Power quality

Solutions for industrial applications

- Maximized operational continuity
- Suitable for harsh environments
- Easy-to-install solution
- Quickly commissioned systems
- Quick return on investment
- Low maintenance requirements
- Maximized sustainability

Quality of electrical power is business critical. As technology advances, electrical tools and machinery become more sensitive to network disturbances (eg, voltage sags), leading to expensive downtime and production loss that impact productivity and revenue.

A power supply affected by harmonics, unbalance and low power factor will lead to penalties on electricity bills, overloading and more rapid aging of electrical infrastructure, thus increasing OPEX and equipment maintenance needs.

ABB offers a wide portfolio of power quality solutions that maximize operational continuity and ensure continuous power for different industrial applications.

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01
Power quality (PQ) trends

Power systems globally are experiencing a transition toward decarbonization of electricity production through the deployment of distributed energy sources (DER). The power electronic converters connecting these systems to the grid can affect power quality.
Power quality in the future is expected to be significantly affected by this shift towards a carbon-free electrical energy system.
Several market trends highlight a degraded power quality in future power systems due to the integration of many power electronics devices, use of power cables at all voltage levels, increasing amounts of fluctuating production and generally reduced system strength.
[See reference 1]

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02
PQ challenges for the industrial segment

Nowadays, facility managers should acquire basic knowledge of power quality to be able to identify (with the help of consultants) operational performance improvements and to be aware of the threats facing their processes and how to mitigate them. Several power quality issues could impact the operation of electrical equipment and the efficiency of industrial facilities.

The most common problems are:
- Sags/swells
- Harmonic distortion
- Spikes/transients
- Voltage unbalance
- Under/overvoltage
- Voltage fluctuations (flickering)
- Poor power factor (PF)
- Power cuts/outages

Figure 1 illustrates how some of these problems affect the shape of a pure electrical sine wave.

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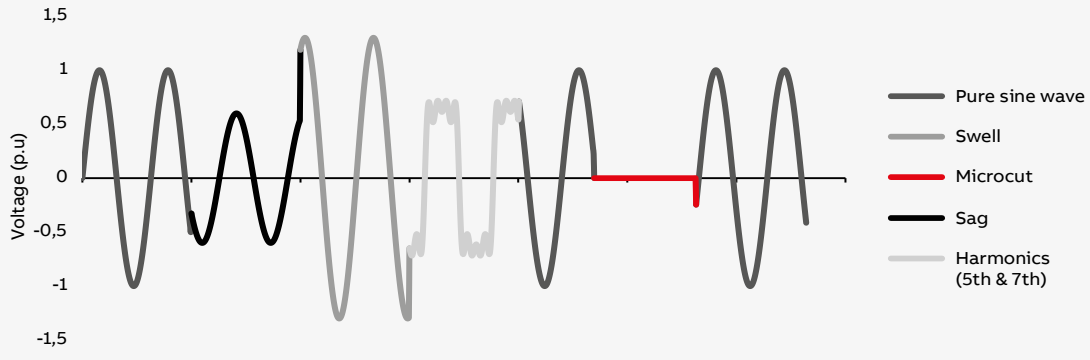
Figure 1 Power quality problems.



PQ problems can originate either from the power grid – for example, due to autoreclosers clearing faults on transmission lines – or from loads within the facility or in another facility connected to the same bus. Load-generated sags arising from large DOL motors inrush currents can also cause PQ problems. Figure 2 shows which types of load can produce PQ problems, which are affected by PQ problems, or, in some situations, which are both source and victim. For instance, induction motors are affected by voltage unbalance and harmonics, but, on the other hand, they typically cause inrush currents during starting, thus generating voltage sags. Induction motors typically have a low power factor and require PF correction.

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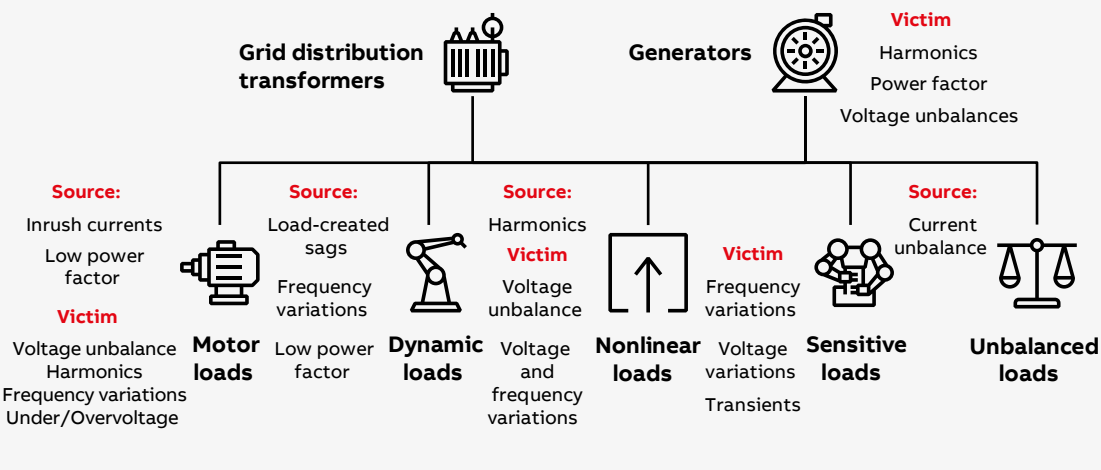
Figure 2
PQ source/victim diagram for electrical loads.



03
Impact of poor power quality in industries

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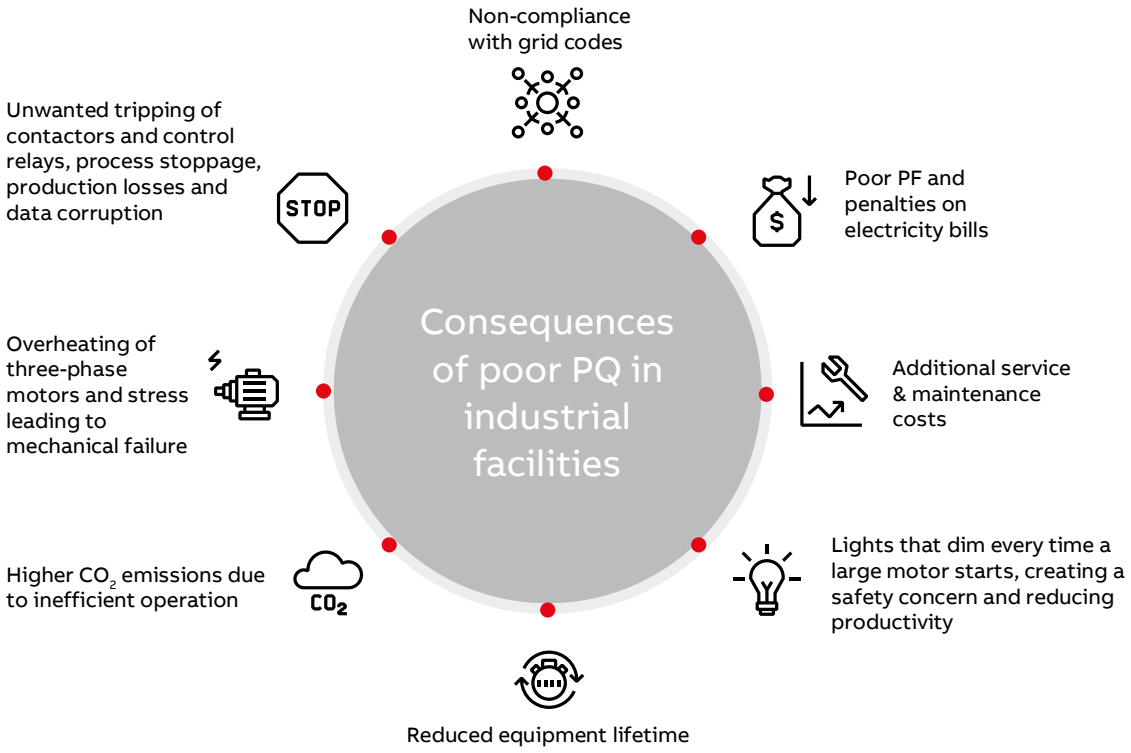
Figure 3 Consequences of poor power quality in industrial facilities.



As described in Figure 3, power quality issues can have serious effects. In business terms, these effects typically translate into negative environmental impact, fixed asset depreciation, operational expenditure increase, safety hazards, downtime and production loss. These consequences of poor power quality can delay scheduled deliveries and affect business reputation.

According to Leonardo Energy "European Power Quality Survey" (see reference 2), it is estimated that industries within the EU are losing more than 150 billion euros annually due to poor power quality. Lack of power supply continuity makes up ~90 percent of this cost, where voltage sags and short interruptions are the costliest factors.

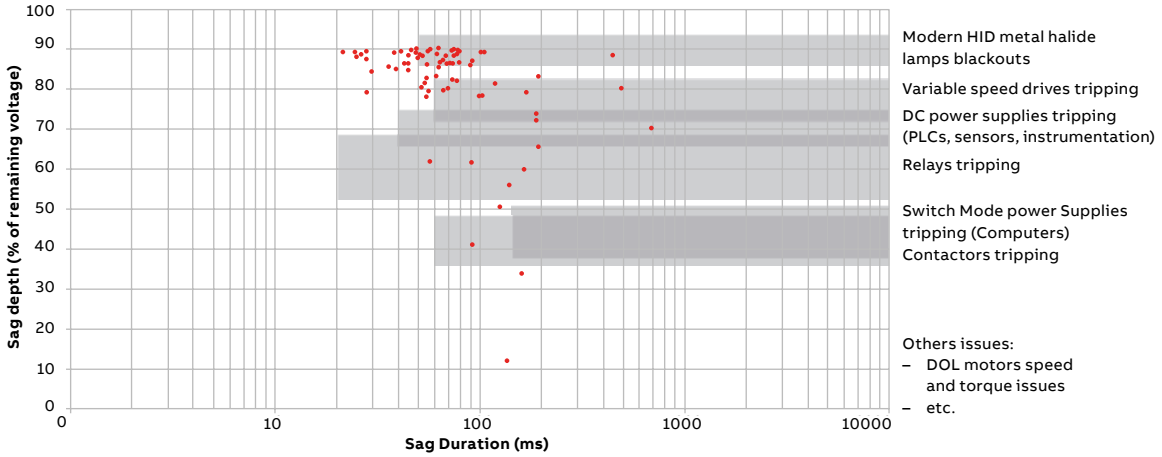


Figure 4 Example analysis of sag data depth/duration and its effect on equipment.

Figure 4 shows an example where voltage sag PQ data are plotted with respect to the remaining voltage, the duration of each event and the effect of such events on various types of loads in the facility.

Much of the equipment mentioned in the figure is used in applications that are critical to an overall process, making downtime due to voltage sags an expensive occurrence.

Having been an expert in the power quality field for decades, ABB can provide a wide range of solutions designed to handle such power quality issues in almost all the most critical and most demanding industrial applications.

04
Power quality monitoring

The first step in determining a facility's PQ situation is to monitor and analyze the power quality. The analysis helps achieve two main targets:

a) Optimization of the power consumption of the process and electrical network.
b) Definition of the appropriate solutions to either correct an already existing problem or mitigate possible issues before they happen.

Several PQ parameters can assist in the decision-making process and can help explain the status of the facility's electrical network:

- Power factor
- Total harmonic distortion (THD)
- Sag depth and duration
- Voltage unbalance
- Current and voltage measurements
- Power outage duration

04.1 PQ monitoring solutions

ABB has PQ monitoring solutions for different applications in industrial facilities.

Embedded Network Analyzer

The Ekip trip circuit breaker monitors power and detects power anomalies like harmonics, micro-interruptions and voltage sags, eliminating the need for dedicated, expensive instrumentation.

The Ekip UP unit can provide monitoring with no impact on the existing installation for ABB and third-party circuit breakers.

All the following parameters are continuously monitored:

- Harmonic analysis (up to 50th harmonic)
- Hourly average voltage values
- Short voltage interruption
- Short voltage spikes
- Slow voltage sags and swells
- Voltage unbalances

The accuracy of the network analyzer's voltage measurements is 0.5 percent and there is an option to add waveform capture and dataloggers that can be viewed from Ekip Link.

M4M Network Analyzer

M4M is the new, fully connected, state-of-the-art ABB network analyzer range that guarantees complete power quality analysis in industrial facilities.

Compliant with the main IEC standards, M4M analyzers provide a complete set of electrical parameters and power quality key performance indicators, from THD to individual harmonics.

M4M network analyzers are certified Class 0,5S for IEC 62053-22 and Class 0,5 for IEC 61557-12, including compliance with specific IEC accuracy classes on power quality KPIs such as voltage and current unbalances (Class 0,2) and THD and harmonics (Class 1).

M4M network analyzers feature:

- Harmonic analysis (up to the 40th harmonic order)
- Demand power management
- Electrical monitoring of equipment
- PF management
- A data logger feature with 32 MB flash memory for time-stamped load profiles and max/min demand of main instantaneous parameters
- Continuous monitoring of voltage and current phasors on each phase and, for waveforms, storage of signal samples over two-line cycles for voltage and current, providing a real-time snapshot of network conditions

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04
Power quality monitoring

04.2 PQ monitoring example

An example single-line diagram (SLD) illustrating potential use cases for ABB solutions in an industrial facility is shown below.

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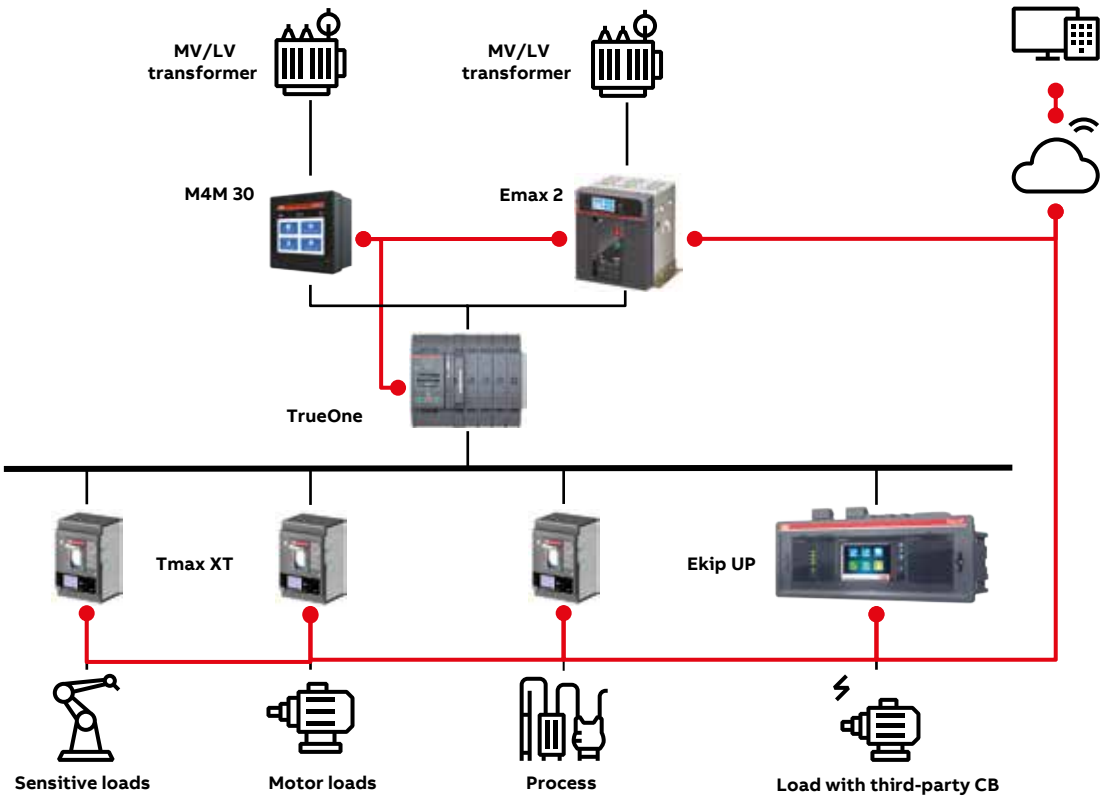
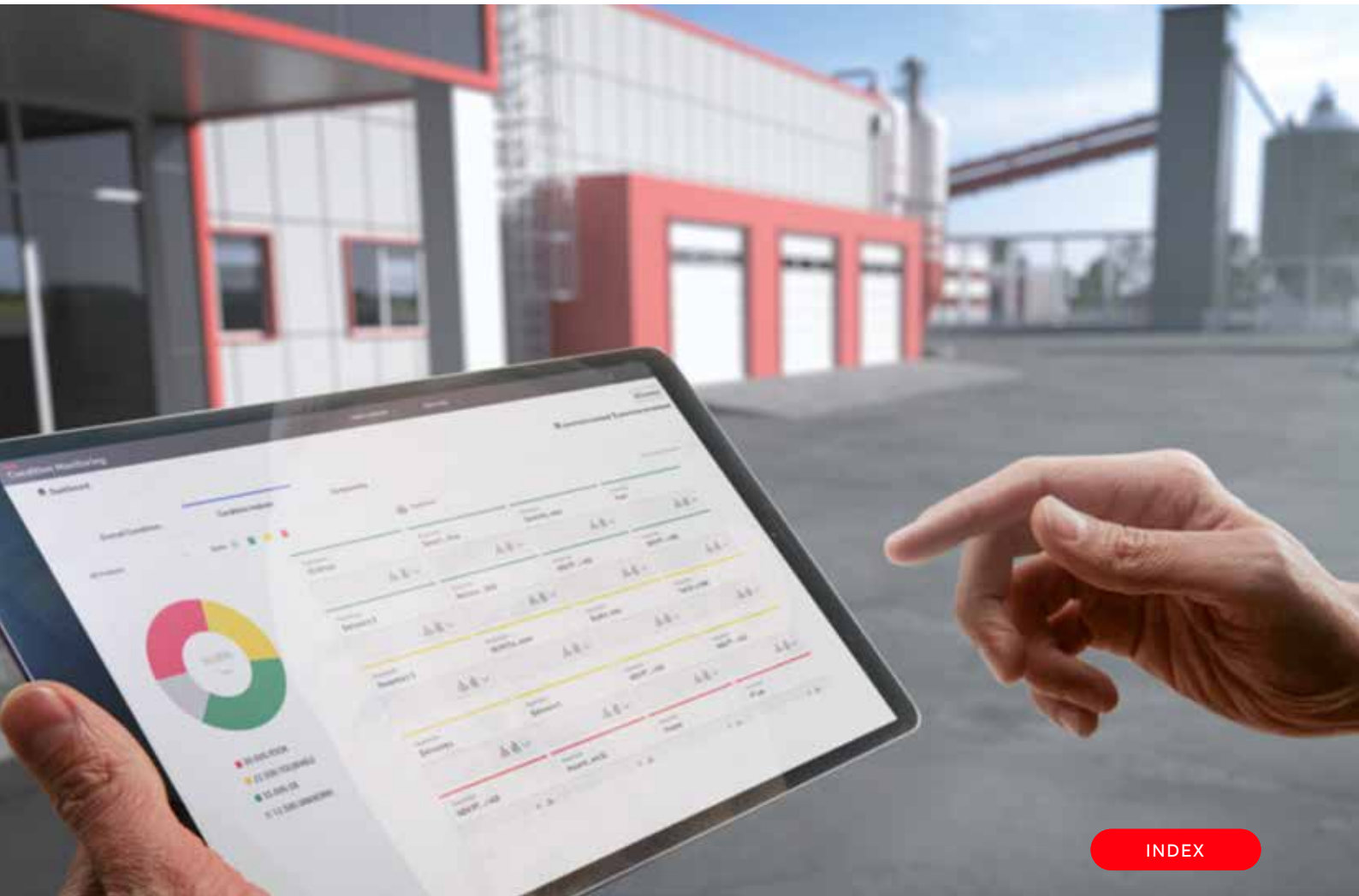
Figure 5.



Product	Use case examples
Emax 2	Verification of facility PQ performance
	PQ inspection/verification at point of common coupling (PCC)
Tmax XT	Monitor equipment in a greenfield project to assist asset health monitoring (ensure power parameters are acceptable to avoid equipment damage)
	Add PQ monitoring capability to upgrade a brownfield site with an already-installed ABB breaker
	Investigate damage in equipment or unexplained interruptions in a production process with already-installed ABB breakers
	Collect data on how to optimize an industrial process and make it more energy-efficient
M4M 30	Monitor bilateral power quality contracts
	PQ measurements (harmonics, unbalances, etc.) based on regulations
	Datalogging one-year historical data of power quality KPIs, including maximum demand and load profiles
	PQ monitoring in compliance with IEC 61557-12
Ekip UP	Troubleshooting in a brownfield site with a third-party breaker
	Upgrade a brownfield site to have PQM with a third-party CB
TruOne	Harmonics measurement/ verification on two different power sources



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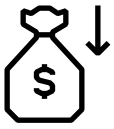
04
Power quality monitoring

04.3 PQ monitoring benefits

Reduce maintenance costs
Enables quick problem identification and resolution to reduce maintenance costs and improve reliability.

Monitoring voltage unbalance helps identify actions to eliminate up to **14 percent** of AC motor premature failures [See references 2].



Reduce electricity bills
Avoid penalties by verification of performance and compliance with regulations and standards.

Improving power factor from 0.7 to 0.9 for a 5 MVA facility saves up to **167 kEUR** in electricity bills annually.

Increase equipment lifetime
Optimizing the power supply and early detection of problems allows longer equipment lifetime.

Monitoring harmonic distortion helps avoid about **50 percent** of a transformer's loss of life due to thermal stresses produced by harmonic currents. [See references 3]

Maximize sustainability
Support CO_2 savings and improve energy efficiency by monitoring a facility's electrical parameters and reducing the energy wasted by poor PQ.

Increasing the efficiency of a continously operating 150 kW system by 1 percent reduces CO_2 emissions by **3.89 tons** annually.

04
Power quality monitoring

04.4 PQ monitoring – digital connectivity

ABB's PQ monitoring solutions can also be integrated into the plant SCADA system, enabling management of alarm thresholds for specific PQ parameters and full awareness of the network connectivity and behavior.
Full integration into ABB's scalable solutions for energy and asset management protects assets and optimizes costs and energy needs.

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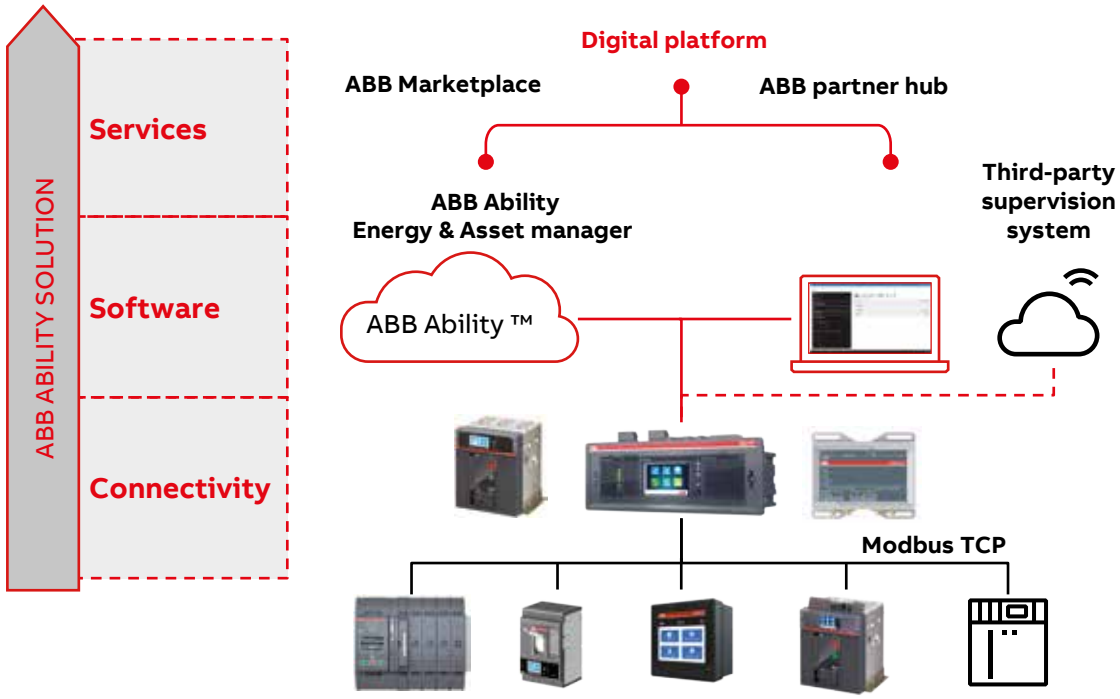
Figure 6 PQ monitoring connectivity example.



05
Power quality solutions

The PQ data gathered from power quality monitoring helps define losses due to power quality issues and identify areas where equipment is performing inefficiently.
The data can be used later to justify any CAPEX investment needed to improve the system performance and mitigate further losses.

After analyzing the power quality parameters in the data received from the monitoring systems deployed in the facility, along with a review of the facility's SLD and utility reliability information, the consultant and the facility engineering team can pinpoint the weaknesses in the electrical infrastructure and the issues arising from the power supply (or from within the internal facility electrical network) that threaten the stability and continuity of supply for their critical and sensitive loads.

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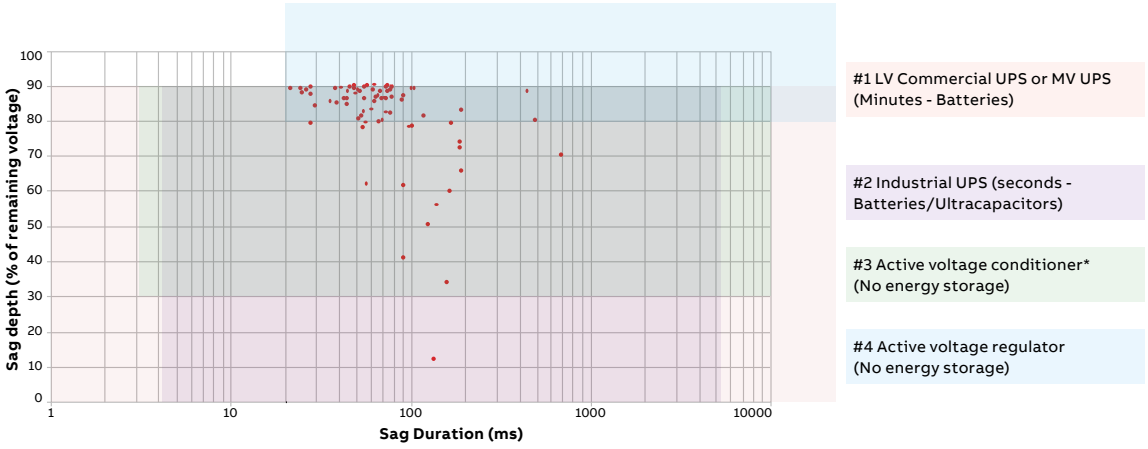
Figure 7 PQ sag data analysis with possible solutions overlaid.



* Based on PCS100 AVC-40 performance during single-phase sag event

Figure 7 shows the same example as figure 4, with the potential solutions that could correct the problem overlaid.

Typically, the solution choice is based on the financial investment involved and ROI compared with the financial and non-financial impact due to the downtime mentioned in the Impact of Poor Power Quality in Industries.

For example, in Figure 7, only one or two events are below the 40 percent remaining voltage level, while most events that can cause problems are in the region between 40 and 80 percent remaining voltage. It might then make sense financially to use a voltage conditioner - if the load is not critical - instead of a UPS, saving the energy storage and covering the most important range of issues.

05
Power quality solutions

05.1 Load immunity solutions

AF contactor range
Suppose the problem facing a facility is voltage sags that are shallow in magnitude and short in duration. In that case, the solution could be to change the contactors in the facility to ABB protection and control solutions represented in

the AF contactors range, which will be an optimal solution to keep the load immune to voltage sags.

The AF contactors range can meet SEMI F47 conditions of use on request.

AF contactors range is the industry benchmark.

The integrated electronically controlled coil offers multiple benefits over conventional alternatives, and together with ABB's wide product range provides optimal configuration every time.

AF contactors are available as 3-pole contactors from 9 A up to 1060 A AC-3 or up to 2850 A AC-1, with AC / DC wide operational voltage range coils.

AF contactors are also available as 4-pole contactors from 25 A up to 525 A AC-1, with AC operational voltage coils, DC operational voltage range coils or AC / DC wide operational voltage range coils.

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05.2 Power conditioning solutions

Voltage variations and sags represent one of the biggest threats to manufacturers and industrial facilities around the world. They can originate from:

Faults on transmission lines that are translated to voltage sags in the LV distribution system.

Weather conditions that heavily affect energy production, eg, on solar farms, where there can be voltage sags on cloudy days and voltage swell on sunny days.

Starting a large motor in a factory, which can cause a voltage drop that affects the loads connected to the same bus.

Arc welders and furnaces, which can cause rapid variations in current, leading to voltage fluctuations that affect lights and human health.

Another problem that affects industrial loads is voltage unbalance. The direct impact of this effect on the working life and characteristics of an electric motor is defined in standards such as NEMA Motors and Generators Standard 1 (MG-1). For example, if the voltage unbalance was at 3 percent, the motor loading should be derated to 90 percent of its rated load. Excess loading reduces motor life significantly and causes the unit to operate with lower efficiency and, in extreme cases, can cause motors to overheat and burn their windings.

05
Power quality solutions

Active Voltage Conditioners (AVCs)
The ABB PCS100 AVC is an inverter-based system that protects sensitive industrial loads from voltage disturbances.

PCS100 AVC has been optimally designed to provide equipment with immunity from power quality events on the supply network.
The PCS100 AVC will:

- Reduce the cost of sag events
- Improve plant operation
- Reduce damage to equipment
- Deliver a good return on investment

This active voltage conditioner has two product variants: the PCS100 AVC-40 for sag correction that goes from 150 kVA up to 3,600 kVA with full correction <10ms and the PCS100 AVC-20 for continuous voltage regulation that goes from 250 kVA up to 3,000 kVA with full regulation <20ms.

Both AVC product variants have important power-quality functionalities such as

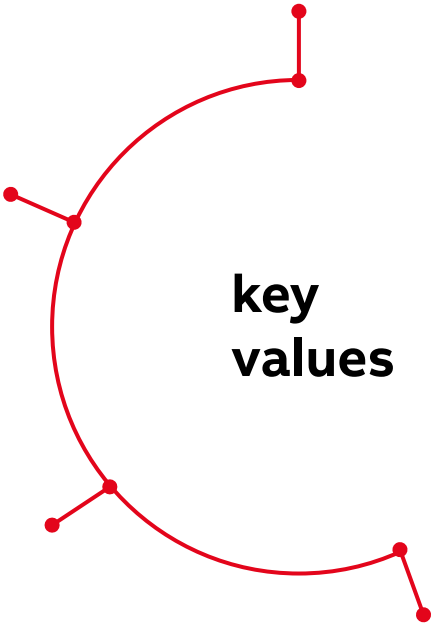
- Correction of voltage unbalance
- Attenuation of flickers from the utility supply side
- Correction of phase-angle errors

Maximized operational availability
The unit's modular construction and fast response time increase operational continuity by protecting sensitive loads and avoiding downtime.

The PCS100 AVC is used by industry giants in a wide range of sensitive applications in critical industries such as semiconductors, automotive, food and beverage, and water and wastewater.

Intuitive design
The design of this AVC has several advantages such as:

- Very fast response time **<Half cycle** for the PCS100 AVC-40 to correct voltage sags
- Small footprint (industry-leading power density)
- Modular construction
- Low maintenance requirements
- High reliability



key values

Maximized sustainability
The PCS100 AVC has a high efficiency of **>98 percent** even at partial loading to optimize energy use and reduce costs. Increasing a continuously operating 150 kW system efficiency by 1 percent reduces CO_2 emissions by **3.89 tons** annually.

Quick ROI
The PCS100 AVC has a low cost of ownership and a quick return on investment. The AVC typically has a payback period of **<1 year**.

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05
Power quality solutions

Reactive Power Conditioner (RPC)
ABB's PCS100 Reactive Power Conditioner is the ideal solution for improving power quality in industrial electrical installations across a wide range of industries.

The PCS100 RPC saves money on utility reactive power charges, it provides:
- Leading and lagging power-factor correction
- Load current unbalance correction
- Load-created sag correction

The PCS100 RPC is a high-performance, modular, power electronic system with instant response. The PCS100 RPC is designed to solve power quality problems by injecting reactive current to stabilize the voltage and control reactive power flow into the AC network. The RPC can provide a very cost-effective solution and correct the most common PQ problems.

The PCS100 RPC is rated from 100 kVA up to 2,000 kVA and can help to mitigate some common supply voltage problems caused by fast-changing loads such as welders or arc furnaces, or fast-changing embedded power generation such as photovoltaic (PV) solar.

The RPC has a 2nd voltage control mode that acts as a mini-Statcom in industrial microgrids to provide voltage clamping and avoid fluctuations.

Benefits
- High overload capability up to 200 percent
- Very fast response within milliseconds
- Modular construction and industry- leading footprint

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05.3 Power protection solutions

ABB has the bases covered when it comes to power protection of sensitive loads. Covering applications from control rooms through to complete industrial plant protection, ABB has the uninterruptible power supply (UPS) technology for every need. From a few kW to applications of many MW and a wide range of supply voltages to protect against deep voltage sags, power cuts and complete outages.

PowerLine DPA
PowerLine DPA is an online double conversion UPS that ensures clean power to critical industrial applications with varying temperatures, humidity conditions and levels of pollution.

PowerLine DPA features a 15-year design life for maximum reliability and uptime. Each module has all the hardware and software necessary for autonomous operation, from rectifier to inverter, battery charger, static bypass switch, back-feed protection, control logic and HMI mimic display for control and monitoring.

PowerLine DPA is designed for industrial environments and provides:

- Protection against deep sags, power cuts and several minutes of outage (full power protection).
- High efficiency, up to 95 percent, and high short-circuit and overload capability.

Benefits

- Maximized availability thanks to modularity of design
- Fail-safe design with no single point of failures
- Short mean time to repair

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05
Power quality solutions



	1ph UPS	3ph UPS - standalone	3ph UPS – modular
IEC offering	PowerValue • 11T G2 (1-10 kVA) • 11RT (1-10 kVA) • 11/31T (10-20 kVA)	PowerScale • 10-50 kVA PowerWave • 33 60-500 kW	DPA UPScale • 10-200 kW DPA 250 S4 • 50-250 kW
Segments/applications	• Small IT rooms • Building • Control rooms	• IT / server rooms • Building • Light industries	• IT / server rooms • Telecom • Building



	UPS – industrial applications		3ph UPS – Medium Voltage
IEC offering	PowerLine DPA • 20-120 kVA	PCS100 UPS-I (single conversion process UPS)	PCS120 MV UPS 2.25 MW • 7.2 kV IEC (6 - 6.6 kV) • 12 kV IEC (10 – 11 kV) • 24 kV IEC (20 – 22 kV)
Segments/applications	• Chemical, oil & gas • Mining • Critical process & automation	• Chemical, oil & gas • Mining • Critical process & automation • Semiconductor • Manufacturing	• Chemical, oil & gas • Mining • Critical process & automation • Semiconductor • Manufacturing

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06
Application examples

06.1 Cost of downtime

“Eight key U.S. market segments studied by energy consultant E Source forfeit about $27 billion per year due to power outages. On a more granular level, the E Source report found that manufacturers tend to suffer the most from long outages, followed by financial service companies, healthcare, and grocery stores”

E Source market resource "Outages costs."
See reference 5

“In manufacturing, a recent survey found that more than a quarter of manufacturing businesses experienced an outage at least once a month in 2017, with 58 percent reporting an outage lasting longer than an hour. For large manufacturing enterprises, a single hour of downtime tops the $5 million mark.”

Bloom Energy blog "A day without power: outage costs for businesses."
See reference 6.

The statements above show the devastating effects of an outage for an industrial facility.
The cost of downtime due to poor power quality can include labor cost, lost revenue due to downtime, production loss, damaged material, damaged equipment, etc.

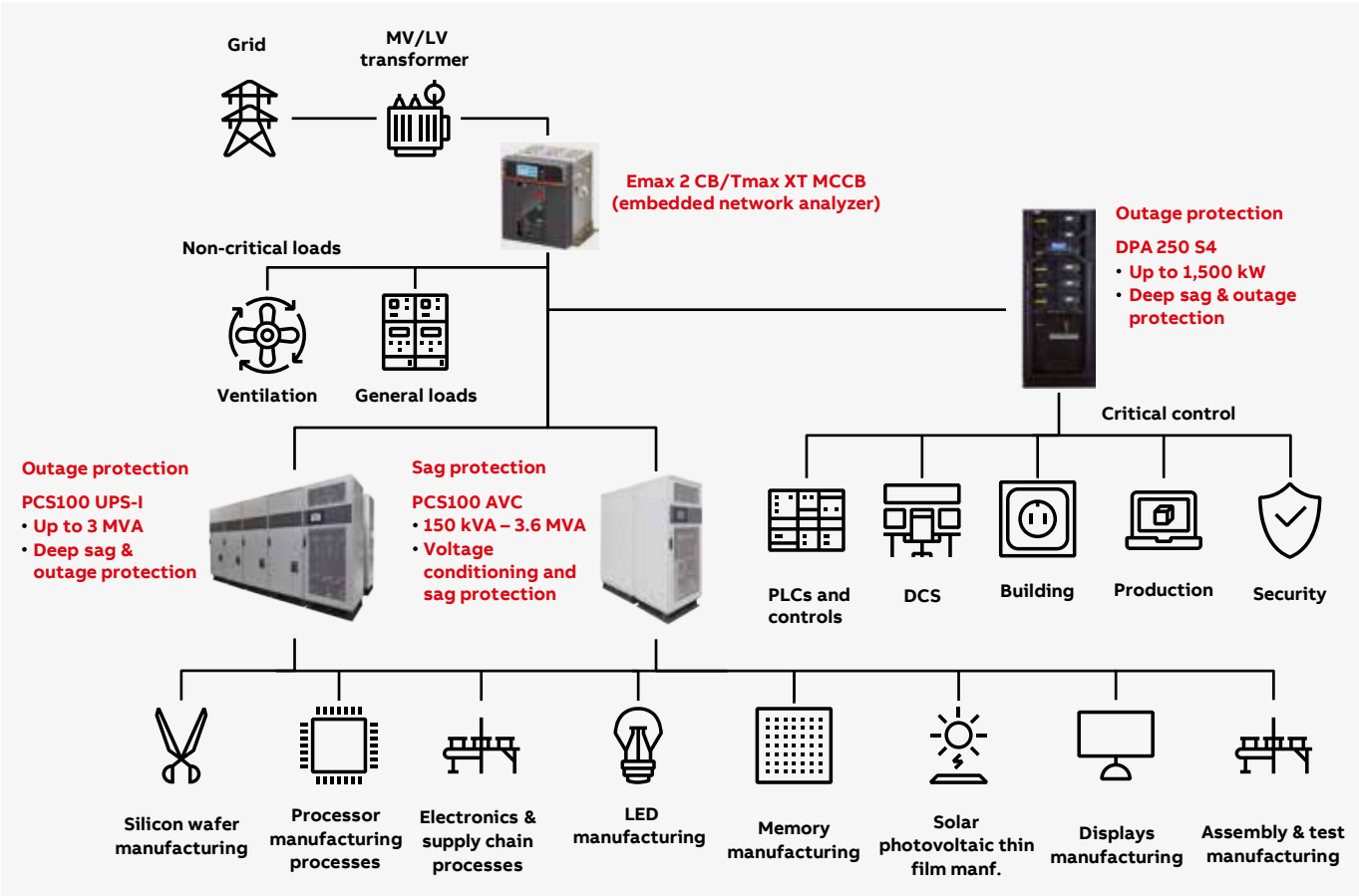
06
Application examples

06.2 Semiconductor industry

The semiconductor industry has some of the most demanding applications in motion control. A combination of extreme accuracy and precision requirements makes power protection super-critical. The cost of lost production, poor quality, downtime and, eventually, lost profit and market share, can be massive for semiconductor FABs. The cost of a single power disturbance in a semiconductor facility can be as high as 3.8 million euros (see reference 7).
The semiconductor industry has several manufacturing segments that require power conditioning and protection, such as silicon wafers and ingots, memory chips, processors, sensors, power devices, displays, light-emitting diodes, electronics and solar photovoltaic cells.

The decision whether to use an AVC or UPS is based on the PQ monitoring analysis as well as how critical clean power is for the application. In a typical semiconductor fabrication plant, critical areas that depend on a continuous, clean electricity supply are lithography, etching, chemical vapor deposition and implantation. A voltage sag or interruption, especially those beyond the SEMI-F47 profile, will cause equipment to trip and stop, causing downtime and material wastage throughout the entire process. Besides production equipment, supporting facility equipment such as pumps and chillers should also be protected against poor power quality.

Figure 8



06.3 Food and beverage industry

In the F&B industry, power supply disturbances can interrupt the operations of the precision machinery used in production, resulting in:

- Lost material
- Loss of certain production units
- Non-delivery and hours spent clearing and cleaning equipment to restart
- Contamination issues
- Long delays

Power problems can lead to millions of dollars of unnecessary costs and – much worse – dangerous health situations.

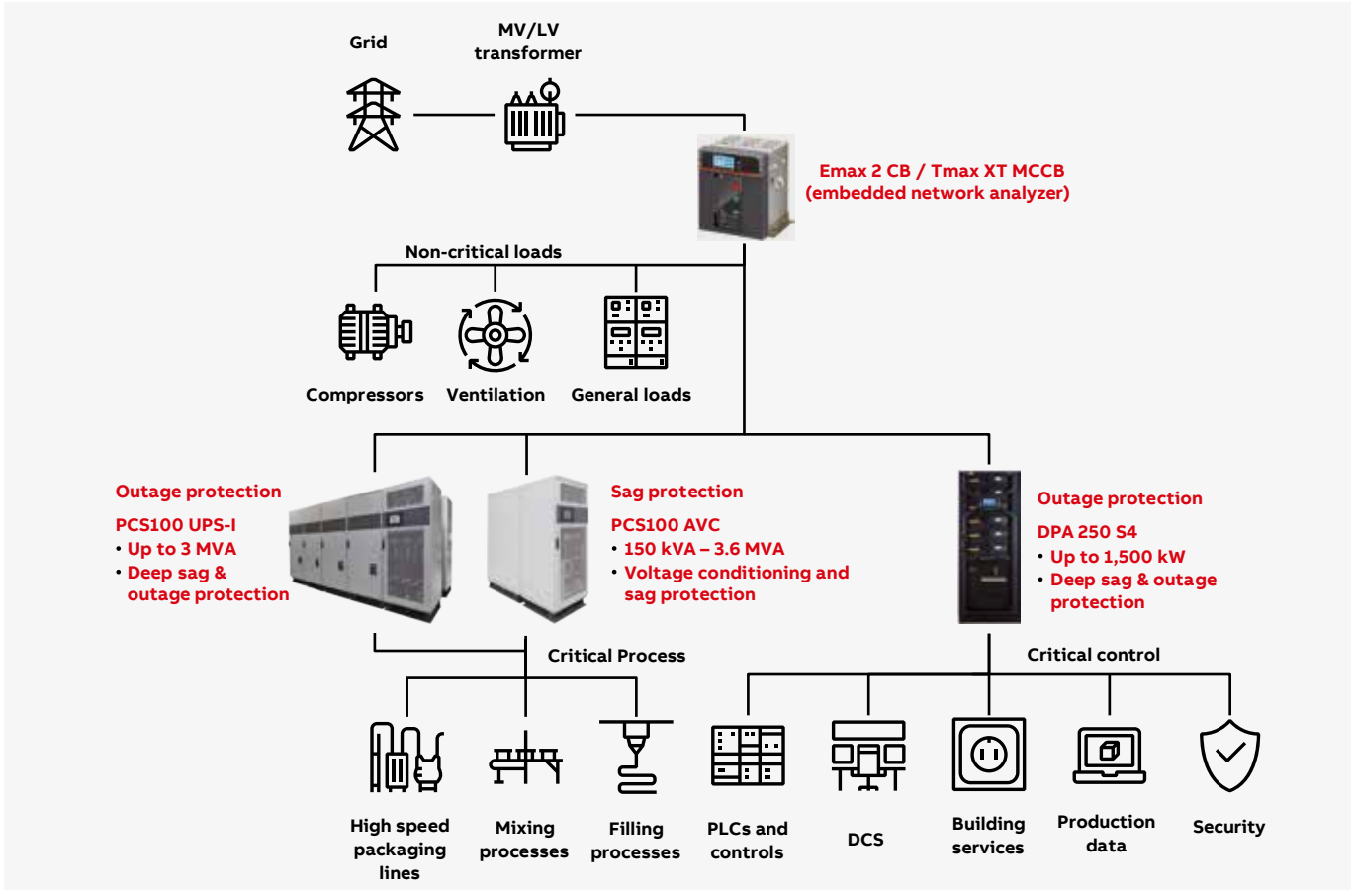
F&B has several segments that require power conditioning and protection, such as bakery and confectionary, beverages, dairy, edible oil, grain, meat, poultry, seafood, sugar and aquaculture.

For example, dairy producers must precisely track the temperature of their milk throughout the process, so even a small power system disturbance can mean discarding an entire batch of perfectly good product if it causes temperature sensors to fail.

Also, any unexpected downtime can cause spoilage, resulting in the dumping of valuable milk products. Lost production time, while more milk is sourced and sterilized, can cost many hours and many thousands of dollars.

Cost of downtime is estimated by industry analysts to be between $100,000 and $1 million per hour.

Figure 9



06
Application examples

06.4 Water and wastewater industry

A typical water treatment plant's electrical load profile is different from most other industries in that two or three major loads consume most of the electrical power and govern the power quality. These loads are usually large motors for water pumps, compressors and aerators.

As in any business, power quality issues result in severe side effects:
- Energy losses
- Low efficiency
- Unplanned stops or unreliable functionality of equipment

These can have devastating consequences for the public.
The water industry has many segments that need power protection, such as water and wastewater treatment, desalination, pumping stations and water transmission and distribution.

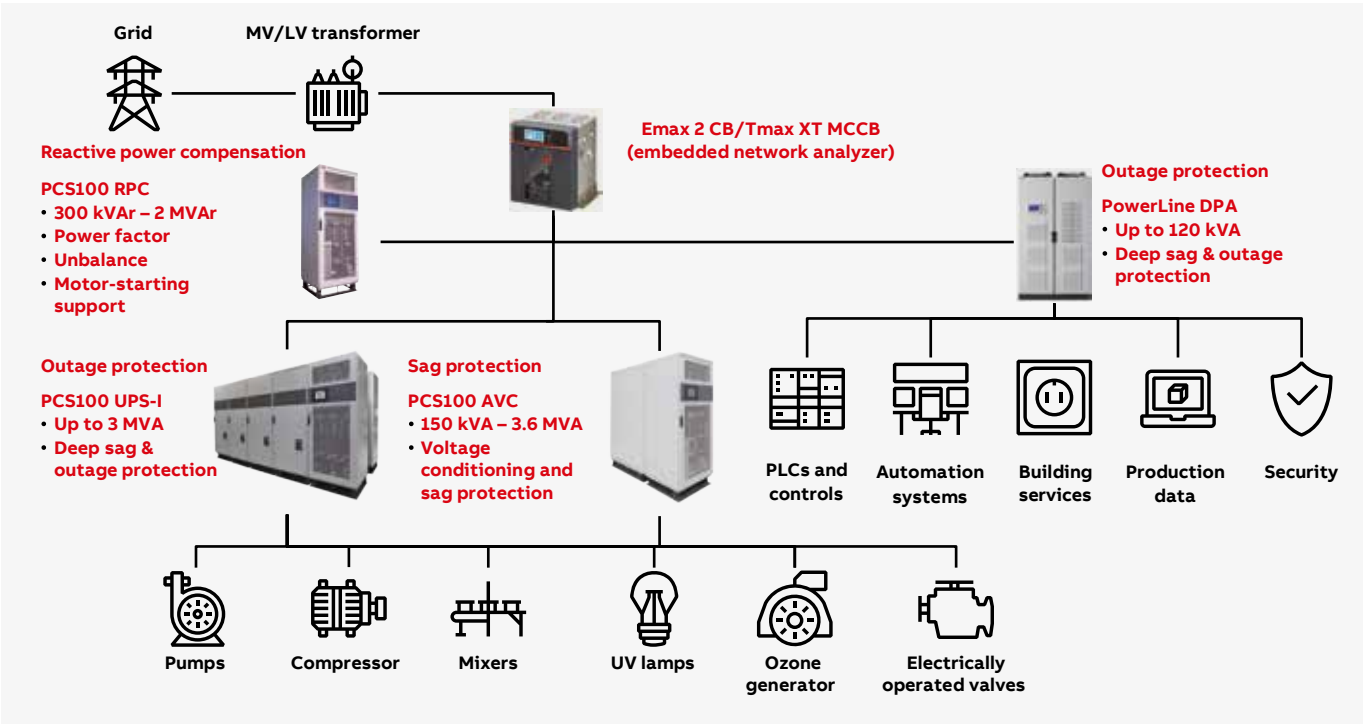
If processes impacted by poor power quality involve biological stages, living organisms are affected, making the consequences even more severe.

One example of such a process is sterilization using a submerged UV lamp. This treatment method is becoming popular as a way to achieve required water quality standards at a reasonable cost.

A 5 percent drop in voltage equates to a 10 percent drop in UV lamp power. Any larger sag will result in unacceptably low UV intensity levels. Typically, if the supply sags to 65 percent of nominal supply for as little as 35ms, the UV lamp will shut down. It will automatically restart only after the bulb has cooled down sufficiently to allow a re-strike, which can take as long as 5 to 10 minutes.

Unfortunately, during this time, water passes through the system and emerges untreated. In this instance, untreated water must be ejected from the system or managed with an alternative process.

Figure 10



06.5 Chemical, oil and gas

Oil and gas operations typically take place in environments that are harsh for electrical equipment, especially if it utilizes power electronics. Such conditions typically mandate the use of robust, reliable power conditioning and protection products to protect sensitive loads and applications.

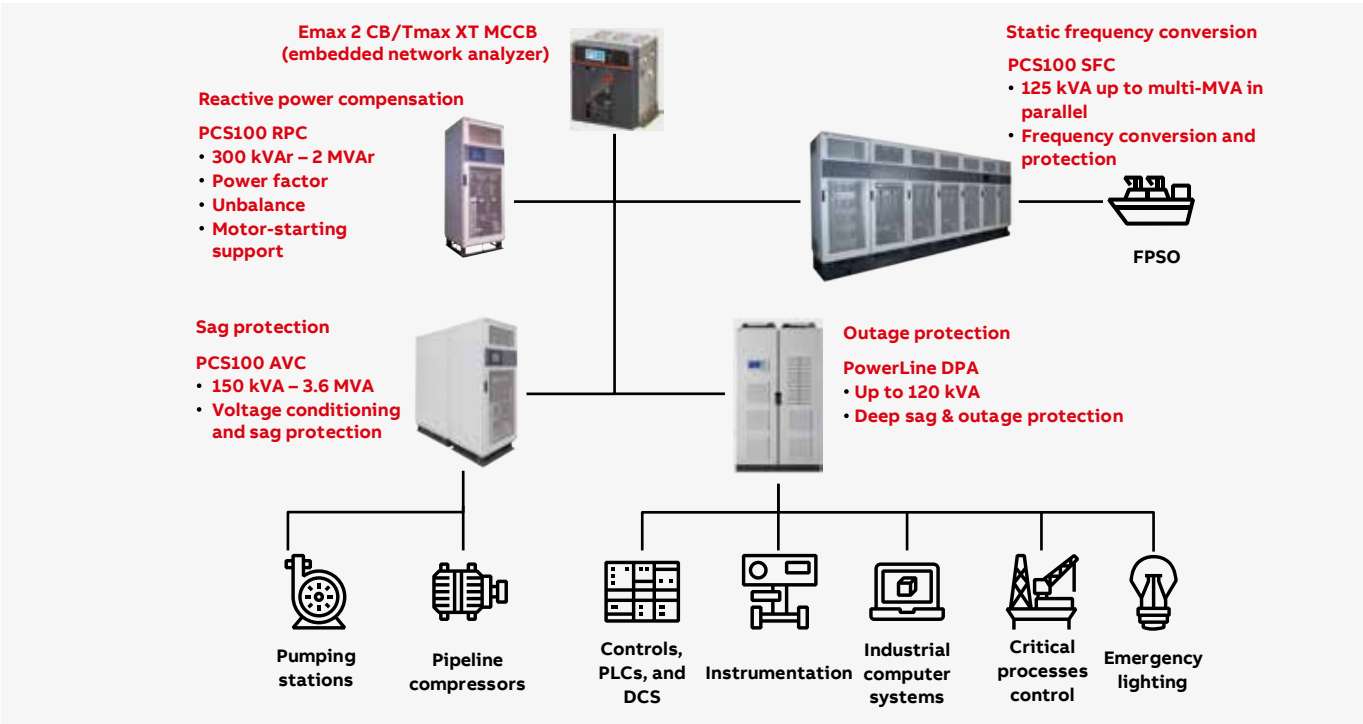
Oil and gas operations are driven by increasing environmental pressures and the quest for more efficient, cleaner and cheaper production methods. Success in this business environment requires advanced technology, both in equipment and in control functions.

ABB's comprehensive portfolio of UPSs offers proven solutions to protect processes and systems in the chemical, oil, and gas industries. ABB can provide backup power for all systems for upstream, midstream and downstream applications – such as emergency shutdown, process control systems, gas turbine control, motor control, navigation, automation and data processing (control rooms, SCADA systems).

For example, refineries and processing plants use DCSs, PLCs and sophisticated industrial computer systems to control the equipment that requires power protection. Without power protection for these systems too, millions of dollars can be wasted annually in resources and materials should power problems affect them.

To avoid production loss and equipment damage in oil and natural gas refineries, it is crucial to minimize electrical disruptions and prevent power failures. Ensuring a reliable power backup for vital loads such as a DCS or emergency switchgear panels improve the productivity of the plant.

Figure 11



07
PQ solutions summary for industrial applications

Power quality monitoring

ABB solutions for PQ monitoring of electrical installations

Tmax XT | Emax 2 | Ekip UP

M4M Network Analyzer

Transient surge protection

Solutions to protect against transient surges for industrial, commercial and residential applications

Surge protective devices (SPDs)

Reactive power compensation

Active power factor correction solution for industrial applications and data centers

PCS100 RPC

Voltage and frequency protection

Active voltage conditioning solutions for industrial and commercial applications

PCS100 AVC-20 - PCS100 AVC-40

Static frequency conversion solution for frequency-sensitive load protection, cogeneration and industrial relocation

PCS100 SFC

Power cuts and outage protection

Wide range of ABB solutions to protect against utility deep sags and outages

PowerLine DPA

PowerValue 11T G2
PowerValue 11RT
PowerValue 11/31T

DPA 250 S4
(modular)

PCS100 UPS-I

PCS120 MV UPS

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March 2008
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