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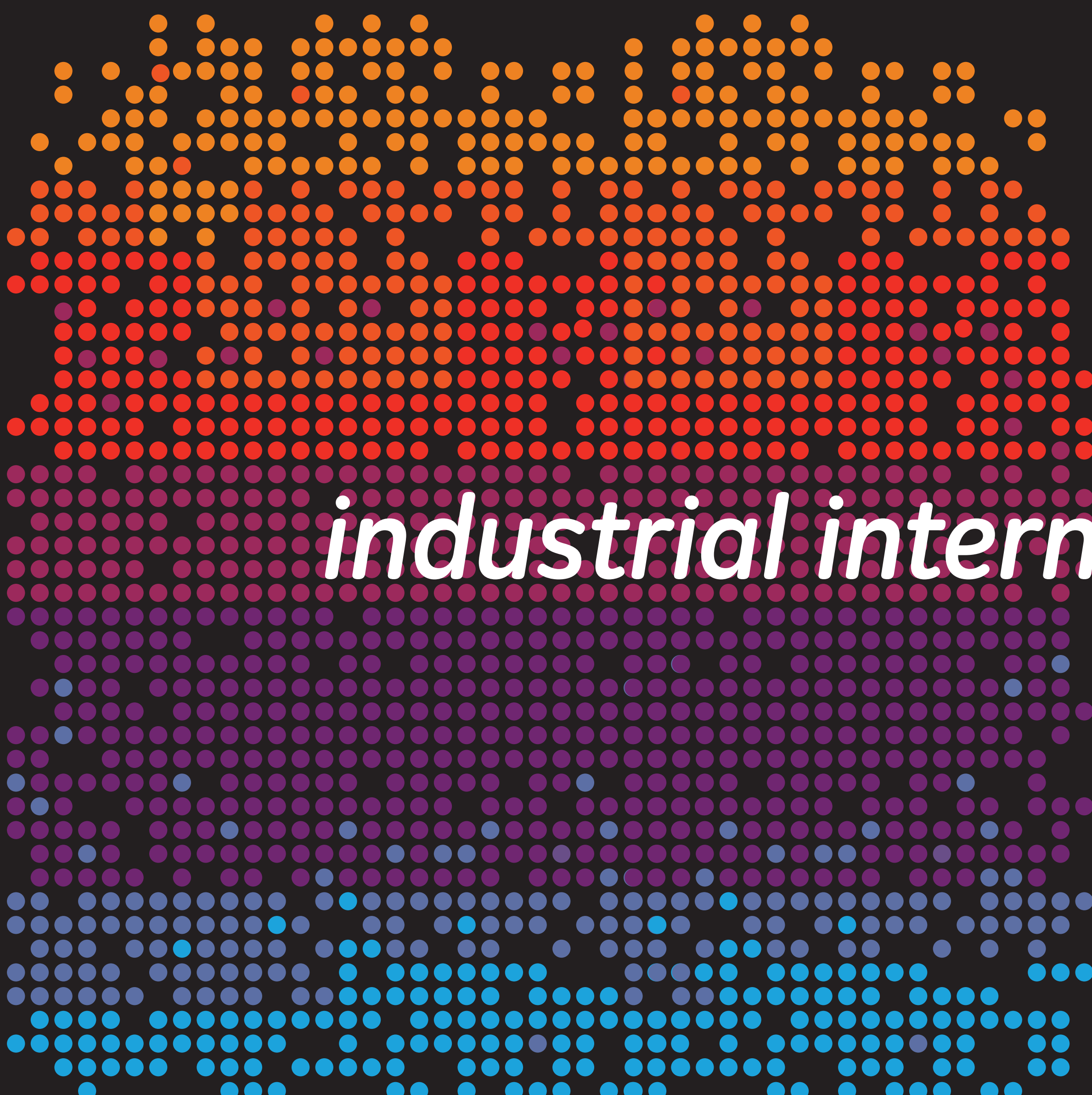
A Technical Publication for Advancing the Practice of Operating Asset Condition Monitoring, Diagnostics, and Performance Optimization



industrial internet

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A Technical Publication for Advancing the Practice of Operating Asset Condition Monitoring, Diagnostics, and Performance Optimization

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Editor's Notepad

Gary Swift
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Orbit Magazine
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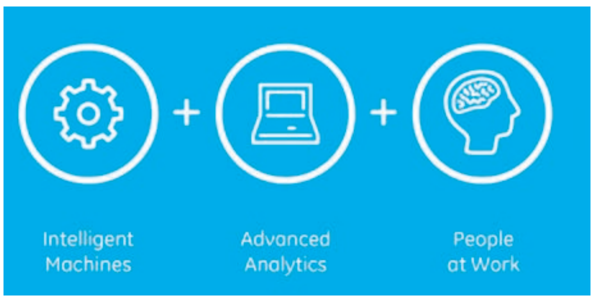
Greetings, and welcome to *Orbit!* Throughout 2013, we have traced the evolution of the Bently Nevada* product line, with a brief history of our company roots in the January issue followed by an update of our modern Minden facility in April. As an example of our international presence, we expanded our focus to the India region in July. In this issue, we are taking this expanding view one step further, to the completely global concept of the "Industrial Internet."



The Industrial Internet is a broad term that refers to the growing synergy between machinery condition monitoring data, analytic software, and the communication capabilities required to deliver important information to the right people when they need it for decision-making. Our friends at the GE Software Center summarize these three key pieces as Intelligent Machines, Advanced Analytics, and People at Work. I predict that we will all be hearing a lot more about the Industrial Internet as it evolves during the coming decade!

Our news in this issue includes several product updates, an interview with our General Manager and a well-deserved API award for one of our employees. Features include an interesting example of how System 1* software is being used to monitor the health of Continuous Emission Monitoring Systems at a refinery, and a report on engineering field trials of thermal energy harvesters as power sources for our wireless monitoring system. Departments include back-to-basics, case history and SCOUT Camp articles. We also include a shout-out to the 42nd annual Texas A&M University-hosted Turbomachinery Symposium, and it's hard to believe a year has already passed since the last one!

Finally, our back cover introduces a new option for delivery of Orbit content, which we developed in response to reader requests. Starting with this issue, you now have the option to go paperless and convert to an e-mailed digital newsletter edition of Orbit magazine, with links to online content. I'm happy to introduce our digital newsletter format, and if you are struggling with piles of old magazines on your desk (like I am), I think you will enjoy this convenient way to reduce some of the clutter!

Cheers!
Gary

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Announcing the TDISecure* Communication Processor

Joseph K. Taylor
Bently Nevada Product Manager
josephk.taylor@ge.com

The TDISecure Communication Processor is a multi-channel data acquisition device that acquires up to 24 channels of dynamic signals using parallel sampling with bandwidths from DC to 30k Hz, and can acquire an additional 24 channels of process measurement inputs configurable as 4-20 mA or a variety of DC voltage ranges. TDISecure is used with System 1* Optimization and Diagnostic Software and connects to a System 1 data acquisition computer using Ethernet TCP/IP.

It can be used to replace legacy Bently Nevada* communication processors such as TDXnet*, but more importantly can be used in new and current installations to acquire analog signals from any vibration monitor system or plant process points and bring the data into System 1 software – providing you with a plant-wide view into machinery asset condition.

Effective plant asset management, and particularly effective fleet management of machinery assets often depends on remote access using condition monitoring software such as System 1. In most vibration monitor systems (VMS), there is a module in the vibration monitor rack that acquires waveform data from monitors in the rack and serves the data over Ethernet to the condition monitoring software.

In most cases a direct Ethernet connection to the VMS is acceptable using good network design and partitioning along with firewall and router rules. This is our recommendation for Bently Nevada systems. However in extreme cases (Reference 1), a direct Ethernet connection to the VMS (the machinery protection system) may not be desirable or even allowed. In such a case, TDISecure can acquire the analog signals from a machinery protection system, and because it is not providing the protective function, it offers a cyber security solution for remote access that is more cost-effective than data diodes.

Key Features (Reference 2)

- Designed for permanent installations and continuous on-line data acquisition
- 24 Dynamic analog signal inputs with parallel sampling and synchronization to a Keyphasor* signal
- 24 Direct process measurement inputs that can be configured as independent process inputs or can be associated to a dynamic input
- Up to four Keyphasor inputs and ability to directly power four Keyphasor Proximitors*
- 24 Discrete Inputs for Channel Alarm/OK
- 4 Discrete Inputs for Rack Alarm Status. (one per Keyphasor Collection Group)
- 4 Discrete Outputs for Rack Alarm Status (one per Keyphasor Collection Group) for daisy-chaining to other devices
- Waveform data collection configurable using time intervals or machine speed intervals
- Transient (startup/coastdown) waveform collection on rpm changes
- Simultaneous collection of synchronous and asynchronous waveforms
- Waveform collection triggered on Alarm Events from any of the configured Alarm Event sources (collects pre and post-event data)
- Ability to replicate protection system configuration for common channel types (replication ensures data quality and integrity in cases where cyber security prevents direct connection to a machinery protection system)
- Ethernet 10/100 Base-T communication to System 1 for configuration, data collection, and data display
- Serial Data Interface (SDI) RS-232 or RS-422/485 for Modbus communication
- Same footprint as legacy Bently Nevada communication processors such as TDXnet

Benefits

Use TDISecure to connect non-Bently Nevada Vibration Monitor Systems to System 1 Optimization and Diagnostic Software.

Connect process variable inputs to TDISecure for viewing, analysis and management in System 1, thereby increasing your level of analytic capacity.

Replace your legacy Bently Nevada TDXnet communication processors and upgrade to our current product for improved waveform collection performance equivalent to our 3500 Machinery Protection System. ■

References

1. Orbit V32 N1, M. Whaley, G. Aralikatti. “Introduction to Cyber Security.”
2. GEA30722, “TDISecure Communication Processor Overview”

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REDESIGNED BENTLY NEVADA* HSCT HOUSING NOW HAS SLOTTED MOUNTING HOLES FOR MORE FLEXIBLE ORIENTATION DURING INSTALLATION.

High Sensitivity Current Transformer (HSCT) Update

Brant Wilhelm
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Last year, we announced our new Motor Stator Insulation Monitor (MSIM) for the 3500 system. As reported in the JAN 2012 Orbit issue (Reference 1) this new permanently-installed system accommodates the continuous online monitoring of winding insulation condition in medium to large three phase ac motors. It depends on the unique capabilities of the HSCT to measure changes in very low amplitude leakage current that indicate the slow degradation of winding insulation over time. The HSCT sensor, interface module and MSIM module work together to make the monitored motor "smart," so that it can continuously send data to be evaluated by the analytic capabilities of System 1* software.

THE MSIM SYSTEM IS APPLICABLE FOR LINE-FED 3-PHASE EXTERNALLY-WYE-CONNECTED (6-LEAD) MOTORS UP TO 7.5 KV.

FIGURE 1: HSCT sensors during installation in a motor termination enclosure. For each of the three phases, an HSCT sensor (with clear anodized natural aluminum housing) is installed adjacent to the corresponding normally-installed protection CT (the large coils potted in dark -brown resin).

FIGURE 2: Close-up view of slotted mounting holes in HSCT housing

Through additional field testing (Figure 1), we determined that the original HSCT housing – which was mounted using bolts through four evenly-spaced bolt holes – could be improved by the addition of slotted mounting holes. This arrangement facilitates adjusting the orientation of the sensor to more closely match existing mounting points, which reduces the requirement for mounting brackets and adapters.

The new slotted mounting holes allow for approximately 15 degrees of adjustment in the angular orientation of the HSCT housing during installation (Figure 2).

For More Information

Visit our Motor Stator Insulation Monitor webpage for Datasheet and Fact Sheet on the monitoring system – including the HSCT, which is a key component of the system.

http://www.ge-mcs.com/en/bently-nevada-monitoring/continuous-online-monitoring/motor-stator-insulation-monitor.html ■

References

1. Orbit Vol 32 No 1 JAN 2012, Whitefield, C. David. "New Online Motor Stator Insulation Monitor (MSIM) for 3500 System.

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Interview with Art Eunson

Art Eunson is our General Manager for the Bently Nevada* product line. It has been awhile since our last interview, and it was nice to catch up for this issue – Editor

Art Eunson
Bently Nevada
General Manager

ORBIT: Thanks for taking time to talk with our readers, Art. After two years in the business, are there any opening thoughts you'd like to share with us?

ART: Sure, Gary. When I started in June of 2011, I quickly learned how passionate this team is about customer service, product quality, and delivering new, innovative solutions to address our customer's problems. While we don't always get it perfect, this team is constantly dedicated to supporting our customer needs, pushing the boundaries with new technologies, and constantly aiming to be leaner, smarter, and better about producing quality products.

ORBIT: Where have you spent your time and energy over the past 24 months, and what else have you learned, particularly from our customers?

ART: I've taken the time to visit our region teams as well as many customers – learning quickly that the landscape we serve is both complex and diverse. We are mainly focused in the Oil and Gas and Power Generation sectors, but we also serve customers in metals and mining, pulp and paper, and other industries. The good news is that, while there's a wide diversity of problems we are trying to solve, the breadth of our portfolio allows us to address just about all of them.

ORBIT: Can you share some of the key messages you've heard from our customers?

ART: Quality, of course, is a consistent theme regardless of the product being delivered. Quality in everything from the commercial offering, delivery, the product itself, and service implementation and support are critical regardless of the industry segment or product application. Another consistent theme is the rapidly changing landscape around data and analytics.

Customers are quickly realizing that to optimize production, maintenance, asset availability, and reliability, they will need to leverage the power of advanced analytics. So we spend a lot of time thinking about how we develop new hardware platforms that are "intelligent," with embedded analytics in the sensors and monitors themselves, as well as how we advance our analytic software platforms. We recently conducted a Customer Advisory Board (CAB) with ten companies represented across various industries, and these were consistent themes throughout our discussions.

ORBIT: Speaking of business solutions, do you have anything to share on the product updates in this issue?

ART: Our two biggest announcements are around the newest members of the Advanced Distributed Architecture Platform Technology (ADAPT) 3701 family and the next generation of System 1* software. Both of these releases support GE's Industrial Internet by enabling monitored assets to be "smart" and by providing powerful analytics that convert reams of raw data into useful Actionable Information* for making asset management decisions. Both of these products will help our customers realize the value of a true condition monitoring program that goes beyond protecting their most critical assets.

It's also worth mentioning we are working closely with our friends in GE Intelligent Platforms to integrate Proficy** SmartSignal anomaly detection software as part of our solution. Early detection with the SmartSignal product provides foresight, and we can then dive deeper with System 1 software to gain more insight around a potential problem. Brought together, these tools are proving to be a powerful solution in many of our customer's condition monitoring and reliability strategies.

ORBIT: What do you mean by "smart" assets? Is this different from our System 1 software?

ART: Yes, absolutely. It's easy to focus on the software part of the Industrial Internet equation, but unless the monitored assets can provide accurate and meaningful data in the first place, the software won't have anything to correlate and evaluate.

ORBIT: So the Industrial Internet is more than just software...

ART: Right. The Bently Nevada product line has actually foreshadowed most of the key concepts of the Industrial Internet - in a somewhat smaller setting – for several years now. Our sensors and transducers, properly installed on monitored machines, send accurate signals to our monitoring instruments. These instruments then apply appropriate signal processing techniques to provide automatic protective machine trips if needed, and create digital data that can be analyzed for condition monitoring.

The final piece of the equation is to have a properly integrated services strategy with each customer to fully extract the value of these products. That might mean remote monitoring support for one customer, full or part time support on the site from our local service teams, or both. Using the data to its maximum capability through a complete product and service offering is the key to success.

ORBIT: Can you tell us more about how this data is used for condition monitoring?

ART: Yes. Some of our customers want to do monitoring onsite, with their local monitoring installation, while other customers provide us with remote access – often as part of an ongoing Supporting Services Agreement (SSA). This kind of setup allows our experts to provide timely advice to our customers without the delays and added cost that would be required to travel to the site in person. In addition to using the logic we've embedded in System 1 RulePaks, we are increasingly using Proficy SmartSignal software to provide early indications of anomalies that need to be looked into more deeply.

ORBIT: How would you describe the new 3701 distributed platform and System 1 software?

ART: I'll address the 3701 family first. Our first member of the family was the 3701/60A Wind Turbine Monitor product (Reference 1). Now we are adding the 3701/55 ESD (Emergency Shutdown) System and 3701/40 Gas Turbine Monitoring Module to the family. While a 3500 or 3500 ENCORE* rack-based system essentially starts out as a blank slate that is custom configured with appropriate settings for each specific installation, we can supply the 3701 monitors with pre-engineered templates that include signal processing algorithms and protective setpoints created specifically for the type of assets being monitored.

We have done this for various models of wind turbines with the established 3701/60A Wind monitor. These templates save time during installation and commissioning of a monitoring system, and ensure that a more consistent methodology is used – with fewer chances for personnel error during the configuration process. We will continue to develop engineered templates for specific applications of our new 3701 monitors, and will make them available to our customers.

ORBIT: That sounds like a great idea. What have our customers said about the 3701 distributed platform?

ART: We shared details of these two new monitors, as well as our strategy for developing future members of the family with the participants in our most recent CAB event. They were very enthusiastic about the concept, and they are looking forward to the development of additional monitors and templates that will be specifically focused on other types of assets.

ORBIT: This sounds like some good validation of the distributed architecture philosophy. Did you also share details of the new System 1 software with the CAB group?

ART: Yes. We did a hands-on demonstration, and our existing System 1 users were very excited with the features of the new software.

ORBIT: What did they like best?

ART: The first thing they appreciated was the simpler and more intuitive user interaction. The legacy software is very powerful, but it can also be complex and challenging to use. We have done significant work to gather input from a wide variety of users, and to incorporate improvements based on their experience. Just as we can use pre-engineered configuration templates for the new 3701 monitors, the new System 1 software uses a growing set of standardized and very consistent configuration tools.

ORBIT: It sounds like the expanding 3701 family and evolving System 1 software share a lot in common.

ART: Exactly. We anticipate that they will work very well together – and with other aspects of the Industrial Internet – as development continues over the next decade.

ORBIT: Thanks for taking the time to talk with our readers, Art. Do you have any closing thoughts?

ART: The biggest thing I want our readers to take away from this interview is that we are absolutely committed to the traditions established in this business over many decades. Those traditions include a continuous reinvestment in our portfolio, a desire to solve tough problems for our customers, and going to market with a reputation of the highest quality, the best people, and an absolute commitment to outstanding customer service. The business has grown substantially over the years, and while we've become more diverse from both a geographical, as well as a portfolio standpoint, we remain committed to these fundamental values. ■

References

1. Orbit Vol 32 No 1 JAN 2012, J. Hanna, C. Hatch, M. Kalb, A. Weiss. "Detection of Wind Turbine Gear Tooth Defects."

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**Trademark of GE Intelligent Platforms, Inc. SmartSignal is a trademark of SmartSignal Corporation, a wholly owned subsidiary of GE Intelligent Platforms, Inc.

Landon Boyer Receives American Petroleum Institute Award

GE's Bently Nevada* Product Line Manager Landon Boyer was recently recognized with a Resolution of Appreciation for his outstanding work with the American Petroleum Institute (API). This award is presented to volunteers who do exceptional work supporting the various API Sub-Committees. Boyer was recognized for his seamless integration into the Mechanical Equipment Sub-Committee of the API 670 Taskforce and for his ability to execute his responsibilities while producing a quality product. His involvement began five years ago and he has since been committed to the Taskforce, devoting a substantial amount of his personal time and resources to its initiatives.

Boyer's commitment to API arose out of his strong desire to preserve the Bently Nevada tradition of leading the industry through standards committees. API is the only national trade association representing all aspects of the U.S. Oil and Natural Gas Industry. GE's Bently Nevada is one of API's more than 500 corporate members that champion its mission is to influence public policy in support of a strong and viable industry.

Boyer also realized the tremendous benefits to Bently Nevada's customers from his involvement. "When customers decide to purchase an API 670 protection system, they have high expectations of how that system should perform," he said. "My involvement helps protect customers from getting the unexpected. When customers use the purchasing specification, all vendors are required to declare the areas where they take exception. In the end, this creates transparency in the bidding process for the benefit of the customer."

A Little API History From our Orbit Archives...

Because API 670 was the result of a request for standardization from end-users, it significantly addresses their real-world needs. This makes it a very practical standard, detailing how to properly select, install, and document an instrumentation system that will adequately protect critical machinery. API standards incorporate the accumulated knowledge of thousands of users – not just in America, but throughout the world. Hence, these standards embody the very essence of "good engineering practice" when it comes to machinery that is designed, instrumented, and operated properly to meet the demands of industrial use (Reference 1).

Note: Landon is the latest in a continuous line of Bently Nevada team members who have participated on the API 670 Taskforce since the development of the very first edition of API 670, which was published way back in 1976! — Editor

References

1. Orbit Vol 22 No 1, First Quarter 2001, Sabin, S. "A New Edition of API 670 – 25 Years and Still Going Strong."

http://www.ge-mcs.com/download/orbit-archives/2001-2005/1st_quarter_2001/1q01sabin2.pdf

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Proficy* Monitoring & Analysis Suite

But how do you harness and leverage all your operational data and advanced devices and equipment to achieve it? GE has developed the Proficy Monitoring & Analysis Suite—a GE Predictivity* offering. It's industry's first and only integrated suite of software products to handle all your Industrial Internet needs for collection and analysis of equipment and process data. This solution addresses exponentially growing industrial data sets, combines asset health with process optimization, and does it all more cost effectively.

What is the Industrial Internet?

The Industrial Internet is the convergence of intelligent machines, advanced analytics, and people at work. GE's Proficy Monitoring & Analysis Suite in an Industrial Internet solution that combines these elements to accelerate business growth. We're on the cusp of a paradigm shift. We've moved from the Industrial Revolution to the Internet Revolution, and now to the Industrial Internet. Read about this shift in the white paper *Industrial Internet – Pushing the Boundaries of Minds and Machines.* **http://www.ge-ip.com/files/files/13505.pdf**

Proficy Monitoring & Analysis Suite Overview

Because it already has been integrated by GE, the Proficy Monitoring & Analysis Suite reduces your implementation costs and time-to-benefit. Because it has been proven at GE monitoring centers, it helps to minimize your risk. And because we offer full implementation, monitoring, and maintenance services from GE equipment and software experts, the suite can be used by any company regardless of level of IT and engineering expertise. The suite includes six software packages that work together to accommodate data management, asset health monitoring, process optimization and data visualization. Full managed services are available through GE's Industrial Performance & Reliability Center.

DATA MANAGEMENT: Using Proficy Historian (Enterprise-wide data collection engine) and Proficy Historian HD (Industrial Big Data historian) the suite can manage all your process and equipment data from disparate systems and sources. It can aggregate the data in an accessible fashion, so your analysts can drive value from it. It even has the capability to collect, archive, and distribute tremendous volumes of real-time, time-series data – Industrial Big Data – at extremely high speeds and low storage costs – in the cloud, as never before possible. Having more data over longer periods of time can allow for more advanced analysis and greater insight into actual vs. optimal equipment and process performance.

ASSET HEALTH MONITORING: Using Proficy SmartSignal, the suite can apply advanced capabilities to analyze all your data. Using industry's most advanced predictive analytics and diagnostics, the software can monitor all critical assets across all OEMs. It can predict, diagnose, and prioritize impending equipment problems – automatically, continuously, and relentlessly, 24 hours/day. The software's early warnings can reduce surprise and catastrophic equipment failure and enable efficient proactive maintenance vs. costly reactive maintenance – reducing unplanned downtime and increasing availability.

PROCESS OPTIMIZATION: With Proficy CSense, the suite also can optimize processes. Its advanced analytics can identify unknown correlations in your process variables that can lead to poor performance. The software allows for 'what-if' analysis to find solutions that optimize your processes – at the same time as optimizing for asset health. This allows you to increase yield, while reducing variability.

DATA VISUALIZATION: Data and analytics have no use if they cannot be accessed or delivered in context to the right person at the right time. The Proficy Monitoring & Analysis Suite has web-browser based data and results visualization to deliver role- and asset-based information that unlocks the value of the data. Visualize trends with Proficy Historian Analysis and analyze fleets of assets with Proficy Knowledge Center.

For More Information

Download the GE product brochure GFA-1958, "Proficy Monitoring & Analysis Suite" **http://www.ge-ip.com/files/files/13513.pdf**

GE Intelligent Platforms Contact Information

Americas: 1 800 433 2682 or 1 434 978 5100
Global regional phone numbers are listed by location on our web site at **www.ge-ip.com/contact.**
www.ge-ip.com/monitoring-and-analysis

The Evolution of System 1* Software

Scott Roby
System 1 Product Manager
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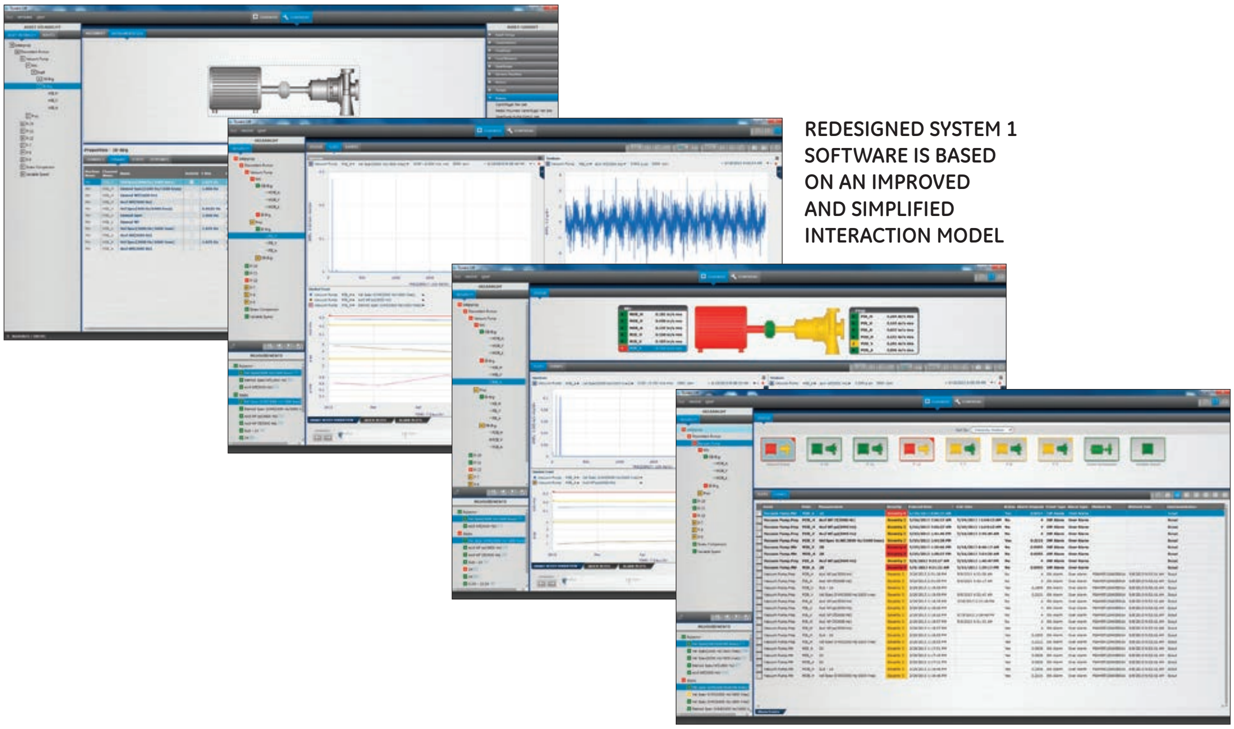
Originally launched in 2000 (Reference 1), our legacy System 1 software has continued to grow, adding an ever-expanding set of tools and capabilities, and accommodating data from a widening variety of assets. While we will continue to support our users of the legacy System 1 platform, we are also working to improve the capabilities of the software, with a completely re-engineered version that is much easier to use.

System 1 for Portables includes full native support for our SCOUT100 and SCOUT140 portable vibration data collectors and analyzers.

As our General Manager mentioned in his interview (page 9), we have learned from more than ten years of listening to and working with our System 1 customers. From an understanding of our users' needs and goals, we have redesigned the system to deliver a better and more productive experience as well as integrating full native support for our SCOUT series of portable instruments. Watch for more details in upcoming Orbit issues.

For now, I just want to summarize a few of the guiding principles that we have applied during the development process. I think of these as revolutionizing the Usability, Capability and Accessibility of our software.



REDESIGNED SYSTEM 1 SOFTWARE IS BASED ON AN IMPROVED AND SIMPLIFIED INTERACTION MODEL

Usability

One of the things we hear most often about our legacy System 1 software is that, although it is very flexible and includes many powerful features, the "user experience" is not very intuitive. We have taken this input seriously, and have greatly simplified the way that the new software presents information to meet your goals quickly and easily. New features making life easier are:

- Pre-defined data presentations in the context of your assets and events
- Embedded industry best practices for configuration and information viewing
- Work space linked to hierarchy and machine train diagram navigation tools
- Access to the most commonly used tools right at your finger-tips

Capability

In addition to making the new generation of System 1 software easier to use, we have added some powerful new capabilities, based on input from our users. One of the main areas where we have made huge improvement is with the condition monitoring and diagnostics of machines that use rolling element bearings. These new tools are optimized for a variety of commonly-encountered machines, and include an embedded bearing database for convenience. Also, we have created the architecture of the new software so that it can tap into a huge variety of available data sources without requiring expensive and time-consuming redesign of the software itself. This list summarizes a few of the new capabilities:

- Complete Fault frequency identification and analysis tools
- Comparative data analysis and plotting tools
- Re-engineered reporting features
- Asset library for improved configuration speed, quality and consistency

Accessibility

One Industrial Internet concept that is important for us to emphasize is the ability of our users to share their data with remote experts who can provide vital input without having to physically travel to the site. Of course, this requires careful integration with their communications network, so that we can ensure the required level of data security is maintained, while at the same time accommodating an appropriate level of access. The next evolution of System 1 software addresses these key topics:

- Industry standard communications protocols
- Security and product hardening designed for secure deployments
- New information access tools leveraging mobile and web technologies

System 1 for Portables

The System 1 for Portables solution extends our patented condition monitoring intelligence and diagnostics framework to all plant equipment – including assets that are monitored using periodic collection as part of walk-around programs. Data can now be collected from assets from every class and criticality level by using our intelligent suite of portable vibration monitoring and analysis instruments. Our integrated System 1 for Portables package supports increasing asset productivity and safety.

For More Information

We have created a new microsite that will provide updated information as we continue our System 1 development journey. **http://www.ge-mcs.com/microsites/system1/** ■

References

1. ORBIT Vol 22 No 3 Third Quarter 2001. "System 1 – What it is, what it does, how it fits."

*Denotes a trademark of Bently Nevada, Inc., a wholly owned subsidiary of General Electric Company.

The Growing 3701 Product Family

Don Marshall
Product Manager
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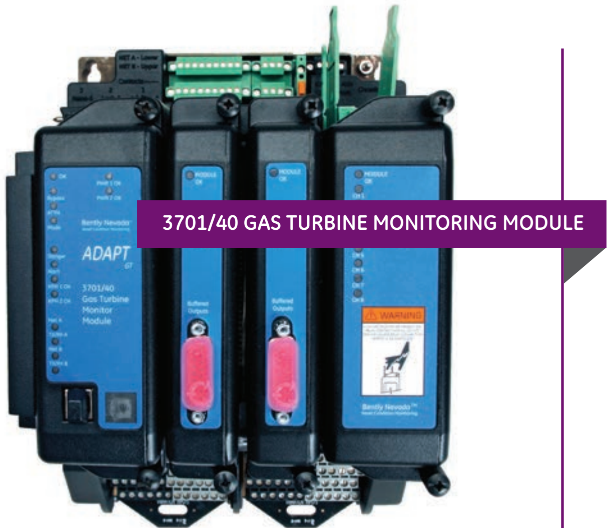
Over the past several decades, Bently Nevada* monitoring systems have become familiar installations at a wide variety of industrial sites, where they provide continuous machinery protection and condition monitoring for important plant assets. Examples of these monitoring instruments include centralized rack-based systems such as 7200, 3300, 3500 and 3500 ENCORE systems. Another set of smaller distributed instruments was developed for specific applications that don't require a centralized "rack" design with dozens of monitoring channels. These include the legacy 1701 FieldMonitor* system, which is mainly used for small to medium-sized gas turbine monitoring. The newer 3701 system is based on Advanced Distributed Architecture Platform Technology (ADAPT) concepts, and is adding some new members to its family.



3701 Family History

We started developing the advanced distributed architecture fundamentals of the 3701 product family back in the early 2000s This technology involves integrating the very latest electronic hardware and firmware components in order to produce a small rugged monitor with very powerful signal processing that can be optimized for protection and monitoring of specific assets.

The first commercial offering in the family was the wind monitor, which was launched in 2009 (Reference 1). This monitor was optimized for monitoring the condition of the wind turbine drivetrain – including the complex planetary gearbox. We expanded the family with the gas turbine monitor, which was designed to provide monitoring and protection for heavy duty gas turbines. Most recently, we have added the Emergency Shutdown (ESD) System to the growing family.

ADAPT 3701/40 Gas Turbine Monitoring Module

We designed the gas turbine monitor to accommodate a wide range of heavy duty gas turbines where an alternative to rack-based systems is needed. It is a network-enabled distributed system that provides continuous monitoring and protection, and is suitable for applications that require high reliability and availability. As with all 3701 monitors, it has a small footprint with lightweight skid-mountable modular design.

Kit Contents

- 3701 Simplex Terminal Base
- 3701/40 Gas Turbine Monitoring Module
- 3701 PAV Proximitor/Acceleration/ Velocity Input Module(s)
- 3701 PAS Proximitor/Acceleration/ Seismic Input Module(s)
- 3701 8 Channel Relay Output Module
- 3701 Configuration Software

Features Summary

- 12 dynamic and 2 Speed channels
- Supports multiple sensors types including displacement, velocity, acceleration, magnetic and proximitor pickups
- Configurable band-pass filtering
- Small footprint, light weight skid-mountable modular design
- API 670 (5th edition) compliant
- Hazardous area ratings
- Graphically configurable relay logic
- Ethernet, EGD, and Modbus TCP/IP
- Network Time Protocol (NTP)
- Hot-swappable I/O modules
- Loop check capabilities
- LEDs for local indications
- Local buffered outputs
- Easy to use with SCOUT portable vibration analyzers

ADAPT 3701/55 Emergency Shutdown (ESD) System

Almost all industrial machines have automatic trips for harmful conditions such as high temperature, low lubricating oil pressure, overcurrent, etc. Trips for these and other off-normal conditions are typically incorporated into the machine's control system. However, it is sometimes the case that the control system doesn't meet regulatory requirements for API670 and SIL-3 certification. In such a situation, the 3701/55 ESD System provides a compact, robust self-contained overspeed protection system that incorporates full Triple Module Redundancy (TMR).

ESD System Inputs

The inputs to the system are guarded from failure using three CPU modules to provide TMR. Each CPU processing module processes two unique speed input channels, for a total of six speed channels for the system. The processing modules also monitor an array of 32 discrete input (DI) and process variable (PV) signals. Twelve channels of this input signal array may be configured either as discrete inputs or 4-20 mA recorder process variable inputs. Remaining channels in the array are reserved for discrete input signals only. System control contacts are provided for administrative functions.

ESD System Outputs

Machinery shutdown functionality of the 3701/55 ESD system is actuated by TMR relay output modules. Each relay output module has five relays with a level of configurability that accommodates a variety of applications and requirements. Four of the five relays in each module are used to annunciate system logic. The remaining relay reflects the OK / NOT OK status of the protection module. The Bently Nevada Monitor Configuration* software provides a graphical interface to configure relay logic. The state of each relay is determined by the system inputs and configured system logic in conjunction with the control state of the relay. Relay control states depend on the application, and may be set as normally energized/de-energized and independent one-out-of-one, (1oo1), voting or TMR two-out-of-three, (2oo3), voting. Each CPU module in the system has two, internally powered, 4-20 mA recorder outputs controlled by the full scale speed set by the user through the Monitor Configuration software.

ESD System Kit Contents

- 3701 ESD Terminal Base Assembly
- 3701/55 Overspeed/Emergency Shutdown Monitor Modules
- 3701 4 Channel ESD Relay Output Modules
- 3701 Configuration Software

ESD System Features

- TMR stand-alone safety Electronic Shutdown Device
- Overspeed protection
- SIL 3 and hazardous ratings
- Graphically configurable trip logic
- 6 Speed Inputs
- 2 redundant speed inputs per module
- Magnetic Pickup or Proximity
- 32 Discrete Inputs, 12 Analog Inputs
- 4-20mA Outputs, 12 Relay Outputs ■

References

1. Orbit Vol 29 No 1 2009. "An All-New Monitoring Solution for Wind Turbines."

For more information…

Visit our Continuous Online Monitoring webpage:
http://www.ge-mcs.com/en/bently-nevada-monitoring/continuous-online-monitoring.html

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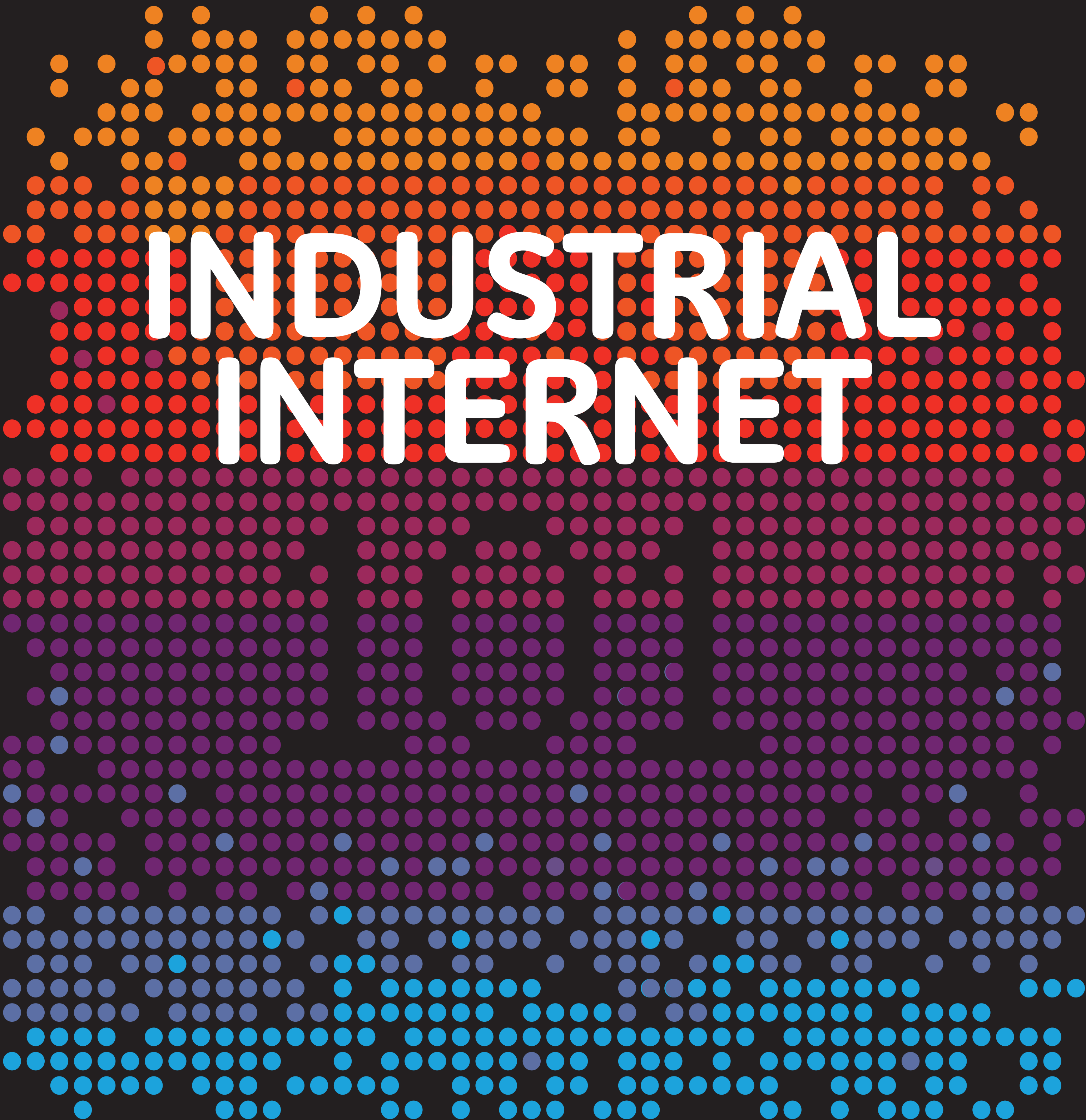
INDUSTRIAL INTERNET



Our feature story was contributed by our friends at the GE Software Center in San Ramon, California – who are dedicated to helping the Industrial Internet grow over the next decade and beyond. I look forward to publishing additional articles as the new paradigm evolves. — Editor

If

you recently picked up a copy of the *New York Times*, *Forbes*, the *Wall Street Journal* or any number of other publications, you've probably run across something called the Industrial Internet.

SO, WHAT IS IT?

The Industrial Internet connects machines, via embedded sensors, with advanced analytics and people at work to enable intelligent decision making. Every day, millions of machines critically important to daily life – from MRIs to gas turbines to aircraft engines – share vast amounts of information. Collecting and sifting through these bits of information unlocks new insights into how we can more efficiently and economically run our businesses, promote sustainability, and boost economies around the world.

GE is helping companies across industries tap into the powerful potential of the Industrial Internet. The GE Software Center uses agile development to create innovative next generation software-based solutions that deliver dramatically better outcomes for customers through the application of advanced analytics and machine intelligence.

With more than 30 percent of the world economy directly attributed to industrial activity, it is critically important that we can better understand and interpret the language of machines. Within the Industrial Internet, complex optimization algorithms decide tradeoffs between "the right repair at the right time," for example, and the need to avoid needless delays and cancellations.

Businesses can optimize decisions, and apply the lessons of all components to enhance performance and to react accordingly and automatically. With more than 3.2 million "big things that spin" operating in industries around the globe, the Industrial Internet is poised to dramatically increase enterprise profitability and productivity (Reference 1). Early projections for the Industrial Internet are promising.

- ✔ AVIATION: A reduction of 1% in jet fuel costs would save $30 billion over 5 years.
- ✔ ENERGY: At gas-fired power plants alone, efficiency gains driven by software and network optimization as well as more effective coordination of gas supply to meet power system load requirements would save $66 billion over 15 years.
- ✔ HEALTHCARE: Global healthcare systems waste at least $732 billion annually. GE Healthcare has identified $100 billion in annual savings driven by the Industrial Internet.
- ✔ RAIL: The Industrial Internet could reduce costs nearly 2.5%, or $5 billion a year, at rail system operations worldwide.

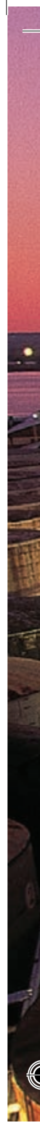
The GE Software Center is working with more than 10,000 software developers across GE's diverse divisions to create services and solutions for asset optimization and enterprise optimization under our GE Predictivity** Industrial Internet offerings. Think of software solutions that identify problems and issues BEFORE they occur. The goal is to increase efficiency. By predicting a machine's future through analytics, GE will help businesses eliminate downtime and reduce waste. The analytical data could even help develop better ways to use GE's industrial products.

Complex systems can generate vast quantities of data about themselves. But sheer data is a latent commodity. Organizations able to mine data, understand context, and get information to the right person at the right time can make intelligent decisions in real-time vs. after the fact. This creates a tremendous advantage in fiercely competitive markets. Doing so requires deep proficiency in the science of data analytics.

GE Software specializes in the creation of tools to analyze data generated by complex systems found in domains such as transportation, health sciences, and energy. These tools enable customers to maximize profits by minimizing operational costs and downtime for repair and maintenance. Airplanes only earn revenue when they fly, and they only fly when engines are in top shape. The same is true for railroads and their locomotives, health systems and their imaging and diagnostic equipment, and energy producers with their turbines.

GE Software's unique combination of industrial expertise, software experts, and historical perspective is delivering the next chapter of the Internet's evolution.

BENTLY NEVADA TRANSDUCERS AND MONITOR SYSTEMS HELP TO MAKE MACHINES "INTELLIGENT," SO THEY CAN SEND CONDITION MONITORING DATA TO BE ANALYZED.



Bently Nevada: At the Center of the Industrial Internet

The work being done and the data generated by Bently Nevada are "natural resources" that will power the Industrial Internet.

The Industrial Internet is bringing vibration data and diagnostics to the experts, instead of the experts going to the data. Historically, vibration data needed to be "reduced" and evaluated on-site by a diagnostic expert – first with oscilloscope cameras and later with FM tape recorders, vibration analyzers and x-y plotters.

As analog instrumentation was replaced with digital systems, the data facilitated the use of software analytics. And with the Industrial Internet, we are now able to take that vibration data to the experts who reside in Bently Nevada Remote Monitoring Centers or at our customers' own centralized locations.

But, how can System 1* data be mined and presented in an automated fashion that puts the intelligence directly in the hands of customers in a usable fashion to better serve their need to optimize plant production, and reduce maintenance costs?

Enter the Industrial Internet.

The mechanical vibration of gas turbines can be measured and analyzed to predict maintenance issues before a failure occurs. By collecting data across a significant population of machines, we can provide new insights that will enable condition-based maintenance and optimize outcomes. Software engineers can identify patterns and correlations in machine behavior through big data analysis, convert the data into actionable insight, and proactively alert customers when repairs need to be made – eliminating unscheduled maintenance, maximizing uptime, and preserving respect for the GE brand.

The Industrial Internet is changing the way we manage and maximize global economic output. For the first time in human history, vitally important machines across the globe are communicating their activities in real time. Combining these brilliant machines with best in class analytics delivers valuable new customer insights that were never before possible.

Fulfilling the promise of the Industrial Internet requires a robust ecosystem of software, hardware, and service providers. GE's Industrial Internet efforts are spearheaded by the GE Software Center but cannot be successful without visionary partners such as the Bently Nevada team. ■

References

1. Industrial Internet: Pushing the Boundaries of Minds and Machines white paper by Peter C Evans and Marco Annunziata. This paper is available online for viewing and download: **http://www.ge.com/sites/default/files/Industrial_Internet.pdf**

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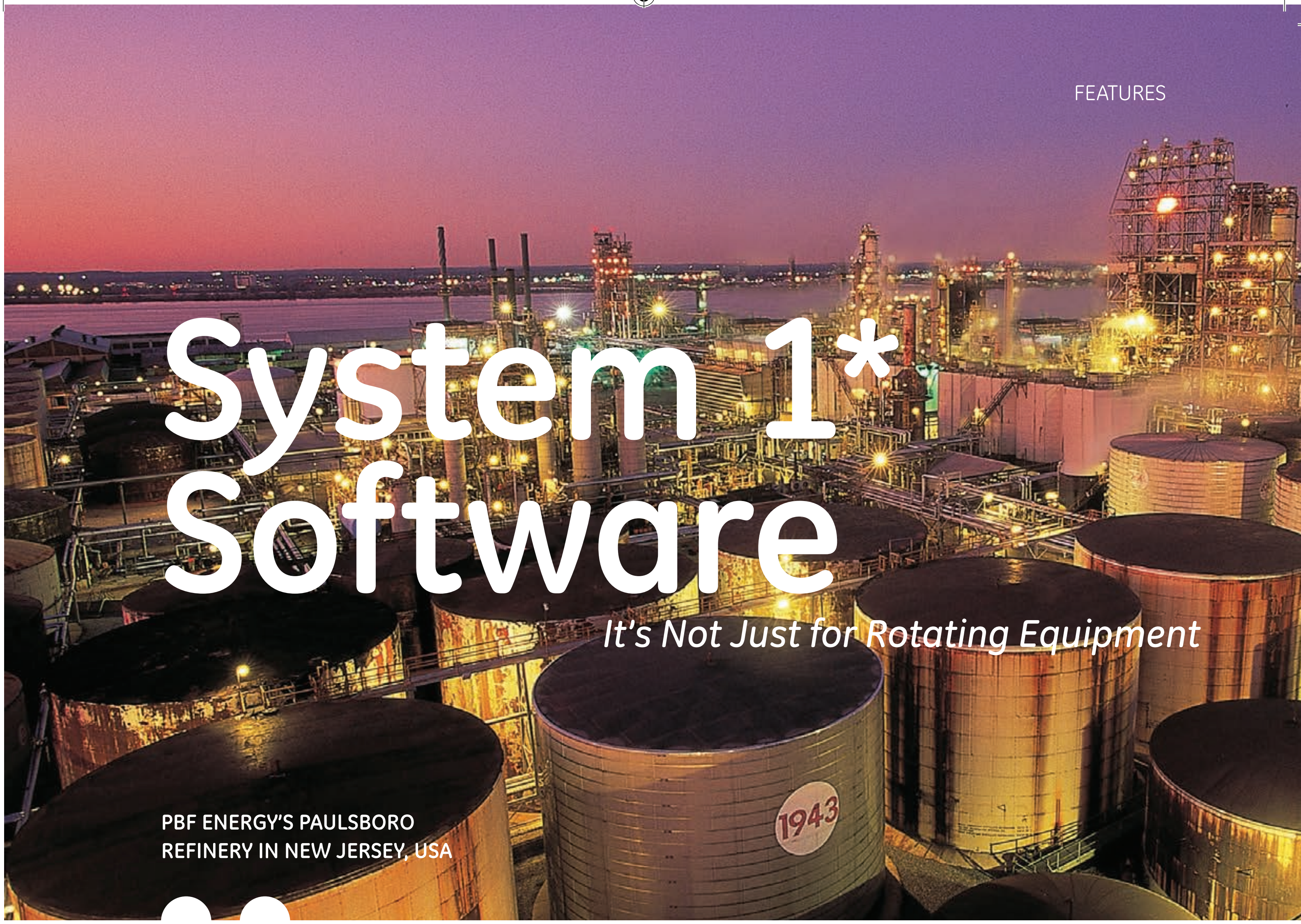
**Predictivity is a trademark of General Electric Company.

System 1* Software

It's Not Just for Rotating Equipment



PBF ENERGY'S PAULSBORO
REFINERY IN NEW JERSEY, USA

IN TODAY'S REFINERIES, power plants and other industrial settings, there are plenty of DATA sources, but few sources of readily available INFORMATION. Examples of condition monitoring data include oil analysis results, infrared thermography surveys, motor current data, portable vibration data, hand-logged data, instruction manuals and other technical documentation, thermodynamic performance parameters, etc.

But how can technical staff members assimilate all of this data and glean useful information from it? At PBF Energy's Paulsboro Refinery in Paulsboro, NJ they have been using Actionable Information* provided by GE's System 1 software.

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Decision Support*

The Decision Support (DS) capabilities built into System 1 with optional RulePaks and DS Studio capture knowledge and transform data into actionable information. This article demonstrates exactly how this transformation can help continuously improve maintenance processes and manage more than just rotating equipment.

From a process standpoint, the System 1 platform collects data from sources such as 3500 protection systems, Trendmaster* condition monitoring system, SCOUT portable vibration analyzers, process control systems, and GE Multilin electrical protection relays. System 1 software also stores manually entered data and imported oil analysis laboratory results.

System 1 software takes the data from sources and sends it through a Decision Support "rules engine" that applies various logic functions to the data. The rules are based on an understanding of the properties and characteristics of the monitored assets, as well as on historical baseline data. While System 1 software accommodates dynamic (waveform) data, the Decision Support features work with or without waveform data.

Decision Support uses pre-programmed rules – called RulePaks – for your rotating machinery assets, as well as rules you write using DS Studio based upon your own specific operating history. DS can also take multiple inputs and perform calculations on them to derive results, which are called calculated variables.

Once the calculated variables are derived, they can be sent back to DS to be used by other rules. They can also be sent to your DCS for trending (or viewed in System 1 Display). DS also triggers a System 1 event whenever a rule determines that conditions match pre-configured logic for the event. These events are recorded in the System 1 event log and broadcast to System 1 users using Smart Notifier. Figure 1 shows this process as a flow chart.

Non-Rotating Equipment

How do Decision Support capabilities relate to non-rotating equipment? System 1 software is very flexible, and can query any system that allows OPC communications. The requested data can be any parameters that are useful for monitoring the health of the monitored assets. For example, the data could be pressure values that are used to detect plugged filters, temperatures that are used to determine gas turbine burner can conditions, or other appropriate data that is used to determine if your Continuous Emissions Monitoring System (CEMS) is operational (Reference 1).

CEMS Requirements

For industrial facilities such as refineries and power generation facilities, the CEMS is required by law (by the Environmental Protection Agency, or EPA, in the USA) to be operational for more than 90% of the time on a static quarterly basis. The CEMS components and stack gas sampling system are sensitive to many factors that if abnormal can increase downtime and decrease reliability. As you might imagine, very stiff penalties can be levied if a CEMS is not operating properly.

Using System 1 DS Studio, PBF Energy wrote a set of rules that checks the CEMS data to determine if the emission monitoring system is operating properly. Further, if the information determines that action needs to be taken, PBF also utilizes the Smart Notifier feature to request timely corrective action from appropriate staff members.

Prior to writing a logic rule, it is important to perform a Failure Modes & Effects Analysis (FMEA) on the assets being monitored. Some examples of failure modes for the CEMS systems are: loss of data; update failures and validation misses or failures, each of which requires specific corrective rules to be written.

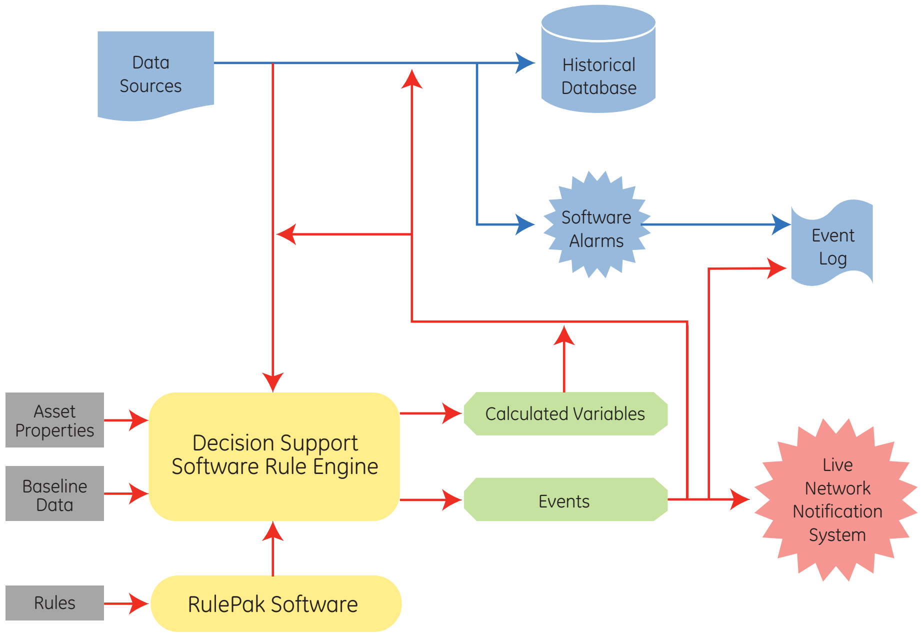


FIGURE 1: Flowchart shows how System 1 Decision Support software converts input data into calculated variables and events.

Loss of Data

CEMS systems communications have been found to be susceptible to some sporadic errors that result in loss of data. A data loss that occurs for less than one hour is deemed an intermittent issue, and after correcting itself, there is no need for human intervention. Therefore, this rule continuously checks the "OK" status of the reporting variable. If a NOT OK condition is observed, the rule sets a timer and continues to check the status of the reportable variable. If the status returns to OK within an hour, the rule resets itself. Otherwise, the System 1 platform generates an event with Severity-2 and notifies the appropriate employee(s) to check for communication problems.

The System 1 rule logic continuously updates "uptime" (OK) and "downtime" (NOT OK) of the analyzer as calculated variables. These calculated variables are then utilized in another rule to calculate the downtime percentage and time remaining until violation for each of the respective analyzers.

Update Failures

Due to the dynamic nature of combustion, CEMS data is constantly changing, or at least, it should be. Therefore, if two samples taken 5 minutes apart appear to be exactly the same, it is usually the effect of an update failure. Consequently, if the DS rules detect that the CEMS hasn't updated its information for 30 minutes, the System 1 platform generates a Severity-2 event, indicating a possible analyzer performance problem. For this low severity issue, the action item given is to monitor again within six hours for any changes. Smart Notifier is used to send this low severity alarm to the analyzer technician for action. Data during this period is given an orange color.

The rule for this issue has been designed to capture a rolling average of six samples over a 30 minute period (one sample every 5 minutes), with a first in, first out buffer. After the System 1 DS auto buffer has six samples the rule compares the maximum value with the minimum value over the time period. If they are equal to each other (indicating that the analyzer may not have updated), the rule creates a Severity-2 event and sends an email to the responsible employee(s) to correct the problem.

A clever person might note that if the boiler isn't operational, the CEMS may report non-varying values. This would result in false alarms and excessive, useless emails. To make sure that this isn't the case, the rule first checks to make sure that the stack temperature is above 400 °F, in which case the CEMS should be operational.

Validation Misses or Failures

The CEMS performs a self-test every 24 hours using appropriate calibration gases. If during these self-validations, either the zero or span drifts are greater than the allowable tolerance, a severity 4 validation failed event is generated, and the data color is turned to red. The rule starts calculating, and storing the elapsed time for this validation failure condition.

The Environmental (ENV) team monitors any validation failures that exceed twice the allowable tolerance of the drift value. If these occur, the ENV Engineer manually adds 24 hours to the downtime for the stack gas analyzer based on analysis of problem. This is the highest severity event, and results in notification from the technician level to the plant manager via email. The Action item requested in the notification is to manually recalibrate the analyzer and sampling system functionality, as well as to check the analyzer functionality as soon as possible.

If the zero drift and span drift remain the same after a 24-hour period, then the analyzer may have missed its self-validation. This also generates a Severity-4 Validation missed event with automatic notification of appropriate employees. The requested action includes checking the analyzer, rectifying any problems, and manually recalibrating the analyzer.

Downtime Reporting

Four System 1 severity levels have been generated for this reporting:

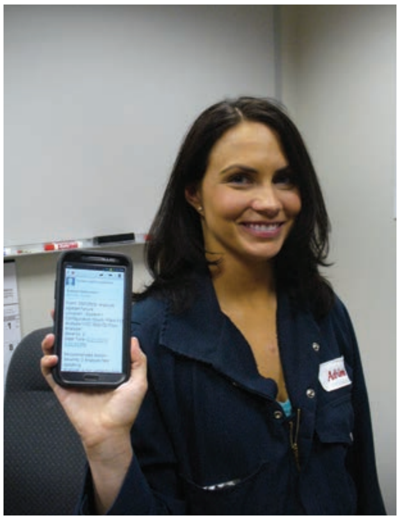
	Downtime	Time to violation	Data code
Severity-1	>3%	<150 hours	Blue
Severity-2	>5%	<100 hours	Orange
Severity-3	>7%	<75 hours	Yellow
Severity-4	>9%	<25 hours	Red

These downtime severities help with deciding the criticality of the particular analyzer and with planning maintenance work to avoid any violations of emission regulations and associated fines. Analyzer Preventive Maintenance (PM) work can also be scheduled based on data available from the logic rules. Similarly, rule-based notifications can be used to schedule an analyzer technician during off hours and on weekends, based on the severity of the situation.

Automated Notification

After the rules are written, the team determines who should receive automated event notifications. The Smart Notifier system makes it easy to set up selective distribution lists based upon event severity levels. Each of the rules listed above has a specific severity level assigned to it, as described. Notification is escalated to higher levels of management as severity increases.

Those who might be notified include: Information Technology (IT) Manager, Machinery Engineer, Maintenance Technician, Plant Operator, Instrument Technician, ENV Engineer, and Reliability Engineer...all the way up to the Plant Manager (Figure 2).



ADRIENNE (ENVIRONMENTAL ENGINEER) AUTOMATICALLY RECEIVES NOTIFICATION OF CEMS VALIDATION MISSES OR FAILURES.

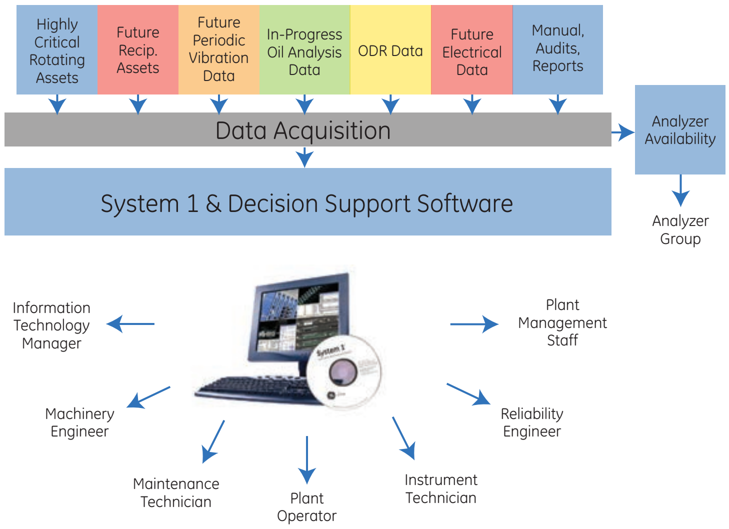


FIGURE 2: System 1 software uses data from many sources, and helps a wide variety of decision-makers to make better decisions. "Analyzer Availability" refers specifically to the Continuous Emissions Monitoring System (CEMS), which is operated and maintained by a dedicated group of specialists.

Each of the e-mail messages generated by the Smart Notifier includes event type, severity level, asset name, and date and time when the parameter entered the alarm state – and probably most important of all – a recommended action. This is why we call the notifications Actionable Information. If the System 1 platform is logging events continuously, an initial e-mail notification will be sent at the beginning of each day, which requires the impacted person to monitor the situation for the rest of the day, and avoids sending a constant stream of "nuisance" notifications.

System 1 Decision Support capabilities have resulted in greater reliability and availability of CEMS, and the System 1 Docuview function is linked to the emission analyzer's maintenance logs. The System 1 Journal Editor is used to record all of the Environmental group's comments when they manually update the entries for their time recordings. This assists in creating mandatory EPA reports.

As can be seen by the above example, System 1 management can be expanded beyond rotating equipment to ANY monitored assets. When incorporated into your plant's daily routine, your System 1 platform can help you manage all your assets, retain your corporate learning, and help you continuously improve your plant's profitability!

References

1. Orbit Vol 29, No 1, 2009, Jayesh Patel, Al Gomes; John Kingham. "Using Decision Support to Reduce OpEx at Valero Paulsboro."

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Wireless Condition Monitoring

Extending Battery Life Using Thermal Energy Harvesters

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BENTLY NEVADA* WIRELESS SIGNAL INPUT MODULE (WSIM) WITH EXTERNAL POWER MODULE BASE, CABLE, AND PERPETUA POWER PUCK** POWER SOURCE

One of the main benefits of our wireless condition monitoring system is that the processed signals are sent to the data acquisition unit via radio transmission, rather than through physical field wiring that requires costly conduit to protect the signal cables. When powered by internal batteries, our wSIM and Repeater modules are not required to be located near sources of ac power. This allows for broad flexibility in selecting mounting locations at an industrial site. However, the very batteries that allow our wireless modules to be so flexible eventually become depleted and need to be replaced. This is why we developed the External Power Module.

An External Power Module (Reference 1) contains the same kind of lithium thionyl chloride batteries that our normal battery packs do. However, it also incorporates a connector for accepting direct current input from any source capable of providing 5 vdc at 0.5 mA. If the output of the external power source drops below this value for any reason, the internal battery pack automatically takes over, performing its duty the same as a normal battery pack that doesn't have the external power option. As long as the external power source is carrying the load, the internal battery simply serves as a standby source of power, and its life is extended to the full limits of its normal "shelf-life."

We have evaluated several possible sources of external power over the past few years, with mixed results. Recently, however, we had some very satisfactory results with a thermal energy harvester called the Perpetua Power Puck. At the heart of any thermoelectric generator – including the Power Puck – is a device that generates electrical energy when it is subjected to differential temperature.

Ordinary thermocouples are familiar examples of this principle, relying on the Seebeck Effect for their operation. Whenever two dissimilar materials are connected in two places, with one junction in a warmer location and the other junction in a cooler location, an electrical potential, or voltage is developed between them. When the circuit is completed through a load, useful current flows. Modern thermal energy harvesters, such as the Power Puck, add onboard electronics to regulate the supplied voltage for added stability.

The Power Puck design includes an integral magnet that allows the base to be securely attached to any hot (magnetic) surface. The fins on the top of the unit use natural convection with ambient air to provide the cool junction needed for operation.

Engineering Field Trials

For the field trial described here, we selected a natural gas fired multi-technology power generation facility with peak generating capacity of just over1000 MW. The newest units at the site use combined-cycle technology, incorporating heavy-duty gas turbines with Heat Recovery Steam Generators (HRSGs) and steam turbines. The site also includes simple-cycle dual-fueled gas turbine peakers and older-technology gas-fired steam plants.

The wide range of plant equipment provided ample opportunity to test the Power Puck modules on a variety of different hot equipment surfaces, a few of which are shown here (Figures 1 through 3). Most of the selected surfaces provided adequate differential temperature (delta-T) for the Power Puck to fully supply a wSIM for the entire evaluation period. One of the surfaces that we tested was too cool to provide the required delta-T, yet it still contributed a significant amount of power to the wSIM and extended the life of the battery. The results of this interesting test are included in Figure 4.

FIGURE 1: Warm Gland Seal Condenser support structure, with magnetically-mounted Power Puck and the thermocouple being used to monitor surface temperature for data collection. The temperature signal was processed and transmitted by the wSIM that the Power Puck was energizing.

FIGURE 3: Hot Boiler Feedwater Pump (foreground). Again, the surface temperature sensor used for engineering data collection is visible in this photo, next to the Power Puck. The air-cooled pump drive motor is at the left side of this photo, and the wSIM is just outside the field of view at the top.

FIGURE 2: Hot Boiler Feedwater Line. In this example, the wSIM was hanging upside down from the overhead structure and the Power Puck was attached on top of the piping tee at the bottom of the photo.

Test Results

Our results were very positive. In multiple trials, we verified that if the temperature difference between the hot surface and ambient air is 20 °C or more, the Power Puck will reliably power the attached wireless device continuously, and will not require the internal batteries to expend any of their stored energy. One of the more interesting tests used a Lube Oil Pump as the heat source (test data in Figure 4). This test showed that the Power Puck will actually provide power for a significant fraction of the time even if the delta-T is significantly less than 20 °C. In fact, the delta-T only exceeded this value once (red circle) during the five-day time period shown here.

Test Conclusions

Power Puck modules met our expectations, and operated reliably in a hot, dry, high-desert environment. Installation of the modules with the integral magnet was simple and took very little time, once a suitable warm surface was located. With a differential temperature of 20 °C or more, a Power Puck will reliably power a wSIM or Repeater module.

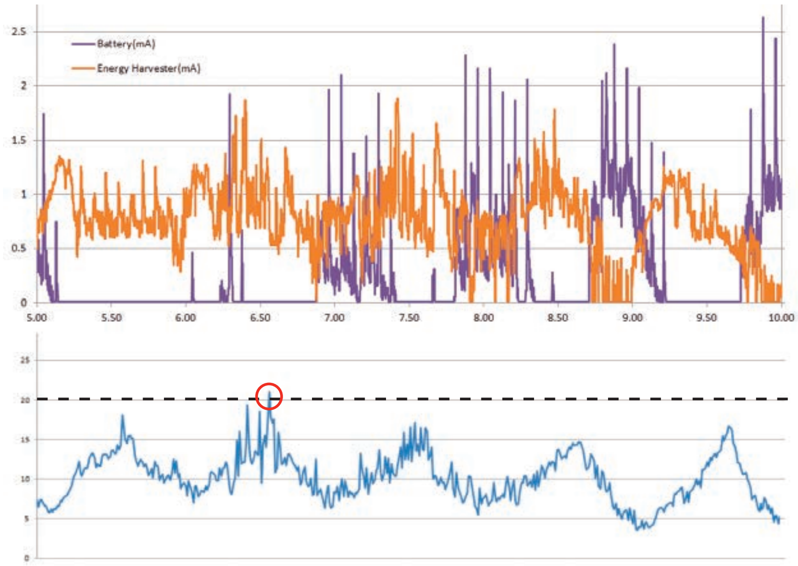

FIGURE 4: Five days of data for the Lube Oil Pump test. The upper plot shows wSIM internal battery current in purple, and Power Puck current in orange. The lower plot shows differential temperature in Celsius, with the 20 degree value indicated by the dashed line. Purple spikes in the upper plot represent brief periods when the External Power Module battery pack powered the wSIM.

Power Puck Benefits & Features Summary (Reference 2)

- Reduces the need to buy and install replacement batteries
- Reduces environmental impact from recycling expended batteries
- Enables more frequent collection, processing and transmission of data
- Meet IP67 requirements, and are RoHS compliant
- No moving parts, maintenance-free – thermoelectric generators are known for long-life operation – typically more than 20 years

What's Next?

At the time of this writing, we are working on including Perpetua's Power Puck thermal energy harvester in our wireless accessories. Our website will include this external power source when it is available. **http://www.ge-mcs.com/en/bently-nevada-monitoring/wireless-surveillance-scanning/essential-insight.html** ■

References

1. Specifications and Ordering Information, Part Number 185301-01. "Essential Insight.mesh – Wireless Condition Monitoring External Power Module datasheet, **http://www.ge-mcs.com/download/monitoring/185301_CDA_000.pdf**

2. Power Puck information is available at the Perpetua website, **http://www.perpetuapower.com**

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Accelerometer Mounting

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Accelerometers play a central role in providing vibration signals used in the diagnostics of gears, bearings, reciprocating compressors, and many other machines. While the sensor system often receives much attention during procurement and installation, too little consideration is sometimes given to the machined surface that will be receiving the transducer. This article provides an overview of the mounting requirements and describes methods to check existing installations, and to correct any problems that are found. The article focuses on permanently installed transducers; however many of the concepts apply to portable systems as well.

Mounting Requirements

Proper accelerometer mounting begins by evaluating the environment in which the transducer will be installed. This checklist includes some important factors to consider:

- **Ambient and Surface Temperatures:** All accelerometers have a fixed temperature range over which they can operate reliably. Both the ambient and surface conditions must be within this range over all operating regimes of the monitored machine.
- **Electrical Isolation:** Accelerometer designs vary. So if the accelerometer is to be installed on electrical equipment, it is important to consult the accelerometer datasheet to confirm that the internal electronics have sufficient isolation from sensor casing. In situations where the accelerometer does not have sufficient isolation, an isolation adaptor may be installed. Note that installation of an adaptor can alter the frequency response of the accelerometer system and this must be accounted for in adaptor selection.
- **Weather:** Accelerometer systems installed outdoors generally need protection from the elements. Usually this protection takes the form of a housing that installs around the accelerometer and allows the accelerometer case to connect directly to the machine case. Figure 1 shows an example of the Bently Nevada housing #43212 that allows such a mounting.
- **The Machined Surface:** This feature has a significant effect on accelerometer performance. In order for the accelerometer system to faithfully report the machine vibration, the mechanical mounting surface must be flat, clean, and perpendicular to the mounting stud. The finish and mounting requirement for most accelerometers are quite high. Figure 2 shows an example of the finish and machining tolerances for the 330400 and 330425 accelerometers. To maintain the required perpendicularity tolerance a combination drill

and spotface tool or a piloted counterbore tool may be used. These are available commercially; however some modification may be required. For example, the piloted counterbore tool part number 3102A37 from McMaster-Carr* comes with a 6.35 mm [0.25 in] pilot. This pilot must be turned down to 5.54 mm [0.218 in] to fit into the ¼"-28 tap drill hole. The 0.813 µm (32 µin) RMS Total Indicated Runout (TIR) surface finish can be obtained by placing emery cloth between the spotfacing tool and surface to provide a final polish.

- **Thread Lubrication and Transducer Torque:** All threaded accelerometers will have thread lubrication and torque requirements. These requirements must be followed exactly to avoid a poor transducer response or damage to the transducer. The torques frequently have low values (on the order of 3 N-m or 30 in-lbs) so an appropriate torque wrench must be selected. Generally, thread locking compounds should be avoided; however if locking compound is used, care must be taken to ensure it contacts only the threads of the transducer. Any locking compound that seeps into the area between the transducer and the machine surface during installation and torqueing lifts the transducer from the surface as it cures and expands. This lift results in higher effective torques that can damage the transducer and reduce signal response.

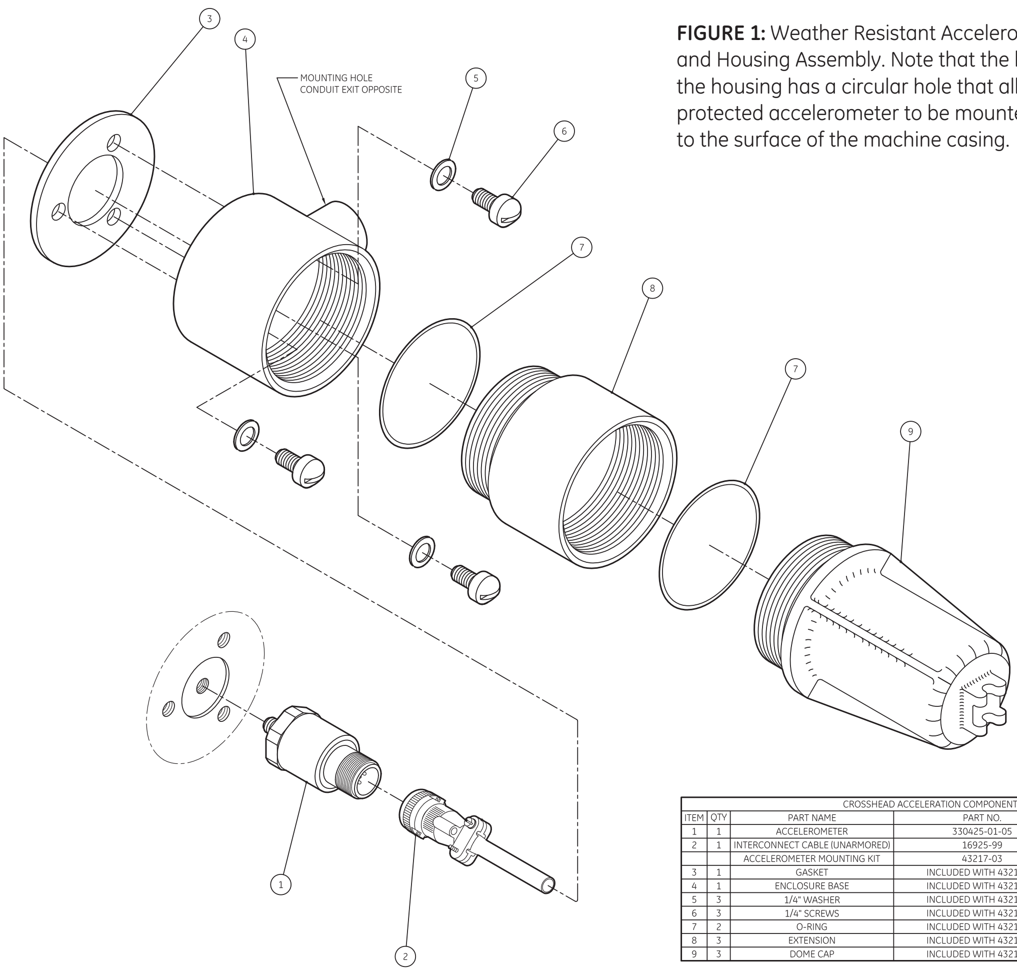

FIGURE 1: Weather Resistant Accelerometer and Housing Assembly. Note that the base of the housing has a circular hole that allows the protected accelerometer to be mounted directly to the surface of the machine casing.

CROSSHEAD ACCELERATION COMPONENTS				
ITEM	QTY	PART NAME	PART NO.	TORQUE
1	1	ACCELEROMETER	330425-01-05	30 IN-LB
2	1	INTERCONNECT CABLE (UNARMORED)	16925-99	N/A
		ACCELEROMETER MOUNTING KIT	43217-03	N/A
3	1	GASKET	INCLUDED WITH 43217-03	N/A
4	1	ENCLOSURE BASE	INCLUDED WITH 43217-03	40 IN-LBS
5	3	1/4" WASHER	INCLUDED WITH 43217-03	5 IN-LBS
6	3	1/4" SCREWS	INCLUDED WITH 43217-03	N/A
7	2	O-RING	INCLUDED WITH 43217-03	N/A
8	3	EXTENSION	INCLUDED WITH 43217-03	N/A
9	3	DOME CAP	INCLUDED WITH 43217-03	N/A

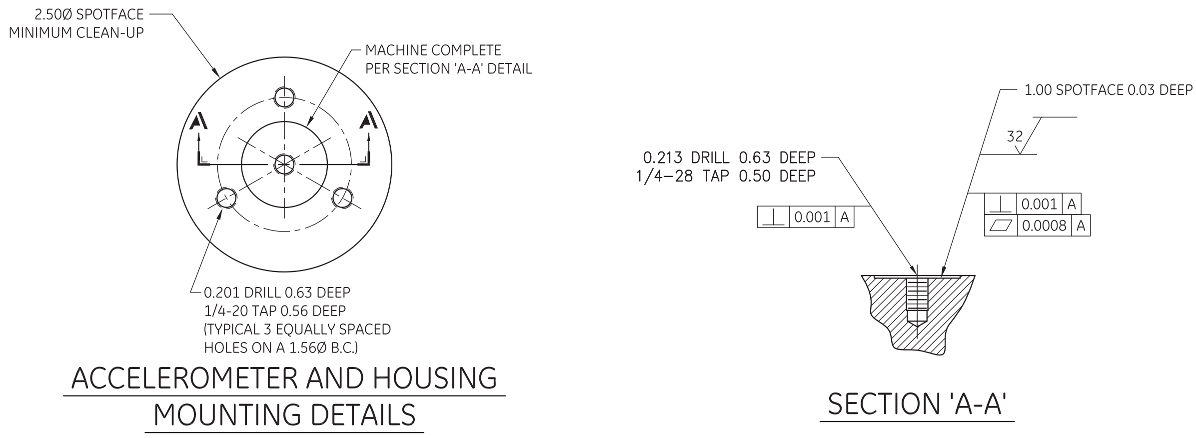

FIGURE 2: Accelerometer and Housing Mounting Details


FIGURE 3: EXAMPLE OF CONTACT AREA CHECK ON ACCELEROMETER.

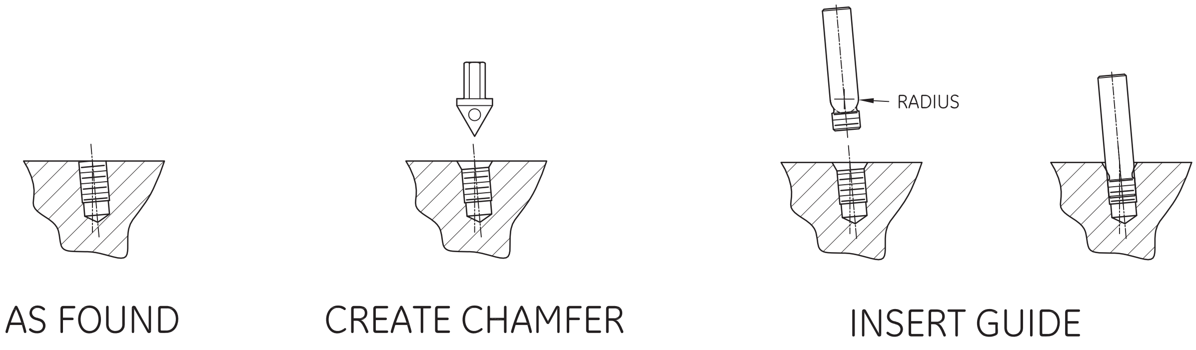

FIGURE 4: Process and tooling for locating centerline of tapped hole

Verifying Proper Installation

For any given installation it can be difficult to quantitatively determine if the features meet the tolerances called for in the accelerometer manual. One method of verification that has proven to be reliable in the field is to apply a thin layer of soft machinist's blue (or transfer blue) to the machine surface. The accelerometer is threaded into the hole until it contacts the surface, no more than finger tight. Then the accelerometer is removed from the mounting and the amount of bluing agent that transferred from the surface to the accelerometer can be observed. Figure 3 shows an example of this method. The bluing covers approximately 80% of the accelerometer which is acceptable. A good installation will have a contact area of at least 80% and more is desirable.

Correcting an Improper Installation

Minor defects, such as incomplete threads or burs on the machine surface, can usually be fixed quickly once they are identified. Systemic machining defects, such as a rough or warped surface or a surface not perpendicular to the threaded hole, are more difficult to correct. The following process has proven to be effective for correcting these types of machining problems.

The most difficult part of repairing or renewing the surface under the accelerometer is making sure that the tooling face remains perpendicular to the centerline of the tapped hole. To ensure perpendicularity, the process and tooling in Figure 4 is used.

First, a chamfer is machined at the surface using a conical de-burring tool. This ensures that the chamfer is concentric with respect to the intersection of the tapped-hole centerline to the surface.

Once the chamfer is complete, a guide pin with a radiused end is threaded into the hole. The guide has a diameter slightly larger than the nominal thread size. This ensures that the radius contacts the chamfer at a single line. The pin will be held concentric and parallel to the centerline of the tapped hole. With the pin in place, tooling can be inserted over it to repair or renew the mounting surface while maintaining acceptable tolerances for perpendicularity.

Surface Correction Example

A 2 in x 2 in (~5 cm x 5 cm) steel beam used for modal testing provides a good illustration of the effectiveness of an improved accelerometer mounting surface. Figure 5 shows the guide pin threaded into the hole on the 2"x2" steel beam.

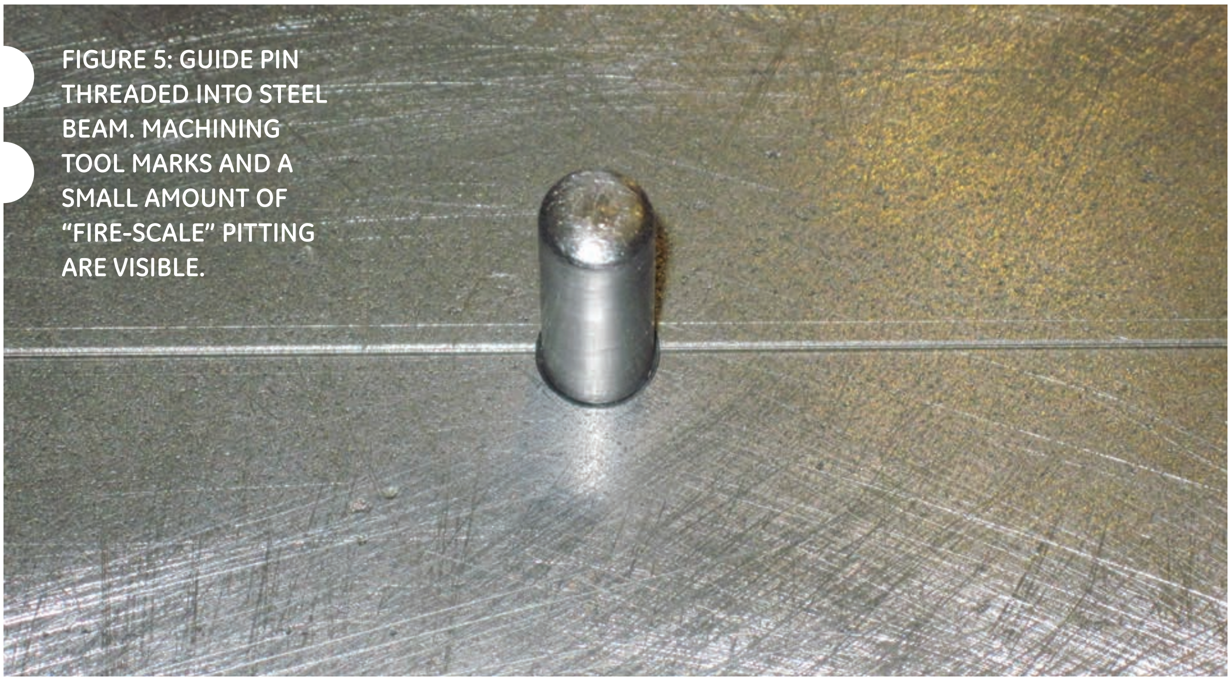

FIGURE 5: GUIDE PIN THREADED INTO STEEL BEAM. MACHINING TOOL MARKS AND A SMALL AMOUNT OF "FIRE-SCALE" PITTING ARE VISIBLE.

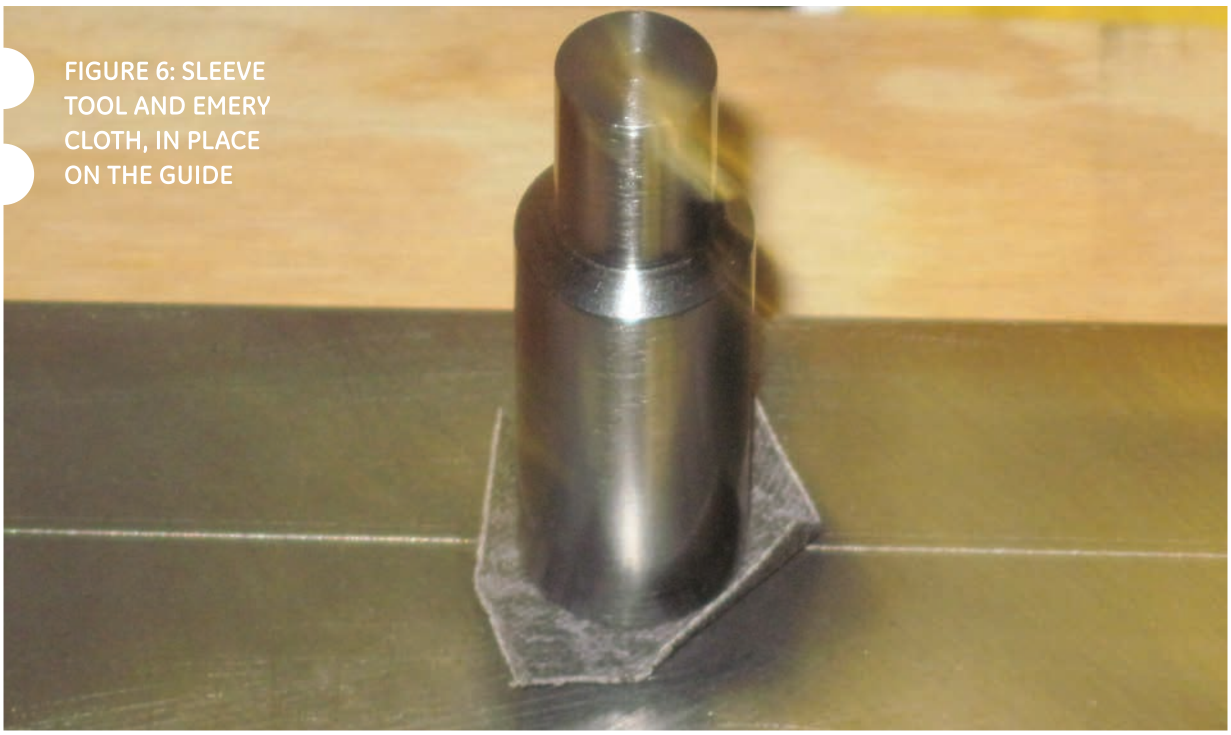

FIGURE 6: SLEEVE TOOL AND EMERY CLOTH, IN PLACE ON THE GUIDE

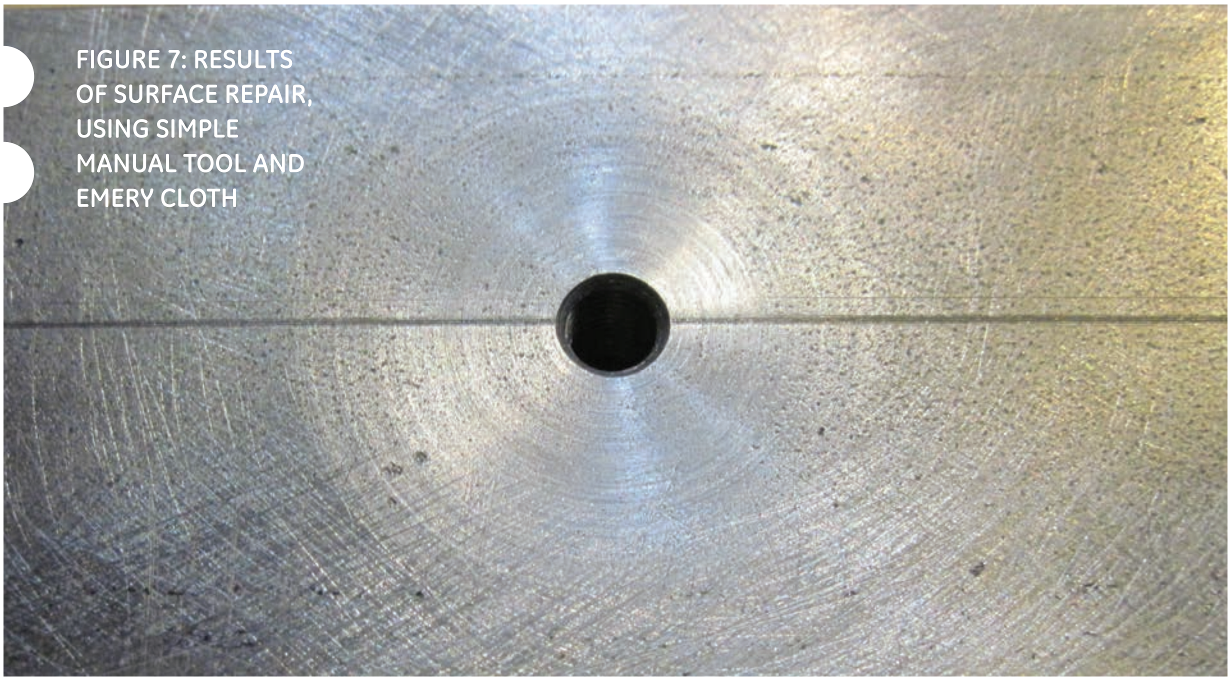

FIGURE 7: RESULTS OF SURFACE REPAIR, USING SIMPLE MANUAL TOOL AND EMERY CLOTH

The next step in the process is to install a machining fixture over the guide. Since this installation needed correction to the surface finish, emery cloth and a sleeve-style tool (with perpendicular end) were installed over the guide. More aggressive correction might warrant the use of a counterbore tool, which has been machined to fit over the guide pin. Figure 6 shows the sleeve tool and emery cloth arrangement. The tool was turned by hand to polish the surface.

Working from coarse (80 grit) to fine (600 grit) abrasive removed most of the pits from the mill scale and noticeably improved the surface finish of the steel bar (Figure 7). Visually, it appears that the surface has been smoothed and evened out.

Vibration Measurements – Before and After Surface Correction

The modal testing beam was simply supported at each end. The accelerometer was installed in the vertical orientation on the beam, and the beam was excited with an impact hammer. Vibration samples were collected before and after the correction of the accelerometer mounting surface, and the results were compared.

The lower plot in Figure 8 shows the transfer function (TF) obtained prior to the surface correction as the gray line and after the correction as the blue line. The TF magnitude for both lines shows a large peak at 2.7 kHz, which is very close to the predicted value of 2.8 kHz for the first bending mode of the beam. The second mode of the beam is predicted to be 8.1 kHz. The gray line shows two peaks below this value, but no distinct peaks above 8 kHz.

The upper plot in Figure 8 shows the coherence function (CF), which is an indication of the relationship between the frequency content in the accelerometer and the impact hammer. The gray (before correction) line shows good agreement only to about 6.5 kHz, which is below the estimated second mode response of the beam. With the surface finish corrections (blue line), the CF is stable out to about 8.5 kHz, which is far enough to allow the accelerometer to accurately capture the second mode response.

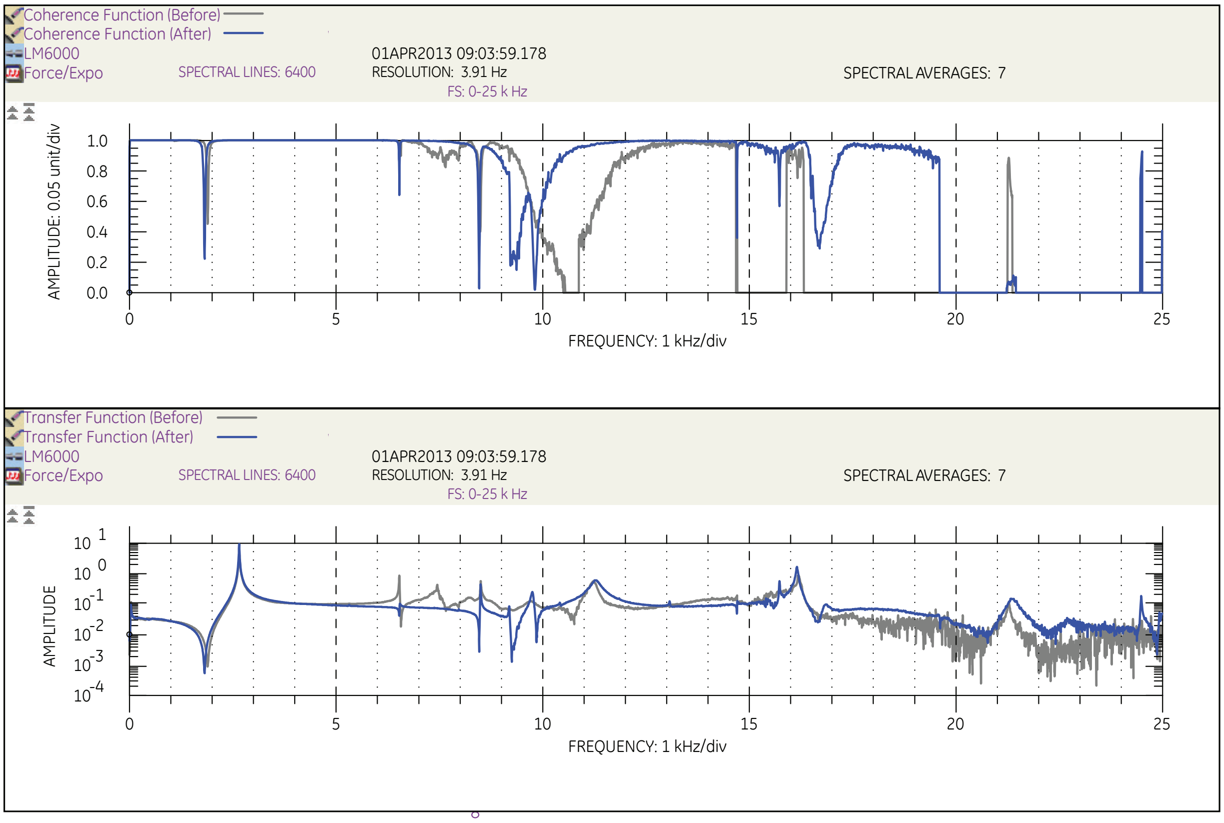

FIGURE 8: Impact hammer results. Upper pane shows Coherence Function (CF) and lower pane shows Transfer Function (TF). The blue line is data from after the surface was corrected, and the gray line is data from the original rough mounting surface.

The TF for the corrected surface clearly shows a peak at 8.3 kHz, which is very close to the predicted value of 8.1 kHz. In this case, polishing the surface enabled accurate measurement of the second mode of the beam, although it had been unable to be measured with the original rough mounting surface.

Conclusion

This article provides methods for checking and improving accelerometer installations. Ensuring that the installation matches the specifications for a given accelerometer results in a faithful representation of the vibration at the machine. This, in turn, allows for improved condition monitoring and earlier detection of machinery malfunctions.

*McMaster-Carr is a trademark of McMaster-Carr Supply Company.

Puget Sound Energy (PSE) Identifies Bearing & Alignment Problems

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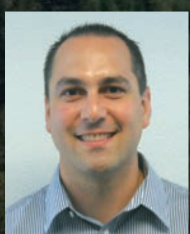

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Located about 18 miles (29 km) southeast of Tacoma, Washington, PSE's Frederickson Generation Station primarily provides "peaking" energy for the utility's power system during daily or seasonal spikes in customers' power usage. An additional benefit is the plant's ability to be started remotely from PSE's electric-dispatch center and to reach full generating output within 10 minutes. This quick-start capability helps to ensure service reliability for PSE customers during electrical-system emergencies. The plant, built in 1981, contains two simple-cycle General Electric frame 7E combustion turbine generating units.

MOUNT RAINIER PROVIDES A SCENIC BACKDROP TO PUGET SOUND IN USA'S PACIFIC NORTHWEST

PSE'S FREDERICKSON GENERATION STATION

Executive Summary

In 2010 a Bently Nevada* 3500 vibration monitoring system was installed during a major maintenance outage on Frederickson Generation Station's Unit 1, one of two early 1980's vintage GE frame 7E, simple cycle gas turbine generators. Following the major inspection, the unit began suffering high vibration alarms, and occasionally tripping during startup while accelerating to operating speed. Using the newly installed 3500 system, it was discovered that an issue existed with the gas turbine's casing alignment. Information from the 3500 system helped the plant staff to avoid operating the unit with these issues, saving unnecessary wear and potential failure. It also helped PSE and their outage contractor to determine the best course of action for an effective repair.

Outage Activities

In the late fall of 2010, PSE undertook a major reconditioning of Unit 1 at their Frederickson Generating Station. This work included a major inspection of the gas turbine, replacement of the inlet and exhaust systems, combustion turbine generator (CTG) inspection and stator re-wedge, retaining ring replacement, and installation of a Bently Nevada (BN) 3500 monitoring system. Plans are to integrate the 3500 system with the existing GE Mark** VI control system, although this had not yet been accomplished at the time of the events described in this article.

A major inspection can be thought of as a complete overhaul of the combustion turbine. The upper half of the engine casing is removed, and all internal components are either inspected or replaced. In this case, the rotor was separated into its three components—compressor, turbine, and generator field—and then shipped offsite for shop inspection and repair. The stationary gas path and compressor components were all replaced or inspected.

As the unit was being disassembled, a Bently Nevada Project Manager arrived on site to provide mechanical designs for installing XY non-contacting proximity transducer systems at each of the 5 radial bearings. Based on the drawings he developed, the bearing liners were machined and brackets were fabricated to accept the probes.

While the unit was disassembled and parts were off site, the crew began installation of conduit and junction boxes to support the new BN 3500 system. 3300XL proximity probe pairs were installed at the three turbine bearing and two generator bearing locations. A Keyphasor* transducer was installed for phase reference, and two axially mounted proximity probes were installed to measure thrust position at the number 1 bearing location.

The CTG is also equipped with five self-generating velocity transducers; one located on each of the five bearing housings (Figure 1). These seismic (casing-mounted) transducers are original equipment used by the GE Mark VI Turbine Controls system for high vibration detection and machine protection.

Event Details

Upon the first startup of the unit following the major inspection outage (Feb 9, 2011), it alarmed on high vibration from the original CTG bearing seismic transducers. Over the course of testing during the next few days velocity values up to 0.9 in/s pk were recorded at the #2 bearing. 1.0 in/s pk was the unit trip threshold.

On February 15 and 17, 2011 a GE MDS engineer was on site to commission the 3500 system and analyze data using an ADRE* 408 DSPi data collector and ADRE Sxp software. Data was obtained during a cold start, normal base load operation at thermally stable operating conditions, and a fired shutdown.

Vibration Analysis Results

- Gas turbine vibration during cold starts was high, reaching relative displacement of nearly 9 mil pp (229 microns) on the X channel at Bearing 2 at 2850 RPM during the second mode change (Figure 2). During fired shutdown, the Bearing 2 X-channel proximity probe measured 2.6 mil pp (66 microns) at the same speed & mode change.

- Number 2 bearing in the mid turbine position appeared to be lightly loaded compared to bearings 1 and 3 (Figure 3), as indicated by the unusually high position for average shaft centerline.

- Support was sought from the GE Engineering team in the evaluation of this data. Their evaluation was that the number 2 bearing was likely positioned low as a result of the turbine casing slipping with respect to the exhaust frame. This may cause the rotor to ride on the upper half of the number 2 bearing which could also result in heavier loading to, and uneven wear of, the number 3 bearing.

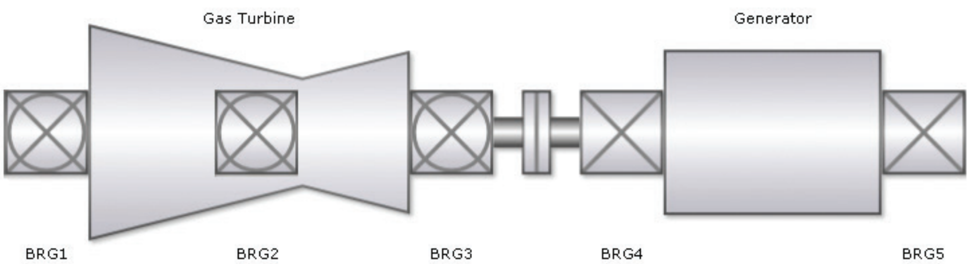


FIGURE 1: Bearing configuration for the direct-drive turbine and generator.

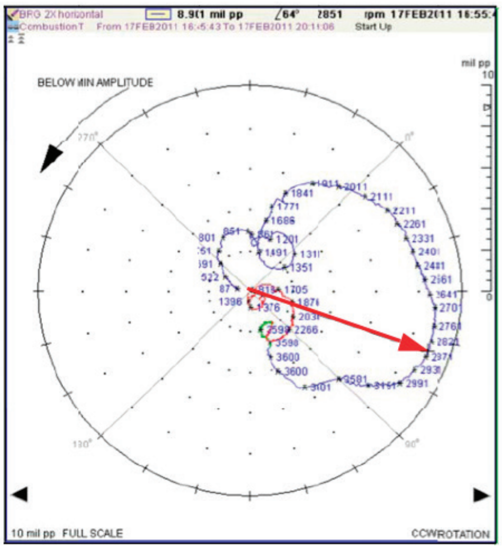


FIGURE 2: Polar plot of gas turbine Bearing 2 X-channel vibration during startup. Notes: Maximum displacement amplitude reached 8.9 mil pp at 2850 rpm during cold startup (blue trace), and 2.6 mil pp at 2850 rpm during hot shutdown (red trace). The red vector arrow was added to emphasize the maximum displacement measured during cold startup.

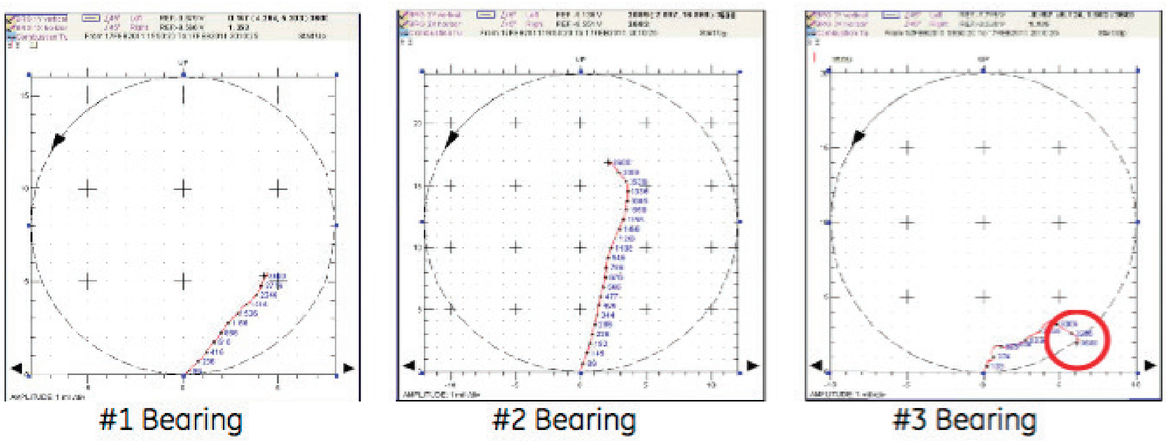
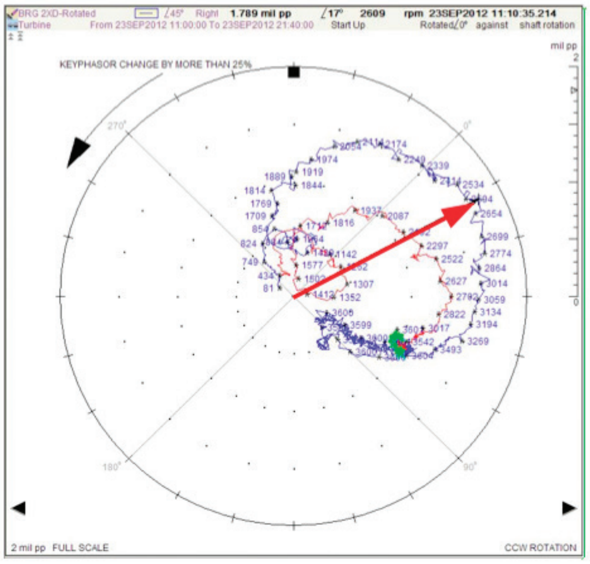


FIGURE 3: Average shaft centerline plots for gas turbine Bearings 1, 2 and 3 during a Hot Shutdown. Note: the red circle in the #3 Bearing plot points out the unusually low centerline position at this bearing during synchronous operation at 3600 rpm.



INFORMATION FROM THE 3500 SYSTEM HELPED THE PLANT STAFF TO AVOID OPERATING THE UNIT WITH THESE ISSUES, SAVING UNNECESSARY WEAR AND POTENTIAL FAILURE.

FIGURE 4: Polar plot of Bearing 2 channel X following machine realignment. The red vector arrow indicates the point of maximum displacement at peak resonant ("critical") speed. Maximum displacement was 1.8 mil pp at 2609 rpm during cold startup (blue trace) and 1.3 mil pp at 2687 Hz during hot shutdown (red trace)

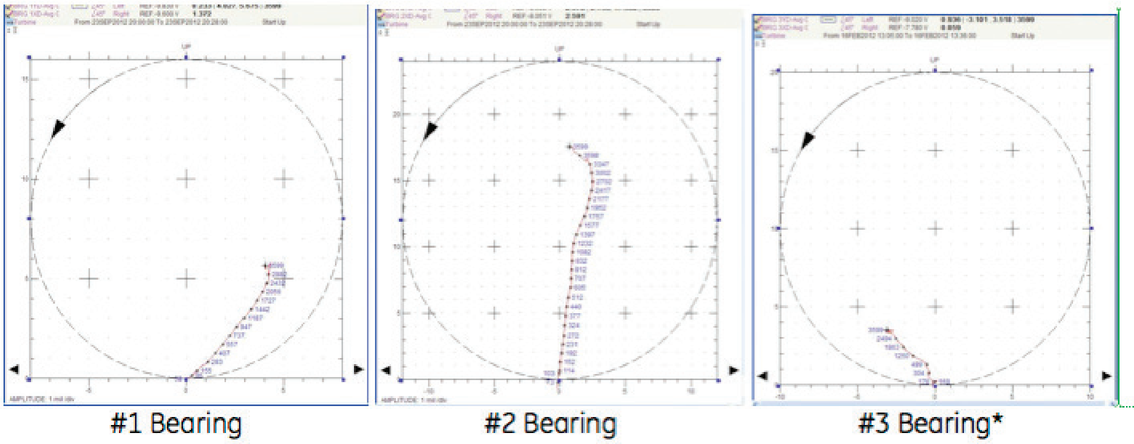


FIGURE 5: Average Shaft Centerline Plots for Bearings 1-3 during a Hot Shutdown on Sept 23, 2012. Note: Individual scales are identical to average shaft centerline plots from Figure 3. (Data from #3 bearing was not available during the Sept 23 data set. It was instead taken from the earlier data taken Feb 16, 2012.

Following completion of the testing, GE Engineering recommended that the turbine bearings be inspected at the earliest opportunity along with performing a turbine rotor alignment. PSE entered into dialog with the outage contractor to resolve the situation. The contractor verified the testing results with their own representatives and proceeded towards resolution. Their similar findings and recommendations confirmed the GE conclusions, as listed here.

- The #2 bearing is positioned incorrectly. The cold alignment setting places the elevation of this bearing low relative to the #1 and #3 bearing centerlines resulting in a temporary unloading of the #2 bearing which compromises the rotor support in the form of reduced bearing stiffness and damping. Reduced damping through the critical speeds results in an observed increase in amplitude on cold startups. Once the unit has heated up to normal thermal equilibrium, the #2 bearing is elevated and provides more support to the rotor system resulting in drastically reduced vibration at all three bearings in the shutdown phase.

- The #3 bearing appears to be heavily loaded and displays some degree of misalignment. See the Shaft Centerline Plot (rightmost plot in Figure 2) which shows the very low average shaft position at synchronous speed.

Corrective Actions

Following verification of the original GE findings, the maintenance contractor disassembled the major casings, couplings, housings, and turbine rotor allowing access to realign the turbine bearings. Work began on July 18, 2011.

It was verified from physical measurements that a misalignment between the three turbine bearings existed and determined that the best approach was to raise the #2 bearing in conjunction with lowering the #3 bearing. Eventually the best results were achieved by raising the #2 bearing .035" and lowering the #3 bearing .07", resulting in final static alignment within acceptable tolerance. After the turbine rotor was reinstalled it was necessary to make adjustments to the generator alignment as well.

Conclusions

Work was completed on August 8, 2011 and the unit went back into service on August 17. Vibration data from the seismic sensors showed the vibration levels did not exceed 0.25 in/s pk (6.4 mm/s) during a cold start.

Data was taken on February 16, 2012 and later on September 22, 2012 by PSE personnel using an ADRE 408 DSP data collector and analyzed using the ADRE Sxp software. Note the maximum observed displacement of 1.8 mil pp (45.7 microns) during a cold startup (Figure 4), compared with 8.9 mil pp (226 microns) before the realignment. The average shaft centerline plots of Figure 5 show some improvement in the shaft position between the three bearings. Although the #2 bearing was raised, it still appears to be more lightly loaded than the other two gas turbine bearings. However, the #3 bearing does reflect the decreased loading from the realignment.

The benefit of the Bently Nevada instrumentation and software was evident in identifying and resolving this issue. Without it, pinpointing the exact nature of the misalignment would have been more difficult and likely more costly to PSE. ■

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Collecting Observational Data

Portable Vibration Data Collection Programs Provide Much More Value than Just the Digitized Data they Acquire

The greatest value provided by a portable vibration data collection program derives from the simple fact that, periodically, someone whose sole concern is the functional reliability of the machine visits it specifically to evaluate its condition. This article describes the easy way to record and communicate valuable qualitative observations with your Bently Nevada* SCOUT portable vibration data collector!

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Adding Human Senses to Your Portable Vibration Data Collection Activities

Reliability professionals often tend to focus on objectively measured data and forget about the fact that the human senses and mind make up one of the best data acquisition and evaluation systems available. Four of our five senses provide a wealth of information about the operational integrity of our production systems, and if we talk about the food and beverage industry, often the fifth comes into play!

Observations worth noting when evaluating a system for indications of its reliability can be divided into two categories; those that can be quantified and those that cannot.

Quantifiable observations are typically structured for consistency and can be represented by a numeric value, which often has an associated alarm to alert the reliability analyst when something is observed that needs to be elevated as a concern, similar to alarms set on vibration data. Qualitative observations typically cannot be reduced to a finite, predictable set of numbers and although often repeatable – think reusable – require more detail than a set of numbers would allow.

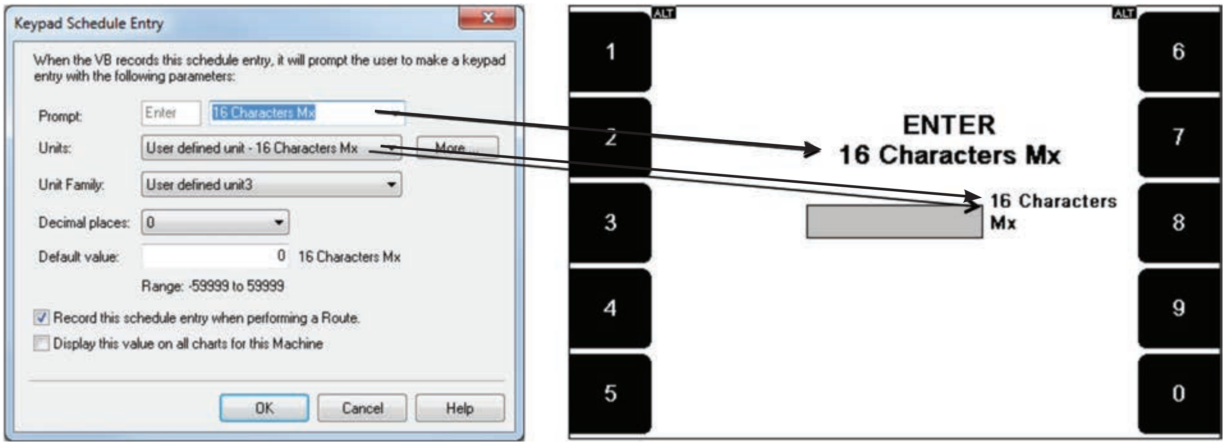

FIGURE 1: Ascent software Keypad Schedule Entry data entry dialog box (left) and SCOUT Instrument Keypad Data Entry Screen (right).

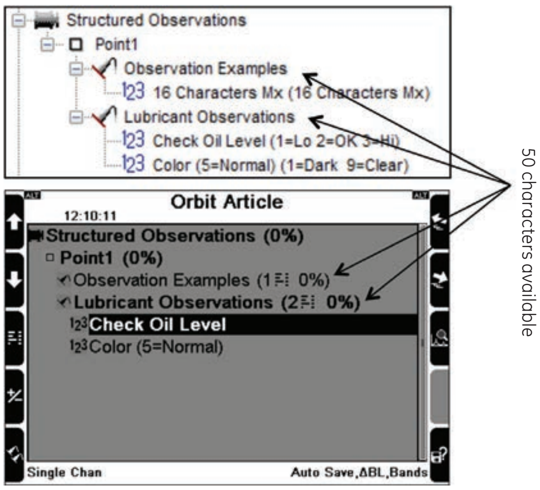

FIGURE 2: Ascent Software Hierarchy (upper) and SCOUT Instrument Hierarchy (lower)

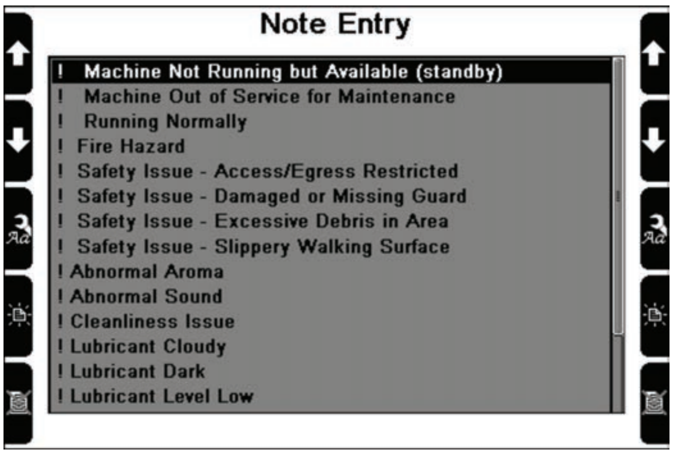

FIGURE 3: SCOUT Instrument Note Selection List

COLLECTING GOOD QUALITY VIBRATION DATA ON A MACHINE, BUT FAILING TO NOTE AND REPORT A LOW LUBRICANT LEVEL OR COOLANT LEAK TURNS THE WHOLE ACTIVITY INTO A WASTE OF TIME AND EFFORT!

Quantifiable Observations – Keypad Schedule Entry

Quantifiable observations range from truly objective values, such as gauge or meter readings, to simple yes/no questions, represented for example by 1 for yes and 0 for no, to the more complex opinion surveys we often take where we rate our thoughts on a statement from 1 to 9, where 1 means extremely dissatisfied, 5 means neutrally satisfied and 9 means extremely satisfied, with gradations in between.

Each of these three scenarios – gauge reading, yes/no and choosing from a range of values, can be handled through the use of **Keypad Schedule Entry** points and alarms, created in the Ascent database. Keypad schedule entry points have one limitation that must be considered and this is the number of characters that can be used to let you know what information needs to be entered. Both the Prompt and Units fields are currently limited to 16 characters, as shown in Figure 1.

Units text is edited by creating or changing available user-defined Units via the More button in Figure 1. Grouping related observations together, as shown in Figure 2, enables effective use with few characters. Note that 50 characters are available at the Measurement Location level in the hierarchy.

Keypad schedule entries are great for structured observations that can be summarized numerically and easily interpreted. And any combination of above and below certain value alarms can be applied to alert the analyst to conditions that require attention. But what happens when the observed condition is not easily summarized numerically or requires further explanation?

Qualitative Observations – Notes

Freeform notes can be entered by hand into the SCOUT data collector while out in the field making observations. The method uses multiple presses of the numeric keys, similar to entering a text message into a mobile telephone with a traditional numeric keypad. This provides you with great flexibility because just about any text can be entered into the instrument and associated with a machine, point, location or measurement. Perhaps more convenient, however, is the ability to simply select one or more notes that are already stored in the SCOUT instrument and apply them, as appropriate. The characters that can be entered in the freeform notes are listed here.

blank space, !, #, &, -, ., 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, :, ?, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z, a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, (,).

Note the order of the characters above as they are shown in their ASCII sort order. This will be important later in this article. Any printable character can be included in a note and displayed in the instrument when it is initially entered into the Ascent database, thus enabling the full range of printable characters to be used. The full listing of ASCII characters and their order can be found at online reference sites such as www.asciitable.com.

The Ascent software does not provide a dedicated notes management utility, but using a simple approach will enable you to create, group, order and pre-load notes in to the SCOUT instrument for easy use when collecting data in the field. All notes that are entered into the Ascent database become available in the SCOUT instrument once the folder that contains them is loaded into it. Similarly, once a note is entered manually in the instrument, it becomes available to be used again simply by selecting it from the list of notes stored within its database.

Note Organization and Consistency

Clear, consistent communication is an essential part of any route-based measurement and observation recording and reporting system. Standard, clearly understood terminology should be used by all. You can achieve this consistency by creating a machine in a folder, with no measurement points, locations or schedule entries, and use it to hold all of the standard notes that you would like to be available in the data collector, for easy access in the field.

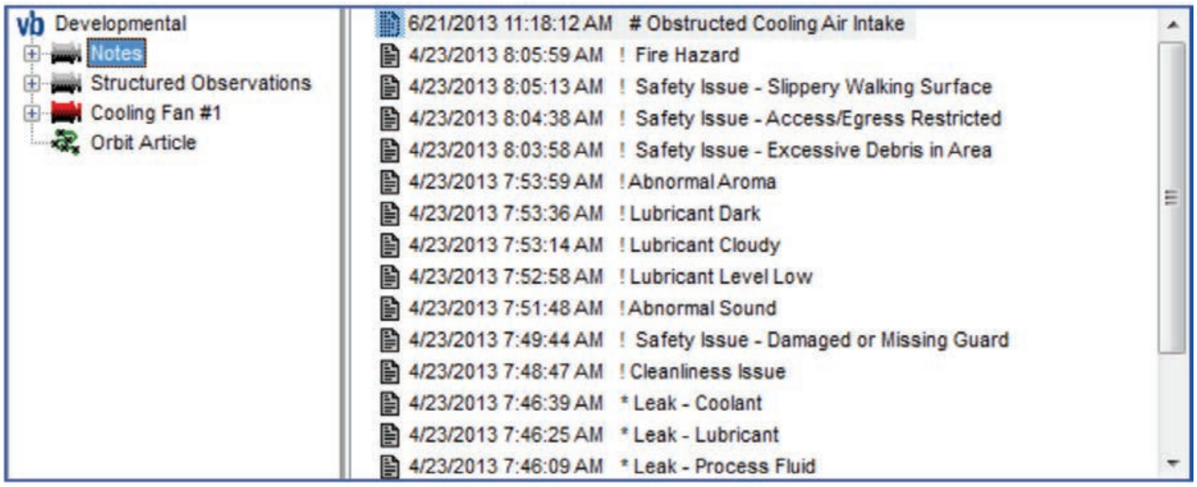

FIGURE 4: A Sample of Notes Attached to the Notes Machine in the Database

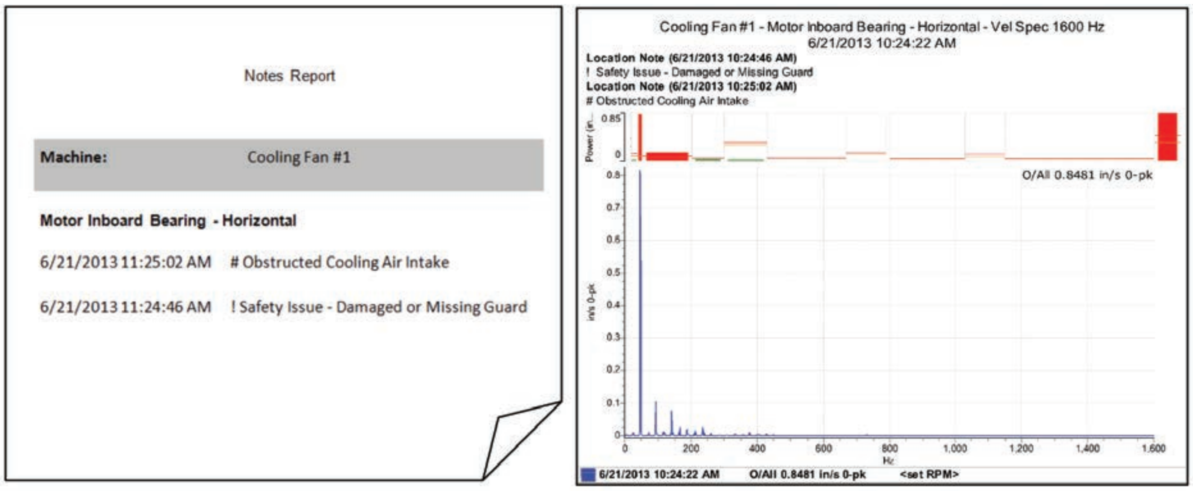

FIGURE 5: Sample Notes Report (left) and Notes Displayed on a Plot (right)

All notes, regardless of whether they were entered manually into the data collector or via the computer, are stored in the SCOUT instrument in pure ASCII character order, top to bottom. Figure 3 shows an example of pre-entered notes that were originally entered into the Ascent database in random sequence, but were grouped and ordered within the SCOUT instrument.

Figure 4 shows these notes attached to the notes machine in the Ascent database. The dates and the order that the notes were originally entered have no meaning in the context of creating the standard notes list to be used in the data collector.

The ASCII character sort order is important because it enables us to group notes together so that they appear in the instrument in a logical sequence. Most users will either want the most frequently used or most critical observation statements to be near the top of the list. The example Notes shown in Figures 3 and 4 were created and ordered using a deliberate method. All of these were entered into the Ascent database first as notes attached to the Notes machine. The exclamation point (! character) at the beginning is the first visible character in the sort order sequence. The most commonly used notes in the instrument are likely to be those that explain why data might not have been taken on a machine that is on a route and scheduled for collection. Following the ! character with three blank spaces puts these at the top of the list. Critical observations, such as safety issues that require notification, can be grouped together with the ! character followed by two blank spaces with other observations grouped together using other characters and levels of blank space indenting.

Schemes can be established where different starting characters can be used to group pre-established notes together for specific purposes, like safety issues, process issues or unusual conditions. One of the biggest benefits of using this method is that the special characters at the beginning of each note easily draw attention to them in printed or email reports, and can be used to prioritize how Planning, Operations and Maintenance personnel are expected to react to them. The convention that all observational notes assigned to a machine by the data collector operator in the field must be preceded by a special character ensures that they will be noticed when a notes report is run after uploading to the computer.

Communicating the Information Recorded in the Field

The Ascent software provides two methods for communicating the information logged in the SCOUT instrument that are shown in Figure 5. A Notes Report, with the date range set to "Last 1 Day" will show all of the observational notes that were assigned or recorded into the instrument immediately after the data was received into the Ascent database. This is where using special characters can easily draw the readers' attention to specific types of observations.

The vibration analyst can also display notes on diagnostic charts. This is very helpful in evaluating data, particularly when the person performing the evaluation is not the same person who collected the data in the field. Displaying the data collectors' notes can provide valuable insight into the data and aid in the interpretation process. Notes both in the report and on the chart are always displayed in the order of their time stamp when entered or assigned in the SCOUT instrument.

Remember that the goal of both collecting objective data and recording qualitative observations is to use consistent, logical methods and provide effective communication concerning issues that may challenge plant-wide reliability, operability and safety. ■

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