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Bleaching Process Chemical Optimization and Control in Chemical Bagasse Pulpmill in TNPL

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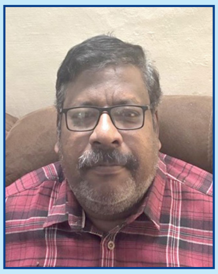

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Abstract:

Chemical Bagasse-Elemental Chlorine Free (CB-ECF) plant processes bagasse, a fibrous byproduct of sugarcane, to chemically separate cellulose fibers for Pulp production. The use of bagasse, a renewable resource, aligns with TNPL's commitment to sustainable manufacturing practices and environmental conservation. The CB-ECF Pulp-making Process involves several critical stages that transform bagasse into high-quality Pulp for Paper production. Key steps include cooking, washing, screening and bleaching. In particular, the bleaching stage is essential to achieve the desired brightness and cleanliness in the Pulp.

Over time, it was observed that most of the controls in the Washing and Bleaching stages were operating in an open-loop system. This led to significant variability in the desired Process parameters and either excessive or insufficient chemical consumption, which negatively impacted the overall efficiency and cost-effectiveness of the Process.

The addition of bleaching chemicals, such as chlorine dioxide (ClO_2), Hydrogen Peroxide (H2O2) and pH control agents like Sulphuric acid (H2SO4) at the D stages, as well as sodium hydroxide (NaOH) at the E stage were also manually controlled. The effects of these adjustments make it difficult to maintain consistent brightness and optimal chemical usage. This manual control approach led to significant variability in Pulp brightness, increased chemical consumption and disruptions in plant operations.

It also impacted the overall efficiency and quality of the bleaching Process. It includes Intermittent Control, Inconsistent Chemical Dosage, High Chemical consumption and Variation in pH.

In response to these challenges, Advanced Process Control (APC) was identified as a potential solution to optimize the chemicals in the bleaching Process.

The implementation of APCs in bleach plant has led to significant improvements like

1. *Reducing Process variability,*
2. *Optimizing chemical usage,*
3. *Effluent load and*
4. *Cost reduction.*

The details of controls are discussed in detail.

Keywords: *Advance Process Control (APC), Optimization, Variability, Cost.*

Introduction

a) Pulp Making Process:

The Pulping Process at Chemical Bagasse Plants begins with the handling and storage of bagasse, a fibrous byproduct from sugar mills. Upon arrival, the bagasse undergoes a de-pithing Process in which pith is removed. De-pithed bagasse is then stored in an open yard through a stacker system, ensuring an adequate and steady supply of raw material. The stored bagasse is then transported via conveyor systems to the continuous digesters for further Processing.

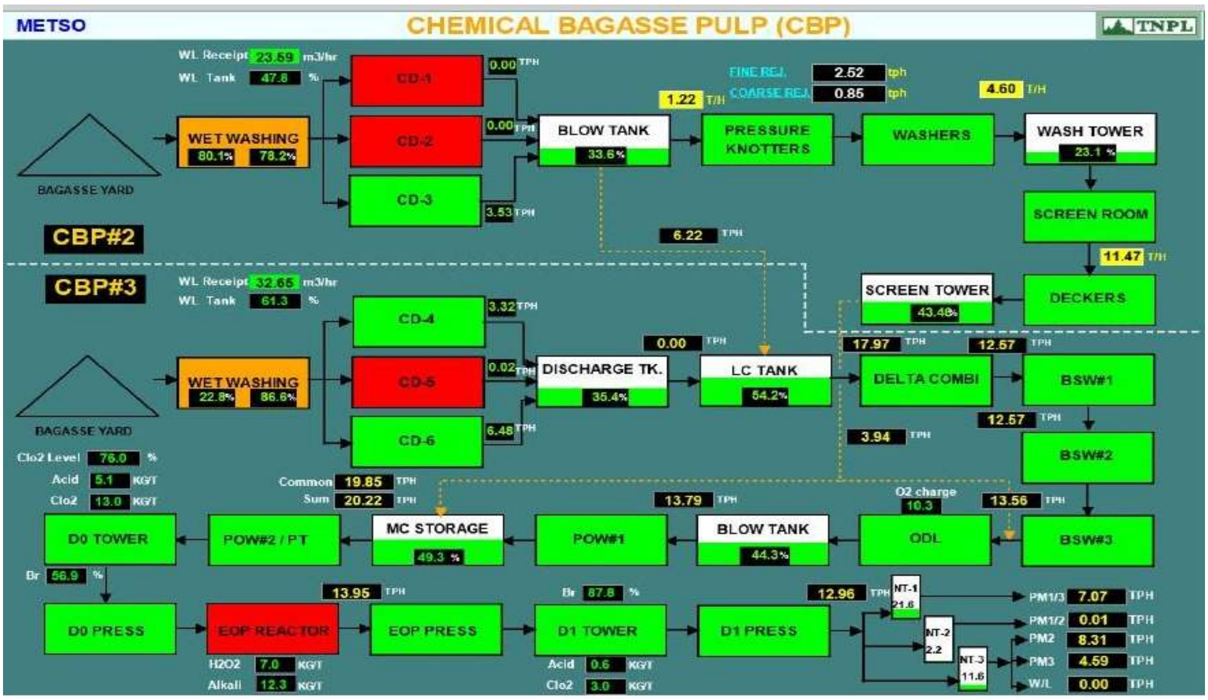
The chemical bagasse-based Pulping Process includes stages such as wet washing, continuous digesters, screening, Pulp washing, Oxygen Delignification (ODL) and bleaching. Sand separation is conducted through sand rifflers and wash beaters to ensure that sand is removed from the digester feed, thus maintaining Pulp quality. Bagasse wash water is treated in a Back Water Clarification Plant, where pith and sand are separated and discarded.

Coarse and fine rejects generated during Pulp screening are reprocessed in the washers before entering the bleaching Process. This integrated approach enhances material recovery and minimizes wastage.

After screening and washing, pulp is then stored in the MC Storage Tower. This marks the starting point for the bleaching stage. The combined Pulp from two different plants undergoes a multistage bleaching Process in the Chemical Bagasse Elemental Chlorine Free (CB-ECF) Plant, which includes the following stages:

- **Pre-Thickening (PT):** Initial thickening of the Pulp before chemical treatment.
- **D0 Stage:** The first chlorine dioxide bleaching stage.
- **EOP Stage:** Extraction with oxygen and hydrogen peroxide, enhancing Pulp brightness.
- **D1 Stage:** The final chlorine dioxide stage for further brightening.

The fully bleached Pulp is stored in three towers and is then transported to three Paper machines for Paper production. This ensures a steady and consistent flow of high-quality Pulp to the Paper Machines, optimizing TNPL's production capacity.



Overview of Chemical Bagasse Pulpmill Process

b) Chemicals in the different stages of bleaching process:

D0 Stage:

☐ Dilute Sulphuric acid (H_2SO_4) and Chlorine dioxide (ClO_2) are added in this stage. These chemicals help to reduce the pH of the Pulp and improve its brightness.

EOP Stage:

☐ Sodium hydroxide (NaOH), hydrogen peroxide (H_2O_2), Oxygen (O_2), and MP steam are added to the Pulp during this stage. The purpose is to brighten the Pulp while also enhancing its strength by removing residual lignin.

D1 Stage:

☐ Dilute Sulphuric acid (H_2SO_4) and Chlorine dioxide (ClO_2) are again added, similar to the D0 stage, to achieve the desired brightness while maintaining Pulp quality.

Neutralization:

☐ Sulphur dioxide (SO_2) is added at the outlets of both the D0 and D1 stage towers to neutralize any residual chlorine that may still be present in the Pulp. This is critical for ensuring that no excess chlorine remains in the Pulp.

c) Earlier Chemical Controls:

Before APCs were implemented, the dosage of chemicals at various stages of the bleaching Process was largely based on manual controls and periodic laboratory measurements.

☐ Dilute Sulphuric acid (H_2SO_4) dosage at both the D0 and D1 stages was set by the operator based on the production rate, acid concentration and a target specific charge (Kg/ton) determined by laboratory pH readings and alkali loss.

- Chlorine dioxide (ClO_2) dosage at the D0 and D1 stages was similarly set based on the production rate, the concentration and a target specific charge (Kg/ton), which was adjusted according to Pulp kappa number and brightness readings.
- Sodium hydroxide (NaOH) dosage at the EOP stage was controlled based on production rate, concentration and target specific charge (Kg/ton), relying on laboratory pH readings.
- Hydrogen peroxide (H_2O_2) dosage at the EOP stage was determined by the production rate, concentration and target specific charge (Kg/ton), with Pulp brightness being the main factor in setting the dosage.

d) Setbacks in earlier Chemical Controls:

The earlier method of chemical control had several limitations that impacted the overall efficiency and quality of the bleaching Process.

- Intermittent Control: The operator set chemical dosages based on laboratory readings taken at specific intervals. Any variations in Pulp properties between these intervals were not controlled, leading to potential inaccuracies in chemical application.
- Inconsistent Chemical Dosage: Due to this manual control system, there were frequent instances of excess or insufficient chemical dosages. This led to variations in the specific charge (Kg/ton of Pulp), which directly affected the bleaching Process's efficiency.
- High Chemical Consumption: The specific consumption of Sodium hydroxide and Sulphuric acid often exceeded the target norms, leading to higher operational costs and deteriorating Pulp quality.

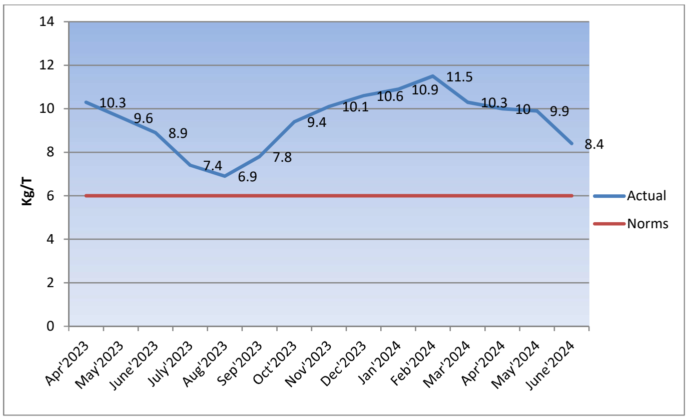


Fig. 1 Specific Consumption of Sulphuric Acid (H_2SO_4) before APC Implementation

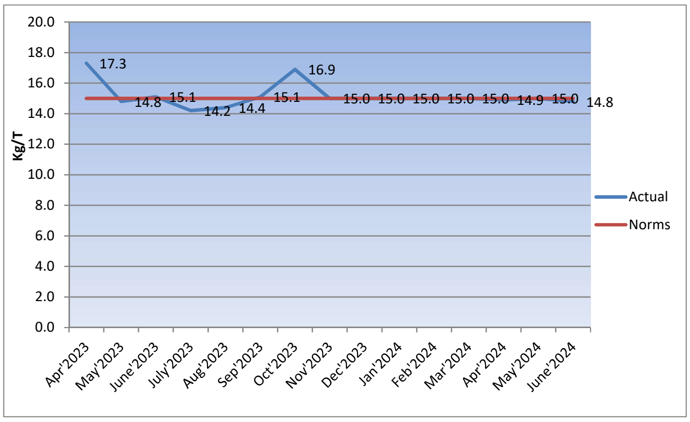


Fig. 2 Specific Consumption of Sodium Hydroxide (NaOH) before APC Implementation

- Variations in pH Control: The following standard deviations for pH control in different stages of the bleaching Process reflect the challenges in maintaining consistent chemical reactions:
  - D0 stage: **2 Sigma** deviation of pH = **0.85**
  - EOP stage: **2 Sigma** deviation of pH = **0.79**
  - D1 stage: **2 Sigma** deviation of pH = **1.69**

The higher deviations in pH, especially at the D1 stage, led to inconsistent bleaching results, affecting both the Pulp's quality and the overall consumption of chemicals.

ADVANCED PROCESS CONTROLS (APCs):

In response to the setbacks experienced with earlier manual controls of chemical dosing in the bleaching Process, Advanced Process Control (APC) systems was developed and implemented using online analyzers for closed-loop control. These APC systems have been designed, programmed, and commissioned in the Honeywell DCS Controller to improve chemical efficiency and Process stability. The APCs being implemented include:

1. **D0 Stage pH Control**
2. **EOP Stage pH Control**
3. **D1 Stage pH Control**

1. D0 Stage pH Control

The primary goal of the D0 Stage pH Control system is to optimize the addition of Sulphuric acid (H_2SO_4) to the D0 stage for achieving the desired pH. Accurate pH control is crucial for better reaction of Clo_2 with Pulp.

Inputs:

- **POW#2 Filtrate pH Measurement:** Online pH measurement from the POW#2 press filtrate.
- **D0 Filtrate pH Measurement:** Inline pH measurement from theD0 press filtrate
- **H_2SO_4 Flow Measurement:** Monitoring the flow rate of Sulphuric acid to ensure accurate dosing.

Output:

- **H_2SO_4 Flow Control Valve:** The control system adjusts the Sulphuric acid flow valve to optimize the addition of H_2SO_4 and maintain the target pH at the D1 stage.

Loop Function:

The D0 pH control system operates based on the principle of cascade control, utilizing both a primary and a secondary controller to ensure precise control over the Sulphuric acid dosing Process.

Primary Controller Function:

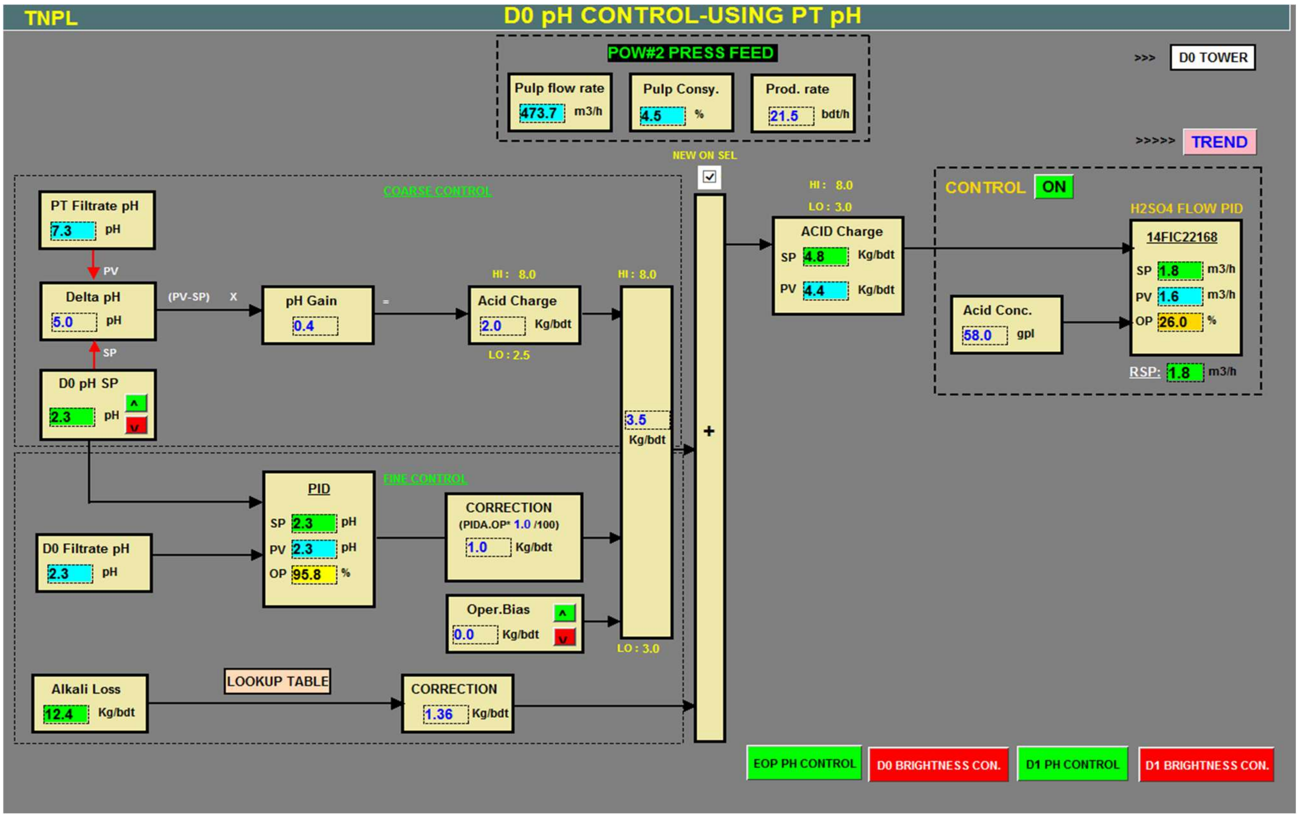
The Primary controller includes Coarse and Fine control action.

- Coarse Control: The desired pH at the D0 stage is compared with the POW#2 stage filtrate pH. Any deviation between these values is multiplied by a factor to calculate the coarse control charge requirement. This forms the foundation of the control action.

- Fine Control: The D0 press filtrate pH measurement is compared with the desired D0 stage pH in a single-loop PID controller. The fine control action output varies between -100% and +100% to make small, precise adjustments to the Sulphuric acid dosing. This action output is multiplied with a factor is to arrive the Fine control charge requirement.
- **Alkali loss correction:** An operator based entry of Laboratory Alkali loss is added as a fine correction into the primary controller's output to fine-tune the control Process.
- **Operator Bias:** An operator bias is incorporated manually into the primary controller's output to fine-tune the control Process and further minimize errors if any in maintaining the target pH.
- **Summation:** The outputs from coarse control, Fine control, Alkali loss correction and Operator bias are summed up to arrive the Primary controller output.

Secondary Controller Function:

- Remote Set Point (RSP): The secondary controller's Remote Set Point (RSP) is calculated based on primary controller total acid charge, the production rate at POW#2 press feed and the concentration of acid in the system.
- Acid Flow Control: The secondary controller then adjusts the dilute Sulphuric acid flow rate to maintain the desired pH level at the D0 stage, ensuring that the Pulp undergoes the better clo2 reaction under acidic conditions.



D_0 Filtrate pH Control

2. EOP STAGE pH CONTROL:

Purpose:

The purpose of the EOP Stage pH Control system is to optimize the addition of Sodium Hydroxide (NaOH) at EOP Stage for achieving desired pH.

Inputs:

- **D0 Filtrate pH Measurement:** Inline pH measurement from the D0 Press filtrate, providing baseline input for coarse control actions.
- **EOP Filtrate pH Measurement:** Inline pH measurement from the EOP Press filtrate is monitored continuously to guide fine control actions.
- **Sodium Hydroxide Flow Measurement:** Measurement of the NaOH flow rate to ensure precise regulation of chemical dosing.

Output:

- The APC system adjusts the NaOH flow control valve to optimize sodium hydroxide addition and maintain the target pH at the EOP stage.

Loop Function:

The control system operates based on the principle of cascade control, incorporating both primary and secondary controllers. The primary controller calculates the required NaOH specific dosage and it is included in set point calculation of the secondary controller, which regulates the flow of sodium hydroxide.

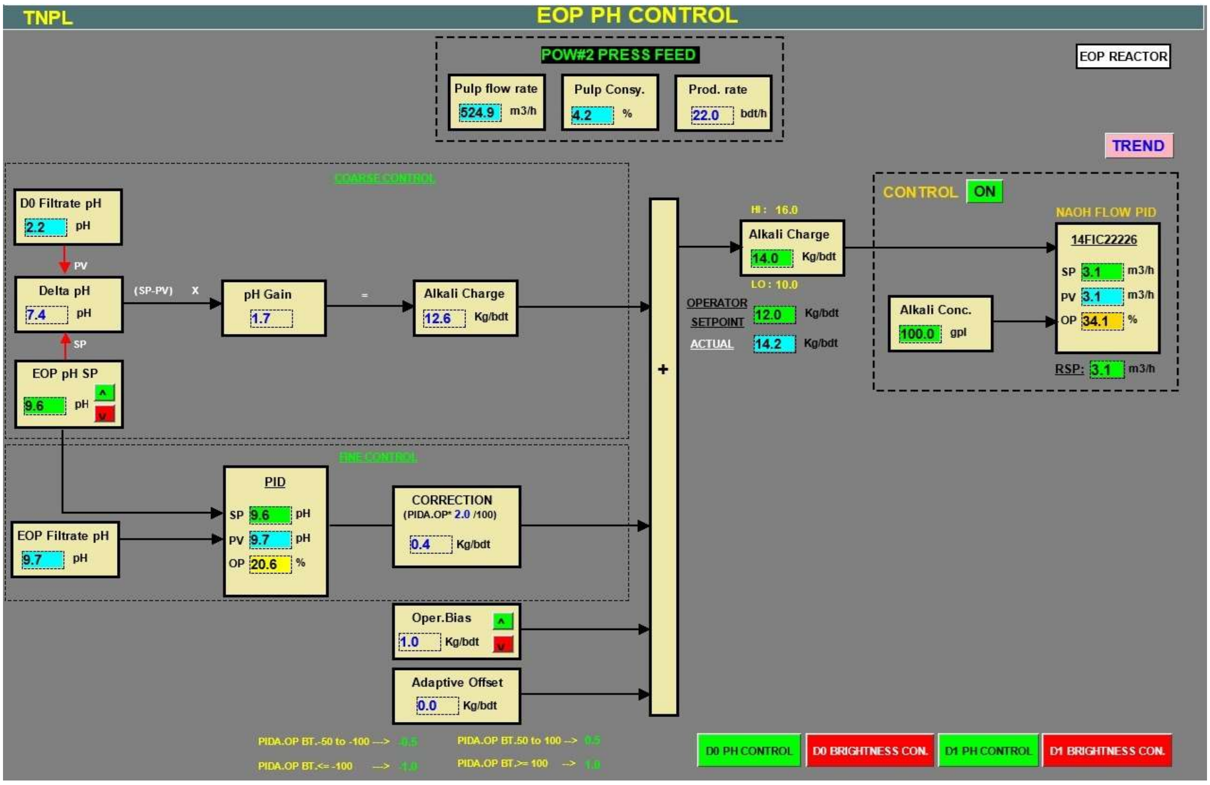
Primary Controller Function:

The Primary Controller includes Coarse and Fine control action

- **Coarse Control:** The Coarse Control action is initiated by comparing the desired pH at the EOP stage with the actual pH values from the D0press filtrate. The deviation between these values is multiplied by a predetermined factor to calculate the Coarse Control charge requirement.
- **Fine Control:** A single-loop PID controller compares the measured EOP filtrate pH with the desired pH value for the EOP stage. The fine control action, derived from this comparison varies between -100% and +100%, and it fine-tunes the NaOH charge requirement. This action output is multiplied with a factor is to arrive the Fine control charge requirement.
- **Preventing Controller Saturation:** To prevent the PID controller from saturation, an adaptive offset based on PID output is added to the primary controller output. This dynamic adjustment keeps the system responsive and prevents excessive swings in NaOH addition.
- **Operator Bias:** An additional operator bias is incorporated into the primary controller output to reduce error if any and fine-tune the system's response to changing Process conditions.
- **Summation:** The outputs from Coarse control, Fine control, Adaptive offset and Operator bias are summed up to arrive the Primary controller output.

Secondary Controller Function:

- **Remote Set Point (RSP):** The secondary controller's Remote Set Point (RSP) is calculated based on primary controller total NaOH specific charge, the production rate at POW#2 press feed and the concentration of NaOH in the system.
- **NaOH Flow Control:** The secondary controller then adjusts the NaOH flow rate to maintain the desired pH level at the EOP stage, ensuring that the Pulp undergoes the bleaching Process under optimal conditions.



EOP Filtrate pH Control

3. D1 Stage pH Control:

The primary goal of the D1 Stage pH Control system is to optimize the addition of Sulphuric acid (H_2SO_4) to the D1 stage for achieving the desired pH. Accurate pH control is crucial for better reaction of Clo2 with Pulp.

Inputs:

- ☐ EOP Filtrate pH Measurement: Inline pH measurement from the EOP press filtrate.
- ☐ D1 Filtrate pH Measurement: Inline pH measurement from theD1press filtrate
- ☐ H_2SO_4 Flow Measurement: Monitoring the flow rate of Sulphuric acid to ensure accurate dosing.

Output:

- ☐ H_2SO_4 Flow Control Valve: The control system adjusts the Sulphuric acid flow valve to optimize the addition of H_2SO_4 and maintain the target pH at the D1 stage.

Loop Function:

The D1 pH control system operates based on the principle of cascade control, utilizing both a primary and a secondary controller to ensure precise control over the Sulphuric acid dosing Process.

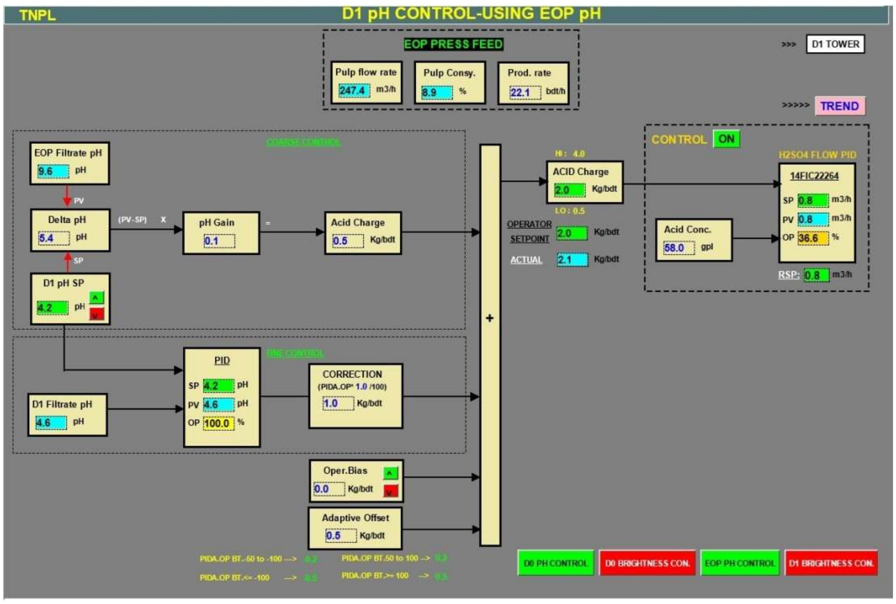
Primary Controller Function:

The Primary controller includes Coarse and Fine control action.

- **Coarse Control:** The desired pH at the D1 stage is compared with the EOP stage filtrate pH. Any deviation between these values is multiplied by a factor to calculate the coarse control charge requirement. This forms the foundation of the control action.
- **Fine Control:** The D1press filtrate pH measurement is compared with the desired D1stage pH in a single-loop PID controller. The fine control action output varies between -100% and +100% to make small, precise adjustments to the Sulphuric acid dosing. This action output is multiplied with a factor is to arrive the Fine control charge requirement.
- **Preventing Controller Saturation:** To prevent the PID controller from saturation or becoming ineffective, an adaptive offset based PID output is applied to the primary controller's output. This keeps the system responsive to Process variations and maintains control efficiency.
- **Operator Bias:** An operator bias is incorporated manually into the primary controller's output to fine-tune the control Process and further minimize errors if any in maintaining the target pH.
- **Summation:** The outputs from coarse control, Fine control, Adaptive offset and Operator bias are summed up to arrive the Primary controller output.

Secondary Controller Function:

- **Remote Set Point (RSP):** The secondary controller's Remote Set Point (RSP) is calculated based on primary controller total acid charge, the production rate at EOP press feed and the concentration of acid in the system.
- **Acid Flow Control:** The secondary controller then adjusts the dilute Sulphuric acid flow rate to maintain the desired pH level at the D1 stage, ensuring that the Pulp undergoes the better clo2 reaction under acidic conditions.



D1 Filtrate pH Control

Table:1 2-Sigma Value Before APC control

Period	Average	Min Value	Max Value	2 Sigma	Variability Reduction
25/06/24 – 05/07/24	2.79	1.94	3.64	0.85	0 %

Table:2 2-Sigma Value After APC control

Period	Average	Min Value	Max Value	2 Sigma	Variability Reduction
07/07/24 – 22/07/24	2.60	2.04	3.16	0.56	34%
08/08/24 – 31/08/24	2.53	2.12	2.94	0.41	52 %

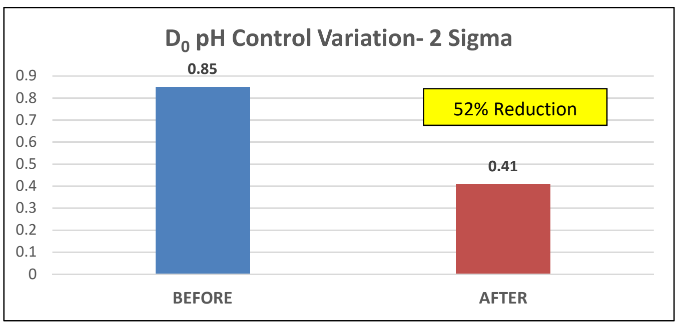


Fig. 3 D_0 pH Control Variation

b. EOP pH:

Table:3 2-Sigma Value Before APC control

Period	Average	Min Value	Max Value	2 Sigma	Variability Reduction
25/06/24 – 05/07/24	9.07	8.28	9.86	0.79	0 %

Table:4 2-Sigma Value After APC control

Period	Average	Min Value	Max Value	2 Sigma	Variability Reduction
07/07/24 – 22/07/24	9.73	9.08	10.38	0.65	18%
08/08/24 – 31/08/24	9.58	9.13	10.03	0.45	43%

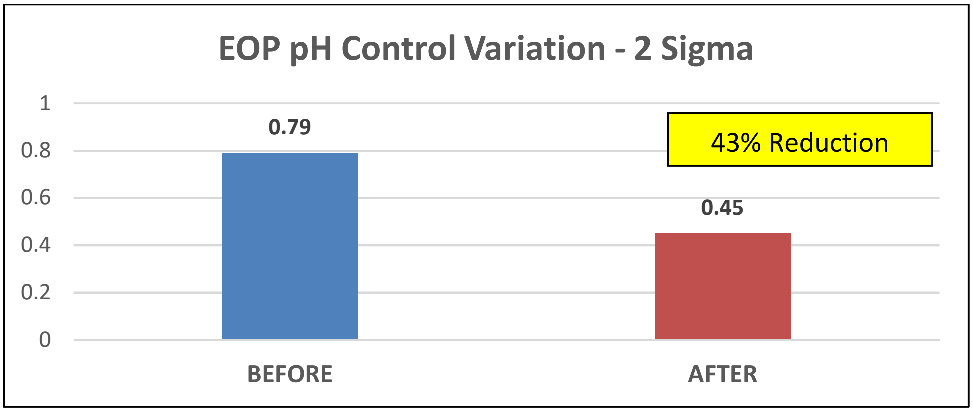


Fig. 4 EOP pH Control Variation

c. D1pH:

Table:5 2-Sigma Value Before APC control

Period	Average	Min Value	Max Value	2 Sigma	Variability Reduction
25/06/24 – 05/07/24	5.41	3.72	7.1	1.69	0 %

Table:6 2-Sigma Value After APC control

Period	Average	Min Value	Max Value	2 Sigma	Variability Reduction
07/07/24 – 22/07/24	4.61	3.35	5.87	1.26	25%
08/08/24 – 31/08/24	3.92	2.80	5.04	1.12	34%

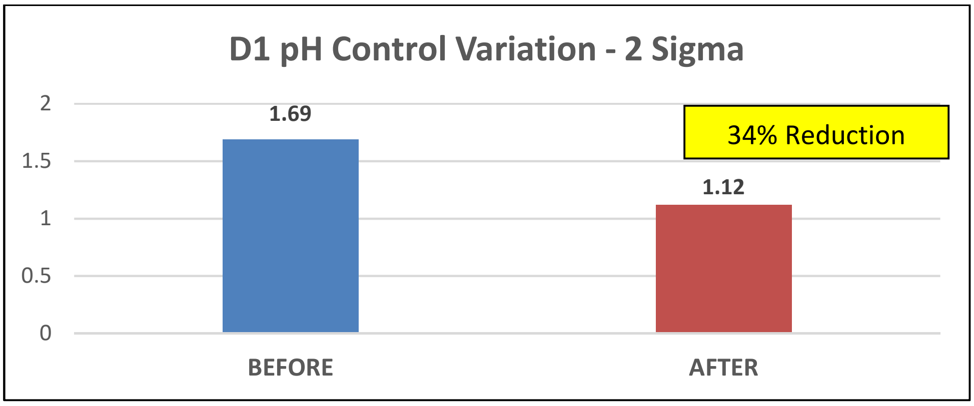


Fig. 5D1 pH Control Variation

II. Chemical Specific Consumption Reduction:

a) H2SO4:

Sulphuric acid (H2SO4) specific consumption is reduced from 9.4 Kg/t of Pulp to 6.3 Kg/t of Pulp in the month of August'24 with 33% reduction in chemical consumption.

Table:7 Average Specific consumption of H2SO4& reduction

S. No	Month	Norms (Kg / T)	Consumption (Kg/T)	Average Consumption (Kg/T)	Chemical Consumption Reduction
BEFORE					
01	Apr 2024	10.0	10.0	9.4	0 %
02	May 2024	10.0	9.9		
03	Jun 2024	10.0	8.4		
AFTER					
04	Jul 2024	10.0	6.4	6.4	32 %
05	Aug 2024	10.0	6.3	6.3	33 %

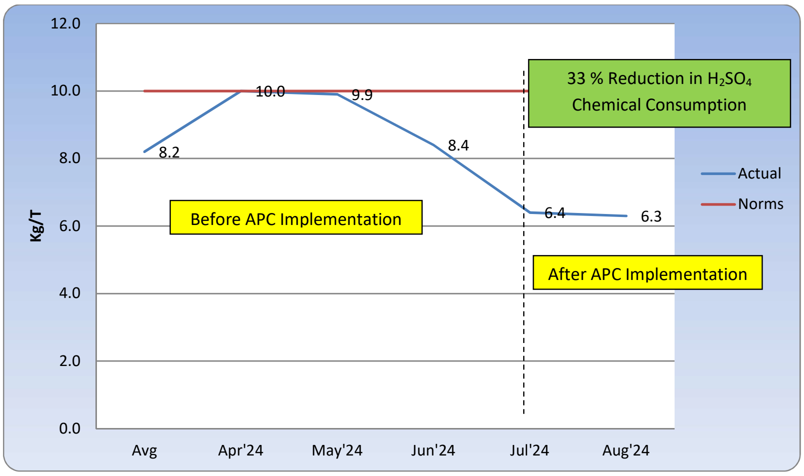


Fig. 6 Specific Consumption of Sulphuric acid (H_2SO_4)

b) NaOH:

Sodium Hydroxide (NaOH) specific consumption is reduced from 14.9 Kg/t to 14.8 Kg/t of Pulp in the month of Aug'24 with 0.7% reduction in chemical consumption.

Table:8 Average Specific consumption of NaOH & reduction

S. No	Month	Norms (Kg / T)	Consumption (Kg/T)	Average Consumption (Kg/T)	Chemical Consumption Reduction
BEFORE					
01	Apr 2024	15.0	14.9	14.9	0 %
02	May 2024	15.0	15.0		
03	Jun 2024	15.0	14.8		
AFTER					
04	Jul 2024	15.0	14.7	14.7	1.3 %
05	Aug 2024	15.0	14.8	14.8	0.7 %

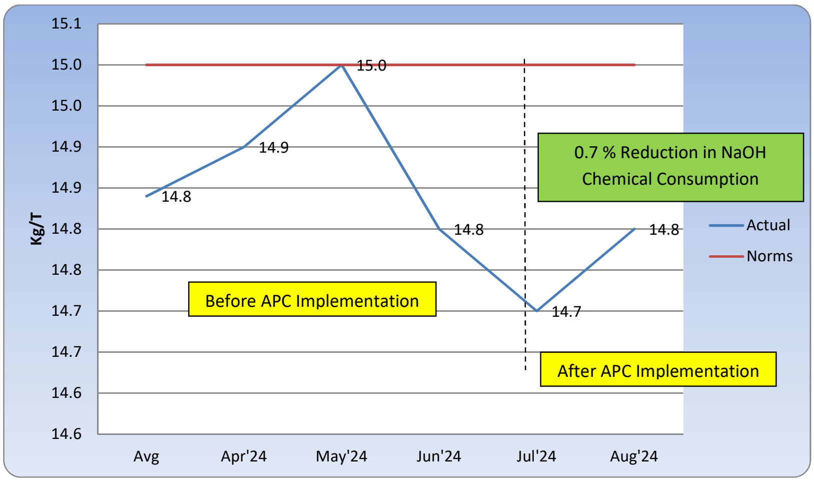


Fig. 7Specific Consumption of Sodium hydroxide (NaOH)

III. Cost Benefits:

Net Benefits:

Table:9 Chemical reduction & Savings

Chemical Name	Norms (Kg/T)	BEFORE APC (Kg/T)	AFTER APC (Kg/T)	Reduction (Kg/T)	Unit Rate (Rs/Kg)	Total Pulp Prod. (MT)	Savings (Rs.)
	2024-25	Apr-Jun'24	Aug'24		Aug'24	Aug'24	
H_2SO_4	10.0	9.4	6.3	3.1	6.95	12636	2,72,243
NaOH	15.0	14.9	14.8	0.1	31.32	12636	39,576
Total Savings (Rs.)							**3,11,819**

Table:10 Cost Benefits of Sulphuric acid and Sodium hydroxide

Sl. No.	Parameter under Control	pH Variability Reduction	Reduction in Specific Chemical Consumption	Cost Savings / Month (Rs.)
		Aug'2024	Aug'2024	Aug'2024
1.	D0Stage pH	52 %	33%	2,72,243
2.	D1 Stage pH	34 %		
3.	EOP Stage pH	43 %	0.7%	39,576
Total Savings / Month (Rs.)				**3,11,819**

IV. Financial Investment: Nil

Conclusion:

The implementation of APCs in CBP bleach plant has led to significant improvements like reducing Process variability and optimizing chemical usage.

- **pH Variability Reductions:**
  - o D0 stage: 52%
  - o EOP stage: 43%
  - o D1 stage: 34%
- **Specific Chemical Consumption:**
  - o Sulphuric Acid (H_2SO_4) reduced by 33% in the month of August'2024
  - o Sodium Hydroxide (NaOH) reduced by 0.7% in the month of August'2024

These reductions resulted in significant **Cost savings of Rs. 3.12 lakhs** for the month of August'2024.

The Benefits of APC Implementation includes

1. Improved Process Efficiency
2. Enhanced Product Quality
3. Reduced Operator Intervention
4. Reduced Operational Costs
5. Enhanced Data Utilization
6. Reduction in Environment load

The plant continues to explore opportunities to transition of more open-loop systems to closed-loop control by implementing APC across various stages of production. Such efforts would contribute to further improvements in overall system performance, resulting in a more efficient, reliable, and competitive operation in today's fast-paced industrial environment.

References:

1. *"Soft Computing Based PID Controller Tuning and Application to the Pulp and Paper Industry", *B. Nagaraj, P. Vijayakumar, Sensors & Transducers ISSN 1726-5479 http://www.sensorsportal.com.*
2. *Ziegler, G. and Nichols, N. B, Optimum settings for automatic controllers, Trans. ASME, 64, 1942.*
3. *https://www.valmet.com/automation/services/Process-performance/pid-tuning-Process-control/pid-tuning-tutorial/*