Multivariable Interactive Logic Control System For Batch Digester

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(I) PROCESS :

The process of digestion consists of cooking the prepared fibrous raw material with chemicals to isolate the cellulose fibre from the lignin. Digestion can be carried out on a batch or continuous basis. For small mills (e.g. producing upto 30 tonnes per day), batch cooking is preferred. A tumbling digester or a rotating spherical digester is the most common in small paper mills The advantage of the batch digester lies in its ability to cook different fibres for different schedules with ease. Fig. 1 shows the various resource inputs during cooking.

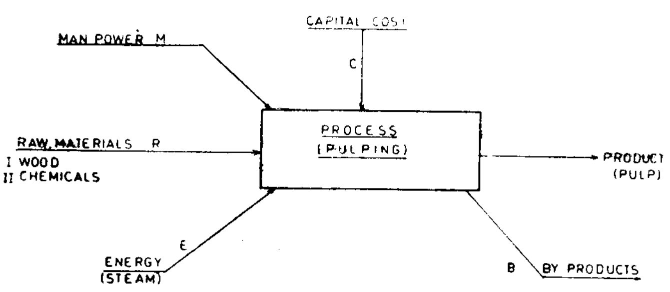

FIG 1 — RESOURCE FLOW DIAGRAM

A batch digester is a pressure vessel of a specified volume to withstand pressures upto 10 kg/cm². The digester is mounted on bearings to enable it to revolve slowly during the cooking cycle. The digester operation is controlled by (1) Time and temperature of cooking (2) chemical concentration and amount of liquor (bath ratio).

A typical batch cooking cycle is as follows :—

(a) Filling with raw materials and charging with liquors - 1.5 — 2 Hrs.

(b) Raising to steam pressure — 1 Hr.

(c) Cooking the raw material at the desired pressure — 2—2 5 Hr.

(d) Blowing and emptying — 0.5 - 1 Hr.

Total : 5 —6.5 Hrs.

The cooking is carried out at temperatures of 160°C to 165°C. There are variations depending on the raw materials used and end products made.

(II) BACK GROUND OF THE SYSTEM DEVELOPMENT :

The application of control system in pulp and paper industry for improving production and efficiency can be effectively done in three distinct phases—

(1) The first stage involves the elimination of waste.

(2) The second phase entails minor changes or adjustments of the existing instrumentation system.

(3) The third stage consists of modifying or replacing the existing equipments/instrumentation to improve efficiency. This stage require an advanced control with the use of computers or multiloop microprocessors. Considerable study, engineering, long term planning and large capital investment may be required in this case.

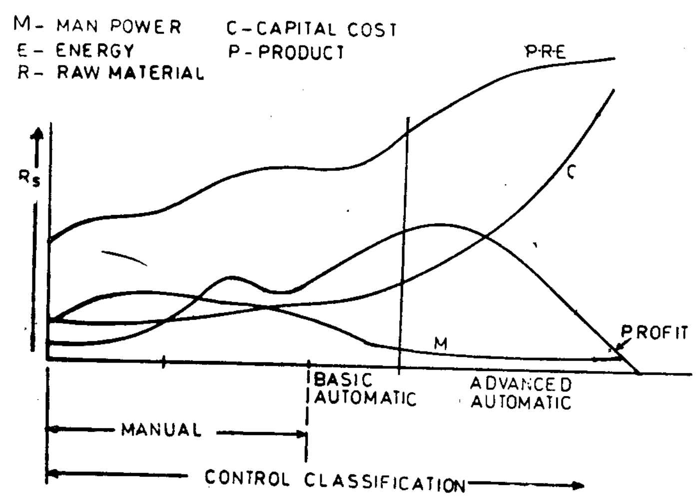

FIG. 2-ECONOMICS OF CONTROL HIERARCHY

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The present investigations describe the possibility of making the application of digital logic circuits in a batch digester to improve the uniformity and yield of pulp particularly in small paper mill where there is practically no instrumentation and control. The work falls in the second category in the above classification, which proposes minor changes in the existing plant/equipments thereby making the process control basic automatic. The attributes of the system are shown in fig. 2. These are :

(i) Reduced operator requirements

(ii) medium hardware requirements

(iii) limited process sensing/control interfacing

(iv) improving the quality and profits.

(III) PROCESS VARIABLES ENCOUNTERED IN THE SYSTEM :

The operation of a batch digester is influenced by two basic parameters. Namely (a) the quality of raw material and (b) the desired quality of the final cooked pulp. This is controlled by measuring a set of variables and inputs to the digester. These are listed as under.

(1) Raw material chip size, chip moisture content, information on raw material analysis (proximate analysis etc.).

(2) Finished pulp quality-residual lignin content (Kappa Number), residual alkali in black liquor. The information of the above lead to control of a large number of process variables effecting digester operations.

These are listed below :

(1) Temperature in the digester.

(2) Time to temperature schedule.

(3) Pressure in the digester.

(4) Quantity of cooking chemicals (Bath ratio)

(5) Concentration of cooking chemicals (active alkali, effective alkali).

The operation of the digester requires a proper control of the above variables through easily measureable and controllable parameters. It also require proper corrective actions when the digester is in a position to accept the corrections. Hence the usual variables controlled in the digester operatior are—

(1) Temperature (2) Pressure

(3) Steam flow rate (4) Cooking time

(5) Angle of tilt (a) of the digester

(6) Chip parameters (bulk density, moisture).

(7) Cooking chemical concentration and bath ratio.

(IV CONTROL STRATEGY :

(a Temperature :

Temperaturei n the digester is of utmost importance as it indicates the state of cook. In general it is observed that the temperature between top and bottom of a digester can vary significantly if turbulance is not proper and this is controlled by the rotation of the digester or by circulation of liquid in the stationary digester.

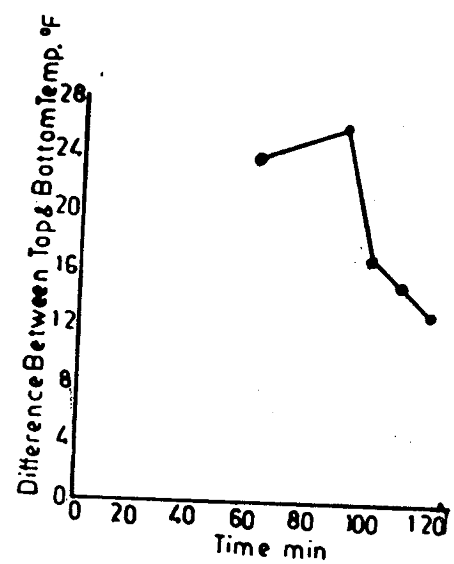

FIG. 3-AVERAGE TEMP. DIFFERENCE BETWEEN TOP AND BOTTOM OF DIGESTER.

Temperature in the digester is strongly related to rate of steaming and the pressure in the digester. Keeping in view above points it is proposed to make use of 3 thermocouples marked as T_1, T_2, T_3, in the figure–4. The output of the thermocouple is fed to an analog multiplexer (MUX.) followed by Analog to Digital converter (ADC) to give digital display of the four temperatures T_1, T_2, T_3, Tav top, middle, bottom and average temperature and the digester. An averaging circuit has been incorporated to find the average temperature inside the digester. This also has been fed to the multiplexer as input no. 4 to indicate its valve on the 3 digit LED display. The rate of scanning the temperature can be fixed by suitably selecting the clock frequency which operates the multiplexer. The channel indicator indicates T_1, T_2, T_3 and T av. The temperature values in the digester can maintained by properly selecting set point/proportional band or setting the potentiometer Tset Ref. Fig. 4 logic ckt I.

(b) **PRESSURE :**

The record of temperature and pressure is essential for establishing the relief flow operation. An electrical transducer used will give us the value of pressure transducted in electrical units and is expressed as binary variable. Since in the pulp production the variable is not directly controlled but is to be interacted with temperature hence multivariable interactive logic control circuit is proposed.

Ref. to Fig. No. 4, logic circuit No. I. The logic circuit design is based on the Boolean functions of the two variables i.e. Pressure (P) and average tempera-

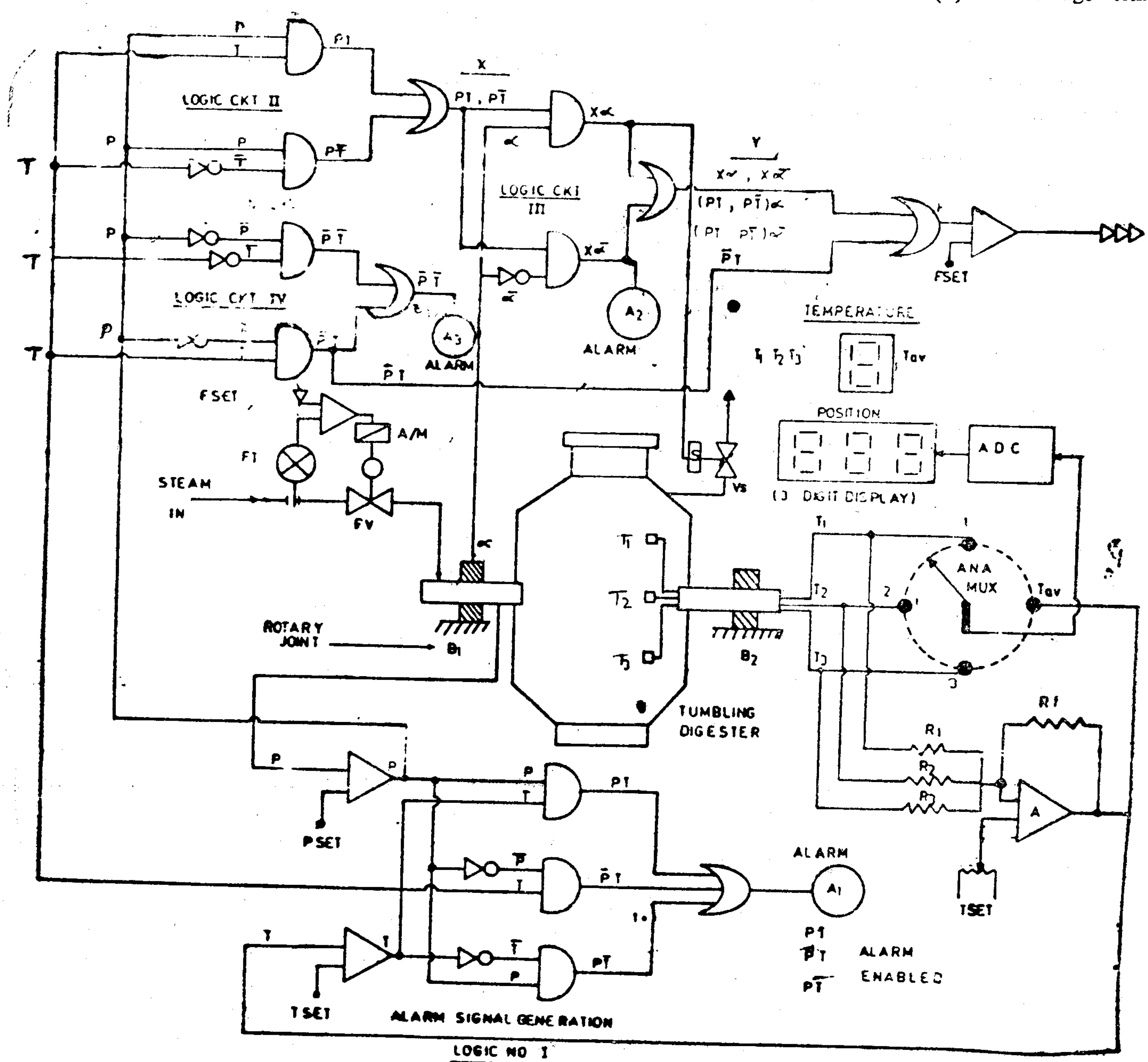

FIG.4-MULTI VARIABLE INTERACTIVE LOGIC CONTROL SYSTEM FOR BATCH DIGESTER

ıure (Tav.). The logic circuit design is implemented through logic gates. The logic circuit No. I is the "Alarm signal Generation circuit." The alarm circuit is disabled only when the condition $\bar{p}$ and $\overline{T}$ i.e. (P) low and (T) low occurs whereas in other three cases i.e. from Sr. No. 1,2,3 in the table No. 1, the alarm is excited indicating that (P) and (T) is high or (P) or (T) is high.

Truth Table No. 1 :

Alarm signal Generation Circuit and Functions

Sl. No.	Process Temp.	Variables/logic (T)	State Pressure	(P)	Alarm		Remark
1.	T	1	P	I	A	1	Improper operation
2.	$\overline{T}$	0	P	1	A	1	False Pressure
3.	T	1	$\bar{p}$	0	A	1	Not likely to occur
4.	$\overline{T}$	0	$\bar{p}$	0	$\overline{A}$	0	Starting

1 = High Stage 1. Enabled
0 = Low Stage 0. Disabled

(C) Angle of tilt (α) of the digester :

In small mills we find a tumbling digester. Which rotates at a speed of 0.25 r.p m.

When the pressure inside the digester goes little beyond the setvalve it needs to be blown out for safety operations. This should be essentially done only when the digester is in up-right position. If the angle of tilt is (α) then it has been assigned two valves i.e. $\alpha=1$ when the digester is in up-right position and $\alpha=0$, when it is in other than vertical position at which digester should not be blown. Thus the control logic is to be so designed that it operates the safety valve (VS) in fig. No. 4. when the interacting variables attain the condition of $\alpha=1$ and (PT), ($\overline{PT}$). However when $\alpha=0$ and (PT) ($\overline{PT}$) occurs it should not open the valve (VS). If the digester is rotating at a speed of 0.25 rpm then it will take maximum 4 minutes to attain the position $\alpha=1$. Thus allowance in pressure settings should be so kept that the pressure do not cross the dangerous limits within 5 minutes time. The set valve should be kept little below the desired pressure to be maintained.

Logic circuit II in fig. 4 operates with pressure (P) and Temperature (T) as the two interacting varisbles giving the outputs as X=PT, and $\overline{PT}$. The (X) and (α) further interact to give (Xα) and ($\overline{X\alpha}$) i.e. (PT, $\overline{PT}$) (α) and (PT, $\overline{PT}$) ($\overline{\alpha}$).

The logic circuit III in fig. 4 operates with X andα to give X α and $\overline{X\alpha}$ states i.e. (PT, $\overline{PT}$) α and (PT,$\overline{PT}$) (α). The solenoid operated relief valve will operate only when (PT, $\overline{PT}$) (α) condition is achieved, i. e. when (PT, $\overline{PT}$) (α)=1. When (PT, $\overline{PT}$) (α)=0. The solenoid valve is disabled i.e. do not operate or is closed.

(d) STEAM FLOW CONTROL :

When pressure and temperature inside the digester is equal to set valve the steam control valve FV. is to be closed. Thus the control logic IV is designed to operate the valve (FV) with the logic operations as indicated in the truth table No. 2.

TRUTH TABLE NO. II

STEAM CONTROL VALVE OPERATION LOGIC CIRCUIT NO. IV.

Sl. No.	Process Pressure		Variable Temperature		Valve (FV) position
1.	P	1	T	1	FV = 0 closed
2.	P	1	$\overline{T}$	0	FV = 1 Open
3.	$\bar{p}$	0	T	1	FV = 1 Open
4.	$\bar{p}$	0	$\overline{T}$	0	FV = 1 Open

The above logic design gives an on-off or two position control of steam control valve and relief valve.

The above discussion indicate the close control and operation of steam lines, through the control of temperature, pressure and angle of tilt as variables. The other process variables namely bath ratio active alkali are required to be controlled once in every cycle. Similarly the quality of the pulp should be checked at the end of the cycle to control the inputs for the next cycle. In a continuous digester these variations can be built into the control logic.

5. CONCLUSION :

Mill wide process control is not just an exciting technological frontier to be achieved in our Indian Paper mills. It should have long term survival in world competition and is a key to achieve better cost control, product quality and also process improvement. We need to develop new control systems fitting them into the old mills, as the old mills can not be closed to adopt new control system.

Robert Moore, Vice President of Manufactring International Paper Company, New York pointed out in the 1985 TAPPI Process Control Sympoium, held in Boston that there are five major obstacles in adopting the mill wide implementation.

1. Mistrust of new technology stemming from history of bad experiences with process control in the past.
2. Lack of support and understanding at the mill manager level.
3. Unreliable instrumentation in the existing control loops.
4. Inadequate planning.
5. Ineffective capital budget proposals.

There are four levels of sophistication to reach TRUE mill wide control.

1. Basic regulatory and interlook control.
2. Advanced supervisory control.
3. Inter unit process/product information system.
4. Overall planning, coordination and control of production towards the optimum level of mill profitability.

The proposed work is the first sophistication for a mill wherc we find almost no instrumentation.

The basic objective of the paper is to investigate the possibility of making the direct application of logic circuit, to solve the basic control problems for upgrading the old system particularly in small paper mills.

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