A MODEL FOR SIMULATION OF A PROCESS CONTROL SYSTEM

Thesis submitted in partial fulfillment of the requirement
for the award of the degree of

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G.KANNAN

SYNOPSIS

Though India is the largest producer of sugar it does not rank among the best in terms of sugar quality. Most of the sugar industries use conventional control techniques, which found fall short of providing effective means of controlling the processes when the process is complex. With the increasing demand for better quality and productivity, there is a need to automate the manufacturing processes. Many processes are however complex, non-linear, stochastic and even ill defined in some cases. In fact operation of many processes still relies on the operator's skills due to lack of robust control methods. However, it is well known that humans, once trained or experienced, can successfully control various complex systems without having to depend on mathematical models. This fact leads to the need to develop intelligent monitoring and control schemes.

In this project, effort has been made for intelligent optimization and control of complex process to achieve better quality of sugar using intelligent control schemes based on fuzzy logic, simulink and the simulation is achieved through the fuzzy-simulink software. Already the data has been collected at sakthi sugars, manufacturing sugar and beverages.

An attempt has been made to study the entire process of sugar, various factors that affect the quality of sugar, existing control methods and its effect on final product. The study aids to develop a new model for underlying non-linear dynamic process using fuzzy logic and the simulation is performed using 'simulink ' the simulation software available in the matlab toolbox.

The project is a systematic attempt to design knowledge based fuzzy-simulink model for a complex system to make the plant to operate safely and efficiently. The above intelligent control schemes overcome the limitations of conventional control methods for complex problems.

ABBREVIATIONS

AD	–	Activation Degrees
FI	–	Fuzzification Interface
FIS	–	Fuzzy Inference System
FP	–	Functioning Phase
HA	–	High Acidic
HL	–	High Lime
HS	–	High Sulphur
ICUMSA	–	International Commission for Uniform Methods of Sugar Analysis
LA	–	Low Acidic
LL	–	Low Lime
LOM	–	Largest Of Maximum
LP	–	Learning Phase
LS	–	Low Sulphur
MA	–	Medium Acidic
Mf	–	Membership function
MOM	–	Middle of Maximum
PID	–	Proportional + Integral + Derivative controller
PLC	–	Programmable Logical Control
PPM	–	Parts Per Million
TRIMF	–	Triangular Membership Function
VHA	–	Very High Acidic/Alkali
VHL	–	Very High Lime
VHS	–	Very High Sulphur
VLA	–	Very Low Acidic
VLL	–	Very Low Lime
VLS	–	Very Low Sulphur

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1. INTRODUCTION

1.1 Introduction About The Project

Today sugar is the most widely used sweetener. It is most often used to sweeten foods and beverages. Sucrose is generally known as cane sugar, which is used as a sweetening agent for foods as in manufacture of candies, cakes, puddings preserves, soft and alcoholic beverages and many other foods. Sucrose is a basic foodstuff supply approximately 13 % of all energy that is derived from foods. Sucrose is a disaccharide that it is made up of two simple sugars namely glucose and fructose.

The extraction of sucrose from cane sugar is a complex process, which undergoes several treatments before manufacturing final product. Though India is the largest producer of sugar, it does not ranks among the best in terms of sugar quality, since most of the sugar mills in India follows traditional method of manufacturing sugar which lacks in monitoring and in process control techniques. In order to produce sugar of superior quality that would be saleable in international market a cost effective route and modern process control technique s have to be implemented to produce quality sugar.

The conventional method of juice extraction suffers from drawback of pH control of juice, control of limewater, sulphurdioxide, impurities in juice, dextrons (bacterial content), control of temperature, pressure, and flow of juice etc which affects the quality of juice.

Modern control techniques like fuzzy controller (PID controller) and combination of fuzzy-simulink approach can be used to efficiently control the process of juice. Improper control of pH, limewater, and sulphurdioxide not only affects the quality of sugar but also leads to Abnormal condition of sugar plant. Therefore information on abnormal events should also be considered important for risk assessment in process industries.

Thus the operator is forced to focus through large amounts of interrelated data to identify the causes, which leads to poor quality of sugar. This requires integration and analysis of large amount numerical and abstract data. Therefore a knowledge based artificial intelligence system is more appropriate for such situations. Fuzzy and simulink separately and in combination, plays an increasingly important role in understanding human cognition and to simulate human decision making under uncertain and imprecise environments. They learn from experience with numerical and linguistic sample data. Learning from samples involves construction of a model of the system from the knowledge of collection of input-output pairs.

1.1.1 Need and scope of the project

- Lack of experience in modeling on the dynamics of the process industry.
- Lot of training is required for the proper maintenance of the system
- Continuous improvement of quality which is incorporated with the process industry.

1.1.2 Aim Of The Project

- To build a model for the manufacturing system
- To have an experience of modeling to integrate Simulink - Fuzzy computing in the process manufacturing system
- To analyze how the quality is affected or changed with the simulated model

1.2 INTRODUCTION TO FUZZY LOGIC SYSTEM

1.2.1 Definition:

Fuzzy logic is all about the relative importance of precision: How important is it to be exactly right when a rough answer will do? .

Here is what some clever people have said in the past about fuzzy logic.

Precision is not truth. - **Henri Matisse**

Sometimes the more measurable drives out the most important.

- **René Dubos**

Vagueness is no more to be done away with in the world of logic than friction in mechanics. -**Charles Sanders Peirce**

I believe that nothing is unconditionally true, and hence I am opposed to every statement of positive truth and every man who makes it.

-**H. L. Mencken**

So far as the laws of mathematics refer to reality, they are not certain. And so far as they are certain, they do not refer to reality. -**Albert Einstein**

As complexity rises, precise statements lose meaning and meaningful statements lose precision. -**Lotfi Zadeh**

Fuzzy logic sometimes appears exotic or intimidating to those unfamiliar with it, but once you become acquainted with it, it seems almost surprising that no one attempted it sooner. In this sense fuzzy logic is both old and new because, although the modern and methodical science of fuzzy logic is still young, the concepts of fuzzy logic reach right down to our bones.

1.2.2 Uses of Fuzzy Logic:

1. **Fuzzy logic is conceptually easy to understand.**

The mathematical concepts behind fuzzy reasoning are very simple. What makes fuzzy nice is the "naturalness" of its approach and not its far-reaching complexity.

2. Fuzzy logic is flexible.

With any given system, it's easy to massage it or layer more functionality on top of it without starting again from scratch.

3. Fuzzy logic is tolerant of imprecise data.

Everything is imprecise if you look closely enough, but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end.

4. Fuzzy logic can model nonlinear functions of arbitrary complexity.

You can create a fuzzy system to match any set of input-output data. This process is made particularly easy by adaptive techniques like ANFIS (Adaptive Neuro-Fuzzy Inference Systems), which are available in the Fuzzy Logic Toolbox.

5. Fuzzy logic can be built on top of the experience of experts.

In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, fuzzy logic lets you rely on the experience of people who already understand your system.

6. Fuzzy logic can be blended with conventional control techniques.

Fuzzy systems don't necessarily replace conventional control methods. In many cases fuzzy systems augment them and simplify their implementation.

7. Fuzzy logic is based on natural language.

The basis for fuzzy logic is the basis for human communication. This observation underpins many of the other statements about fuzzy logic.

The last statement is perhaps the most important one and deserves more discussion. Natural language, that which does ordinary people on a daily basis use, has been shaped by thousands of years of human history to be convenient and efficient. Sentences written in ordinary language represent a triumph of efficient communication. We are generally unaware of this because ordinary language is, of course, something we use every day. Since fuzzy logic is built atop the structures of qualitative description used in everyday language, fuzzy logic is easy to use.

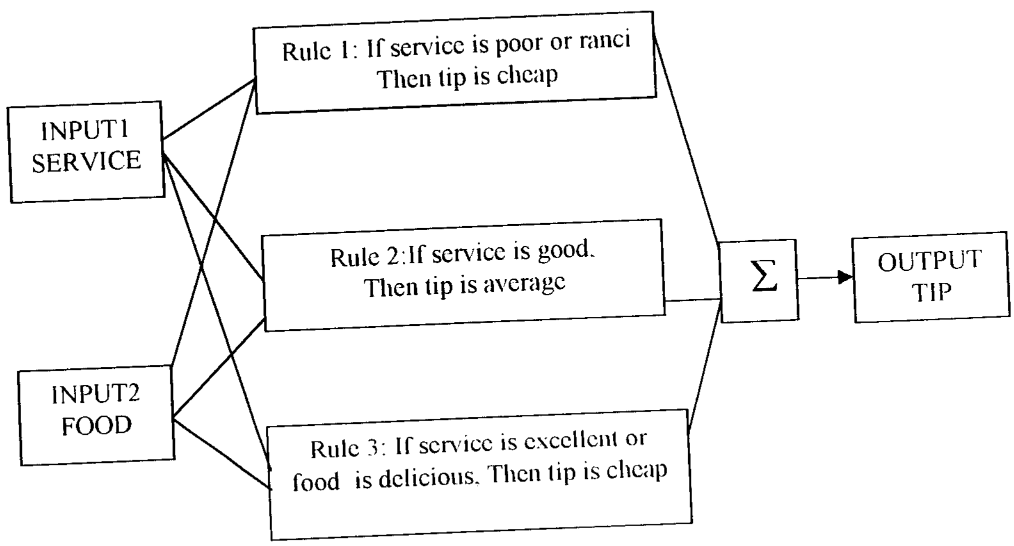
1.2.3 An Introductory Example: Fuzzy vs. Non-Fuzzy

A specific example would be helpful at this point. To illustrate the value of fuzzy logic, we'll show two different approaches to the same problem: linear and fuzzy. First we will work through this problem the conventional (Non-fuzzy) way, writing MATLAB commands that spell out linear and Piecewise-linear relations. Then we'll take a quick look at the same system using fuzzy logic.

Consider the tipping problem: what is the "right" amount to tip your Waitperson? Here is a clear statement of the problem.

Dinner For Two, Repeat

In this section we provide the same two input one output three rule tipping problem that you saw in the introduction, only in more detail .The basic structure of this example is shown in the diagram below.



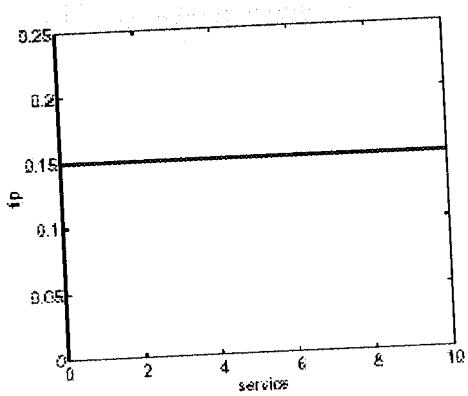
The Basic Tipping Problem. Given a number between 0 and 10 that represents the quality of service at a restaurant (where 10 is excellent), what should the tip be?

Cultural Footnote This problem is based on tipping as it is typically practiced in the United States. An average tip for a meal in the U.S. is 15%, though the actual amount may vary depending on the quality of the service provided.

1.2.3.1 The Non-Fuzzy Approach

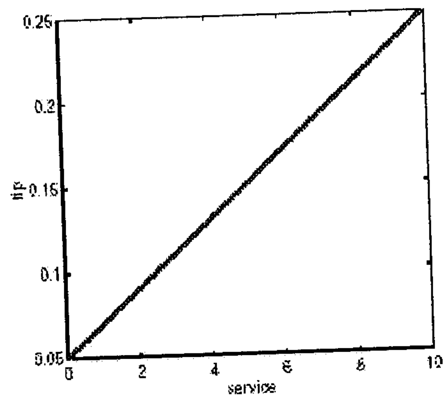
Let's start with the simplest possible relationship. Suppose that the tip always equals 15% of the total bill.

Tip = 0.15



This doesn't really take into account the quality of the service, so we need to add a new term to the equation. Since service is rated on a scale of 0 to 10, we might have the tip go linearly from 5% if the service is bad to 25% if the service is excellent. Now our relation looks like this.

Tip=0.20/10*service+0.05

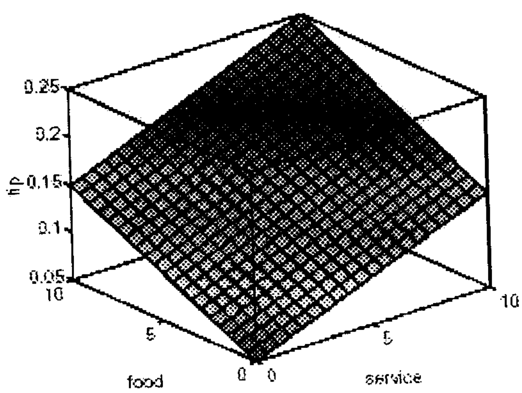


So far so good. The formula does what we want it to do, and it's pretty Straightforward. However, we may want the tip to reflect the quality of the food as well. This extension of the problem is defined as follows.

The Extended Tipping Problem. Given two sets of numbers between 0 and 10 (where 10 is excellent) that respectively represent the quality of the service and the quality of the food at a restaurant, what should the tip be?

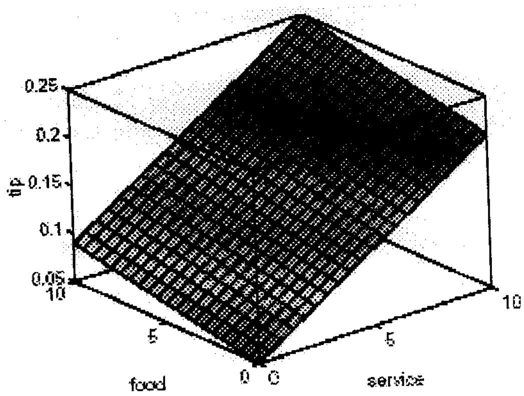
Let's see how the formula will be affected now that we've added another variable. Suppose we try

Tip = 0.20/20*(service+food)+0.05;



In this case, the results look pretty, but when you look at them closely, they don't seem quite right. Suppose you want the service to be a more important factor than the food quality. Let's say that the service will account for 80% of the overall tipping "grade" and the food will make up the other 20%. Try

```
ServRatio=0.8;
Tip=servRatio*(0.20/10*service+0.05) +...
(1–servRatio)*(0.20/10*food+0.05);
```

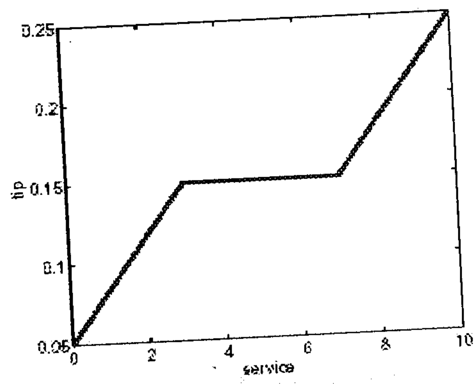


The response is still somehow too uniformly linear. Suppose you want more of a flat response in the middle, i.e., you want to give a 15% tip in general, and will depart from this plateau only if the service is exceptionally good or bad. This, in turn, means that those nice linear mappings no longer apply. We can still salvage things by using a piecewise linear construction. Let's return to the one-dimensional problem of just considering the service. You can string together a simple conditional statement using breakpoints like this.

```
if service<3,
Tip=(0.10/3)*service+0.05;
elseif service<7,
tip=0.15;
elseif service<=10,
tip=(0.10/3)*(service–7)+0.15;
```

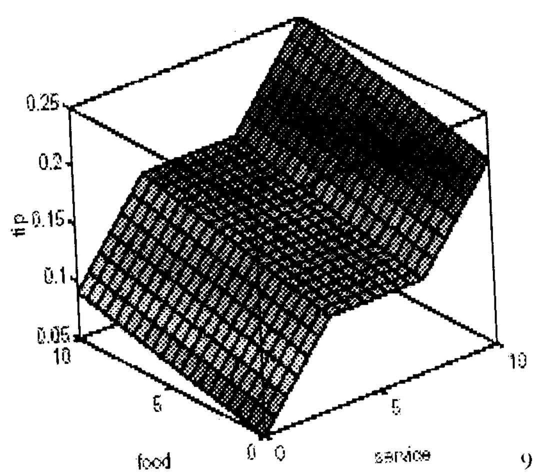
end

The plot looks like this.



If we extend this to two dimensions, where we take food into account again, something like this result.

```
servRatio=0.8;
if service<3,
tip=((0.10/3)*service+0.05)*servRatio + ...
(1-servRatio)*(0.20/10*food+0.05);
elseif service<7,
tip=(0.15)*servRatio + ...
(1-servRatio)*(0.20/10*food+0.05);
tip=((0.10/3)*(service-7)+0.15)*servRatio + ...
(1-servRatio)*(0.20/10*food+0.05);
end
```



The plot looks good, but the function is surprisingly complicated. It was a little tricky to code this correctly, and it's definitely not easy to modify this code in the future. Moreover, it's even less apparent how the algorithm works to someone who didn't witness the original design process.

1.2.3.2 The Fuzzy Approach

It would be nice if we could just capture the essentials of this problem, leaving aside all the factors that could be arbitrary. If we make a list of what really matters in this problem, we might end up with the following rule descriptions.

1. If service is poor, then tip is cheap

2. If service is good, then tip is average

3. If service is excellent, then tip is generous

The order in which the rules are presented here is arbitrary. It doesn't matter which rules come first. If we wanted to include the food's effect on the tip, we might add the following two rules.

4. If food is rancid, then tip is cheap

5. If food is delicious, then tip is generous

In fact, we can combine the two different lists of rules into one tight list of three rules like so.

1. If service is poor or the food is rancid, then tip is cheap

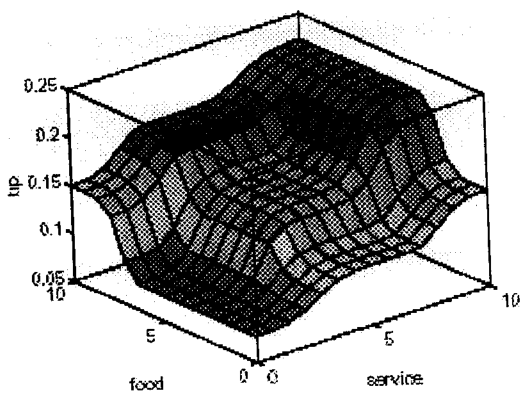
2. If service is good, then tip is average

3. If service is excellent or food is delicious, then tip is generous

These three rules are the core of our solution. And coincidentally, we've just defined the rules for a fuzzy logic system. Now if we give mathematical meaning to the linguistic variables (what is an "average" tip, for example?) we would have a complete fuzzy inference system. Of course, there's a lot left to the methodology of fuzzy logic that we're not mentioning right now, things like:

- How are the rules all combined?
- How do I define mathematically what an "average" tip is?

The details of the method don't really change much from problem to problem — the mechanics of fuzzy logic aren't terribly complex. What matters is what we've shown in this preliminary exposition: fuzzy is adaptable, simple, and easily applied.



Here is the picture associated with the fuzzy system that solves this problem. The picture above was generated by the three rules above. Thus we have seen the elaborate introduction about the fuzzy and non-fuzzy approach.

1.2.4 Fuzzy Logic Toolbox:

The Fuzzy Logic Toolbox is a collection of functions built on the MATLAB numeric computation environment. It provides tools for you to create and edit fuzzy inference systems within the framework of MATLAB. This toolbox relies heavily on graphical user interface (GUI) tools to help you accomplish your work, although you can work entirely from the command line if you prefer.

The toolbox provides three categories of tools:

- Command line functions
- Graphical, interactive tools
- Simulink blocks and examples

1.2.5 Steps In Fuzzy Tool Box:

1. Fuzzy Inputs

The first step is to take the inputs and determine the degree to which they belong to each of the appropriate fuzzy sets via membership functions. In the Fuzzy Logic Toolbox, the input is always a crisp numerical value limited to the universe of discourse of the input variable (in this case the interval between 0 and 10) and the output is a fuzzy degree of membership in the qualifying linguistic set (always the interval between 0 and 1). Fuzzification of the input amounts to either a table lookup or a function evaluation.

2. Apply Fuzzy Operators

Once the inputs have been fuzzified, we know the degree to which each part of the antecedent has been satisfied for each rule. If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the antecedent for that rule. This number will then be applied to the output function. The input to the fuzzy operator is two or more membership values from fuzzified input variables. The output is a single truth-value.

3. Apply Implication Method

Before applying the implication method, we must take care of the rule's weight. Every rule has a weight (a number between 0 and 1), which is applied to the number given by the antecedent. Generally this weight is 1 (as it is for this example) and so it has no effect at all on the implication process. From time to time you may want to weight one rule relative to the others by changing its weight value to something other than 1. Once proper weighting has been assigned to each, the implication method is implemented. A consequent is a fuzzy set represented by a membership function, which weights appropriately the linguistic characteristic that is attributed to it. The consequent is reshaped using a function associated with the antecedent (a single number). The input for the implication process is a single number given by the antecedent for each rule. Two built-in methods are supported, and they are the same functions that are used by the AND method: min (minimum), which truncates the output fuzzy set, and prod (product), which scales the output fuzzy set.

4. Aggregate All Outputs

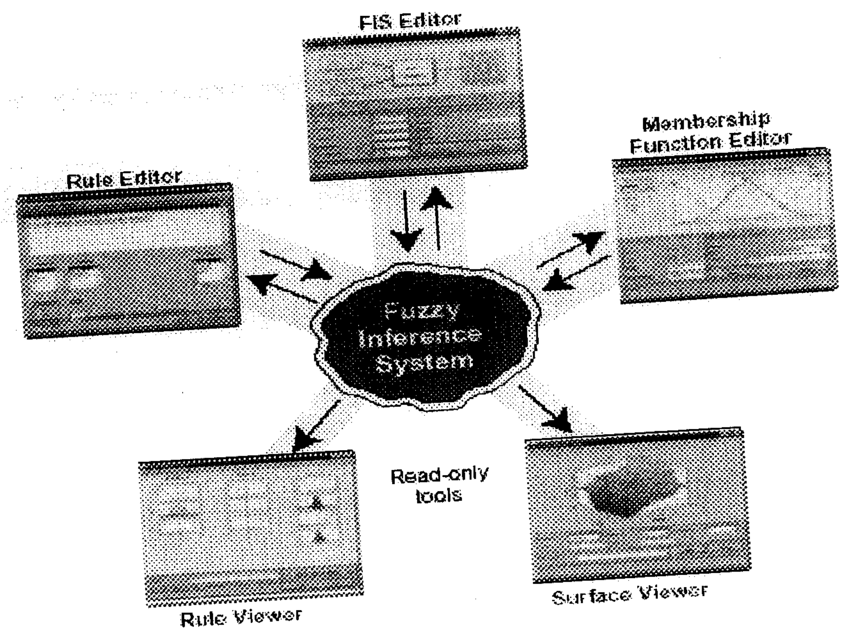
Since decisions are based on the testing of all the rules in an FIS, the rules must be combined in some manner in order to make a decision. Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. Aggregation only occurs once for each output variable, just prior to the fifth and final step, defuzzification. The input of the aggregation process is the list of truncated output functions returned to the implication process for each rule. The output of the aggregation process is one fuzzy set for each output variable.

Notice that as long as the aggregation method is commutative (which it always should be), then the order in which the rules are executed is unimportant. Three built-in methods are supported: max (maximum), probor (probabilistic or), and sum (simply the sum of each rule's output set).

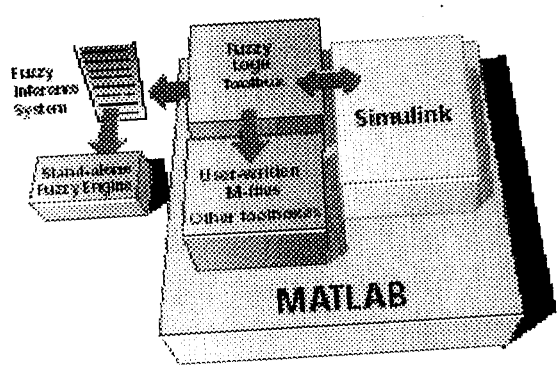
5. Defuzzify

The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired out put for each variable is generally a single number. However, the aggregate of a fuzzy set encompasses a range of out put values, and so must be defuzzified in order to resolve a single output value from the set. Perhaps the most popular defuzzification method is the centroid calculation, which returns the center of area under the curve. There is five build in methods supported: centroid, bisector, middle of maximum (the average of the maximum value of the output set), largest of maximum, and smallest of maximum.

1.2.6 Structure Of Fuzzy System:



1.2.7 Over All View Of The Fuzzy Toolbox:



1.2.8 Advantages Of Using Fuzzy Logic To Build A Model:

1. Fuzzy logic is conceptually easy to understand. The mathematical concepts behind fuzzy reasoning are very simple. What makes fuzzy nice, is the 'naturalness' of its approach and not its far reaching complexity.
2. Fuzzy logic that is a qualitative model is highly flexible.
3. Fuzzy logic is tolerant of imprecise data.
4. It is used to model non-linear function of arbitrary complexity.
5. The experts who are having much experience in particular fields can build fuzzy logic.
6. Fuzzy logic can be blended with conventional control techniques.
7. Fuzzy logic is based on natural language .The basis for fuzzy logic is the basis for human communication.

1.3 INTRODUCTION TO SIMULINK:

1.3.1 Definition:

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Systems can also be multirate, i.e., have different parts that are sampled or updated at different rates.

For modeling, Simulink provides a graphical user interface **(GUI)** for building models as block diagrams, using click-and-drag mouse operations. With this interface, you can draw the models just as you would with pencil and paper (or as most textbooks depict them). This is a far cry from previous simulation packages that require you to formulate differential equations and difference equations in a language or program. Simulink includes a comprehensive block library of sinks, sources, linear and nonlinear components, and connectors. You can also customize and create your own blocks by *Writing S-Functions*.

Models are hierarchical, so you can build models using both top-down and bottom-up approaches. You can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact.

After you define a model, you can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in **MATLAB's** command window. The menus are particularly convenient for interactive work, while the command-line approach is very useful for running a batch of simulations (for example, if you are doing Monte Carlo simulations or want to sweep a parameter across a range of values). Using scopes and other display blocks, you can see the simulation results while the simulation is running. In addition, you can change parameters and immediately see what happens, for "what if" exploration. The simulation results can be put in the **MATLAB** workspace for post processing and visualization.

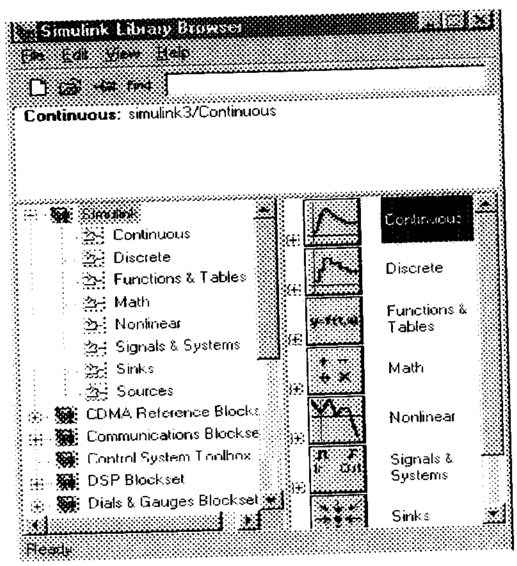
Model analysis tools include linearization and trimming tools, which can be accessed from the **MATLAB** command line, plus the many tools in MATLAB and its application toolboxes. And because MATLAB and Simulink are integrated, you can simulate, analyze, and revise your models in either environment at any point.

1.3.2 Starting Simulink

To start Simulink, you must first start **MATLAB.** You can then start Simulink in two ways:

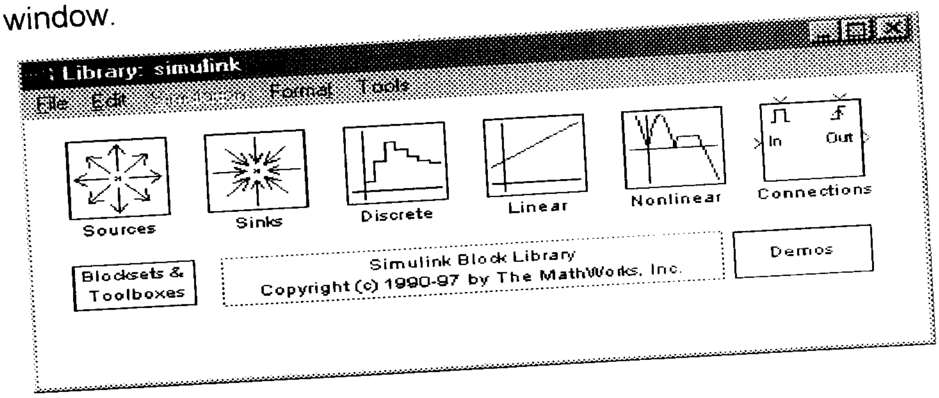
- Click on the Simulink icon on the **MATLAB** toolbar.
- Enter the simulink command at the **MATLAB** prompt.

On Microsoft Windows platforms, starting Simulink displays the Simulink Library Browser.



The Library Browser displays a tree-structured view of the Simulink block libraries. You can build models by copying blocks from the Library Browser into a model window.

On UNIX platforms, starting Simulink displays the Simulink block library window.



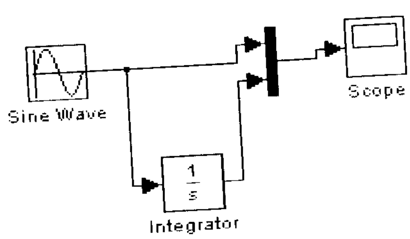
The Simulink library window displays icons representing the block libraries that come with Simulink. You can create models by copying blocks from the library into a model window.

1.3.3 Creating A New Model

To create a new model, click the **New** button on the Library Browser's toolbar (Windows only) or choose **New** from the library window's File menu and select **Model**. You can move the window as you do other windows.

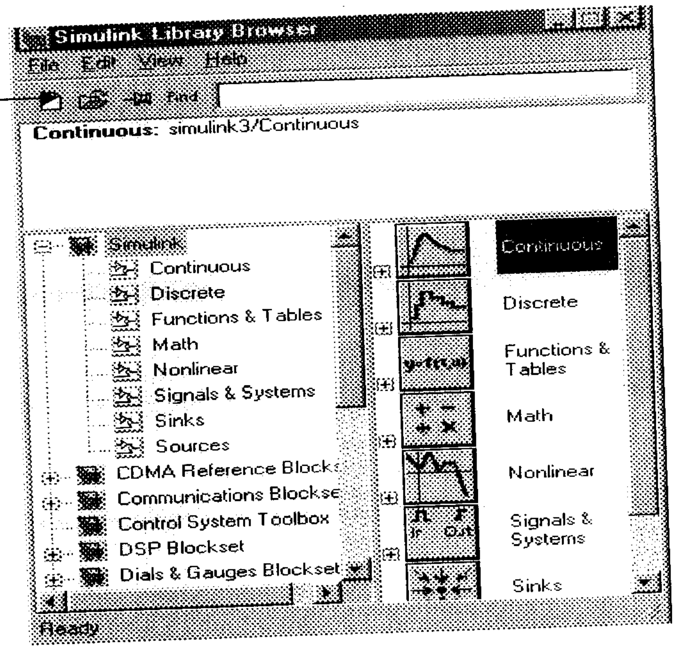
1.3.3.1 Building a Simple Model

This example shows you how to build a model using many of the model building commands and actions you will use to build your own models. The model integrates a sine wave and displays the result, along with the sine wave. The block diagram of the model looks like this.

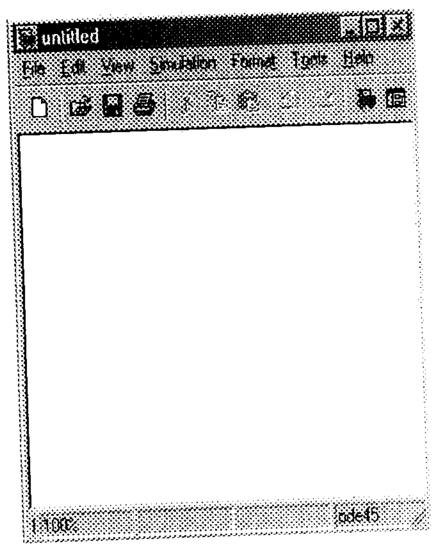


To create the model, first type simulink in the **MATLAB** command window. On Microsoft Windows, the Simulink Library Browser appears and to create a new model on Windows, select the **New Model** button on the Library Browser's toolbar.

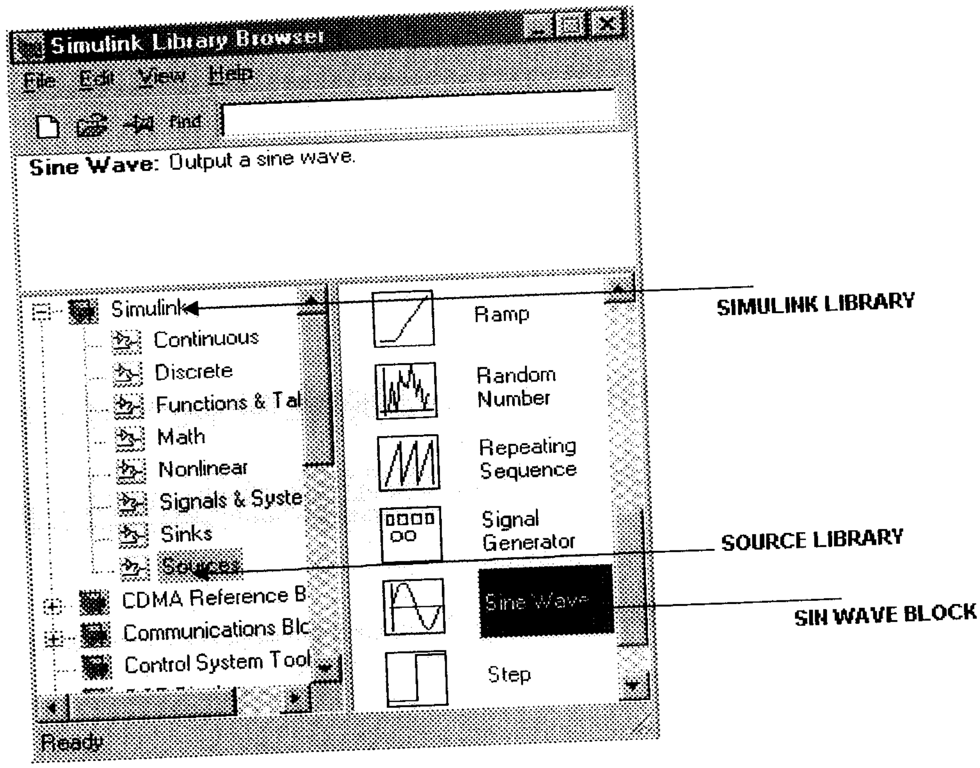
NEW MODEL BUTTON



Simulink opens a new model window.



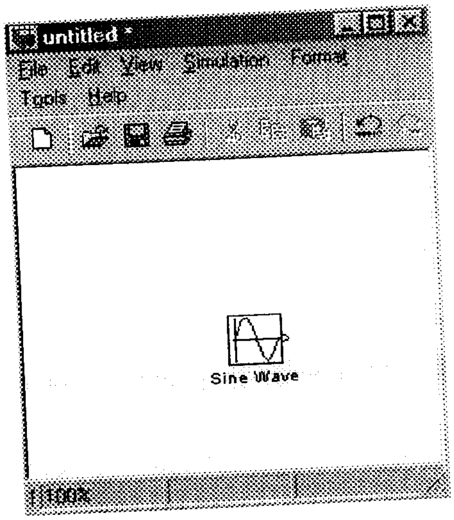
To create this model, you will need to copy blocks into the model from the following Simulink block libraries:



- Sources library (the Sine Wave block)
- Sinks library (the Scope block)
- Continuous library (the Integrator block)
- Signals & Systems library (the Mux block)

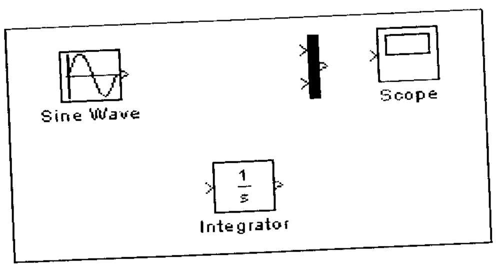
You can copy a Sine Wave block from the Sources library, using the Library Browser (Windows only) or the Sources library window (UNIX or Windows). To copy the Sine Wave block from the Library Browser, first expand the Library Browser tree to display the blocks in the Sources library. Do this by clicking on the Sources node to display the Sources library blocks. Finally click on the Sine Wave node to select the Sine Wave block.

Now drag the SineWave block from the Sources window to your model window.



Copy the rest of the blocks in a similar manner from their respective libraries into the model window. You can move a block from one place in the model window to another by dragging the block. You can move a block a short distance by selecting the block, then pressing the arrow keys.

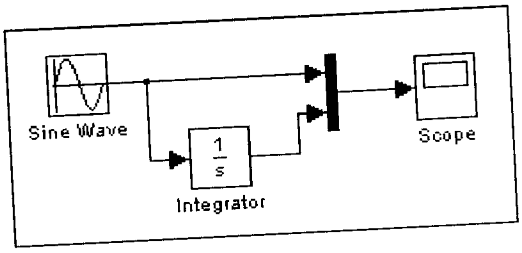
With all the blocks copied into the model window, the model should look



something like this.

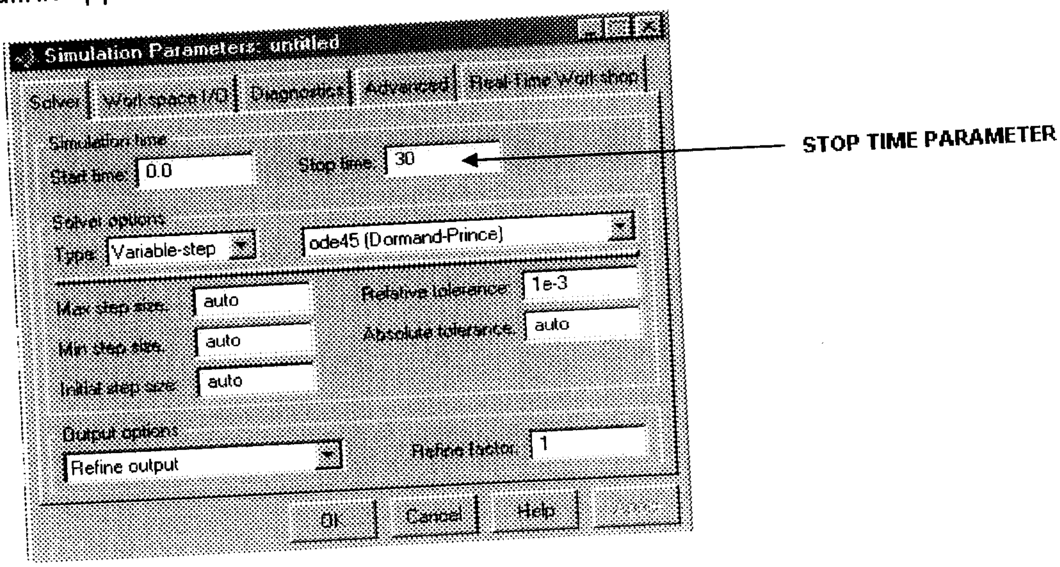
Now it's time to connect the blocks. Connect the Sine Wave block to the top input port of the Mux block. Position the pointer over the output port on the right side of the Sine Wave block. Notice that the cursor shape changes to cross hairs.

Finish making block connections. When we done that,our model will look like this.

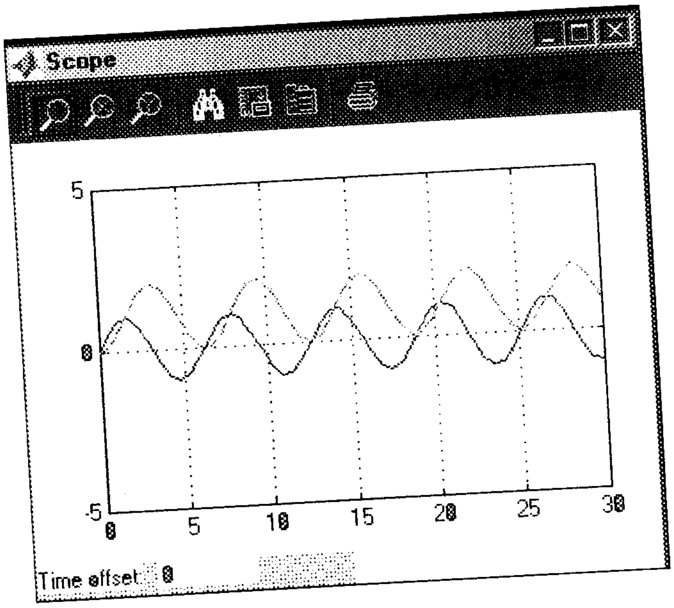


Now, open the Scope block to view the simulation output. Keeping the Scope window open, set up Simulink to run the simulation for 30 seconds. First, set the simulation parameters by choosing **Simulation Parameters** from the **Simulation** menu. On the dialog box that appears, notice that the **Stop time** is set to 30.0 (its default value).

Close the **Simulation Parameters** dialog box by clicking on the **OK** button. simulink applies the parameters and closes the dialog box.



Choose **Start** from the **Simulation** menu and watch the traces of the Scope block's input.



The simulation stops when it reaches the stop time specified in the **Simulation Parameters** dialog box or when you choose **Stop** from the **Simulation** menu. To save this model, choose **Save** from the **File** menu and enter a filename and location. That file contains the description of the model. To terminate Simulink and MATLAB, choose **Exit MATLAB** (on a Microsoft Windows system) or **Quit MATLAB** (on a UNIX system). You can also type quit in the MATLAB command window. If you want to leave Simulink but not terminate MATLAB, just close all Simulink windows.

Chapter 2

LITERATURE SURVEY

2. LITERATURE SURVEY

The first phase of any research work is to survey the available or existing literature relevant to the selected topic in order to avoid duplication of work and to study what is not investigated in that area of the subject. This aspect of study not only helps to avoid wastage of time, energy and material in carrying out the basic work by starting from the scratch match, but also helps one to concentrate on advanced research work from a fairly high level because the already existing or established methods can be easily adapted for studying or developing new methods. It was therefore decided to carry out the survey of the available literature to gain the maximum advantage of it. A brief and selected review of the relevant available information collected is presented.

In this thesis work the author gives much importance to improve the quality of sugar using advanced process control techniques and hence the initial phase of the study begins on conducting literature survey on process details of cane juice, purity of juice, sucrose content in juice, brix level, factors that affect the quality of juice and final product, impact of agricultural factors on quality, Effect of low and high pH of juice, process control techniques e.t.c.

Most of the information about the process details of sugarcane juice is collected through Internet by means of web address. The entire process details of sugarcane were collected from the website www.india sugar online.com/mis/lib-sugar manfa.asp.

The detailed analysis of cane juice, to test and control the pH value, purity, sucrose content, brix percentage, dextrons, sulphur content, colour of the juice, moisture content and grades of the sugar are found in the book "system on technical control for sugarcane factories in India" written by N.C Verma (1988) pub. The sugarcane technologists association of India – Kanpur 208017 India P.No 54-60.

The formula for calculation of purity of juice pol (sucrose) percentage, brix percentage, moisture content ,ash content and dextron percentage which helps to determine the quality of sugar is also found in the book "systems on technical control for sugarcane factories in India" by author N.C Verma (1988) ,chapter IX calculations P.No 145-165.

The detailed analysis is conducted at several stages during processing of juice for which supporting materials are collected from several books. The purpose of conducting analysis is to find out whether the process is with in the control or out of control. The main factors which affect the quality of sugar crystals was given by Donavan, M and Williams , J.C (1992) 'The factors influencing the transfer of colour to sugar crystals' proceedings of the 1992 sugar processing conference P .NO 31-48 It was also reported by the author Shore, M., Broughton, N.W.,Dutton, J.V and Sissons,A (1984) 'Factors affecting sugar', Sugar technology reviews, 12 :1-99.

The quality of sugar not only depends on process control technique but also varies according to the purity of cane juice .The purity of juice, sucrose content in juice, presence of impurities in juice, dextrin (bacterial content), brix of juice depends on agricultural factors like presence of nutrients in soil, pH value of soil, deficiency of nutrients, climatic conditions, post harvesting of cane, trash content e.t.c. The above details are found in the book namely 'Developments in sugarcane agriculture that affects processing' by Legendre

B.L., Clarke M.A., Godshall M.A., and Grisham M.P.,(1998) ,sugar proc .Res.Savannah USA 160-175.

Clarke M.A (1997) Dextron in sugar process paper presented at the ATAM (Mexican sugar technologists association) conference (1997) , Clarke, S (1994) cane quality .sugj 56(11): 14 Solomon ,S ; A.K Shrivasta B.Lsrivastava and V.K Madan 1997 Premilling sugar losses and their management in sugarcane.Indian institute of sugarcane research publications ,Lucknow, India PP 289-310.

The method of separating sugar and molasses, removing impurities,developing sugar crystals, grain size, colour and grading of the sugar is explained in the book namely "An innovative process for white sugar production" by chung chi chou , Kholid Iqbal , Y.G Min, Da Wei Gao , and Emmanuel Duffaut. Sugarcane processing research institute,Inc,New Orleans, Louisiana 70124 , USA and it was also available in "Impurity transfer during A-Massecute of the south Africa sugar technologists Associates PP 70-75 .

The poor control of pH of cane juice and addition of excess or deficient supply of limewater and sulphurdioxide gas affects the quality of juice and which reduces the nature of quality of sugar. Low pH or high pH due to excess addition of sulphurdioxide or due to excess addition of lime water leads to transient conditions of the plant by affecting the entire system .The details about pH , effects of low pH and high pH is collected from the book "Engineering chemistry" – Chemistry of Engineering materials by Jain and Jain , chapter 5 and chapter 6 P.No 253-387.The literature was also collected from the book "Hand book of Industrial water conditioning " by BETZ (1980) P.NO 81, 105 – 115,122-125.

The second phase of study includes literature survey on fuzzy systems, fuzzy applications, simulink model and a combined fuzzy-simulink controller. An advanced process control technique is vital to control a complex process in better efficient manner than the existing control method to get a desired output quality of sugar .

A wide literature survey was conducted in above mentioned intelligent systems by referring various journals, books, and proceedings.
The definition of fuzzy logic, its principles, application of fuzzy logic in control and signal processing was given by Lofti, Zadeh , the author of the book "Fuzzy systems and its Appications". According to Zadeh Fuzzy logic is all about the relative importance of precision. As complexity arises precise statement lose meaning and meaningful statements lose precision. The author says that fuzzy logic is a fascinating area of research because it does a good job of trading between significance and precision.

According to Munakata and Y.Jain," Fuzzy systems" An overview communication.ACM, Vol 37 pp 69-76 March 1994, Fuzziness means multivaluedness or multivalence. Multivalued fuzziness corresponds to degrees of uncertainity, partial occurrence of events or relations. Fuzzy logic can be used in control systems to control the process effectively. The functioning of fuzzy logic controller is found under the topic "Fuzzy logic in control system; Fuzzy logic controller - Part I ", IN IEEE Trans syst man cybern by C.C Lee vol 20 pp 404418 mar/Apr 1990 .

The process can be further effectively controlled by developing fuzzy-simulink controller, where the simulink is used to see the online resuls based on the simulation process according to the dynamic changes in the behaviour of the system. Once the simulationis done it initiates the fuzzy controller to take appropriate control actions. Several authors have explained the above control methods for solving various problems in different fields.

The author also discuss that operation of many complex processes still depends on operators skill due to lack of robust control methods. Humans once trained or experienced can successfully control such complex systems .The author stress that fact and emphasis that there is a need to develop an Intelligent monitoring and control schemes for the non-linear process.

The basic idea behind the proposed scheme is first to capture the non-linear relationship between the operating parameters (control variables) and the resultant process conditions from empirical data which is collected during normal operation using the excellent modeling capability of simulink and then to use the model based fuzzy control scheme proposed by Shin et al (1992) to determine the control output.

It has been recently reported that Advanced process control technique can improve the sugar yield, reduce energy consumption, increase capacity, improve sugar quality and consistency, improve process safety and reduce environmental emissions [Anderson, 1992]

Chapter 3

PROBLEM DESCRIPTION

3. PROBLEM DESCRIPTION

3.1 Problem definition

- Though India is the largest producer of sugar and sugarcane it does not ranks among the best terms of sugar quality.
- The main reason that India couldn't able to produce sugars to meet international standards is due to failure in implementing advanced process control techniques.
- The major problem in sugarcane process industry while processing is improper control of pH of cane juice, milk of lime, sulphur-di-oxide, presence of impurities in cane juice, grain size of sugar, suspended matters and colour of the syrup etc affects the quality of sugar.
- There are several other non-technical factors like soil, nutrients, cane varieties climate, Trash, sucrose and non-sucrose content, nature of juice etc which also affects the quality of sugar.
- The above problem can be solved by advanced control techniques like fuzzy-simulink controller.
- A fuzzy-simulink model have been built up using matlab to show the effect of pH, lime water, sulphurdioxide, impurities and colour of juice on the quality of the final product
- The quality of sugar manufactured should meet the international standard ICUMSA (International Commission for Uniform Methods of Sugar Analysis), which is a worldwide body that brings together the activities of the National Committees for Sugar Analysis in more than thirty member countries.
- The effects of factors such as pH of juice, limewater, sulphurdioxide and other factors which affect the quality of sugar are not so far discussed using advanced techniques.

- Implementation of fuzzy-simulink model or controller into the real system

3.2 Factors That Affect The Quality Sugar

1. Nature of Juice
2. Presence of non-sucrose in cane.
3. PH of juice.
4. Excess or deficient supply of limewater and sulphurdioxide.
5. Brix of lime.
6. Brix of juice.
7. Adequate or deficiency of nutrients in soil.
8. Colour of the juice.
9. Temperature and flow control of juice.
10. Delay in harvesting and crushing.
11. Loss of sucrose in cane.
12. pH of soil.
13. Trash of cane.
14. Grade and grain size of sugar.
15. Conventional process control methods.

3.3 PARAMETERS USED TO MEASURE THE QUALITY OF SUGAR

There are several parameters to be measured based on which the quality of the sugar can be tested, graded and confirmed whether it has to be accepted or not.

Some of the parameters to be measured are

1. Grade of the sugar as per ISS

L 31	M 31	S 31
L 30	M 30	S 30
L 29	L 29	S 29

2. Grade of the sugar as per ICUMSA

100	–	Standard
Between 80 to 90	–	Good Quality
Between 40 to 70	–	Superior Quality
Between 100 to 125	–	Accepted Level
Greater than 125	–	Inferior Quality

3. Grain size

L	–	Extracourse (> 1mm)
M	–	Standard (0.25 TO 0.75 mm)
S	–	Small (Or) Fine Grain Size (< 0.25mm)

4. Colour of the sugar

Pure White	–	Superior Quality
Dull White	–	Good
Dark Brown	–	Inferior

5. Presence of Sulphur

0 to 16 ppm	–	Accepted
0	–	Good
> 16 ppm	–	Inferior

6. Presence of Lead – Nil

7. Presence of Ash

0 to 0.05%	–	Accepted
> 0.05%	–	Inferior
0	–	Good

8. Presence of Moisture

0 to 0.04%	–	Accepted
0	–	Good
>0.05%	–	Inferior

Chapter 4

METHODOLOGY

4 METHODOLOGY

4.1 The Engineering Method Of Finding Solution For A Problem

1. Problem formulation
2. Setting objectives and project plan
3. Identification of initiating events that leads to problem
4. Analyzing the causes of initiating events
5. Find out the effect of the problem due to various causes using cause and effect diagram
6. Studying the existing method followed its pros and cons.
7. Propose a new model for the problem, using scientific and engineering knowledge
8. Data collection and analysis
9. Constructing a new model
10. Conducting appropriate experiments
11. Manipulate the model to assist in developing solution to the problem [Model translation]
12. Verifying the model
13. Validating the model
14. Experimental design
15. Documentation and report
16. Draw conclusions or make recommendations based on the problem solution
17. Implementation and follow up

4.1.1 Problem Formulation

Process plants like sugar plants are becoming larger and more sophisticated in terms of capital outlay as well as complexity. This makes it essential for the process to be controlled properly and efficiently. Information on poor control of process is considered important for risk assessment in process industries which not only affects the final quality of the sugar but also brings the entire plant to halt due to abnormal conditions of the sugar plant.

For the process to be successfully executed, it should be continuously monitored and controlled to find whether the operations are taking place as per the requirement or not. Hence if anything goes wrong in the process it becomes vital to control the process for which information on process details is essential for the process operator. Therefore it becomes vital to collect and organize the overall process data of sugar which aids the process operator in better diagnostic of overall process. The operator is forced to focus on large amount of process data's which are found to be interrelated and complex in nature .It is not possible for the operator to remember all the process data's. Therefore it requires an artificial intelligence system to integrate and analyze large amounts of numerical and abstract data in order to identify the causes and effect of the problem.

In case of conventional fault diagnostic system it is difficult to collect and organize the overall process data of which is found to be a tedious process, time consuming and may give an inaccurate results. Therefore knowledge based system like fuzzy, simulink or a combination of fuzzy-simulink approach is more appropriate for such situations which play an increasingly important role in understanding human cognition and to simulate human decision making under uncertain and imprecise environments.

A fuzzy-simulink model is built using matlab to show the effect of pH of juice, limewater, sulphurdioxide, impurities of juice and colour of the juice on quality of sugar. The quality of the sugar manufactured should meet the international standards ICUMSA (International commission of uniform methods of sugar analysis), which is a world wide body that brings together the activities of the national committees for sugar analysis in more than thirty member countries.

4.1.2 Setting Objectives And Project Plan

The purpose of conducting study in sugarcane industry is to find the drawbacks of existing control system and to find the effect of the causes of process variables and other technical and non-technical factors that affects the quality of sugar .The study also includes the details about the proposed advanced control technique, its structure, method of functioning of new controller, comparison of functional details and efficiency of existing and proposed controller etc.

Planning is nothing but estimating the future activities very well in advance manner. The over all project plan is to conduct a study on manufacturing quality sugar, collecting various data's related to sugar quality. Using the above data's it was also planned to develop and analyze the structure and functioning of fuzzy-simulink model based on which a suggestion is forwarded to the management to replace the existing controller by an advanced fuzzy-simulink controller by explaining its advantages over existing controller in terms of its efficiency in process control and the impact of its result in final quality of the product. The cost of the new controller its operating cost and its implementation cost though not included in the study can also be worked out and compared with the existing controller.

A new method is proposed because in conventional control method due to improper and poor control of process, it becomes difficult to manufacture sugar of superior quality which couldn't be able to compete with the international standards. By developing and implementing modern control techniques like fuzzy-simulink controller it becomes easy to control the entire process of sugar such as control of pH of juice can be done effectively by sensing the incoming pH value of mixed juice using a pH sensor. The sensed pH data's are simulated using simulink and the simulated results are converted to electrical signals and passed to the PID fuzzy controller. These electrical sensed signals are converted to multi logic digital values between 0 and 1 and are assigned to the values of various membership functions according to its significance and preciseness. Based on the assigned values the PID controller initiates the spring, which controls the opening of the lime valve and sulphurdioxide gas valve. Fuzzy-simulink controller thus exactly controls the quantity of limewater and sulphurdioxide to be mixed with juice.

4.1.3 Identification Of Initiating Events

Various factors that determines the nature of quality of sugar are as follows

1. Nature of juice
2. Presence of non –sucrose in cane
3. Low or High pH of juice
4. Excess supply or deficient supply of lime water, sulphurdioxide and Phosphate
5. Brix of lime
6. Brix of juice
7. pH of soil

8. Nutrients in soil
9. Grade of the sugar
10. Grain size of the sugar
11. Colour of the sugar
12. Loss of sucrose in cane
13. Trash content in cane
14. Delay in harvesting and crushing
15. Temperature and flow control of juice
16. Control techniques
17. Other technical and non-technical factors

4.1.4 Analyzing The Causes Of Initiating Events

There are several causes, which initiate or act as hurdles in manufacturing quality sugar. The main factors to be analyzed are pH of juice, supply of limewater and sulphurdioxide. Improper control of pH of juice, limewater and sulphurdioxide gas leads to a major problem in manufacturing sugar of superior quality.

A brief note of pH of juice

The harvested cane from the field is transported to the sugar industry where the Cane is crushed by the rollers where the juice is extracted from the crushed cane .The extracted juice is tested by pH meter to analyze the pH of juice.

pH describes the degree of acidity or alkalinity of a sugar solution. pH is measured on a scale of 0 to 14.The term pH is derived from 'p' the mathematical symbol of the negative algorithm and 'H' the chemical symbol of hydrogen. The formula definition of pH is the negative logarithm of the hydrogen ion activity.

$pH = -\log [H^{+}]$

pH provides the needed quantitative information by expressing the degree of the activity of an acid or base in terms of hydrogen ion activity. The pH value of a sample juice is directly related to the ratio of hydrogen ion $[H^{+}]$ and the hydroxyl ion $[OH^{-}]$ concentrations. The pH of the juice is tested by a pH measuring electrode. The glass pH electrode can be considered as a battery with a voltage that varies with the pH of the measured solution. The pH measuring electrode is a hydrogen ion sensitive glass bulb, with a multivolt output that varies with the changes in the relative hydrogen ion concentration inside and outside of the bulb. The reference electrode output does not vary with the activity of the hydrogen ions. The glass pH electrode has high internal resistance.

If the 'H' concentration of the measured sample juice is greater than 'OH' than the sample is treated as acidic in nature which have to be treated with lime water to increase the concentration of 'OH' ions in order to convert it in to alkaline (base). The main reason for converting the juice from acidity to base is to remove the impurities found in the mixed juice.

When the sample juice of low pH is treated with lime water, its 'OH' concentration increases, which is found to be greater than 7 that ranges between 8 to 9.2. Once the juice attains the pH value of 9.2 the addition of lime has to be stopped and the impurities present in the juice have to be filtered out.

The filtered juice whose pH ranges between 8 to 9.2 cannot be sent as such to the vacuum pans for further processing. It has to be again treated by sulphurdioxide gas which aids in reducing the base and makes the pH of juice to reach to a neutral value. The sample is neutral, with a pH of 7 when amounts of [H^+] and [OH^-] ions are equal. If the pH of juice (acid or base), addition of milk of lime and sulphurdioxide are not properly controlled then the result of pH of juice may be of low pH or high pH which severely affect the final product and the entire processing system.

The process variables like pH of juice, addition of limewater and sulphurdioxide can be effectively controlled by installing advanced process controller. The detailed analysis of pH of juice shows data's on pH ranging from 4.2 to 5.5 (acidic in nature) , pH ranging from 8 to 9.2 (base-after treatment of lime) and pH ranging from 7 to 7.1 (after treating juice of high pH with SO_2). The analysis also suggests that approximate quantity of lime water should be mixed with juice of low pH (below 7) to convert it to high pH of alkalinity. The quantity of lime added to juice should vary according to the pH of juice ranging between 4.2 to

9.2.Similarly the analysis also reveals that quantity of SO_2 gas to be added to juice to bring the pH of juice to neutral value should vary according to the pH of juice ranging between 8 to 9.2.

The analysis on agricultural factors like pH of soil , nutrients in soil , climatic conditions, varieties of cane, trash content etc shows that the above factors plays a vital role in cane growth. Also percentage of sucrose and non-sucrose content present in the cane , presence of impurities in cane etc shows serious impact of above factors on final quality of sugar.

4.1.5 To Find Out The Effects Of The Problem

Effect Of Low pH Of Juice

Low pH of juice, whose pH value is less than 7 is acidity in nature, when processed without proper treatment will affect the parts of the system and quality of the sugar. Low pH of juice results in formation of scale along the inner walls of the pipe line, vacuum pans and other parts in the system. Scales are hard deposits which stick very firmly to the inner surfaces of the metallic components. Scales are difficult to remove even with the help of hammer and chisel. Formation of scales due to acidity of juice is the main source of troubles found in sugar plant. Formation of scale may be due to

1. Decomposition of calcium bicarbonate
2. Deposition of calcium sulphate
3. Presence of silica – Presence of silica in small quantities deposits as calcium silicate or magnesium silicate. These deposits sticks out very firmly on the inner side of the metallic parts and react with the metals.

Effects Of Scale Formation

1. Formation of scale causes severity in corrosion in metallic parts of the plant.
2. Lowering of safety of the sugar plant.
3. Decrease in overall efficiency of output.
4. Danger of explosion
5. It affects the quality of the sugar.

Prevention Of Scale Formation

External treatment includes efficient softening of water added with crushed juice and control of pH of juice by adding milk of lime to bring its pH to neutral value. Internal treatment can be accomplished by adding proper chemicals to the mixed juice either to precipitate the scale forming impurities in the form of sludge or to convert them in to compounds which stay in dissolved form.

Effect Of High pH Of Juice

Highly alkaline juice, when processed may cause caustic embrittlement. High alkalinity of juice may also increases the sulphur content in sugar which is highly poisonous and may make the sugar unsuitable for consumption. Caustic embrittlement may cause inner crystalline cracking which has long been a serious form of metal failure. The failure occurs due to presence of highly concentration caustic solution [OH^-] ions in mixed juice.

Effects Of Embrittlement

1. Severe cracks in pipelines
2. Leakage of juice in pipe lines.
3. Severe attack on metals by highly concentrated caustic soda.
4. High metal stress in the area of concentration.

The other effects are

1. Adding high SO_2 gas to juice may increase the sulphur content of juice which is highly poisonous.
2. Low amount of SO_2 gas added to juice may reduce the colour of the sugar, since SO2 gas also acts as a bleaching agent.

3. Improper treatment of juice may increase the dextron content in sugar.
4. Failure on poor analysis of soil may lead to immature cane growth.
5. Failure on nutrient analyses of soil leads to high impurities which may decrease sucrose content in juice and increase non sucrose contents.
6. Presence of moisture in sugar exceeding 0.05% may also affect the sugar quality.
7. The purity of juice decreases due to presence of impurities and non-sucrose contents in cane juice.
8. Delay in harvesting and crushing may reduce the sucrose content in cane and increase the percentage of dextron which makes sugar unsuitable for consumption.
9. Presence of dissolved gases like oxygen and carbon dioxide in cane juice is highly corrosive and results in serious problems.

4.1.6 propose A New Model For The Problem, Using Scientific And Engineering Knowledge

Models can be defined as the representation of the real system for the purpose of studying the system. To create a model, it is vital to study the entire process of sugar. The success of building up a right type of model depends on accuracy of process data which has been observed and collected from the on line system. To conduct a detailed study on sugarcane processing system it is sometime possible to experiment with the system itself. It is vital to consider certain aspects in processing system that affects the final quality of sugar. These aspects are represented in the model of the system.

Generally models can be classified as follows

1. Mechanistic model
2. Black box models
3. Qualitative model
4. Statistic model

Mechanistic Model

The mechanistic model is usually described from the physics and chemistry governing the process.

If much is known about the process and its characteristics are well defined then a set of differential equations can be used to describe its dynamic behaviour. The mechanistic model can be further classified as follows

a. Lumped parameter models which are described by ordinary differential equation.
b. Distributed parameter model which use partial differential equations.

Ordinary differential equations are used to describe the behaviour in one dimension normally time (e.g.) the level of liquid in a tank.

PDE models arise due to dependence on spatial locations. (e.g.) Temperature profile of liquid in a tank

Both lumped and distributed parameter models can be further classified in to linear and non-linear descriptions.

Limitations of mechanistic model

Due to financial and time constraints mechanistic model development may not be practically feasible. Since the process of sugar is so complex and dynamic in behaviour the resulting equations cannot be solved. Under such circumstances Empirical or Black box models may be built using data collected from the plant.

Black Box Models

Black box or empirical models simply describes the functional relationship between system input and system output. The parameters of these functions do not have any physical significance in terms of equivalence to process parameters such as heat or mass transfer coefficients. Black box models are very effective in representing some trends in process behaviour. Cost of modeling is less compared to development of mechanistic models.

Black box models can be further classified in to linear and non-linear forms. In linear category transfer functions and time series model predominates. Non-linear category can be further divided in to time series and neural network based model. In non-linear time series, the non-linear behaviour of the process is modeled by combination of weighted cross product and powers of the variables used in the representation.

Qualitative Model

Qualitative models can be used when a situation arise, where nature of the process may eliminate the mathematical model. (e.g.) When the process is operated at different process conditions, it results in discontinuities, where mathematical models cannot be used. The simplest form of qualitative model is the 'rule-based' model that makes use of If-Then –Else constructs to describe the process behaviour.

The rules are made by human expert's .Genetic algorithms, fuzzy logic and neural network can be applied to process data to generate these describing rules. Qualitative transfer functions is most common suitable for process control applications. It describes the relation between an input and output variables.

Models derived based on fuzzy set theory can also be classified as qualitative models. Fuzzy proposed by LOFTI ZADEH, contains an algebraic and a set of linguistic that facilitates description of complete and ill defined systems. The fuzzy models are rule based models.

Statistical Models

Describing process in statistical terms is another modeling technique. The statistical approach is made necessary when there are uncertainties in process systems.

Out of the above-classified models it is best to select Black box and Qualitative model to solve the problem because it is simple to construct the above model, it is economical and efficient in solving problems. The above models are now widely used to build and solve different kinds of problems in various fields like in process engineering, Aeronautics, telecommunications, Aerospace, transportation, air conditioners, automobiles, consumer electronics, robotics, computers and other industries such as steel, chemical, power generation, construction, nuclear, medical diagnosis system, information technology and material processing.

4.1.7 Data Collection And Analysis

Data collection in complex process such as sugarcane process industries is one of the biggest tasks in solving a real problem. There is a constant interplay between the construction of the model and the collection of the needed input data from the sugarcane processing system. Various data's collected from sugarcane processing system are as follows.

- pH of cane juice and its range before treatment of lime [4.5 to 5.5]
- Lime water treatment with juice and its range.
- pH of juice after treated with lime [8 to 9.2]
- Addition of SO_2 gas with juice of alkalinity content and its range.
- pH of juice after SO_2 gas treatment [7 to 7.1]
- Grade of the sugar

- Grain size of the sugar
- Colour of the sugar
- Sulphur content in sugar
- Lead content in sugar
- Dextron content in sugar
- Ash and moisture content in sugar

Data's are also collected from sugarcane field which have impact on quality of sugar and also aids in constructing the model. These input data's provides a driving force in constructing a model. The objective of the study will be fulfilled based on accuracy on the accuracy of the input data collected from the system. As the complexity of the model changes, the required data elements may also change. Model structure is valid only if the input data are accurately collected and properly analysed. The data's collected from the sugarcane processing system are found to be adequate in constructing a model.

Analysis of data

Data's collected from the sugarcane processing system are properly analyzed to find whether it is useful to build a model or not. The data's which are found to be similar are combined. The similarities of data's are checked in successive time periods and during the same period on successive days. While examining the data's the relationship between two variables and its effect on final product is carefully analyzed.

Chapter 5

CONSTRUCTING A NEW FUZZY-SIMULINK MODEL

5 CONSTRUCTING A NEW FUZZY-SIMULINK MODEL

A new application of FUZZY-SIMULINK system to the processing of sugar is developed. Using matlab software package. The first step in constructing a model is to observe the real sugarcane processing system and the interaction among its various components and system behaviour. The second step in model building is construction of a conceptual model by collection of various data's and the structure of the system. The third step is the translation of the operation model in to computer recognizable format. While building a model there is a need for continuous verification and validation by comparing the real system to the conceptual model and repeated modification is done to improve its accuracy.

Mapping an input data vector in to a scalar output using fuzzy logic develops three fuzzy models of type mamdani. In first model pH of crushed juice is taken as input and lime water to be added to juice is taken as output and the mapping between these data's which are non-linear mapping are performed using fuzzification, fuzzy inference and defuzzification components found in fuzzy logic tool box in matlab. Similarly in the second model pH of juice after treatment of lime water is taken as input and sulphurdioxide to be added to juice is taken as output and the data's are mapped in a similar manner and in the third fuzzy model the parameters which is used to test the quality of sugar is taken as input and the quality of sugar is taken as output and the data's are mapped in a non-linear manner.

The fuzzy system can be integrated with simulink and the model can be simulated. The fuzzy models can be created using graphical tools or by using command line functions.

5.1 CONSTRUCTION OF SIMULINK MODEL WITH OUT FUZZY:

Simulink model:

Simulink model is the process of building (mapping) several input (ph) to an output (lime) using simulation software. Simulink model includes the membership function, input port, display unit, subsystem, scope block and the output port.

5.1.1 MODEL: 1 TREATMENT OF pH OF JUICE WITH LIMEWATER

Aim: To convert pH of juice acidity to pH of juice alkalinity

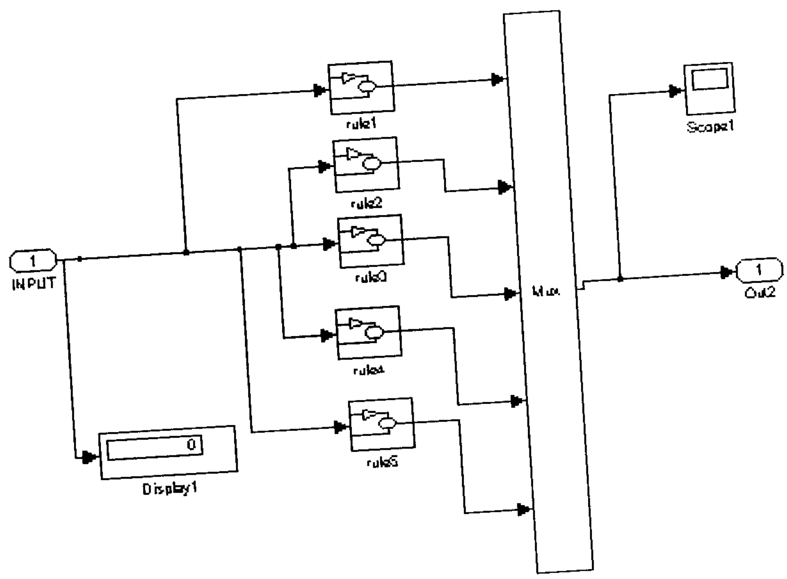
Input : pH of mixed juice.

Output: Milk of lime

Step by step procedure:

1. Initially to start Simulink, first start **MATLAB** and then click Simulink icon on the **MATLAB** toolbar.
2. To create a new model, click the **New** button on the Library Browser's toolbar.
3. Here the model integrates a treatment of ph of juice with lime water and display the results.
4. To create this model you will need to copy blocks in the model from the following simulink libraries
   - Sources library (input port block)
   - Sinks library (input port block ,the Scope block, display block)
   - subsystem library (the subsystem block)
   - Signals & Systems library (the Mux block)

You can copy all the blocks indicated above from the corresponding libraries by dragging the respective blocks from the respective libraries.
The Model for the **TREATMENT OF PH OF JUICE WITH LIMEWATER** is shown below



REACTION OF LIME WATER WITH PH(ACIDITY) OF CANE JUICE

Blocks used in the model:

Display block:
It is used to display the numerical input values.

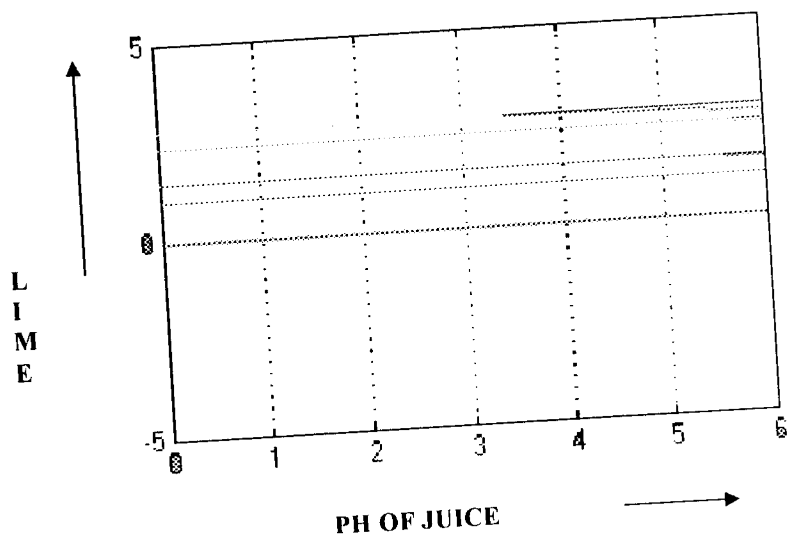
Mux:
It will combine (or) multiplex scalar, vector (or) it will make a multi input into a single one to obtain the results

Scope block:
The scope block is used to view the results of the model.

Subsystem block:

This system consists of five rules which will make the ph of juice acidity to ph of juice alkalinity. This sub system includes input port, membership function (fro fuzzy logic tool box), display block.

Now we can connect the input port to the various rules and display block. The output of 5 rules blocks are connected to the mux and are connected to the scope block (to view the results) and to the output port block.
Now, open the Scope block to view the simulation output. To run the simulation, first, set the simulation parameters by choosing Simulation Parameters from the Simulation menu. On the dialog box that appears, notice that the Stop time is set to 6. Close the Simulation Parameters dialog box by clicking on the OK button. Now choose Start from the Simulation menu and watch the traces of the Scope block's input by choosing the stop menu we can stop the simulation. Now the output would look like this



5.1.2 MODEL: 2 TREATMENT OF pH OF JUICE WITH SO2

AIM: The main objective of treatment of pH of alkalinity of juice with SO_2 Gas is to bring the pH alkalinity of juice to pH neutral value.

Input : pH of mixed juice. (Base)

Output : SO_2 gas

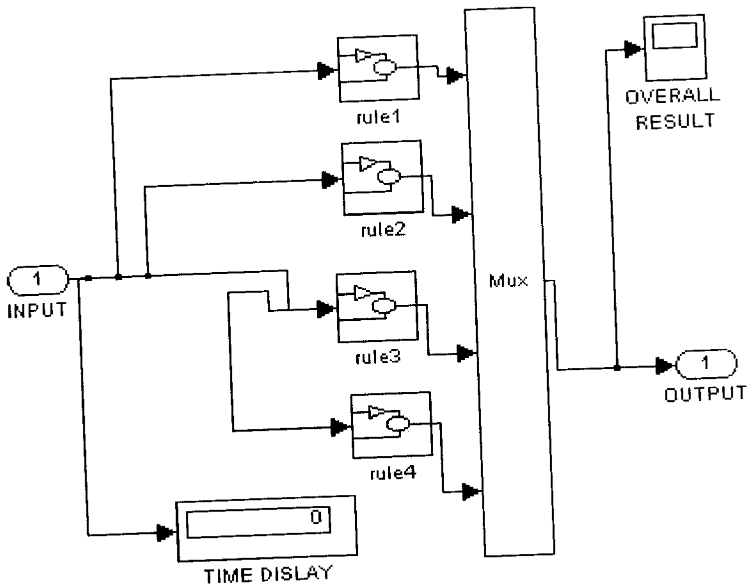
Step by step procedure:

1. Initially to start Simulink, first start **MATLAB** and then click Simulink icon on the **MATLAB** toolbar.
2. To create a new model, click the **New** button on the Library Browser's toolbar.
3. Here the model integrates a treatment of ph of juice with sulphurdioxide and display the results.
4. To create this model you will need to copy blocks in the model from the following simulink libraries

- Sources library (input port block)
- Sinks library (input port block ,the Scope block, display block)
- subsystem library (the subsystem block)
- Signals & Systems library (the Mux block)

You can copy all the blocks indicated above from the corresponding libraries by dragging the respective blocks from the respective libraries.

The Model for the **TREATMENT OF pH OF JUICE WITH SO2** is shown below



TREATMENT OF PH OF JUICE WITH SULPHURDIOXIDE

Blocks used in the model:

Display block:

It is used to display the numerical input values.

Mux:

It will combine (or) multiplex scalar, vector (or) it will make a multi input into a single one to obtain the results

Scope block:

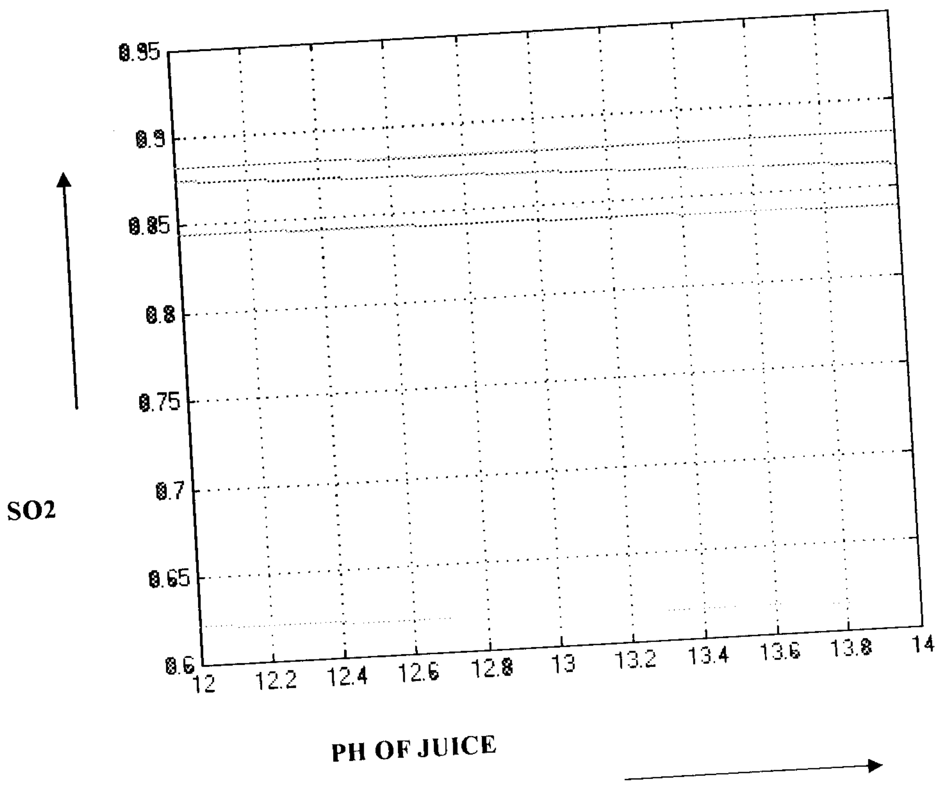
The scope block is used to view the results of the model.

Subsystem block:

This system consists of five rules which will make the ph of juice acidity to ph of juice alkalinity. This sub system includes input port, membership function (fro fuzzy logic tool box), display block.

Now we can connect the input port to the various rules and display block. The output of 4 rules blocks are connected to the mux and are connected to the scope block (to view the results) and to the output port block.

Now, open the Scope block to view the simulation output. To run the simulation, first, set the simulation parameters by choosing Simulation Parameters from the Simulation menu. On the dialog box that appears, notice that the Stop time is set to 14. Close the Simulation Parameters dialog box by clicking on the OK button. Now choose Start from the Simulation menu and watch the traces of the Scope block's input by choosing the stop menu we can stop the simulation. Now the output would look like this



5.1.3 MODEL: 3 DETERMINATION OF QUALITY OF SUGAR

AIM: The main objective is to determine the quality of sugar

Inputs: Grain, Colour, Ash, Moisture, Dextron

Output: Quality

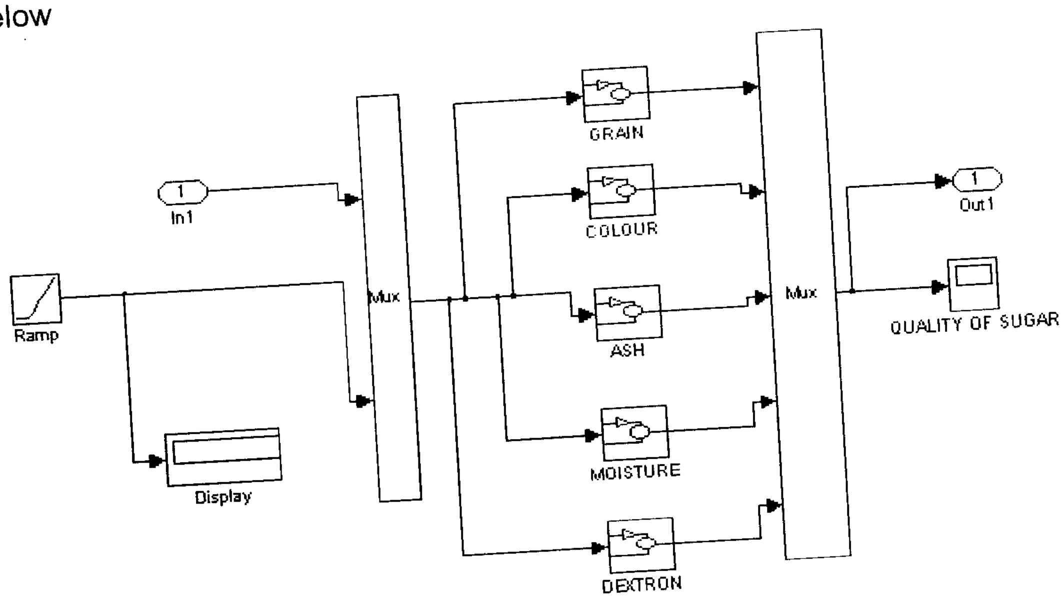
Step by step procedure:

1. Initially to start Simulink, first start **MATLAB** and then click Simulink icon on the **MATLAB** toolbar.
2. To create a new model, click the **New** button on the Library Browser's toolbar.
3. Here the model integrates the determination of quality of sugar and display the results.
4. To create this model you will need to copy blocks in the model from the following simulink libraries

- Sources library (input port block)
- Sinks library (input port block ,the Scope block, display block)
- subsystem library (the subsystem block)
- Signals & Systems library (the Mux block)

You can copy all the blocks indicated above from the corresponding libraries by dragging the respective blocks from the respective libraries.

The Model for the **DETERMINATION OF QUALITY OF SUGAR** is shown below



DETERMINATION OF QUALITY OF SUGAR

Blocks used in the model:

Display block:

It is used to display the numerical input values.

Mux:

It will combine (or) multiplex scalar, vector (or) it will make a multi input into a single one to obtain the results

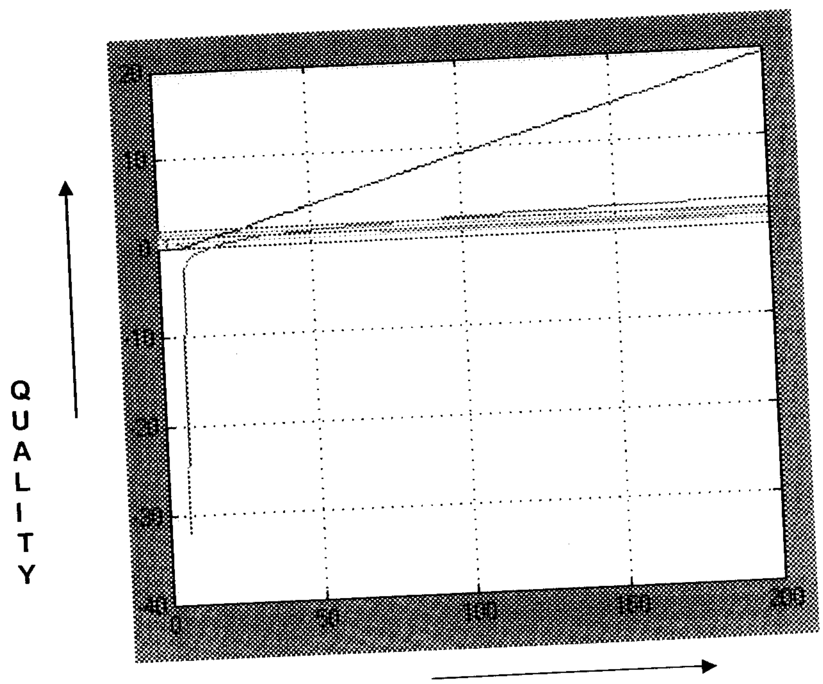
Scope block:

The scope block is used to view the results of the model.

Subsystem block:

This system consists of five rules which will make the ph of juice acidity to ph of juice alkalinity. This sub system includes input port, membership function (fro fuzzy logic tool box), display block.

Now we can connect the input port to the various rules and display block. The output of 4 rules blocks are connected to the mux and are connected to the scope block (to view the results) and to the output port block.
Now, open the Scope block to view the simulation output. To run the simulation, first, set the simulation parameters by choosing Simulation Parameters from the Simulation menu. On the dialog box that appears, notice that the Stop time is set to 200. Close the Simulation Parameters dialog box by clicking on the OK button. Now choose Start from the Simulation menu and watch the traces of the Scope block's input by choosing the stop menu we can stop the simulation. Now the output would look like this



Grain VS Quality, Ash VS Quality, Colour VS Quality, Moisture VS Quality, Dextron VS Quality,

5.2 CONSTRUCTION OF SIMULINK MODEL WITH FUZZY:

Simulink model:

Simulink model with fuzzy is the process of building (mapping) a model with the help of fuzzy logic controller already stored in the work space. Simulink model includes, input port block, fuzzy logic controller with rule viewer block, scope block and the output port block.

5.2.1 MODEL: 1 TREATMENT OF pH OF JUICE WITH LIMEWATER

Aim: To convert pH of juice acidity to pH of juice alkalinity

Input : pH of mixed juice.

Output: Milk of lime

Step by step procedure:

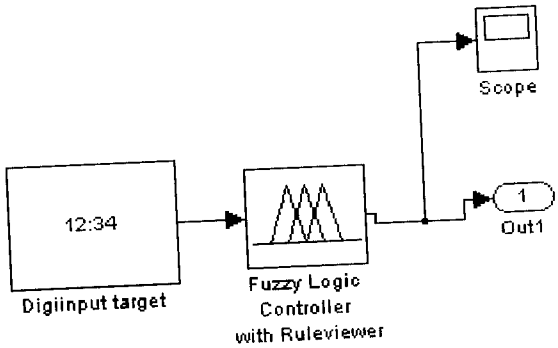
1. Initially to start Simulink, first start MATLAB and then click Simulink icon on the MATLAB toolbar.
2. To create a new model, click the New button on the Library Browser's toolbar
3. Here the model utilizes the fuzzy logic controller with rule viewer for a treatment of ph of juice with lime water and display the results.
4. To create this model you will need to copy blocks in the model from the following simulink libraries

- Sources library (digital clock block)
- Sinks library (the Scope block, out port block)
- Fuzzy logic toolbox library (fuzzy logic controller with rule viewer block)

You can copy all the blocks indicated above from the corresponding libraries by dragging the respective blocks from the respective libraries.

Now we can connect all the blocks and the model will look like this

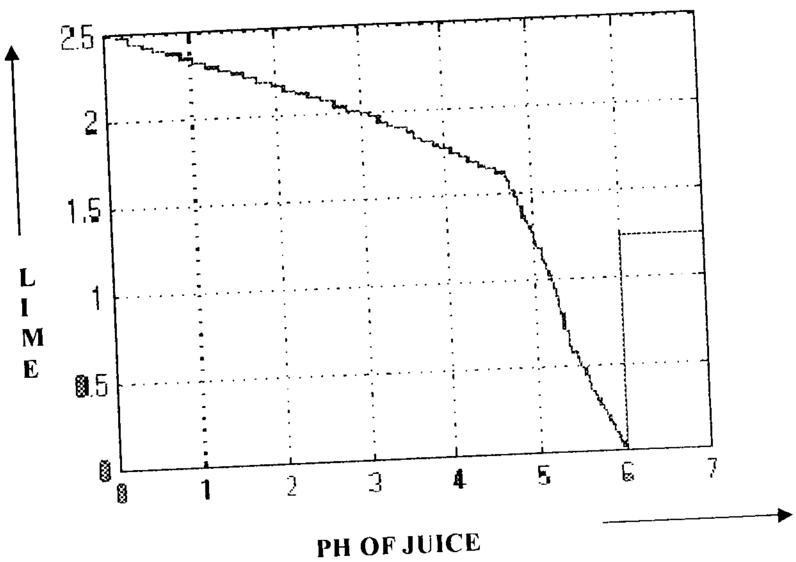
The Model for the **TREATMENT OF PH OF JUICE WITH LIMEWATER ALONG WITH FUZZY CONTROLLER** is shown below



SIMULINK MODEL FOR THE REACTION OF LIME WATER WITH PH(ACIDITY) OF CANE JUICE WITH FUZZY LOGIC CONTROLLER

Open the simulation menu to start the simulation. Set the close time to stop the simulation. Now, open the Scope block to view the simulation output.

Now the output would look like this



5.2.2 MODEL: 2 TREATMENT OF pH OF JUICE WITH SO2

Aim : The main objective of treatment of pH of alkalinity of juice with SO_2 Gas is to bring the pH alkalinity of juice to pH neutral value.

Input : pH of mixed juice. (Base)

Output : SO_2 gas

Step by step procedure:

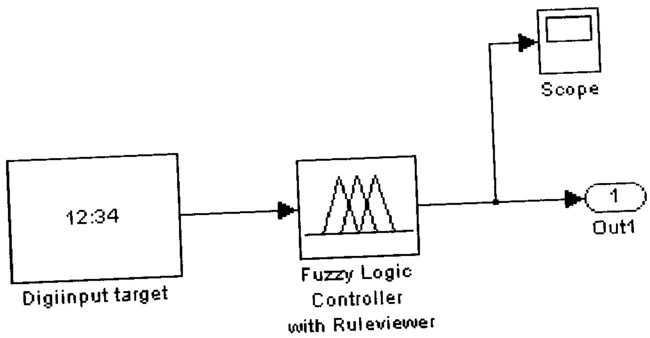
1. Initially to start Simulink, first start MATLAB and then click Simulink icon on the MATLAB toolbar.
2. To create a new model, click the New button on the Library Browser's toolbar
3. Here the model utilizes the fuzzy logic controller with rule viewer for a treatment of ph of juice with sulphurdioxide and display the results.
4. To create this model you will need to copy blocks in the model from the following simulink libraries

- Sources library (digital clock block)
- Sinks library (the Scope block, out port block)
- Fuzzy logic toolbox library (fuzzy logic controller with rule viewer block)

You can copy all the blocks indicated above from the corresponding libraries by dragging the respective blocks from the respective libraries.

Now we can connect all the blocks and the model will look like this

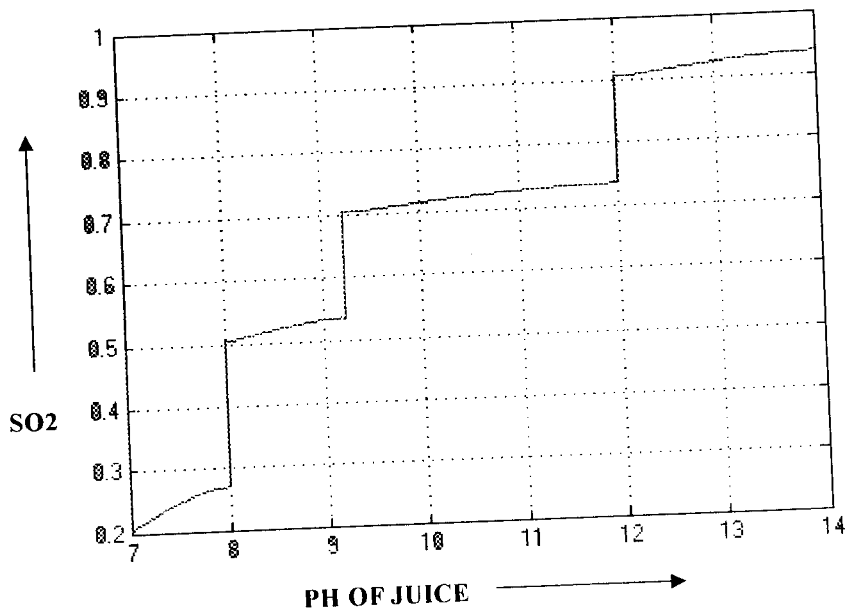
The Model for the **TREATMENT OF pH OF JUICE WITH SO2 ALONG WITH FUZZY CONTROLLER** is shown below



SIMULINK MODEL FOR THE TREATMENT OF PH OF JUICE WITH SULPHURDIOXIDE WITH FUZZY LOGIC CONTROLLER

Open the simulation menu to start the simulation. Set the close time to stop the simulation. Now, open the Scope block to view the simulation output.

Now the output would look like this



5.2.3 MODEL: 3 DETERMINATION OF QUALITY OF SUGAR

AIM: The main objective is to determine the quality of sugar

Inputs: Grain, Colour, Ash, Moisture, Dextron

Output: Quality

Step by step procedure:

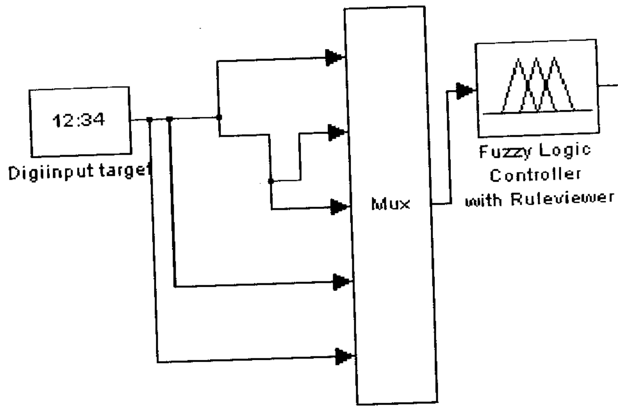
1. Initially to start Simulink, first start MATLAB and then click Simulink icon on the MATLAB toolbar.
2. To create a new model, click the New button on the Library Browser's toolbar
3. Here the model utilizes the fuzzy logic controller with rule viewer for the determination of quality of sugar and display the results.
4. To create this model you will need to copy blocks in the model from the following simulink libraries

- Sources library (digital clock block)
- Sinks library (the Scope block, out port block)
- Fuzzy logic toolbox library (fuzzy logic controller with rule viewer block)

You can copy all the blocks indicated above from the corresponding libraries by dragging the respective blocks from the respective libraries.

Now we can connect all the blocks and the model will look like this

The Model for the **DETERMINATION OF QUALITY OF SUGAR ALONG WITH THE FUZZY CONTROLLER** is shown below

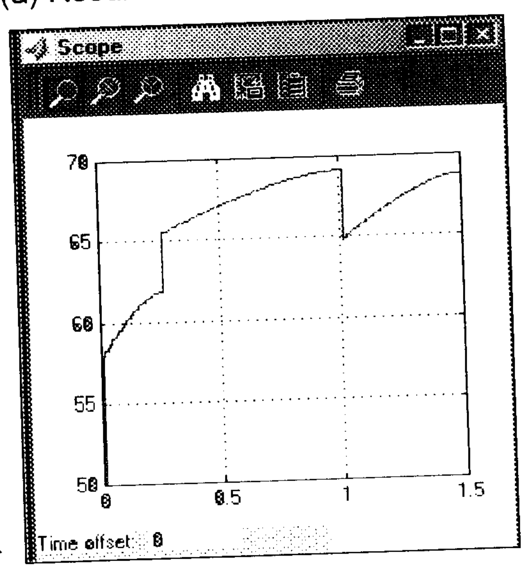


SIMULINK MODEL FOR THE DETERMINATION OF QUALITY OF SUGAR WITH FUZZY LOGIC CONTROLLER

Open the simulation menu to start the simulation. Set the close time to stop the simulation. Now, open the Scope block to view the simulation output.

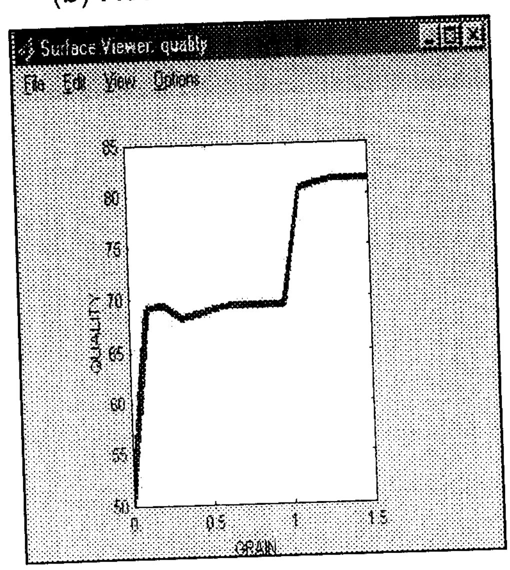
Now the output would look like this

(a) Results With Out Fuzzy

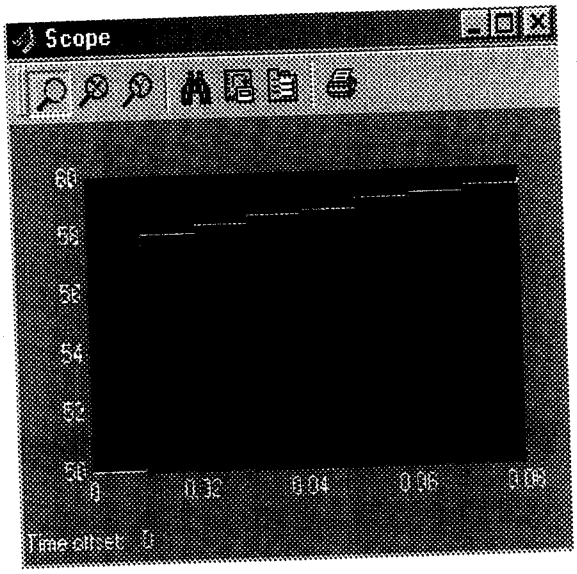


(a) Grain VS Quality

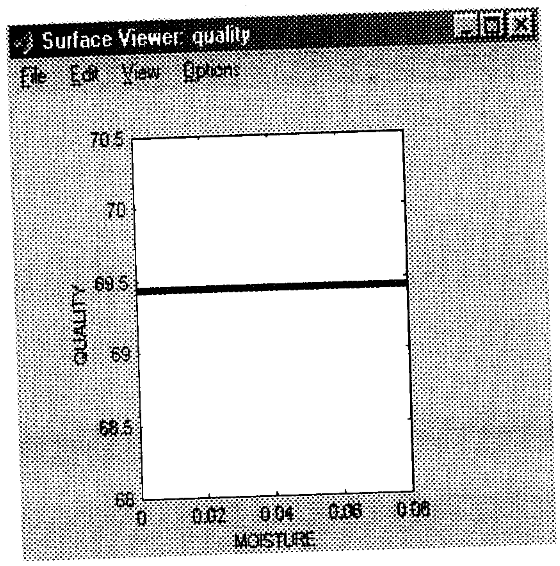
(b) Results With Fuzzy



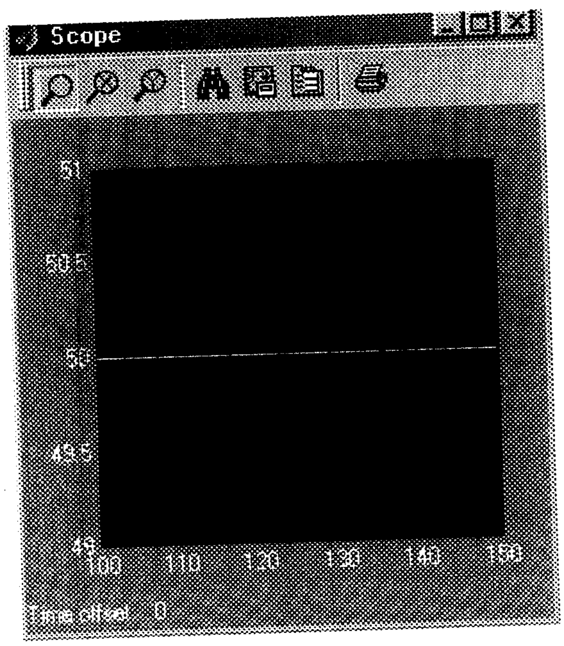
(b) Grain VS Quality



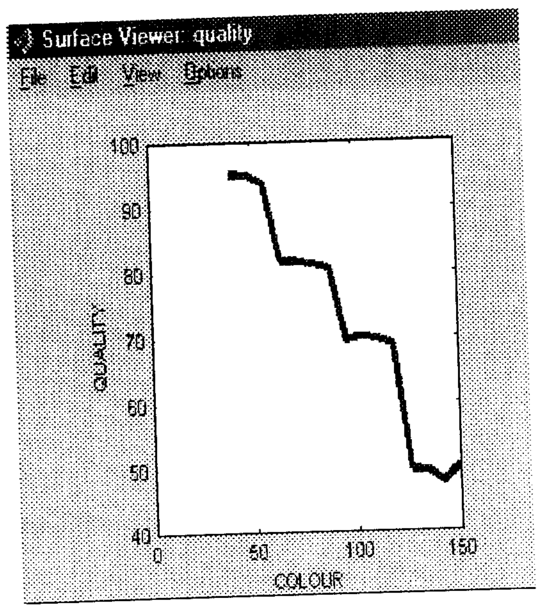
(a) Moisture VS Quality



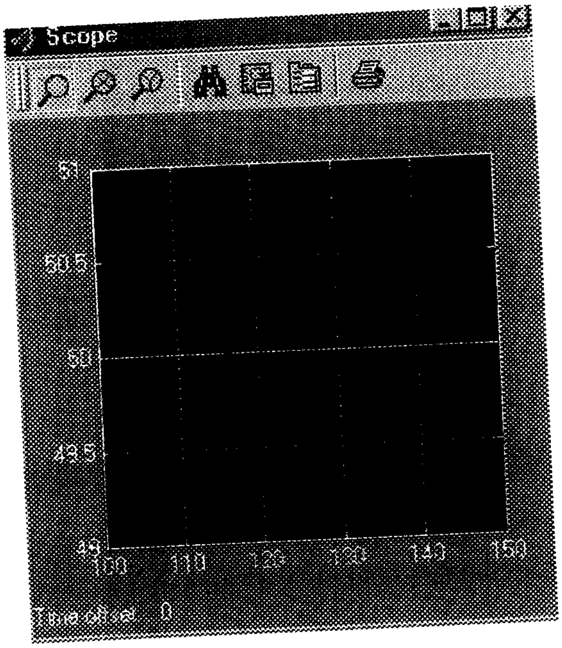
(b) Moisture VS Quality



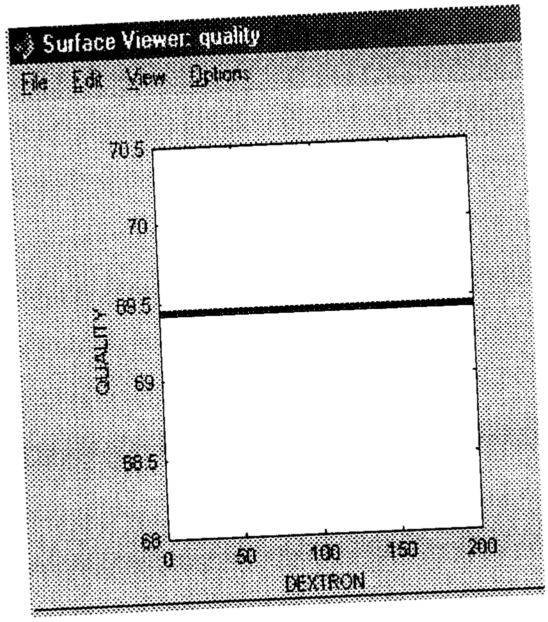
(a) Colour VS Quality



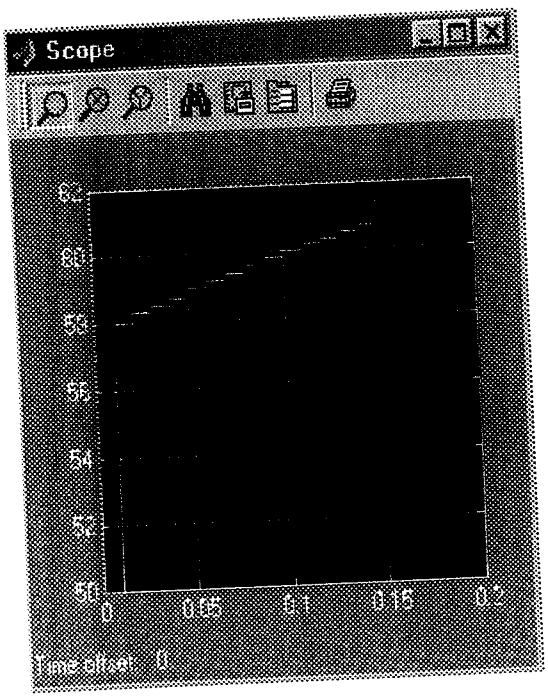
(b) Colour VS Quality



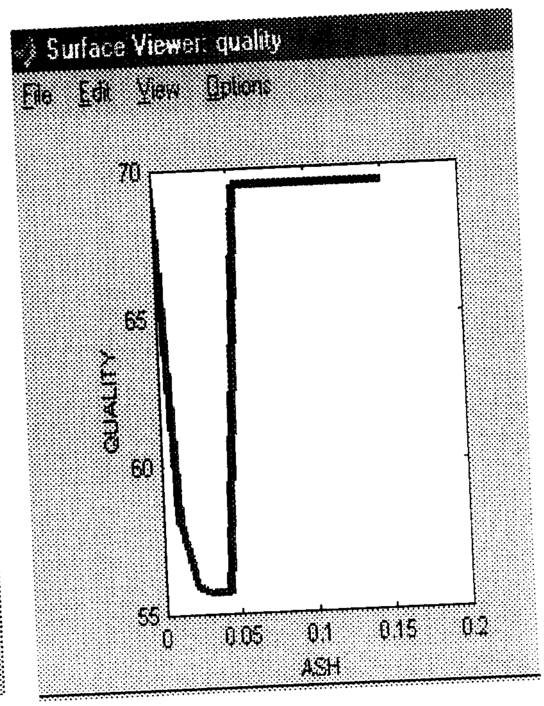
(a) Dextron VS Quality



(b) Dextron VS Quality



(a) Ash VS Quality



(b) Ash VS Quality

Chapter 6

RESULTS AND DISCUSSIONS

6 RESULTS AND DISCUSSION

In this thesis work the quality of sugar is determined by considering various factors which have an impact on quality using fuzzy-simulink approach and an advanced fuzzy-simulink process controller is developed and its control technique is compared with the existing Automatic fuzzy pH controller.

The fuzzy-simulink model is developed in matlab using the sample data's of pH of juice, milk of lime, sulphurdioxide and other quality testing parameters collected from the process expert in the sugar industry. It has been observed that poor control technique fails to sense the pH of juice accurately and it leads to excess or less addition of lime water and sulphurdioxide which fails to achieve the desired pH value of juice .It was also observed that low pH or high pH of juice not only affects the final quality of the product but also affects the entire operation of sugar plant due to transient conditions of the plant. The collected online process data's of critical process variables are created using the simulink model till the desired values are achieved. A fuzzy model is created using If-Then rules. By combining simulink model and fuzzy logic a fuzzy-simulink controller is developed which is an Advanced process controller that overcomes the drawbacks of existing fuzzy PID controller..

The problem is solved by developing a fuzzy-simulink model for a continuous process using matlab package. This Advanced fuzzy-simulink controller can learn this dynamic behaviour of the process and change the parameters automatically, according to which it controls the addition of limewater and sulphurdioxide gas with juice.

Three fuzzy models are built for continuous process in sugar industry. The result of the first model depicts that for increasing pH value of juice from 0 to

6, the limewater to be added to juice is found to be gradually decreasing. From the above result it was concluded that pH and limewater are inversionally proportional to each other. If pH is 0.3 (High acidity), then high amount of lime, say 2.5g / litre is added to juice to convert pH of acidity to alkalinity. When pH of juice increases then the amount of lime water to be added to juice is found to be in decreasing rate and when pH approaches to 6 milk of lime to be added declines to zero.

The result of the second model shows that for increasing pH value of juice from 7 to 14 , the sulphurdioxide to be added to juice is found to be gradually increasing.From the above result it was concluded that pH and sulphurdioxide are directly proportional to each other.If pH is 7.5 (Very Low alkalinity), then very low amount of sulphur dioxide gas is sufficient say 0.2 ppm / litre is added to juice to convert pH of alkalinity to pH neutral. .When pH of juice increases then the amount of sulphurdioxide gas to be added to juice is found to be in increasing rate and when pH approaches to 14 sulphurdioxide gas to be added reaches maximum.

The final fuzzy model is the model built to determine the quality of sugar and to find the relationship between quality and other quality measuring parameters like grain size, colour, ash, moisture and dextrin.The result of the final model shows that these input quality parameters have serious impact on sugar in terms of sugar quality.Though there are several other quality parameters which are not mentioned in this model due to its complexity nature , grain size and colour are considered to be the most important parameters in fixing the quality of sugar.

It was found that if colour is greater than 120 (unacceptable) and grain size is fine (< 0.25) then quality of the sugar is found to be highly Inferior (Quality is below 30)

If the colour of the sugar is below 120 (Acceptable), and grain size is 1 (Extracourse) then the quality of the sugar is found to be between 60 to 70% (Average).

If the colour of the sugar is found to be between 75 to 100 (White) and grain size is between 0 to 0.5 mm (Fine size) then quality of the sugar is just above 60% (Average)

If the colur of the sugar is between 0 to 50 (Pure white) and grain size is above 0.5 mm then quality of the sugar lies between 70 to 85% (Good).

If the grain size is above 1 mm and the colour of the sugar is less than 50, the quality of the sugar is above 85% (Superior).

If the grain size is less than 0.5 mm (Fine) and ash content of sugar is found to be less than 0.05% (Accepted level), then the quality of the sugar is below 50% (Inferior). Also if the grain size is between 0.5 to 1 mm and even the ash content is above 0.05 ppm the quality of the sugar is below 50%.

7 CONCLUSION

This thesis study is an organized approach to solve the quality problem in sugar industry using advanced process control techniques, where number of process variables involved is high. These process variables are interrelated with each other. A change in one variable may affect the other and may have a serious impact on the final quality of sugar. Therefore the process has to be monitored and controlled by installing advanced automatic process controller.

Under this study, various problematic areas are identified in existing method and an advanced controller namely fuzzy-simulink controller has been developed using available data. The development of fuzzy-simulink controller accurately senses, trains and accordingly it control the process variable, which aids the sugar industry to produce quality sugar.

The move towards advanced process control technique namely fuzzy-simulink controller is definitely a boon to the company since it accurately controls the process variables according to the dynamic change in the behaviour of the system.

There is lot of procedures involved in implementing advanced process control technique. It can only run on trial basis till the process engineers are satisfied with its control performance. Once they are satisfied the next step is to interface the automatic pH fuzzy-simulink controller to the computer, where the online process can be continuously governed, trained and controlled by the user using the system itself.

BIBLIOGRAPHY

WEB SITES

1. www.sugar online.com/journal/articles
2. www.india sugar online.com
3. www.process details of sugar.com
4. www.icumsa . com
5. www.quality sugar.com
6. www.mathworks .com
7. www.fuzzy PID controller .com
8. www.fuzzy logic .com
9. www.Simulink .com

JOURNALS

1. International journals of fuzzy sets and systems (IJFSS) – The official publication of the international fuzzy system association.

2. International journal of uncertainty, fuzziness and knowledge based systems (IJUFKS) - intended as a forum for research on methods for managing imprecise, vague, uncertain and incomplete knowledge.

3. IEEE Transactions on fuzzy systems.

4. [Chi 94] chiu, s., "Fuzzy model identification based on cluster estimation", Journal of intelligence and fuzzy systems, vol 2 , No 3 sept 1994.

5. [Mam 75] Mamdani, E.H., and S.Assilian "An experiment in linguistic synthesis with a fuzzy logic Controller,"International Journal of man-machine studies, vol 7, NO 1 PP 1-13 1975.

7. [Mam 76] Mamdani, E.H., "Advances in the linguistic synthesis of fuzzy controllers", International Journal of man machine studies, vol.8, pp. 669-678, 1976.

8. [Mam 77] Mamdani, E.H.,"Applications of fuzzy logic to reasoning using linguistic synthesis, "IEEE Transactions on computers, vol 26 No -12, pp 1182-1191, 1977

9. [Zad 73] Zadeh, L.A., "Outline of a new approach to the analysis of complex systems and decision Processes," IEEE Transactions on systems, man and cybernetics, vol.3, No-1, pp. 28-44 Jan 1973.

10. [Zad 89] Zadeh, L.A., "Knowledge representation in fuzzy logic ", IEEE Transactions on Knowledge and data engineering, vol-1, pp. 89-100, 1989

11. P.Pivorika., M.Findora, "The alternative realization of fuzzy controllers", Automatizace, 41 (1998), No 10, 11, 12 pp. p 31-38, in Czech.

BOOKS

1. *N.C Verma (1988) System on technical control for cane sugar factories in India. Pub The sugar technologies association of India. Kanpur 208017 India.*
2. *Meade G.P and Chen J.P.C (1985), Cane sugar hand book, John Wiley & sons (1985)*
3. *Solomon, S; A K Shrivasta, B.L Srivastava and V.K Madan – Premilling sugar losses and their management in sugarcane. Indian Institute of sugarcane research publications Lucknow, India-1997.*
4. *Clarke.S Cane Quality (1994)*
5. *Hand book of Industrial water conditioning by BETZ (1980).*
6. *An innovative process for white sugar production by chung chi Chou, khalid iqbal Y G Min , Da wei Gao and Emmanuel Duffaut – New Orleans , Louisiana , USA 1996*
7. *Jain & Jain Engineering chemistry-Chemistry of engineering materials-1998*
8. *LOFT A.ZADEH, Fuzzy Logic Tool box –For use with matlab, version 2 Berkley, CA 1995.*
9. *E.COX, The fuzzy systems hand book: A practitioner guide to building, using and maintaining fuzzy systems. Cambridge, MA; A P Professional, 1994.*
10. *E.Mamdani and S.Assilian , " Applications of fuzzy algorithms for control of dynamic plant",-1974*
11. *Wang, Parl .P., "Theory of fuzzy sets and their applications", Shanghai science and technology Shanghai, 1982.*
12. *Zimmerman , Hans J.,"Fuzzy set theory", Boston, 2nd Edition 1991*
13. *Kosko, Bart. "Fuzzy thinking: The new science of fuzzy logic", Warner, 1993.*
14. *M C Neill, Daniel and Freiberger, Paul, "Fuzzy logic: The discovery of computer technology" Simon and Schuster 1992.*