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WHITEPAPER

ENERGY MONITORING AND CONDITION MONITORING: SUSTAINABLE OPERATING COST SAVINGS AND INCREASING PRODUCTION CAPACITIES

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IPF ELECTRONIC

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1 INTRODUCTION

With the invasion of Ukraine by Russian troops in February 2022, fears of a lack of security of supply increased in Europe and with it energy prices, particularly for gas, oil and electricity. However, the situation eased over the course of the year as a result of the shift in procurement markets, which had previously prioritized gas in particular, partly due to political measures, the accelerated construction of LNG terminals and a mild winter in 2022/23. Although energy prices no longer rose as exorbitantly as at the beginning of the crisis, they remained extremely volatile and at a comparatively high level.
Since February 2022, energy efficiency has been a particularly high priority for German companies. However, even before the crisis, attention was already focused on the complex issue of energy costs in connection with more sustainable production.

However, sustainable energy cost savings are generally only possible if the causes of unnecessarily high consumption are known. If this prerequisite is met, the challenge of collecting and analyzing the relevant data still remains. However, anyone who thinks that noticeable energy savings are directly linked to high investments in the necessary infrastructure for energy monitoring is wrong, as this white paper will show.

What applies to efficient energy monitoring also has its justification with regard to end-to-end condition monitoring. This is because the measurement data available from machines, systems and processes via the use of specific sensor solutions can be used to reduce spare parts costs in terms of predictive and therefore condition-based maintenance and, via this, sustainably increase the availability of machines and systems and therefore important production capacities.

The first part of this white paper describes how efficient energy monitoring can be implemented easily, quickly and, above all, without high initial investments and follow-up costs. The white paper also deals with the topic of condition monitoring and shows how, on the basis of a gateway used for energy monitoring used as a network node for energy monitoring, a consistent and extremely economical condition monitoring system (CMS) can be set up and subsequently expanded as required.

Finally, an application example is used to show the potential that can be leveraged through targeted energy monitoring with regard to significant cost savings in compressed air consumption.

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2 LEVERAGING POTENTIAL FOR ENERGY SAVINGS WITH TARGETED MEASUREMENT DATA

Energy is required in countless industrial applications in a wide variety of ways: for example, to generate heat or cold, to provide compressed air or various liquid media or for the production and use of technical gases. The areas of application in which energy is indispensable today are so wide-ranging that even the attempt to provide an almost complete list would fail at this point.

As complex as the use of very different production systems and processes may be, they all have one thing in common: they all provide some form of measurement data.

Data that may not have been particularly relevant from the perspective of one company or another for a long time, but which is a valuable asset today and in the future with regard to energy as a scarce and costly resource. This is because measurement data, possibly linked or supplemented by further information, e.g. on correlating workflows and production processes, provides the key to continuous energy monitoring with many possibilities for targeted analyses. The more granular such measurement data is obtained, the more accurate statements can be made about a company‘s energy consumption and the more substantial and therefore helpful the information and findings that can be derived from it will ultimately be. In this way, precisely the potential that leads to truly sustainable energy savings can be leveraged.

3 HIGH INVESTMENTS, COMPLEX IMPLEMENTATION AND CONTINUOUS ADDITIONAL COSTS

The option of successively implementing an energy monitoring system in different manufacturing and production areas, which makes perfect sense, requires a solution that is as modular as it is variable. In other words, a flexible solution as a straightforward interface with which the data can be recorded, merged, processed and flexibly analyzed in order to initiate very targeted measures for cost savings.

However, many energy monitoring systems are often far too inflexible in terms of straightforward handling and can only be implemented with greater effort in terms of interfaces to various sensor solutions. In addition, such solutions, quite apart from the high initial costs for their acquisition, lead to regular additional costs due to, for example, software license fees, necessary cloud connections or maintenance contracts, which together must first be amortized through corresponding energy savings.

4 MANUFACTURER-INDEPENDENT, HIGHLY COMPATIBLE PLATFORM

For the reasons mentioned above, ipf electronic therefore deliberately opted for a completely different approach to energy monitoring and, in the interests of a solid calculation with always manageable costs and comparatively low implementation costs, opted for a solution based on a manufacturer-independent platform and open source software.

This solution can be implemented without complex conversions and does not incur any additional costs after implementation. It also ensures a high level of compatibility with all hardware and IT systems currently available on the market.

The solution from ipf electronic is based on a manufacturer-independent platform with open source software and does not cause any additional or extra costs after implementation.

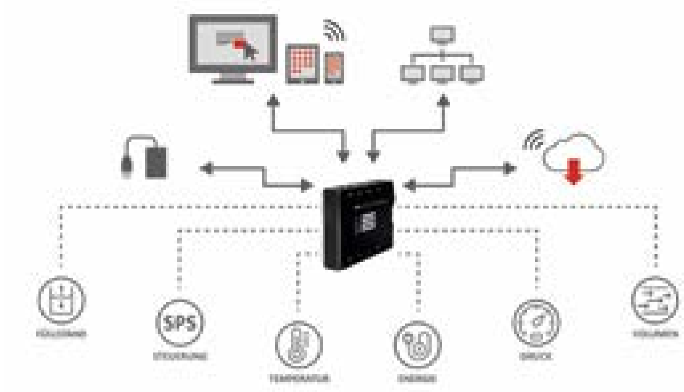
4.1 VERSATILE GATEWAY WITH OPEN SOURCE SOFTWARE AS STRAIGHT SYSTEM COMPONENT

The IIoT gateway **BY000002** with ARM processor forms the powerful „heart" of the system, so to speak. Both the Linux-based operating system, which is easy to set up, and the web client for processing, providing and visualizing the measurement data on a dashboard (Grafana), which can be accessed via any standard Internet browser, are already on the gateway as open source solutions.

ADVANTAGES AT A GLANCE	BY000002
Processor	2 x ARM Cortex-A7 CPU 1 x Cortex M4 CPU Cores
Large internal memory	1GBD DDR3L RAM 4GB eMMC
Numerous interfaces	100MbE USB2.0 Host USB2.0 Device CAN RS485 GPIO 4x analog input (4...20mA/0...10V)

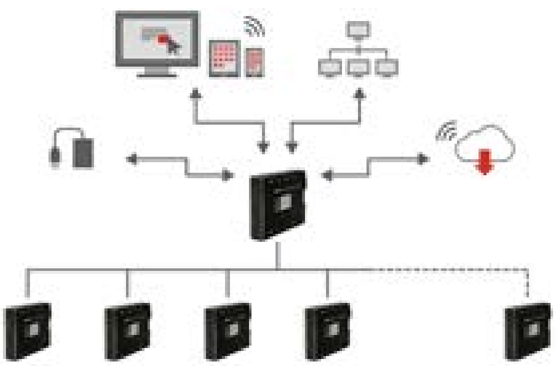
Overview of the features of the IIoT gateway **BY000002**.

The outstanding features of the gateway for recording energy flows include a high degree of application flexibility and scalability. The IIoT gateway enables continuous monitoring of an individual system, e.g. through connection to a PLC (programmable logic controller), or can be implemented as a networked factory-wide solution that can be flexibly open-ended at any time.



The gateway can be connected directly to a control unit (PLC) at machine level, for example, or to corresponding sensors and actuators at system level.

When using a gateway, the data and measured values determined from a machine, system or process are stored in the device‘s large internal ring memory or alternatively on an external storage medium via a USB 2.0 device interface. In addition, the measured values can be transferred to a local server or stored in a cloud via a secure VPN connection (VPN: Virtual Private Network).



Example of the use of gateway as a company-wide, networked solution.

In a factory-wide solution, the data collected decentrally on the individual gateways is transferred to a straight gateway as a master and thus merged. The measurement data can then be visualized via the dashboard for analysis and evaluation. However, the straight gateway can also access a company network, a storage medium or a cloud, for example, and process the data or measured values stored there at the same time.

4.2 HIGH CONNECTIVITY AND SIMPLE NETWORK INTEGRATION

Another decisive advantage of the gateway is its high connectivity thanks to a large number of interfaces. Up to six digital and four analog sensors can be connected directly to one gateway. The **BY000002** provides four analog inputs (4...20mA/0...10V) and six digital IOs for this purpose. Alternatively, users also have the option of connecting sensors via Modbus, for example, whereby up to 32 devices can be connected via Modbus RTU and up to 200 devices via Modbus TCP.

Along with the interfaces mentioned above, the gateway offers further interfaces: 100MbE, USB2.0 Host (Micro-USB) for connection to a PC for configuring the operating system, USB2.0 Device for connecting external storage media, CAN, RS485 and a backplane bus connector for AddOn modules.

The gateway also demonstrates a high degree of communication capability with regard to the network protocols that can be processed, including Modbus, CAN, http, Cloud of Things, OPC U/A, DB/SQL and MQTT (Message Queuing Telemetry Transport), a simple network or messaging protocol that has become increasingly popular in recent years and has established itself as an important component of many IoT solutions. A WLAN module (802.11b/g/n.150 Mbits/s) is also available as an option for establishing a network connection.

4.3 EXTREMELY VERSATILE, POWERFUL VISUALIZATION

The dashboard, which can be accessed via any standard web browser, provides a clear visualization of all previously collected measured values on a PC or mobile device. Here, too, ipf electronic opted for Grafana as a web client, a cross-platform, free open source application for the graphical display of measurement data from a wide variety of sources, e.g. InfluxDB, MySQL, PostgreSQL, Prometheus, etc.

The interactive, individually configurable and extremely powerful dashboard offers a wide range of data visualization options, e.g. in the form of tachometer, bar or curve charts, heat maps, histograms, etc. Individual detailed views with enlarged displays and thus higher resolutions, e.g. of time axes etc., can also be realized. In addition, warning thresholds for certain measured values can be set via the operating system, with the possibility of the user receiving a push message, e.g. on their cell phone, when a specific threshold is reached or overrun. However, this is only a small fraction of the numerous options provided by the versatile open source solution.

Example of an individually configured dashboard. The visualization software offers a variety of options for graphically displaying a wide range of measured values.

Once configured, dashboards can be exported in a compact JaveScript data format to transfer them to other gateways and open them with the visualization software. Via a platform-independent VNC connection (VNC: Virtual Network Computing), the dashboard view can also be shared with other users on various PCs or mobile devices, enabling smooth team-wide collaboration with seamless data exchange without media disruptions.

5 WIDE RANGE OF SENSORS FOR DECENTRALIZED CONSUMPTION MEASUREMENTS

In addition to the gateway as an essential basis for potential energy cost savings, ipf electronic offers a wide range of sensor solutions for decentralized consumption measurements.

5.1 FLOW, VOLUME AND TEMPERATURE MEASUREMENT OF ELECTRICALLY CONDUCTIVE LIQUIDS

The magnetic-inductive sensors of the **SM**-series were developed for precise flow measurement, dosing and temperature measurement of electrically conductive liquids such as water, coolants or pastes and are suitable for highly flexible use even under particularly demanding environmental conditions.

Magnetic-inductive sensors from the **SM**-series for electrically conductive media enable high-precision measurements.

The **SM**-series devices are made entirely of stainless steel and consist of a compact unit comprising a sensor and evaluation electronics. The sensors are available via various process connections (G1/4“, G1/2“, G3/4“, G1“, G2“) and cover measuring ranges up to a maximum of 650 l/min.

All settings can be made via the buttons on the color digital display, including functions for dosing or temperature measurement with a PT1000 temperature sensor on quick selection buttons. The display also offers numerous options for on-site configuration and calibration to prepare the devices for almost any measuring situation. The sensors in the **SM**-series integrate two analog outputs (0...10V, 0...20mA, 4...20mA, 2...10V) as well as switching, pulse and frequency outputs.

5.2 FLOW, CONSUMPTION AND TEMPERATURE MEASUREMENT OF TECHNICAL GASES

With flow sensors from ipf electronic, the flow and consumption quantities as well as temperatures of technical gases such as compressed air, natural gas, nitrogen, carbon dioxide, etc. can be precisely determined. The flow sensors of the **SL**-series with TFT display are optimally prepared for these tasks and are also used to measure the flow velocity of technical gases. The sensors, which are pre-calibrated at the factory for various

gases, are suitable for media temperatures from -30°C to +80°C or from -30°C to +110°C and can be recalibrated for other gases.
So-called insertion sensors and solutions with an integrated measuring section are available for installation.

Flow sensors from the **SL**-series are available as solutions with an integrated measuring section (above) or as so-called insertion sensors.

The insertion sensors are ideal as an entry-level solution and can be easily installed under pressure via a ball valve. Devices with an integrated measuring section are also available, which can be easily installed in an existing piping system to obtain reliable measurement results. The flow sensors in the **SL**-series have an analog output (4 to 20mA), pulse output and an RS485 interface.
Modbus Ethernet TCP and M-Bus are optionally available.

With the **SM**- and **SL**-series solutions presented in the previous two chapters, a wide range of consumption measurements of electrically conductive liquids and technical gases can already be realized, whereby the devices can be easily integrated into a wide variety of internal supply networks. The precise measurement data provided by the sensors for visualization on the dashboard can be used, for example, to quickly identify deviatingly high consumption and take appropriate measures for sustainable cost savings.

5.3 LEVEL MEASUREMENT OF LIQUIDS AND PASTY MEDIA

The **FK**, **FM** and **UT**-series are used to determine the filling level of various liquid and paste-like media, e.g. process water, coolants/lubricants or cleaning emulsions, in different containers. The measured values determined by the sensors in turn allow conclusions to be drawn about the consumption of a medium via a predefined period of time (volume information). Information can then also be derived from this, for example via the switch-on and switch-off cycles of pumps for media delivery. There is potential for optimization in this context, e.g. through the use of larger containers that need to be filled less often and thus reduce the use of pumps, among other things. However, this is just one of many examples of how the measurement data from fill level sensors, in combination with additional data and information recorded at other points within the company, can be used to identify potential savings.

The filling level and level sensors of the **FK**-series with M12 plug connector for the electrical connection have measuring probes in various lengths (235mm to 1185mm) and are suitable for media temperatures from -25°C to +100°C. Various switching points can be set flexibly via the integrated digital output (2 x 100mA). The analog output (4...20mA), on the other hand, provides a continuous signal for permanent level inquiry. The tried and tested sensors are particularly suitable for level monitoring in storage tanks, e.g. for cooling emulsions in machines.

The level sensors in the **FM**-series enable high-precision level measurements without prior media calibration. Designed for media temperatures from -20°C to +80°C, the devices have a switching output along with an analog output for continuous level measurements. The response sensitivity of the very easy-to-install solutions is adjustable via the membrane keyboard with LED display. Potential applications for the **FM**-series include level detection in containers with oils, alkalis, cleaning agents or release agents, to name just a few examples of the extremely wide range of applications.

The level sensors in the **FM**-series enable high-precision level measurements without prior media calibration. Designed for media temperatures from -20°C to +80°C, the devices have a switching output along with an analog output for continuous level measurements. The response sensitivity of the very easy-to-install solutions is adjustable via the membrane keyboard with LED display. Potential applications for the **FM**-series include level detection in containers with oils, alkalis, cleaning agents or release agents, to name just a few examples of the extremely wide range of applications.

Various solutions from ipf electronic for level measurement: **FM**-series sensor with parallel rod and integrated switching output for immediate use without media adjustment (top), an **FK**-series device with measuring probe for media temperatures up to +100°C (middle) and an ultrasonic sensor from the **UT**-series with long range for non-contact level measurements (bottom).

Ultrasonic sensors from the **UT**-series offer the advantage in connection with level detection that they are contactless and therefore completely wear-free. These devices can therefore also be used to measure levels in containers with aggressive media. Another advantage of the **UT**-series is the high range of the devices of up to 6,000mm. The ultrasonic sensors are suitable for level monitoring of all media that are capable of reflecting the sound pulse of the devices in sufficient quantities. With this in mind, a preferred area of application for the sensors is e.g. the inquiry of highly transparent liquids.

5.4 POWER CONSUMPTION MEASUREMENTS OF COMPONENTS, SYSTEMS AND OPERATING SITES

The measuring transducers (AC) of the **NZ**-series with integrated current transformer have a measuring range of up to 600A and provide a direct analogue signal (0...10V or 0...20mA) for decentralized recording of the power consumption of individual components, machines or systems, for example. This makes it possible, among other things, to determine the exact distribution of energy consumption in a production facility and also to identify areas where power consumption may be particularly high based on the measurement data collected via a specific time period. The **NZ** measuring transducers with mounting base can be mounted on either a busbar or a round conductor.

The measuring transducers for alternating current of the **NZ-**series with integrated current transformer have a measuring range of up to 600A and provide a direct analog signal (0...10V or 0...20mA) for decentralized recording of current consumption.

5.5 PRESSURE MEASUREMENT OF GASEOUS AND LIQUID MEDIA

Pressure is required in every conceivable industrial sector and must be generated with the corresponding use of energy, e.g. for hydraulic and pneumatic applications. The most effective way of evaluating energy consumption for pressure generation is at the point where the pressure is needed and can be measured.

By recording pressure curves, it is possible to make statements about the current status of a system, among other things. It is also possible, for example, to determine how the status changes during ongoing system operation and what pressures are required in certain periods, to name just a few examples. Whatever the purpose of the pressure measurements, the pressure sensors always provide valuable data, e.g. to be able to establish correlations between energy consumption and production, but also to the system statuses, etc.

The **DW3-**series sensors were developed for pressure measurements of gaseous and liquid media. The devices in the **DT16**, **DT24**, **DW16** and **DW06**-series are designed for measurements of gaseous media such as compressed air or nitrogen.

The **DW3** device series with front-flush diaphragm or installation thread cover pressure ranges from -1bar to +600bar or -1bar to +1bar and are suitable for a variety of pressure measurements of gaseous and liquid media due to the robust version of the media touching parts, among other things.

The devices are equipped via two switching outputs that supply up to 250mA per channel. The second output can also be used as a switching, analog or alarm output.

ipf electronic offers a wide range of solutions for pressure measurement of gaseous and liquid media (**DW3**): **DW3** and **DW16**-series devices (top left and right) and **DT16** and **DW06** (bottom left and right).

The **DT16** pressure transmitters from ipf electronic for pressure and vacuum applications are particularly compact and, with a weight of 25g, also very light devices that are suitable for a wide range of applications in all conceivable handling and automation systems.

The robust sensors in stainless steel housing with M8 plug connector and G1/8“ process connection are designed for ambient temperatures from-10°C to +70°C and are therefore also recommended for demanding operating conditions. The measuring cell is suitable for filtered, dry or oiled compressed air and neutral gases. For evaluation, the devices integrate an analog output (4...20mA) with an overall accuracy of ±0.5% and a repeat accuracy of ±0.2%. The **DT16** pressure transmitters are available with four different pressure ranges (-1 to 0bar, 0 to +10bar,-1 to +1bar and-1 to +10bar).

The extremely compact electronic IO-Link vacuum and pressure sensors from the **DW16**-series for filtered, dry or lubricated compressed air and neutral gases cover detection ranges from -1...10bar and have a response time of <2.5ms and a switching frequency of 200Hz. The calibrated and temperature-compensated devices provide high-precision measured values and thus enable variable and versatile use in all conceivable areas of handling and automation systems (e.g. pressure monitoring, vacuum control for vacuum traverses, compressor control, etc.). The pressure sensors are equipped with two independently adjustable signal outputs with precisely adjustable switching points. The associated switching point hysteresis can also be freely defined.

The pressure sensors in the **DW04**, **DW06** and **DW08**-series are designed for direct installation in compressed air lines. For this purpose, they are equipped with a push-in connection into which the hose lines can be inserted and locked in place instantaneously. At the same time, the locking technology ensures that the lines are absolutely tight after installation. The series is therefore available for different line diameters of 4mm, 6mm and 8mm with pressure ranges of-1 to 0bar, 0 to 10bar,-1 to +1bar and-1 to +10bar. The pressure sensors are each offered in two different device versions. One solution is via a switching output and a potentiometer.
The corresponding sensor variant integrates two switching outputs and an IO-Link interface. The sensors with M8 connectors have protection class IP68 and are designed for ambient temperatures from-10°C to +60°C

5.6 TEMPERATURE MEASUREMENT OF TECHNICAL GASES AND LIQUID MEDIA

In many areas and processes, the generation of temperature or heat has a direct influence on the consumption of the energy sources required for this (electricity or natural gas). A decisive question here can be, e.g., how efficiently the energy is used for temperature generation, whereby a corresponding evaluation and more detailed statements are only possible on the basis of valid data from temperature sensors.

Temperature sensors from the **YT35** (left) and **YT45**-series. The PT100 thermal resistors are available with different probe lengths.

The temperature sensors in the **YT35** and **YT45**-series have been developed for the wetted temperature measurement of technical gases and liquids. In combination with a

PT100 thermal resistor, the **YT353100** and **YT353120** measuring transducers are suitable for measuring temperatures in a very wide range from -40°C to +300°C. The measuring transducers are equipped with two switching outputs, one of which can be parameterized as an analog output (0...10V / 4...20mA). The analog output has a high repeat accuracy of 0.1%.

The temperature sensors in the **YT45**-series with stainless steel sensing elements are available as screw-in fittings with a 1/2" process connection and are designed for media temperatures from -40°C to +120°C. The devices integrate a switching output as well as an analog output (4...20mA) and can be parameterized using three buttons on the front.

The **YT90**-series temperature transmitters in stainless steel with G1/2" process connection and PT100 thermal resistor are available via an analog output (4-20mA) and in six versions with two sensor lengths (50 and 100mm) for three different temperature ranges (-50 to +150°C, -20 to +120°C and 0 to +100°C).

6 ECONOMICAL SOLUTIONS FOR CONDITION MONITORING

Condition monitoring is an important building block for companies with regard to the ever-increasing digitalization of their processes. Condition monitoring systems (CMS) can be used to monitor subcomponents, processes, machines and complete production plants from anywhere. This increases productivity due to higher machine and system availability and also increases transparency via the actual available production capacities. The most important objectives of condition monitoring include avoiding unnecessary production downtime and identifying potential for optimization based on valid data. Every unplanned machine downtime and every process that does not run smoothly leads to a drop in productivity and also consumes valuable resources for troubleshooting, which ultimately means a lot of effort and high costs.

As already mentioned in the introduction to this white paper, the IIoT gateway presented here meet all the requirements for targeted condition monitoring and, as with energy monitoring, without complex conversions or high investment and follow-up costs. As described in chapter 4.1 in connection with energy monitoring, either condition monitoring at machine level or a factory-wide, networked CMS can be implemented.

6.1 HIGHER SYSTEM AVAILABILITY THROUGH TARGETED ANALYSIS

Permanent condition monitoring of machines, systems and processes is essential to keep unnecessary production downtimes to a minimum or, at best, to avoid them altogether. The data collected by sensors and actuators is stored on the IIoT gateway for this purpose and can be visualized and analyzed on a dashboard via the software (Grafana) already presented in chapter 4.3, optionally enriched with further data from programmable logic controllers (PLC) and servers (BMD, MDE, etc.). With the help of the clearly displayed machine, system and process data, users are thus informed at all times about what is happening in production and can take instant action before major errors and thus problems occur.

Depending on the condition monitoring requirements, certain threshold or limit values can also be defined in the gateway via the operating system, e.g. in connection with the monitoring of temperature curves, compressed air consumption, filling levels, etc. When a previously defined value is reached, an automatic notification can then be generated and transmitted, for example, as an email or SMS via a WLAN connection or with an LTE stick connected to the gateway.

In this context, it is also possible to intervene via the digital IOs of the gateway, for example by transmitting specific signals directly to a higher-level control unit (PLC (programmable logic controller)), e.g. to stop a specific process or machine if a threshold or limit value is overrun, to name just one example.

6.2 SENSOR SOLUTIONS FOR CONDITION MONITORING OF SYSTEMS, MACHINES AND PROCESSES

In principle, the sensors presented in chapter 5 can also be used for continuous condition monitoring. These include solutions for flow, consumption, volume and temperature measurement of conductive liquids and technical gases such as the **SM**, **SL**, **YT35**, **YT45** and **YT90** sensors for detecting filling levels in containers with liquid and pasty media (**FK**, **FM** and **UT**-series), devices for pressure measurement of gaseous or liquid media (**DW3**, **DT16**, **DT24**, **DW16** and **DW06**) and the **NZ**-series measuring transducers for power consumption measurements. As the technical properties of these solutions have already been discussed in more detail above, the following are some application examples of the potential use of these devices in the course of condition monitoring.

Flow sensors: e.g. for monitoring specific liquid and gas quantities for the recognition of possible leaks or leaks or to identify decreasing pump performance due to wear or technical defects.

Level sensors: e.g. for measuring and checking filling levels in containers in order to detect leaks in the containers or lines in good time or to optimize the switch-on and switch-off cycles of feed pumps.

Pressure sensors: e.g. for monitoring hydraulic and pneumatic processes and their specific control circuits.

Temperature sensors: e.g. for continuously recording the temperatures of technical gases and liquids in order to avoid potential machine or system damage by taking quick countermeasures in the event of noticeable deviations.

Current transformers: e.g. for monitoring the current consumption of units and components (e.g. motors) in order to initiate suitable measures against increasing wear in the event of massive changes (increased current consumption).

6.3 SIMPLE COMMUNICATION THROUGH STANDARDIZED INDUSTRY PROTOCOLS

As can be seen from the overview in Fig. 2, the gateway master numerous communication protocols, including the standardized OPC U/A protocol (Open Platform Communications Unified Architecture) for communication and data exchange in the industrial automation environment. This alone opens up further options for communicating with a PLC (programmable logic controller) in a variety of ways. With regard to the performance spectrum of the sensors connected to the gateway, this opens up a wide range of declaration and definition options.

6.4 INTEGRATION OF IO-LINK SENSORS IN CONDITION MONITORING

In addition to the sensor solutions listed as examples in chapter 6.2, a whole range of other sensors from ipf electronic are suitable for condition monitoring, including above all devices that provide a wide variety of status messages on device functionality via their IO-Link interface, which in turn can be further processed and evaluated on a PLC (programmable logic controller).

However, instead of integrating such additional tasks into the program sequence of a PLC (programmable logic controller) (which can lead to a higher program scope or longer cycle times, for example), such sensor status messages can be transferred directly to a gateway via OPC U/A protocol and used for condition monitoring. The PLC (programmable logic controller) is therefore only responsible for the system functionality, while the additional sensor data can be processed and analyzed for status monitoring. Here are two examples.

6.4.1 MONITORING POSITIONING AND FEEDING PROCESSES WITH INDUCTIVE SENSORS

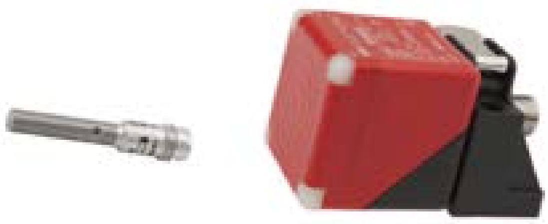
ipf electronic has a whole range of inductive sensors with an IO-Link interface. The majority of proximity switches provide additional information via IO-Link, including whether a sensor is within its safe switching range during an inquiry and thus always reliably detects an object.

If you want to use this information for condition monitoring, the inductive sensor must be connected to the PLC (programmable logic controller) of a system via an IO-Link interface, whereby the control (unit) transmits the corresponding sensor information to a gateway using the OPC U/A protocol. Based on this data stored in the gateway, it can then be seen very quickly via the display on the dashboard whether a proximity switch is operating within the safe switching range or is possibly already within its response limits or no longer exhibiting the expected switching behavior. Reasons for this can include
This could be due to changed and therefore faulty processes, e.g. in an automated component feed system, so that the mechanics of a feed or positioning system can be checked and, if necessary, corrected in good time before a complete system shutdown occurs.

The **IC080172**, **IC120122**, **IC180122** and **IC300122** inductive sensors with IO-Link interface from ipf electronic are able to perform the monitoring function described above. The proximity switches for flush mounting have high ranges of up to 10mm and are extremely robust, as they have a housing made entirely of stainless steel (protection class IP69K), which is also absolutely impermeable to liquids and gases on the active surfaces. The sensors were developed in particular for applications where very high demands are placed on the reliability and durability of the sensor technology, e.g. areas of application with oil, dirt, high pressures or heavy mechanical loads.

Inductive sensors with IO-Link: **IC080172** (top, left), **IC120122** (top, right), **IC180122** (bottom, left) and **IC300122** (bottom, right).

If inductive sensors with increased switching distances are required in applications that also need to provide diagnostic data via their switching states via IO-Link, then the **IB050176** or the **IN450423** with maximum switching distances of 1.5mm to 40mm are ideal for this. Both devices have protection class IP67, with the **IN450423** also achieving IP69K as a cuboid version for non-flush mounting with a suitable connection cable.



Inductive sensors designed for increased switching distances: the **IB050176** (left) and **IN450423** with IO-Link interface.

The proximity switches mentioned are examples of a whole range of inductive sensors from ipf electronic with IO-Link, which are suitable for continuous condition monitoring in addition to their original tasks. In this context, the chip-resistant inductive sensors should also be mentioned, which easily recognize target objects made of steel, non-ferrous metals and stainl. steel without malfunctioning due to metal chips.

Chip-resistant inductive sensors: on the left the **IO30012F** in size M30, next to it the **IO18012F** in size M18 and the **IO12012F** in size M12.

6.4.2 MONITORING THE DEGREE OF SOILING OF FORK LIGHT BARRIERS

Another example of the integration of IO-Link sensors into condition monitoring using the IIoT gateway from ipf electronic is provided by forked light barriers such as the **OG500572**, which can output the light intensity of the transmitter detected by the receiver as a measured value via IO-Link. The measured values can be transferred to a PLC (programmable logic controller) and then to a gateway via OPC U/A in order to continuously assess and monitor the degree of soiling of the light barrier based on the data analysis.

Among other things, the **OG500572** fork light barrier is able to output the light intensity of the transmitter detected by the receiver as a measured value via the IO-Link interface.

In the case of an unattenuated fork light barrier with non-soiling optics, the measurement or intensity value of the receiver is 100%. As a switching threshold is usually defined on the basis of this reference, which usually corresponds to half the value for an undamped light barrier (50%), the power reserve of the device is also known. A critical process state is therefore reached when the intensity value with a free forked light barrier (no object in the detection range) approaches the previously defined switching threshold.

If the intensity value is continuously monitored and recorded when the light barrier is free, the measurement data collected in the gateway can be used to determine the intervals at which the device reaches a critical degree of soiling and therefore needs to be cleaned. As the quality or intensity of the light barrier‘s received signal is always known, it is also possible to set a threshold or limit value and send a push message, e.g. by email or SMS, to the person responsible when this value is reached.

6.5 NEW POTENTIAL FOR MORE EFFECTIVE MAINTENANCE STRATEGIES

The examples and solutions presented from chapter 6.2 onwards illustrate how the IIoT gateway in combination with sensor solutions from ipf electronic can also be used in many ways for efficient condition monitoring via energy monitoring in order to leverage previously untapped potential for more effective maintenance strategies, among other things.

In contrast to reactive maintenance, which only becomes active when a fault or problem has already occurred, the data provided via the gateway can be used to implement a predictive maintenance strategy. This means that it is always possible to react in good time and therefore before a component or system fails. This also has clear advantages compared to preventive maintenance, as there is no need to replace machine or system components that may still be completely intact at regular intervals, for example in the course of inspections. A condition-based maintenance strategy is expected to prolong the average operating time of systems, machines or processes between two failures (mean time between failures), shorten the average time to repair (mean time to repair) and reduce the average cost of spare parts per system failure (mean cost of replacement parts).

7 APPLICATION: TARGETED REDUCTION OF COMPRESSED AIR LOSSES IN PRODUCTION

Compressed air is a valuable resource, but in many companies it often goes completely unused. Diamond Tooling Systems GmbH (DTS) from Kaiserslautern wanted to find out just how high compressed air losses and the associated costs can actually be. The company specializes in the development, production and sale of precision tools equipped with ultra-hard cutting materials. Compressed air is required in almost all areas of production.

7.1 NO OVERVIEW VIA CONSUMPTION AND POSSIBLE WASTE

By 2023, however, DTS had no idea how much compressed air was actually being used in production, nor how much of it was potentially being wasted. The company therefore decided to investigate consumption in more detail as part of a project. In this context, the aim was also to show what measures could be taken to reduce the consumption of compressed air and the costs of producing it.

7.2 DETAILED ANALYSIS INCLUDING POTENTIAL SAVINGS

One of the straightforward requirements of the project was to create an overview of the compressed air consumption per machine and department and to determine the corresponding annual consumption, which was to lead to a subsequent cost analysis with potential savings. At the start of the project, a survey of the current situation was carried out with all the boundary conditions, concrete goals were defined from the requirements and possibilities and recorded in a project order.

A total of 14 machines in various production areas (lasering, grinding and soldering) were examined more closely. The compressed air for these systems is generated by two compressors, which are in operation on a weekly basis so that one supply unit always serves as a backup. During project planning, a multi-moment recording of the compressors was carried out, among other things, as their utilization and pressure can be directly related to the volume flow and vice versa, as well as to the power consumption.

7.3 PRECISE MEASUREMENTS WITH INTELLIGENT DATA PROCESSING

The equipment for recording the compressed air consumption and processing the data was supplied by ipf electronic. Specifically, this involved the **SL920021** flow sensor and the **BY000002** IIoT gateway (detailed information in chapter 4.1). The flow sensor is suitable for installation even in confined spaces and already integrates a flow straightener. The sensor elements are therefore always optimally flowed against for the measurements, as a calming of the currents (laminar flow) is essential for this. An additional inlet and outlet section, as with other solutions, is not necessary. The **SL920021** is therefore particularly suitable for measurements within hose lines. The measured values recorded by the sensor are stored in the ring buffer of the IIoT gateway **BY000002**.

The **SL920021** flow sensor with integrated flow straightener is ideal for integration into hose lines.

7.4 SPECIFICATION OF COMPRESSED AIR CONSUMPTION AND LOSS

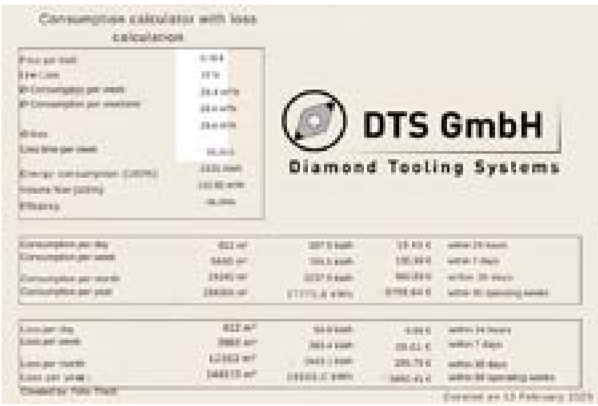
Two previously developed Excel programs were used to standardize the calculations and visualize them clearly. The data exported from the gateway as a CSV file was used to create a general consumption overview that took into account all periods in which the machines consumed compressed air or not.
The second Excel application, also based on the data from the gateway, served as a

self-test cost calculator to specify the consumption and losses of compressed air of the individual machines. The combined analysis of both lists also made it possible to derive appropriate measures for compressed air savings. A line loss of 15% for each system, due to the compressed air connection to the machines, and an electricity price of 0.18euro cents per kilowatt hour were used as the basis for the cost calculator.

7.5 SIMPLE INTEGRATION OF SENSOR AND GATEWAY

For the measurements, the flow sensor was integrated into the compressed air lines of the respective machines via quick connectors and connected to the gateway via the Modbus RTU interface. The gateway's operating system was previously preconfigured by preconfigured by ipf electronic. The data recorded by the sensor and stored by the gateway could be retrieved via a WLAN connection and displayed on a PC via the web client of the visualization software. With the exception of the predefined line loss and the electricity price, all the data provided via the gateway could be used for the consumption and loss calculator.

The visualization software was used to create a wide variety of flow diagrams over the course of the project. It was also possible to select individual detailed views with an enlarged display and higher measured value resolution. This visualization shows the flow curve (1) and the average flow curve (2) in m³/h, the daily consumption of compressed air (3) in m³ and the total consumption (4). (Image: DTS GmbH)



All the data provided via the gateway could be used for the consumption and loss calculator. The Excel program thus provided reliable figures on compressed air consumption and loss within different time periods.
(Image: DTS GmbH)

The average consumption of compressed air during the week and at weekends, the average loss in cubic meters per hour and the loss time per week in hours were taken into account.

This made it possible to calculate the energy consumption and the volume flow, so that valid figures on consumption and loss per day, week, month and year were available. And with surprising results, as just two examples show.

7.6 SAVINGS POTENTIAL OF MORE THAN 13,000 EUROS PER YEAR

For example, a faulty pneumatic module on a laser machine resulted in a loss of 1.71 m³/h in 168hours per week and led to annual costs of
395.49euros.

The costs determined for another laser machine were far more serious, amounting to EUR 2,212.86 per year. A large part of these costs were incurred because the machine did not switch off its pneumatically operated axes after the end of a production order and therefore 11.4m³/h (i.e. a total of 1607.4m³) were continuously blown off in 141 hours per week. The machine was in operation for an average of 5.4 hours a day and was idle the rest of the time and at weekends. However, the compressed air losses and therefore costs could have been avoided by switching off the axes manually after each job.

Defective pneumatic module: 1.71 m³/h compressed air loss in 168 hours per week = **395,49** Euro

Pneumatic axes not switched off during machine standstill: 11.4m³/h compressed air loss in 141 hours per week = **2.212,86** Euro

With the help of ipf electronic's solutions, it was ultimately possible to uncover unnecessarily high compressed air consumption and also identify specific optimization potential. After all, at the end of the project work, the calculated total annual costs for compressed air consumption amounted to 23,964.16 euros and the total optimization potential to 13,277.76 euros per year, whereby the costs could be reduced to 10,686.40 euros, i.e. by around 55%, after implementation of all measures.

Total annual costs: **22.964,16** Euro | Annual savings potential: **13.277,76** Euro

7.7 WORTHWHILE INVESTMENT CONSERVES RESOURCES

The successful project work ultimately prompted DTS to invest in several flow sensors, the measurement results of which are to be output regularly in the form of a measurement log. The aim is to detect deviations in compressed air consumption at an early stage in order to be able to react quickly. In addition, warning limits are to be programmed for any malfunctions and appropriate messages sent automatically.

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