BRINGING EXISTING LONG ROLLING MILLS INTO INDUSTRY 4.0*

Delio Amorim[1]

Resumo
Industry 4.0 concepts is the new biggest challenge on the industry nowadays and every company in every industry in every part of the globe is looking to implement this somehow on their factories and machines. To do that on the newest long rolling mills, that brings already onboard state-of-the-art technologies, is for sure a challenge of machinery builder industry, but how to become the long rolling mills built on 70's, 80's or 90's part of this innovation process and connected to the new trends? This is the main mission here, to show some examples of applications that goes in this direction.
Palavras-chave: Industry 4.0; Long Rolling Mills, Revamps and Upgrades, Digitalization.

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Abstract
Industry 4.0 concepts is the new biggest challenge on the industry nowadays and every company in every industry in every part of the globe is looking to implement this somehow on their factories and machines. To do that on the newest long rolling mills, that brings already onboard state-of-the-art technologies, is for sure a challenge of machinery builder industry, but how to become the long rolling mills built on 70's, 80's or 90's part of this innovation process and connected to the new trends? This is the main mission here, to show some examples of applications that goes in this directio..
Keywords: : Industry 4.0; Long Rolling Mills, Revamps and Upgrades, Digitalization.

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1 INTRODUCTION

Digitalization is the key-word in this process and at industry 4.0.
Only through digitalization will be possible to connect on real time basis the production and maintenance management for the through process optimization.

Advantages of digitalization
- *Increased utilization and productivity*
- *Higher process consistency*
- *Continuous quality monitoring*
- *Fewer manual product inspections and quality downgrades*
- *Reduced downtime through condition monitoring and predictive maintenance*
- *Greater process and equipment understanding from smart sensors and system learning*
- *Less repetitive and heavy manual work*
- *Improved operator safety*
- *Immediate return on investment*

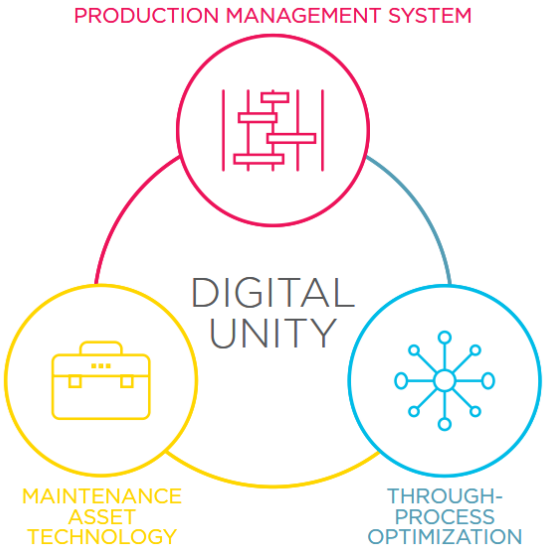


Fig.1 – Digitalization Concept

2 Methods and Materials

The digital transformation of steel production brings the intelligent combination of process automation, information technology and connectivity.

This is possible by:

- Understand and measure the processes
  Through Smart sensors provide previously unavailable, continuous real-time process and plant data, whether directly measuring physical values or by using existing sensors to indirectly calculate additional information. Smart sensors support advanced automatic functions, process models and condition monitoring.

- Automate Processes
  Fully automated functions removing tasks which are repetitive, labor-intensive and dangerous.

- Digital “Twin” Plant
  Implement Process models that works as digital “twins” of the plant, enabling process optimization in real-time as well as offline simulation. This capability improves process guidance and provides full support for further process development.

- Plant “Own” Features
  Acknowledgement how that plant feels, know how that particular plant feels and behave.

Condition monitoring supplies comprehensive information about the status of the equipment and its respective processes. This service facilitates predictive maintenance and reduces unplanned outages, thus improving plant availability and increasing plant productivity.

Fig. 2 – Digitalization Integration

Advanced technologies now allow for information to be communicated beyond former limitations and get the things connected anywhere and anytime. From the collection of sensor data in harsh environments or from mobile equipment, to displaying information on smart devices, digitalization moves data from the shop floor to the high level management.

2.1 Application Examples

2.1.1 Smart sensors

Provide valuable real-time data on the process and product of your long rolling mill, either by directly measuring physical values or by using existing measurements.
These sensors enable the implementation of advanced automatic functions to create process models and monitor conditions. The continuous flow of mill information facilitates increasingly sophisticated monitoring and control of the entire plant.
Installing software packages developed around targeted smart sensors provides new and improved process metrics, leading to a more intelligent rolling process and minimizing mill setup time.

Examples of smart sensor functions:

- Dynamic speed, dimension and length measurement
- Laying head pattern control on the Stelmor® conveyor
- Remote product tracking
- Bar counting
- Crop optimization
- Phase transformation monitoring

Fig. 3 - Bar height measure sensor

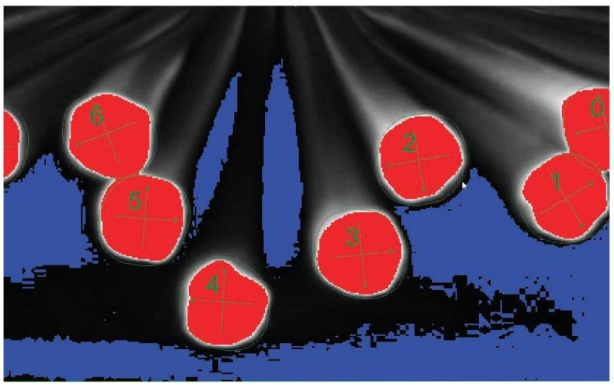


Fig. 4 - Bar Counter

2.1.2 Vision Systems

Optics and image processing go beyond what the human eye can see. Artificially intelligent vision systems can provide valuable information on the rolling process for both control and operational functions throughout the plant.

Laser Gauges
The ability to measure actual speed directly increases product quality, metallic yield and mill utilization. These devices can be used for measuring both actual product speed and length. Models are designed to withstand extremely harsh environments, covering the full range of mill conditions from caster area to finishing end.

Applications include:

- Product speed setup
- Tension control
- Billet length measurement
- Cut length optimization
- Laying head pattern control

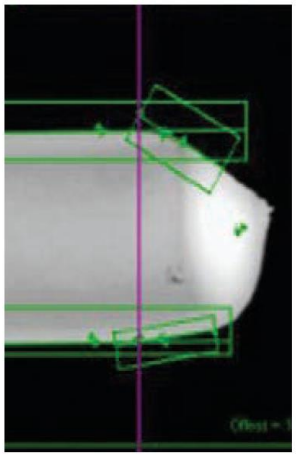


Fig. 5 – Shear Crop Measurement

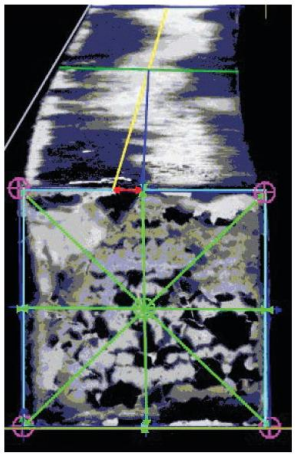


Fig. 6 - Billet Size Monitoring

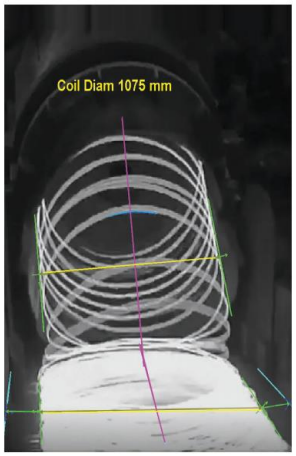


Fig. 7 – Laying Head Coiling

Fig. 8 – Property Sensor

2.1.3 Automatic functions using Robots

Robots finally arrives at long rolling process with industry 4.0 coupling information from smart sensors enabling a high level of automation within the plant.
Repetitive, labor-intensive and dangerous tasks are optimal candidates for automation technology.
Long rolling applications can include:

- Guides change, adjustment and maintenance
- Shear blade change
- Bar sampling and testing

- Cobble removal
- Short bar removal
- Block ring and guide changes
- Laying head pipe change
- Coil ring trimming
- Product marking
- Product labeling
- Storage and logistics
- Parts cleaning

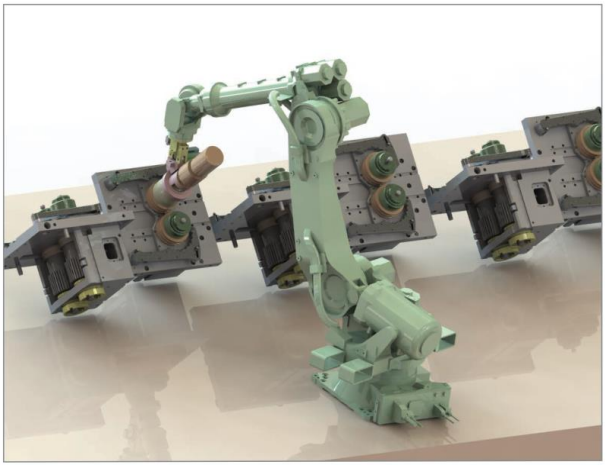


Fig. 9 – Finishing Block Roll Changing Robot

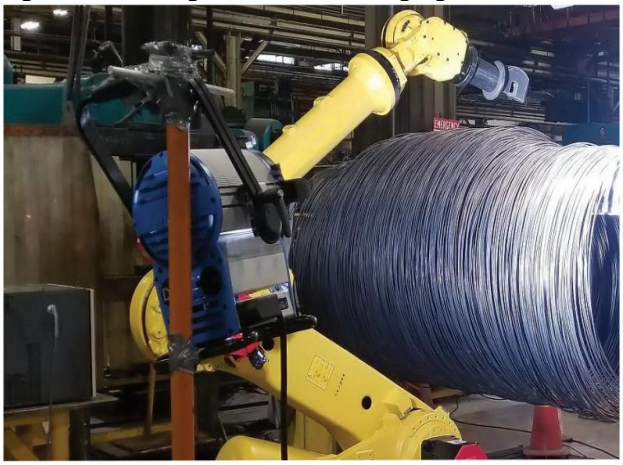


Fig. 10 – Coil Trimming Station Robot (Patented)

2.1.4 Equipment Condition Monitoring

Comprehensive information about the condition of the equipment and the respective processes enables predictive maintenance, helping to avoid unplanned outages.

The strategic placement of sensors in and on mechanical equipment throughout the plant provides digital information about the condition of that equipment and is collected and analyzed.

A maintenance management system combines this real-time data with predictive models, based on years of operational know-how and maintenance experience.

The resulting service schedule enables:

- Improved plant availability and productivity
- Optimization of maintenance costs
- Rationalized schedule of maintenance workforce
- Higher product quality

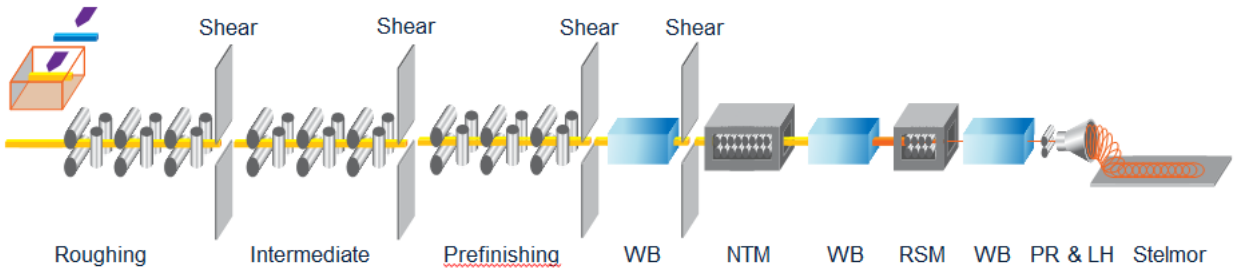
2.1.5 Vibration and Fluids Monitoring

Those are examples of the techniques applied at long rolling mill plants that follows the world-class facilities benchmarking that spend 80% of maintenance resources acting on *predictive* and *preventive* actions.
Vibration is a kind of predictive service that could be done online on a 24/7 basis and allow a continuous monitoring of rolling mill following the pre-conditions of industry 4.0.

Vibration analysis could be performed in all sections of a rolling mill, from roughing up to inspection line, including auxiliaries systems.

This kind of monitoring, applied on motors, gearboxes, pinion stands, pumps, fans, compressors allow several problems identification as early roller bearing degradation, coupling misalignment/looseness, Mechanical looseness, soft foot, Gear wear, worn or broken gear teeth, Improper lubrication, worn seals, Imbalance, Vane/blade-pass, recirculation and cavitation, early roller bearing degradation, coupling misalignment/looseness, looseness soft foot, Gear wear, worn or broken gear teeth, Improper lubrication, worn seals, etc

Mill Areas	Roughing	Intermediate	PFM	NTM	RSM	PR & LH	Shears	Stelmor Conveyor
Equipment	Motors, Gearboxes, Pinion Stands							
Methods	Vibration							
Identifiable Problems	Early roller bearing degradation, coupling misalignment/looseness, Mechanical looseness, soft foot, Gear wear, worn or broken gear teeth, Improper lubrication, worn seals, Electrical problems							



Auxiliary	Fluids Systems					Cranes	Electrical
Parts	Lubricants	Motors	Fluids Pumps	Fans	Compressors	Gearboxes	Cabinets
Methods	Oil/Grease Analysis	Vibration					IR Scan
Identifiable Problems	Oil/grease quality as iron content, water content, temperature, etc.	Imbalance, Vane/blade-pass, recirculation and cavitation, early roller bearing degradation, coupling misalignment/looseness, looseness soft foot, Gear wear, worn or broken gear teeth, Improper lubrication, worn seals, Electrical problems					Loose connection, open circuit, overloads, inductive heating, harmonics

Fig. 11 – Methods and Problems Identification on a Long Rolling Process

Vibration monitoring could be done also manually and periodically, and by different methodologies, what it is recommended by mill builders is the online monitoring that allow not only 24/7 monitoring but as well mostly precise data due the consistency on accelerometers positioning.

Regarding methodology it is recommended to adopt the one called “full signature” that is capable to act in various kinds of failure modes.

We can established as the biggest advantages of full signature vibration monitoring:

- Fastest problem identification
- Highest failures modes coverage
- More precise identification of the problem location
- Tighter vibration limits
- Escalating levels of alerts (1/2/3/4 stars)

In the end full signature vibrating monitoring allows the problem acknowledgement on a very early stage and in a categorized levels becoming able a better maintenance prediction.

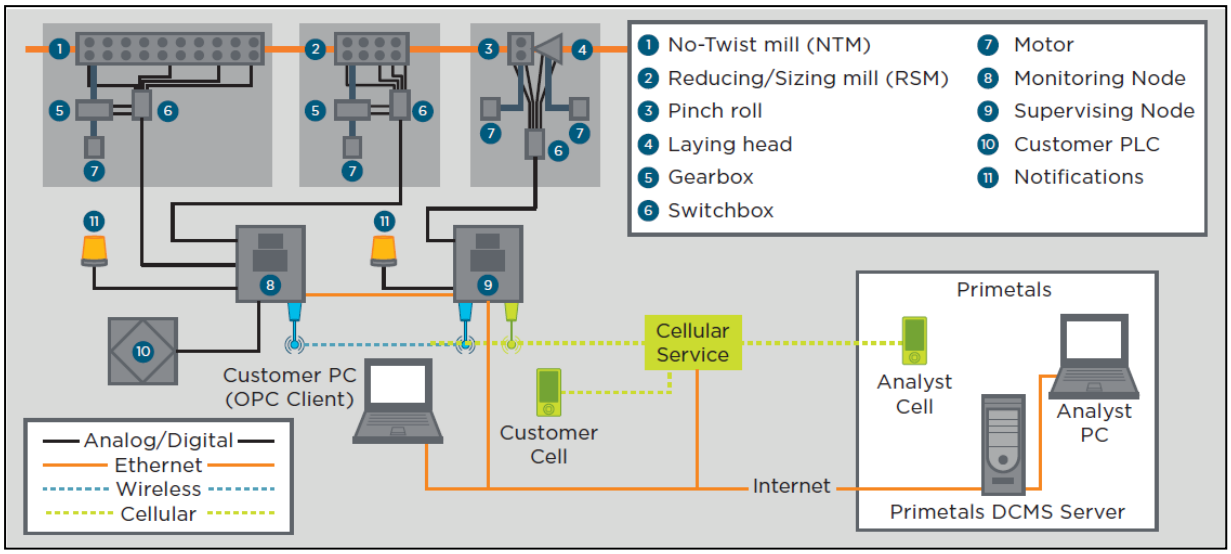


Fig. 14 – Dedicated Condition Monitoring System Configuration (Online 24/7)

Failure Mode	Full Signature	RMS Trending	Shock Pulse	Human Being
Imbalance	✓	✓	✗	✗
Coupling misalignment	✓	✗	✗	✗
Overall looseness	✓	✓	✗	±
Early bearing defects	✓	✗	✓	✗
Gear defects (wear / broken Teeth)	✓	±	±	✗
Improper Lubrication	✓	✗	✗	±
Electrical related faults	✓	✗	✗	✗
Belts problem	✓	✗	✗	✗
Vane / blade pass	✓	✗	✗	✗
Cavitation / recirculation of pumps	✓	✓	✗	✗
Resonance	✓	✗	✗	✗
Sleeve bearings	✓	✗	✗	✗

✓ Effectively Application ± Works Intermittently or Occasionally ✗ Ineffective or N/A

Fig. 15 – Vibration Monitoring Methodologies

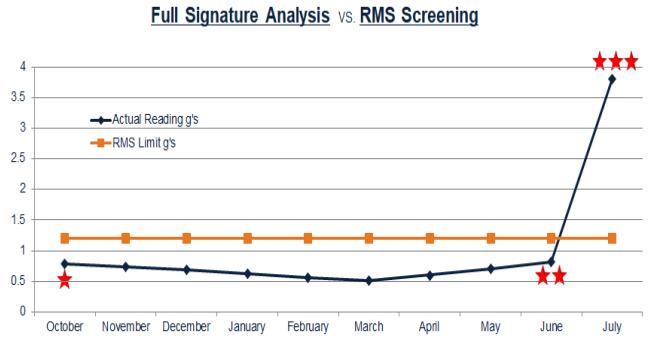


Fig. 16 – Full Signature vs RMS Screening

Other important monitoring recommended is related to lubricants as they have direct relation and impact on mechanical damages on bearings, gears, etc.

The main focus to be applied on lubricants are the ones related to contamination with iron fines and water, in the steel mills there is an extremely high potential of water ingress into the oil as water is need to cool the rolls during rolling process, water contamination in lubricating fluids can cause devastating problems in the mechanical equipment as reduction on bearings life.

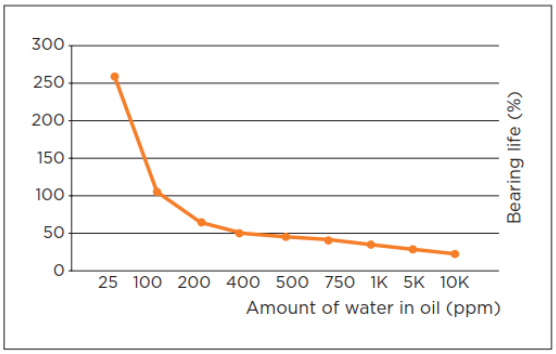


Fig. 12 – Bearing Life versus Water in Oil

Fig. 13 – Vacuum Dehydration System

The maximum acceptable water content in the oil on high speed equipment of long rolling mills as for example pre finishing mills, now-twist mills, reducing/sizing mills is 0,2%.

Water can enter into the lubrication system in either ways, as vapor or liquid state, by failed seals, failed heat exchanger, or by condensation inside the main lube tanks.

In order to remove this water from the close loop lubrication systems is also recommended to install auxiliary systems as for example vacuum dehydration system.

Attached to the main lube system vacuum dehydration system will allow a continuous control of the water content on lube systems, and will keep this water content level on an acceptable basis.

2.4 Results

Below some of results on some of the applications part of this paper

PRODUCT MEASURING SYSTEM

Location: Nucor Connecticut, USA

Plant type: Single strand rod mill

Solution
Provide a laser-based speed measuring system

Technical data
Plain carbon steels, 150,000 tpy, 35 tph, 5.5 - 14.3 mm plain rounds

The result
Section control through the roughing and intermediate mill has improved with accurate measurement of stock speed between stands.

BILLET DIMENSION MEASURING SYSTEM

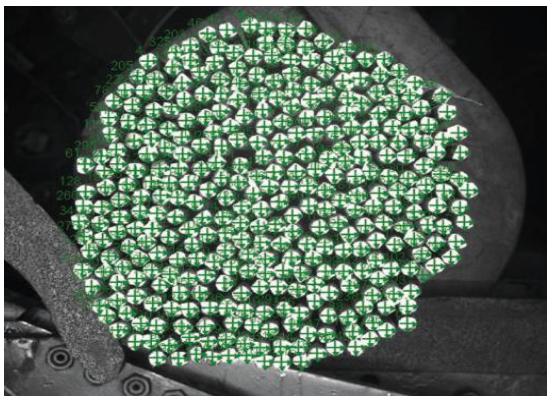
Location: Valsabbia, Italy

Plant type: Single strand bar mill

Solution
Provide a vision-assisted billet dimension measuring system to ensure billet-to-billet size consistency

Technical data
Reinforcing bar 6 - 40 mm, bar bundles 6 - 15 m long

The result
Dimensions of billets from the billet yard can now be reliably verified before preparing for the rolling mill.

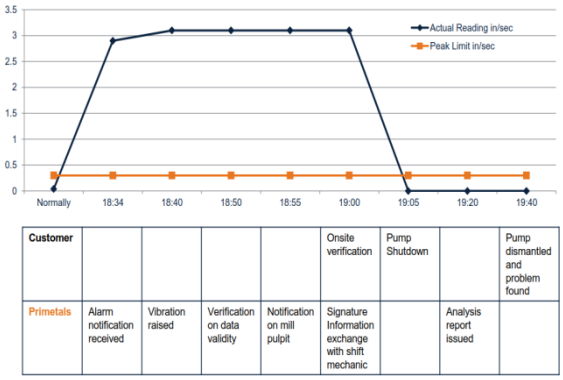


NON-CONTACT BAR COUNTING

Location: OneSteel, Melbourne, Australia

Plant type: Single strand bar mill

Solution
Install a non-contact bar counting system ahead of the bar bundling station



Customer					Onsite verification	Pump Shutdown		Pump dismantled and problem found
Primetals	Alarm notification received	Vibration raised	Verification on data validity	Notification on mill pulpit	Signature Information exchange with shift mechanic		Analysis report issued	

DEDICATED CONDITION MONITORING SYSTEM (VIBRATION)

Location: North American, USA

Plant type: Hot Strip Mill (HSM)

Solution
Install 3-axis accelerometers on 3 descale pumps

Technical data

Plain rounds 26 - 33 mm, reinforcing bar 12 - 40 mm, bar bundles 1.5 - 2.4 t

The result
The new bar counting system provides accurate and repeatable bar bundle count, without a need for manual verification.

Case Study

At 18:34pm OEM analyst received notifications suddenly increased than expected
At 18:40 amplitude increase additional 0,2 in/s
18:50h OEM analyst verify steady-state and validate the date
18:55h analyst call mill pulpit and request urgent mechanical inspection and possible shutdown
19:05 pump was inspected and shutdown
19:40h pump was dismantled and mechanic notice loose/worn on thrust pads of outboard pump bearing and a crack at main shaft

The result
- Immediate actions (aprox. 1h) avoiding catastrophic failure, damages and additional costs
- Successful monitoring of remote, unsafe and inaccessible locations on 24/7 basis
- Previous and fast analysis by a dedicated specialist before mill operation people involvement

3 CONCLUSION

In a fully automated factory, the digitalization of the mill plant can be complete, from the liquid phase to the finished product. Digitalization makes this possible, utilizing the individual tools and portfolios mentioned to bring all this information together, with the addition of:

- Production planning
- Plant maintenance
- Product quality

The full process is monitored from meltshop to the final shipping of the finished product.

Operators and managers need both reliable data and accurate reporting on one platform.
Multiple interconnected systems can evaluate plant-to-plant performance at the corporate level.

By collecting and utilizing this information to measure and compare KPIs against set targets or world standards, an operation can be monitored and measured from a performance and improvement standpoint. The same possibility is available for high level management that could make the comparisons and take actions on individual plants to meet global KPIs benchmarkings.

Its domain extends from enterprise resource planning (ERP), through Manufacturing Execution Systems (MES) down to control systems and sensors. The system delivers valuable mill reports to the operations staff and management, so they can easily assess the plant‘s performance through the KPIs and optimize production.