Remotely monitoring functionality and availability of Metsä Group's bioproduct mill

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The advent of the internet era has enabled Collaborative Operations to rapidly emerge. It encompasses performance management, remote monitoring and analytics to improve availability, performance and quality, whilst ensuring cyber security. It also allows pulp and paper mills to leverage their expertise by using the data-driven ecosystem that is created through collaborative operations engagement, connecting people within their enterprise-wide production facilities and headquarters, and to suppliers' technology and global expertise.

Metsä Group's new bioproduct mill, Metsä Fibre in Äänekoski, Finland, has connected the ABB electrical systems installed at the mill to the ABB Ability™ Collaborative Operations solutions portfolio. The solutions include remote monitoring of electrical systems using cloud services, and remote access to ABB experts 24/7, with the aim of raising performance and reliability of the electrical systems to a new level.

KEY EQUIPMENT IN A PULP MILL POWER SYSTEM

- High voltage switchgear for grid connection (Mill Substation)
  - 110 kV gas insulated switchgear
  - Protection relay system
- Medium voltage switchgear units for plant distribution (33 kV Power Distribution)
  - Four 33 kV gas insulated switchgear
  - Protection relay system
- Low voltage system for plant process power supply and distribution
  - Low voltage 690 V and 400 V motor control centers – 1000 meters – for 2400 motors
  - Protection relays system on incomers
  - Low voltage breakers (ACB's) – also connected to collaborative operations system
- Totally the mill power distribution control and monitoring system includes close to 200 protection relays connected to collaborative operations system with IEC 61850
- Distribution transformers
- High voltage motors for large feed water pumps
- Low voltage motors for rotating equipment on the process
- Variable speed drives to enable accurate process control and energy savings
  - Over 700 low voltage drives for accurate process control
  - medium voltage drives for feed water pumps
- Uninterruptible power supply – UPS
  - 14 UPS systems in different process areas

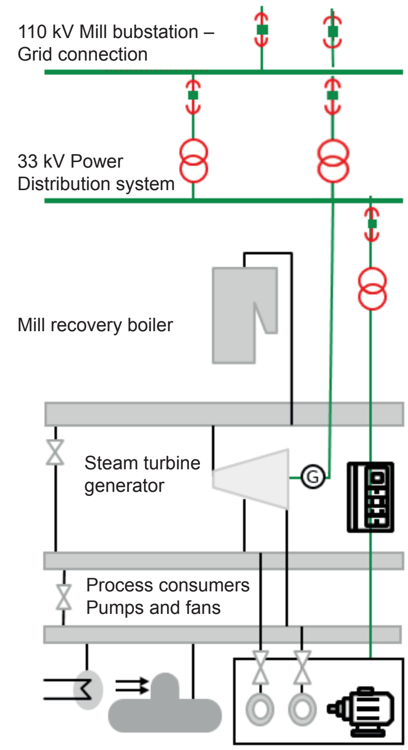

Figure 1. *A typical pulp mill power system.*

OPERATIONAL NEEDS

Metsä Group's bioproduct mill has an output of over 1.3 million tons of pulp per year. It started up in August 2017, and features the highest levels of energy, material and environment efficiency in the world. The electricity self-sufficiency of the bioproduct mill is some 240%. The mill produces 1.8 TWh of electricity per year – the equivalent of 2.5% of total electricity production throughout Finland.

Such cost and environment efficiency requires stable and reliable process control that helps keep production costs down – for instance, by minimising raw material usage and ensuring low energy consumption. In addition to outstanding process control, a reliable power system helps to avoid process disturbances.

The supervision of a large amount of electrical equipment and related technical data creates an additional issue for the mill operation and maintenance personnel that is unique in today's mills. Therefore, a system that can locate & identify any early warning signals from the electrical equipment before failure, to give maintenance people time to address the problem before it comes out, is of high value to the customer. However, if a shutdown is required to fix the problem, the customer preference is to have time for a planned, controlled

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shutdown, providing a window to prepare and carry out other urgent maintenance actions in the pulp mill.

The pulp mill electrical power distribution system starts with the connection to the high voltage power grid and continues with the mill's internal medium voltage power distribution network that feeds different parts of the mill. The steam turbine generator feeds power to the mill high voltage power grid.

All of the electrical equipment has failure modes that represent a risk to availability of production. High and medium voltage disturbances could cause large section stoppages or complete mill shut down, and low voltage equipment could cause process disturbances in their related department. Redundancy can be built in for many critical applications, but most of the equipment could potentially cause an unplanned shutdown. There is a need to manage electrical system reliability and availability for the lifecycle of plant. This drives certain operational needs:

- Tools to monitor single pieces of equipment, as well as the whole system's equipment reliability and availability
- Early identification of warning signals, which typically indicate impending failures
- Decision support for how to prioritise maintenance and shutdown activities
- Estimate equipment remaining lifetime and define the right time to replace it
- Reduce time needed for troubleshooting in failure situations
- Validation of original design and operational parameters during production ramp-up phase

OVERALL EQUIPMENT EFFECTIVENESS IS A COMMON WAY TO MEASURE PRODUCTIVITY

To measure any industrial plant performance, Overall Equipment Effectiveness (OEE) is typically used. OEE is the result of three factors which form one indicator to measure total effectiveness.

OEE = A × P × Q

Availability – is reduced by equipment failure, setup and adjustment.
Performance – is reduced by idling and lower speed.
Quality – is reduced by process defects and startup losses.

Improvements in OEE can be made by enhancing one or more of the three contributing areas:

Availability – can be improved by avoiding unplanned downtime caused by failures, by detecting them before they occur. Availability can also be increased by reducing troubleshooting and repair times by having all relevant information immediately available, and by having backup support from supplier specialists.

Performance – can be positively impacted by detecting possible bottlenecks and performance issues from equipment data.

Quality – can be improved by cooperative efforts toward process optimisation by using precision measurement from the electrical equipment, for example high-resolution measurements from the drive system.

EQUIPMENT MONITORING

In a pulp mill, the usage of individual equipment varies according to the process area, applications and production volume. Knowing how equipment has been used and in which environmental conditions are key to making smart maintenance decisions that will improve OEE. Collecting all needed data and transforming it into useful information for maintenance

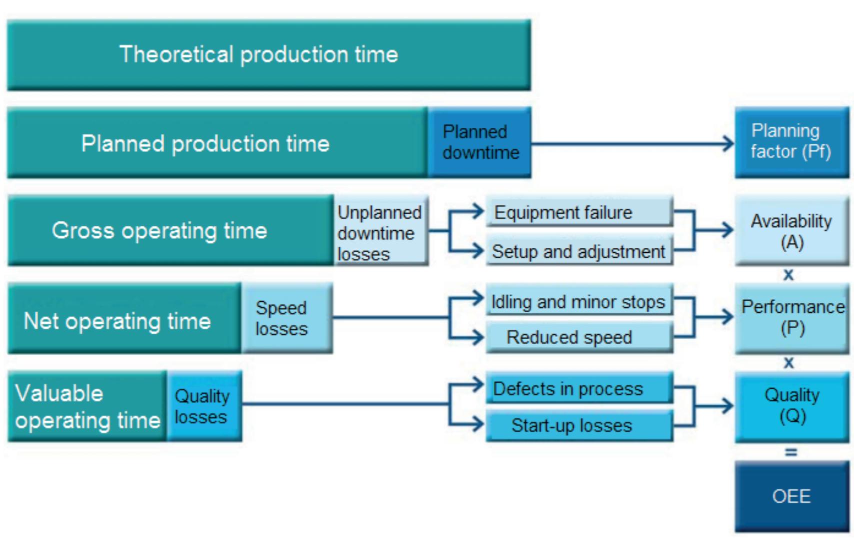


Figure 2. *OEE model, in the context of plant electrical equipment.*

There is a need to manage electrical system reliability and availability for the lifecycle of plant

staff is the most important requirement for a condition monitoring system. The electrical system in this user case is monitored in such a way to support the mill's overall OEE objectives.
The following sections describe the monitoring methods by equipment category.

High and medium voltage

Modern protection relays monitor the electrical network and protect it in a failure situation to limit impact to the smallest possible area. Today, relays are also used as a data source to monitor switchgear and breaker operation and condition. Breaker maintenance is usually based on the number of operations and other measurable values. Typically these operations are being measured by protection relays, but not efficiently collected and utilized for maintenance decisions.

Examples of monitoring points for high and medium voltage equipment in this case:

- ANSI and IEC standards define circuit-breaker mechanical endurance ratings that impact mechanism designs, and typically range from 1,500 to 10,000 operations. Information on the number of operations is directly used to schedule next breaker maintenance.
- Inactive time indicates in days how long a breaker has not been operated and could result in the need to open and close it to validate its functionality.
- Breaker wear is determined by how many normal and short-circuit operations the breaker has experienced. Excess wear can be detected and the appropriate maintenance planned.
- Self-monitoring of protection relays indicates internal or protection circuit failure which should be investigated and repaired quickly to minimise the risk of larger failures.
- Protection system coordination in failure situations can be validated against design values when detailed recorder data is stored and easily available.

Low voltage breakers

Low voltage breakers have built-in protection with additional condition monitoring features. When breakers are operated several times per hour, it leads to a need for more frequent maintenance between scheduled plant shutdowns. Based on breaker operation and condition, data-driven decisions can be made to improve reliability, for example:

- Maintenance interval of installed 800A to 5000A breakers is between 1500 to 5000 operations. The number of operations is used to schedule the next time for maintenance. In some applications, breakers may be heavily operated; this could lead to a situation where maintenance is needed much earlier than scheduled in the maintenance management system. Active monitoring provides warnings in these situations in order to schedule maintenance at the right time.
- Breaker internal contact wear monitoring is used for estimating the maintenance need. Numerous full load operations of breakers cause excessive wear on contacts and could lead to breaker damage if not replaced on time.
- Self-monitoring is done on current measurements and tripping circuits. In case of failure, investigation and repair is done in a timely manner to minimise the risk of larger failures.

UPS (Uninterruptible Power Supply)

UPS systems needs regular monitoring and maintenance to ensure maximum reliability. The battery is the most vulnerable part of any single UPS system, regardless of its capacity, topology or brand. Understanding the causes of battery degradation is important to prevent failure, and maintenance actions are fundamental to ensuring the highest system availability. Reasons for batteries prematurely failing in a single UPS system can be:

- The number of charging and discharging cycles affects the service life of the battery.
- Improper charging and discharging – the lifetime of a battery can be greatly affected by the current and voltage control on the battery during charge and discharge cycles.
- Batteries will have a shorter life when operated at a higher temperature.

Drives

Variable speed drives are used to enable smooth process control and energy savings. Hundreds of pumps and fans are controlled with drives; their reliability and availability have a major impact on plant productivity. Failures typically cause production slowdown or full stoppage.
Drives are electronic devices where

Knowing how equipment has been used and in which environmental conditions are key to making smart maintenance decisions that will improve OEE

usage and environment has the biggest impact on their reliability:

- Drives are typically specified to operate in up to 40°C ambient at full load. Even as they work at high temperatures, their expected lifetime and reliability will be heavily reduced in such conditions. Optimal ambient conditions are low humidity, and maximum 25°C ambient. Monitoring of environmental conditions based on available drive signals helps to maintain electrical room temperatures at optimal levels.
- Drives are typically air cooled with fans, both externally and internally. The lifetime of a cooling fan is typically 3 to 10 years. Continuously monitoring the cooling fans helps to reduce the risk and helps to plan the right timing of cooling fan replacements.
- Drives' internal components (such as semiconductors and capacitors) impact their life cycle. Certain conditions such as cyclic loads can significantly reduce these components' (and therefore the drives') life cycle. Monitoring algorithms are used to identify the conditions that can shorten the drives lifespan. Improvements in control or conditions can then be applied in advance to extend the expected drives lifespan.

Edge computing is defined as solutions that facilitate data processing near the source of data generation, usually on site

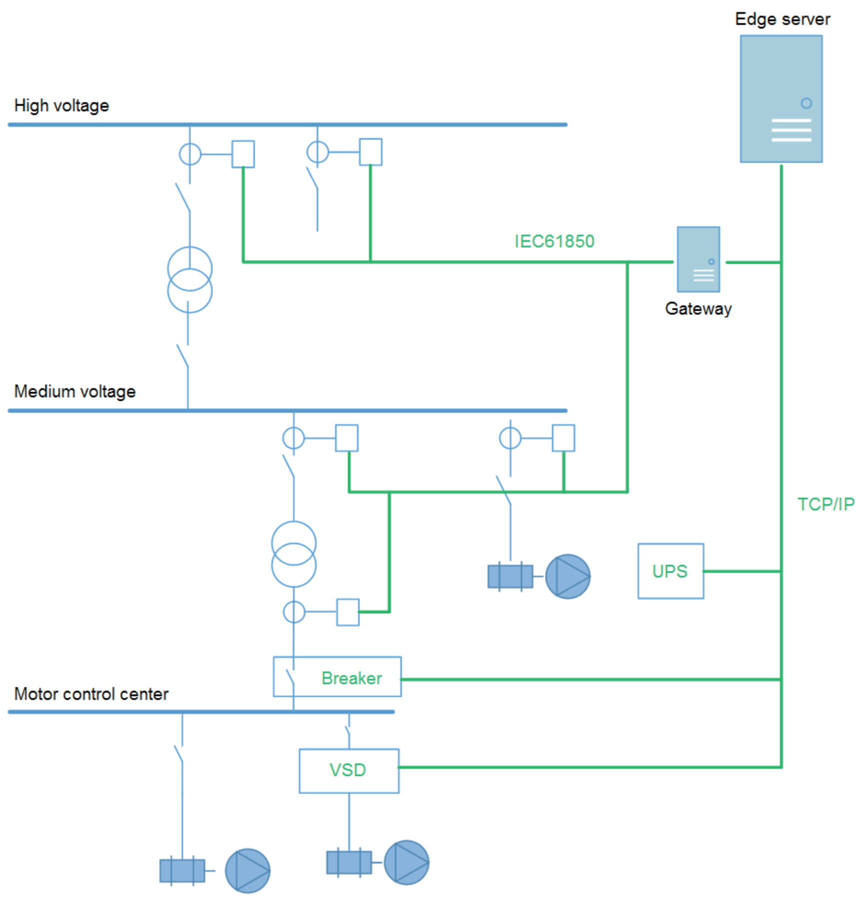


Figure 3. *Metsä Fibre's condition monitoring architecture for its electrical system.*

Communication

The local communication to equipment is based on industry-standard Ethernet protocols (such as the IEC 61850 standard regulating the communication of the electrical power grid), which facilitates open systems, flexible architectures and ensures interoperable systems for a future-proof investment. Today's protection relays are communicating over the IEC 61850 protocol, which enables efficient data collection. In addition to control and monitoring signals, maintenance related signals are also transmitted using Modbus TCP – an Ethernet based protocol used to connect breakers and variable speed drives. (Figure 3 shows the communication architecture).

Edge Computing

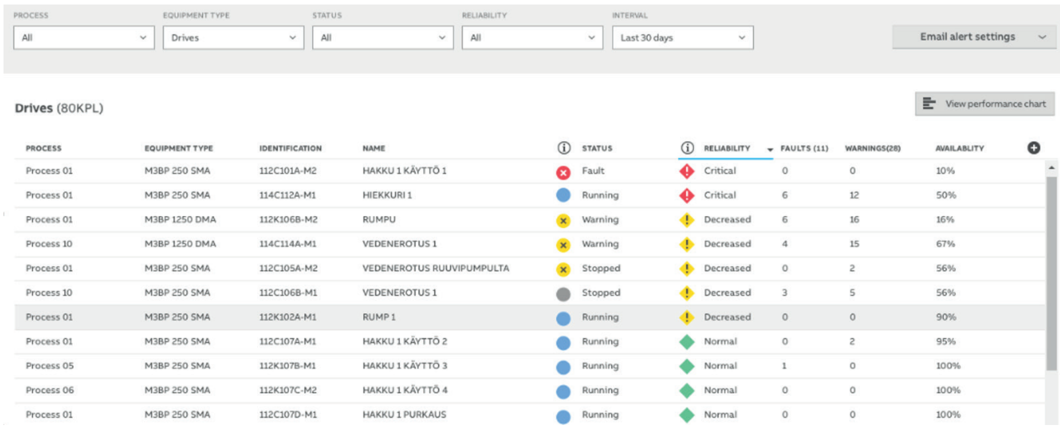
Edge computing is defined as solutions that facilitate data processing near the source of data generation, usually on site. Equipment normally communicates data directly to edge servers. Edge data storage and processing power needs to be dimensioned for the right balance of data resolution and intermediate data storage. High-resolution data is used for trouble-shooting purposes and can be stored for a few months. Averaged or compacted data becomes useful after months or years of operation.

In this particular case, an average of 40 signals are collected from each electrical device every second:

- Currents and voltages
- Power
- Speed and torque
- Internal controller signals

A sampling interval of minute, hour or day is applied for slow changing signals:

- Temperature
- Service counters
- Wear indicators



PROCESS	EQUIPMENT TYPE	IDENTIFICATION	NAME	STATUS	RELIABILITY	FAULTS (11)	WARNINGS(28)	AVAILABLITY
Process 01	M3BP 250 SMA	112C101A-M2	HAKKU 1 KÄYTTÖ 1	Fault	Critical	0	0	10%
Process 01	M3BP 250 SMA	114C112A-M1	HIEKKURI 1	Running	Critical	6	12	50%
Process 01	M3BP 1250 DMA	112K106B-M2	RUMPU	Warning	Decreased	6	16	16%
Process 10	M3BP 1250 DMA	114C114A-M1	VEDENEROTUS 1	Warning	Decreased	4	15	67%
Process 01	M3BP 250 SMA	112C105A-M2	VEDENEROTUS RUUVIPUMPULTA	Stopped	Decreased	0	2	56%
Process 10	M3BP 250 SMA	112C106B-M1	VEDENEROTUS 1	Stopped	Decreased	3	5	56%
Process 01	M3BP 250 SMA	112K102A-M1	RUMP 1	Running	Decreased	0	0	90%
Process 01	M3BP 250 SMA	112C107A-M1	HAKKU 1 KÄYTTÖ 2	Running	Normal	0	2	95%
Process 05	M3BP 250 SMA	112K107B-M1	HAKKU 1 KÄYTTÖ 3	Running	Normal	1	0	100%
Process 06	M3BP 250 SMA	112K107C-M2	HAKKU 1 KÄYTTÖ 4	Running	Normal	0	0	100%
Process 01	M3BP 250 SMA	112C107D-M1	HAKKU 1 PURKAUS	Running	Normal	0	0	100%

Figure 4. *Overview page for the monitoring application.*

- Software versions
- Setting parameters
- Nominal values

Approximate 10Tb of data is collected annually in this specific case. To optimise use of data storage, high resolution data is stored for three months for troubleshooting and calculation purposes. Minute or hourly averaged values are stored for 20 years as a foundation of future analytics. This long-term history data is more valuable after many years of operations. In case of reliability issues, calculation and comparison of operational and conditions data may be used to avoid future downtime and improve reliability.

The main server runs the Real Time Data Base (RTDB) with over 50,000 signals. Calculations are done by the main edge server. The server architecture is virtualised.

APPLICATIONS

The applications for electrical condition monitoring include a user interface intended to be used by customer technicians or engineers, and by supplier specialists. The interface presents measured and calculated data in useful formats to support daily activities and deeper investigations.

The customer's system is monitored from the ABB Ability Collaborative Operations Centre in Helsinki, Finland.

Overview

The system overview provides a quick summary of installed equipment status.

Equipment details

Each type of product has an individual display to show product status, alarms and trends (Figure 5 shows an example of an equipment monitoring detail page). Availability is calculated for each device whilst reliability has product-specific calculations.

Examples of monitored KPI's in the system and on the dashboards:

High and medium voltage units

- Breaker condition indication based upon the opening and closing times of breakers
- Protective health monitoring of protection relays based upon self-monitoring features

UPS

- Charging and discharging analytics
- Battery condition estimation
- Battery lifetime estimation

Low voltage breakers

- Breaker condition index based upon contact wear
- Predictive health monitoring of protection relays based upon self-monitoring feature
- Operations analytics of excessive use of breakers

Drives

- Environment monitoring for ambient temperatures
- Stress calculation to detect conditions shortening key component lifespan
- Cooling fan lifespan estimation

COLLABORATIVE OPERATIONS

The customer's system is monitored from the ABB Ability Collaborative Operations Centre in Helsinki, Finland. Basic activities performed in the center:

Monitoring service – includes daily checks of customer data by ABB specialists. This supplements the customer's own efforts, and is extended to many customers regionally and globally.

Setting up drives and other electrical equipment and systems correctly for each application is the key to guarantee trouble-free operation for the coming years. Comparison and validation of the settings after commissioning are being carried out with recommendations given to fix potential risks. Corrections are applied remotely under an agreed upon safety protocol, or during the next planned shutdown. Safety is always the number one priority when making adjustments to the plant in full production.

Remote assistance – provides rapid response support by accessing data in real-time. The local drives service team delivers a one-hour response time where a specialist may connect to the system. Specialists can then guide customers through troubleshooting processes and repairs. Customer spare parts stocks are optimised and available to make fast repairs. By supporting

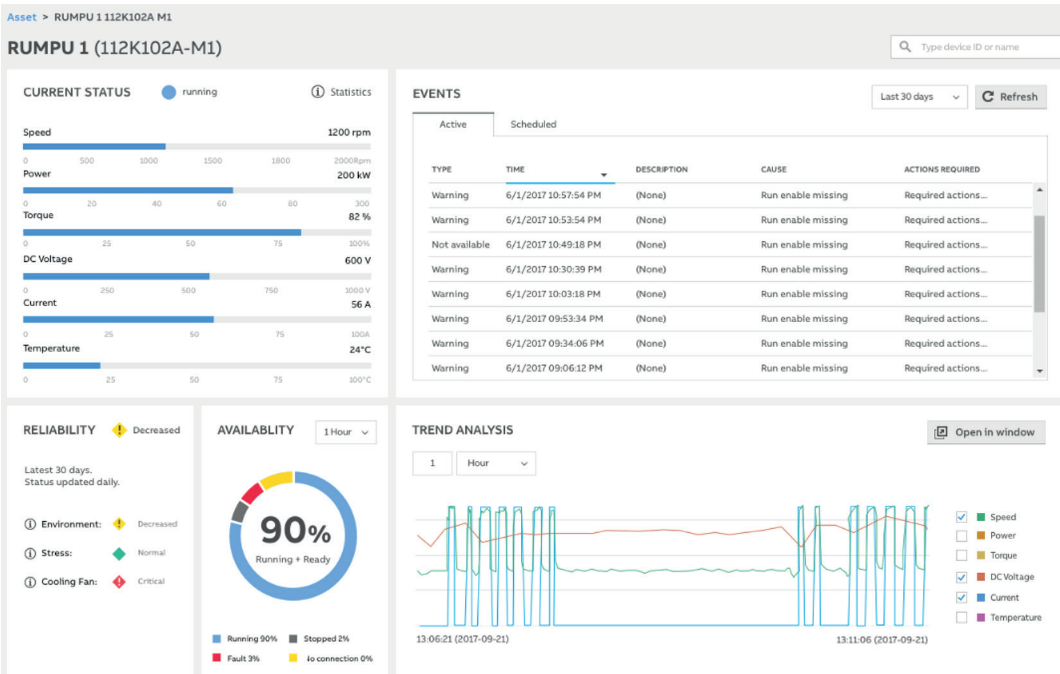


Figure 5. *Example of equipment detail page in the monitoring application.*

customers remotely, the impact of failures on production can be reduced.

The collaborative operations system delivered to Metsä Group's bioproduct mill is currently in the data-verification stage before it enters into full operational use. The system is already enabling the remote monitoring and diagnostics of electrical maintenance data. During the data verification process, a potential problem was identified and corrected: the incoming cooling air temperatures on some of the drives was higher than recommended. If left uncorrected, this would have reduced the drives' lifespan and lowered their availability, but corrective actions were made to adjust the electrical room air conditioning to an optimal level. Finding these types of issues in an early stage of the plant life cycle provides a solid foundation for maximising equipment lifespan, plant reliability and availability.

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Figure 6. *Metsä Group's bioproduct mill (Photo: Metsä Group)*