

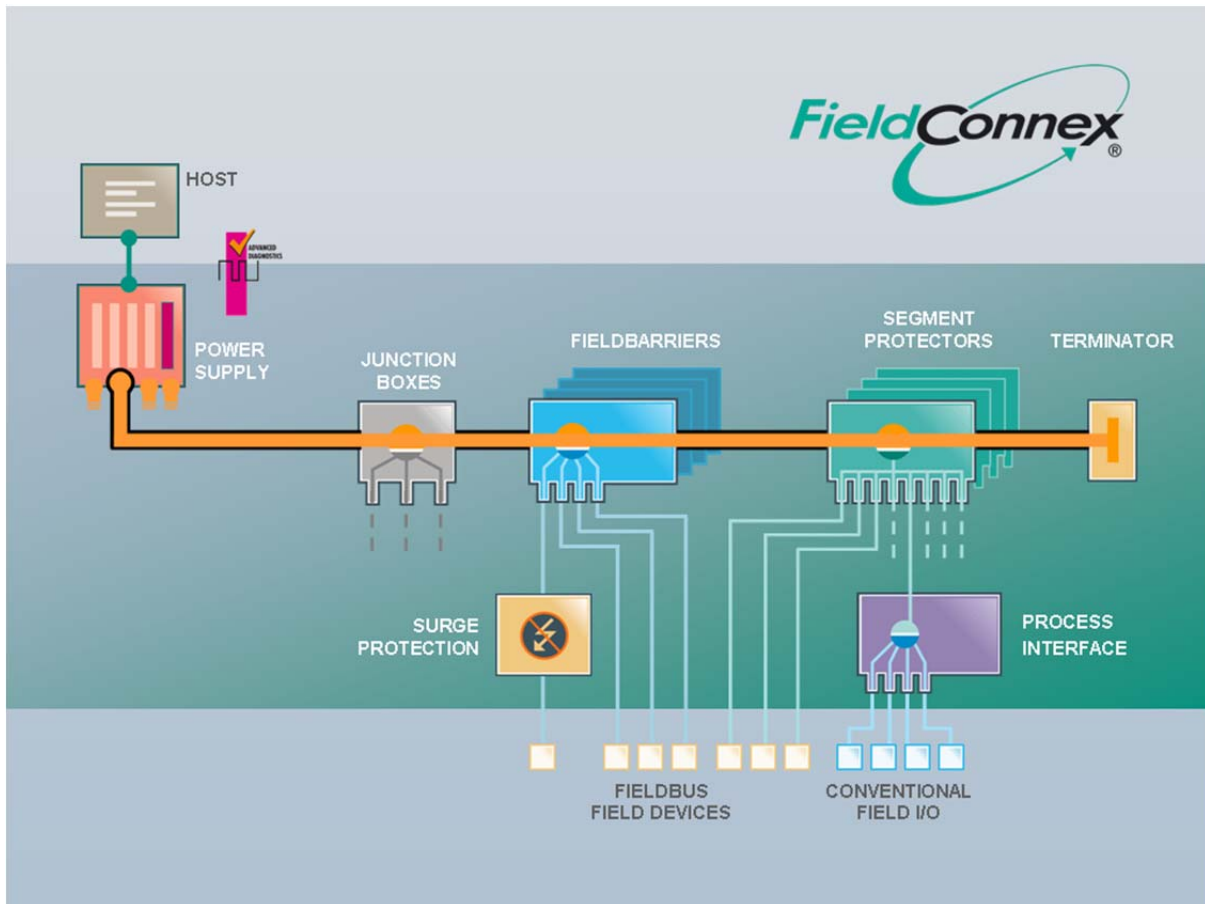
TECHNICAL WHITE PAPER

ADVANCED DIAGNOSTIC FIELDBUS SURGE PROTECTION

This paper will cover advanced diagnostic surge protection devices specifically designed for fieldbus networks, outlining the technical steps taken. The methodology that supports fieldbus network integrity beyond the current offerings will be explained. A case study will demonstrate the significant reductions in operational expenditure when using a fully diagnostic fieldbus surge protection system.

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Quality Information from a Quality Supplier

This technical white paper utilizes Pepperl+Fuchs' expertise and knowledge to provide a clear insight into the many new technology and application issues you may face with a fieldbus installation. It corresponds with our way of working and thinking: combining state-of-the-art technologies with years of research and innovation to simplify planning, installation and commissioning, operation, and plant upkeep.

If the content of this paper sparks comments or questions, we invite you to contact your Pepperl+Fuchs office or representative to get in touch with the experts. We are glad to share our expertise with you for your business success.

Our promise is to simplify your work processes: You can stay focused on your day-to-day business with a reliable FieldConnex® fieldbus infrastructure. It ensures the connection between DCS and instruments—fully digital with explosion protection for any hazardous area. We are driven to provide innovation with proven reliability for process automation practitioners:

- FieldConnex is robust, reliable, and the first choice of many well-known end users worldwide.
- Advanced physical layer diagnostics reach down to spurs, accessories, and instruments; interpret data, and provide detailed fault analysis. Water ingress and worn-out surge protectors are identified without manual checking.
- The High-Power Trunk concept allows long cable runs and high device counts and is now an industry standard. DART Fieldbus makes the High-Power Trunk intrinsically safe.

We hope that the contents of this paper are helpful to your daily work or decision process. We look forward to hearing from you.

Table of Contents

- 1 Introduction2**
- 2 Reliability and failure modes of surge protectors2**
- 3 Commonly used diagnostics for surge protectors3**
- 4 Advanced diagnostic solution for surge protectors3**
 - 4.1 Surge Protector Diagnostics: quantitative and qualitative measurement 3
 - 4.2 Continuous measurement of the impact of surge protector components degradation..... 4
 - 4.3 Relaying the diagnostic information into the DCS 4
 - 4.4 Diagnostic information and reporting..... 4
- 5 Case study6**
 - 5.1 Maintenance procedure..... 6
 - 5.2 Cost Comparison.....7
- 6 Summary.....9**
- 7 References9**

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1 Introduction

Surge protection (SP) is a common addition to any electrical power or communication system since it protects sensitive, expensive electronic equipment from any lightning strike damage.

IEC61158-2-based communication systems like FOUNDATION™ Fieldbus H1 and PROFIBUS PA are one example where surge protection is used not only to protect the physical hardware, but also to ensure continued process measurement and control following a lightning strike.

Furthermore, surge protection devices (SPDs) are required for hazardous areas that contain explosive materials. The international standards IEC 60079-14 and IEC 62305-3 annex D outline the requirements for such devices, and the need to regularly maintain or test the devices on a yearly basis, and after each lightning strike.

This paper will provide an overview of the impact on the availability of fieldbus segments using surge protection. It will also cover the methods used to increase the availability of fieldbus segments using the surge protector's integrated diagnostics in combination with Advanced Physical Layer Diagnostics. Finally, a case study will show the significant savings gained by using integrated diagnostics within surge protectors.

2 Reliability and failure modes of surge protectors

Surge protection devices comprise semiconductors (TVS) for high-speed suppression, gas discharge tubes (GDT) for high-power absorption, and resistors or inductors.

These components are under a great deal of stress during a strike, but they are specifically designed to cope with this stress. Nevertheless, they can only tolerate a certain amount of stress before they eventually fail.

This failure point occurs after a certain amount of stress has been reached and is due to two factors: the energy levels they have shunted, and the number of times they have been operated at a given energy. The higher the energy, the lower the number of operations they can tolerate before they fail.

Typically, the failure modes of TVS and GDT result in a short circuit. If series resistors are used, their typical failure mode is an increase in

resistance due to the fracturing or thermal damage of the film or resistance wires.

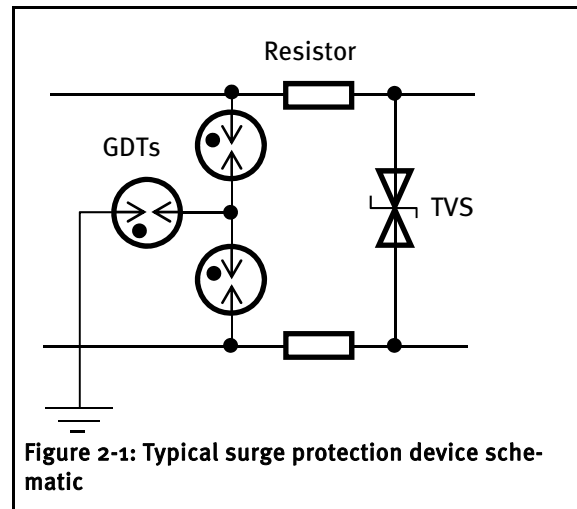


Figure 2-1: Typical surge protection device schematic

Each failure mode will lead to a fieldbus failure, including the loss of an entire segment.

But not all protection components will fail in the failure modes described above.

The resistors can gradually show an increase in series resistance, for example, an increase from 1 Ohm to 5 Ohms due to film or resistance wire damage. TVS and GDT can also show signs of fatigue before they actually avalanche into total short circuit failure. Typical leakage current for a functional device is generally in the region of micro amps (μA). This can increase to tens, if not hundreds of milliamps (mA) if the device has been slightly damaged following a lightning strike.

For most electrical power systems, this degradation is not a real issue. But for fieldbus (and equally for classic 4 mA ... 20mA systems), there are many surge protectors connected to the same network, and collectively, any leakage currents or impedance changes add up.

The increase in shunt current contributes to the total segment current and eventually trips the fieldbus power supplies and/or creates segment imbalance leading to increased noise susceptibility.

Equally, any increases in impedance affect the signaling performance in many ways, to the point of segment failure.

Therefore, the introduction of diagnostics to monitor these effects is invaluable.

3 Commonly used diagnostics for surge protectors

In electrical power systems, surge protection failures can cause a circuit breaker and/or residual current detector to trip, cutting the supply to any attached loads.

Surge protection manufacturers have understood that the protection devices can tolerate more than one large strike before they fail. Therefore they have been quick to realize that if the strike event can be monitored and communicated to a local indicator, then the user has a better chance to replace a device before it becomes a problem, in a more proactive way.

Different technologies have been introduced in order to detect lightning strike events. Some methods are superior to others, but there are always costs to consider. The more advanced methods are very much more expensive, of course, but there is a balance between diagnostic costs and adequate monitoring.

Some of the more basic solutions include using a thermal fuse or thermally sensitive chemical indicators. By monitoring temperatures, these indicators reveal whether the surge protector has been thermally stressed. This type of detection only—locally—indicates if the device has been overstressed, but not how many times it has been stressed or to what magnitude. Even lower stresses that are not detectable by the thermal trip/indicator system can lead to a surge protection device failure or degradation.

A more advanced diagnostic solution uses a magnetic coil that is positioned around a common ground connection to measure the current flowing through the grounding cable. The signal from the coil during a strike is then used by an electronic trip circuit to locally indicate if the surge protection device has been operated above a given threshold.

In both of the examples above, the surge protection diagnostics provides information only for a single high-level strike, rather than monitoring if there are any performance degradations or providing any quantitative or qualitative measurements.

At this point, it is common practice to either replace the surge protector (or group of surge protectors that use a single measurement point on a common grounding bus) or to use dedicated portable surge protection diagnostic equip-

ment to measure or test for any failures or performance degradation.

In all cases, it is not known how severely the surge protection device has been struck or how much further protection the surge protector can give.

Relaying or cabling the strike diagnostic information to a centralized maintenance terminal is expensive and rarely implemented. Even if it is used, the need to check each surge protector with suitable diagnostic equipment is still a requirement, particularly where degradation can affect a system such as a fieldbus segment.

4 Advanced diagnostic solution for surge protectors

Pepperl+Fuchs understands the need for cost-effective proactive diagnostics and has used this very effectively for its fieldbus applications, by relaying the diagnostic information from the surge protector through the Advanced Physical Layer Diagnostics infrastructure.

4.1 Surge Protector Diagnostics: quantitative and qualitative measurement

Pepperl+Fuchs has studied and tested surge protectors, and knows where the protection component's failure points are, or will be. Within this failure envelope, the number of tolerated strikes is proportional to the strike intensity:

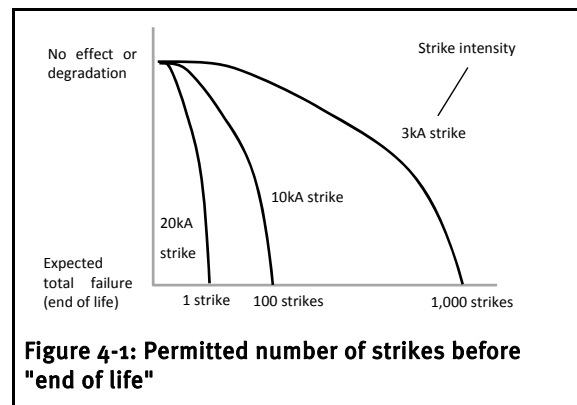


Figure 4-1: Permitted number of strikes before "end of life"

By measuring the strike number (quantitative) and the strike intensity (qualitative), using a magnetic coil pickup and an energy integrator, an accurate prediction can be calculated as to when the surge protector will need to be replaced.

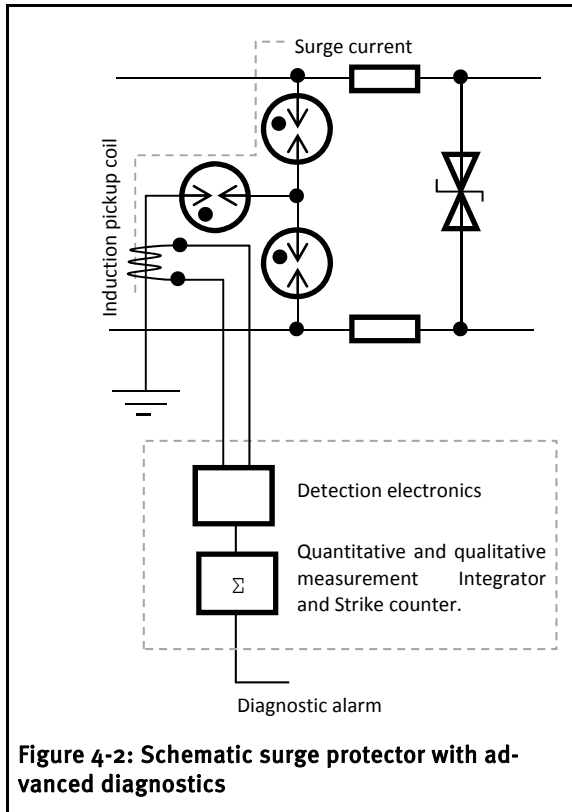


Figure 4-2: Schematic surge protector with advanced diagnostics

4.2 Continuous measurement of the impact of surge protector components degradation

Between the surge protectors initially installed specification and total failure, the surge protection device can degrade in performance following a series of low-level strikes, which can lead to qualitative fieldbus physical layer changes, and inevitable fieldbus segment failure, with very little warning.

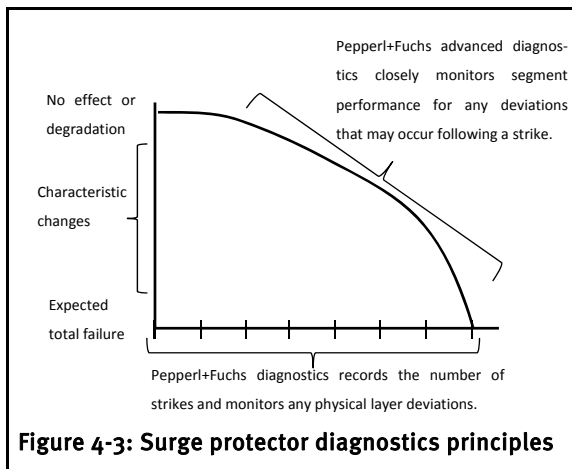


Figure 4-3: Surge protector diagnostics principles

During the time between installation and "end of life," the Advanced Physical Layer Diagnostics solution continually monitors the segment for any qualitative physical layer changes:

The degradation of any surge protector can affect the physical layer variables in many ways. Each of the effects can be detected by the Advanced Diagnostic Solution located at the fieldbus power supply (Power Hub).

Surge protector degradation can affect at least one of the following physical layer parameters:

- Trunk or spur unbalance, caused by a leaking positive or negative TVS or GDT.
- Signal attenuation, caused by a shunt TVS or GDT reduction in impedance or an increase in the series resistance.
- Increase in quiescent current, caused by a leaking shunt TVS or GDT.
- Difference in signal amplitudes, caused by an increase in series resistance.
- Signal jitter changes, caused by a reactive impedance fault in any of the TVSs or GDTs.

4.3 Relaying the diagnostic information into the DCS

As mentioned previously, cabling the surge protector's diagnostic information back to a maintenance terminal is never implemented as a point-to-point diagnostic monitoring solution or even using a dedicated serial bus. This would be too expensive for any hazardous area cable installation.

Instead, the existing advanced physical layer infrastructure can more effectively be used to communicate the surge protector diagnostic information back to the maintenance terminal or to the DCS, where the details are shown in the diagnostic manager software.

4.4 Diagnostic information and reporting

The diagnostic information must be processed to be effective.

Qualitative and quantitative diagnostic data analysis is first performed by the surge protector using specific algorithms. This information is processed and passed to the relevant local display and/or to the maintenance terminal depending on severity. The diagnostic severity status is shown only on the surge protector's local LED indicator.

If the surge protector is in need of immediate attention or replacement, this is indicated by the surge protector's status LED. An alarm is issued through the advanced physical layer infrastructure, back to the Advanced Diagnostic Module, and finally to the maintenance terminal's diagnostic manager software.

In addition, the physical layer diagnostic module continuously monitors for any changes in the physical layer attributes.

If a surge protector issues an alarm, the diagnostic manager advises the operator which

surge protection device needs to be replaced, eliminating the need for any control room or field surge protection device testing.

The diagnostic manager generates a report with a mouse click to document the health status of all the connected surge protectors and identify which surge protection devices need to be replaced after a lightning strike or during scheduled maintenance.

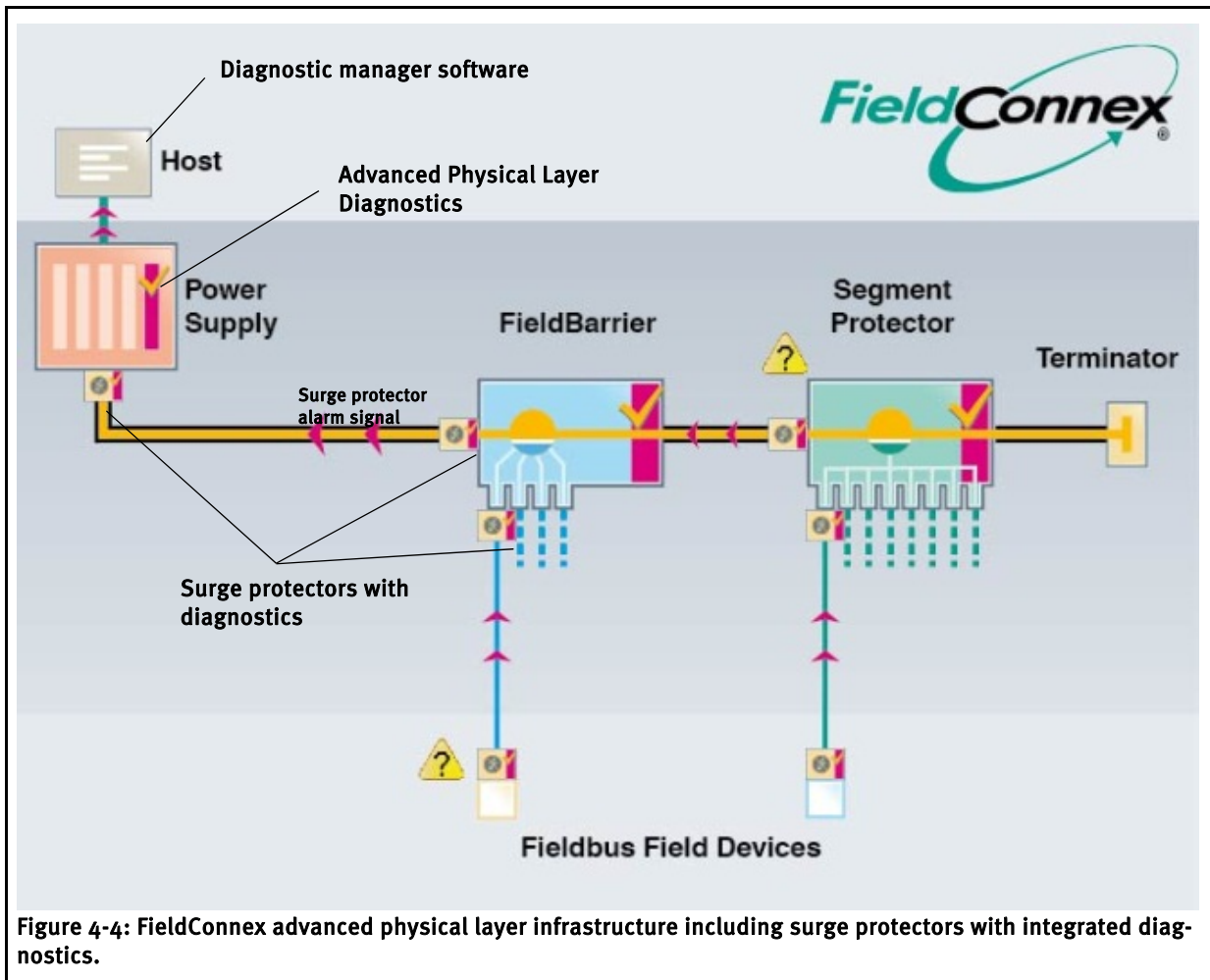


Figure 4-4: FieldConnex advanced physical layer infrastructure including surge protectors with integrated diagnostics.

5 Case study

This case study will consider a small process plant comprising 100 fieldbus segments with 8 fieldbus devices connected to each segment.

Geographical location determines how many lightning strikes a process plant can expect to receive in any given year. Locations in the far northern hemisphere (or southern) are unlikely to be exposed to many strikes. In typical process plant locations throughout the world, strike rates are often on the order of 5 to 10 per year per km².

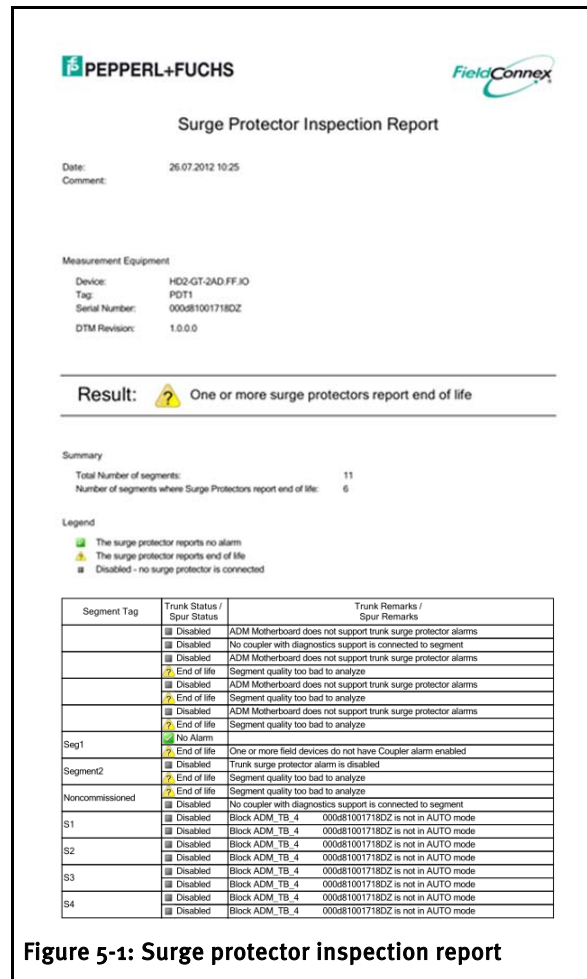
One and three strikes each year are considered for this case study, which is a realistic yet conservative estimate. A yearly surge protector test or a test after each strike is the recommended testing frequency in accordance with **IEC62305-3 Annex D** (see note 1). Higher strike rates require a higher number of checks.

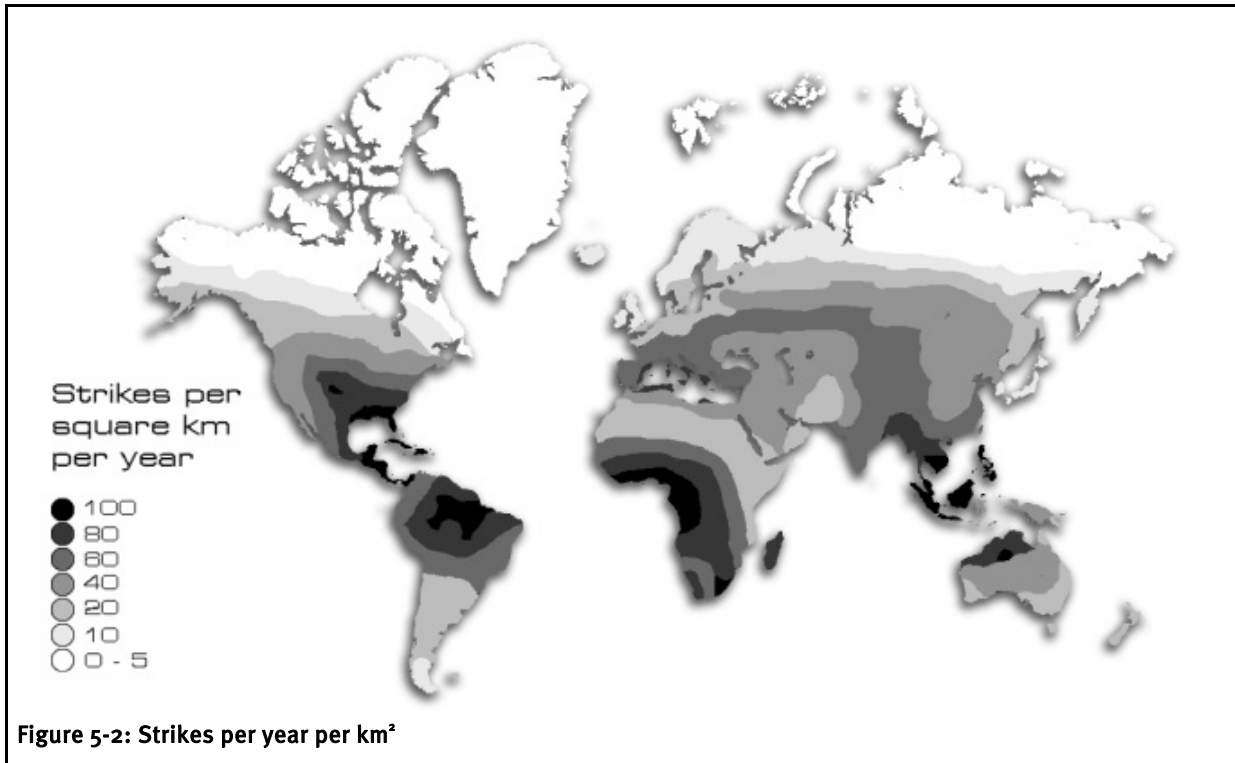
5.1 Maintenance procedure

Pepperl+Fuchs surge protectors (SPs), with predictive failure diagnostics (diagnostic SPs), only require access to the diagnostic manager software for SP testing. This is a simple procedure taking no more than 5 minutes to access the data for all SPs. The software is able to identify any faulty SPs for replacement.

In the case of non-diagnostic SPs, the maintenance procedure requires a functional test of all fieldbus SPs, where high costs must be faced due to the need to access all SPs in the control room **and** out in the field enclosures.

Note 1 IEC62305-3 Annex D recommends a yearly test for all SPDs, unless there is evidence or data that allows for longer intervals. With a fully diagnostic system, testing is continually performed.





5.2 Cost Comparison

Of course, diagnostic SPs with predictive failure diagnostics are more expensive when compared to non-diagnostic SPs. However, for Pepperl+Fuchs diagnostic SPs, there are no additional wiring requirements. As a result, the costs for implementing a diagnostic communication system, apart from the additional hardware costs, are zero.

However, the additional costs for diagnostic SPs can be recovered in a very short time period:

Table 1: System Dimension	
Automation Infrastructure	Count
Number of segments	100
Number of devices/segment	8
Number of devices	800
Number of SPs/segment	18
Total number of Surge Protectors	1,800

Table 2: Cost base	
Case study figures	Value
Average number of strikes/year	1 or 3
Added costs of diagnostic SPs	\$35 US
Hourly maintenance costs	\$70 US
With diagnostics	
Operate diagnostic manager S/W	5 min
Costs for procedure at each strike event: 0.083 hrs x \$70	\$6 total
Without diagnostics	
Test & report time per device	10 min
Costs for testing at each strike event: 1,800 x \$70/hr x 10 mins	\$21,600

Table 3: Cost calculation with ONE strike per year							
Product and costs	Product cost	YEAR					TOTAL
		1	2	3	4	5	
Inspection/reporting costs for non-diagnostic SPs	-	21,600	21,600	21,600	21,600	21,600	\$108,000
Additional costs for diagnostic monitoring hardware. 1,800 x \$35	63,000	-	-	-	-	-	\$63,000
Inspection/reporting costs for diagnostic SPs	-	6	6	6	6	6	\$30
BREAK EVEN		X (4 Years)					
Total cost over 5 years			Non-diagnostic Surge Protectors			\$108,000	
			Diagnostic Surge Protectors			\$63,030	

Table 4: Cost calculation with THREE strike per year							
Products and Activities	Product cost	YEAR					TOTAL
		1	2	3	4	5	
Inspection/reporting costs for non-diagnostic SPs	-	64,800	64,800	64,800	64,800	64,800	\$324,000
Additional costs for diagnostic monitoring hardware. 1,800 x \$35	63,000	-	-	-	-	-	\$63,000
Inspection/reporting costs for diagnostic SPs	-	18	18	18	18	18	\$90
BREAK EVEN		X (2 Years)					
Total cost over 5 years			Non-diagnostic Surge Protectors			\$324,000	
			Diagnostic Surge Protectors			\$63,090	

6 Summary

Utilizing qualitative and quantitative measurements for surge component stress monitoring and failure prediction, combined with online physical layer monitoring, significantly increases fieldbus segment availability through early warning and proactive maintenance. The solution certainly takes away the need for testing every surge protector yearly and/or after each lightning strike. This reduction in testing and unnecessary replacement of surge protection devices is a significant savings in overall maintenance costs, particularly where work permits or gas clearance is required for each site visit.

Economically, the diagnostic system makes sense with its use of the existing diagnostic infrastructure. Therefore, the added cost of diagnostic integration is initially low and the hardware cost for surge protection diagnostics is recovered within a very short time frame.

Without doubt, this combined diagnostic approach is an important step in the prevention of a fieldbus segment failure in what is essentially a product protection system.

7 References

- [1] Pepperl+Fuchs white paper: "Fieldbus testing with online Physical Layer Diagnostics," 2007
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- [5] Surge Protection Anthology, April 2003. By various authors.
- [6] "Effectiveness of worldwide existing ESE lightning protection systems manufactured in Europe."

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.

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