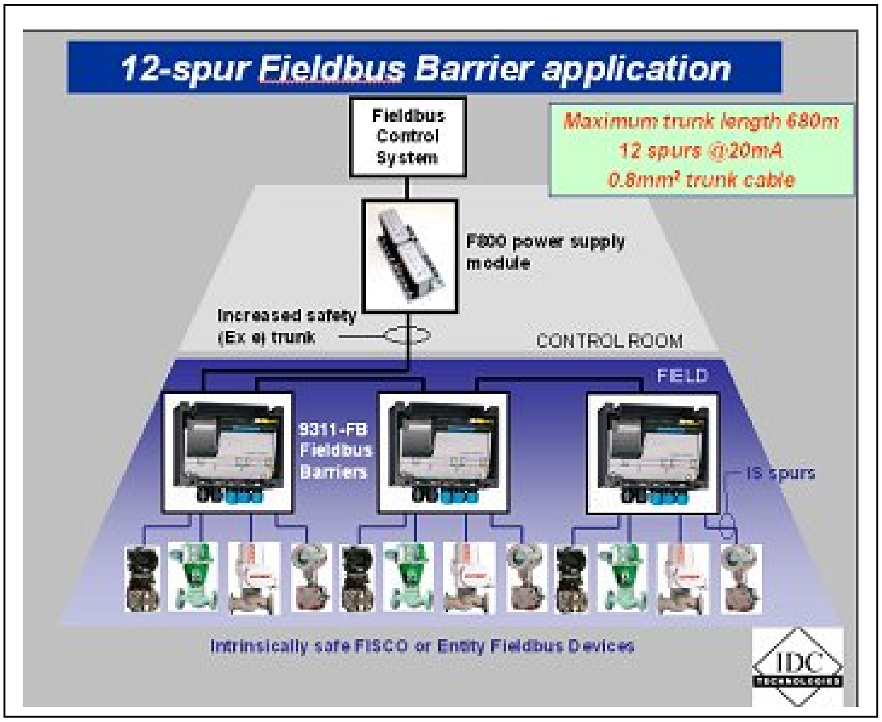

Figure 2

The primary advantage of the Fieldbus barrier is that it allows longer trunks to be used. The advantage is reduced by the additional voltage drop [16V] required by the barrier and the additional current used to operate the barrier. Nevertheless the advantage gained is significant. A further advantage is that the power supply can be made redundant. The disadvantages are that there is a significant amount of complex electronics in the field, the use of two explosion protection techniques complicates the installation and maintenance procedure and it is frequently more expensive

Maintenance and Inspection

Fieldbus systems [in common with other "smart" equipment] are relatively easy to monitor for operational reliability and there are a number of modules specifically designed for this purpose. A Fieldbus system can be continuously monitored to check that it is operating correctly and also by recognising deterioration in signal quality can anticipate some forms of failure. In particular early recognition of damage to cables is a significant improvement on conventional techniques.

Theoretically an instrument could operate successfully and have failed to a dangerous condition but this is not likely. The safety components in an intrinsically safe apparatus have all been derated and hence any misuse or deterioration with time is more likely to preferentially affect operational components. In any case it is often impossible to check the integrity of safety components, [for example under encapsulation,] hence a frequent operational check is an improvement on the previously accepted norm. If this system is to be effective in increasing safety it must be backed up by removing the defective device within a short time. The removal of defective equipment is part of good housekeeping on all plants but is arguably more important in hazardous locations.

The need for routine inspections and the tedious reading of illegible unintelligible labels can be removed because the monitoring system can detect any changes in the equipment used in the system. If the initial inspection is thorough it is only changes that can cause danger. An infrequent check on mechanical condition is all that is required to supplement what is effectively continuous inspection

Intrinsically Safe Ethernet

A limitation of Foundation Fieldbus and Profibus in some applications is its speed. There is an increased use of Ethernet in process control within hazardous areas and there are a number of intrinsically safe devices available to facilitate its use. Quite how far and fast its use will grow is open to speculation but there are some attractive possibilities which take advantage of its higher speed and of the range of components and facilities created by its wider use. Whether the application of Ethernet will develop so as to maintain the desirable ‘open system’ approach will be interesting to watch.

This note is only intended to draw attention to the development. The subject would require another paper to be adequately considered.

Conclusion

The use of Fieldbus in hazardous areas is now a mature subject from both a standards and available equipment viewpoint. In particular the use of “ic IIB” systems in Zone 2 locations offers a simple solution to a large number of problems. In general full advantage of the ‘smart’ element of the available equipment to reduce inspection and maintenance requirements has not been taken at the present time.

Longer term it may be that imposing FISCO type limitations on other types of apparatus and associated cables could be used to create a simpler and safer way of creating systems. This would help to reduce the common misapprehension that intrinsic safety is complicated. It would make the design of apparatus more complex but this is done once in controlled circumstances under ‘certified’ surveillance. In contrast systems are created under less well supervised circumstances and hence the rules for combining equipment should be kept as simple as possible. However this desirable development is unlikely to occur in the foreseeable future.

The FISCO standard IEC 60079-27 will be replaced by annexes in the apparatus and system standards in the next few years