Optimization of Lime Kiln Performance through Collaborative Operations

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Agenda

- Lime Kilns
  - Process Introduction
  - Typical Challenges
  - Traditional Control Schemes
- Advanced Process Control for Lime Kilns
  - Regulatory and Supervisory Control
  - Model Predictive Control
- Case Study
  - Setup
  - Results and Discussion
- Collaborative Operations
- Conclusions
Pulp Mill Operations
Operations and Control System Setup
Chemical Recovery Section
Produce High Quality White Liquor at Lower Operating Costs

OPT800 Vapor (Evaporator Control)
- Prod Rate control
- Dry solids control
- Temp control

Evaporators

OPT800 Caust (Causticizer Control)
- TTA control
- Diff Temp Control
- Caust. Efficiency Control

Causticizing

OPT800 Lime (Lime Kiln Control)
- Temp target
- Prod Target
- Draft control
- Fuel control
- Hot End Temp

Lime Kiln
Lime Kiln Operations

Objectives

- Produce High Quality Lime
- Maintain Stable Hot End Temperature
- Maintain Stable Cold End Temperature
- Maintain Oxygen within Limits
- Prevent CO Formation
- Achieve Production Targets
- Minimize Energy Requirements
Optimization of Lime Kilns
Challenges in Lime Kiln Operations

**Typical Control Issues in a Lime Kiln**
- Varying Fuel Quality
- Tight environmental regulations
- Many different types of process delays
- Solids moves slowly
- Quickly moving gases
- Strong interactions between the Process inputs and outputs – a multivariable problem
- Process characteristics change over time due to ring formation, makes it difficult to tune single loop controller.
- Long recovery time from disturbances, such as Feed change, Kiln speed increase .etc.

**Typical Operation Issues in a Lime Kiln**

* Source: Sabrina Francey, Honghi Tran, and Niklas Berglin, "Global survey on lime kiln operation, energy consumption, and alternative fuel usage", AUGUST 2011, TAPPI JOURNAL

* Source: TAPPI
Lime Kiln Operations

Typical Industrial Control Schemes

Typical Measurements

• Lime Mud Flow (l/s)
• Lime Mud Density (kg/m³)
• Cold End Temperature (°C)
• Hot End Temperature (°C)
• Kiln Rotation (rpm)
• Fuel Flow (l/s or Kg/h)
• PA and ID Fan Speed (%)
• ID Damper Position (%)
• Oxygen in Lime Kiln (%)
• Oxygen in Stack (%)
• TRS Emissions (ppm)
• CO in Lime Kiln (ppm)

• Lab Residual Carbonate (%)  
• Lab Reburned Lime Quality (%)
Advanced Process Control for Lime Kilns

Regulatory versus Advanced Process Control

SISO (Single Input Single Output)

PID

MIMO (Multiple Inputs Multiple Outputs)

Process

Input

MV1

MV2

MV3

FF1

FF2

Output

CV1

CV2

CV3

Multi Variable interaction

Real-time process data

Process Control Application

Advanced Process Control

APC

Benefits due to optimization

Stabilize

Manual set point

Optimized set point

Manual

Production rate

Multi-variables

Σ
Advanced Process Control

Model Predictive Control

\[
\begin{align*}
\dot{x} &= F(t, x, u), \\
J(u) &= \int L(t, x, \dot{x}, u) dt \\
\end{align*}
\]
Advanced Process Control for Lime Kilns
Minimizes Energy Consumption & Improves Lime Quality

Features and Benefits

- **Level 2 – Advanced controls**: Optimize the Lime mud temperature profile in the kiln while maintaining the combustion efficiency.
  - Controls hot end temperature and cold end temperature
  - Constraints handling; Excess O2
  - Manipulates Fuel & ID Fan Speed

- **Level 3 – Expert controls**: Provides supervisory set points to Level 2 controls
  - Quality Control module - Maintains Residual Carbonate
  - Coordinated production rate change – Ramps the kiln parameters
Advanced Process Control for Lime Kilns

How APC will improve the performance and lower costs?
Advanced Process Control for Lime Kilns

Technology: 800xA APC system
APC for Lime Kilns: Case Study

Introduction

- Pulp mill produces 425,000 tons, Totally Chlorine Free (TCF) bleached Kraft pulp
- 95,000 tons of chemical thermo–mechanical pulp for hygiene packaging products
- Multi Fuel Lime Kiln, Saw dust used as main Fuel
- Heavy Oil, Odor Gases, and Stripper gases as auxiliary Fuel

<table>
<thead>
<tr>
<th>Manipulated variables</th>
<th>Feed forward variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fuel (654FC249)</td>
<td>Fan speed (654SC0062)</td>
</tr>
<tr>
<td>Total fuel FF (654FC249_FF)</td>
<td>Production (654FC027)</td>
</tr>
<tr>
<td>Pressure powder feeding (654P350)</td>
<td></td>
</tr>
</tbody>
</table>

- Cold End Temperature is controlled to setpoint
- Hot End Temperature & Oxygen are controlled within limits
- Fuel Flow & ID Fan Speed are manipulated.
- Oxygen Safety Logics Included
- Production Rate Control Included
APC for Lime Kilns: Case Study

Temperature Control Results

CET range = 6 deg C (657 to 663)
APC for Lime Kilns: Case Study

Oxygen Control Results
APC for Lime Kilns: Case Study

Production Rate Change Control Results
APC for Lime Kilns: Case Study

58% Temperature Variation Reduction & 5% Energy Reduction
APC for Lime Kilns: Case Study

25% O2 Variation Reduction and 31% Quality Variation Reduction
ABB Ability™ Collaborative Operations

Collaborative Operations provides ability to improve plant availability, performance, and quality
Collaboration in data-driven ecosystem

People make the difference

Data gets aggregated and analyzed in the cloud and is available to key stakeholders of the collaborative operations ecosystem so they can make data-driven business decisions.

Customer
Apps, view installed assets, view operations

Consultant
Analysis, advanced maintenance, operations optimization

3rd party
Analytics, services, generate solutions

ABB engineer
Remote connection, update task list, live monitor progress

ABB collaboration expert
Root Cause Analysis, advanced services

Web portal

Collaborative Operations center

Cloud

Advanced algorithms analyze data automatically and present actionable insights for engineers at the mill level.

Edge devices/Fog

Data from devices like motors, drives etc. are gathered by sensors and transferred to Edge devices for analysis.

Typical Pulp & Paper Mill:
50,000 connection points, 10 TB’s of data’s/year, 40,000 I/O Control system, QCS, WIS and Lab Equipment, 6000 LV Motor, 150 MV Motor and Motor Starters, 130 Distribution Transformer and MV switchgear

Customer

Collaborative Operations Ecosystem

Services

People

Field devices
ABB Ability for Pulp and Paper

Turning insights into actions

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### Fleet

<table>
<thead>
<tr>
<th>Status</th>
<th>Location</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>Portland, Maine</td>
<td>Paper Machine 1</td>
</tr>
<tr>
<td>Stopped</td>
<td>Portland, Oregon</td>
<td>Paper Machine 2</td>
</tr>
<tr>
<td>Running</td>
<td>Appleton, Wisconsin</td>
<td>Power Plant 1</td>
</tr>
<tr>
<td>Running</td>
<td>Appleton, Wisconsin</td>
<td>Power Plant 2</td>
</tr>
<tr>
<td>Running</td>
<td>Mobile, Alabama</td>
<td>Power Plant 3</td>
</tr>
<tr>
<td>Running</td>
<td>Augusta, Georgia</td>
<td>Paper Machine 3</td>
</tr>
</tbody>
</table>

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**Alert**

- **Paper Machine 1 Stopped**: 5:14 PM – 7:26
- **Paper Machine 2 Steam Pressure Low**: 12:01 PM – 7:26
- **Pulp Mill 1 Refiner2 Tripped**: 6:32 AM – 7:26
- **Paper Machine 2 Started**: 7:20 AM – 7:25

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**Overall Efficiency**: 76%

**Availability**: 81%

**Performance**: 71%

**Quality**: 100%

**Unit per Hour**: 83 pounds

**kWh per Hour**: 82
ABB Ability for Pulp and Paper

Turning insights into actions
ABB Ability for Pulp and Paper

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Turning insights into actions
ABB Ability™ Collaborative Operations

Uniquely qualified

**Analytics**
- Interpret results
- Understand context of results
- Data analysis

**Digital technology**
- Platform
- Algorithms

**Expertise**
- Industry
- Automation
- Geography
- Process

**Industry technology**
- Electrical
- Mechanical
- Process
Collaborative Operations Lime Kiln Dashboards

KPI and Performance Monitoring 24x7

- Energy Consumption (GJ/Ton): 6.27
- Production Rate (T/Hr): 19.37
Conclusions

APC through Collaborative Operations Significantly Improves and Maintains Lime Kiln Performance

Benefits:
- 58% reduction in Cold End Temperature (CET) variation
- 26% reduction in Oxygen variation
- 5.02% reduction in energy consumption
- 62% reduction in residual carbonate (RC) variation has allowed a 31% reduction in target

Other indirect benefits:
- Reduction in make up lime consumption
- Reduction in downtime

Collaborative Operations:
- 24x7 Monitoring with Advanced Analytics
- Sustained Performance