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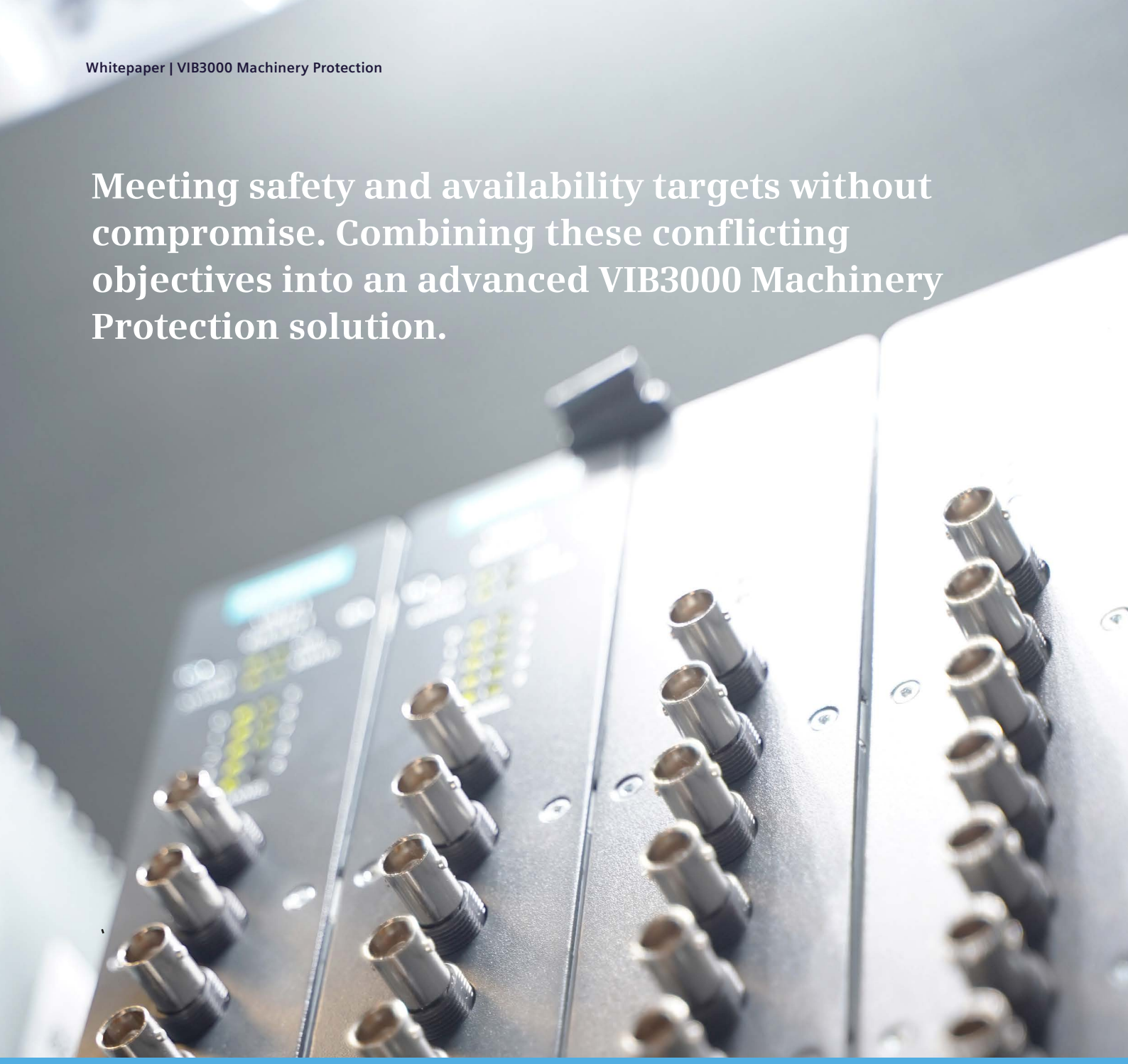
VIB3000 Machinery Protection

Whitepaper

Meeting safety and availability targets without compromise. Combining these conflicting objectives into an advanced VIB3000 Machinery Protection solution.



A vibration-based VIB3000 Machinery Protection system is expected not only to protect the operating personnel and the plant from the machine, but also to protect the machine itself from damage. The avoidance of adverse effects on availability due to spurious tripping is a further requirement.

Up to now, it has only been possible to combine these two requirements to a limited extent. When safety is paramount, a machine is always shut down prophylactically when information about the machine condition is incomplete, e.g. due to a fault in the monitoring system. For this reason, it has been necessary to accept certain compromises in availability in order to achieve greater safety for the personnel, the plant and the machine.

VIB3000 Machinery Protection solution has managed to meet all three requirements simultaneously.

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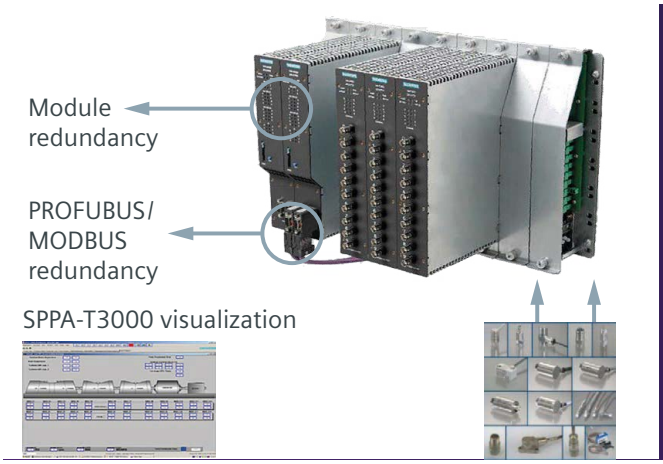
1. Standard Characterization

VIB3000 Machinery Protection is a fully redundant and scalable solution for the monitoring of vibration, expansion, position and various other operating parameters and is thus designed to provide extremely high fault tolerance. The integration into the I&C system is implemented via the PROFIBUS DP or the MODBUS interface, thus ensuring complete operability straight from the I&C. The data collected from field devices, such as sensors, supplied to the I&C constitute the basis for further decisions relating to operation of the monitored machine. Fig. 1 shows the structure, design and features of the rack. These features are described in detail below.

The analog values supplied by the sensors are digitized immediately during measured value acquisition, offering real-time edge analytics. Both the dynamic (AC) and the static (DC) components of the original signal are available in digital form for further processing. Fig. 2 shows an example of the signal flow. Both signal components are further processed in a digital signal processor (DSP). In addition to signal adaptation and digital filtering, characteristic values are produced which can then be checked for compliance with specified limit values. Fully digital data processing means that the regular alignment procedures required in analog systems due to aging are no longer necessary.

Machinery monitoring



Reliable transmission of results
- Redundant PROFIBUS
- Safety relay
- Analog signals

Reliable processing of signal data
- Derivation of overall readings
- Limit comparison
- Logic gating
- Self-monitoring

Reliable sensing of signal data
- Vibration
- Pressure fluctuations
- Expansion and positions
- Speed/direction of rotation
- Differential pressure
- Analog signals

Fig. 1 Design and features of the VIB3000 Machinery Protection system

1.1 State-of-the-art instrumentation

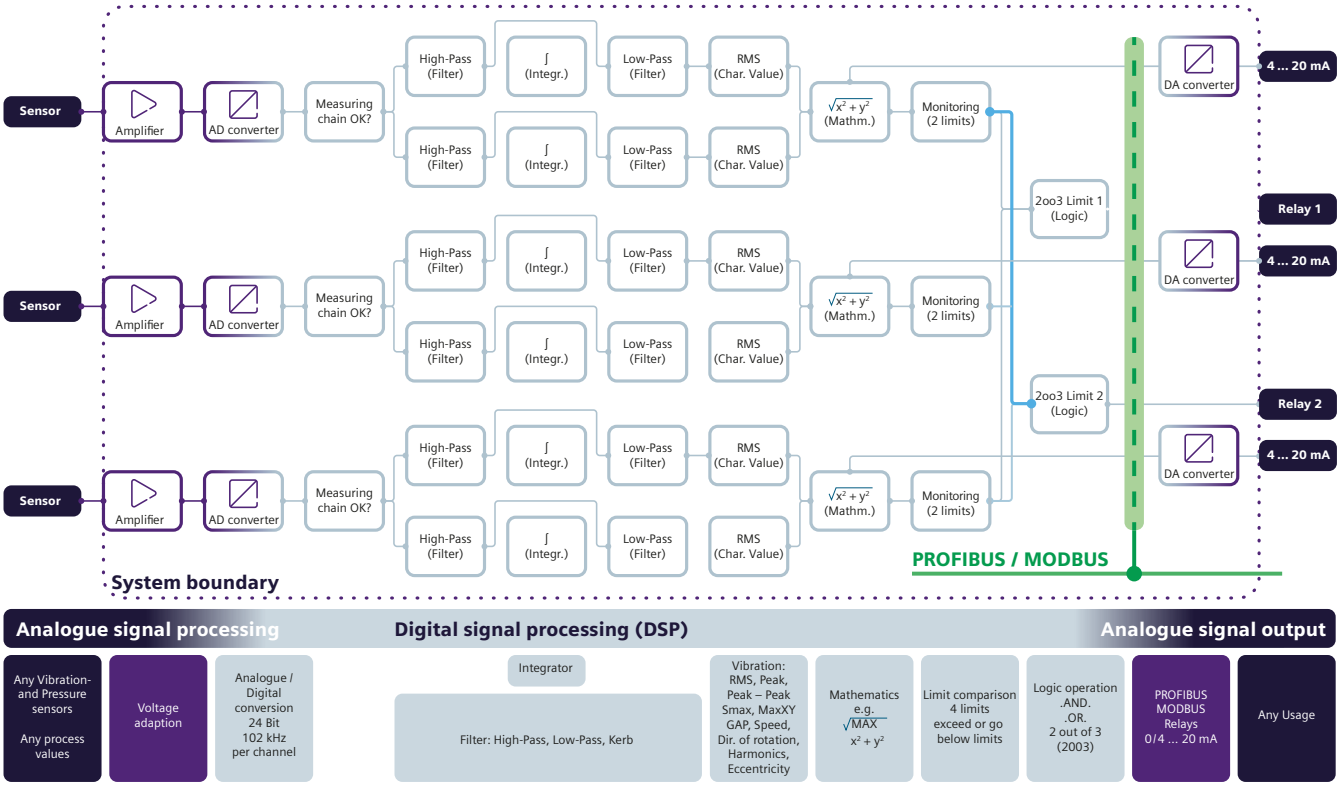


Fig. 2 Design and features of the VIB3000 Machinery Protection system VIB3000

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The rack comprises the VIB310 monitoring module and the VIB320/321 processing module. The processing modules supply voltage and current to the connected instrumentation chains and handle the acquisition and processing of the measured signals. These signals are forwarded to the VIB310 monitoring module, which includes a central voting function in addition to limit value monitoring.

Communication with the higher-level automation system via PROFIBUS DP/MODBUS also takes place from here (VIB310 module). The module can also provide analog and relay outputs in addition to binary inputs.

A single processing module, VIB320/321, basically performs all the measurement tasks thanks to loadable applications. Even customer-specific applications can be developed on request. The small number of module options also minimizes the costs of spare parts management.

With the 24-bit resolution of the VIB320/321 processing module instrumentation chains can be monitored faster and more accurately for proper operation based on an evaluation of the total signal comprising AC and DC components. In addition to short circuit and cable break, overloading of the instrumentation chain can be reliably detected. The excellent resolution of the AD converter also means that measuring range switchovers are not necessary. The system is capable of immediately tracking widely fluctuating measured values and overloading of the measuring electronics is excluded.

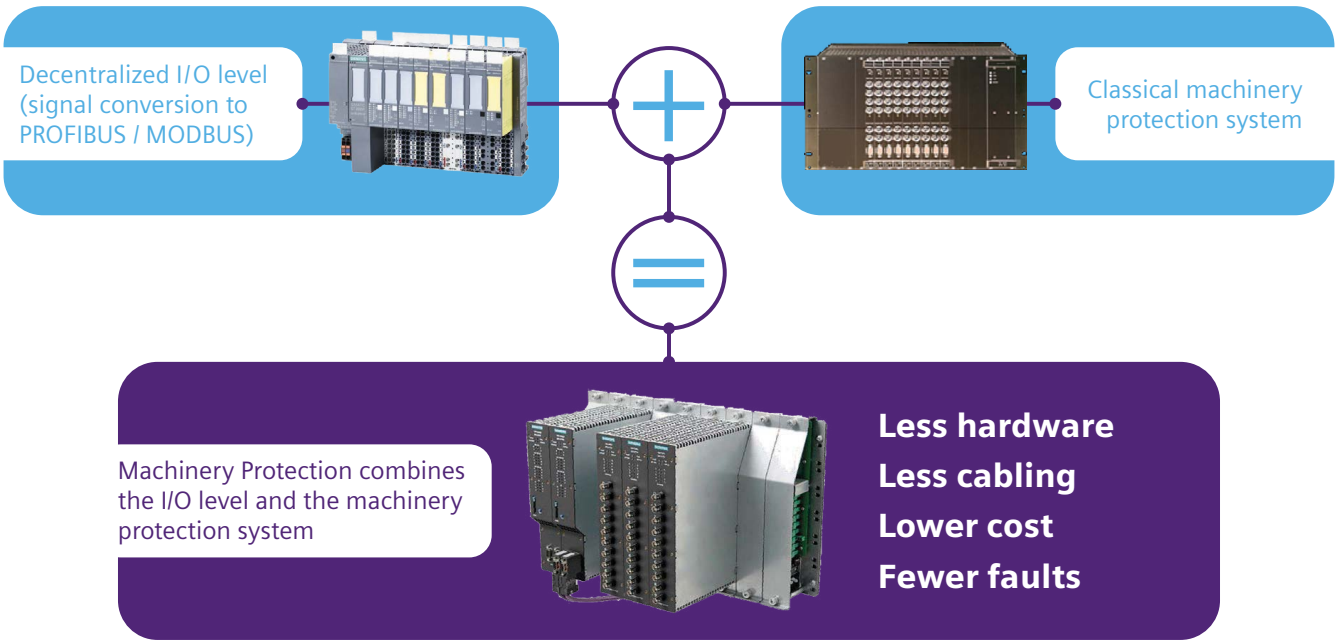
A sampling rate of 102.4 kHz per measuring channel permits the acquisition of signals in the range 0 Hz to 50 kHz. This makes it possible to monitor anything from simple parameters in accordance with DIN/ISO through to diagnostic characteristic values which are a mandatory requirement for the effective monitoring of gearboxes and rolling-contact bearings, for example. The monitoring range is thus extended to include all the machines in the power plant.

If monitoring is to be moved from the I&C to the field level or if VIB3000 Machinery Protection is to be used as a standalone solution, the existing programmable logic offers further advantages.

All the limit value violations detected in the system can be routed to voters, where they can be combined with other events in VIB310. Logic operations, such as 2-out-of-3 operations, can be created in Boolean algebra using these voters. The result of the logic operation can be used to trigger other actions, such as switching off the machine by means of safety relays (onboard voting).

The automation layer of the I&C receives the characteristic values calculated in the protection system and their statuses directly in the form of PROFIBUS DP/MODBUS messages. No additional modules are required for the integration of VIB3000 Machinery Protection in the I&C. Less hardware is required, not to mention fewer cables and subracks. This ultimately reduces the amount of effort required for installation and commissioning, as well as the number of possible sources of error (Fig. 3).

The amount of cabinet space required is also reduced due to the high channel density (10 channels per processing module) and the ability to install 6 processing modules in each 19 inch rack.



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1.2 Fail-safety due to maximum fault tolerance

VIB3000 Machinery Protection systems are frequently only used for displaying measured values and for reporting abnormal values when these occur. If the idea of safety is the prime concern, however, machines are automatically shut down by protection systems of this kind.

Even with redundantly configured conventional systems, certainty about the machine condition is already compromised when only one measuring channel fails, as there is no second signal for evaluation which can confirm the correctness of the measured values. And because no diagnostics are possible from the I&C in classical protection systems, the fault in the measuring circuit can only be found by means of local trouble-shooting procedures (at the machine, in the control cabinet or directly at the cabling). This is time-consuming and not cost-effective. Now if the second measuring circuit is also interrupted – due to a cable fault or failure of the acquisition electronics – the I&C prophylactically shuts the machine down, even if it is still fully operational.

These problems are largely avoided by the high fault-tolerance capabilities of the new solution. This is achieved by insuring complete redundancy throughout the entire signal chain. The effect of the redundant structure is explained below with reference to Figs. 4-8.

Fig. 4 shows the four theoretically possible faults which can affect machine availability in conventional systems (see left side of Fig. 4):

- Failure of measuring channel
- Cable fault between classical protection system and distributed I/O level
  Note: Distributed I/O level: Module for converting analog signals to PROFIBUS DP/MODBUS messages used in classical VIB3000 Machinery Protection systems
- Failure of channel in distributed I/O level
- Failure of cable to I&C

The right side of Fig. 4 illustrates the principle of fault prevention in VIB3000 Machinery Protection. Figs. 5-8 describe this principle of fault prevention in detail for each of the possible failures.

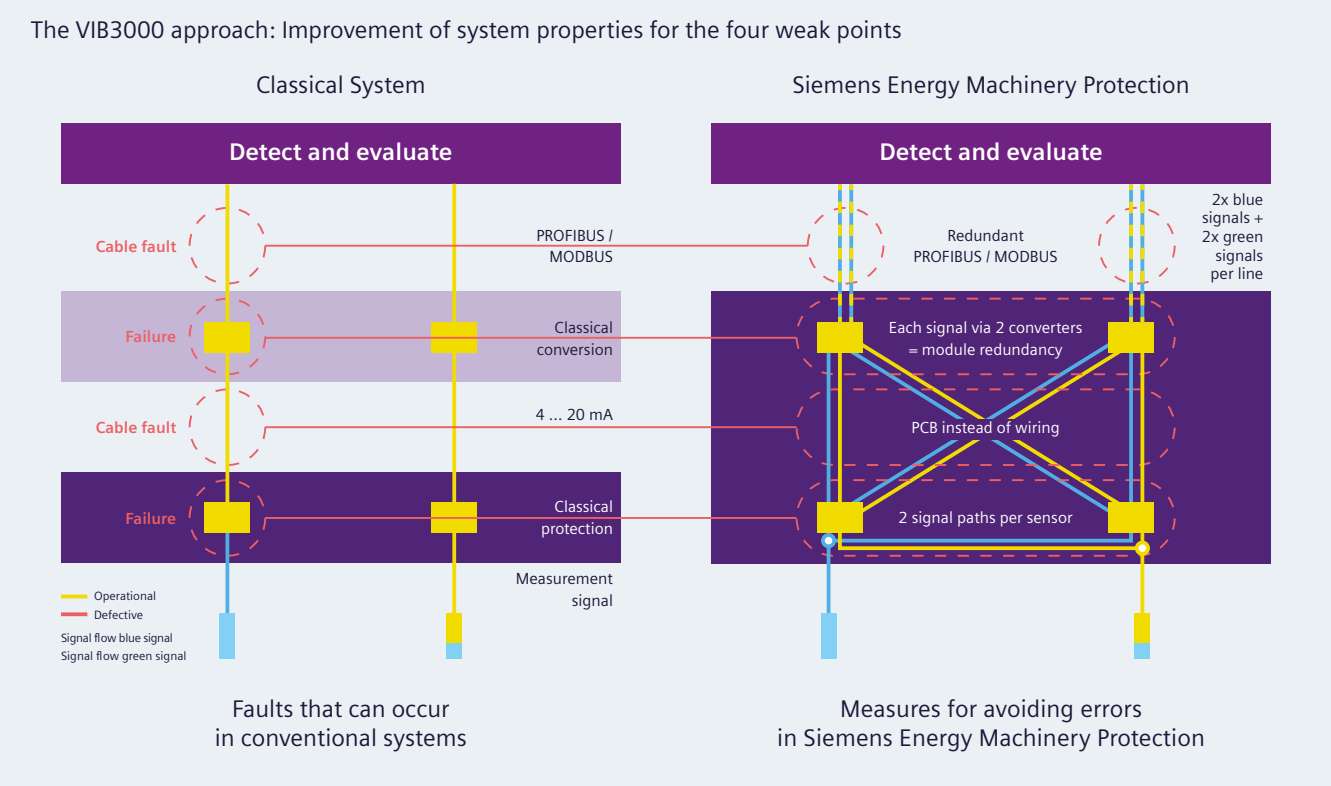

Fig. 4 The redundancy concept: Improving the system properties at the four potential weak points

Failure of measuring channel

If a fault occurs in a measuring channel of the protection system, the entire measuring circuit fails. A safe and unambiguous assessment of the machine condition is no longer possible for this reason. A sensor signal can be connected to two processing modules, i.e. in a redundant configuration. If a fault occurs in one measuring channel, the sensor can be supplied via the second unfaulted processing module and the sensor signal is forwarded to this processing module. Both sensor signals are still available for processing, thus permitting a correct and reliable assessment of the machine condition. System diagnostic functions available from the I&C also permit fast fault analysis detection.

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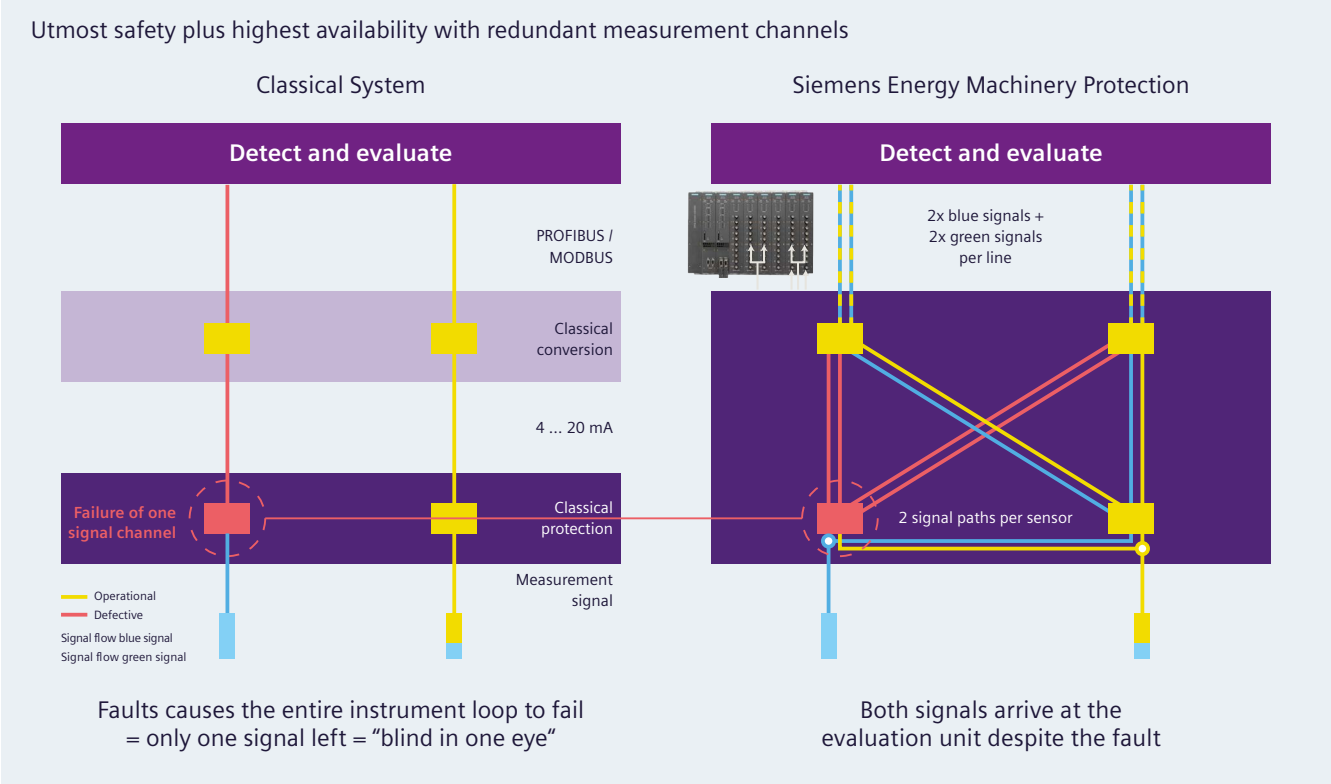

Fig. 5 Extra safety thanks to redundancy of measuring channels

Cable fault between measuring channel and distributed I/O level

With classical systems, the entire measuring circuit also fails when this fault occurs (left side of Fig. 6). With this new solution, signals are routed via redundant printed conductors on the backplane. The fault described above is therefore excluded from the new system.

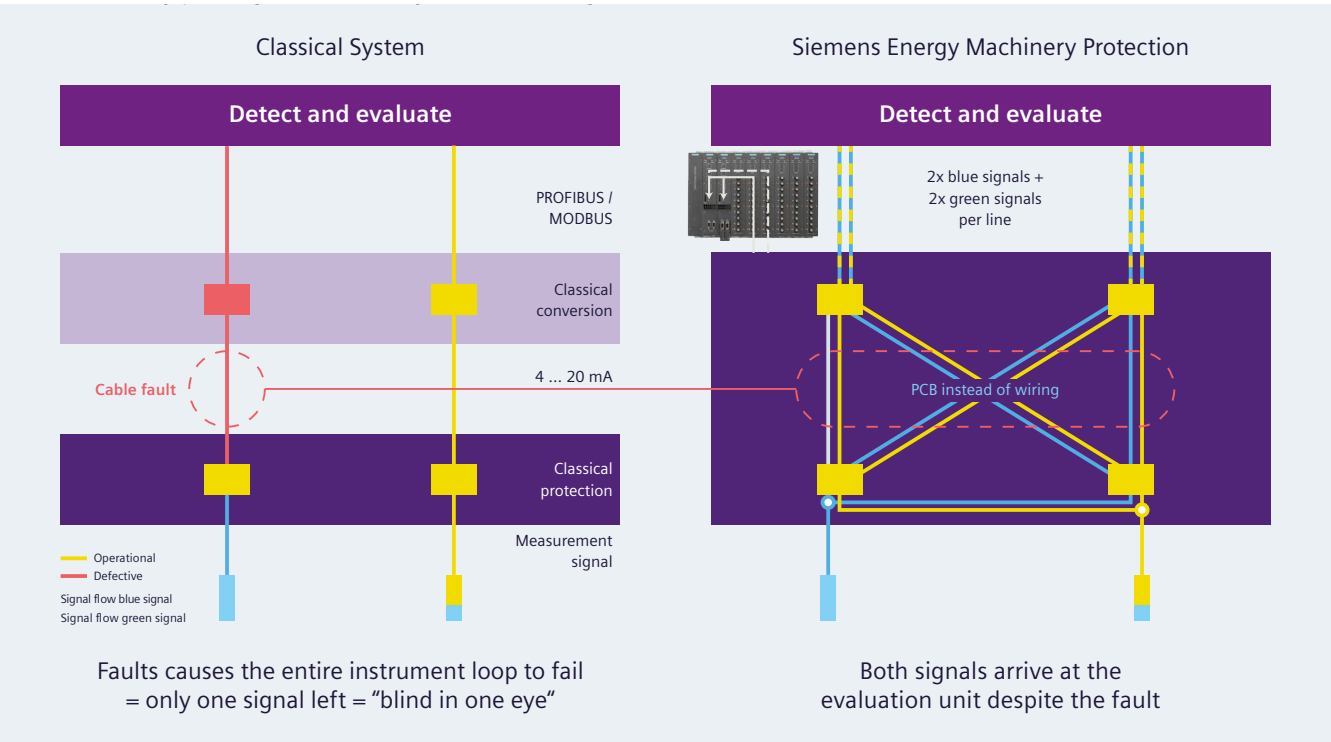

Fig. 6 Extra safety due to less wiring

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Fault or failure of converter (distributed I/O level) or fault between converter and I&C due to failure of cable

The new solution also offers module redundancy for the converter, which means that both signals can be processed in both converters and remain available for evaluation in the I&C even in the event of failure of a converter.

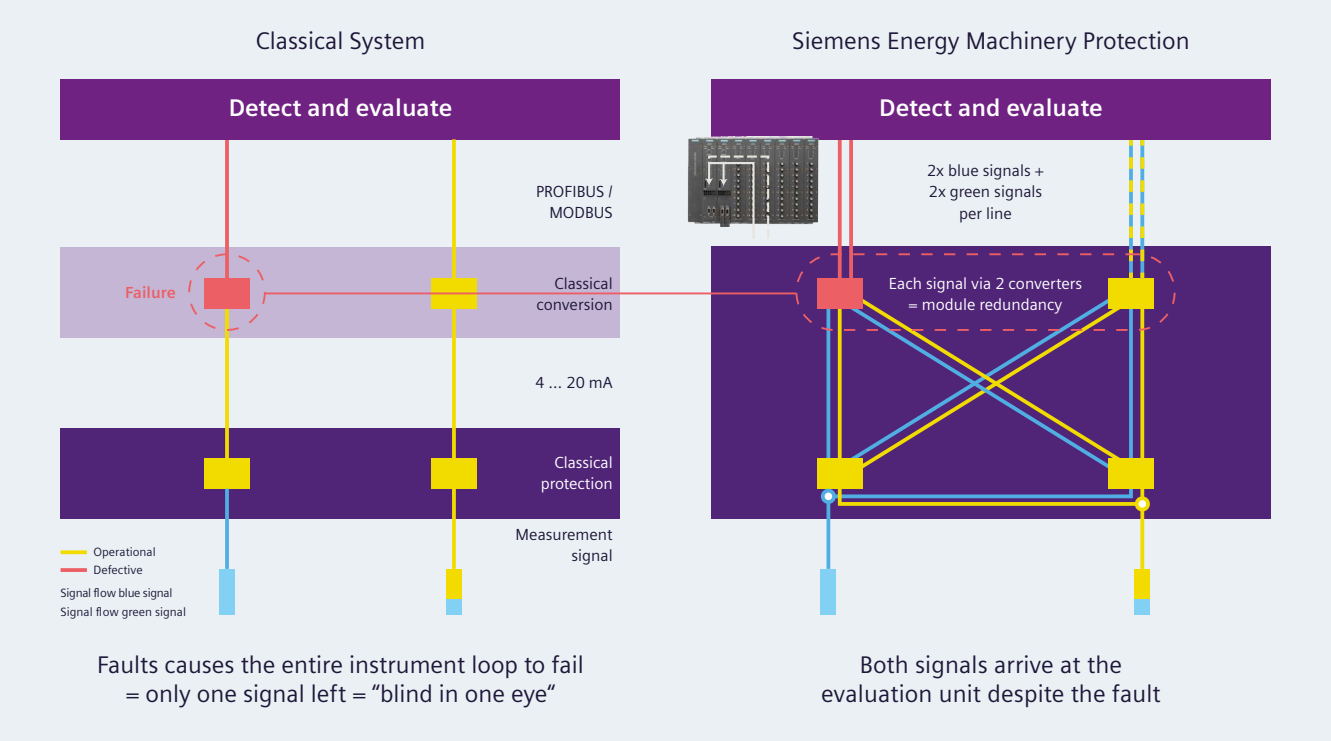

Fig. 7 Extra safety thanks to redundant converter modules

If a cable between the converter and the automation system fails, the entire measuring circuit fails in classical systems. Therefore only one signal is available for evaluation (Fig. 8 on the left).

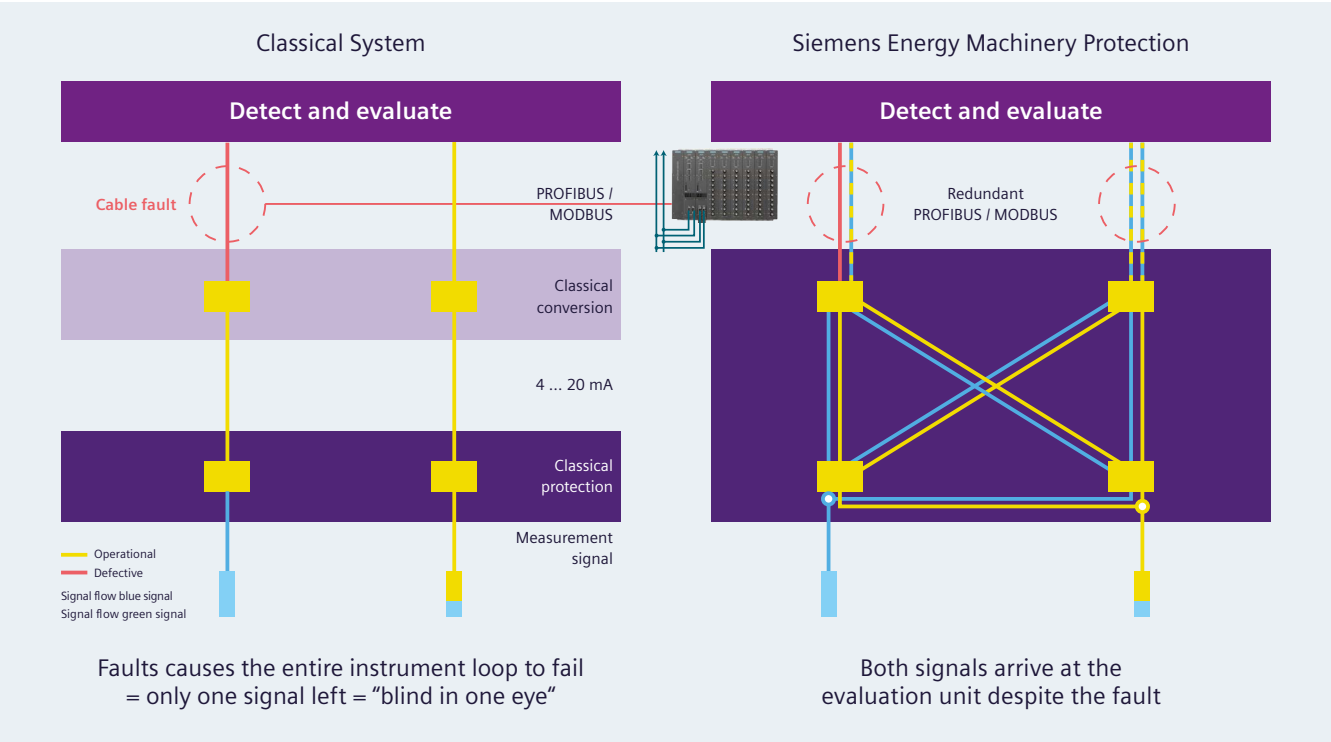

Fig. 8 Extra safety through redundant PROFIBUS DP/MODBUS connection

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Thanks to its redundant PROFIBUS DP/MODBUS connections, the new system also forwards both signals to the I&C's automation server (Fig. 8 on the left) in the event of failure of one bus. Its high fault-tolerance capabilities avoid prophylactic shutdowns of the machine due to deficient information, thus contributing to an increase in availability.

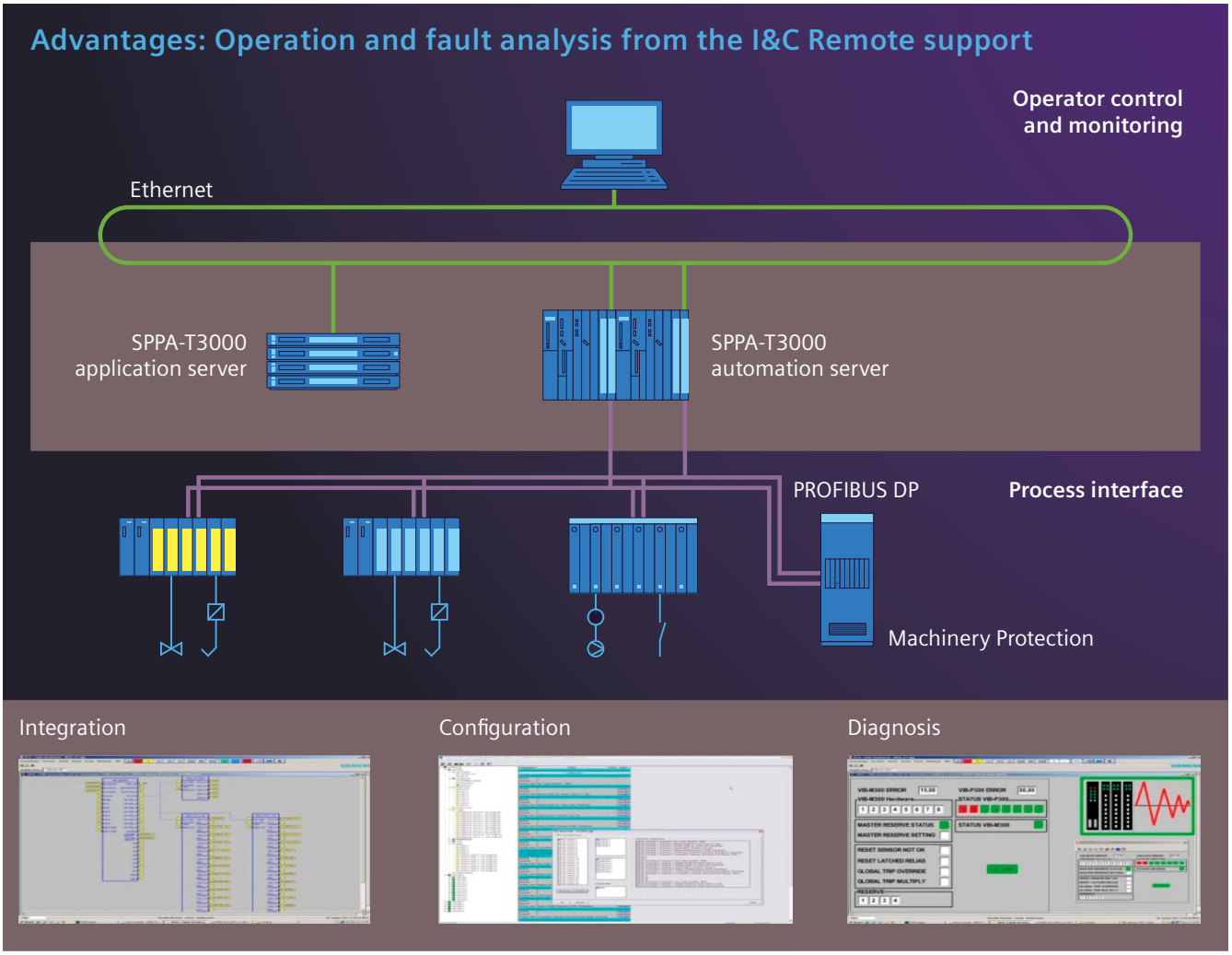

Fig. 9 Integration into the I&C permits direct operation (example: SPPA-T3000 with PROFIBUS DP)

1.3 Field device with integrated bus interface

Fig. 9 illustrates the architecture of the integration of VIB3000 Machinery Protection in Siemens Energy I&C systems SPPA-T3000 and SIMATIC PCS 7 via PROFIBUS DP/MODBUS. This integration means that all information and messages are available in the I&C and are automatically archived. Parameterization (configuration) and control of the protection system is also possible directly from the I&C.

System faults can be located and diagnosed from here as well. This bus concept also permits the creation of distributed systems by distributing main and auxiliary equipment units to different vibration monitoring racks.

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2. Summary

So far, compromises in availability were always involved when looking at vibration-based VIB3000 Machinery Protection systems. In favor of achieving greater safety for the personnel, plant and machine, prophylactic shutdowns had to be accepted. The fully redundant solution VIB3000 Machinery Protection combines safety and availability for the first time. State-of-the-art measuring technology and a high level of fail-safety due to maximum fault tolerance achieve not only safety for personnel and machine. It also reaches the higher level of safety from spurious tripping and therefore increases availability.

VIB3000 Machinery Protection is a solution for every application: it is capable of complete integration into Siemens Energy I&C, it can be easily connected to I&C systems from other suppliers and it can also be used as a stand-alone system.

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