Automatic Control of Massecuite Temperature in the Sugar Processing Industry

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Abstract. Sugar industries process sugarcane to produce the sugar and Brix is one of the vital parameters to be measured out of several parameters. Brix is the amount of sucrose present in the massecuite. Massecuite solution contains suspended sugar crystals in it. The mixture of 1 gram of sucrose in 100 grams of solution is quantified as One Degree Brix. Brix value influences the efficient output of the sugar industry. Hence it is essential to maintain Brix value as 65°Brix at a controlled temperature between 40°C and 45°C. In this work, with the help of temperature sensor, heater and Arduino controller, the temperature is controlled. At this controlled temperature, Brix is measured with the use of the conductivity sensor to maintain Brix value.

Keyword : Sugar industry, Temperature, Automatic control

1. Introduction

India leads in the global sugar market, which is the second-largest producer producing 15% of global sugar. It is a significant contribution to the socio-economic development of the nation. There are about 597 sugar mills, 309 distilleries and 213 cogeneration plant and numerous pulps, paper and chemical making units are associated with the Indian sugar industry [1]. The quality analysis of sugarcane juice plays a vital role in various processes like refining, breeding, cultivation, and production of sugar. The key indices such as Brix, purity, polarisation, sucrose content are analysed in all sugar processing industries [2]. The cane variety, climatic conditions, and fluctuations in the season influence the juice characteristics [3]. Optical and digital Brix refractometers were evaluated, and also the measurement of Ig concentration was done. For fresh and frozen samples, the correlation between both optical and digital Brix refractometers was concluded as high [4]. A NIR spectrophotometer generates spectral data of wavelength 700 to 2500 nm. It is one of the specially designed fruit drawers. Samples are taken as a slice of 3 cm thickness of the outer layer. In each fruit, upper, middle and lower parts are taken as a sample. In the skin-side and the flesh-side of the sliced pieces, NIR measurements were made. A sugar-acidity analyser was used to measure Brix and acidity. It consists of an electrical conductivity meter and refractometer [5].
Two selection methods were determined to relate infrared spectra with degree Brix in sugarcane juice samples. The first selection depends on the PLS regression coefficients. The second selection depends on minimum error searches conducted through interval PLS (i-PLS), genetic algorithms (GA), particle swarm optimisation (PSO), and variable-size moving-window (VS-MW). The best results were obtained on natural computation. The results are furnished after the inspection of the regression coefficients spectrum [6]. An apparatus was used to control the flow of liquid into a beverage forming machine. This apparatus includes a beverage forming station, a liquid supply, and a control circuit. The fluid collection consists of first and second valves which are placed in series for controlling the flow of liquid. The control circuit may contain at least first and second valves to open and close to control the flow of liquid to the liquid supply. The beverage forming apparatus is controlled by controlling the flow of liquid with the help of first and second valves [7].

The first valve is arranged along with, upstream of, the second valve and for fluid coupling to the liquid source. Total dissolved solids (TDS) and Conductivity (EC) are water quality parameters. They are used to describe the salinity level. The above two parameters are correlated by a simple equation, TDS = k.EC (25 °C). TDS analysis is better than EC analysis. It is because seawater intrusion can be easily identified by TDS analysis, and also the water quality is specified. From EC value TDS can be measured with the help of ratio value. However, the determination of ratio is challenging. The ratio is strongly influenced by salinity contents and materials contents [8]. Conductance data on the interaction of potassium, sodium, magnesium, and calcium in salt form with an aqueous solution of plantation white sugar and AR sugar has been reported. These salts are soluble constituents of sugarcane juice and help to study the interaction of nonelectrolytes – electrolytes system in aqueous solution. It is found that hydration of ions and hydrogen bonding tendency of plantation white sugar/AR sugar and water plays a vital role in combined as well as in an independent state [9].

One of the modern technologies used in industry for process measurement and control is the microwave concentration measurement. Measurement systems are active for Brix control on pans (batch and continuous) in the sugar making process. Current developments allow the technology to be applied to virtually all measurement points requiring the process variable determination and control of concentration, density, or total solids in sugar plants [10]. The process of flow of cane juice is essential to produce high-quality sugar. This work presents a project which controls the operation of raw sugar production. The problem stated is to control the surge tanks in juice circuit to create steady flow into the settling vessel (clarifier). The clarifier’s efficiency is reduced by rapid flow rate variations with the ultimate result being a reduction in raw sugar quality due to increased extraneous matter in the sugar is an incredibly important problem. The new solution involves using gain-scheduled feedforward techniques to control the existing surge tanks so that the available capacity is used efficiently [11]. The parameter identification approach is used to determine the dynamic behaviour of an industrial five-effect evaporator in sugar manufacturing. The purpose is to obtain an accurate mathematical model that can be used for advanced control design. The evaporation process in the sugar industry is highly complex. This process is characterised by strong disturbances with nonlinearities, many constraints and considerable time delays. Experiments were conducted at the sugar factory. Data acquisition involve measurements of syrup Brix (sugar concentration) as output, juice flow and steam flow as inputs, syrup flow and vacuum at the fifth effect as measurable disturbances [12].

The literatures reveal that Brix is one of the key indices to be measured and monitored in a sugar processing industry. Optical, digital Brix refractometers and NIR spectrophotometers are used in several cases for the measurement of Brix. The price involved for the refractometers and photometers are high and there arises need for low cost solution. The Brix can be calculated from TDS and temperature of the measurand and it can be maintained using the conductivity analysis. This paper focusses on measuring the brix value using TDS, temperature sensors and conductivity meter.
2. Methodology
The methodology used for automatic control of massecuite’s temperature in sugar industries is shown in the block diagram figure 1.

To maintain the temperature of the massecuite between 40°C and 45°C and to measure the (°Bx) value at the controlled temperature is the main objective of this system. Initially, the temperature is sensed with the help of a thermometer DS18B20. The output of thermometer is given to the controller. Suppose the temperature is below 40°C, the heater gets ON and if it is above 45°C the heater gets OFF. The controller is programmed accordingly for the above process. TDS and conductivity play a role in finding Brix value. Hence TDS is measured with the help of the TDS sensor.

\[ \%Brix = \%TDS/0.849108 \]

1

\[ 1^\circ Brix = 1^\% Brix \]

2

Conductivity is measured with the help of the conductivity sensor.

\[ Brix = (K + 1)/Conductivity \]

3

Here K value depends on temperature and conductivity. After measuring Brix, its value is maintained at 65°Brix. If °brix is greater than 65, water is fed into the vessel through the pump. If °brix is less than 65, the solution is heated using the heater.

3. Materials Used
The hardware components used in the system are detailed in table 1.

| S. No. | Components required | Specifications |
|-------|---------------------|----------------|
| 1.    | Thermometer         | -55°C to +125°C |
| 2.    | TDS Sensor          | 0-200 ppm       |
| 3.    | Relay               | 12V DC          |
| 4.    | Pump                | 12V DC          |
| 5.    | Arduino Controller  | Flash memory 32KB |
3.1 Thermometer

The thermometer is used for temperature measurement of an object. The DS18B20 digital measuring device provides 9-bit to 12-bit Celsius temperature measurements. Its associate degree alarm performs with non-volatile user-programmable lower and higher trigger points. The DS18B20 needs only one information line (and ground) for communication with a central silicon chip since it communicates over a 1-Wire bus, by definition it.

The core practicality of the DS18B20 is its direct-to-digital temperature detector. The resolution of the temperature detector is user-configurable to 9, 10, 11, or 12 bits, cherish increments of 0.0625°C, 0.125°C, 0.25°C and 0.5°C, severally. The default resolution at power-up is 12-bit. The DS18B20 powers up during a low power idle state. To initiate a temperature activity and A-to-D conversion, the master should issue a ConvertT [44h] command. Following the conversion, the ensuing thermal knowledge is held within the 2-byte temperature register within the computer storage and therefore the DS18B20 returns to its idle state. If the DS18B20 is hopped-up by an associate external offer, the master can issue "read time slots" when the Convert T command and the DS18B20 will respond by transmission zero. In contrast, the temperature conversion is current, and one once the conversion is finished.

3.2 TDS Sensor

TDS (Total Dissolved Solids) indicates that what number milligrams of soluble solids dissolved in one litre of water. Total Dissolved Solids (TDS) square measure the overall quantity of mobile charged ions, as well as metals, salts or minerals dissolved in a given volume of water, expressed in units of mg per unit volume of water (mg/L), conjointly spoken as per million (ppm). A TDS meter works on the electrical conductivity of the liquid. Pure H2O has virtually zero conductivity. Some dissolved solids return from organic sources like leaves, silt, plankton, and industrial waste and waste product, and different sources return from runoff from urban areas, road salts used on the street throughout the winter, and fertilisers and pesticides used on lawns and farms. Dissolved solids additionally return from inorganic materials like rocks and air that will contain bicarbonate, nitrogen, iron, phosphorous, sulphur, and different minerals. Several of those materials are kind of salts, which are compounds that contain each a metal and a non-metal. Salts usually dissolve in water forming ions. Ions are unit particles that have a positive or charge.

3.3 Relay

The relay is an electrically operated switch. An electromagnet is given a power source with the help of a power switch and contacts. The energisation of the electromagnet is done whenever the current flows through the control coil. This energisation causes the intensification of the magnetic field. Lower fixed arm attracts the upper contact arm, and as a result, the contacts get closed, and the circuit is short-circuited. An open circuit will happen when there is an opposite movement of the contact. This process is done when the relay is de-energised.

3.4 Pump

A pump is a device that transforms fluids (gases or liquids), or sometimes slurries, by its mechanical action. It could be classified into three major groups according to the way they use to transforms the fluid: displacement, direct lift and gravity pumps. Pumps usually operate by some mechanism (typically rotary or reciprocating), and they consume energy to perform mechanical work to transform the fluid. Pumps operate through many energy sources. It includes manual operation, electricity, wind power or engines come in many sizes, from microscopic to large industrial pumps.
Mechanical pumps serve in an exceedingly wide range of applications like pumping water from wells, storage tank filtering, lake filtering and aeration, within the automobile trade for water-cooling and fuel injection system, within the energy industry for pumping oil and fossil fuel or for operational cooling towers and alternative parts of heating, ventilation and air-con systems.

3.5 Arduino UNO

Arduino UNO could be a microcontroller board that supported the ATmega328P (datasheet). As specified in [15], microcontroller can also be used to detect overloading issues. For temperature and pressure measurement, automated monitoring and control using Arduino was stated in [14]. It contains fourteen digital I/O pins (of that six will be used as PWM outputs), six analogue inputs, a sixteen megahertz ceramic resonator (CSTCE16M0V53-R0), a USB affiliation, an influence jack, associate ICSP header, and a push. Everything required to support the microcontroller is available. Arduino controllers have their scopes scopes extended for speed control applications[16]. Merely connect it to a laptop with a USB cable or power it with an AC-to-DC adapter or battery to urge started. A resettable polyfuse in Arduino protects the computer's USB ports from short circuits and overcurrent. Most of the computers will provide internal protection on their own.

4. Hardware Prototype

The hardware arrangement for the proposed system is shown in figure 2.

5. Results and Discussions

The brix values obtained for various samples are listed in table 2. Samples of massecuite were collected from industries and were tested with the developed model. After conducting multiple sample analysis in the developed instrument model, the average brix value has arrived at 65° Brix. The controller program is made based on this average value, and the results are tabulated in table 3.
# Table 2. Brix value for various samples

| Parameters | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
|------------|----------|----------|----------|----------|----------|
| Temperature | 42       | 43       | 41       | 42       | 40       |
| Brix        | 67       | 102      | 135      | 54       | 87       |

The process executed in this work is shown in table 3. This table shows the working of the heater and pumps during different Brix values. It is noticeable from the table 2 that the controller works perfectly for the maintained 65 Brix value. The heater goes OFF when the 65 Brix is reached, and the pump goes ON if the value goes beyond 65 Brix. Thus, the process of heating the massecuite and the flow of water into the massecuite tank is maintained. The above process is done according to the Brix existent in the massecuite. This process involves continuous monitoring of Brix content due to which any errors occurring in manual adjustment of flow in steam and hot water into the massecuite can be minimized.

## 6. Conclusion

Massecuite Brix Analyser finds broader application in all sugar industries for maintaining the quality of sugar. This hardware setup is simple and cost-effective, and the software is user friendly. This setup can be used with minimal maintenance and increased safety in the workplace. This setup does not need highly skilled labor for maintenance. The automatic setup detection of Brix reduces time and risk for workers. It improves the quality of sugar and enables continuous monitoring of Brix without manual intervention. The accuracy can be improved by using non contact type sensors for measurements.

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