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Automation Strategy for Black Tea Production Line

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Abstract. Tea is one of the primary beverages consumed with its added health benefits. India enjoyed supremacy in its production till a significant period. But, recently it is lagging behind in the race being surpassed by some neighbouring countries. The aforesaid issue is a matter of serious concern as it has a major share to contribute in the Gross Domestic Product (GDP) of the country and hence is a sizeable foreign exchange earner. The effect has arisen due to lack of varieties and cumbersome approach to the production of tea. Hence, this paper focuses on Computer Integrated Manufacturing (CIM) of tea industry which leads to automated production and scope of implementation of mixed assembly lines, thereby increasing the scope of the global market capture of sales. The automation is designed on Programmable Logic Controller (PLC) based control of the CTC (Crush, Tear & Curl) tea manufacturing processes. The user interface has been proposed to be developed with the help of a SCADA software. The interfacing of PLC and SCADA can be achieved by OPC communication. Virtual commissioning of the entire production line can be achieved by plant simulation.

1. Introduction

Tea has always been known to be the most popular beverage globally having an unrivalled reinvigorating effect as well as many health benefits. It is often a tradition to relax and have a myriad of conversations with the culture of drinking tea. India once was the largest producer of tea in the world for nearly a century. Recently, it was surpassed by countries like China and Sri Lanka [1] [2].

In India, Assam is the largest producer of tea covering about 53% of the total production [3] which embarks a major contribution to the countries' Gross Domestic Product. Assam's Black Tea often famous for its strong malty flavor comes in two forms. One is CTC (Crush, Tear & Curl) tea and the other is Orthodox.CTC tea is preferred for its dark colour and economic aspects while Orthodox for its taste and flavor [4][5][6][7].

The decline in the share of foreign exchange of Assam Tea can be attributed to many factors. It is crucial to know that there has been a substantial increase in the cropping area with the entry of unorganized small tea growers (STG) since the beginning of early 90's.Currently, they have nearly 47%share in total Assam Tea production. As a result, there should have been an increase in exports, but the trend is opposite. Migration of skilled labour from the Assam tea industry to more worker friendly counterparts and non-tea sectors has been the reason for lack of availability of the required workforce.

Hence, the replacement of manual labour is the answer to this primary crisis which can very well be accomplished through industrial automation.

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Among other factors, lack of variety is letting the industry fail in the global competition. Moreover, the production process being very cumbersome, is suggesting improvements in the technological aspects for sustenance in the global market.

Automation of the production lines shall build a base for Computer Integrated Manufacturing (CIM) which can very well encompass market and supply fluctuations along with the greatest advantage of mixed product variety. The effort for an automated production line involves the study of existing techniques and hence understanding the scope of automation [8]. Buridehing Tea Company (BTC) has been used for the case study of Assam CTC tea production and henceforth to build an automated model of the production line.

2. Buridehing Tea Company – A Case Study

Buridehing Tea Company (BTC) is a major CTC tea producing company encompassing right from production to processing of CTC tea. It is located in Pengaree of the Tinsukia District of Assam. Around 771 tons of CTC tea is produced annually. The plantation covers an area of 300 hectares.

Figure 1. Buridehing Tea Factory

One of the production lines in the processing factory of the Buridehing Tea Company of CTC tea has been considered in the study. The idea of automation is to achieve a mixed production line for different varieties of tea such as green tea, white tea, oolong tea, orthodox tea and CTC tea in the same factory.

3. CTC Tea Manufacturing Processes

The major processes involved in CTC production are indicated in the form of a block diagram in figure 2.

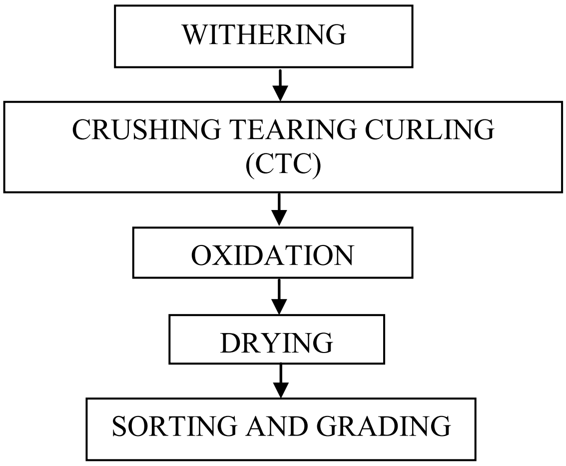

Figure 2: CTC tea manufacturing process in Buridehing Tea Company

When tea leaves are plucked, they start sagging due to loss of water which is termed as withering. Withering plays an important role in aroma and flavor fixation due to development of volatile compounds. Withering is controlled in tea manufacturing by means of control of flow rate and the temperature of the air. Use of withering troughs is most common in tea industry. The trough basically consists of wire-framed meshes on which the leaves are spread. Hot air is then blown underneath by a fan and burner system to dry the leaves until moisture content is reduced to 60-70% which is determined by measurement of weight of the leaves [4][7]. In CTC production, it is maintained in the range of 70- 72%.The withered leaves are then fed to the CTC section where the leaves are passed under rollers moving in opposite direction. Here the leaves are cut and hence the cell walls are broken to release the juices for oxidation. The oxidation is then done with the help of Continuous fermenting Machines (CFM) where humidified air is passed over the crushed leaves at a temperature of 23-29^{0}C.Oxidation leads to biochemical reactions producing different flavours in the tea. After the required amount of oxidation (60%) has occurred, it is fixed by drying which leads to the degradation of enzymes causing oxidation. Finally, sorting and grading of tea is based on particle size and packed in wooden boxes or bags [4][7].

4. Literature Survey

Endi et al. [9] made a study of the developmental trends of SCADA architecture. A three layered SCADA architecture is then designed for a boiling system. SCADA/HMI is developed with the help of Labview. The control architecture is achieved with Siemens PLC i.e. S7-CPU222 and EM231.Yan et al. [10] designed an automatic logistics system based on QR code scanning of cylinder blocks for automatic PLC control of delivery, storage and material handling. Zhang et al. [11] did a detailed study of the PLC automatic production lines showcased in the National Electrical Automation Contest. Deogratias Mzurikwao and Zhijun Pei [12] together made an effort towards “Smart Production” by the incorporation of a recognition system configured by a camera and MATLAB for sorting of products and automatic packaging into customized trays by PLCs. Panchal et al. proposed the replacement of the PID controller with the more versatile programmable logic controllers. Further, a mathematical model was developed and validated. SCADA was developed with NI-Labview and interfacing with PLC was done with MODBUS RTU communication protocol. Set-point tracing and auto-tuning features hence may be incorporated into the PLC rather than using PID controllers. Navid Rajabpour and Yasser Sedaghat [14] proposed a method-PLCCFC to investigate the errors in the Remote Terminal Units (RTUs), interfaced with a SCADA architecture. The method is universal to all industrial controllers including PLCs and the experimental study was done on PLC systems. PLCCFC detected nearly 96.76% of the incoming errors. Xibin et al. [15] developed a PLC based SCADA system for the petroleum industry. The system provided a strong database based on real-time data to pioneer advanced research for building newer trends in technological aspects of petroleum industry. Sweta Upadhyay and Dr. Jyoti Srivastava [16] developed an automated load frequency control of a solar thermal power plant. Centralized control and supervision was achieved by a SCADA architecture.

5. Industrial Automation Techniques

Industrial automation is the delegation of human control activities to control systems aiming towards lesser human intervention. Hence industrial automation leads to increased productivity, a safer working environment, enhanced quality, lesser dependencies on manual labour, etc. The most common control systems are:

1. Proportional–Integral–Derivative(PID) controller
2. Programmable Logic Controller (PLC)
3. Distributed Control System (DCS)
4. Industrial computer control(PC based)

Proportional Integral Derivative(PID) control is a feedback process control based on customized algorithms to determine the reference point and the deviation to correct the input variables based on proportional, integral or derivative functions [17][18]. Distributed control systems(DCS) is often used for a large number of feedback process control with the help of dedicated microprocessors for individual functional blocks(FG).However, centralized control to integrate the individual control loops is also supplied [19]. PC based control is the use of dedicated computers for process control of a production process [20] [21].

Among the discussed industrial controllers, PLC stands out as the most viable option for mixed production line due to many reasons. PLC’s offer wider variations in programming encompassing greater application needs .Nowadays, with the use of a centralized control like SCADA, DCS can easily be replaced by PLC based SCADA giving the added advantage of remote centralized control. Moreover, if a PC based control fails the back-up if not at hand shall make it a cumbersome job to get the production line back to work [20]. In case of PLC we simply need to load the program into a newer one and run it. Hence considering the economic feasibility along with the variety of application abilities, PLC’s come out as the most suitable option for a mixed production line [22].

6. Programmable Logic Controller

The PLC is an industrial automation control device which controls the input and output operations discretely or in sequence with the help of sensory feedback.

A typical PLC consists of a processor unit, a power supply unit, input/output modules and the programming device. The output switching devices may include transistors, relays, triacs, MOSFET, etc., [22][23][24]. The most common programming mode is the ladder logic. The program is downloaded into the PLC and each rung in the program is executed for sequential control based on IF-THEN statements basically [22][23][24].

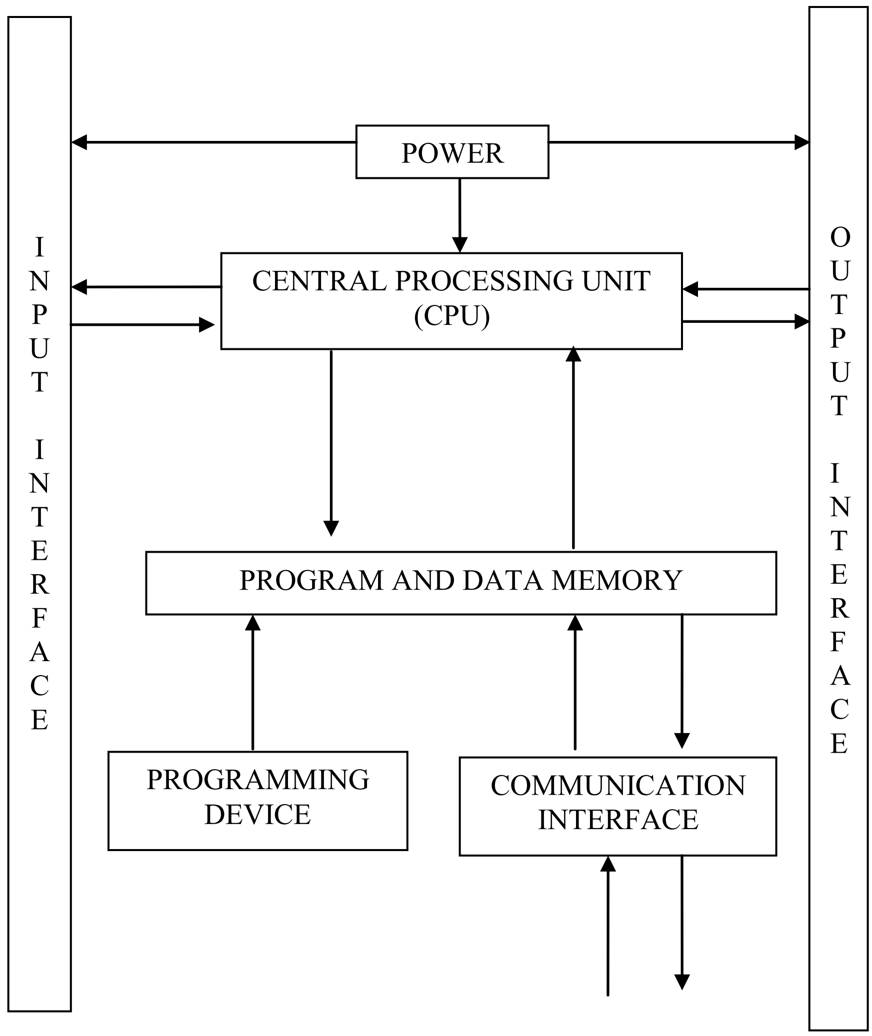

Figure 3. Block diagram of PLC system

7. Programming PLC

Initially PLC's were developed to replace relay logic. Until 1980's PLC's were programmed with the help of dedicated function keys in programming panels or terminals. The customized function keys were developed around the logical operations of the PLC. The storage of programs was challenging due to limited memory capacity using a nonvolatile magnetic core. But now PLC's use battery backed up RAM or a non-volatile flash memory. IEC 61131-3 defines five basic programming languages of the control program inside PLC. These are Ladder diagram (LD), Function block diagram (FBD), Structured text (ST), Sequential function chart (SFC), and Instruction list (IL).Among these, two are graphical (LD and FBD) and two are textual (ST and SFC) [25]. The most popular language to program a PLC is ladder logic which strongly resembles relay-logic. It gets its name due to the similarity to a ladder having two vertical rails enclosing horizontal rungs. Each rung executes a sequential control of a process from left to right which are basically IF-THEN statements. The ladder logic is further connected to SCADA or HMI interfaces for human interface control [25].

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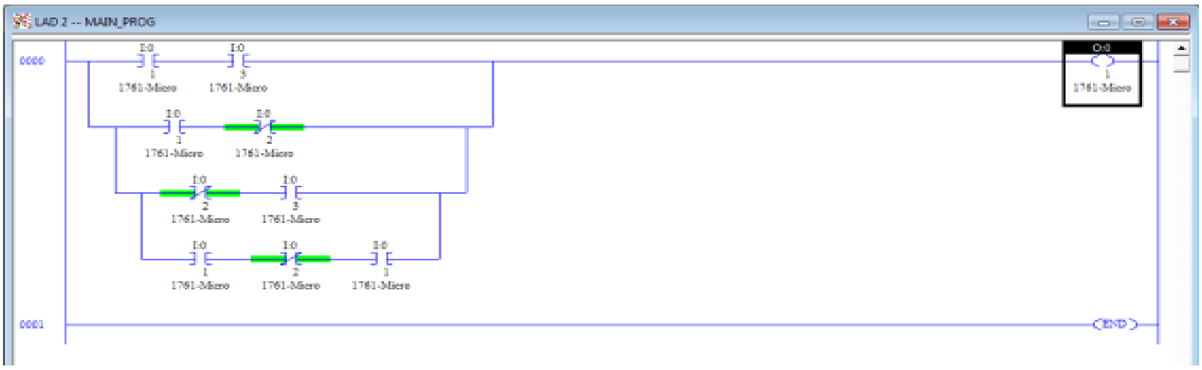

Figure 4. Example of Ladder Logic diagram in RSLogix

Advanced PLC's can now use high level languages like C, BASIC, FORTRAN, MATLAB for programming. Another high level programming is the State Logic, which makes the PLC highly intuitive being based on state transition diagrams. Although the very basics of PLC are universal for all manufactures, but due to variations in memory architecture, addressing modes and function sets interchangeability is a challenge. Even the different models of the same manufacturer show uniqueness.

8. User Interface

The man–machine interface in case of PLC is often established by means of a HMI (Human-Machine interface) device for the purpose of configuration and use of the controller. The data from and to the PLC controller is often translated into visual graphics and representations deployed on Windows based machines [26].PLC may also be in a network for communication with other systems over a Supervisory Control and Data Acquisition system (SCADA). Hence for interconnectivity of multiple systems and controllers a SCADA system comes to rescue for employing automation in a production line [27][28].

9. Supervisory Control and Data Acquisition

Supervisory Control and Data Acquisition (SCADA) is a system software application which allows monitoring and control of processes and devices based on real-time data. It persistently collects information from the plant and processes them for display and issues commands to control systems if needed for corrective measures to be taken. Hence to interface SCADA with control systems like PLC allows us to have a graphical representation of the entire process control of the production line and serves as the user interface with the control of the plant [27][28].

10. PLC based SCADA and Computer Integrated Manufacturing

Computer Integrated Manufacturing (CIM) to be realized in practice in any manufacturing system shall need the incorporation of industrial controllers like PLC with other machines and equipment. For advanced and highly automated control, PLC's need further incorporation and interfacing with robots, automated guided vehicles, and hierarchical computer-based systems. Further supervision and integrated control of the entire plant can be achieved through systems like SCADA. Moreover, to realize the dream of artificial intelligence PLC's needs incorporation with fuzzy logic I/O systems, etc., [29].

11. Proposed Automation

To keep up with the growing competition, product variety with enhanced quality is a necessity in every industry and tea industry is not exception. The aforesaid standards can be achieved by means of industrial automation and PLC can be a great answer for that. PLC is preferred as it encompasses the future scope of modification in the control and sequencing of processes for addition of mixed production lines with increasing demand for variety without modification of the hardwired interfaces. Moreover PLC is unaffected by industrial noise and can be troubleshot easily. Further for monitoring and control, a continuous information access of the processes can be obtained by interfacing PLC with SCADA (Supervisory Control and Data Acquisition) and accessing real-time data. SCADA enables graphical representation of the ongoing processes which enables monitoring and control of the production processes. Thus PLC based SCADA is the foundation for Computer Integrated Manufacturing (CIM) for a plant. The basic machineries used in the CTC production line are proposed to be interfaced with the PLC's (Allen-Bradley Micrologix 1000) through the control panels. The humidity and temperature sensors are used for feedback control. The ladder programs for the Micrologix 1000 [30][31] may be written in a programming software viz. RSlogix [32] and Open Platform Communication (OPC) can be established with RSlinx [33] communication software and RSlogix Emulator 500 can be to validate the results. The user interface with the help of animation and diagrams can be developed in SCADA software viz. Intouch by Wonderware for process control [34]. Hence virtual commissioning of the automated production line can be obtained by emulator and SCADA software.

12. Proposed Automated Process Control and its importance

The proposed automated CTC production line of Buridehing Tea Factory with the process control has been depicted in form of a block diagram in figure 5. The basic machinery viz. the withering trough, the Crush Tear Curl (CTC) machine, the Continous Fermenting Machine (CFM) unit, the Vibratory Fluid Bed Dryer (VFBD) and the Sorting unit have been suggested to be interfaced with requisite sensors which shall serve for feedback (closed loop control) to the PLC which in turn will send signal based on the program control to the control panels for proper sequencing and execution of operations. The inbuilt timers in the PLC program shall account for synchronized operations of subsequent machines based on customized delays.

The control units may be graphically represented in SCADA systems for control and supervision which shall be the infrastructure for a control room facility, thereby leading to mixed production line. The temperature and humidity sensors would control the flow of tea leaves with the help of monorail conveyors and conveyor belts in the withering section. The rotor vane crushing may be done with the help of proximity sensors, load sensors with programmed delay in the PLC. Oxidation may be controlled with the help of colour sensors and electronic nose [35] in the CFM. The mist chamber can be operated by the PLC with the help of humidity sensor to maintain the perfect state of wet-steam for oxidation and hence aroma fixation. The exhaust fans can automatically be operated based on the feed of the humidity sensor. Once the oxidation is complete i.e. nearly 60 % the leaves are to be sent to the Googie or the CFM directly. Googie, made of gun metal, is used to give the granular shape to the tea facilitating lesser void spaces in packaging. Googie is rotated anti-clockwise and also helps in removing redundant fibers. Then the sensory feedback shall activate the feed conveyor to the VFBD. The VFBD does the fixation of oxidation by enzymatic degradation. After drying, sorting into various grades is done with the help of jumbo sorter and meshes to be controlled by fixed timers in the PLC and also load sensors. The entire CTC line hence may be fully automated by incorporation of PLC with the requisite sensors. The automated model as depicted in figure 5 has been based on the necessities of nature of the feedback signal required for control of the processes for the aroma and quality fixation of the processed tea.

With the proposed automated CTC production line, the proper monitoring and control of the production line may be achieved, as the CTC line operates for nearly 22 hours per day. Manual fatigue and proper hygiene standards shall be able to be achieved and hence the entire processing may be labeled as "Not Touched by Man" which shall very well comply with international standards of food processing. Moreover, the use of PLC shall lay the base for implementation of flexible manufacturing systems (FMS) to accommodate greater variety of tea like Green Tea, Oolong Tea, Orthodox Tea, etc.

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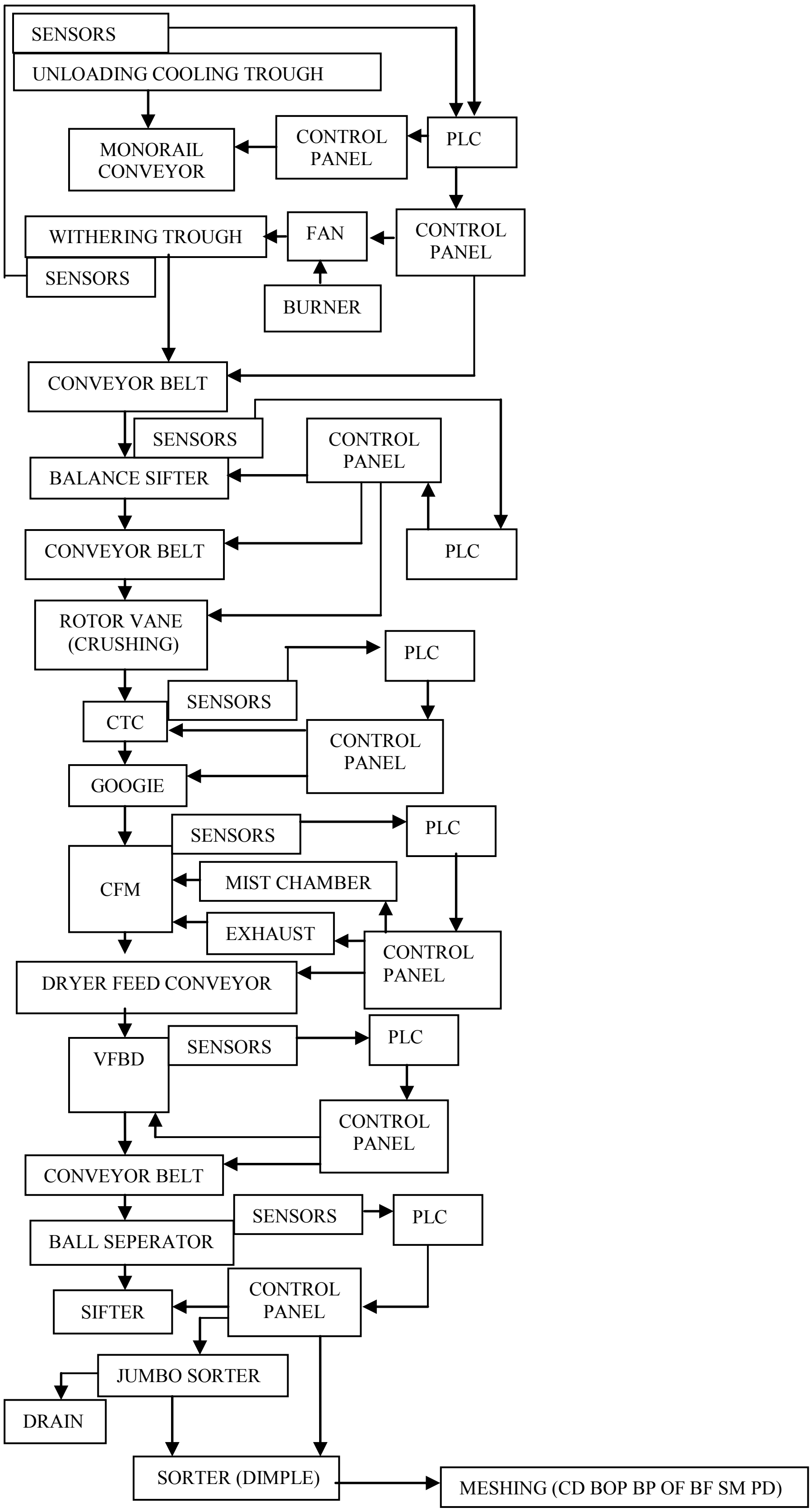

Figure 5: Proposed automated model of CTC production line in Buridehing Tea Company

13. Virtual Commissioning and Validation

PLC controlled production line of the plant can be virtually commissioned and hence validated by means of a virtual PLC environment which consists of Application stratum and Model stratum. The application stratum encompasses the plant visualizer like Arena [36][37] or Siemens Technomatrix Plant Simulation software [38] and PLC emulator. The model stratum consists of the process and instrumentation model, the PLC program and the input/output module.

14. Conclusion

The reason for automation of the CTC production line with the help of PLC and SCADA is to control and supervise the production line which runs for long hours i.e. nearly twenty hours per day during the peak season. The idle production time accounts for maintenance activities to keep the production machinery away from development of unwanted bacteria affecting the infusion of tea adversely. Hence such a continous production demands great vigour and commitment from the workers .Hence it is quite a need to automate the production line to keep up the quality, accuracy and the economic feasibility of the production process. Moreover, the integration of the production line into mixed production line is the demand of the day as many machines are ideal during processes of withering, oxidation and drying. The different lengths of time of the various processes for different varieties of tea like Green tea, White tea, Orthodox tea, Oolong tea help to sequence the machines in a mixed manufacturing line for the optimum production time of the machines reducing idle time to a minimum. The very first incorporation may be of orthodox tea in the same factory as both the varieties need similar machinery. Hence a composite integration of the entire mixed production line can be done with the help of a centralized control like SCADA through the industrial controller PLC for proper sequencing of operations, timing, delay and flow of raw material in the different production lines employing Flexible manufacturing Systems (FMS).

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