Applying Predictive Models in process controls

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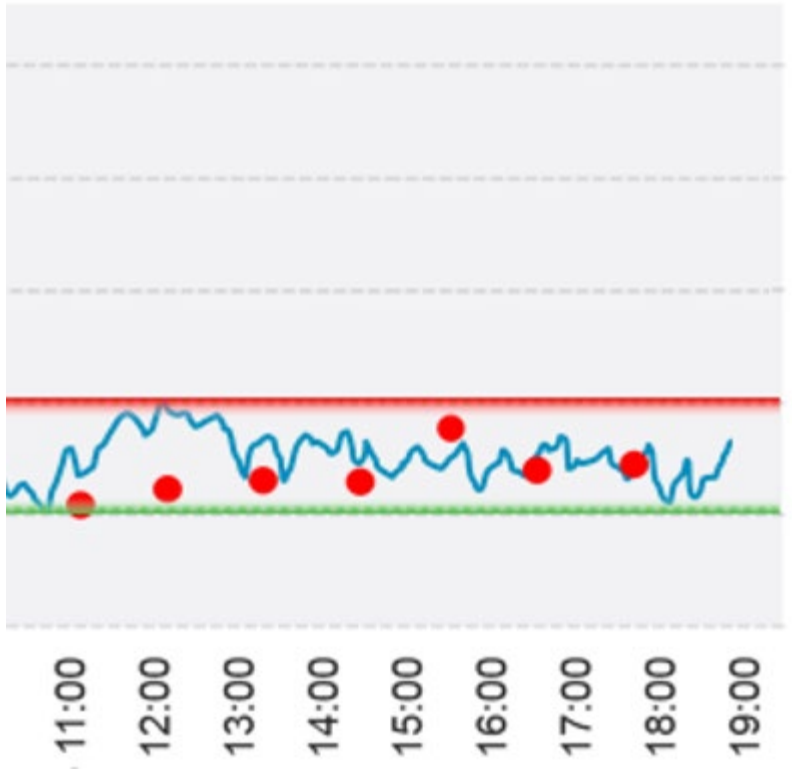
Introduction

Introduction

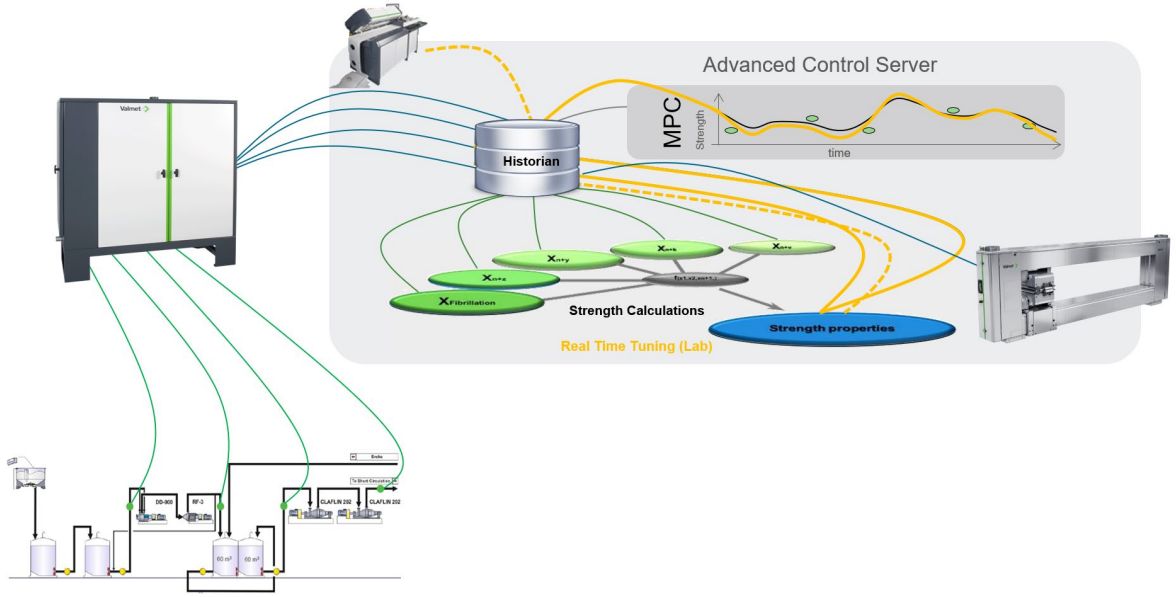
- Traditionally, process controls use physical measurements
- Developing technology predictive models (soft sensors) to complement
- Feedback from end-product quality available real-time
- Predictive models have clear benefits for process controls



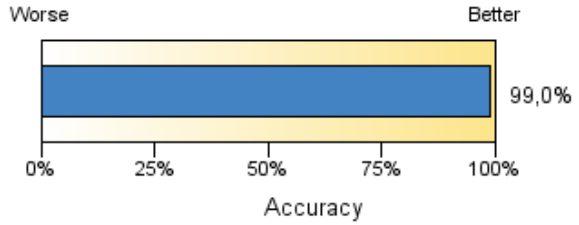
Modeling and Model update

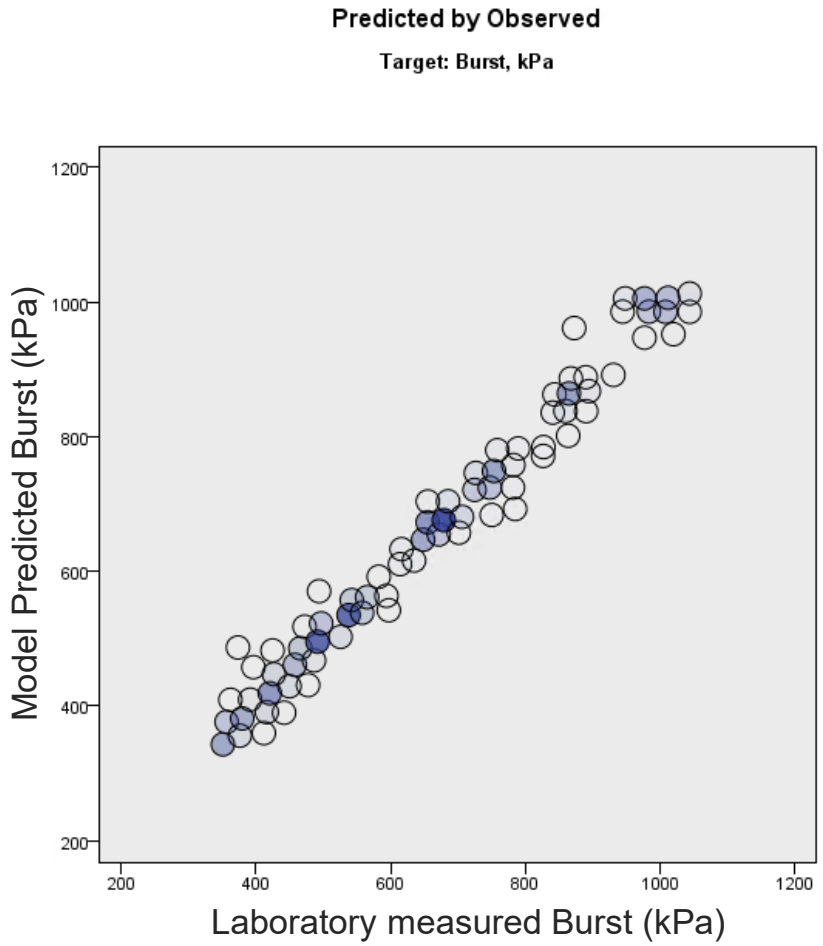
Modelling and model update

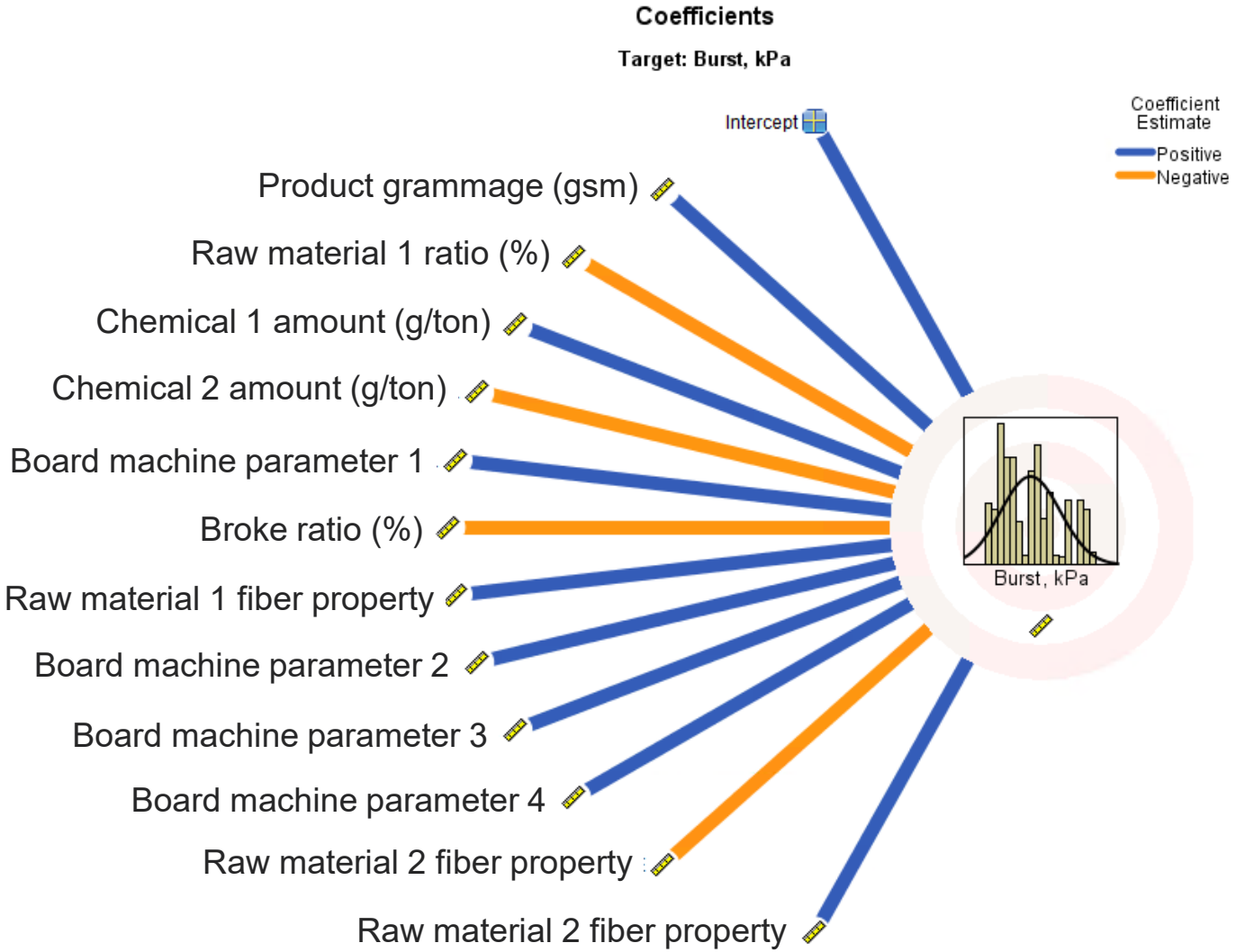
- The goal is predictive modeling of end-product paper quality
- Listed below are some of the data requirements:
  - Historical process (sensor) data for a sufficient time period at high frequency
  - QCS data
  - DCS data
  - Online fiber properties data
  - Historical laboratory measurements from the same time period



Model development and performance tracking



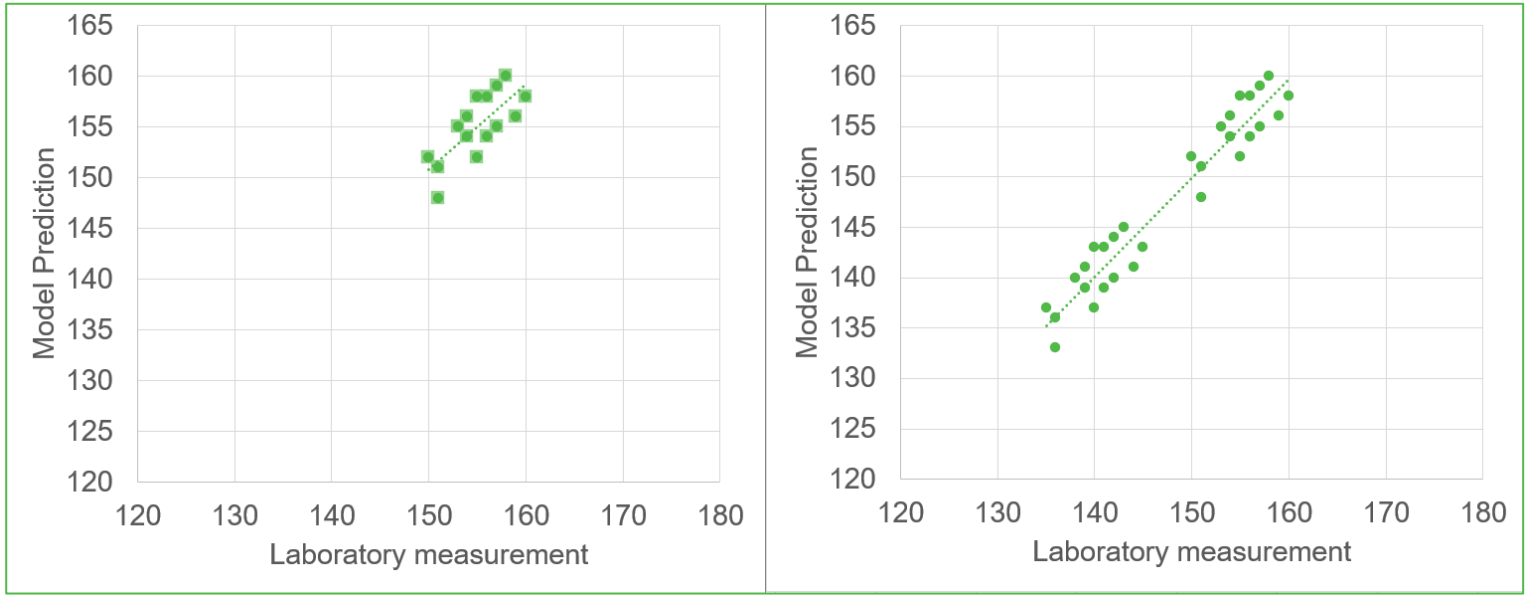




Model types

- White box (or first principle)
  - Relies on nature sciences and process knowledge - based causalities between input variables and prediction
- Black box (or statistical)
  - Based on historical data and relations, found by analyzing historical statistics
- Grey box
  - Takes the advantage on both methods
  - First, correlations are pointed out based on data analytics
  - Then, paper technologist, reviews and selects the input variables
- When prediction is part of process control, emphasis needs to be on the “white box” methods where possible
  - Simple and robust model needed
  - Wrong causalities and unexplained relations might lead to unexpected behavior
  - Process control reduces errors along the time -> some model accuracy can be sacrificed for robustness and simplicity

Model accuracy, MRE



R^2 = 0,5563 MRE = 1,29 % *R^2 = 0,9283 MRE = 1,36 %*

Two data sets with similar MRE but different R2. It is recommended to use MRE for measuring predictive model accuracy due to its behavior - different value ranges tend to give different R2 values.

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Example of model's input variables

Model input parameter (predictor)	Coefficient	
Ratio of raw material component 1 (%)	8.5 N	Each 1% increase in raw material component 1 will incrase strength by 8.5N
Filler content of product (%)	- 5.6 N	Each 1% increase in filler content of product will decrease strength by - 5.6N
Paper machine process parameter 1 (kPa)	- 3.4 N	Each 1kPa increase in process parameter 1 will decrease strength by - 3.4N
Fiber property 1 of raw material component 1 (mm)	21.1 N	Each 1mm incrase in raw material component 1 fiber property will increase stength by 21.1N

Simplified list of typical strength model input variables

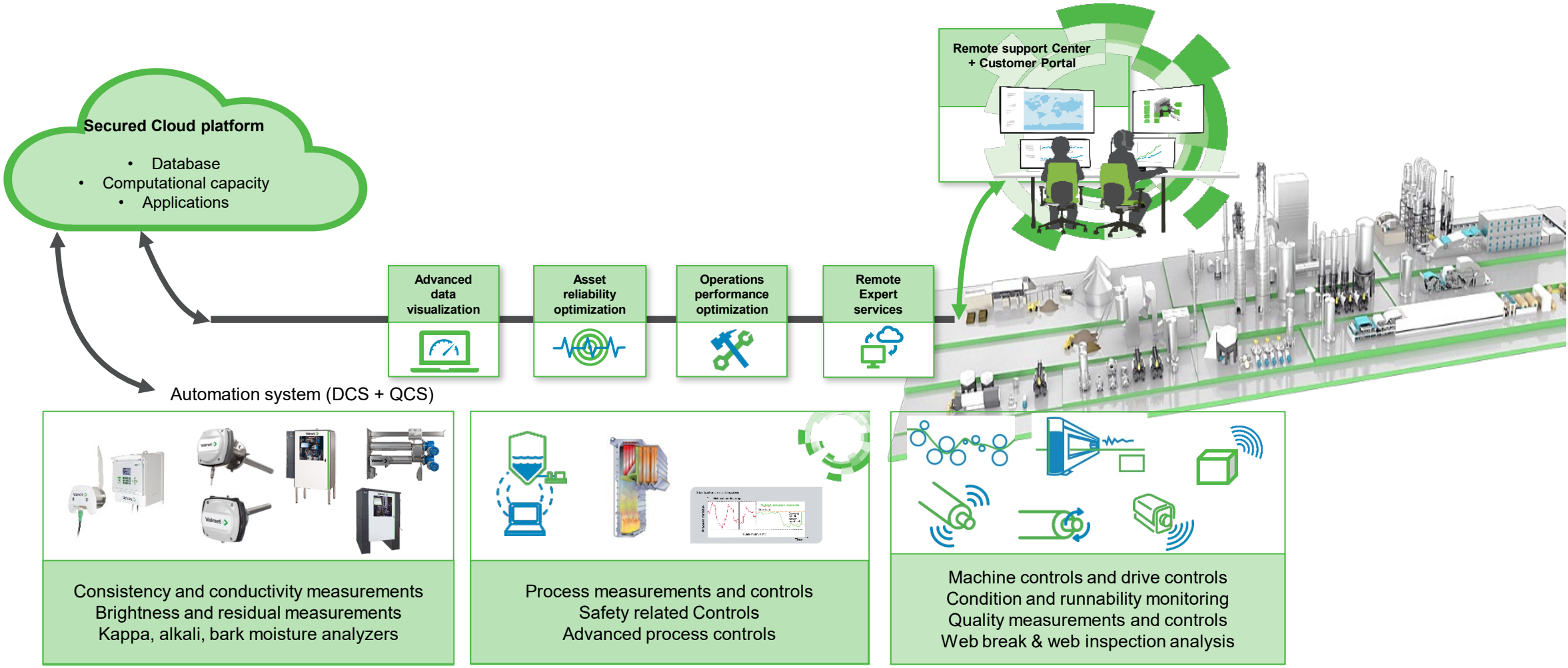
Cloud and local environments

Cloud and local environments

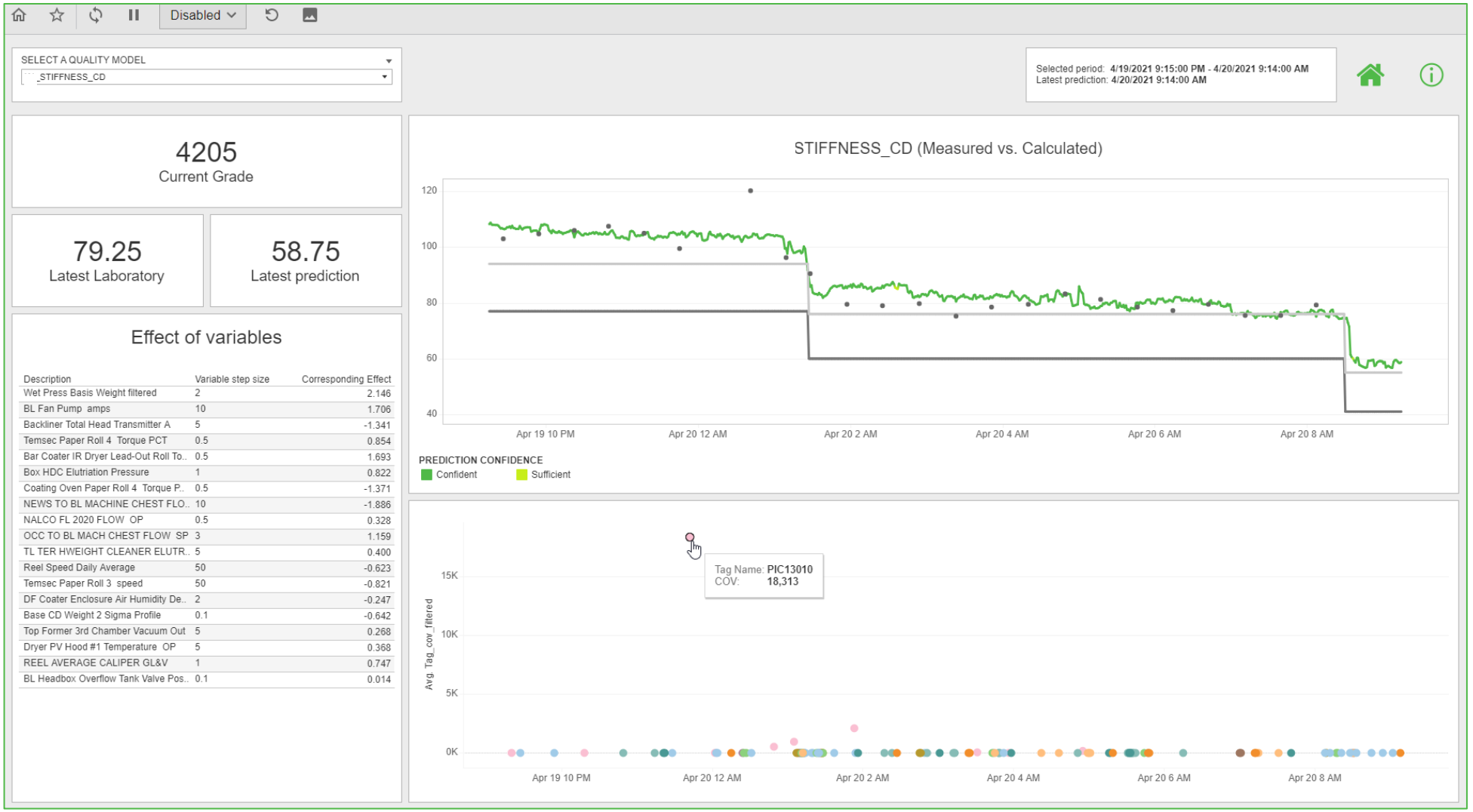
- For use of predictive models, local and cloud environments need to be combined in a smart manner
- First, all relevant data need to be transferred to the cloud environment
- Prediction can run in cloud for operator use, but for process control it is needed in local system

- Cloud environment offers clear benefits:
  - Advanced and real-time tools for data analytics and model retraining
  - Capabilities for remote support
  - Model diagnostics tools, e.g. averages, accuracy and confidence indicators
  - Updates to newest tools with no need for separate local patching and installation actions
- Once built in the cloud, predictive model can then be replicated to the local system

Cloud system layout



Operator guidance tool



Integration to process control

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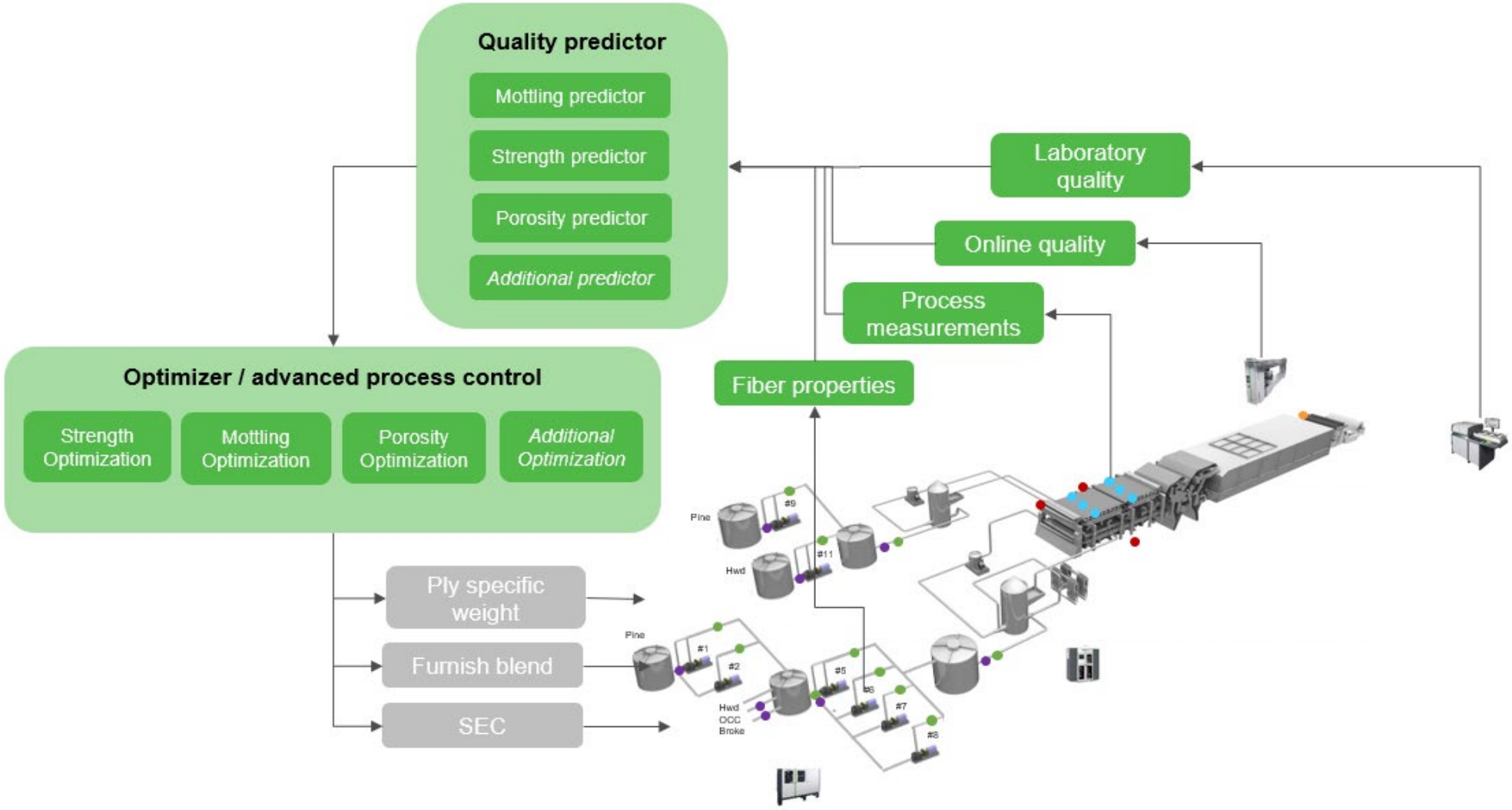
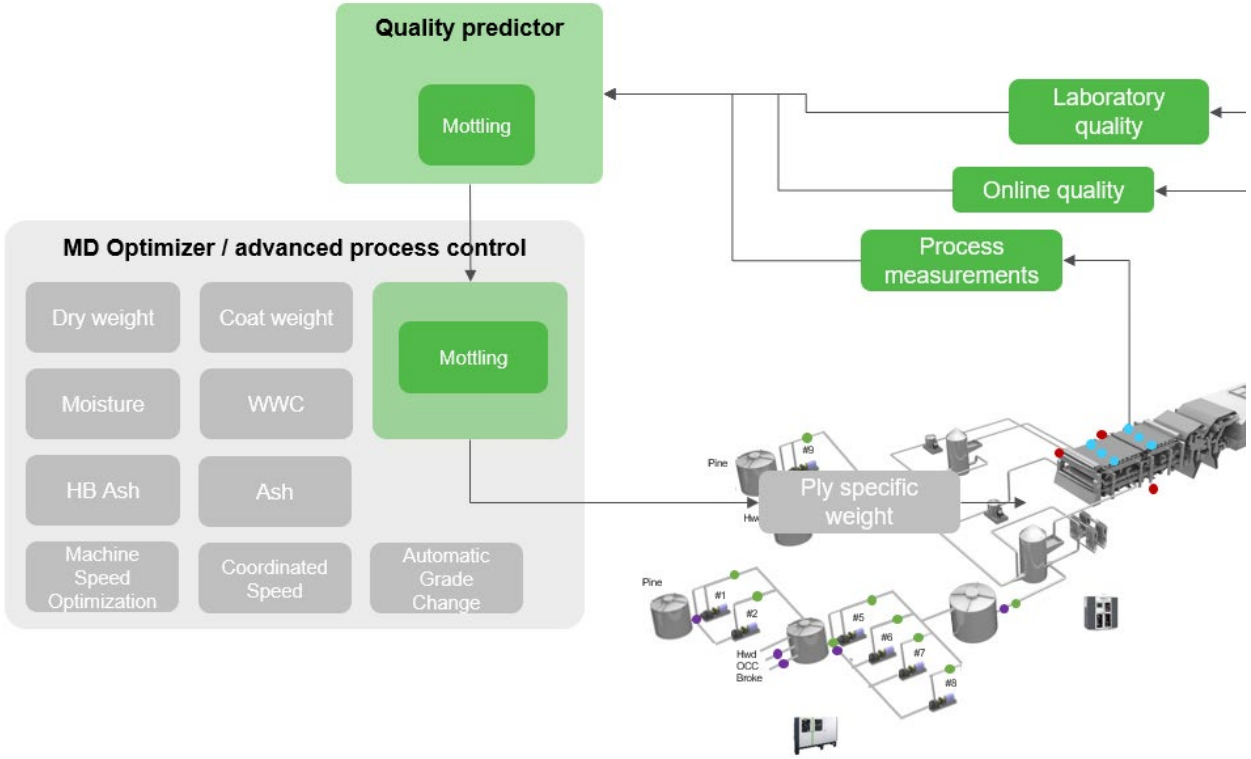


Role of quality control system

Role of quality control system

- Sometimes, the APC is implemented on a new server as a stand-alone solution
- A more common and beneficial method is to add the control as part of the QCS
- The automation system stays unified, and the machine direction (MD) quality is managed holistically without overlapping and contradictions between sub-optimizations



Benefits

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- Some examples of possible benefits are:
  - If the fiber furnish is composed on several fractions with various price levels, there might be great savings potential, if the consumption of most expensive fraction can be minimized
  - Part of the fiber raw material can be replaced with less expensive filler
  - Refining electricity consumption can be decreased by avoiding unnecessary refining
  - The amount of starch or other additives can be kept as low as possible
  - Off-spec production can be avoided by reacting fast, when prediction indicates the need for adjustments
  - Printability can be kept high and customer claims can be avoided
  - Additional production can be gained by removing bottlenecks, e.g. minimizing the restricted raw material fraction

Benefit examples

- Several cases with proven results utilizing predictive models in process control have been documented

- Listed below are a few case examples:

  – Mottling: Improving mottling value stability and on target, while minimizing the thickness of the expensive top ply. Top ply gsm savings 3-4 gsm (depending on grade), resulting to $1.8M - 2.4M annual savings

  – Strength: Maintaining sufficient strength values while replacing as much of expensive kraft pulp with filler as possible. Up to 40% reduction in strength variation with simultaneous reduction in raw material cost


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