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Consistency Controller for Conserving Energy by Controlling the Speed of the motor using Variable Frequency Drive

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Abstract: Most common method of speed control which is employed in paper and pulp industries is by using level controller. In this method, level is maintained constant at each stage. But this method of level control leads to power loss at each stage. Another method is speed control of medium consistency pump using consistency control. By employing consistency control and maintaining consistency at a constant value, power loss can be reduced. Initially the method of speed control that is employed in Seshasayee Paper & Boards Ltd, is by the use of level control. Power loss was more while employing level control method. It has been synchronized level control with consistency control. By this method power loss was reduced to some extent. Variable Frequency Drive (VFD)'s are used where there is fluctuation in load. Distributed Control System (DCS) is used to control the level of water in the pulp. By taking several samples and analyzing, we found that by maintaining consistency at a value of 3.5, power loss was considerably reduced. If the value consistency level increases or decreases, the power loss also increases.

Keywords: Variable Frequency Drive (VFD), Distributed Control System (DCS), Consistency Control, Level Control. Oxygen-delignification stage (ODL)

I. INTRODUCTION

1.1 Overview:

Variable speed drives are playing a vital role in present day Industries. Our paper deals with "Conserving Energy" by controlling the speed of the motor depending on the consistency of the Pulp. This is achieved through "Variable Frequency Drive (VFD)". VFD's are used where there is fluctuation in load. They use their output devices (IGBTs, transistors, thyristors etc.) only as switches. Attempting to use a linear device such as transistor in its linear mode would be impractical, since power dissipated in the output devices would be about as much as power delivered to the load. Using this concept, the paper aims at conserving considerable amount of energy in the Pulp Mill section, which is need of the hour. Variable-frequency drives are widely used. For example, in ventilations systems for large buildings, variable-frequency motors on fans save energy by allowing the volume of air moved to match the system demand. Variable frequency drives are also used on pumps, conveyor and machine tool drives. It is also employed in paper industries to control speed in an effective manner.

1.2 Problem statement:

While analyzing the factors that lead to power loss in the paper mill, it was noticed that speed is a prime factor to be considered. So VFD was employed. Some reduction in power loss was noticed. There was some other factor that leads to power loss. We found that the value of consistency is another important factor which leads to power loss. Distributed Control System (DCS) is used to control the level of water in the pulp. Our objective is to design a closed loop controller to maintain the consistency at a constant value.

1.3 Literature Review:

Case study of the paper manufacturing sector[1] explains the processes involved in paper manufacturing, which is used to understand the pulp and paper manufacturing process across the globe. Modernization and Wood chip fiber flow rate control and refining energy saving [2]-[4] helps in implementing consistency control for saving power. Improving the system operation [5]-[10] using various technologies reveals that each and every parameter can be optimized to get desired performance.

II. BLOCK DIAGRAM

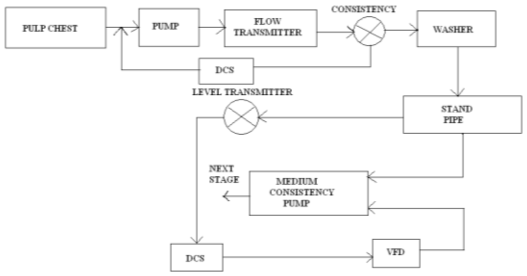

Fig 2.1 Block Diagram for paper manufacturing

Figure 2.1 shows the block diagram of paper manufacturing. Pulp which is present in the pulp chest is transferred through the pump to the flow transmitter followed by the washer. Then the pulp is transferred to the flow transmitter. This flow transmitter controls the rate of flow of pulp. Consistency of the pulp which is coming out of the flow transmitter is checked and if there is any variation in the consistency, the Distributed Control System (DCS) comes into picture and corrects the error.

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Error is corrected by means of providing feedback to the control valves.

Consistency which is to be maintained at all stages is 10%. Then the pulp enters the washer. The washed pulp flows into the stand pipe. DCS is employed to control the level of water in the pulp. In case, there is variation in the level, then DCS comes into action and corrects the error which is given as a direct feedback to the Variable Frequency Drive (VFD). VFD alters its speed according to both level and consistency.

III. Classification of Raw Material

A. Wood fibers B. Non-wood fibers

3.1 Wood Fibers

Soft wood: Gymnosperm, seeds are born naked

Example : Spruce, Fir, Pine etc.

Hard wood: Angiosperm of dicotyledonous variety. Broad leaf trees.

Example: Gum, Beech, Birch etc.

Hardwoods contain vessel elements (short, non-fibrous cells) that have little or no radial alignment of fiber and contains more parenchyma cells. They have shorter and narrower fibers. Worldwide 600 species of softwood and 12000 species of hardwood are said to be available.

3.2 Non-Wood Fibers

Fibers from plants which are neither trees nor shrubs nor climbing variety, are called as herbaceous plants. From papermaking point of view, it is classified as follows.

Corp fibers (subdivided into three types):

1. Bast stem fibers like jute, hemp, flex etc.
2. Leaf fibers like sisal, manila etc.
3. Seed hair fibers like cotton fiber and linder etc.

Secondary or recycled fiber is another source of fibrous raw material.

Pulp Mill and Bleach Plant Data of SPB

Fibrous raw materials used :

Hardwood (Eucalyptus Hybrid, Casuarina Eucalyptus Globulus, Wattle, etc.)

Bagasse (Purchase Pulps)

Pulp used:

Imported bleached Hardwood pulp

Imported bleached Softwood pulp

Secondary Fiber like New Double Lined Kraft Cuttings (NDLKC)

Procurement of Wood Raw Material

From man made forests of Tamil Nadu state.

PROCUREMENT OF BAGASSE

Major quantity from sister concerned Sugar mill (PONNI) and remaining quantity from in and around sugar mill.

STORAGE OF WOOD RAW MATERIAL

Logs of about 3 feet are stacked at mill site in Yard area.

STORAGE OF BAGASSE

Stored as piles in loose form with 50% moisture at mill site.

3.3 CHIPS PREPARATION FROM WOOD

Table 3.1 Data of Chips Preparation from Wood.

DATA	VALUE/RANGE
Number of chippers present	Two
Type of chipper	Disc
Capacity of chipper, tons/hr	20
Number of rechipper	one
Type of conveyor to shift chips to silo	Belt
Number of Silo to store accepted chips	Four
Power consumption/ ton of chips, Kwh	1-10

3.4 FIBER PREPARATION FROM BAGASSE

Table 3.2 Data of Primary unit fiber preparation from bagasse

DATA	TYPE/RANGE
Depither Type	Horizontal Horkel
Depither capacity	7tons/hr
Size of opening	8-10mm
Power/ ton of depithed bagasse	10 Kwh

Table 3.3 Data of Secondary unit fiber preparation from bagasse

DATA	TYPE/RANGE
Depither Type	Slushing type
Depither capacity	20 tons/hr
Sand removal system	Riffler
Bagasse dewatering system	Aqua-separator
Pith dewatering system	Belt press

Table 3.1, Table 3.2 and Table 3.3 shows the Chips Preparation from Wood data , Primary unit and secondary data fiber preparation from bagasse data respectively.

3.5 WOOD PULPING PROCESS DATA

Table 3.4 Data of wood pulping process

DATA	TYPE/RANGE
Type of pulping process adopted	Kraft pulping batch
Type of digester	Stationary
Number of digesters	Four
Volume of each digester	80 m^3
Cooking temperature	168 ^{0}C
Cooking time at specified temperature	90 minutes
Pressure during cooking	8 kg/cm^2
H-factor	1300-1350
Total cooking cycle	5.30 Hrs
Active Alkali charge(as Na_2O)	14.25-15.75%
Pulp production per blow	8.5 tons (approx.)
Unbleached pulp yield	43-45%
Total steam per blow	15-17 Tons
Steam per ton of pulp	1.8-1.9 Tons
Power per ton of pulp	92 Kwh
Unbleached pulp Kappa number	20-2

3.6 BAGASSE PULPING PROCESS DATA

Table 3.5 Data of bagasse pulping process

DATA	TYPE/RANGE
Type of pulping process adopted	Kraft pulping
Type of digester	Pandia(with two tubes)
Number of digesters	Two
Cooking temperature	170 ^{0}C
Cooking time at specified temperature	18 minutes
Pressure during cooking	8 kg/cm^2
H-factor	385
Bagasse feed rate	8.0-8.5 Tons per hour
Active Alkali charge(as Na_2O)	14.0-14.5%
Steam per ton of pulp	2.30 Tons
Bagasse pulp yield	45-47%
Unbleached pulp Kappa number	10-12

Table 3.4and Table 3.5 shows the process data of wood pulping and bagasse pulping respectively.

3.7 WOOD PULP WASHING DATA

Table 3.6 wood pulp washing Data

DATA	TYPE/RANGE
Type of washing system	Counter-current
Number of washing stages	Four
Pulp washing rate	6.5 Tons/Hr
Soda loss as Na_2SO_4	13-15 Kgs/ton
Weak Black Liquor per ton of pulp	10.0 Tons
Black Liquor Solids per ton of pulp	1.6 Tons

3.8 BAGASSE PULP WASHING DATA

Table 3.7 Bagasse pulp washing Data

DATA	TYPE/RANGE
Type of washing system	Counter-current
Number of washing stages	Four (Two streets)
Pulp washing rate	4.0Tons/Hr
Soda loss as Na_2SO_4	25-30 Kgs/ton

Table 3.6and Table 3.7 shows the washing data of wood pulping and bagasse pulping respectively.

WOOD PULP SCREENING PROCESS

Washed pulp is fed to Voith and Hooper screen. The accepts are taken for bleaching through thickener. The rejects are fed to Ahistom screen through KMW chest. The accepts of this screen are sent back to high density chest and rejects are going to drain.

3.9 BAGASSE PULP SCREENING DATA

Table 3.8 Bagasse Pulp Screening Data

DATA	TYPE/RANGE
Type of screens	Centrifugal gravity feed
Number of screens	1 no
Size of screens	1.8 mm perforated plate
Type & number of cleaners	Centrifugal / 2 stage
Capacity	90 / day
Screening / washing loss	2 %
Pulp consistency	1%
Water used	Only recycled water is used

Table 3.8 shows the screening data of bagasse pulping.

IV. Layout of Pulp Mill

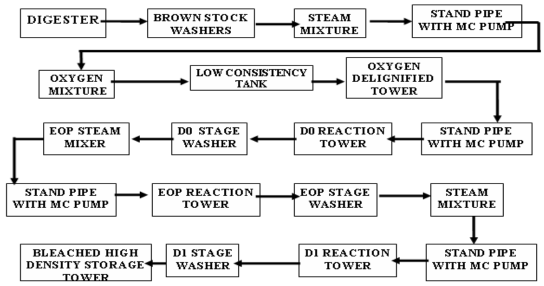

Fig: 4.1 Layout of Pulp Mill

Figure 4.1 shows the pulp mill layout. Digester filled with chips, using either liquor or steam to improve compaction density. Digesters are filled with warm liquor. Air is displaced from the digesters and discharge valves are closed. The chips are pre-impregnated with weak liquor and the digester is hydraulically filled. Hot white & black liquors are pumped into the digester. Digesters are brought to 160 oC before any steam is added by displacing warm liquor to the accumulator. On a continuous basis, hot black liquor is passed through an indirect heater to heat the incoming white liquor and stored in an accumulator. Digesters are brought to direct steaming and 'H' factor is maintained. Then the washer filtrate is pumped through the digester displacing hot liquor to the accumulators. 70% of the hot liquor displaced remains at the cooking temperature. Hotter and cooler liquors are displaced in separate tanks. Pulp can be stored in the digester without occurrence of any cooking reaction. A blow heat recovery system would require to condense flash steam so that non condensable gases cannot go to atmosphere.

4.1 DISTRIBUTED CONTROL SYSTEM IN SESHASAYEE PAPERS & BOARDS LIMITED

The Distributed Control System (DCS) used in SPB, is “Honey Well” made. The latest version used in DCS is R300 and the software used is “Experion- Process Knowledge System (PKS)”. There are four controllers employed in the instrumentation section of the pulp mill.

They are:

i. RDH- Rapid Displacement Heating
ii. FBL- Fiber Line
iii. BL- Bleaching
iv. ClO2- Chlorine di oxide

All these controllers form closed loop. There are four ways in which input and output can be given. They are as follows:

ANALOG INPUT (AI)

The Analog Input consists of 16 inputs. Parameters such as pressure, temperature etc. constitutes the Analog Inputs.

ANALOG OUTPUT (AO)

The Analog Output consists of 16 outputs. Parameters such as consistency and level constitutes the Analog Outputs.

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DIGITAL INPUT (DI)

The Digital Input consists of 32 inputs. Conditions such as opening/closing of valves and starting/stopping of pumps forms the Digital Inputs.

DIGITAL OUTPUT(DO)

The Digital Output consists of 32 outputs. Potential free contactors constitute the Digital Output.

TOPOLOGY

The DCS in SPB uses topology for communication such as

1. Hart bus topology
2. Field bus topology
3. Profibus topology

The above bus topologies are used for the field-DCS communication, according to the requirement these topologies are also used for controller- instrument communication.

4.2 SCHEMATIC DIAGRAM

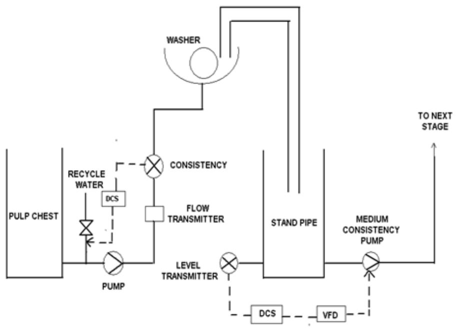

Fig 4.2 Schematic Diagram of DCS

Figure 4.2 shows the Schematic Diagram of DCS. The following are the faults that can occur in operating systems. The Distributed Control System (DCS) recovers these faults from occurring in the system. The network components can neither transmit nor receive data, if complete failure occurs in the system. If the partial failure occurs in the system, the network components can either transmit or receive data.

Table 4.1 BEFORE EMPLOYING CONSISTENCY CONTROL

S.NO	CONSISTENCY (%)	LEVEL (%)	CURRENT (Amperes)	POWER (kW)
1	2.45	83	90.1	86.49
2	3.19	92	97	93.12
3	2.22	79	85	81.60
4	3.85	99	113.25	108.72
5	3.35	96	102.52	98.41

Table 4.1 shows the Power consumption before employing consistency control in ODL stage.

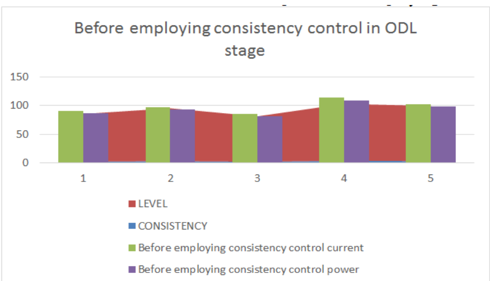

Fig. 4.1 overall graph for before employing consistency control in ODL stage

Fig. 4.1 shows the graph of consistency, level, current and power relationship in before employing consistency control in ODL stage. IN this he level, current and power parameters are not consistent.

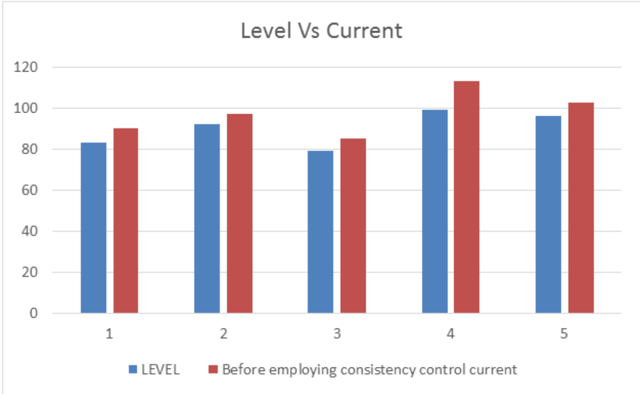

Fig. 4.2 level Vs current for before employing consistency control in ODL stage

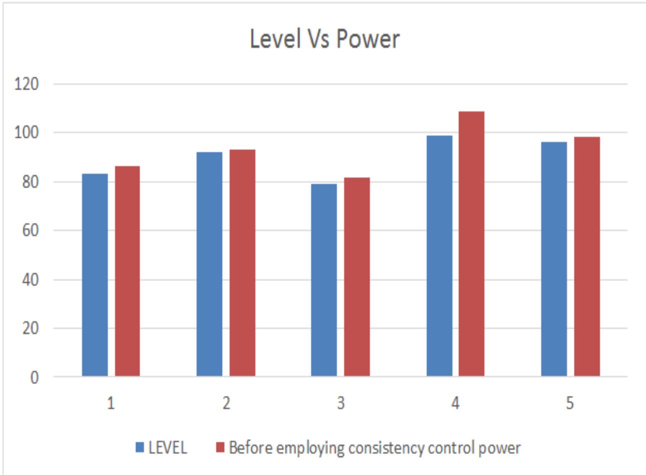

Fig. 4.3 level Vs Power for before employing consistency control in ODL stage

Fig. 4.3 shows the graph of level Vs Power before employing consistency control in ODL stage

Table 4.2 AFTER EMPLOYING CONSISTENCY CONTROL

S.NO	CONSISTENCY (%)	CURRENT (%)	POWER (kW)
1	3.82	90.2	86.59
2	3.50	90.0	86.40
3	3.00	92.4	88.70
4	2.75	90.6	86.97
5	2.85	91.8	88.12

Table 4.2 shows the Power consumption after employing consistency control in ODL stage.

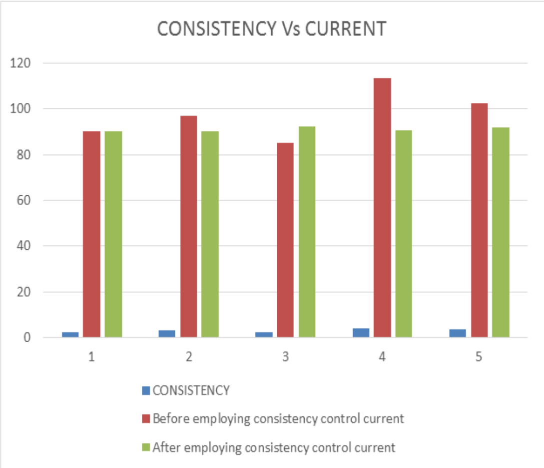

Fig. 4.4 Consistency Vs Current for before and after employing consistency control in ODL stage

Fig. 4.4 shows the graph of Consistency Vs Current for before and after employing consistency control in ODL stage. It indicates after employing the consistency control in ODL stage the current consumption is minimum when compare to the before employing the consistency control in ODL stage.

Fig. 4.4 Consistency Vs Power for before and after employing consistency control in ODL stage

Fig. 4.4 shows the graph of Consistency Vs Power for before and after employing consistency control in ODL stage. It indicates after employing the consistency control in ODL stage the power loss is minimum compare to the before employing the consistency control in ODL stage.

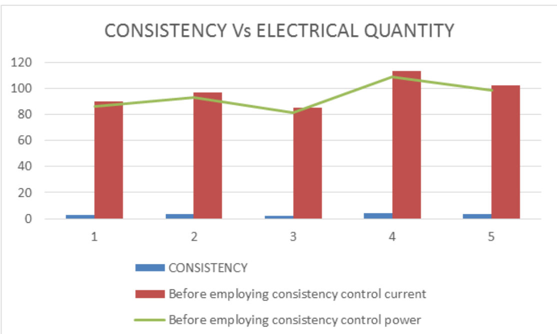

Fig. 4.4 Consistency Vs electrical quantity of current and power for before employing consistency control in ODL stage

Fig. 4.4 shows the graph of Consistency Vs Power for before and after employing consistency control in ODL stage

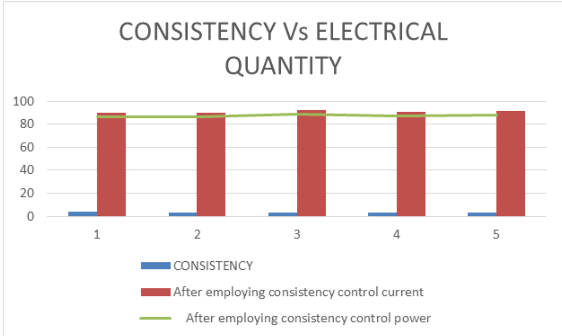

Fig. 4.4 Consistency Vs Power for after employing consistency control in ODL stage

Fig. 4.4 shows the graph of Consistency Vs Power for after employing consistency control in ODL stage. It indicates after employing the consistency control in ODL stage the current and power loss is minimum also constant level when compared to the before employing the consistency control in ODL stage.

V. CONCLUSION

5.1 Conclusion

In SPB, although consistency is maintained constant in each stage, It is noticed that the power loss is not minimized. While analyzing the factors which lead to power loss is found that when consistency is maintained at 3.5, power loss is minimum and if consistency increases above this value power loss also increases. It is also noticed that if the value decreased below 3.5, power loss increases. So in order to cater to these conditions, a control loop is developed to maintain the consistency at 3.5. After implementing this control loop in instrumentation section, power loss was considerably reduced. It is designed to in instrumentation part as a closed loop to maintain consistency at a constant value. At low value of consistency, quality will be affected. At higher value of consistency power loss is more. So consistency is maintained at 3.5, to minimize losses. By employing this closed loop it is seen that considerable amount of energy is saved.

Future scope:

This method was employed in Seshasayee Paper and Boards Limited for saving energy by controlling consistency. Most of the paper and pulp industries employ level control. In future consistency control can be employed so that power consumption will be reduced and efficiency will increase.

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