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# Software Development of Distributed Control System-Based Sugar Mill Using Visual Studio. Net

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## Abstract:

This research aims to develop the simulation software for the sugar manufacturing factory. The current research project is based on the implementation of distributed control system based sugar mill using Visual Studio.net. The affination stage, carbonatation stage, and crystallization stage are accomplished to implement according to the software simulation anchored in the real sugar manufacturing factory. The client-server model is more suitable for this research. In this research, the simulation of the whole process is described by using Visual Basic.Net programming under Visual Studio 2008 software. The existing DCS can be divided into two sections: the first one is cheap and inflexible control and the second one is expensive but it is flexible control system. This research goes in front of cheap and flexible distributed control system.

## 1. Introduction

The evolution of plant automation systems, from very primitive forms up to the contemporary complex architectures, has closely followed the progress in instrumentation and computer technology that, in turn, has given the impetus to the vendor to update the system concepts in order to meet the user's growing requirements [1]. This has directly encouraged users to enlarge the automation objectives in the field and to embed them into the board objectives of the process, production, and enterprise level. The integrated automation concept has been created to encompass all the automation functions of the company. This was viewed as an opportunity to optimally solve some interrelated problems such as the efficient

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utilization of resources, production profitability, product quality, human safety, and environmental demands [2,3,4,5].

The sugar industry processes sugar cane and sugar beet to manufacture edible sugar. More than 60% of the world's sugar production is from sugar cane; the balance is from sugar beet. Sugar manufacturing is a highly seasonal industry, with season lengths of about 6 to 18 weeks for beets and 20 to 32 weeks for cane. Approximately 10% of the sugar cane can be processed to commercial sugar, using approximately 20 cubic meters of water per metric ton ($m^3/t$) of cane processed. Sugar cane contains 70% water; 14% fiber; 13.3% saccharose (about 10 to 15% sucrose), and 2.7% soluble impurities. Sugar canes are generally washed, after which juice is extracted from them. The juice is clarified to remove mud, evaporated to prepare syrup, crystallized to separate out the liquor, and centrifuged to separate molasses from the crystals [6,7,8,9,10].

Sugar crystals are then dried and may be further refined before bagging for shipment. In some places, juice is extracted by a diffusion process that can give higher rates of extraction with lower energy consumption and reduced operating and maintenance costs. For processing sugar beet (water, 75%; sugar, 17%), only the washing, preparation, and extraction processes are different. After washing, the beet is sliced, and the slices are drawn into a slowly rotating diffuser where a countercurrent flow of water is used to remove sugar from the beet slices. Approximately 15 cubic meters ($m^3$) of water and 28 kilowatt-hours (kWh) of energy are consumed per metric ton of beet processed. Sugar refining involves removal of impurities and decolorization. The steps generally followed include affination (mingling and centrifugation), melting, clarification, decolorization, evaporation, crystallization, and finishing. Decolorization methods use granular activated carbon, powdered activated carbon, ion exchange resins, and other materials [11,12,13].
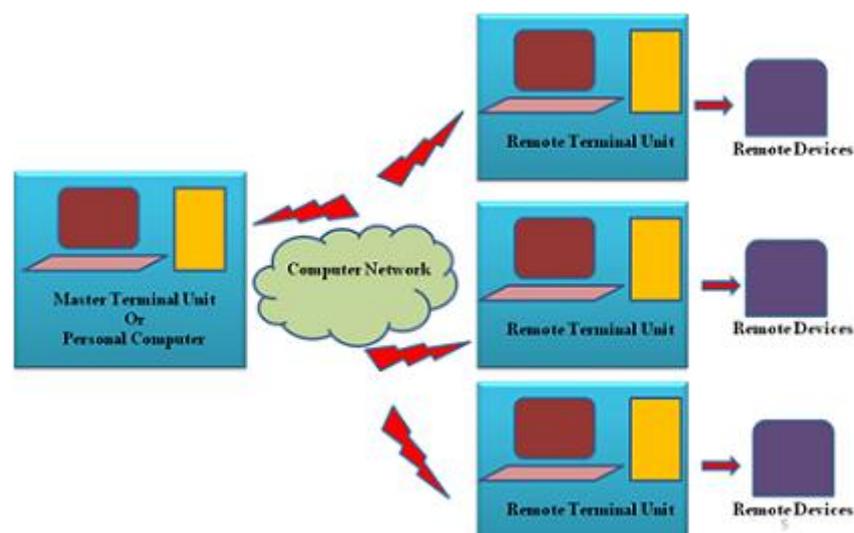


*Figure 1. DCS Based Control System.*

This system block diagram in Figure 1 is the model of Distributed Control System based Sugar Manufacturing Plant. The diagram shows how to monitor and interface between Master station and Remote Terminal Units (RTU). The simulation and running condition is shown on the monitor of server computer or client computers used as Master station. It uses a group of programming as Visual Basic.Net and other programming languages. This work begins the examination of control systems and DCS systems in particularly. It describes the different components in a DCS system

and the variety of open communications protocols that have been defined. The conclusion of implementing simple DCS system, organizational culture issues, perceptions (and misperceptions) of DCS vulnerability, and design state of DCS system. Finally, current advanced development programs, additional countermeasures, and legislation targeted to increase the effectiveness of DCS application in the present and future are described.
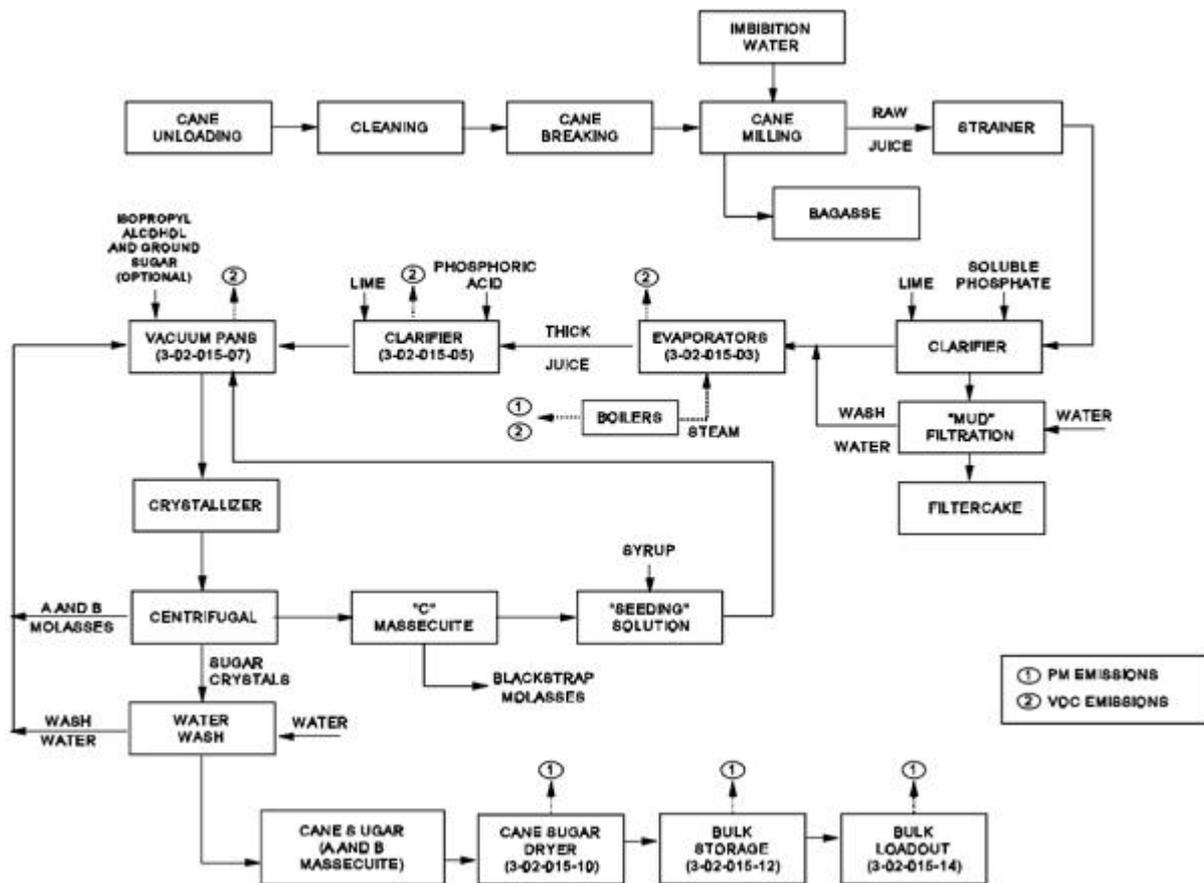
## 2. Cane Sugar Production

Hand cutting is the most common harvesting method throughout the world but some locations have used mechanical harvesters for several years. After cutting, the cane is loaded by hand, mechanical grab loaders, or continuous loaders. Cane is transported to the mills using trailers, trucks, railcars, or barges, depending upon the relative location of the cane fields and the processing plants. When the cane is cut, rapid deterioration of the cane begins. Therefore, unlike sugar beets, sugarcane cannot be stored for later processing without excessive deterioration of the sucrose content.

A simplified process flow diagram for a typical cane sugar production plant is shown in Figure 2. The cane is received at the mill and prepared for extraction of the juice. At the mill, the cane is mechanically unloaded, placed in a large pile, and, prior to milling, the cane is cleaned. The milling process occurs in two steps: breaking the hard structure of the cane and grinding the cane. Breaking the cane uses revolving knives, shredders, crushers, or a combination of these processes. For the grinding, or milling, of the crushed cane, multiple sets of three-roller mills are most commonly used although some mills consist of four, five, or six rollers in multiple sets. Conveyors transport the crushed cane from one mill to the next. Imbibition is the process in which water or juice is applied to the crushed cane to enhance the extraction of the juice at the next mill. In imbibition, water or juice from other processing areas is introduced into the last mill and transferred from mill to mill towards the first two mills while the crushed cane travels from the first to the last mill. The crushed cane exiting the last mill is called bagasse. The juice from the mills is strained to remove large particles and then clarified. In raw sugar production, clarification is done almost exclusively with heat and lime (as milk of lime or lime saccharate); small quantities of soluble phosphate also may be added. The lime is added to neutralize the organic acids, and the temperature of the juice raised to about 95EC (200EF). A heavy precipitate forms which is separated from the juice in the clarifier. The insoluble particulate mass, called "mud", is separated from the limed juice by gravity or centrifuge. Clarified juice goes to the evaporators without additional treatment. The mud is filtered and the filter cake is washed with water.

Evaporation is performed in two stages: initially in an evaporator station to concentrate the juice and then in vacuum pans to crystallize the sugar. The clarified juice is passed through heat exchangers to preheat the juice and then to the evaporator stations. Evaporator stations consist of a series of evaporators, termed multiple-effect evaporators; typically a series of five evaporators. Steam from large boilers is used to heat the first evaporator, and the steam from the water evaporated in the first evaporator is used to heat the second evaporator. This heat transfer process continues through the five evaporators and as the temperature decreases (due to heat loss) from evaporator to evaporator, the pressure inside each evaporator also decreases which allows the juice to boil at the lower temperatures in the subsequent evaporator. Some steam is released from the first three evaporators, and this steam is used in various process heaters in the plant. The evaporator station in cane sugar manufacture

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typically produces syrup with about 65 percent solids and 35 percent water. Following evaporation, the syrup is clarified by adding lime, phosphoric acid, and a polymer flocculent, aerated, and filtered in the clarifier. From the clarifier, the syrup goes to the vacuum pans for crystallization.



*Figure 2.* Process Flow Diagram for Cane Sugar Production.

Crystallization of the sugar starts in the vacuum pans, whose function is to produce sugar crystals from the syrup. In the pan boiling process, the syrup is evaporated until it reaches the super saturation stage. At this point, the crystallization process is initiated by "seeding" or "shocking" the solution. When the volume of the mixture of liquor and crystals, known as massecuite, reaches the capacity of the pan, the evaporation is allowed to proceed until the final massecuite is formed. At this point, the contents of the vacuum pans (called "strike") are discharged to the crystallizer, whose function is to maximize the sugar crystal removal from the massecuite. Some mills seed the vacuum pans with isopropyl alcohol and ground sugar (or other similar seeding agent) rather than with crystals from the process. From the crystallizer, the massecuite (A massecuite) is transferred to high-speed centrifugal machines (centrifugals), in which the mother liquor (termed "molasses") is centrifuged to the outer shell and the crystals remain in the inner centrifugal basket. The crystals are washed with water and the wash water centrifuged from the crystals.

The liquor (A molasses) from the first centrifugal is returned to a vacuum pan and reboiled to yield a second massecuite (B massecuite), that in turn yields a second batch of crystals. The B massecuite is transferred to the crystallizer and then to the centrifugal, and the raw sugar is separated from the molasses. This raw sugar is

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combined with the first crop of crystals. The molasses from the second boiling (B molasses) is of much lower purity than the first molasses. It is reboiled to form a low grade massecuite (C massecuite), which goes to a crystallizer and then to a centrifugal. This low-grade cane sugar is mingled with syrup and is sometimes used in the vacuum pans as a "seeding" solution. The final molasses from the third stage is a heavy, viscous material used primarily as a supplement in cattle feed. The cane sugar from the combined A and B massecuites is dried in fluidized bed or spouted bed driers and cooled. After cooling, the cane sugar is transferred to packing bins and then sent to bulk storage. Cane sugar is then generally bulk loaded to trucks, railcars, or barges.

## 3.  Refined Sugar Production

A simplified process flow diagram for refined sugar production is shown in Figure 3. Cane sugar is refined either at the same location where it was produced as part of an integrated facility or at separate raw sugar refineries. The initial step in cane sugar refining is washing the sugar, called affination, with warm, almost saturated syrup to loosen the molasses film. This is followed by separation of the crystals from the syrup in a centrifugal and washing of the separated crystals with hot water or a high purity sweetwater. If the refinery is part of the cane sugar production facility, the cane sugar may be washed more heavily in previous steps and the affination step omitted.
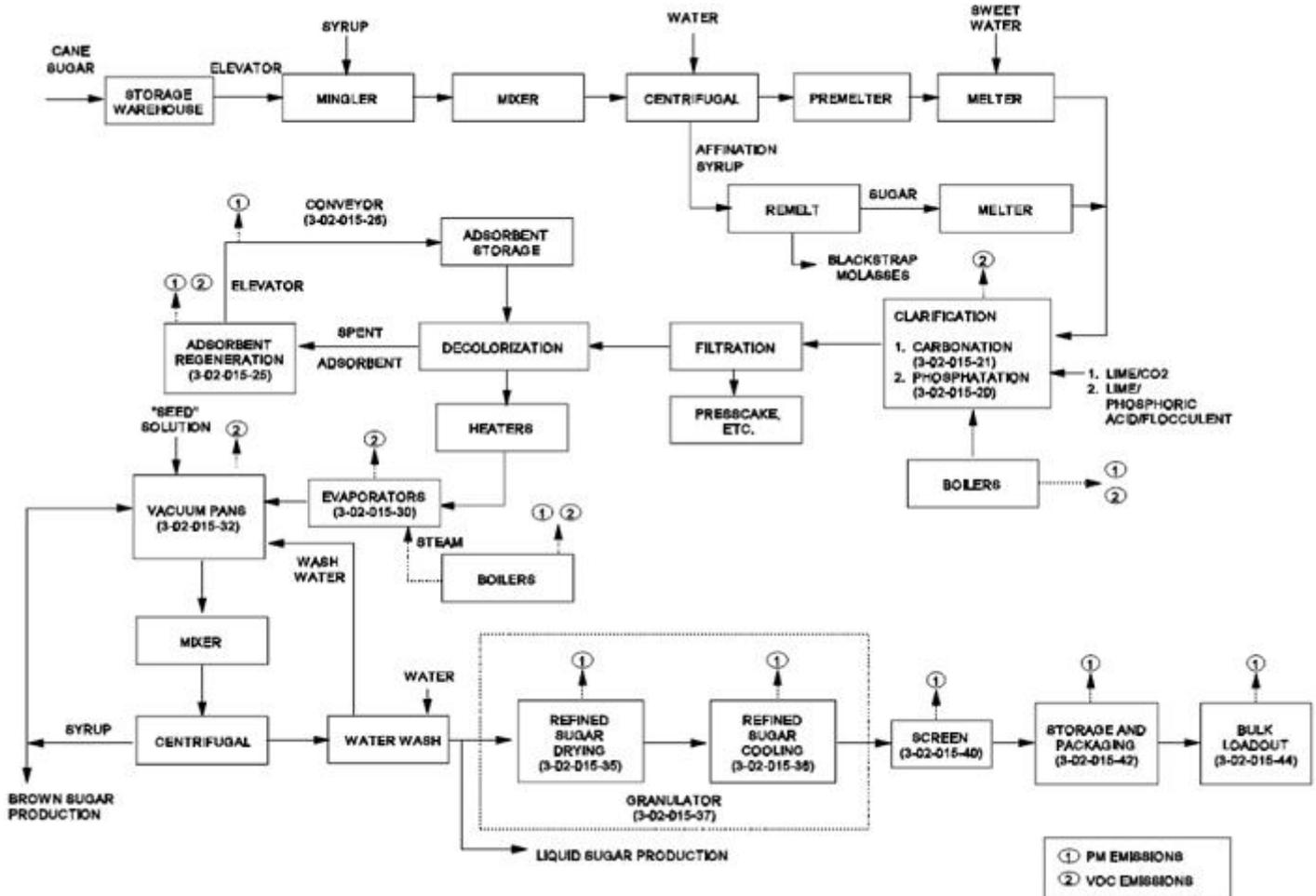


*Figure 3. Process Flow Diagram for Refined Sugar Production.*

The washed raw sugar is sent to a premelter and then to a melter, where it is mixed with high-purity sweetwaters from other refinery steps and is steam heated. The

resultant syrup is passed through a screen to remove any particulate in the syrup and sent to the clarification step. The syrup from the crystal washing, called affination syrup, is transferred to a remelt processing station or reused in the raw sugar washing step. In the remelt station, the syrup volume is reduced to form the massecuite, and the sugar crystals are separated from the syrup. The separated liquor is blackstrap molasses. The sugar crystals are sent to a melter and then to the clarification step. Two clarification methods are commonly used: pressure filtration and chemical treatment; chemical clarification is the preferred method. Two chemical methods are commonly used: phosphatation and carbonation; both processes require the addition of lime. The phosphatation uses phosphoric acid, lime (as lime sucrate to increase solubility), and polyacrylamide flocculent to produce a calcium phosphate floc. Air flotation is usually used to separate the floc from the liquor and the floc skimmed from the liquor surface. Carbonation consists of adding lime to the raw melter liquid and then bubbling carbon dioxide ($CO_2$) through the liquor to produce a calcium carbonate precipitate.

The source of $CO_2$ is boiler flue gas, which contains about 12 percent $CO_2$ by volume. The clarifier systems yield presscakes, muds, or scums which are treated to remove entrapped sugar, and then sent to disposal. The next step is decolorization, which removes soluble impurities by adsorption. The two most common adsorbents are granular activated carbon and bone char, manufactured from degreased cattle bones.

Powdered carbon and synthetic resins are less commonly used. Bone char or activated carbons are used in either fixed or moving bed systems. Spent adsorbent is removed from the bed, regenerated, and stored for reuse.

The decolorized sugar liquor is sent to heaters, followed by multiple-effect evaporators, and then to the vacuum pans; this is the same sequence used in cane sugar manufacture. Basic operation of the evaporators and vacuum pans is the same as for cane sugar. The sugar liquor from the evaporators is transferred to the vacuum pans to further reduce the liquor volume and form the massecuite. In refined sugar production, the most common boiling system is the four-strike system. When the liquor in the pans has reached the desired level of super saturation, the liquor is "seeded" to initiate formation of sugar crystals.

At this point, the strike is discharged to a mixer and then to the centrifugal. In the centrifugal, the white sugar is retained in the inner basket and the liquor centrifuged to the outer shell. The sugar liquor is returned to a vacuum pan for further volume reduction and white or brown sugar production. The white sugar is washed one time in the centrifugal; the separated wash water, containing liquor and dissolved sugar, is returned to the vacuum pans. The moist sugar from the centrifugals contains about 1 percent water by weight. To produce refined granulated sugar, white sugar is transported by conveyors and bucket elevators to the sugar dryers. The most common sugar dryer is the granulator, which consists of two drums in series. One drum dries the sugar and the other cools the dried sugar crystals. Dryer drums typically operate at a temperature of about 110EC. Fluidized bed dryers/coolers are used at some facilities in place of the conventional rotary drum granulators. From the granulators, the dried white sugar crystals are mechanically screened by particle size using a sloping, gyrating wire mesh screen or perforated plate. After screening, the finished, refined granulated sugar is sent to conditioning bins, and then to storage bins prior to packaging or bulk load out. Almost all packaged sugar uses multiwall paper containers, cardboard cartons, or polyethylene bags; bulk load out is the load out of

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the sugar to specially designed bulk hopper cars or tank trucks. In addition to granulated sugar, other common refined sugar products include confectioners' (powdered) sugar, brown sugar, liquid sugar, and edible molasses. The flowchart of sugar refining process is illustrated in Figure 4.
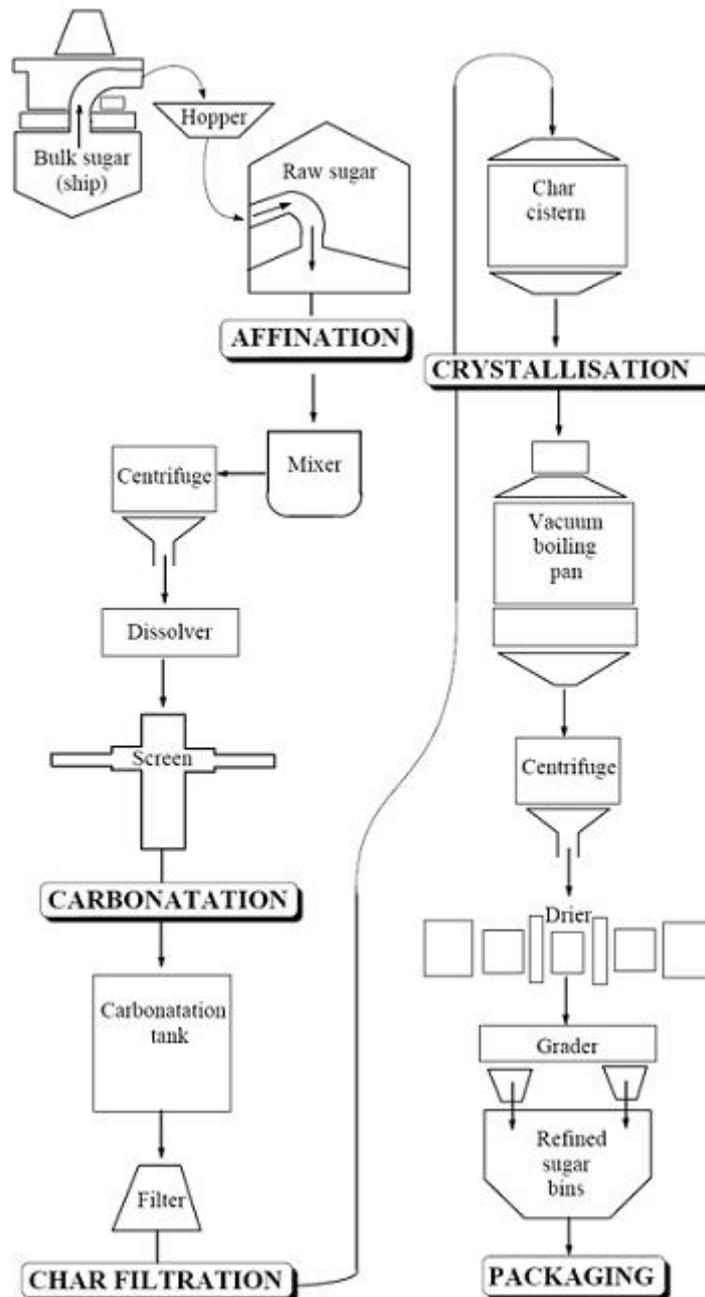


*Figure 4. Flow Chart of the Sugar Refining Process.*

## 4. Overall Block Diagram

The overall block diagram is illustrated in Figure 5. The diagram shows how to monitor and interface between Master station and Remote Terminal Units (RTU). The simulation and running condition is shown on the monitor of server computer or client computers used as Master station. It uses a group of programming as Visual Basic.Net and other programming languages. This paper begins the examination of control systems and DCS systems in particularly. It describes the different components in a

DCS system and the variety of open communications protocols that have been defined. The conclusion of implementing simple DCS system, organizational culture issues, perceptions (and misperceptions) of DCS vulnerability, and design state of DCS system. Finally, current advanced development programs, additional countermeasures, and legislation targeted to increase the effectiveness of DCS application in the present and future are described.
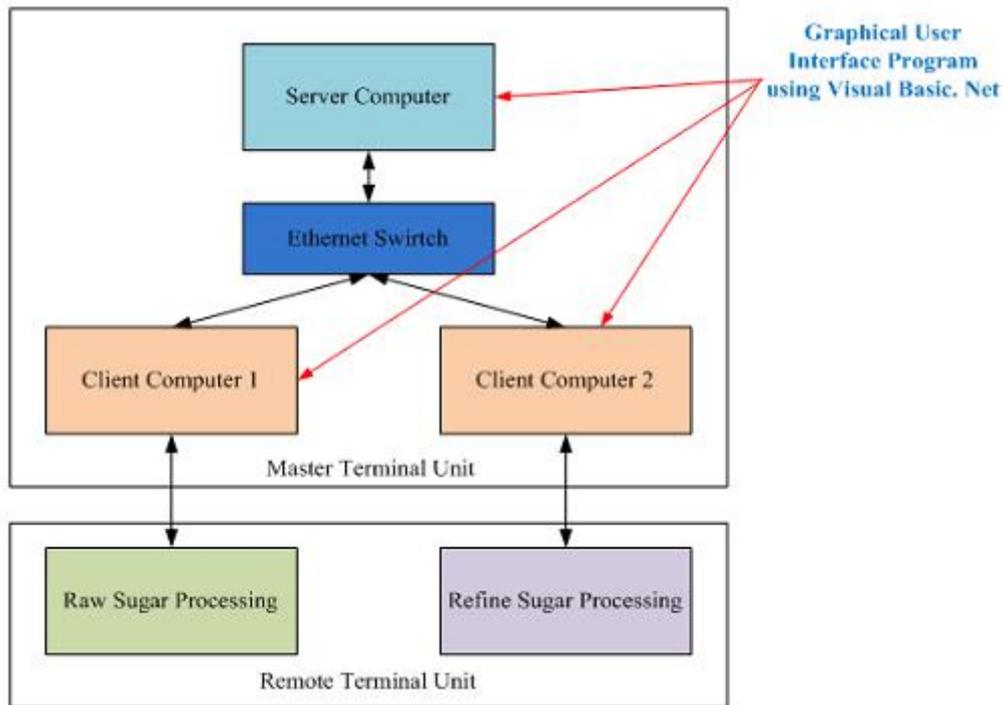


*Figure 5. Overall Block Diagram.*

## 5.  Linking Windows System for DCS Process

The operation of the DCS process can be run and stopped from main page by the operator.
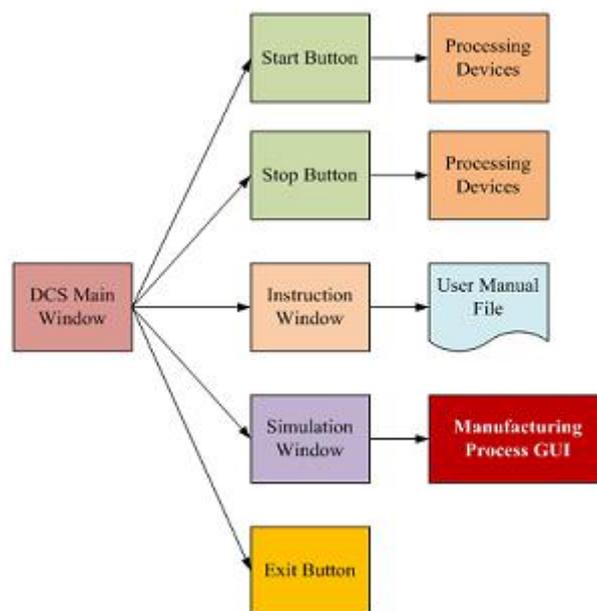


*Figure 6. Block Diagram of Linking Window for Control and Simulation.*

The main page serves to collect data from the operation mode and display in real-time running and save the collected data. The graph line is drawn in approximately 1 second step until the STOP command is accepted. When the main page program is shutdown the data acquisition and processing is shutdown all process except receiving command from the main page. So, the application software can be viewed in pages, the main page of PC and other pages linking each other as software of DCS system. (Figure 6)

## 6. Design Program for Main Page

This program uses the visual basic.net portion of window application from Visual Studio 2005 IDE. It can be designed a window form by using the software application data and used data by depending on the process from the properties of items. The control devices are used by using the toolbox of the form. And the code program for each component is written to the code viewer by using visual basic. Timer tools are used for timing of data interfacing and input/output process data. A Timer is used to raise an event at user-defined intervals. The window timer is designed by a single-threaded environment where UI threads are used to perform the processing. It requires that the user code have a UI message pump available and always operate from the same thread, or marshal the call onto another thread.
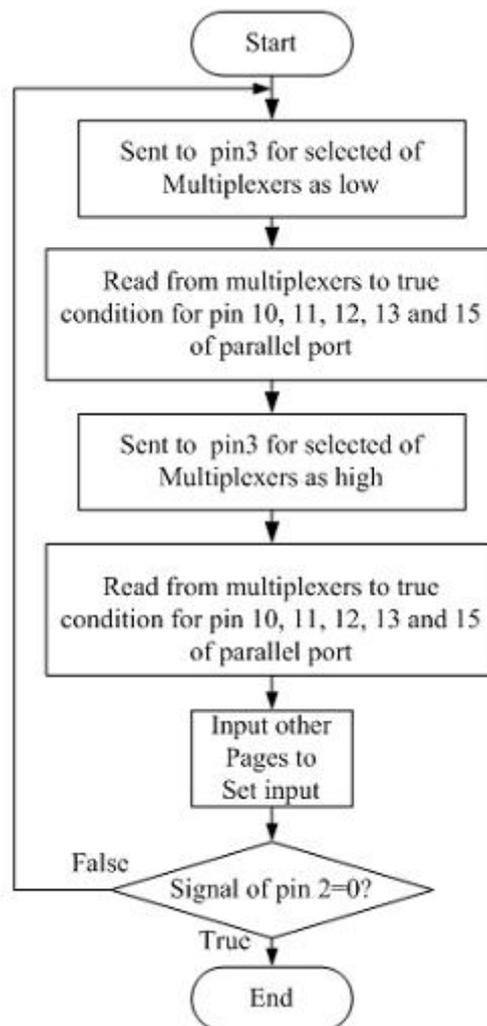


*Figure 7. Flow Chart of Input/Output System.*

Gets or sets the time, in milliseconds, between timer ticks. The Windows Forms Timer component has an Interval property that specifies the number of milliseconds that pass between one timer event and the next. Unless the component is disabled, a timer continues to receive the Tick event at roughly equal intervals of time. This component is designed for a Windows Forms environment.

The read/write signal of I/O system activates every time. It uses timer tool (timIn_Tick) to watch the port system. The signal is flowed to selected pin of multiplexers from timer state. If the input of selected is high, the input signals from parallel port (inAffination, inError, inCarbonatation, inCharFiltration and inCrystallization) are true. The input of each is compare with the particular selecting address. It is shown in Figure 7.

## 7.  Design Program for Monitoring of Simulation Page

This page uses the simulation of components on the form (frmSimulation). The signal of simulation for each is get to display on the page from timer (timIn_Tick) of main page.

So the location of each of image is put on the form using picture box tool (pbName). Next, the text showing the running process and the stopping process displays on the form by using start button on state. It can be written:

pbCrystallization.ImageLocation=Application.StartupPath& "\jpg\Crystallization.jpg"

pbCharFiltration.ImageLocation=Application.StartupPath& "\jpg\CharFiltration.jpg"

If modinout.outStart = 1 Then

lMode.Text = "Running State of Process!!"

Else

lMode.Text = "Stopping State of Process!!"

End If

This system needs to test how the state of input pin is. So it uses timer tool from window application to display the components. The simulation of running conveyor is used timer tool (timCrystallization_Tick) and it is shown in Figure 8. If the input of signal for conveyor (inCrystallization) gets from input timer, the displaying of conveyor shows on the form.

The displaying of image for Affination process is one image of design for affination process stage. It uses timer tool (timAffination_Tick) to get signal from input system. Firstly, the color of work piece sensor (PWPS) puts the light green. If the signal of input pin (inSuagrCane) is true, it displays the image of full affination process (Affination) in the location of image (pbAffination) and the red color of workpiece sensor on the form.

And if it is not the above, it is tested true or false for the signal of input pin (inCharFiltration) and if it is true, it displays the image of CharFilteration (CharFilteration) in the location of image (pbCharFilteration). If it is not true also the above, it displays the image of CharFilteration (CharFilteration). The images of sugar

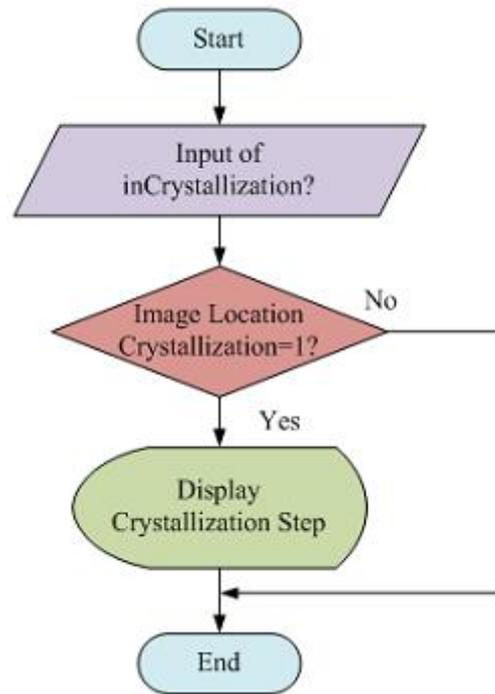refining condition are put in the desired location of the computer. It is shown in Figure 9.



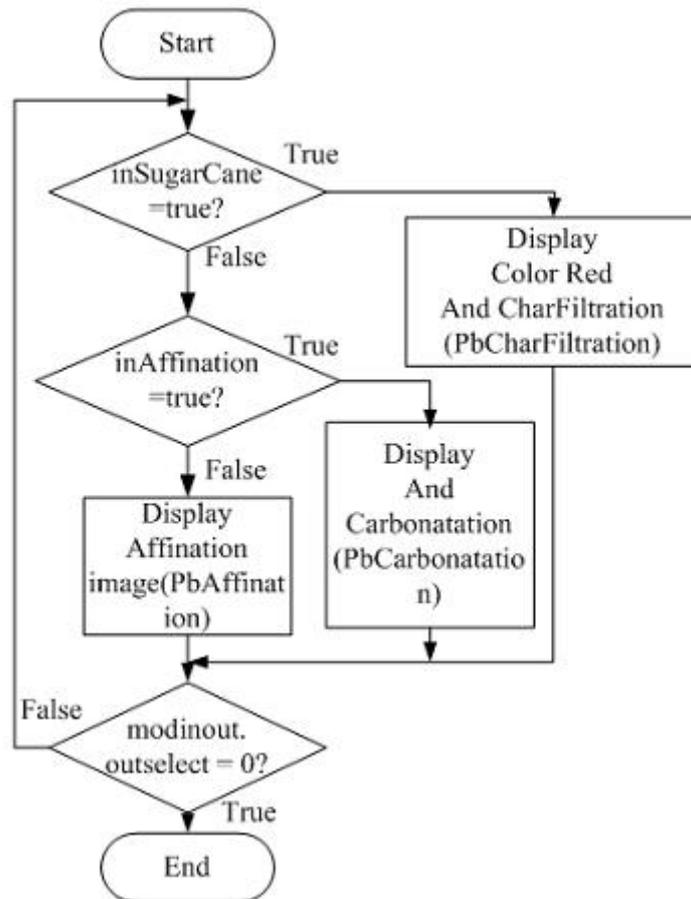*Figure 8. Flow Chart of Simulation for Crystallization Step.*



*Figure 9. Flow Chart of Simulation for Sugar Refining System.*

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## 8.  Display Result of the System

In this system, parallel port pins are used to control the input and output signal of the hardware devices. And it also links to the window application with the VB.net programming. It includes main page which links other pages, operation page which links the device operations, sensor page which expresses the condition of sensors, hardware page that links the monitoring of hardware device sample and data page which expresses as the user guide.

### 8.1. Display Result of Main Page

In this page, it includes five buttons – start, stop, simulation, data, hardware and exit. And it uses two label name including title and designer name, and alarm color system using the condition of error signal. This page is essential for the overall system. It includes the interfacing system for the I/O signal from parallel port and links with other pages and sends to the other pages the condition of I/O signal.

The start and stop buttons are used to run and stop the overall system which is real-time monitoring process. The simulation button is used to display the simulation result of the process. The data button is used to express the user guide for the system. The Affination button is utilized to show the monitoring of affination stage by linking with it. The Carbonatation button is utilized to show the monitoring of carbonatation stage by linking with it. The Crystallization button is utilized to show the monitoring of crystallization stage by linking with it. The exit button is used to end the process and to exit the monitoring system by linking with the yes or no message box. It is shown in Figure 10.
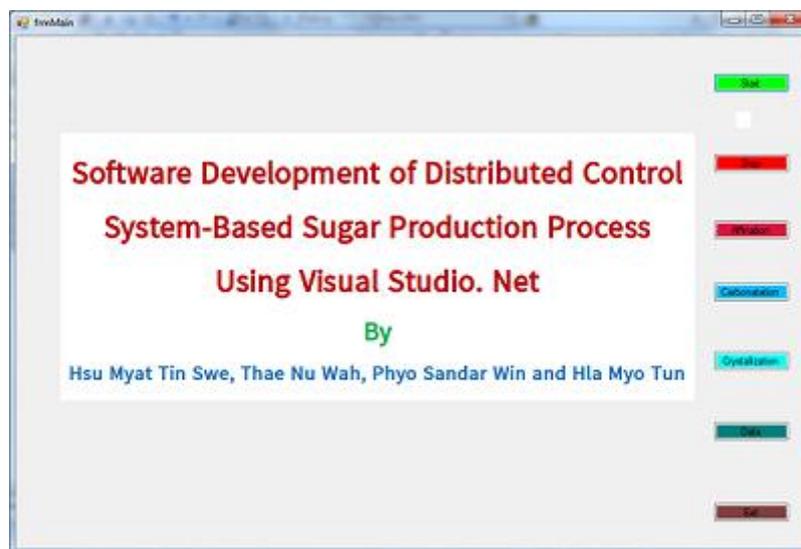


*Figure 10. Display Result of the Main Page.*

### 8.2. Display Result of the Affination Stage

In this page, it includes one button – back. This page is a main process to show for affination processing. On the form, it is designed with the sample components for the real devices of automation process by using the sample figures of actual devices. It shows the monitoring or moving of each components. It uses I/O signal from main page for operation of device by using each signal. It is shown in Figure 11. The back button is used to go back the main page like to close the operation page.
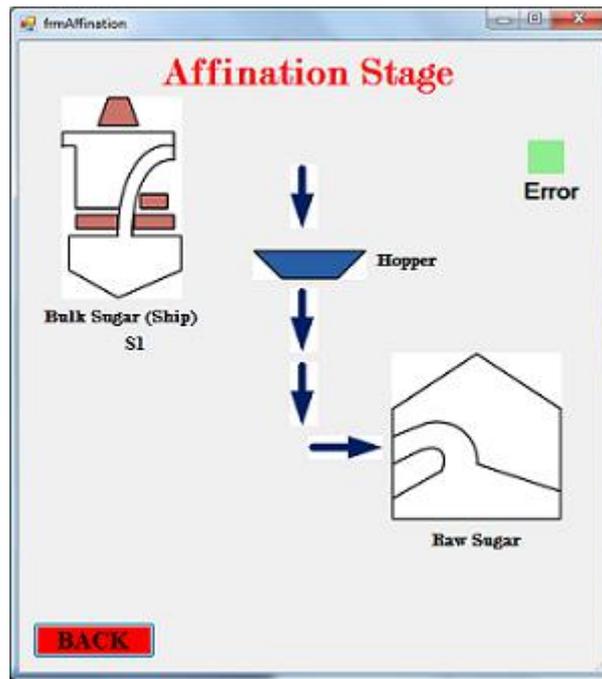
**Figure 11.** *Display Result of Affination Stage.*

## 8.3. Display Result of the Carbonatation Stage

This page is main processes to show carbonatation stage processing. On the form, it is designed with the sample components for the real devices of automation process by using the sample figures of actual devices. It uses I/O signal from main page for operation of device by using each signal. It is shown in Figure 12. The back button is used to go back the main page like to close the operation page.
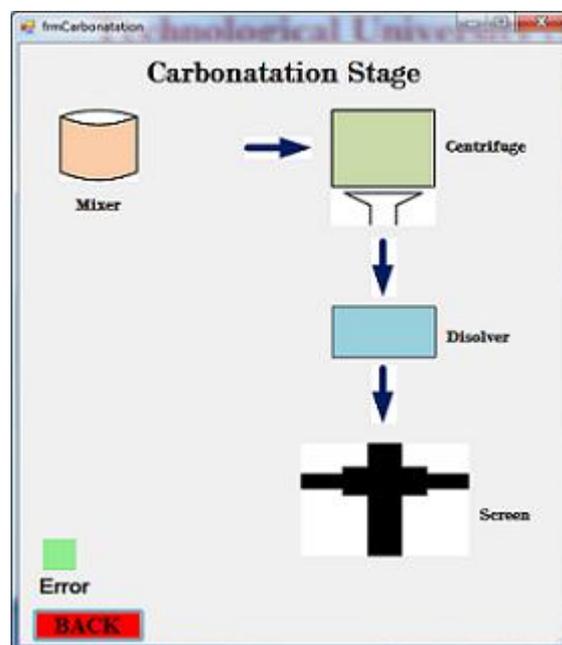


**Figure 12.** *Display Result of Carbonatation Stage.*

## 8.4. Display Result of the Crystallization Stage

This page is main processes to show crystallization stage processing. On the form, it is designed with the sample components for the real devices of automation process by

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using the sample figures of actual devices. It uses I/O signal from main page for operation of device by using each signal. It is shown in Figure 13. The back button is used to go back the main page like to close the operation page.
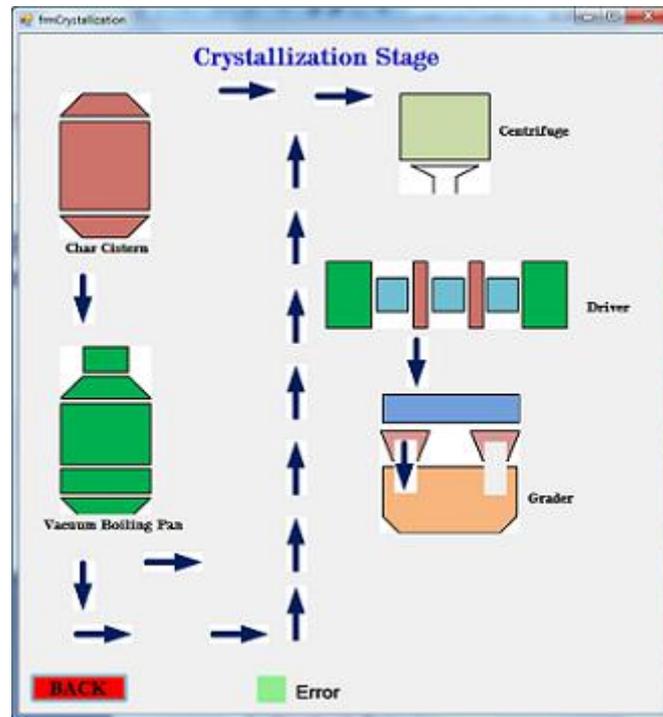


**Figure 13.** *Display Result of Crystallization Stage.*

## 8.5. Display Result of the Data Window

This window shows the user guide for the overall system how to use and what contains it. It is to link with the main page. It is shown in Figure 14. If the user wants to go back the main page, the data window will be closed.
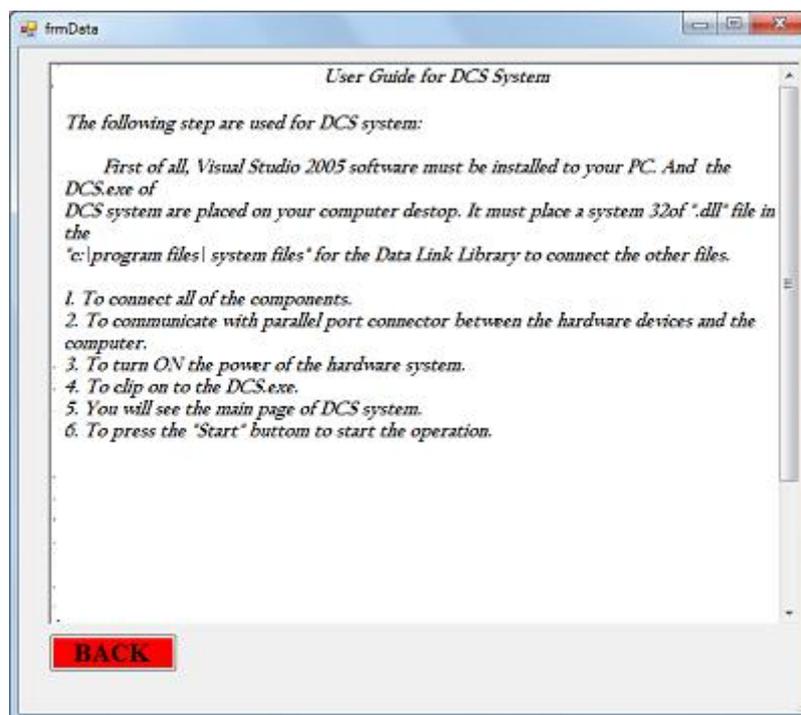


**Figure 14.** *Display Result of Data Window.*

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### 8.6. Display Result of the Exit Window

This window shows the decision making for the user to run or stop of the current condition of the overall system. It uses the message box including yes or no decision that is if it is yes, it will exit from the system otherwise the process will continue the operation. It is shown in Figure 15.



**Figure 15.** *Display Result of the Exit Window.*

## 9. Conclusions

This system really tend to develop the controlling devices from anywhere by monitoring the whole system. This monitoring system can access with the other process. This system is developed to control the automation processes such as electrical distributed system, water waste system, and etc. Using this monitoring control system, it is intended to become security and reliability from the processes.

A low cost data acquisition, processing and monitoring system based on the Distributed Control System has successfully developed in this paper. Since technologies change quickly, this system is only as good as the ease with which it can be adapted to more complicated system. This paper expects technologies of Distributed Control System based sugar mill. It includes motors, sensors and other devices and applies to control the type of visual basic.net programming like DCS software. And the simulating and monitoring for the industrial automation use own programs without popular DCS software. So it can be used that customers want to desire from their application. It is very low cost for applications and has shown that computers and automated control can be used as a tool to increase product quality and production flexibility. In this research, design and implementation of sugar mill process that used Visual Basic.Net programming for the monitoring of DCS system have been studied. Hardware Units for this process is designed with the small sample model and tested by connecting hardware and computer, and it can start/stop with component using monitoring system and can see all of state running for this processes.

## Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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