DYE PREPARATION SYSTEM FOR PAPERMILL USING DCS

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Abstract

The aim of project is to Develop an energy saving dye preparation system because the existing dye preparation system required the large amount of energy (power) and water conservation in TNPL . To reduce the requirement of Power and water Conservation with help of modifying the existing architecture and to implement the Control and Monitoring modules of Dye Preparation by using DCS system. The existing project for dye preparation system has all the dyes are produced separately. There are 3 dye tanks and each tanks having reactor separately for preparing raw materials of dye preparation. There are 3 pipelines from the dye storage tank to the reactor which decreases the speed of reaction. In the proposed method, there are 3 dye tanks. The dye of required composition is prepared in the dye tank. The output of the 3 dye valve goes to the reactor or mixing tank. There is an ON/OFF valve in each outlet of the dye tank (SV1, SV2, and SV3) respectively. Dye-mixing tank (reactor tank) with an agitator, level transmitter and temperature transmitter are used. So the hardware components used are reduced. The initial cost is reduced, due to the decrease in hardware components. The maintenance is less, due to the decrease in hardware components.

Keywords: *Energy conservation, reactor tank, dye preparation*

1. Introduction

The Tamil Nadu Newsprint and Papers Limited (TNPL) was founded by the Tamil Nadu government to produce newsprint and writing paper using bagasse, a residue from sugar cane. In April 1979 Tamil Nadu 's government classified the paper mill as one of the world's most environmentally friendly paper mills. The paper produced by TNPL is environmentally friendly, as the pulp is made from sustainable raw material and is subjected to bleaching by Elemental Chlorine Free (ECF). Because the paper is acid-free, it has longer colour stability and increased strength characteristics of permanence. TNPL meets multifunctional printing requirements such as sheet-fed, web offset and digital printers. The paper reels have a uniform profile with properties of strength to cope with high speed machines. TNPL produces printing and writing papers that range from 50 GSM to 90 GSM in substances. Newsprint is usually manufactured in 49 Gsm reels and is supplied directly by the company to various

newspaper establishments such as The Hindu, Malayalam Manorama, Ananda Bazaar Patrika etc[8]. Printing & Writing paper (PWP) is produced with the Gsm (Grams per square meter – base weight of the paper) in reel and sheet types ranging from 50 to 80. Various reel and sheet sizes are also cut to fit customer needs. Several of PWP 's main end-use products are application printing, note books, computer stationery, office stationery, etc.

A. Paper machine

A paper machine (or paper-making machine) is an industrial machine that is used in the pulp and

paper industry to manufacture paper at high speed in large quantities. Modern paper-making machines are based on the Fourdrinier System principles, which use a moving woven mesh to create a continuous web of paper by filtering out the fibers stored in a paper stock and creating a continuously moving wet fiber sheet. To create a solid paper web this is dried in the process [9].

The basic method is an advanced variant of the historical process of hand-paper making, which could not satisfy the demands of emerging modern society for large quantities of a substratum for printing and writing. Henry and Sealy Fourdrinier invented the first modern paper machine in Britain, and patented it in 1806. The same method is used for manufacturing paperboard on a paperboard machine.

Usually paper machines have at least five different operating parts:

Forming section - The forming portion, generally referred to as the wet end, is where the fibre slurry filters a continuous fabric loop into a wet fibre network.

Press section - Press segment where the network of wet fibres moves through broad loaded rolls under high pressure to squeeze as much water as possible out.

Drying section - Dry section, where the pressed sheet passes a series of vapour-heated drying cylinders in a serpentine way. Drying reduces water content to a level of approximately 6 percent, where it will stay under normal indoor air conditions. Infra-red driers are often used to complement drying of cylinder where appropriate.

Calendar section - A portion of calendar in which the dried paper is smoothed under high load and strain. To keep the sheet, which shrinks through the drying section and is held in tension between the press section (or breaker stack if used) and the calendar, only one nip (where the sheet is pressed between two rolls) is needed. Extra nips offer more smoothing but paper strength at some cost.

Dye section - where the paper is dyed in white and blue and is send to the final stage of the process. Specific composition of dye like Rhodamine and methyl violet are used for the dye process. This composition of mixing of dye is automated and controlled using distributed control system.

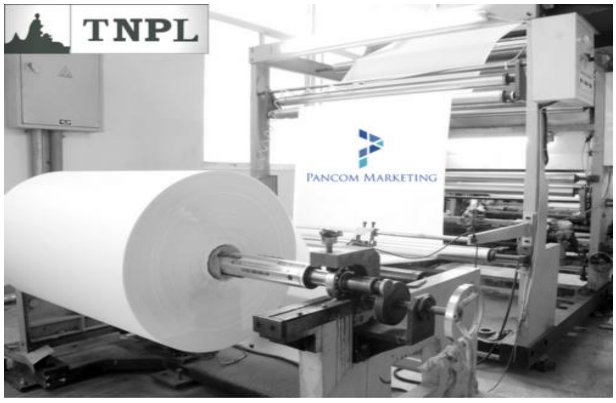

Figure 1 TNPL Paper Machine

2. Existing method

The existing project in the paper mill for dye preparation system is using separate individual dye tanks and individual storage tanks. Figure 2 represents the 3 dye tanks and each tanks having reactor separately for preparing raw materials of dye preparation. The Water Supply is used for Cleaning Purpose. In the case of existing project, there are 3 pipelines from the dye storage tank to the machine chest and silo. It can be modified to only 2 pipelines from the storage tank to the machine chest and silo[2]. In the existing project, the Rhodamine and methyl Violet are prepared separately and added to the process. But in this project, by changing the set point, the required combination of Rhodamine and methyl Violet are prepared and add directly to the process.

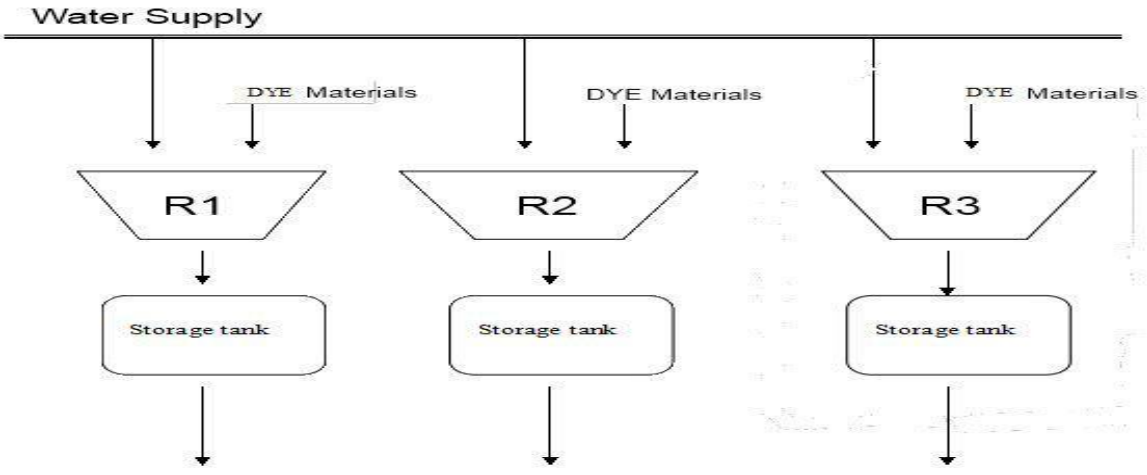

Figure 2 Schematic Diagram of Existing Method in Paper Mill

A. Disadvantages of existing method

The first and foremost disadvantage is, it uses more power and water for its dye preparation. In the case of existing project, it consists of separate dye mixing tank with agitator, level transmitter and temperature transmitter for each tank. There are 3 pipelines from the dye storage tank to the reactor which decreases the speed of reaction.It includes large maintenance due to increase in hardware components.

3. Proposed method

In the proposed method, there are 3 dye tanks. The dye of required composition is prepared in the dye tank. The output of the 3 dye valve goes to the reactor or mixing tank. There is an ON/OFF valve in each outlet of the dye tank (SV1, SV2, and SV3) respectively.Initially all the valves are closed and the agitator is also stopped. When the process is started, the valves of the dye tanks are opened one after the other up to the required composition. In this project, by changing the set point, the required combination of the dyes are prepared and added directly to the process. We are only using one dye-mixing tank (reactor tank) with an agitator, level transmitter and temperature transmitter are used. So the hardware components used are reduced. It can be modified to only 1 pipelines from the storage tank to the machine chest and silo. The speed of reaction of dye with the pulp is increased, so that the delay time is reduced. The flexibility of the system is increased (i.e.) we can prepare the dye separately, and mix it in the reactor tank with specific composition. The initial cost is reduced, due to the decrease in hardware components. The maintenance is less, due to the decrease in hardware components.

4. Hardware description

A. Schematic diagram of dye preparation system

Figure 3 shows the schematic diagram of Dye Preparation System for Paper Mill using DCS. The system consists of three separate dye tanks. The output of the dye tanks are controlled by the three solenoid valves (SV1, SV2, SV3). The dye is mixed in the reactor tank using stirrer motor. The levels of the dye mixing are controlled by the three limit switches (LS1, LS2, LS3)[5]. A Thermocouple and heater is used to maintain the dye mixture at proper temperature maintenance and it is finally stored in the storage tank before sending it to the machine chest and silo.

B. Components used in the dye preparation system

- Dye tanks – 3 (each 3 liters)
- Solenoid valves (12v)
- Reactor tank (10 liters)
- Stirrer(24v)
- Level switches(12v)
- Temperature switch with thermocouple
- Heater
- Storage tank (10 liters)

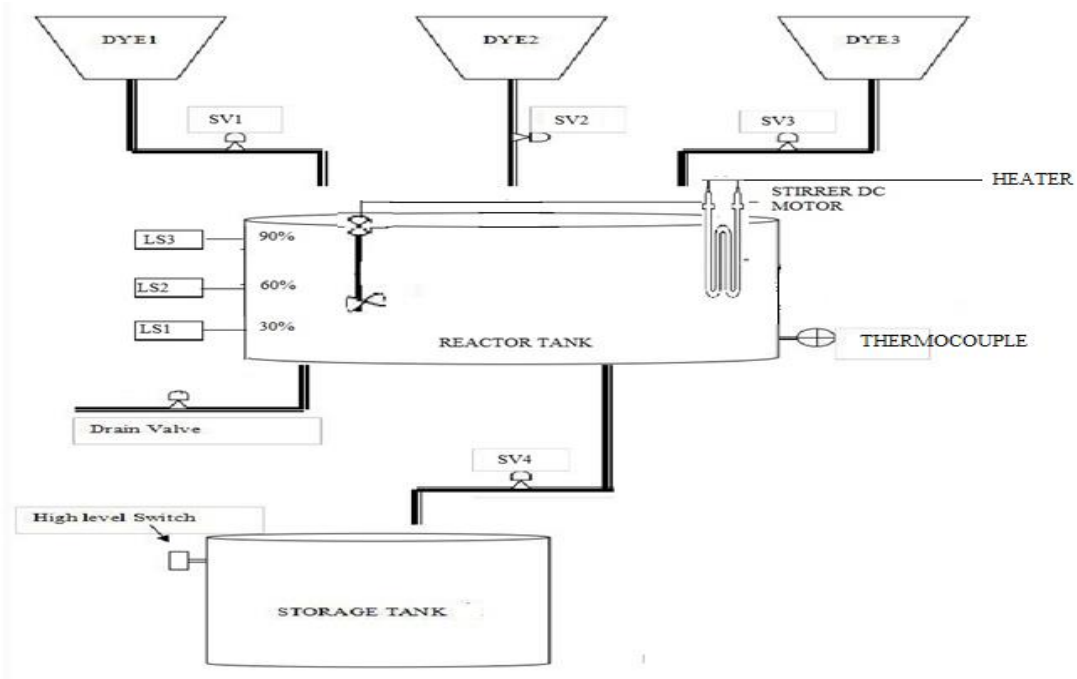

Figure 3 The Schematic Diagram of Dye Preparation System for Paper Mill using DCS

C. Different types of tanks

Dye tanks – There are three separate dye tanks available in which the different combination of dyes are taken to obtain a proper colour of dye for the paper. The dye tanks are of three litres each. Reactor tank – The reactor tank is of 10 litres. It is constructed with three limit switches. The limit switches are placed in the reactor tank at equal percentages of filling of dye from the dye tank. First limit switch (LS1) is placed at which tank the gets filled by 30%. Second limit switch (LS2) is placed for 60% and third limit switch (LS3) is placed at 90%. An arrangement of stirrer and temperature switch with thermocouple is also attached[4].Storage tank – The storage tank is also of 10 litres. After the dye is thoroughly mixed in the reactor tank and before the mixture being sent to the machine chest and silo it is stored in the storage tank. The storage tank prevents the sudden rush entering of dye to the next process.

D. Solenoid valve

Solenoid valves are electrically activated valves, commonly control the float or course of air or liquid in fluid strength structures. Figure 4 shows the model of solenoid valve used in Dye Preparation System. The three solenoid valves (SV1, SV2, SV3) are connected at the outlet of the three dye tanks. It is used in both pneumatic and hydraulic fluid power functions, the spool or poppet design of most solenoid valves makes them perfect for various functions and applications. The most fundamental solenoid valves are two-way, two-position poppet valves, which are commonly open and close, they customize their flow path when their coil is electrified. They are feasible as “normally-open” and “normally-closed” enterpretations, which means either flowing or blocked, respectively. Solenoid valves for either hydraulic or pneumatic applications are available as manifold-hooked up modular units, together with the

pneumatic or hydraulic ISO valves. These valves include general mounting and porting style, permitting valves from many producer to be established upon the equal manifold. Most often, those valves are also pretty least expensive, and comfortably to be had “off-the-shelf.”

Figure 4 Model of Solenoid Valve

E. Stirrer motor

The primary function of the stirrer shaft is transmitting torque to the impeller from the stirrer motor. Torque is a force's tendency to cause rotation of an object. The magnitude of the torque around the shaft axis is related to the power required for the impeller to work. In addition, the stirrer motor performs other mechanical functions: it resists the bending forces created by the impeller, limits any lateral deflections and supports the weight of the impeller. These functions must all be achieved without excessive vibration. The semi-batch reactor considered in this study is a jacketed vessel with a stirrer motor referring to Figure 5, one of the finest agitators for mixing the dye and collecting the end product.

Figure 5 Stirrer Motor

F. Level switches

Level switches, commonly referred to as point level indicators are among the most versatile level instruments on the market. The main function of a level switch refer to Figure 6 is to determine whether a material or liquid reaches a certain value, and once it reaches that value, a signal from the level switch may be sent to another unit, such as a pump, valve actuator or display. Some of the more common level switches for liquids includes float switches, which are more buoyant than the liquid they’re measuring and will float to the top, changing the

angle the float is resting at and causing the switch inside to activate. However point level detection isn't limited to liquids and float switches, one of the more common methods for detecting point level of solids is by using a rotary paddle switch.

Figure 6 Level Switch

G. Temperature switch with thermocouple

When at the end of a circuit two conducers of dissimilar metals join, they form a thermocouple. They do not contain sensing elements such as resistive temperature devices, so the materials used are less limited. They can withstand temperatures far higher than the resistive ones.

A thermocouple building consists of conductors and insulating ceramic powder. Two junctions have thermocouples: hot junction and cold junction. Hot junction is the junction of calculation and cold junction is the junction of comparison. The measuring junction is exposed to the temperature of the operation, and the other junction is held at reference temperature. When the junctions are exposed to different temperatures, a current equal to their difference in temperature can flow in the wire.

Seebeck Effect: When two dissimilar materials at different temperatures are connected together and heat is provided to any one of the metal, there will be flow of electron from hot metal to cold metal. This electron movement will result in generation of current in the circuit. The temperature difference between the metals will induce a potential difference between them.

Type J Thermocouple – Constantan (copper - nickel):

Figure 7 represents the **Type J** thermocouple which has a stronger signal & higher accuracy. The moderate temperature ranges (-199 to 750deg Celsius) and lower.

Figure 7 Type – J Thermocouple

H. Temperature switch

A bi-stable electromechanical system that, upon increasing or falling temperature, actuates / deactuates one or more electrical switching elements at a predetermined discrete temperature (set point) The temperature range between upper and lower limits within which the temperature switch may be adjusted for actuation / deactivation. It is expressed for temperature increases.Set Point-The discrete temperature at which the temperature switch is changed to activate / deactuate on temperature rise or fall. It must remain within the adjustable range and be named as temperature rise or temperature decrease. Fig 8 refers to the changeover in temperature.

The following specifications to be checked in a temperature switch :

- Set point value
- Adjustment on falling or raising temperature
- Dead band value when using dead band switch is adjustable.

Figure 8 Temperature Switch

I. Heater

Immersion heaters are used for heating many liquid items, such as water, gasoline, chemicals, and even for stabilizing gas in tanks. They are used inside various liquid storage tanks in many industries, during the processing of pipes and in pressurizing the storage containers. This product is made to withstand almost any environment, and you can use it either in a pure tank of water or under any acidic medium. The immersion rod is a coiled rod which functions as a resistor. When an electric current passes through the rod, it absorbs electricity, allowing it to electricity up the surrounding area around the rod. This heats up the dye mixture when put in water, until it reaches the set level. The immersion heater is alluded to in Figure 9.

Figure 9 Immersion Heater

5. Distributed control system

A Distributed Control System (DCS) is a computerized control system for a process or plant that typically has a large number of control loops, where autonomous controllers are spread across the system, but central supervisory control of the operator remains. This is opposed to undistributed control systems using centralized controllers; either separate controllers located in a central control room or within a central computer[1]. The DCS concept increases reliability and reduces installation costs by localizing control functions with remote monitoring and supervision close to the process plant.Distributed control systems first appeared in broad, high-value, safety-critical process industries, and were attractive because the DCS supplier supplying both local control level and central supervisory equipment had an integrated kit, thus reducing the risk of design integration. The functionality of SCADA and DCS systems is quite similar nowadays, but DCS tends to be used on large continuous process plants where high reliability and safety are essential, and the control room is not geographically distant. DCS 'main attribute is its reliability, due to the system's distribution of control processing across nodes. That mitigates the failure of a single processor. If a processor fails, only one part of the plant process would be affected, as opposed to a central machine failure which would impact the entire operation. This distribution of local computing power to field connection racks Input / Output (I / O) also ensures fast processing times for the controller by removing possible delays in network and central processing. Process control systems come in two different types.

A. Analog control system

The controller consists of analog devices and circuits in an electronic control scheme, i.e. Expanders. The following signals would be analog in nature (i.e., voltage or current signal). An analog control device automatically detects any change in either fixed point or input, and the amplifiers adjust their output accordingly. The transmitter sends a voltage signal to the operational amplifier, and the operational amplifier sends its command in the current signal to FCE (final control element). Both the transmitting and receiving signals by the amplifier are analog in nature and this control system does not have any signal converters.

B. Digital control system

The controller uses microprocessors to execute the control role in a computer control device. Digital control systems are compared to analog control systems because the data processing can be conveniently interfaced with computers. The bulk of control systems are analog control processes. This means that in many cases the digital control system must first convert analog input data into digital form before it can be processed and likewise the controller output has to be transformed into analog form in the digital form. Digital Control Systems are broken down into two groups.

They are,

Centralised Control Systems(CCS)

Distributed Control Systems(DCS).

6. Centralised Control Systems(CCS)

The monitoring functions and control functions are centralised in this type of control system. All field inputs and all set points of different processes are given to a single processor or CPU and all final control element commands are sent through the same CPU.

A centralized system principle is that it operates on a partnership between Client and Server. The server is hosted at a single location and gives access to several clients[6]. Centralized Version Control is the simplest framework with the idea of 1 central repository that provides the servers with the current code for all clients worldwide. CCS is easy to manage and has more user control and access because it is server from one location.

Disadvantages of ccs

- If the CPU fails this will affect the entire factory.
- The idea of redundancy does not occur in this type of control system. There are two regulators on redundancy. One would have been involved and the other would have been standby. When the active controller fails, the controller in standby must take over.

7. Distributed Control System(DCS)

Activity is distributed in this form of control system management and monitoring is centralised. The entire controller system is connected to the communication and monitoring networks. In the year 1975 Yokogawa launched the first DCS in the world. DCS uses processors as communication controllers and communications protocol. In a range of industries DCS is used to track and manage distributed equipment.

1) Paper Mill Industries
2) Electrical power grids and electrical generation plants
3) Environmental control systems
4) Water management systems
5) On shore and Off shore oil refining plants
6) Metallurgical process plants
7) Chemical plants
8) Dry cargo and bulk oil carrier ships
9) Sugar industries
10) Cement industries

A.Architecture of DCS

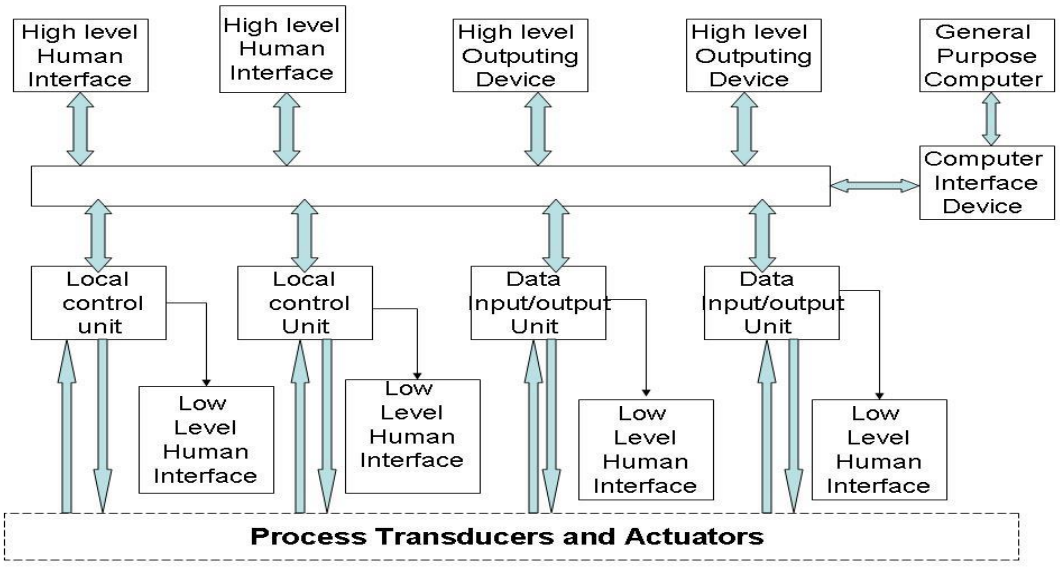

Figure 10 Generalised Architecture of Distributed Control System

B. Local Control Unit (LCU)

The system's smallest hardware set that can do closed-loop power. The LCU directly interfaces into the operation. Figure 10 refers to the generalized distributed control system architecture[3]

C. Low Level Human Interface(LLHI)

A tool that allows the operator or instrument engineer to communicate with the local control unit using a direct connection (e.g. change set points, control nodes, control setup, or tuning parameters). Also, LLHI's can interface directly with the device. At this point, operator-focused hardware is called the low-level operator interface, instrument engineer – the low-level operator interface, instrument engineering interface, is called the focused hardware.

D. Data Input/Output Unit(DI/OU)

A device which interfaces with the process for the sole purpose of data acquisition or production. It does not perform any control method.

E. High Level Human Interface(HLHI)

A set of hardware performing similar functions to the LLHI but with improved functionality and user friendliness. It communicates only over the fatuities of mutual communication to other apps. Operator – High-level operator interface is called oriented hardware at this level; High-level engineering interface is called instrument engineering-focused hardware.

F. High Level Computing Device(HLCD)

A series of hardware based on microprocessors that performs the functions of plant management traditionally performed by a plant computer. It interfaces only the networking facilities shared with other devices.

G. Computer Interface Device(CID)

A series of hardware that enables the shared communication facilities to communicate with other devices in the distributed control system through an external generate purpose computer.

H. Shared Communication Facilities

One or more rates of communication hardware and association software that allows data sharing among all devices in the distributed system should communicate channels within a device between different devices as between hardware elements.

I. Advantages of DCS

- Control feature is distributed between many CPUs (Field Control Stations). Therefore one FCS failure doesn't impact the entire farm.
- Redundancy is available at different rates; software is used to create instruments and interlocks.
- The interlock generation and modifications are very versatile and simple.
- Process information shall be presented to the user in different formats.
- Significantly less ground cabling.
- Maintenance and troubleshooting is extremely simple.
- Long term cost effective.

J. Introduction to Yokogawa CENTUM VP system

In the year 1975 Yokogawa were the pioneers in creating the world's first distributed control system. The new DCS from Yokogawa fold is the CENTUM VP system [7]. Yokogawa continued its work in the field of DCS and other systems in line with technological growth.

K. CENTUM VP

We need an integrated real-time infrastructure to achieve the cohesive development environment. In order to do so, we need to extend DCS' function by breaking down barriers between independent real-time databases and operating systems. And the CENTUM VP program does this. CENTUM VP is the first Vista enabled DCS window in the world.

During the production of CENTUM VP the primary factors considered are:

1) Performing perfect plant service for clients

2) Create a modern organizational and control system to provide more useful information

3) Consisting of a new, flat, intuitive look and feel

CENTUM VP system capacity

- Maximum number of station per domain:64 station
- Maximum number of HIS per domain: 16 station.
- Station number for HIS: 1-64 in descending order Station number for FCS: 1-64 in ascending order.
- Maximum number of domains: 16 per systems
- Numbering of domains: 1-64
- Maximum number of station per system: 256 per system.

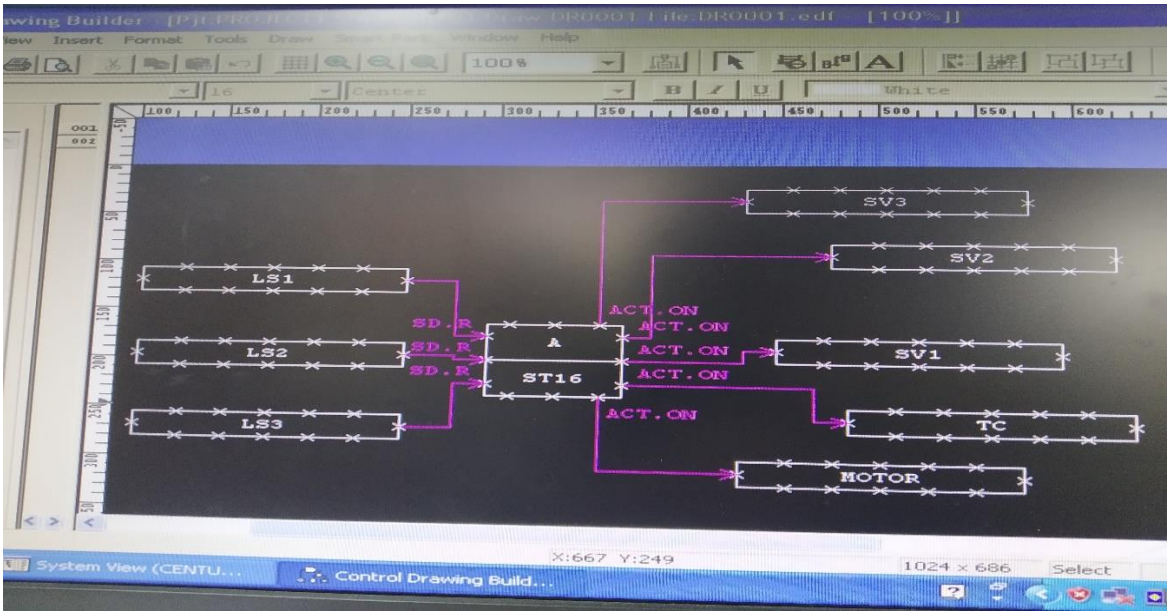

Figure 11 Functional Block Diagram

L. Functional block

The CENTUM VP includes basic blocks for tracking, managing, manipulating, measuring, and sequencing logic functions. In a redundant, stable, and reliable controller system, not only continuous control but also advanced control, complicated sequence control, and batch control are all implemented. Via the combination of these control blocks, plant systems can be built flexibly, ranging from small to large. Figure 11 references the distributed control system 's interactive block diagram.

M. Sequence table processing flow

Input processing:

The signal's condition true / false status is calculated by doing condition testing based on the input signal.

Condition rule processing:

The true / false state of the rule condition is determined by comparing the condition signal's true / false status to the Y / N pattern of the condition law defined in the sequence table.

Action rule processing:

The output of the action signal is determined by the action rule Y / N pattern, when the condition status is true.

Output processing:

Status manipulation of the target action is carried out on the basis of the action signal description. Contact outputs and other feature blocks can be used for the state manipulation, start command transmission, data setting, and status update. There are two types of tables of sequences: Phase and Non-step. The processing of the rule varies by sequence table sort.

8. Results

When the process starts, the solenoid valve(SV1) of dye1 is opened. Once the reactor level reaches 30% SV1 is closed and then stirrer motor will be turned ON simultaneously solenoid valve (SV2) is opened and temperature switch is ON which is connected with thermocouple, based on the temperature set value heater is turned ON.
Once the reactor tank level reaches 60% SV2 is closed and solenoid valve (SV3) is opened, when the reactor tank level reaches 90% SV3 is closed. Table 4.5 refers to the condition for valve opening and closing.When the temperature reaches the set point (of 45deg Celsius) the heater is stopped and the outlet valve is opened to store it in the storage tank. By changing the set point the required combination of dye can be obtained.

9. Discussion

In the pulp and paper industry, it is full of difficult processes and aggressive matrices. The usage of three reactors cause more power consumption. The approximate total power consumed by one reactor is 5KW/hr and the level of water consumed in each reactor is 1cubic meter for a batch process. Continuous monitoring of quality and analyses of dye mixing using distributed control system must be carried out to run every phase of the papermaking process optimally. In our actual proposed method there is only one dye mixing reactor tank hence reducing 75% of its actual power. Evaluating vital process parameters at line, inline or online instead of manual offline laboratory study not only saves time but also optimizes process efficiency while lowering operation cost. As a combined part of process control and automation, real time analysis can help one enhance yields and increase production quality.

Reactor Tank Filling(%)	Solenoid Valve (SV1)	Solenoid Valve (SV2)	Solenoid Valve (SV3)
0%	Opened	Closed	Closed
30%	Closed	Opened	Closed
60%	Closed	Closed	Opened
90%	Closed	Closed	Closed

Table 1 Condition for Valve Opening And Closing

10. CONCLUSION

The automation and the continuous operation of the dye preparation system is necessary in the large scale industry like Tamil Nadu Newsprint and Papers Limited where the workers task is reduced and maintenance is done in a correct manner. All the output functions are first tested in the centum VP software for better understanding of the process[10]. The continuous operation of opening and closing of the solenoid valves, the dye preparation in the reactor tank with specified temperature and with minimal usage of power and water is achieved using the Distributed Control System.

11. FUTURE SCOPE

The different ratio of colours can be mixed together to succeed in attaining more number of dye. If the distributed control system has been installed for the continuous monitoring in the industry it reduces the requirement of power and conserve the water by maximum of 50% than the method followed at present. The initial cost is reduced, due to the decrease in hardware components. The maintenance is less, due to the decrease in hardware components.

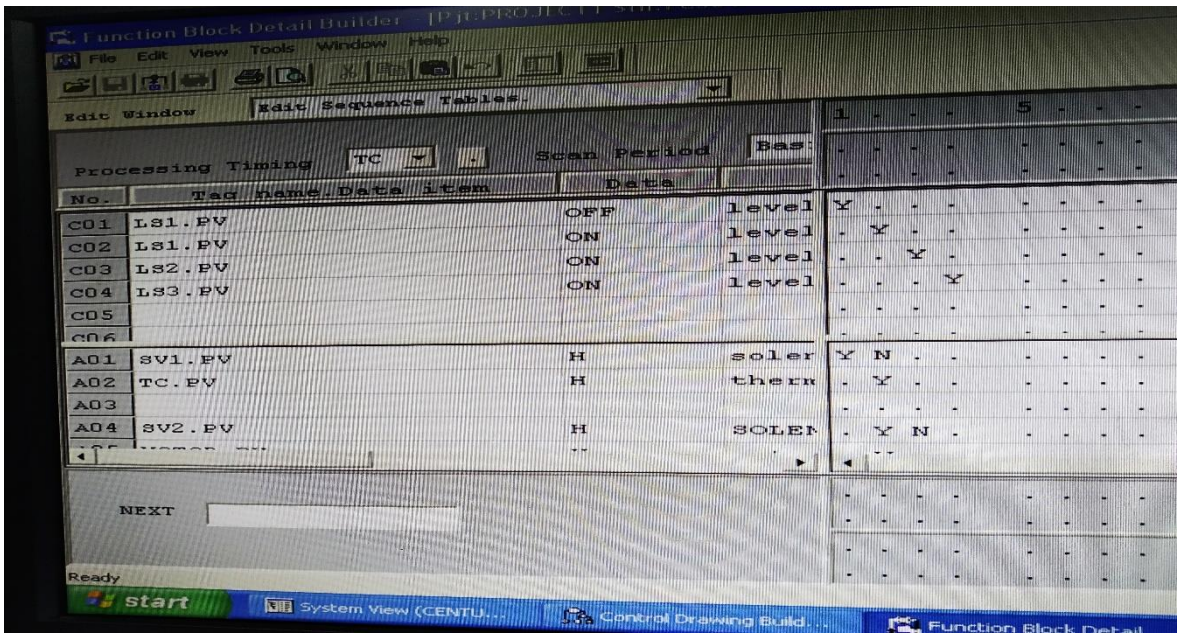

Figure 12 Sequence table programmed in Centum VP

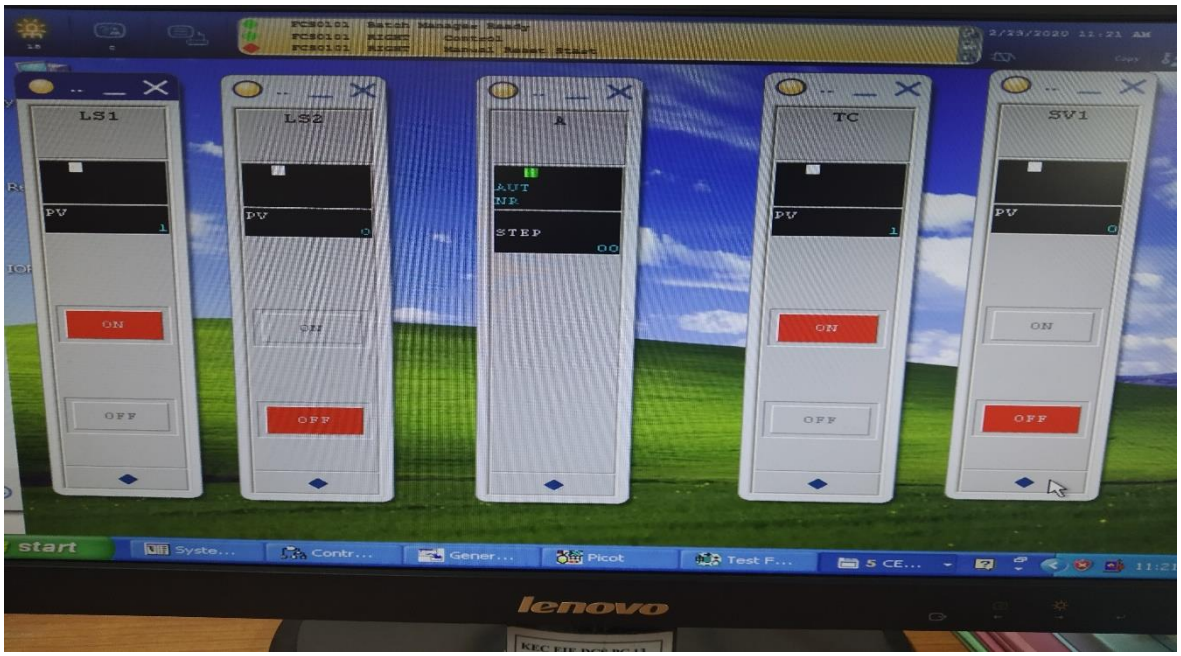

Figure 13 Output in Face Plate

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