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Proof Test Prudently

Understand how to effectively evaluate low-demand safety instrumented functions

By Denise Chastain-Knight and Jim Jenkins, exida

The functional safety lifecycle covers a safety instrumented system (SIS) from concept to retirement. While important activities occur in each phase of the lifecycle, operation phase activities stand out because they are performed repetitively and are critical to long term reliability.

An SIS is a high reliability system comprised of sensors, logic solver(s) and final elements. It includes a number of safety instrumented functions (SIFs), each designed to provide a specified risk reduction. The necessary risk reduction is assigned as a safety integrity level (SIL) that establishes the reliability requirements for the SIF. A clear understanding of the failure rate, failure mode and failure effects for devices as well as implementation of a management program to effectively identify and correct failures on a routine basis are essential for achieving the needed reliability.

SISs operate in one of three modes: continuous, high demand or low demand. In low-demand systems, proof testing is an effective tool because the SIF components generally are dormant for long periods of time — which provides the opportunity to detect and repair failures and then return the component to service between demands.

In this article, we'll review failure rate and failure mode basics, discuss proof test frequency and effectiveness, consider the robustness of the maintenance program, identify information to be collected during a proof test, and provide tips for analyzing the data to ensure continued reliability.

DEVICE FAILURE BASICS

You must overcome three hurdles to achieve the SIL target: probability of failure ($PFD_{avg.}$ in low demand), hardware fault tolerance (HFT) and systematic capability (SC). The failure rate, failure mode and failure effects of the SIF components influence all three hurdles. Reliability theory is based on the premise that components are replaced at the end of their useful life before wear-out affects failure rate. A common mistake in the operating phase is overestimating the useful life of devices. For example, solenoids have a useful life of 3–5 years and should be routinely replaced during refurbishment. Valves can have a useful life as short as 3–10 years — or less if improperly specified, installed in severe service applications or not maintained correctly.

Devices are classified as Type A or B. Type A devices generally are mechanical and usually fail in a more predictable manner. Examples include valves, actuators, solenoids and relays. Type B devices are primarily intelligent and electronic — therefore, they can fail unpredictably. HFT requirements are increased for Type B devices to compensate.

Failures may be random or systematic. Systematic failures stem from design or manufacturing procedures or personnel competency — and can be reduced or eliminated. For certified devices, SC is determined by assessing the ability to control or avoid failures associated with the design and manufacturing process. A certificate will list the SC limits of a device for a specific HFT based on the assessment. Non-certified devices require the reduction of random and systematic failures through proven in use (prior use) data collection and analysis.

Overall device failure rate will include both random and systematic failures. Failure mode is either safe, dangerous or no effect. Failure rates are designated by λ, using subscripts to indicate safe (S) or dangerous (D), and detected (D) or undetected (U). For example, a safe/detected failure would be identified as λ_{SD}. Diagnostics can spot some dangerous failures, λ_{DD}. The goal of proof testing is to identify dangerous undetected failures, λ_{DU}, and repair them in a timely manner. Proof test coverage (C_{PT}), neglecting diagnostics, is the percentage of λ_{DU} failures that the proof test can identify [1]: C_{PT} = (λ_{DU} revealed during test)/(λ_{DU} total).

PROOF TEST AND DIAGNOSTICS

IEC 61511 [2] defines low demand as a “mode of operation where the SIF is only performed on demand, in order to transfer the process into a specified safe state, and where the frequency of demands is no greater than one per year." When the demand frequency exceeds twice the proof test interval, a SIF should be treated as high demand and the benefits of proof testing no longer are realized [3]. Demand rate is fixed based on the frequency of failures that could initiate a trip. As organizations seek to lengthen the time between turnarounds where offline proof tests can be performed, SIFs can shift from low-demand to high-demand mode. Extending a turnaround interval thus necessitates combining diagnostics, online proof testing and offline proof testing to maximize SIF reliability.

Diagnostic coverage is set based on a combination of several factors.

Automatic diagnostics continuously monitor the health of SIF components while SIF protection is in place. They enable identifying some failures immediately, allowing timely repair or replacement. The partial diagnostic credit (PDC) for automatic self-diagnostics depends on the ratio of the diagnostic and demand rates. For example, a ratio of 100× can provide 99% PDC while a ratio of 10× gives 95% PDC [3]. In low-demand systems, repair capability limits diagnostic benefit. Administrative procedures must set a timeline (typically 24–72 hours) to remove the affected device from service, repair or replace, and return to service. Diagnostics most commonly are available for Type B devices such as transmitters; they may be an additional cost option that must be specified prior to purchase. Actuation of a device during normal operation also provides diagnostic value but isn't considered a proof test. System design must include isolation and bypass capability to permit making repairs. Diagnostic coverage is set based on a combination of these factors.

Online proof testing provides some diagnostic benefit. However, the test is performed at a lower frequency than diagnostics, and SIF protection is disabled during the test. An example is partial valve stroke testing (PVST), which is a useful tool where the process can tolerate partial valve stroking without initiating a trip. Typically, an online test will identify only a subset of the failures that a full stroke offline test can detect. Proof test coverage is determined based on the percentage of λ_{DU} failures the PVST can identify. Online proof testing may take place as often as practicable while a unit is in operation. As with diagnostics, system design must provide isolation and bypass capability to permit timely repairs.

SIF response time and some failures, such as leakage, may only be detected during an offline proof test performed during a turnaround — with repairs then completed before returning the process to operation. An offline proof test typically will identify the highest percentage of λ_{DU} failures; however, the test rarely is perfect (i.e., C_{PT} = 100%). In reality, proof test coverage can range from less than 60% to as much as 99% depending on the method [4]. End users should consult vendor safety manuals to determine recommended diagnostic, online and offline proof test methods and associated coverage. Ensure system design and operation procedures are in place to support testing and repair activities. Moreover, it's imperative to conduct proof tests at the intervals defined in the safety requirements specification (SRS). Proof test intervals that extend beyond 15% of the period mandated will start to impact the integrity of the SIF; so, track proof test intervals as a leading indicator.

Diagnostic, online and offline proof testing procedures should be well thought out and designed to maximize failure detection. Table 1 shows an example of the content expected in a proof test for a simple one-out-of-one (1oo1) SIF.

MAINTENANCE CAPABILITY

A quality proof test is important. However, results can vary based on the site maintenance culture. An incomplete or incorrect proof test can significantly misrepresent the reliability of a SIF [5]. Human and procedural elements of a proof test can introduce random and systematic error. Procedures must be in place to ensure proof testing is performed as scheduled, repairs are completed immediately and effectively, and bypasses are removed after testing. Moreover, it's essential to verify that the tools used are properly calibrated; power supplies, pneumatic and hydraulic systems are clean and in good repair; and components selected are compatible with the process and environmental conditions of service and are replaced before end of their useful life. In addition, maintenance technicians should be well trained and periodically assessed per IEC61511.

An organization must clearly understand its maintenance culture before attempting improvements. The testing and maintenance process can introduce systematic errors that negatively impact the reliability of the entire SIS. A tool such as the Site Safety Index (SSI) [6], www.exida.com/SSI, is useful for performing a self-assessment and identifying opportunities for improvement.

DATA COLLECTION AND ANALYSIS

Continued reliability depends on timely and effective proof testing, and routine monitoring of system performance (which the 2nd edition of IEC61511 now requires). Establish data collection and analysis methods to monitor the failures that could lead to demand on SIFs and those that contribute to SIF failure (i.e., lagging indicators). It's important to capture the "as found" condition before disassembling process equipment for testing and repair.

Set up a database to track all demands and failures associated with process and safety instrumentation and controls and other independent protection layers (IPLs). Collect information from near-miss and incident investigations as well as from diagnostics and proof testing. Each dataset should include device make, model and serial number; date of failure; name of technician identifying the failure; results of proof test; trip time and conditions that may have contributed to the failure.

Prepare a written procedure to ensure data analysis is completed in a consistent manner. Classify each failure as safe or dangerous, systematic or random, etc. An analysis method such as predictive analytics [7] can be used to calculate site-specific failure rates. Finally, compare the calculated rates to λ values used in SIL verification. If a device is found to be less reliable than expected, take steps to correct the situation by decreasing the proof test interval or replacing the device.

Evaluate two factors at the system level:

1. Failures of IPLs that could result in demand on a SIF should be trended and compared to the design basis demand frequency given in the SRS. If actual demand rate exceeds expected demand rate, residual risk exists that needs mitigating.
2. SIF trip time must be tested at SIF acceptance and periodically during the lifespan. The results should be trended to confirm that the SIF response time remains within the process safety time to ensure the SIF responds before an event occurs.

A VALUABLE TOOL

The purpose of a SIS is to reduce risk through instrumentation. Proof testing is an effective means to detect failures that reduce system reliability for low-demand SIFs and thus enable timely repair. An operations team must understand how decisions such as extending proof test intervals (turnaround cycle) affect demand rate and SIS reliability. Diagnostics as well as online and offline proof testing can be useful in detecting device failures so repairs can be implemented and devices returned to service. Finally, it's necessary to catalog information about failures discovered though testing, to confirm that the SIS is performing consistent with the design basis.

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Enhance Your Motors' Efficiency

Consider more than just using variable frequency drives

By Tony Young, CP Automation

Chemical companies often completely overlook motor efficiency when seeking energy savings and the associated operating expenditure reductions. That's a serious mistake.

When you consider that electric motor systems account for about 60% of global industrial electricity use, the potential savings become clear. A Siemens' 2014 white paper "Turn Down the Power" includes estimates (termed highly conservative, by the way) of industrial electrical overspending in the five following years directly attributable to non-implementation of variable frequency drives (VFDs). The United States led with $20.9 billion, followed by China with $10.9 billion, Russia with $9.0 billion, and Germany with $8.1 billion.

Electricity costs are rising as global demand continues to grow, ramping up the need for industrial companies to contain electrical consumption. Those firms that do invest time and money in energy reduction rarely get much further than fitting VFDs or haggling on price per kilowatt hour. However, a host of additional measures that require very little capital expenditure all can result in substantial savings that can bolster long-term profitability.

TOP TIPS

Here are some ideas you should consider to ensure the motors in your plant run as efficiently as possible.

Opt for a soft starter where appropriate. Soft starters are increasingly common on pump applications; they dramatically reduce the

energy used when activating a motor. They also are seeing greater use on conveyors, where the smooth start prevents objects from falling. A soft starter may provide a more-profitable alternative to a motor starter resistor or a VFD — but only if the application is assessed correctly in the first instance and the device is sized appropriately.

Time it. The chemical industry hugely underuses timing devices; they are a very cost-effective way to save energy on non-continuous services. For instance, often pumps and ventilators run constantly even though no demand exists during certain times of the day.

Not running a motor unnecessarily not only saves energy but also extends the life of your systems. For example, the hydraulic pumping efficiency of a cooling systems will degrade less over time and remain optimally efficient for longer.

Don't be tempted by cheaper alternatives. Choosing a high-efficiency motor isn't always a given in every application — particularly if someone in the buying chain is looking only at the initial capital expenditure and not long-term running costs.

Mandates in place such as the European Union's Ecodesign Directive should cut down on end users specifying low-efficiency equipment. Similar guidelines exist at present to stop people fitting counterfeit drives and motors but that still happens. A comparison with a highway speed limit is compelling: it's posted but not every driver adheres to it.

So, metaphorically speaking, I advise sticking to the speed limit and purchasing a high-efficiency motor even if you think you can get away without one.

Choose the right motor in the first place. Your initial step always should be to ensure the proper motor is fitted for the application, whether this is for pumps, fans or compressors. A good provider of motors, controls or VFDs usually will offer an audit first to help you achieve this.

If you plan to retrofit a VFD now or later, make sure the motor is VFD-rated. Otherwise, any retrofit project will involve replacing the motor as well.

Design engineers love to over-specify "for tomorrow" but this incurs bigger energy bills. Over-specification also raises maintenance bills. I've seen countless motors for easy jobs like water pumping that are specified at a much higher capacity than required. Sometimes, this leads to spending, say, $2,500 on a motor for a job for which a $1,250 one would suffice.

I've even known of motors sent in for an overhaul with problems on parts that aren't being used at all. Yet, when this situation is reported back, the customer is completely unaware of it because the problem is with functionality not needed in the first place!

Consider another car analogy: you wouldn't buy a minivan for a family of four.

Keep it simple if you can. Always remember the less complex the motor the better. From a repair perspective, if you can use a standard energy-efficient motor, which you can switch on and have spin at the right speed with no bells or whistles, then use it. It will be cheaper to install and have less to go wrong. Moreover, if something amiss does occur, the repair will be easier and less costly.

Of course, this isn't always possible. Occasionally, as we've already discussed, a timing device or soft starter is needed to alter the speed. Or perhaps you require an extremely high-precision motor for your application. Nevertheless, you still can employ some tricks of the trade to make your project cheaper and more energy efficient in the long term.

While simple is best, cheap and simple certainly may not be when choosing a motor. A low-cost mass-produced but unreliable motor never will be cost effective or energy efficient because of the frequency of breakdowns and the high likelihood that you will have to resort to replacement rather than repair. There's also a strong chance the cheaper unit will be sealed, severely impeding maintenance. Indeed, sealing often makes the repair process so expensive that it's cheaper just to replace the motor.

Move away from mass production. If swapping out eventually is required, you must grapple with whether a replacement motor is available at short notice. Of course, keeping a spare in stock can avoid the problem. Ironically, a harder-to-obtain motor sometimes is the best option — because it isn't mass produced and normally is of higher quality. So, while procuring a replacement for it may not always be easy, getting a repair often is.

When choosing a company to do a repair, you always should select a specialist. If you go to a firm that hasn't carved a niche in, say, servo motors, it likely simply will sub-contract your repair to a specialist — increasing your bill in the process.

Another factor to consider is the environment in which the motor will operate. In a harsh environment such as often found in chemical processing, opt for a more-complex drive that can be boxed away. Regulations may demand this anyway but the added bonus is that the motor and drive are protected from ingress and damage.

Stay flexible. If it's possible to do so, choose a motor that can be swapped out with one from a different manufacturer. However, this isn't always an option; for instance, with servos every manufacturer has its own set up. As an example, one maker of a three-phase motor with encoder might align the encoder to a particular phase, say, U phase to signal one, while another manufacturer might decide that V phase to signal one is more appropriate. So, you may end up in a situation where you can never replace your Siemens motor with an Indramat one, to pick two major manufacturers at random.

Be careful not to end end up in a situation where you can never replace your motor with one from a different brand.

When this happens, the design guidelines I've laid out in this article will come to the fore — because your maintenance partner will be attempting to repair the motor or looking for easily sourced equivalent parts if it can't secure a direct replacement in time.

With three-phase induction motors it's little bit simpler because they all are the same. So, in this context, it's simply a case of the more complex the motor, the harder it is to replace.

Right at the specification stage, you should think about the eventual need to replace the motor and consider the potential for obsolescence. The consolidation in the drives industry means that not every supplier around today will exist in the same form in five years' time. As a result, there's a chance that a vendor's products will have been absorbed into other product lines or discontinued. This is another reason to adopt the maxim simple is best.

For instance, we recently had a customer whose motor was beyond repair but no longer in production. Fortunately, we found six identical motors in surplus stock elsewhere. The customer bought them but, when they all fail, it will need to re-design its machine — with new drive cables, mechanical fittings and so on, all of which inevitably will be expensive.

Consider a feed-in tariff. It isn't well known that users of industrial motors can get money back from their energy provider by sending excess energy produced during braking back to the grid. This is done using a feed-in tariff, exactly as it is with wind turbines and solar panels.

A plant can recover the excess energy using either a combination of two inverters or, much more efficiently, via a specialized regenerative unit. Such a unit will work with any AC drive, ensuring that excess energy returns to the power grid efficiently rather than being dissipated as heat in a resistor. A facility with several motors controlling manufacturing equipment, lifts, conveyors and the like can achieve extensive cost savings.

Implementing only a few of these tips will result in a reduced energy expenditure on running motors and, in all likelihood, other associated equipment. You will find that taking advantage of all of them is much more effective than just trying to negotiate a lower kilowatt hour price. ●

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Safely Use Mobile Devices

Understanding ignition sources and levels of device protection are crucial to eliminating risk

By Justin Olivier, Pepperl+Fuchs, Inc.

Mobile devices can solve many challenges in hazardous industrial environments — from monitoring lone workers to enabling predictive maintenance to streamlining field support (Figure 1). But a device that lacks the proper protection could seriously compromise the safety of your plant and personnel. Even something as simple as a hot surface on an unprotected device can have disastrous consequences.

HAZARDOUS ENVIRONMENTS
Figure 1. Mobile devices solve a variety of challenges in hazardous areas.

IGNITION SOURCES

Ignition sources are possible even when unprotected mobile devices are turned off, including:

- A battery short circuit in an unprotected device
- A loose battery in an unprotected device

SAFE MOBILE DEVICES
Figure 2. Intrinsically safe mobile devices ensure potential ignition sources are removed or prevented.

- Electrostatic discharge — for instance, from pulling an unprotected device out of a holster

Other typical ignition sources include:

- Hot surfaces and open flames
- Electrical arcs and sparks
- Lightning
- Mechanical friction or impact sparks
- Electromagnetic and optical radiation — i.e., from radios or barcode scanners in an unprotected device

Intrinsically safe mobile devices ensure that these potential ignition sources are removed or prevented (Figure 2). But to eliminate the risk of explosion, it is not enough to select just any protected device.

ZONE/DIV. 1 AND ZONE/DIV. 2 TESTING

Zone/Div. 2 devices are tested only for the above-listed ignition sources under normal conditions — not if the device develops a fault. Zone/Div. 1 devices, on the other hand, are tested in both normal and fault conditions.

Further, the batteries in Zone/Div. 2 devices are not tested for temperature increase under short-circuit conditions. Only Zone/Div. 1 devices ensure that temperatures remain low enough to prevent an ignition. In short, Zone/Div. 1 devices are subjected to more stringent tests under both normal and fault conditions.

Answer the questions in Table 1 to help determine whether the smartphones,

ELIMINATE RISK

Table 1. Asking the following questions can help determine whether the mobile devices in your plant are putting personnel, assets and the environment at risk. Note: This information is intended for educational purposes only.

QUESTION	RESPONSE	RISK LEVEL
Are you using Zone/Div. 2 devices in Zone/Div. 1 areas?	**Yes**	**High**
Are you carrying switched-off Zone/Div. 2 devices through Zone/Div. 1 areas?	**Yes**	**High**
Does your Zone/Div. 2 device protect against, and has it been tested for, all typical ignition sources?	**No**	**High**
Will your Zone/Div. 2 device be used for multiple applications in the future, in both Zone/Div. 1 and Zone/Div. 2 areas?	**No**	**High**
If your Zone/Div. 2 device develops a fault, is it protected from causing a fire or explosion? (Look for markings such as Ex ic, UL 913, FM2610, or CSA 157.)	**No**	**High**
Are Zone/Div. 2 and Zone/Div. 1 areas clearly marked in your plant? Do mobile workers know when they are in a Zone/Div. 1 area?	**No**	**High**
Does your insurance liability cover incidents caused by Zone/Div. 2 devices found in Zone/Div. 1 areas?	**No**	**High**

tablets, scanners and other mobile devices in your plant are putting personnel, assets and the environment at risk.

ELIMINATE RISK

Using the wrong mobile device creates an enormous amount of risk. To eliminate risk, follow these basic steps:

- Use the correctly certified and marked devices in hazardous areas.
- Select manufacturers with a proven track record of delivering mobile devices for use in hazardous areas.
- Do not compromise on safety. Always consult safety and certification specialists. ●

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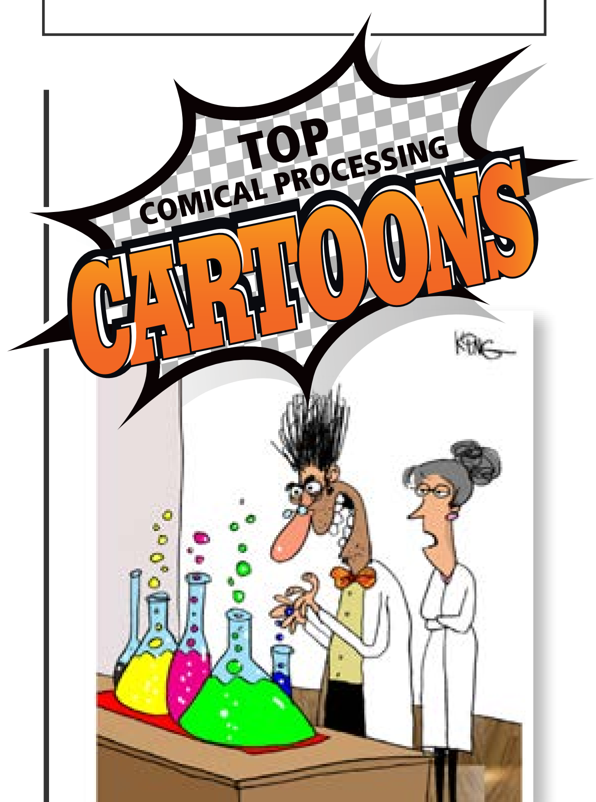

Visit the lighter side, featuring drawings by award-winning cartoonist Jerry King. Click on an image and you will arrive at a page with the winning caption and all submissions for that particular cartoon.