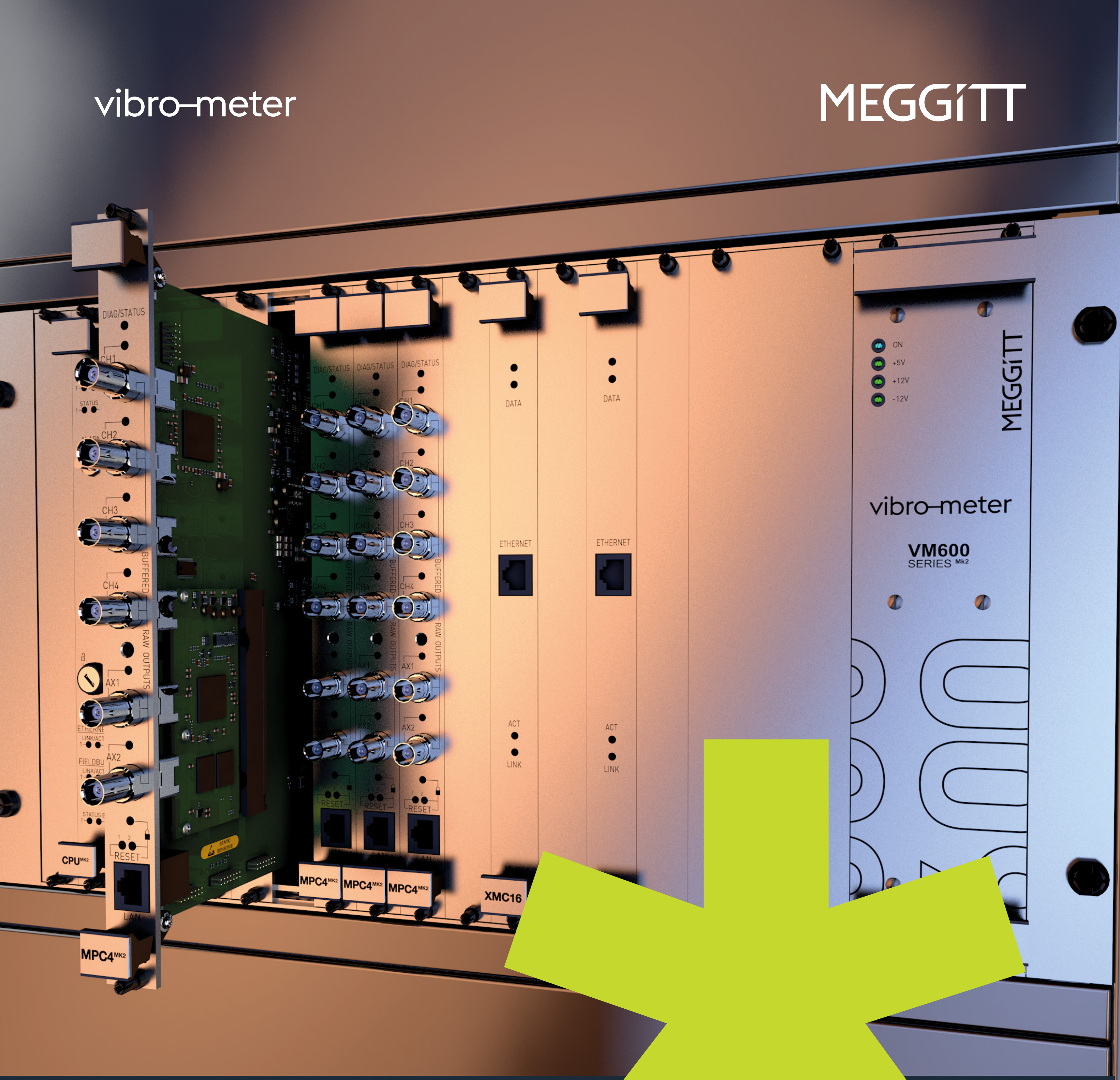

VM600^{Mk2}

A Second-Generation Architecture for a New Era

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Introduction

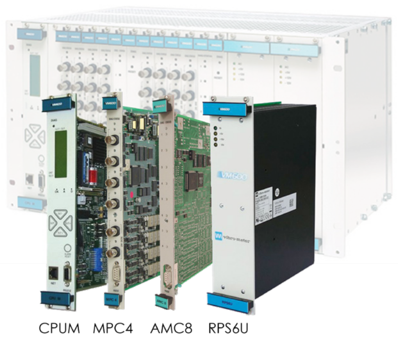
In this whitepaper, we explore the vibro-meter VM600, detailing its innovative roots in the late 1990s, examining the changing customer demands over the ensuing 20+ years, and explaining how a second-generation architecture addresses these demands without leaving any of our existing or new customers behind.

The VM600Mk2 delivers functionality that is simultaneously backwards-compatible and forward-looking, addressing today's as well as tomorrow's challenges.

VM600 First-Generation:

One module does it all

When vibro-meter introduced the VM600 architecture in 2000, it represented a dramatic leap



The VM600 was introduced in 2000 and required only 4 basic module types for comprehensive machinery protection functionality: power, temperature, vibration, and communications.

forward that sent shockwaves through the industry with numerous innovative features.
The most notable of these was the simplicity of an architecture that used a single card type – the MPC4 – to address *all* channel types except temperature. Prior architectures, and the prevailing model embraced by every other leading manufacturer of the time, was a reliance on a large diversity of module types. For example, one well-known manufacturer required more than 20 different module types in their system to achieve the full complement of all available functionality.

Compounding the issue, each monitor module type had as many as 3 different corresponding I/O module variations. The spare parts implications were significant – along with the widely varying costs of each module depending on the channel types supported. It was a complex architecture with a complex diversity of modules, a complex pricing structure, and a complex spare parts burden.

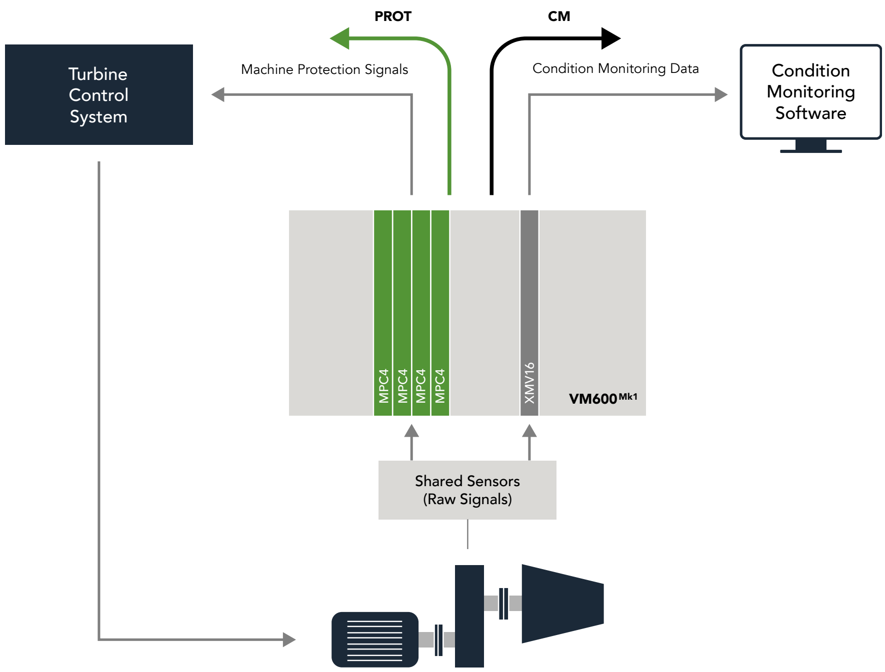
In contrast, the VM600 required only 4 basic card types (power, communications, temperature, and universally configurable vibration) for comprehensive machinery protection, each with only a single type of corresponding I/O module. In a word, the system was uniquely *simple* – without sacrificing functionality. It also introduced the concept of combining speed / phase reference measurements on a single module as auxiliary channels.

This allowed four channels of vibration and two channels of tachometer and/or phase reference to be addressed in a single rack slot via the MPC4 (Machine Protection Card – 4 channel).

In fact, it perhaps would have been better named "MPC4+2" for this very reason
.
In addition, 4 relays were included on each MPC4, turning a single module into a fully self-contained monitor with all required protective functions. Hence, the slogan "one module does it all" aptly described the workhorse of the system: the MPC4 module that provided true "universal" programmability for all required vibration channel types and sensors.

Segregated condition monitoring

Another key innovation of the first-generation architecture was entirely segregated, 16-channel condition monitoring (CM) modules that ensured machinery protective functions could never be compromised by failures in the condition monitoring hardware, yet resided in the same rack chassis and could share input signals with the MPC4 protective modules – or use entirely separate inputs if desired. Two CM module types were available – one for vibration (XMV16) and one for gas turbine combustion dynamics (XMC16). Other manufacturer's platforms of the era used highly integrated condition monitoring that co-mingled protective and CM functions, resulting in a level of integration that amplified rather than attenuated vulnerabilities.



The VM600's first-generation architecture physically separated condition monitoring from protection by using separate modules – the MPC4^{Mk1} for protection and the XMV16 for condition monitoring. A variant of the XMV16 (the XMC16) was used for combustion dynamics monitoring on low-NOx gas turbines.

Full-featured combustion dynamics monitoring

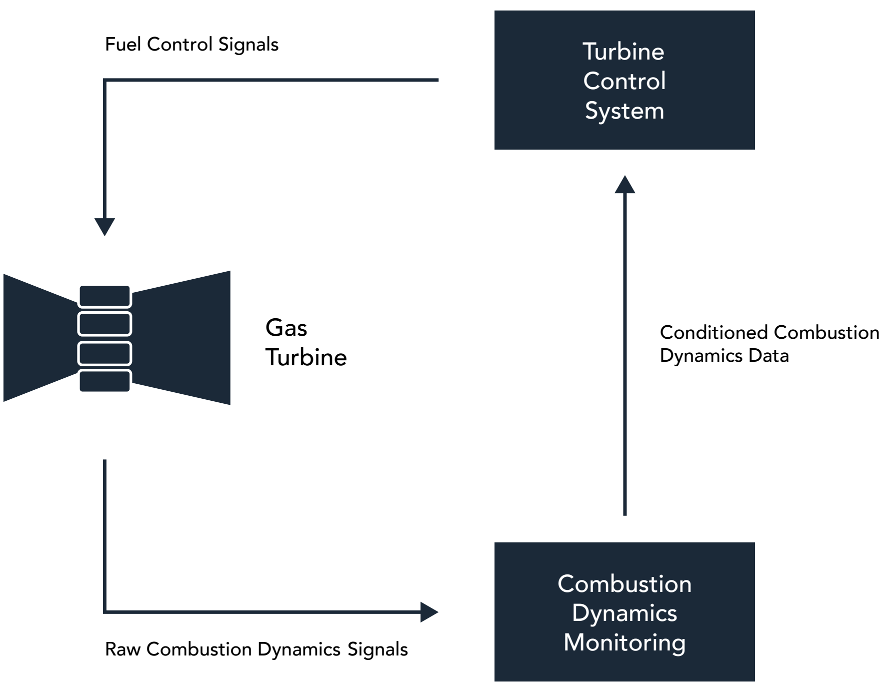
As gas turbine firing temperatures increased in the 70s, 80s, and 90s to achieve greater efficiencies, these efficiencies came at the expense of increased NOx emissions. It was not long before environmental concerns demanded these increased NOx emissions be reduced, and new combustor technology emerged as a result, referred to as Dry Low NOx (DLN) or Dry Low Emissions (DLE) designs[1].

Although these designs did indeed reduce NOx emissions, they entailed so-called "metastable" combustion conditions that could impose extremely damaging dynamic pressure pulsation forces on the combustor[2]. If not very carefully monitored and controlled, combustor life could be severely degraded.

It was out of this fundamental need that gas turbine combustor monitoring emerged.
The concept is quite simple: adjust the fuel/air mixture to be as lean as possible, but not so lean as to introduce an unstable flame and the accompanying dynamic pressure pulsations that will prematurely age (or destroy) the combustor.

Using highly specialized high-temperature pressure sensors, the pressure inside each combustor is monitored for the presence of these damaging pulsations and the fuel/air ratio is continually adjusted using a closed feedback loop between the dynamic pressure sensing system and the turbine control system where the fuel/air mixture is adjusted.
When pulsations are detected, the flame is unstable and the mixture is too lean. The ratio is then adjusted (less lean) such that the combustor is perpetually on the verge of instability, but without actually pulsating. In other words, a precisely controlled balancing act to maintain that tiny operational zone existing between stable and unstable combustion – a zone where efficiency is highest and NOx emissions lowest.
It turns out that monitoring these pressure pulsations requires sophisticated filtering and other signal processing that is not unlike the requirements of monitoring a vibration signal – particularly those from aeroderivative gas turbines where accelerometers are used and extraction of desired signal features can be very demanding.
It was not surprising, then, that gas turbine manufacturers turned to vibration monitoring suppliers to meet these needs. Vibro-meter was among the first to rise to the challenge and offer fully integrated combustion dynamics monitoring with the release of our VM600 platform and its 16-channel XMC16 module.
Indeed, the deep domain expertise of Meggitt for supplying sensors that can survive environmental extremes meant that vibro-meter could supply not only the necessary monitoring system, but the associated high-temperature dynamic pressure sensors, able to survive in one of the most extreme of all machinery environments: gas turbine combustors where conditions at the measurement locations can approach 700°C and 250 bar.

[1] Zink, John C., "Progress continues in gas turbine NOx control" Power Engineering. May 1, 1996. Retrieved September 19, 2021.
[2] Richards, G A, and Lee, G T. "Gas turbine combustion instability". US Dept of Energy. September 1, 1996. Retrieved September 19, 2021.



Combustion dynamics monitoring is part of closed-loop control to ensure that damaging pulsations in low-NOx gas turbines do not prematurely age or destroy the combustor cans. The pulsations occur because today's low-NOx technologies rely on inherently metastable combustion conditions that burn fuel in the leanest possible manner but can produce an unstable flame if not meticulously controlled.

Full API 670 compliance

Within the petrochemical sector, the importance of American Petroleum Institute standards for machinery and its associated instrumentation cannot be overstated.

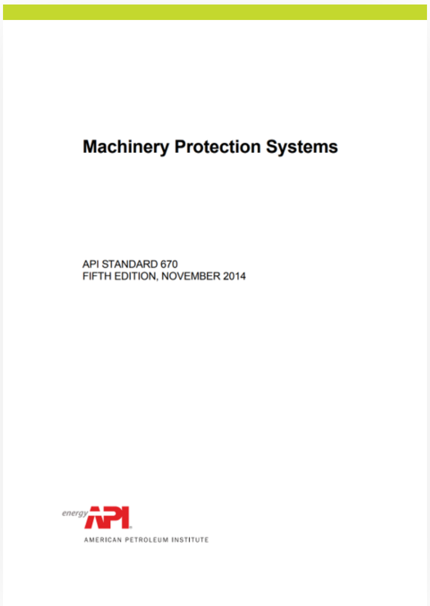
These standards are no longer considered *best* practice employed by the cutting-edge few – they are so universally accepted that they are today considered standard practice and thus widely embraced by the many. Nowhere is this more true than with API Standard 6702[3] which defines the necessary attributes of machinery protection systems.

The first edition of this standard was released in 1976 and has been so successfully embraced that it has resulted in five successive revisions to keep pace with industry's changing needs: the 6th edition of the standard is currently in preparation and is expected to be released by 2023.

Indeed, it provides such value that it has remained among the API's best-selling standards in the more than 45 years since its introduction. Not surprisingly, the VM600 was designed with full API 670 compliance in mind, allowing customers in the oil & gas industries to employ the system with the confidence that it rigorously adheres to the robust feature set and functionality that multiple generations of users and manufacturers have found important.

Indeed, the requirements of 670 are so well-recognized by practitioners in all industries that it is not uncommon to find power generation and other customers using it as the basis of their own purchasing specifications – not just those in the petroleum industries.

3. API Standard 670 "Machinery Protection Systems". American Petroleum Institute. Washington, DC. November 2014.


Machinery Protection Systems

API STANDARD 670
FIFTH EDITION, NOVEMBER 2014

energy API
AMERICAN PETROLEUM INSTITUTE

Both first- and second-generation VM600 platforms are fully compliant with the 5th edition of API 670. Additionally, we participate on the API Task Force that is currently preparing the 6th edition to ensure we remain fully compliant with and abreast of industry changes as the standard evolves.

Why a Second-Generation product?

With such a rich feature set and pedigree of innovation, it is natural to ask why a second-generation platform was even necessary.
There are multiple reasons:

Cybersecurity

When the VM600 was originally designed, the internet itself was not even a decade old. The idea that this global network infrastructure would someday become a remotely accessible means to sabotage industrial instruments and automation systems wasn't even part of anyone's thought process at the time. But the intervening 22 years have changed everything.

Today, cybersecurity is at the very top of customer concerns. What has also changed are the types of customers concerned about cybersecurity. For decades, the most innovative and demanding customers were largely in the petroleum and oil & gas sectors. They were often the ones with remote facilities – such as offshore platforms – where remote access to data was in highest demand.

For years, they had led the way in the defining the features and functions required of condition monitoring and machinery protection platforms because their processes were often worth millions of dollars per hour and machinery failures were potentially so costly. As such, they were the ones with the most sophisticated needs and the deepest pockets to address those needs.

But then, the world began to shift as the most pressing needs began to fall within the power generation sector along with corresponding expenditures to ensure cybersecurity therein. Where a cyberattack might be able to bring down a single petrochemical facility, a similar attack could potentially bring down major portions of the electrical grid in a country, affecting tens of millions of people for days.

The Northeast blackout of 2003[4], for example, left 55 million people in the US and Canada without power – some for as long as two weeks. A similar event in Europe just a few months later left 56 million people in Italy and Switzerland without power[5]. Moving to the southern hemisphere, a 1999 event in Brazil lasted more than three months and impacted 97 million people. And a 2012 blackout event in India[7] affected more than half a billion people for two days. The point here is that cyber vulnerabilities in the power generation sector are particularly serious because they may not necessarily isolate themselves to a single facility; because the generation, transmission, and distribution infrastructure is interconnected via a grid, an attack can impact huge portions of the electrical grid for days, weeks, or months at a time. This also impacts critical infrastructure such as hospitals, law enforcement, banking, water utilities, grocery stores, petrol stations, and other entities that depend on electrical power to deliver vital goods and services. The stakes are indeed exceedingly high.

Coupled with the realization that an attack on the power grid had such devastating implications, industry began to face the reality that cyberattacks were not just able to exploit conventional computer systems – they could exploit industrial control and automation platforms such as SCADA systems and PLCs. In 2007, the Aurora Generator Test[8] conducted by Idaho National Labs demonstrated that it was possible to compromise a protective system via the internet and thereby destroy a diesel generator within a mere 3 minutes. Several years later, the Stuxnet[9] worm showed the world that an industrial cyberattack was no longer just hypothetical – it had actually been accomplished. Iran's nuclear program was sabotaged by Stuxnet-infected PLCs, destroying the enrichment centrifuges they controlled by sending them into overspeed conditions.

All of this is to underscore that cybersecurity moved from not even being on customers' radar a mere 15 years prior, to being their number one concern by 2015. While the VM600 had unwittingly addressed a portion of these concerns by entirely segregating the protection functions from the condition monitoring functions, there were other aspects of the system that represented cyber vulnerabilities – vulnerabilities that would require a new generation of modules.

[4] "Technical Analysis of the August 14, 2003, Blackout: What Happened, Why, and What Did We Learn?". North American Electric Reliability Council. July 13, 2004. Retrieved September 18, 2021.
[5] "Report on the blackout in Italy on 28 September 2003" Swiss Federal Office of Energy. November 2003.
[6] "Wide Power Failure Strikes Southern Brazil". The New York Times. March 12, 1999. Retrieved September 18, 2021.
[7] "India blackouts leave 700 million without power". The Guardian. July 31, 2012. Retrieved September 18, 2021.
[8] "U.S. video shows hacker hit on power grid". USA Today. September 27, 2007. Retrieved September 18, 2021.
[9] Kushner, David. "The Real Story of Stuxnet". ieee.org. IEEE Spectrum. February 26, 2013. Retrieved September 18, 2021.

Integration

While the separation between protection and condition monitoring in the legacy VM600 architecture was desirable from the standpoint of cybersecurity, it was not optimal in other respects. In particular, because there was no communication at all between the condition monitoring and protection environments, it was cumbersome to see the status of the protection system alarms from within the condition monitoring software.
Also, the same measurements (such as overall amplitude or 1X amplitude) were generated in each path (protection and condition monitoring) but could be slightly different due to different circuitry in different cards. Work-arounds were available but the environments for viewing protection and condition monitoring statuses and information were not truly unified.

Also, the system had to be configured twice: once in the protection environment and then again in the condition monitoring environment, without the ability to reuse similar or identical configuration settings from the protection environment into the condition monitoring environment. Instead, the user had to manually replicate the settings – not just re-use the settings – such as transducer types, full-scale values, and even alarm setpoints.

Lastly, due to slight differences in signal processing between the protection hardware and condition monitoring hardware, even identical configurations could result in slight discrepancies between the timing of a protection alarm in the MPC4 card and the emulation of the same alarm in the XMV16 card. While this timing was normally not an issue, it could be more cumbersome to create accurate sequence-of-event reconstructions because a protection alarm archive had to be accessed separately from a condition monitoring alarm archive.

Clearly, in a next-generation system, it would be important to address the above issues.

Component Availability[10]

Users of machinery protection systems generally expect a lifecycle of 15-20 years for the hardware along with a generous, phased obsolescence period that gives time to both plan and then implement replacement of the aging system.

During this time, spare parts must still be available that maintain hazardous area approvals and SIL certifications. Simply substituting newer electronic components on circuit boards may seem like an easy solution, but sometimes there are no form/fit/function replacements.
And even when there are, this can often mean resubmittals to approvals / certification agencies.

Eventually, the situation can become unsustainable, even when last-time buys of components are secured in an attempt to meet future demand. All of these can represent a delicate balancing act and finally the need to introduce a new platform becomes inevitable. However, manufacturers generally view this as an opportunity to not just replace systems, but to provide additional functionality and value because new customer needs have arisen in the meantime. This has certainly been the case with the VM600 platform.

10. "Component Obsolescence Management". electronic-notes.com. Retrieved September 19, 2021.

Deliberately avoiding "Rip and Replace"

One of the challenges inherent in introducing a new platform is to avoid "rip and replace" requirements. No customer enjoys being told that they must rip out the old hardware in its entirety and install new hardware.

This can be compounded when the new system is so radically different compared to its predecessor that wiring connections cannot be reused, panel cutout and mounting dimensions must be modified, different software must be used, and even power and ventilation requirements have changed. The devil, as they say, is in the details.

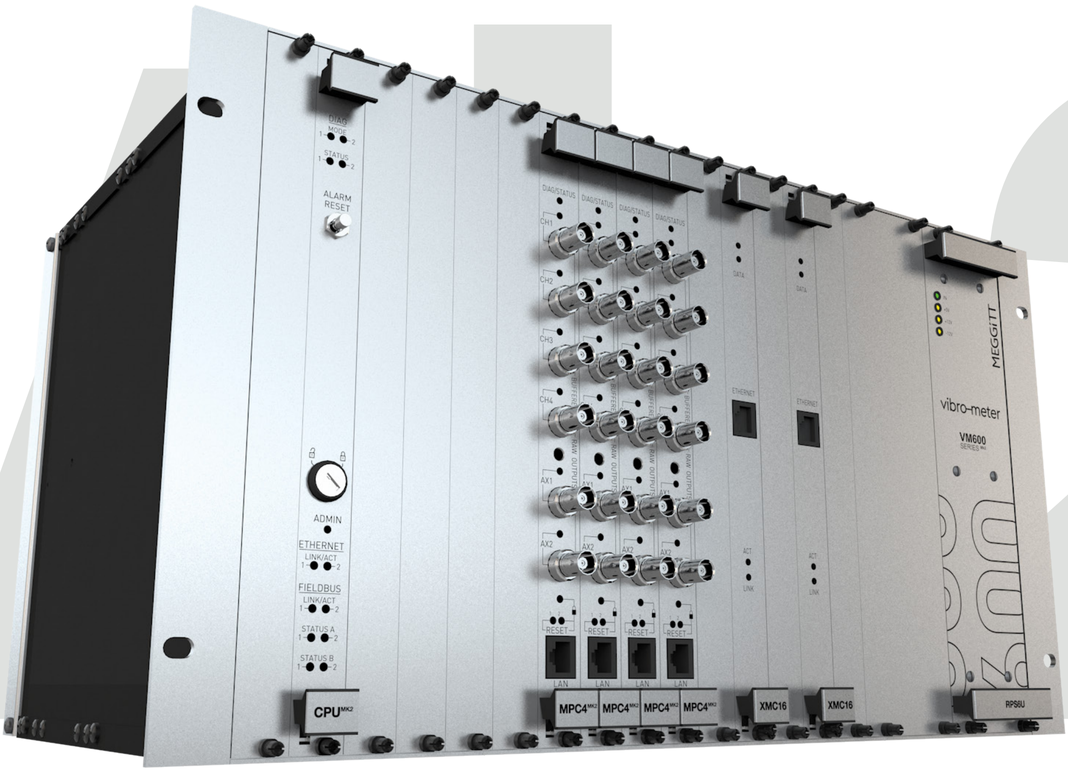
> **"More than 8,000 VM600 systems are installed worldwide and we owed it to those customers to provide them with a thoughtful path forward that allowed them to retain as much of their existing investment as possible."**

From a manufacturer's perspective, "rip and replace" can also be undesirable because it then becomes just as easy and cost-effective for customers to switch to an entirely different supplier as to remain with the incumbent. For numerous reasons, it is thus in everyone's best interests when the new platform represents backwards compatibility with the prior platform while introducing necessary improvements to solve the continually evolving list of customer needs.
As vibro-meter set out to design a second-generation version of the VM600, we purposed that we would not leave existing customers stranded or inconvenienced by "rip and replace" approaches.

but without depriving them of the same feature and function improvements available to customers installing a system for the first time. In other words, existing customers should be rewarded – not penalized – by the release of a new system.

The VM600^{Mk2}

Our second-generation VM600 platform retains all of the innovation inherent in the first-generation product while addressing evolving marketplace needs.



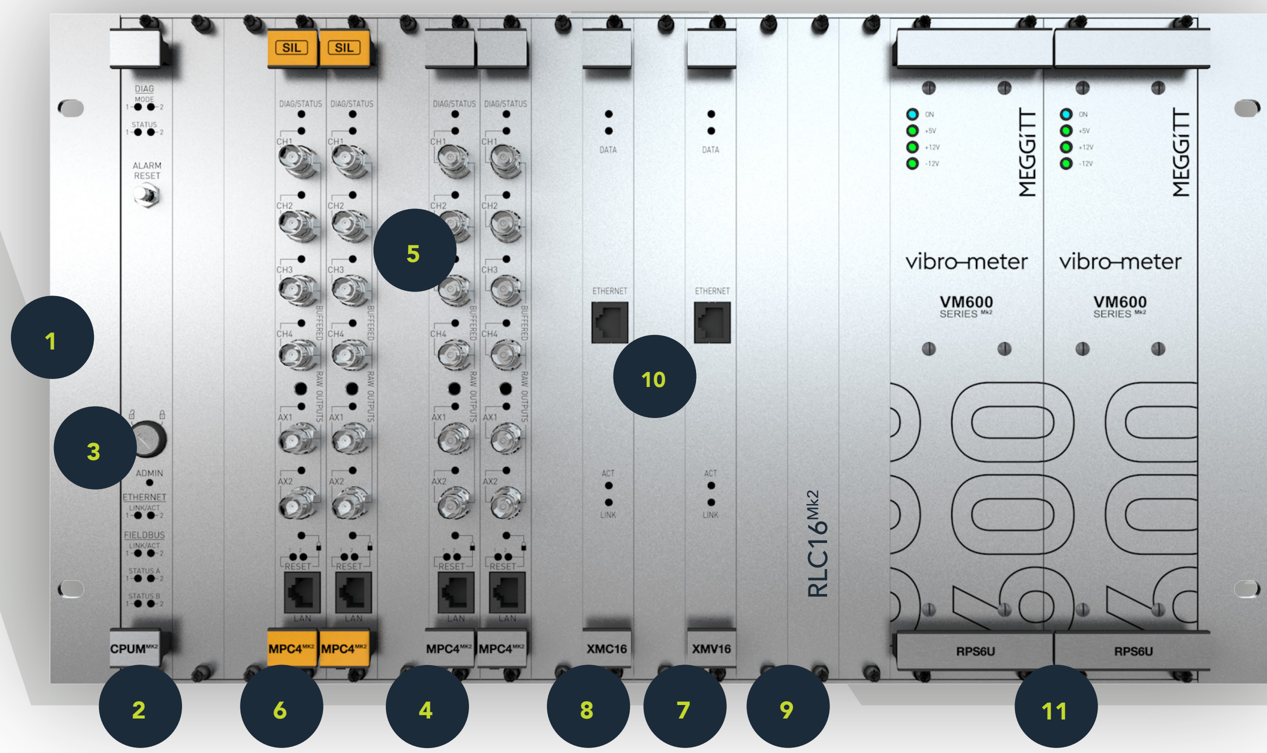
True to our promise, it does this without stranding our customers and their large installed base of more than 8,000 VM600^{Mk1} systems – systems that encompass 240,000 MPC4Mk1 protection channels and 88,000 CMC/XMV/XMC condition monitoring channels.

Because the VM600^{Mk2} uses the same backplane and power supplies as its predecessor, it is not necessary to replace a rack in order to upgrade modules. This also means that existing racks can incorporate a mix of first-generation (Mk1) and second-generation (Mk2) modules if desired, and that Mk2 modules can be used as spares for Mk1 modules[11],[12] if desired.

In addition, the XMC and XMV[12] modules have not changed and continue to provide world-class capabilities for dynamic combustion monitoring and vibration condition monitoring, respectively; we have simply upgraded the faceplates for aesthetic consistency with new modules such as the MPC4^{Mk2} and CPUM^{Mk2}.

11. Mk2 modules are configured using our VibroSight PROTECT software; Mk1 modules are configured using our MPSx software. Also, MPC4Mk2 modules can
only be paired with their associated IOC4^{Mk2} input/output modules and cannot use the existing IOC4T.

12. MPC4^{Mk2} modules retain the ability to share input signals with an associated XMV16 module, but can also provide integrated condition monitoring functionality and thus entirely eliminate the need for a separate condition monitoring module for vibration measurements.



The Second-Generation VM600 retains the same chassis and power supplies, but delivers powerful new modules with improved functionality and cybersecurity.

1 19” EIA chassis, 6U tall, 300mm deep, 21 slots (numbered 0-20).

2 CPUM^{Mk2} Communications and rack control module; supports redundant media with communications with plant control and automation platforms including PLCs, DCSs, turbine controllers, local displays, and more; supported protocols include Modbus TCP, Modbus RTU*, Profibus DP, and Profinet*. Cybersecure design to meet IEC 62443.

3 Keylock provides an extra measure of physical security in addition to password-protected access to configuration changes.

4 MPC4^{Mk2} Universal vibration monitoring module provides 4 channels of dynamic signal inputs and 2 channels of speed/phase or DC inputs; provides integrated protection and condition monitoring while delivering cybersecure performance to meet IEC 62443; up to 12 modules (72 channels) per rack.

5 The MPC4^{Mk2} is capable of specialized measurements such as generator air gap on hydroelectric units, combustion monitoring on gas turbines

6 SIL 2 version of MPC4^{Mk2} modules. Five on-board relays allow alarm and module fault (OK) status annunciation, suitable for auto-shutdown applications meeting SIL 2.

7 XMV16 module can be used for condition monitoring-only applications where protection is not required; allows 16 channels of high-performance condition monitoring in a single rack slot. Ideal for balance-of-plant assets, small hydro units where protection is not required, or for adding condition monitoring to existing third-party protection systems.

8 XMC16 module provides robust gas turbine combustion dynamics monitoring in the same chassis as vibration protection and condition monitoring.

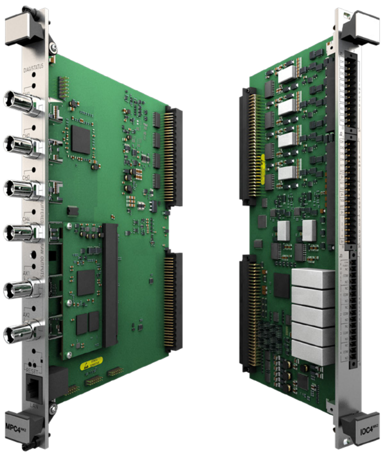
9 RLC16^{Mk2} relay expansion module provides 16 additional relays to augment the 5 relays on board each MPC4^{Mk2} module.

10 Proprietary ethernet communications provide all dynamic and other rack signals to VibroSight software for archival, analysis, and visualization.

11 Simplex or redundant power supplies deliver all required power for rack modules and connected sensors.

Key improvements in our second-generation architecture include:

Integrated condition monitoring



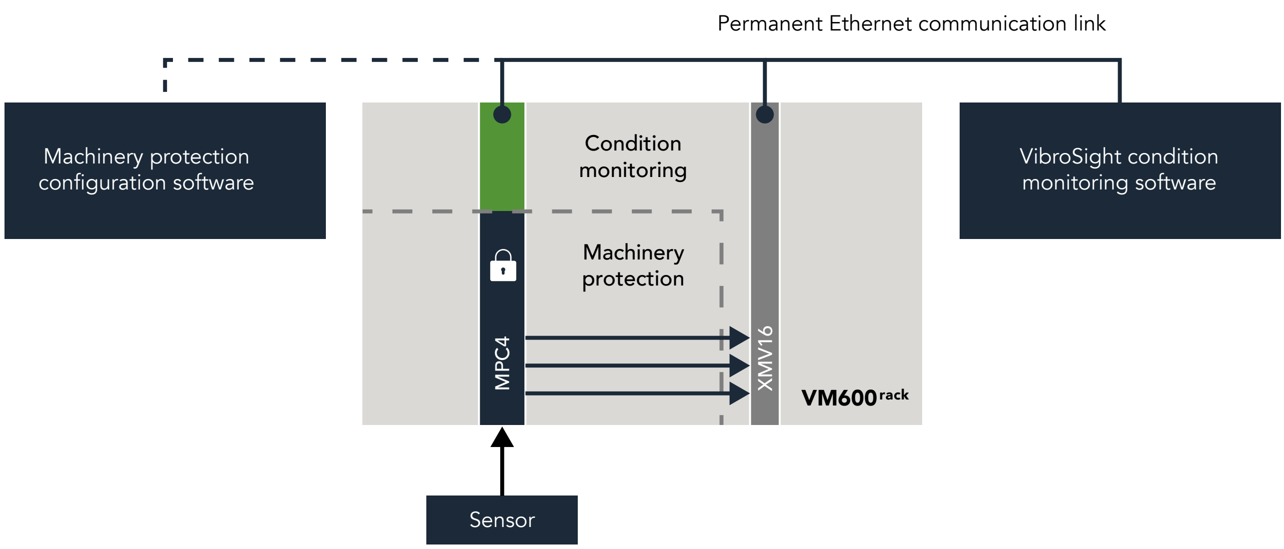
The new MPC4Mk2 module (left) and its companion I/O module (right) provide integrated protection and condition monitoring, eliminating the need for a separate XMV16 module.

It is no longer necessary to use MPC4 cards for protection and separate XMV16[13] cards for condition monitoring. The functionality of the XMV16 is now built-in to the new MPC4Mk2 cards. Not only does this eliminate the cost of unnecessarily redundant hardware, it eliminates the dissimilar-data issues inherent in two separate signal processing paths and alarm processing paths that were noted in the section on integration. Condition monitoring can now focus on supplementary signal processing and alarming to augment the basic protection system measurements – not re-creating them.

This also speeds the configuration process because the configuration elements that are common to both the protection and condition monitoring systems no longer need to be duplicated. Configuration in the condition monitoring environment thus adds to the basic protection configuration. Alarms and data are perfectly synchronized between the two environments and the condition monitoring environment can be used to visualize everything while allowing an additional layer of alarming for earlier warning on any desired parameter – whether a parameter from the underlying protection system or a parameter created only for use in the condition monitoring environment.

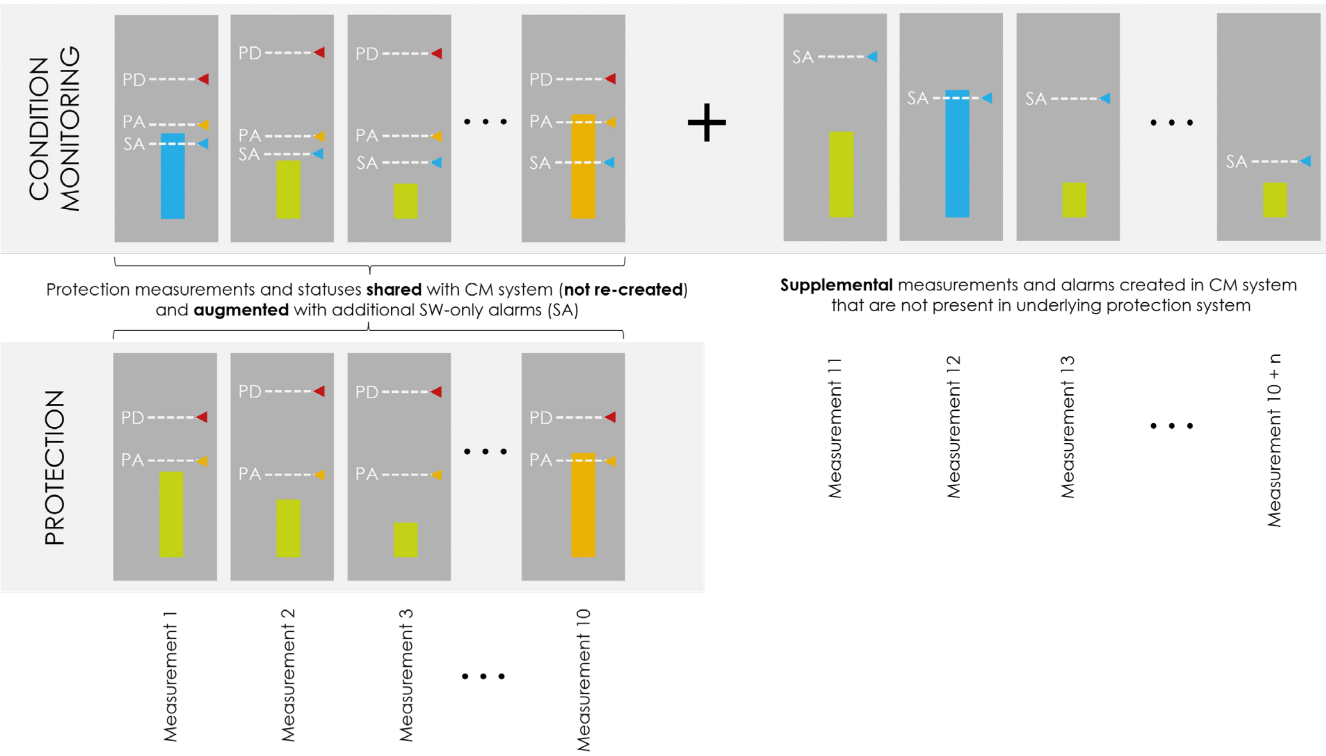
13. When a VM600 rack is used purely for condition monitoring, such as when connected to a separate machinery protection system from another supplier, the XMV16 module provides cost-effective condition monitoring functionality for 16 channels in a single rack slot. MPC4Mk2 modules and their associated machinery protection functions are not required.

And while this integration makes for a more powerful and efficient VM600 platform, we have achieved this without compromising cybersecurity, as discussed next.



The new MPC4Mk2 module provides integrated condition monitoring functionality identical to that of a separate XMV16 module, but in a manner that completely segregates the protective functions (black) from the condition monitoring functions (gray). Like its predecessor, the same sensors can be shared between protective and condition monitoring functions via the rack's backplane.

"Alarms and data are perfectly synchronized between the two environments and the condition monitoring environment can be used to visualize everything while allowing an additional layer of alarming."



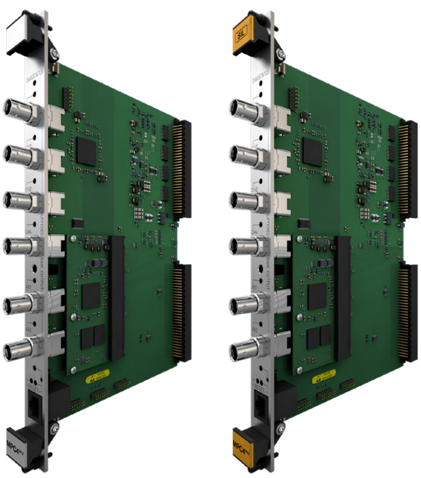
The new MPC4Mk2 cards allow the measurements and statuses to be shared with VibroSight condition monitoring software rather than requiring that they be re-created therein. This eliminates the problem of measurements and statuses that do not exactly agree between the two environments. It also allows the user to augment the underlying protection system data with supplemental measurements and alarms. In this diagram, the capabilities of a single channel in the MPC4Mk2 are depicted.
The protective alert (PA) and protective danger (PD) alarms for each measurement are shown in orange and red, respectively. The MPC4Mk2 is capable of generating 10 measurements and associated alarms from each of its four dynamic channels.

The VibroSight condition monitoring system can then augment these 10 measurements with n additional measurements as shown by 11 through 10+n in the diagram. In addition, software-only alarms (SA) can be implemented for all measurements and allow earlier warning on any desired parameter than is available from the protection hardware alone. In the diagram, a software alarm is present on Measurement 1 even though no hardware alarms are present.
On Measurement 10, a hardware alarm is present (Alert) and is identically annunciated in both the protection and condition monitoring environments.
Measurement 12 is supplemental and does not appear in the underlying protection system at all.

Not only is the measurement available in the software, it has also exceeded the software alarm threshold and thus shows as being in an alarm state. The other supplemental measurements are all green, indicating that they are below their respective alarm thresholds.

SIL 2 by design

A series of high-profile accidents in the process industries began with a toxic gas leak in 1984 at a Union Carbide pesticide plant in Bhopal, India, tragically resulting in more than 3,800 deaths and 558,000 injuries[14]. Additional similar incidents of the era could also be cited, but for purposes of this discussion, sufficient awareness was raised by the Bhopal disaster alone to result in a development of industry standards and practices regarding the use of instrumentation to improve process safety. ISA S84.01[15] was the first such standard to introduce the topic of functional safety and safety integrity levels (SILs)[16] for electric,



The first-generation VM600 platform was available with both standard and SIL 2 versions of protective modules as shown above. VM600Mk2 will likewise be available with SIL 2 versions of protective modules (MPC4Mk2 and RLC16Mk2) later in 2022.

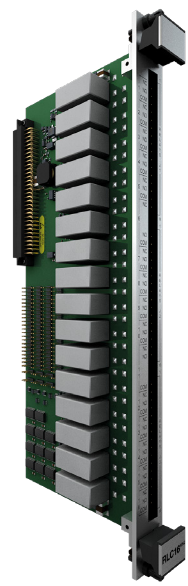
electronic, and programmable electronic safety-related systems. ISA S84.01 later became the basis for IEC 61508[17] and IEC 61511[18], two widely-employed global standards dealing with functional safety systems and instrumentation. For many customers, SIL 1 (risk reduction by a factor of 10^1) or SIL 2 (risk reduction by a factor of 10^2) are suitable to address the reduction in likelihood of a so-called "missed trip" for machinery measurements that are used as part of a safety-critical loop. A thrust bearing failure can be particularly catastrophic because it often destroys seals that can allow entrained toxic gases in compressors and pumps to escape. However, excessive radial vibration can also open seal clearances, resulting in toxic releases. For this reason, requirements for SIL 1 and sometimes even SIL 2 on axial position and radial vibration are appearing with increasing frequency. In contrast, SIL 3 (risk reduction by a factor of 10^3) is normally required only for machinery overspeed measurements.

Today, any company that wants to be taken seriously as a world-class supplier of machinery protection systems must be able to provide SIL-certified instrumentation. Our first-generation VM600 platform achieved SIL 2 certification after many years of proven-in-use (PiU) data had been acquired. This was because it had not been deliberately designed from the outset as a Safety Instrumented System (SIS). To ensure customers do not have to wait years for similar certifications on second-generation modules such as the RLC16Mk2 and MPC4Mk2, we have designed them from the start for SIL 2 certifications rather than needing to rely on collection of PiU data. SIL 2 versions of these modules will thus be available later in 2022, following initial launch of the VM600Mk2 platform in the fourth quarter of 2021.

Because SIL certifications extend down to a module's firmware and do not concern themselves merely with hardware circuitry, special SIL-rated versions of the modules lock down certain aspects such as firmware upgrades and configurable options that are not restricted in standard (non-SIL) modules. The use of specially designated SIL modules also has the benefit of clearly indicating which modules and associated channels are SIL-rated and thus form part of a safety instrumented system (SIS) and which channels do not. Modules that are not part of the protective functions – such as the XMC16 and XMV16 – do not require SIL certification.

Improved relay capabilities

In the VM600Mk2, we have improved our relays both physically and functionally. Relays in the RLC16Mk2 and MPC4Mk2 modules are now epoxy-sealed for improved environmental protection. Each MPC4Mk2 module now includes 5 relays, instead of just 4, allocating the new fifth relay



The relays on the RLC16Mk2 module (shown) and the MPC4Mk2 module (not shown) are now epoxy-sealed as well as being significantly easier to configure and wire.

for module fault annunciation (module OK) without detracting from the capacity to annunciate four additional alert or danger conditions via the other four relays. Wiring contacts for both Normally Open (NO) and Normally Closed (NC) positions are now available from each SPDT relay. In addition, normally energized[19] and normally de-energized operation of relays can now be configured from software instead of via hardware jumpers.

19. Normally energized relays are typically associated with so-called "fail safe" installations where a fault or a loss of power will cause relays to change state and thus initiate an alarm or shutdown. Normally de-energized relays do not change state upon loss of power and thus a machine can continue to operate unprotected. Such a condition is

not desirable in many situations and is strictly disallowed in a safety instrumented system (SIS).

Improved Cybersecurity

Section 4.8 of API Standard 670 deals with segregation of the machinery protection system (MPS) from other systems. While copyright restrictions preclude us from reproducing that section in its entirety, its requirements are generically applicable as "good engineering practice" for all customers, regardless of what industry they may be in.
The note following paragraph 4.8.1 is especially pertinent:

"The intent of this subsection is to prevent the MPS hardware from being combined with hardware from other control and automation systems, thereby eliminating common-cause failure modes and protecting the machine in the event of failure of its associated machinery control system or failure of the process control system. It is not intended to prohibit the inclusion of condition monitoring functionality within the MPS, provided failure of those functions does not impact the protective functions."

Our new MPC4^{Mk2} card has been designed specifically to address this important concern. Not only is an entirely different software environment used for making changes to the protective functions than to condition monitoring functions, a failure occurring only in the condition monitoring portions of the MPC4^{Mk2} cannot impact the protective functions.

This design allows the protective system to share its measurements and alarm statuses with the condition monitoring environment, but without introducing vulnerabilities.

In addition, physical security to prevent unauthorized configuration changes to the protection system is now provided in the rack. Although configuration changes to protection settings either remotely or locally are allowed, a recessed, physical pushbutton on each MPC4^{Mk2} module is used to enable such configuration changes by locking or unlocking each module. This ensures that the rack's modules must deliberately be placed in a configurable state by someone with physical access to the rack.

Changes to the CPUM^{Mk2} module are also protected via a keylock switch on the front of the module,

A keylock switch on the front of the VM600's new CPUM^{Mk2} module precludes any configuration changes to the protection system unless the switch is in the unlocked position; password-controlled access to configuration provides an additional layer of security as well.

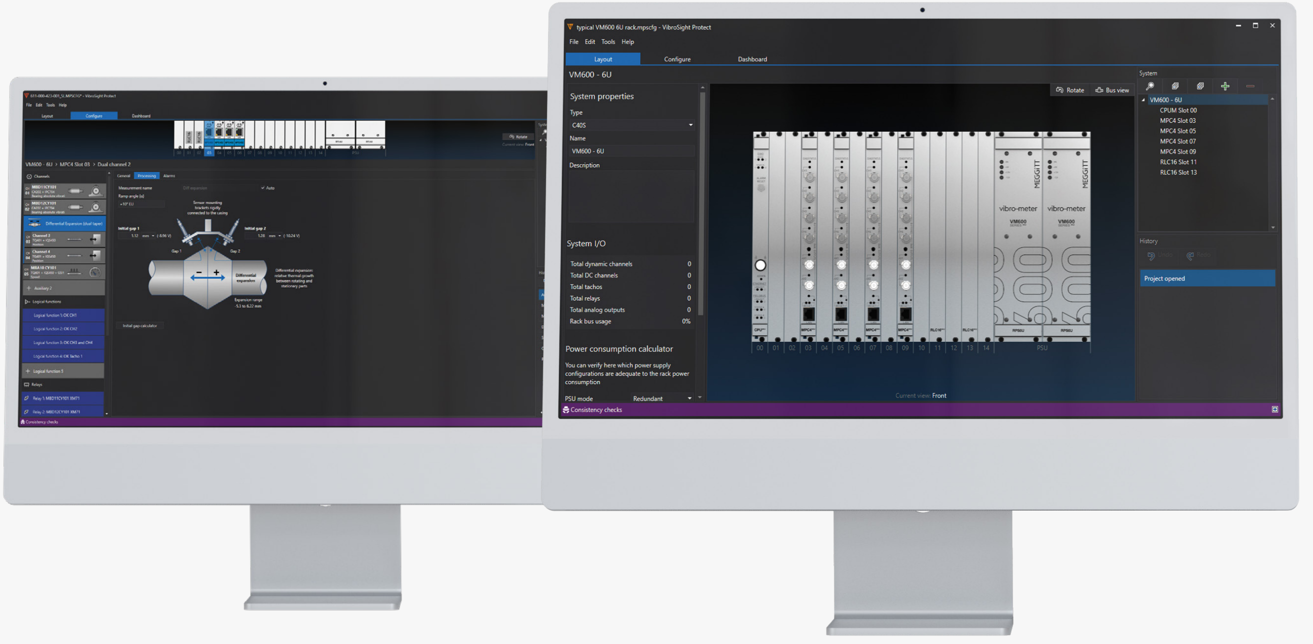
ensuring that its configuration changes can only be made when this switch is in the "unlocked" position.

In addition, password-controlled access provides a second layer of security, ensuring that both the password and access to the physical lock mechanisms are required before configuration changes can be made.

However, while these security measures are in place for changes to the protection system, the user always maintains the ability to make condition monitoring configuration changes because the design of the system does not allow condition monitoring configuration to affect protection configuration.

Lastly, the system is undergoing cybersecurity certifications as discussed in IEC 62443, concurrent with the SIL certifications discussed next.

"The result is cybersecure, more cost-effective, and with improved diagnostic capabilities that no longer reflect discrepancies between what should be identical alarms and data in the two systems."



The VM600's all-new configuration environment is integrated in our VibroSight suite of software. It is called VibroSight Protect and relies heavily on graphical – rather than text-based – input for most configuration settings. Drag-and-drop, copy-and-paste, and other time-saving capabilities are now available that eliminate tedious configuration tasks and reduce the time required to configure a rack by 50% or more.

Improved configuration software

Our first-generation modules were configured using MPSx software. With the release of our second-generation VM600^{Mk2} platform, we have created an entirely new configuration environment that cuts configuration time by 50% or more by using a highly intuitive, graphical approach. Rack sizes and types are selected from a drop-down list, modules are populated in slots, and channels are configured graphically. Where possible, images rather than just words are used. In addition, entire channels and other settings can be copied and pasted rather than tedious retyping of repetitive data for channels that are fully or nearly identical except for perhaps tag IDs or alarm levels.

Configuration in the VM600^{Mk2} is available for a very broad range of channel types and sensors in both single-channel and dual-channel pairings as conveyed in the tabular arrangements on the following page.

"This makes the system suitable for power generation applications including fossil-fueled, nuclear, and hydro plants. It is also broadly applicable to the oil & gas sector"

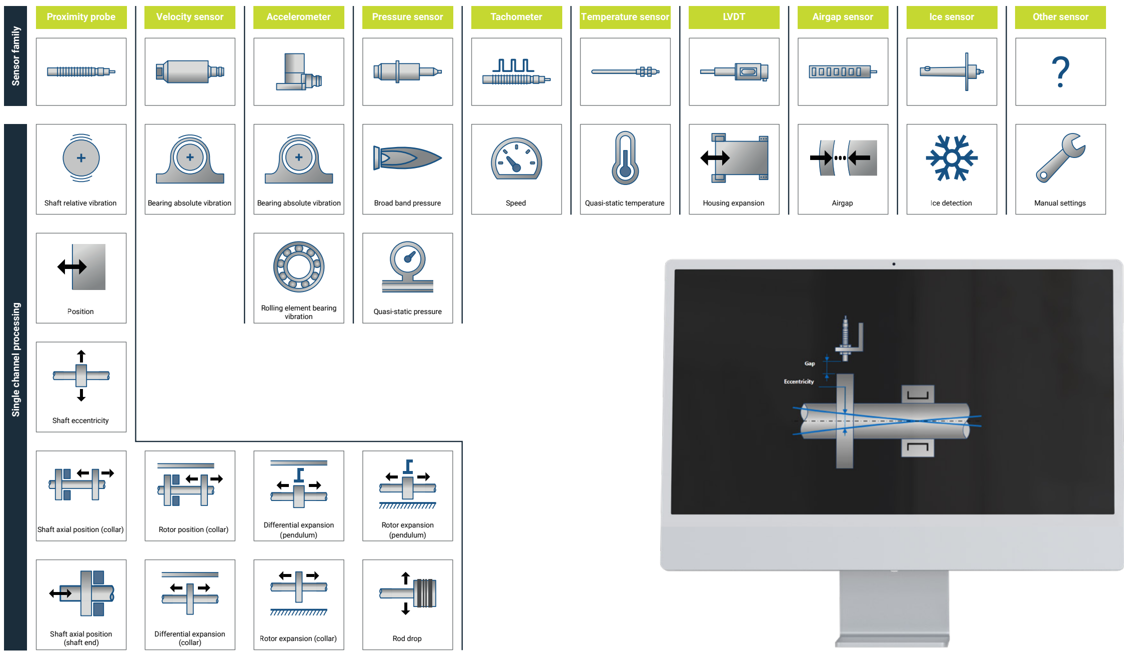
Where motors, pumps, steam and gas turbines, fans, blowers, engines, and compressors (rotating and reciprocating) are used, along with any other industries using these types of machines.

As has been discussed, cybersecurity (IEC 62443) and functional safety (IEC 61508) certifications are underway. In addition, the hardware is in the process of obtaining hazardous area approvals allowing installation in Class 2 / Div 2 environments.

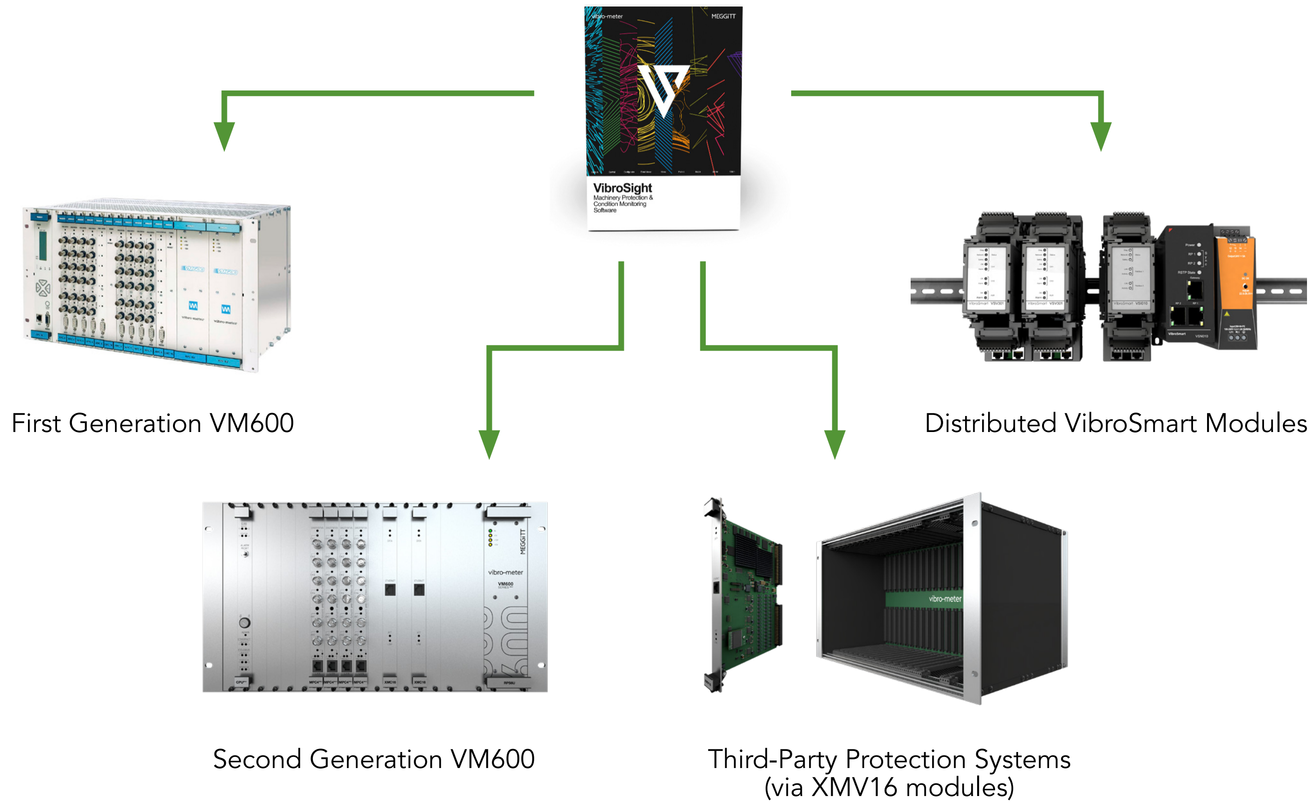
When appropriate safety barriers are used, sensors can be installed in Class 0/1 and Div 1 environments, connected to a VM600 rack located in a safe or Div 2 / Zone 2 area.

Single channel processing functions

VibroSight PROTECT provides a highly intuitive, graphical configuration environment for the VM600^{Mk2} and offers a comprehensive selection of both single- and dual-channel measurements for virtually any application. Capabilities for user-defined transducers and channels types expand the palette of available measurements even further



Dual channel processing functions



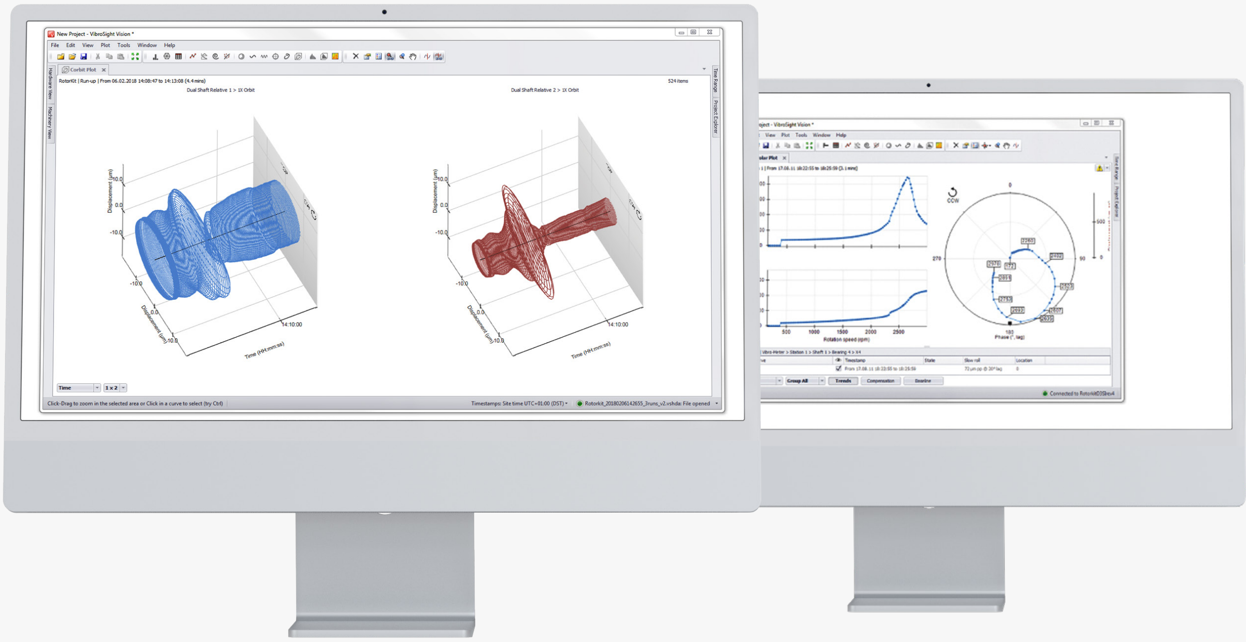
VibroSight integrates various hardware platforms – including third-party platforms – into a unified environment for monitoring and managing machinery condition.

Unified configuration and condition monitoring environment

Because VibroSight is a true suite of software applications, it creates a unified environment for protection system configuration, condition monitoring system configuration, machine mimic diagrams, data archival, visualization, analysis, third-party interfaces, and other important functionality. And because the VM600 platform unifies both vibration data and combustion dynamics data, a unified diagnostics environment exists for all machine types – including gas turbines utilizing DLN/DLE technologies. In contrast, our first-generation VM600 platform entailed a more fragmented software solution that was not entirely within the VibroSight suite.

Of obvious importance to users of a machinery protection system is the ability to also provide full-featured condition monitoring capabilities for all their monitored machinery. VibroSight software acts as a unifying “umbrella” to combine first-generation VM600 racks, second-generation VM600 racks, and even third-party protection systems when using the VM600’s XMV16 modules as hardware interfaces between the underlying protection system and VibroSight.

VibroSight also supports vibro-meter’s VibroSmart hardware when distributed vibration and combustion dynamics monitoring is desired instead of the centralized architecture of the VM600.



VibroSight provides the plot types – such as the Bode and Polar formats shown here – that are familiar to users of critical rotating machinery. However, it also provides dozens of other plot types and visualization capabilities that make it suitable for all classes of machinery.

Full-Featured Condition Monitoring

In addition to unifying the various hardware platforms used to monitor machinery, VibroSight provides full-featured diagnostic capabilities that machinery users rely upon to assess mechanical health.

This allows a comprehensive solution rather than one targeted to only one particular type of machine or industry. Available plot types and analysis capabilities in VibroSight include:

- Polar
- Bode
- Spectrum (half and full)
- Cascaded Spectrum (half and full)
- Waterfall Spectrum (half and full)
- Trend
- Bar
- Tabular
- Orbit
- Timebase (Waveform)
- Corbit (cascaded orbit)
- Air Gap
- Magnetic Flux
- Acceleration Enveloping/ Demodulation
- Calculated variables (virtual variables based on combinatio of and mathematical operations on measured variables)
- Software alarming
- Data import/export to third-party applications via Modbus TCP, Modbus RTU, Profibus DP, OPC Classic, OPC UA, and CSV

Simplicity

The VM600Mk2 not only retains the simplicity of the first-generation platform, but extends it by eliminating the need for separate XMV16 modules when combined protection and condition monitoring functionality is required. We pioneered the concept of a truly "universal" vibration monitor with the original MPC4; with the MPC4Mk2 this concept has been extended to a single module for not only all channel types and sensor types, but both protection and condition monitoring. Because the MPC4Mk2 contains five relays, most users will not need to employ a separate relay module (RLC16Mk2) to have an adequate number of relays for the application.

This results in an exceedingly simple system consisting of only three module types[20]:

When combustion dynamics monitoring is required, addition of a single XMC16 module is usually sufficient and accommodates 16 channels. If redundancy is desired, multiple XMC16 modules can be installed. When temperature measurements are required, users can employ a 4-20 mA temperature transmitter and utilize one of the MPC4's two auxiliary channels. Alternatively, they can use the AMC8 monitor module[21] from the first-generation platform or wait until the AMC8Mk2 is released in the 2022-2023 timeframe.

[20] Each of these modules also has a corresponding I/O module that inserts into the rear of the VM600 chassis.
[21] The AMC8 (Analog Monitoring Card) is an 8-channel module that occupies a single slot in the VM600 chassis. It can accept RTDs, thermocouples, and so-called "DC" inputs such as 4-20mA signals from process transmitters.

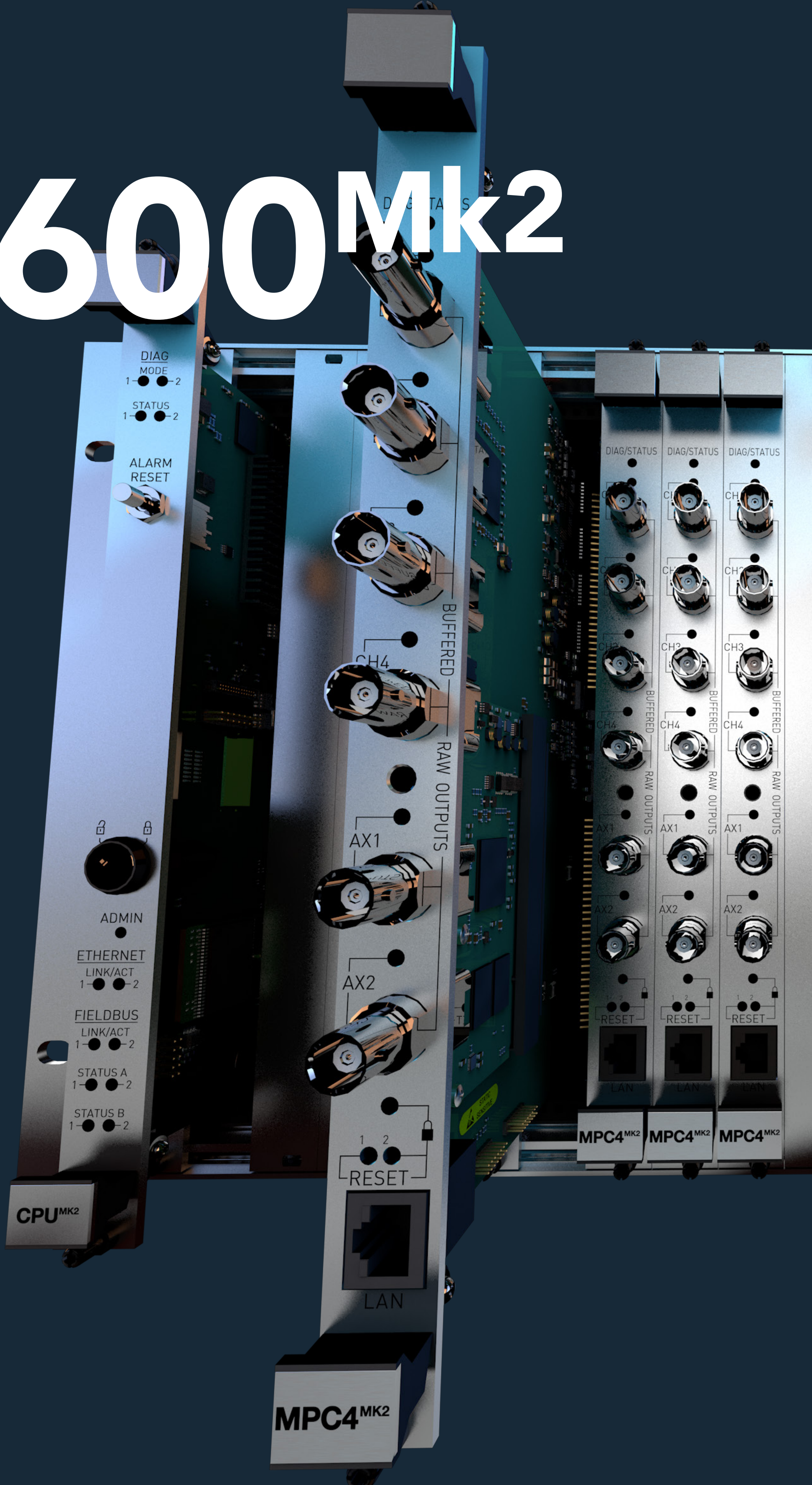
Module Type	Model	Allowable Slots	Rack slots consumed
Power	RPS6U	16-21	3
Universal Vibration	MPC4Mk2	3-14	1
Communications and Control	CPUMMk2	0, 1, or 2	1

Summary

The VM600^{Mk2} builds on the success of the first-generation platform by retaining the same chassis, power supplies, and XMV16/XMC16 modules for backwards compatibility while introducing new versions of the monitoring (MPC4^{Mk2}), relay expansion (RLC16^{Mk2}), and communications (CPUM^{Mk2}) modules[20] that offer increased capabilities and processing power, easier configuration, enhanced cybersecurity, and global approvals/certifications needed by customers globally including hazardous area approvals, SIL 2 ratings, and IEC 62443 certification. A combination of first- and second-generation modules can be mixed in the same rack, allowing second-generation modules to be used as spares for first-generation modules[22]. The proven performance of the first-generation VM600 platform has resulted in more than 8,000 systems supplied worldwide, representing 240,000 protection channels and 88,000 condition monitoring channels (including combustion dynamics monitoring). With the release of the VM600^{Mk2}, customers are assured that they can continue to use the platform well into the next two decades and beyond with the sophisticated signal processing, robust machinery protection, and comprehensive condition monitoring capabilities their operations require.

20. Each of these modules also has a corresponding I/O module that inserts into the rear of the VM600 chassis.
22. First-generation modules are configured with MPSx software; second-generation modules are configured with VibroSight Protect software and are not compatible with first-generation I/O modules; affected first-generation modules must be replaced as a pair consisting of a second-generation front-panel monitor module and its companion second-generation rear-panel I/O module.

VM600Mk2


DIAG
MODE
STATUS
ALARM
RESET
ADMIN
ETHERNET
LINK/ACT
FIELDBUS
LINK/ACT
STATUS A
STATUS B
CPUMK2
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RAW OUTPUTS
AX1
AX2
RESET
LAN
MPC4MK2
DIAG/STATUS
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MPC4MK2

Centralized protection & monitoring system

MEGGITT

About us
Meggitt pioneered high performance sensing and condition monitoring solutions for extreme environments. After working with the world's turbine manufacturers for more than 60 years, Meggitt through vibro-meter portfolio remains master of all aspects of the condition monitoring and machinery protection disciplines. From high performance sensing, data acquisition and management to the high speed digital networking and the signal processing algorithms that can deliver diagnostics for prescriptive maintenance solutions.

Meggitt PLC
Headquartered in the United Kingdom, Meggitt PLC is an international group operating in North and South America, Europe and Asia. Known for its specialised extreme environment engineering, Meggitt is a world leader in aerospace, energy and defence markets. An 11,000-strong workforce serves customers from around 40 manufacturing facilities and regional offices worldwide.

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