Automation of Hardwood Final Tower Dilution in Pulping Process Using Distributed Control System

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Abstract

The Pulp consistency plays a major role in Paper making and it is a very important parameter to be measured and controlled. If the consistency is not maintained in nominal range, it will directly affect the Critical Paper Qualities like Grams per square meter (GSM), Caliper & Moisture and Efficiency of Paper Machine Production. The pulp demand for the Paper Machine in Tamilnadu Newsprint and paper limited (TNPL) is being catered by three pulping streets like hard wood, Chemical Bagasse pulp and De inked pulp at required rate. The final tower which consists of hardwood has no proper consistency. Hence, based on the requirement of individual Paper Machine it is being diluted with proper amount of water by measuring the speed of agitator using Infra-Red sensor and fed to the respective Paper Machine by means of pump. The amount of water to be added is calculated from the speed of agitator. Meeting the tower dilution water demand by manual operation was very difficult and had to be done with utmost care and should be monitored continuously. Hence, with the process being automated, the water used is controlled according to the requirement of Paper Machine. The Elemental Chlorine Free (ECF) hardwood dilution water pump on/off and speed which is controlled manually at paper machine stock preparation is also automated. In this work, Distributed Control System (DCS) is used in the ECF hardwood final tower control, mainly to speed up the process, to increase the productivity and to maintain the Final tower discharge pulp consistency within nominal range. Required results have been achieved and ECF hardwood final tower dilution operation is very efficient by implementing the process with SCADA.

Keywords: *Tower dilution, Pulping Process, Automation, Paper Machine, Distributed Control System (DCS)*

1. Introduction

The hardwood final tower provides a raw material for Paper Machine and Wet lap Machine, which is used for preparing the paper. It is one of the raw materials, which is mixed with the other raw material with certain proportion to produce the result. In hardwood final tower dilution process the raw material for paper, i.e., the hardwood pulp is diluted using water to proper consistency for paper making which is required by the paper machine. The consistency varies for making different kinds of paper materials like chart, A4 sheet, etc., so the required percentage of consistency for paper production is set manually by the operator and the dilution process takes place.

In the manual process of dilution, error in the percentage of consistency can occur since the amount of water to be added will vary for different values of consistency. All the disadvantages of manual method of dilution can be rectified in this automation process of hardwood final tower dilution. The whole process of hardwood final tower dilution takes place in four steps; they are pulp and water inlet to the final tower, dilution of pulp, outlet of pulp to the paper machine and alarming process. The overall process is automated using Distributed control system (DCS).

Distributed control system (DCS) is a specially designed automated control system that consists of geographically distributed control elements over the plant or control area [1, 2]. Nowadays, distributed control system has been found in many industrial fields such as chemical plants, oil and gas industries, food processing units, nuclear power plants, water management systems, automobile industries, etc. In the same way Distributed control system can be used in pulping process in paper mills for the process automation of hardwood final tower dilution. This distribution of control system architecture around the plant has led to produce more efficient ways to improve reliability of control, process quality and plant efficiency.

Karma et al [3] presented Programmable Logic Controller (PLC) based automated water level control where the scarcity of water is a major problem which is controlled using float switch and solenoid valve inside of the water tank. Solenoid valve is used to control the flow of water and on/off operation. Float switch is used to detect the level of water in the tank. All the process controlled by PLC controller. Das et al [4] presented automation of tank level using PLC and establishment of HMI by SCADA. This project is to implement automated water level controlled system in industries. There occurs the vibration of float sensor which would affect the total processing result. Hence this problem can be removed by implementing HMI, PLC and SCADA. Modifications are made for float sensor model. Human supervision is not necessary to conduct this process. Nagaraj and Vijayakumar [9] developed water level control by using PLC and SCADA system. Here the graphical user interface is used to monitor level of tank.

Hardwood is a type of raw material which is used for paper manufacturing. The hardwood is crushed and made into pulp. The consistency of the pulp will be thick which is not suitable for paper manufacturing so dilution has to be done. At present the pulp is being diluted manually using water [5,6,7,8]. The manual way of diluting pulp is not suitable because it includes many disadvantages. The disadvantages are, there is no proper mixing of pulp and water, the consistency of pulp cannot be reached accurately, the variation in consistency for different types of materials is difficult, less accuracy and huge man power requirement. These disadvantages can be rectified using this new methodology of automating the process of hardwood final tower dilution.

2. Proposed Model of Pulp Dilution Process

The dilution of the pulp takes place in three major steps such as consistency measurement, Dilution of water as shown in Figure1.

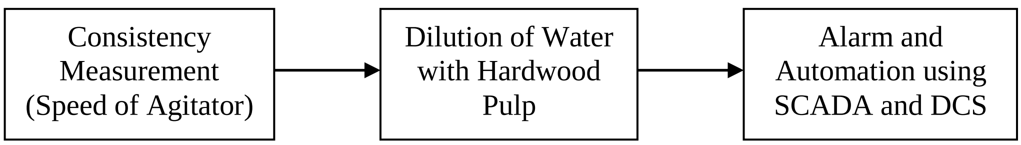

Figure 1. Proposed Model of Pulp Dilution Process

Initially, the approximate quantity of pulp and water fed to the final tower based to the requirement of paper machine and the agitator motor is switched ON which starts the mixing of pulp and water. Then the consistency is measured by measuring the speed of the agitator. The agitator is used to mix the pulp along with water when the motor rotates. The speed measured in RPM differs for different consistency of substance present in the final tower. It is measured using the IR sensor fixed at the agitator. The speed in RPM for the required consistency of pulp is calculated by using trial and error method by testing with different substances with different consistency and viscosity. If the measured value of actual speed (consistency of the pulp) is less than the desired speed (required consistency) set by the operator for the operation of paper machine, the solenoid valve opens and the water is poured into the final tower. Immediately, when the calculated speed is reached the solenoid valve closes and the resultant diluted pulp is sent to the paper machine. This sequential process is automated with the help of a controller and monitored using SCADA [10,11].

The schematic diagram of the Hardwood final tower dilution in pulping process is shown in Figure 2.

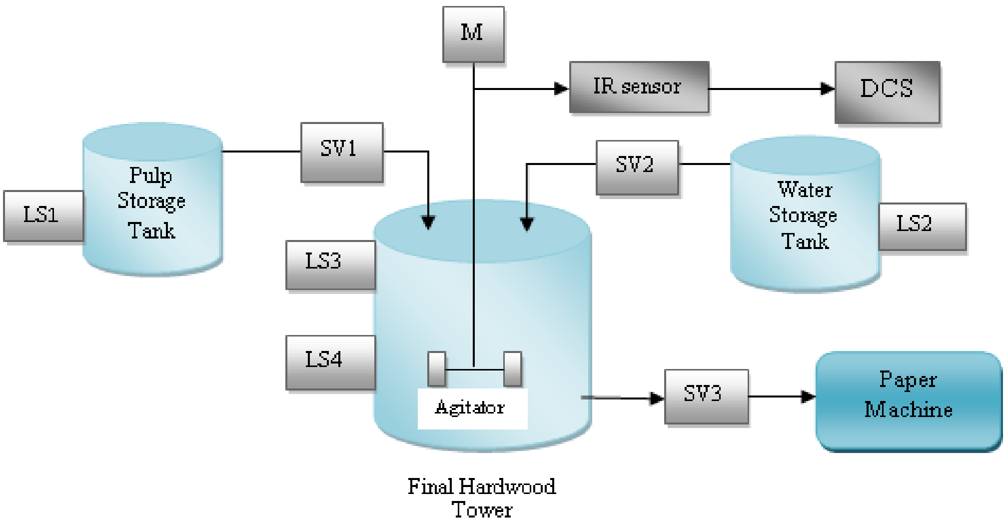

Figure 2. Schematic Diagram of Final Tower Dilution in Pulping Process

Initially the pulp is stored in the pulp storage tank and the water is stored in water storage tank. Once the push button is set ON, the two solenoid valves are open, and the pulp and water are flow into the final tower from the storage tanks. When it reaches the preset value of level in a Tank, the level switch energizes to close the solenoid valves for pulp and water and the motor for the rotation of agitator begins rotating. When the required consistency of the pulp is reached which is measured by measuring the speed of agitator, the agitator motor stops and the outlet valve open to discharge the resultant diluted pulp which is to be send to the paper machine.

2.1 Pulp Inlet

The hardwood raw pulp or undiluted pulp which is present in the pulp storage tank is fed to the final tower through a solenoid valve 1 (SV1) where the pulp is diluted using water and converted into the required consistency in the paper machine for paper manufacturing. Once the push button is ON the process begins, i.e. the undiluted pulp from the pulp storage tank is fed into the final tower through the SV1. The water in the water storage tank is flow to the final tower using solenoid valve2 (SV2) up to the specified quantity required by the paper machine. Level switches are connected to the final tower for the measurement of high and low level of pulp.

2.2 Dilution Process

When the high level switch energizes, i.e. when the amount of pulp inlet reaches the level of the level switch, the solenoid valve for the inlet of pulp and water closes. The agitator motor becomes ON, i.e. the motor which is connected to the agitator for its rotation starts rotating. Hence the pulp starts to get diluted i.e. the pulp and water will be mixed will in the final tower. The speed of the agitator is measured for the purpose of consistency measurement using IR sensor. The number of Revolutions Per Minute (RPM) will be different for different consistency and densities of liquid. Hence, the actual value of RPM for the required amount of consistency is measured by trial and error method and the set point for the required percentage of consistency is obtained. With the help of this value of RPM, the required consistency of pulp can be obtained.

2.3 Pulp Outlet

When the RPM value and the consistency value becomes equal, i.e. when the pulp reaches the percentage of consistency which is required by the paper machine, the agitator motor and the solenoid valve for water outlet goes OFF. Now the pulp present in the final tower is completely diluted to the required amount and thus the diluted pulp is sent out to the paper machine. When the consistency and RPM becomes equal the solenoid valve for the outlet of pulp will get ON, i.e. the solenoid valve for the transfer of pulp from the final tower to the paper machine goes ON. For different qualities of paper different percentage of consistency is required.

2.4 Alarming Process

In this process two bulbs are connected to indicate the level of water and pulp present in the water and pulp storage tank. When the amount of water or pulp goes high, the bulb for the respective tank will glow indicating that the amount of water or pulp present in the tank is getting critically low.

3. Materials and Method

3.1 Agitator

In the prototype model of the proposed work, agitator is constructed with the help of the motor in conjunction with a mechanical impeller. The impeller is connected to the shaft of the motor and the entire agitator setup is placed vertically above the dilution tank.

3.2 Solenoid Valve

A solenoid valve is an electromechanical valve for use with the liquid or gas. The valve is controlled by an electrical current through a solenoid within the case of a two-port valve where the flow is switched on or off; and within the case of a three-port valve, the outflow is switched between the outlet ports. Multiple solenoid valves are often placed together on a manifold design. Besides the plunger-type actuator which is employed most often, pivoted-armature actuators and rocker actuators also are used. A solenoid valve has two main parts: the solenoid and therefore the valve. The solenoid converts electricity into mechanical energy which, in turn, opens or closes the valve mechanically. A direct acting valve has only a little flow circuit. Solenoid valves may use metal seals or rubber seals, and should even have electrical interfaces to permit for straightforward control. A spring could also be used to hold the valve opened or closed while the valve isn't activated.

3.3 IR Sensor

An infrared (IR) sensor is a device that measures and detects infrared in its surrounding environment. An IR sensor can measure the warmth of an object also as detects the motion. IR is invisible to the human eye, as its wavelength is longer than that of visible light (though it is still on the same electromagnetic spectrum). Anything that emits heat (everything that has a temperature above around five degrees Kelvin) gives off infrared radiation. IR Sensors work by employing a specific light sensor to detect a get light wavelength within the Infra-Red (IR) spectrum. By using an LED which produces light at an equivalent wavelength as what the sensor is trying to find, you'll check out the intensity of the received light. This extra-long-range SHARP distance sensor bounces IR off objects to work out how distant they're. It returns an analog voltage which will be used to determine how close the closest object is. It comes with 6" long 6-JST interface wire. The detection of sensors ranges between 100cm-500cm (1-5 meters / 3-15 feet).

3.4 Level Switches

Level switches are used to detect the level of the water and pulp, or the interfaces between liquids. An electrical switching action is used to indicate the level measurements. The principle of the liquid level switches is based on the reed switches which are activated by a permanent magnet inside the float. The reed switch is found inside the tube during a fixed position and therefore the movement of the float changes the situation of the magnetic flux and the contacts of the reed switch are closed or opened. Level switches are used to detect the level of the liquids. These level switches are utilized in various locations where liquid levels must be detected.

3.5 AC Induction Motor

The motor that converts the AC into mechanical power by using an electromagnetic induction phenomenon is named an AC motor. This motor is driven by an alternating current. The stator and therefore the rotor are the two most vital parts of the AC motors. The stator is the stationary part of the motor, and the rotor is the rotating part of the motor. An AC motor is an electrical motor driven by an AC. The AC motor commonly consists of two basic parts, an outdoor stator having coils furnished with AC to supply a rotating magnetic flux, and an indoor rotor attached to the output shaft producing a second rotating magnetic flux. The rotor magnetic flux could also be produced by permanent magnets, reluctance saliency.

3.6 Distributed Control System (DCS)

A distributed control system (DCS) is used to control the process or plant with large control loops in a computerized manner, where the system is distributed by autonomous controllers, but there is no central operator supervisory control. This is in contrast to systems that use centralized controllers; either discrete controller located at a central room or within a central computer. DCS increases reliability and reduces installation costs by locating the control functions near the method plant, through remote monitoring and supervision. Distributed control systems emerged in a safety critical process industry with large and high value, and were attractive because the DCS manufacturer would supply an integrated package which holds both the local control level and also central supervisory equipment, where the design integration risk can be reduced. Today the functionality of SCADA and DCS systems are very similar, with the difference that DCS to be used on large continuous process plants with high reliability and security, and the control room is not geographically remote [18].

4. Results and Analysis

By automating the hardwood final tower dilution process, the various disadvantages and difficulties during operation were overcome. Automation process was implemented using DCS CentumVp software. The functional block diagram of Hardwood final tower dilution in pulping process developed in DCS is shown in Figure 3.

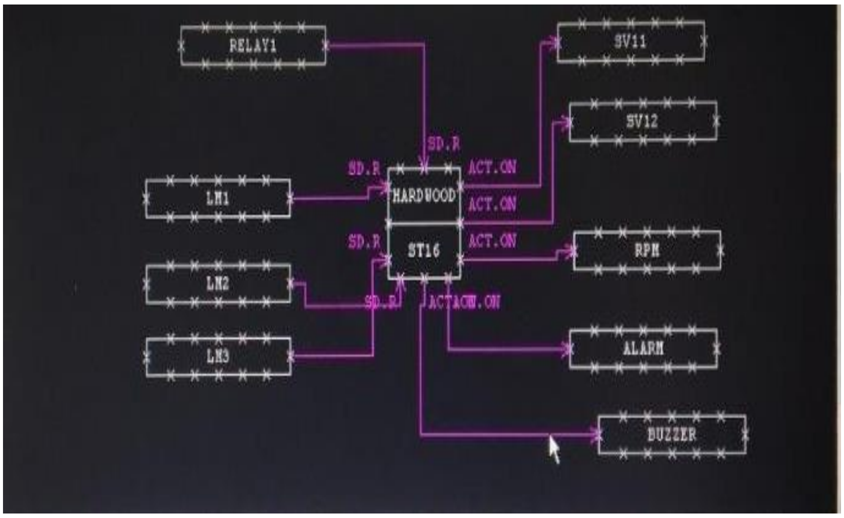

Figure 3. Functional block diagram of Hardwood final tower dilution Process

The function blocks used for the program LM1, LM2 and LM3 indicates limit switches 1, 2 and 3, where LM1(limit switch 1) is placed in pulp storage tank, LM2(limit switch 2) is placed in water storage tank and the LM3(limit switch 3) is place in the final tower where each limit switch monitors the limit of the respective storage tank. Relay 1 is used to indicate the condition whether the present consistency and the required consistency is equal. SV11 indicates the solenoid valve for pulp and SV12 indicates the solenoid valve 38 for water. RPM indicates the consistency of the pulp by measuring the speed of the agitator. ALARM and Buzzer are used to indicate the tank level, when it exceeds certain level it gives indication.

The sequence Logic steps for the dilution process is given below:

Step-1: Initially, Solenoid valve1(SV11) and Solenoid valve2(SV12) will be high

Step-2: When the limit switch 3(LM3) goes high, solenoid valve1(SV11) and solenoid valve2(SV12) becomes LOW and Agitator motor (RPM) becomes HIGH

Step-3: When RELAY1(present and required consistencies are not equal) is HIGH, solenoid valve2(SV12) will be HIGH.

Step-4: When RELAY1(present and required consistencies are not equal) is LOW, Agitator motor (RPM) becomes LOW.

Step-5: When Limit switch 1(LM1) goes HIGH, Level indicator for pulp storage tank (ALARM 1) becomes HIGH.

Step-6: When Limit switch 2(LM2) goes HIGH, Level indicator for water storage tank (ALARM 2) becomes HIGH.

The logical sequence for the hard wood final tower dilution is shown in Figure 4. In this, the logic for the operation is given in sequential order for the step by step functioning of the process.

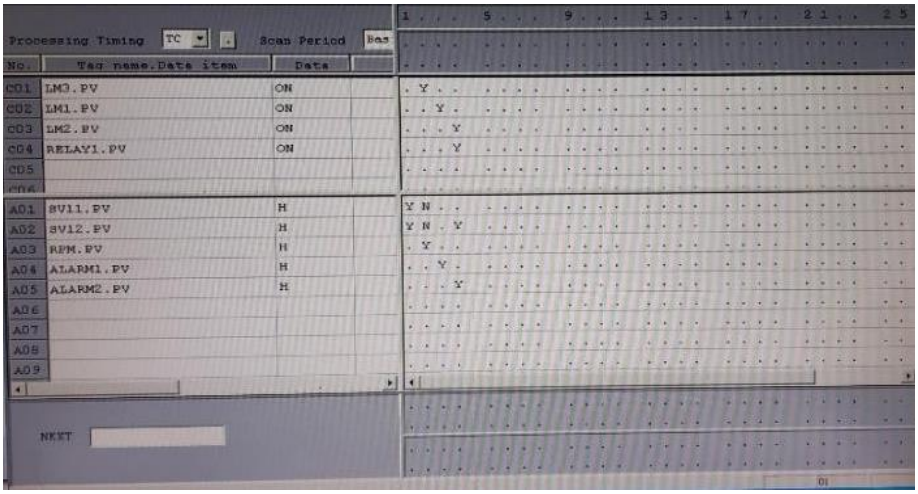

Figure 4. Sequence Logic Diagram of Dilution Process

Table 1 explains the Sequence logic of hardwood final tower dilution process condition and action according to which the dilution takes place during automation.

Table1. Sequence logic of hardwood final tower dilution process

S. No.	CONDITION	ACTION
1	Normal condition	Solenoid valve1(SV11)-OPEN, Solenoid valve2(SV12)-OPEN
2	Limit switch 3(LM3)-ENERGISE	Solenoid valve1(SV11)-CLOSE, Solenoid valve2(SV12)-CLOSE Agitator motor (RPM)-ON
3	RELAY1(required and present consistencies are not equal)-HIGH	Solenoid valve2(SV12)-OPEN
4	RELAY1(required and present consistencies are not equal)-LOW	Agitator motor (RPM)-CLOSE
5	Limit switch 1(LM1)-ENERGISE	Level indicator for pulp storage tank ALARM1-ON
6	Limit switch 2(LM2)-ENERGISE	Level indicator for water storage tank ALARM2-ON

The faceplate simulation output of the hardwood final tower dilution process developed using CentumVp software is shown in Figure 5.

Figure 5. Faceplate Results of Sequential Dilution Process

The snapshot of Hardware model of hardwood final tower dilution process is shown in Figure 6.

Figure 6.Model of Hardwood Final Tower Dilution Process

The advantages of implementing automation in hardwood final tower dilution process include:

- ✓ Fluctuation in pulp consistency got reduced enormously and it is being maintained close to set point
- ✓ Pump poor lifting problem can be solved
- ✓ Tower level raise due to excess tower dilution can be avoided
- ✓ Hardwood final tower dilution has now become very smooth with less effort from the operator
- ✓ The above results are achieved without any financial implication.

5. Conclusion and Future Scope

The proposed method of Automation of Hardwood Final Tower Dilution is developed to increase the productivity and to maintain proper consistency. With the automation for all operations in paper manufacturing, this hard wood final tower dilution using Distributed Control System (DCS) made it very comfortable to increase productivity and to achieve good results in paper quality. The hardwood final tower dilution is taken care automatically and the manual intervention is completely eliminated. This process improved the uniformity in pulp consistency. In future this can be updated for more number of tanks with the same program and it may be possible to implement the same control process using SCADA.

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References

[1] *Mahalic N G P C , Lee S K, "Design and development of system level software tool for DCS simulation", Advances in Engineering Software, Vol. 34, No.7,* ***(2003),*** *pp. 451-465.*

[2] *Vieira M, Tavares C R, Bergamasco R, Petrus J C C, "Application of ultrafiltration-complexation process for metal removal from pulp and paper industry wastewater", Journal of Membrane Science, Vol. 194, No.2,* ***(2001),*** *pp. 273-276.*

[3] *Karma, Deepak, Aar fin, "PLC based automated water level control", International Journal for Research Trends and Innovation, Vol.2,Issue 5,* ***(2016) ,*** *pp. 223-337.*

[4] *Scada Rishabh Das, Sayantan Dutta, Anusree Sarkar, Kaushik Samanta, "Automation of Tank Level Using Plc and Establishment of Hmi",IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE),Volume 3, Issue 12,* ***(2015),*** *pp. 185-189.*

[5] *Ye Daoxing and Li Hong "Fluidization Characteristics of Medium-High Consistency Pulp Fibre Suspensions with an Impeller", International journal of rotating machinery, Vol.2016, Article ID 3902723,* ***(2016****), pp. 1-8.*

[6] *Zhang M, Gordievsky D.M. and Dumont G.A., "Tuning Feedback Controller of Paper Machine for Optimal Process Disturbance Rejection", Pulp and Paper Centre, University of British Columbia,* ***(2008),*** *pp.1-26.*

[7] *Pratibha Singh, Indu Shekhar Thakur, "Colour removal of anaerobically treated pulp and paper mill effluent by microorganisms in two steps bioreactor", Bioresource technology, Vol. 97, No. 2,* ***(2006),*** *pp. 218-223.*

[8] *Patterson S. J., Chanasyk D. S., Mapfumo E & Naeth M A, "Effects of diluted Kraft pulp mill effluent on hybrid poplar and soil chemical properties", Irrigation science, Vol. 26, no. 547****, (2008).***

[9] *Nagaraj B, Vijayakumar P, "Soft Computing Based PID Controller Tuning and Application to the Pulp and Paper Industry", Sensors & Transducers Journal, Vol. 133, no. 10,* ***(2011),*** *pp. 30-43.*

[10] *Firoozshahi A, "Innovative Tank Management System based on DCS," Proceedings ELMAR-2010, Zadar,* ***(2010),*** *pp. 323-328.*

[11] *Noor N. N. Abdulsattar, Faiz F. Mustafa, Suha M. Hadi, "Design and Implementation of SCADA System for Sugar Production Line", Computer Science, Vol. 15,No. 2,* ***(2019),*** *pp. 80-88.*

[12] *Hussain A. Attia, Beza Negash Getu, Abdulhadi Brazi, "Implementation of sequential design based water level monitoring and controlling system", Computer Science, Vol. 9,No. 2**(2019),** pp. 967-972.*
[13] *Lavanuru Ashok, B. Rama Murthy, "Liquid Level Monitoring and Flow based Liquid Distribution System using PLC and SCADA", Environmental Science, Vol. 8, Issue 12, **(2019),** pp. 118-126**.***
[14] *Nissinen A, Rantala T, Huhtelin T, Lautala P, Nokelainen J, "New Process Control Requirements and Solutions for Paper Machine with Dilution Headbox", IFAC Proceedings, Vol. 32, no. 2, **(1999),** pp 6872-6877.*
[15] *Rosemary Marques, Frank Bernardoni , Scott Pollack, Roy Helmy, "Development of an automated system for preparation of liquid scintillation counting samples for radio labeled pharmaceuticals", Journal of labelled compounds and radiopharmaceuticals, Vol.57, Issue.3, **(2013),** , pp. 121-124*
[16] *Banupriya, R .Radha, Basavaraj V M , "Automation of Sectional Drive Paper Machine Using PLC and HMI", International Journal of Engineering Research and General Science, Vol. 3, no. 4, **(2015).** Pp. 842-847**.***
[17] *Jacob J, Kaipe H, Couderc F & Paris J, "Water network analysis in pulp and paper processes by pinch and linear programming techniques", Chemical Engineering Communications, Vol. 189, no. 2, (2010), pp. 184-206.*
[18] *Priyanka E B, Maheswari C, Thangavel S, Ponni Bala M, Integrating IoT with LQR-PID controller for online surveillance and control of flow and pressure in fluid transportation system, Journal of Industrial Information Integration, vol.17, February 2020. https://doi.org/10.1016/j.jii.2020.100127.*