ISSN 2393-8471

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 4, Issue 2, pp: (10-19), Month: October 2017 – March 2018, Available at: www.paperpublications.org

# Implementation of Furnace Process System for Distillation Column

[1]Santhiya.R, [2]V.Ravin Rose, [3]Priya.G, [4]Priyadharshini.R

[1,2,3,4] Department of Mechanical Engineering, Peri Institute of Technology, Manivakkam, Chennai, Tamil Nadu, India

***Abstract:*** **A refinery is a production facility composed of a group of chemical engineering unit processes and unit operations refining certain materials or converting raw material into products of value. The major equipments in a refinery are furnace and a distillation unit. Distillation is the separation or partial separation of a liquid feed mixture into components or fractions by selective boiling (or evaporation) and condensation. The characteristics of the refinery products are dependent on the furnace's outlet temperature and the parameters of the distillation tower.**

**The control scheme at CPCL has drawbacks that affect the performance of the furnace and distillation column. The drawbacks are analyzed and a modified control scheme is proposed. This control scheme will reduce the deviations caused by the existing control system at CPCL.**

**The Furnace's outlet crude oil temperature depends on the inlet crude oil flow and the fuel flow (both fuel oil and fuel gas). By designing control algorithms and modifications, we are going to overcome the unstabilised furnace outlet temperature of CPCL (any refining industry).The furnace inputs are air, gas, steam and oil. By controlling these input parameters using PIC microcontroller, we will get the steady state furnace outlet temperature.**

**In Distillation tower, the level and the temperature of the tray should be maintained in order to obtain the distillation products in an efficient way. In CPCL, there are frequent tray level changes and there is dependency between temperature and level. In order to overcome these disadvantages both these parameters are maintained by controlling the flow of the recycled water from the tray.**

**In real time distillation column and furnace cannot be constructed in small scale. Therefore, an electrical furnace and a simulation of distillation column are created and the closed loop control of the furnace temperature is implemented. The distillation column is simulated as a open loop control process. PIC microcontroller is used for interfacing with the PC and for implementing the control program. PIC microcontroller PIC 16F877A is used.**

***Keywords:*** **Furnace, Distillation column, PIC microcontroller.**

## I. INTRODUCTION

An oil refinery converts crude oil into high-octane motor fuel (gasoline/petrol), diesel oil, liquefied petroleum gases (LPG), jet aircraft fuel, kerosene, heating fuel oils, lubricating oils, asphalt and petroleum coke. Modern industrial civilization depends on petroleum and its products; the physical structure and way of life of the suburban communities that surround the great cities are the result of an ample and inexpensive supply of petroleum. In addition, the goals of developing countries—to exploit their natural resources and to supply foodstuffs for the burgeoning populations are based on the assumption of petroleum availability. In recent years, however, the worldwide availability of petroleum has steadily declined and its relative cost has increased. Crude oil is separated into fractions by fractional distillation. The fractions at the top of the fractionating column have lower boiling points than the fractions at the bottom. The heavy bottom fractions are often cracked into lighter, more useful products. All of the fractions are processed further in other refining units.

ISSN 2393-8471

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 4, Issue 2, pp: (10-19), Month: October 2017 – March 2018, Available at: www.paperpublications.org

## II. PROBLEM DEFINITION

Oil is also depleting at alarming rates. Therefore it is necessary to utilize the available resources in the best possible way. It is necessary to increase the efficiency of the distillation of crude oil.Our control schemes in the furnace and distillation column are aimed at increasing the efficiency of the distillation process and eliminating the problems of the existing system.

## III. METHODOLOGY

**Study and Analysis:** Existing control schemes for furnace and distillation column are studied and the drawbacks are analyzed at CPCL.

**Design of Control:** Based on the analysis of existing control schemes, a control scheme based on feedback and cascade control was designed. It was implemented in the simulation software at CPCL and the results were found to be satisfactory.

**Design of Hardware:** As the process at CPCL cannot be implemented in small scale, a prototype is designed using a real time electrical furnace. The distillation column process is simulated virtually.

**Design of Software:** The furnace process is monitored by the Visual Basic software. The Distillation column process is simulated in Visual Basic by giving inputs through sensors.

**Testing & Troubleshooting:** In this phase the prototype is tested and troubleshooting is carried out to rectify errors if any.

**EXISTING CONTROL SCHEME**

**In Furnace**

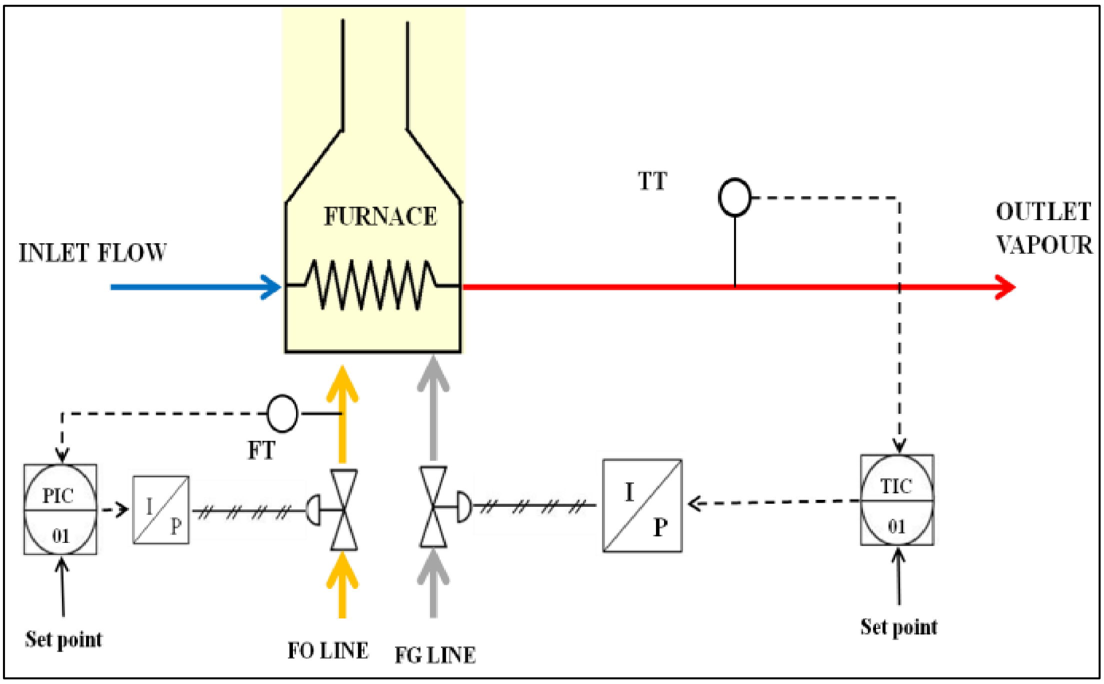


**Fig 1**

The furnace is supplied with fuel oil and fuel gas. Both of them combine and start the combustion process. The crude oil enters the furnace and is converted into vapour because of the increase in temperature provided by the heat in the furnace. As shown in Fig 1, the crude vapour temperature is monitored. It is controlled by feedback control loop by controlling the fuel gas line. The fuel oil line flow is separately controlled by a feedback loop. The control system is implemented in the Distributed Control System (DCS) of the refinery.

ISSN 2393-8471

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 4, Issue 2, pp: (10-19), Month: October 2017 – March 2018, Available at: www.paperpublications.org

**DRAWBACKS OF EXISTING SYSTEM IN FURNACE**

- There are fluctuations in the outlet crude vapour temperature. It is due to the following reasons:
- Change in inlet crude oil flow.
- Change in fuel input.
- In some cases, if there is no sufficient fuel flow, it will lead to dry run in the furnace.
- The flow of fuel oil and fuel gas should be complementing each other, otherwise either one of them will be over utilized affecting the cost.
- Inlet crude oil flow is not being monitored and controlled. Without control it can influence the outlet temperature.

**In Distillation Column**

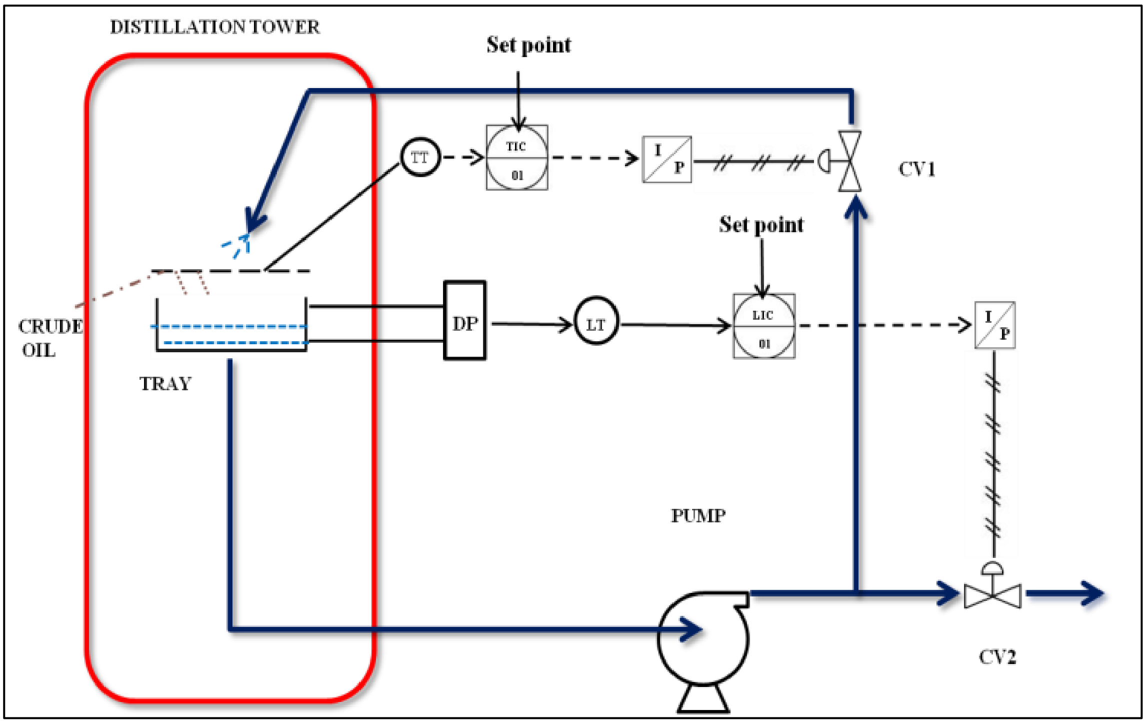


**Fig 2**

The distillation column is supplied with the crude vapour from the furnace. The distillation column is made up of trays maintained at different temperature levels. As shown in Fig. 2, the crude vapour strikes each tray and depending on the temperature at which the tray is maintained distillation occurs. The crude oil products have different flash points. For example, naphtha has boiling point ranging from 160ºC to 200ºC. To separate it from the crude vapour, the tray has to be maintained at a temperature below 160ºC, so that the naphtha is condensed from the vapour and separated in the tray. The remaining vapour rises in the column and each component is distilled in the same manner. Some the products are distilled as vapour while others are condensed. The vapour products rise in the column and are condensed using a cooler. The condensed products are pumped out from the column. The liquid product from the tray is recycled back to be sprayed on the tray so the temperature of the tray is maintained. The remaining water is pumped out. The amount of water to be pumped out is controlled by the level of water in the tray.

**DRAWBACKS OF THE EXISTING SYSTEM IN DISTILLATION COLUMN**

- There are frequent level changes in the tray of the distillation tower. This will affect the temperature of the tray.
- The temperature and level are dependent on each other. Therefore, if there is change in level the temperature of the tray cannot be maintained which is crucial to the products obtained from the distillation column.

ISSN 2393-8471

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 4, Issue 2, pp: (10-19), Month: October 2017 – March 2018, Available at: www.paperpublications.org

**PROPOSED CONTROL SCHEME IN FURNACE**

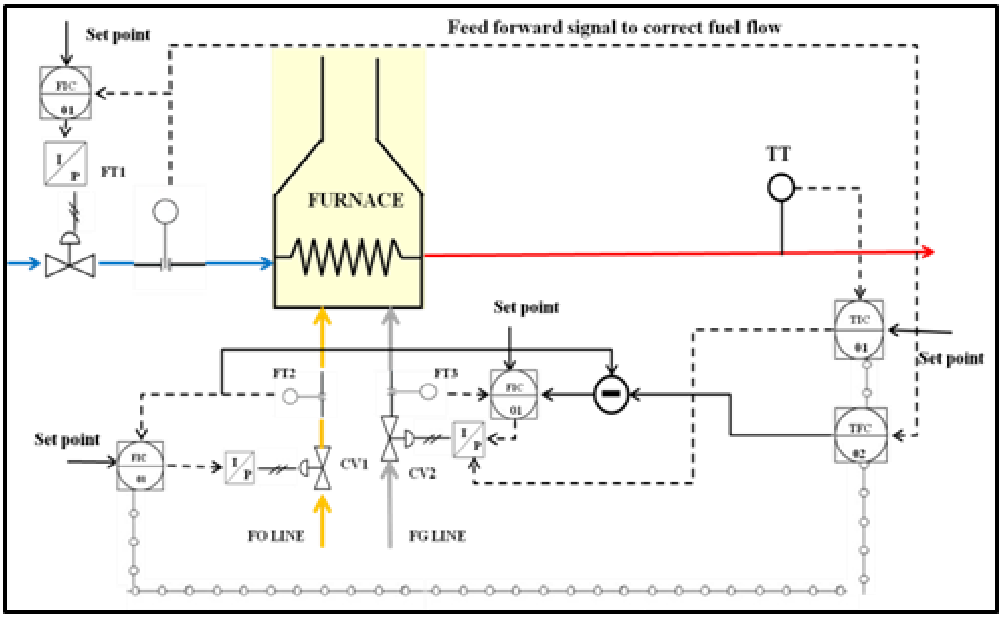


**Fig 3**

In the proposed control scheme as shown in Fig 3, the flow is being monitored by a feedback loop. The outlet crude vapor temperature in furnace is controlled by the inlet flow of the crude oil. The fuel oil and fuel gas line are complemented by using a total fuel controller by ratio control. The fuel oil and fuel gas lines are also monitored by separate feedback loops. Therefore, the fluctuations of the outlet temperature are reduced by this control scheme.

**PROPOSED CONTROL SCHEME IN DISTILLATION COLUMN**

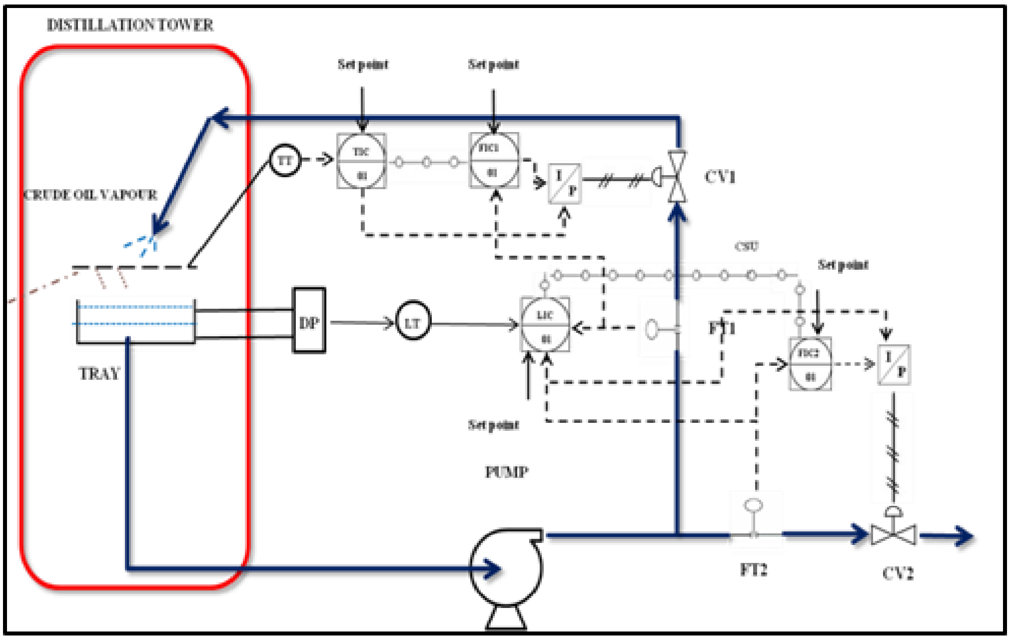


**Fig 4**

The proposed control scheme for distillation column as shown in Fig 2.2 is mainly designed for maintaining the tray temperature which is crucial for the distillation process. The tray level is maintained by using a control valve at the outlet. The liquid from the tray is again pumped back to the tray to maintain the temperature of the tray. The flow of this recycle

ISSN 2393-8471

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 4, Issue 2, pp: (10-19), Month: October 2017 – March 2018, Available at: www.paperpublications.org

line is also being monitored. Instead of feedback loops for temperature and level, flow of these lines are controlled together. The temperature and level fluctuations are reduced.

## RESULTS AT CPCL

### Inlet flow of the furnace:

In the proposed scheme the inlet flow is being monitored and the flow is almost maintained at desired value preventing dry run in furnace as shown in fig 5.When compared to the existing control scheme, the manipulated variable which is indicated by dark blue color is settled with respect to set point indicated by pink color.

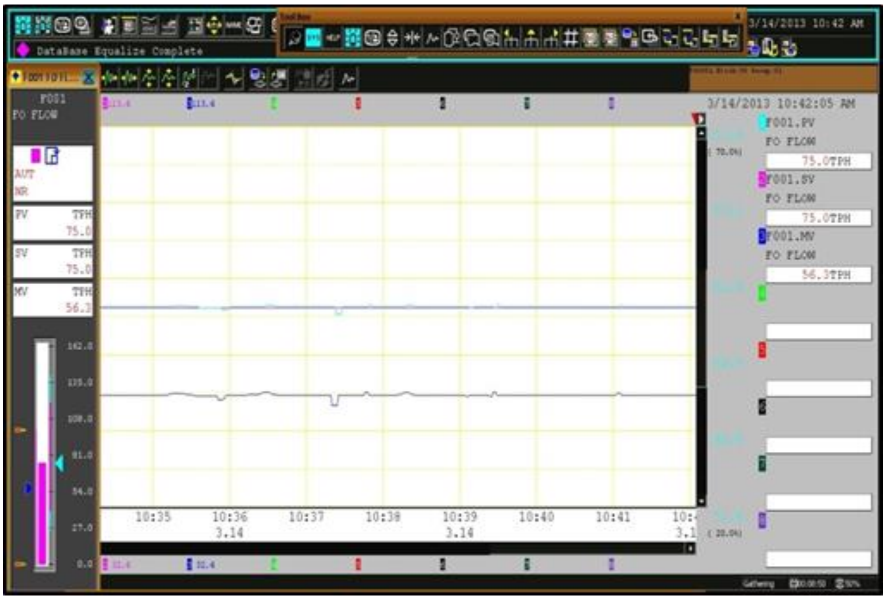


Fig 5

### Outlet temperature of the furnace:

In the proposed control scheme the fluctuations of the outlet temperature of furnace is reduced which is shown in fig 6. When compared to the existing control scheme as, the manipulated variable which is indicated by dark blue color is settled with respect to set point indicated by pink color.


Fig 6

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 4, Issue 2, pp: (10-19), Month: October 2017 – March 2018, Available at: www.paperpublications.org

**Tray level of the distillation column:**

In the proposed control scheme of Distillation column the tray level is maintained as shown in fig 7. When compared to the existing control scheme, the manipulated variable which is indicated by dark blue color is settled with respect to set point indicated by pink color.

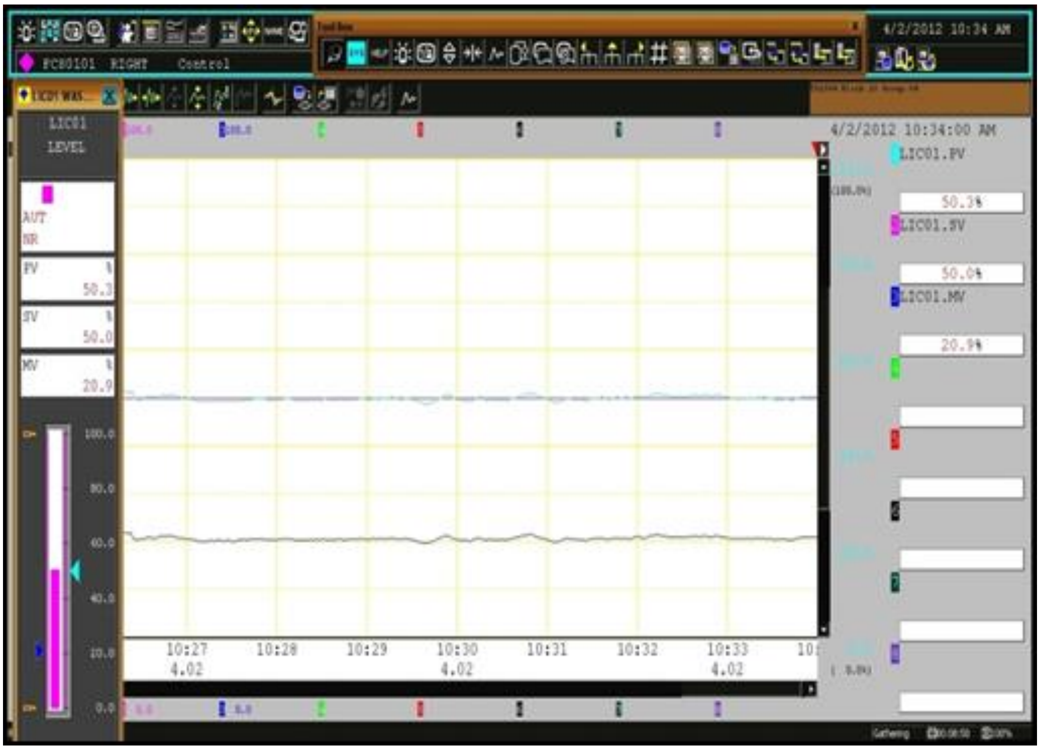


**Fig 7**

## IV. PROTOTYPE DESCRIPTION

The process at CPCL is partially implemented in the prototype. The block diagram of the process is shown in Fig. 8. An Electrical furnace is used instead of the fuel furnace. The furnace temperature is read by the thermocouple inserted into the furnace. The inlet flow is measured by the use of Force sensitive resistor. These values are conditioned using the signal conditioner and converted into digital data by a PIC microcontroller. It is interfaced with the PC through a RS232 cable. These analog data are given to another PIC microcontroller to implement the control scheme with Embedded C program. The output of this PIC is given to a switching device which controls the power supply to the Electric furnace. If the temperature of the furnace is higher than the set point, then the power supply is stopped and is resumed when the temperature is below the set point. The temperature value is scaled down depending on the inlet flow value. These data are monitored in the PC Visual Basic front panel. The distillation column process is simulated in the Visual Basic program in the PC. It is implemented as a open loop process. The tray level and tray temperature values are obtained from a trimming potentiometer and a thermistor respectively. These values control the flow from the collecting tray in the simulation. This is programmed in the VB software.

The power supply unit consists of Transformer and Bridge Rectifier. Dual power supply is used as op-amp requires +12V power supply and +5V for embedded circuit.

Signal conditioner is used to condition (Amplify and filter) the signals obtained from the sensors. Operational amplifier IC741 converts the non-measurable voltage (20mV) into measurable voltage (5V).A vertical type Trimming Potentiometer (type 3296) is used for Zero and Span adjustment. For zero adjustment TRIM POT 103 is used and for span adjustment TRIM POT 104 is used. An Integrative capacitor (1μF, 250V) is used for filtering as discharging is quick. Respective Signal conditioners are used for Thermocouple and FSR.

ISSN 2393-8471

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 4, Issue 2, pp: (10-19), Month: October 2017 – March 2018, Available at: www.paperpublications.org

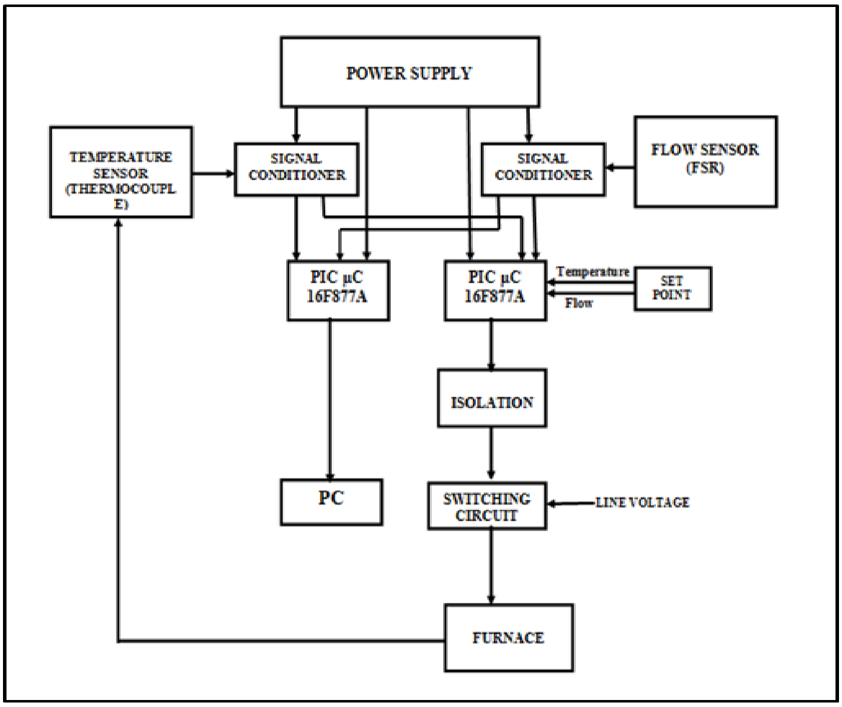


Fig 8

**Thermocouple (type k):**

This is the most common thermocouple type that provides the widest operating temperature range. Type K thermocouples generally will work in most applications because they are nickel based and have good corrosion resistance. Composed of a positive leg, which is approximately 90% nickel, 10% chromium and a negative leg, which is approximately 95% nickel, 2% aluminum, 2% manganese and 1% silicon. It has a range of -270 °C to 1260 °C and an output of -6.4 to 54.9 mV over maximum temperature range.

**Force sensitive resistor:**

A force-sensitive resistor (alternatively called a force-sensing resistor or simply an FSR) has a variable resistance as a function of applied pressure. When external force is applied to the sensor, the resistive element is deformed against the substrate. One of the most common circuits implemented to utilize an FSR's output is the voltage divider. A voltage (usually +5 V) is applied to one of the leads, while the other is grounded. In this way the FSR is able to measure the "voltage drop across a resistor". We use FSR to measure the inlet of water to the furnace. The flow applies pressure on the sensor and we obtain the flow value in terms of resistance. It is used due the unavailability of a cost efficient flow sensor.

**PIC 16F877A MICROCONTROLLER:**

Embedded C language is used for programming the PIC 16F877A. MPLab IDE version 8 is the toolset for the development of the program in the PIC microchip. The program is compiled and dumped into the chip. The control algorithm is written and the program is complied in MPLab IDE.

**Features of PIC16F877A**

- High-Performance RISC CPU
- Lead-free; RoHS-compliant
- Operating speed: 20 MHz, 200 ns instruction cycle
- Operating voltage: 4.0-5.5V
- Industrial temperature range (-40° to +85°C)
- 15 Interrupt Sources
- 35 single-word instructions

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 4, Issue 2, pp: (10-19), Month: October 2017 – March 2018, Available at: www.paperpublications.org

**SERIAL COMMUNICATION:**

**RS232**

RS-232(Recommended Standard 232) is a standard for serial binary single ended data and control signals connecting between a DTE (Data Terminal Equipment) and a DCE (Data Circuit terminating Equipment).It is commonly used in computer serial ports.RS-232 standard is equal to IEEE standard for transmitting serial data without loss up to 50 feet with less thickness cable of low cost.

**MAX 232**

The IC MAX232 is used, which acts as an intermediate between the embedded circuit and PC. It is used between the TTL logic and CMOs logic. The conversion of (0 to +5V) to (-10V to +10V) is known as voltage doubler. And the conversion of (-10V to +10V) to (0 to 5V) is known as VOLTAGE DIVIDER

**SWITCHING CIRCUIT:**

**TRIAC**

Triode for Alternating Current (TRIAC) will conduct current in either direction when it is triggered ON. TRIACs can be triggered by either a positive or a negative current applied to its *gate* electrode. Once triggered, the device continues to conduct until the current drops below a certain threshold, called the holding current. The bidirectionality makes TRIACs very convenient switches for AC circuits, also allowing them to control very large power flows with milliampere -scale gate currents. OPTO TRIAC MOC 3041 is used for isolation and TRIAC PT136 is used in the circuit.

TRIAC is used instead of Relay

- TRIAC saves power
- No power failure
- Response time is quick
- More life time

A SNUBBER circuit is used where the resistance and capacitor are connected parallel to load, to remove the noise from the AC line.

**SOFTWARE DESIGN AND DEVELOPMENT**

The software development consists of 2 MODULES

- PIC 16F877A programming using Embedded C
- Simulation using VISUAL BASIC

In the PIC 16F877A module the PIC microcontroller is configured using program developed based on the requirements using MPLAB development platform.

**PIC PROGRAMMING**

**Program algorithm**

1. Start.
2. Assign X0, X1 and X2 as analog inputs.
3. Assign port D (RD0) for digital output.
4. Declare a function for delay.
5. Check for the conditions.
6. End.

ISSN 2393-8471

International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)
Vol. 4, Issue 2, pp: (10-19), Month: October 2017 – March 2018, Available at: www.paperpublications.org

**Flowchart**

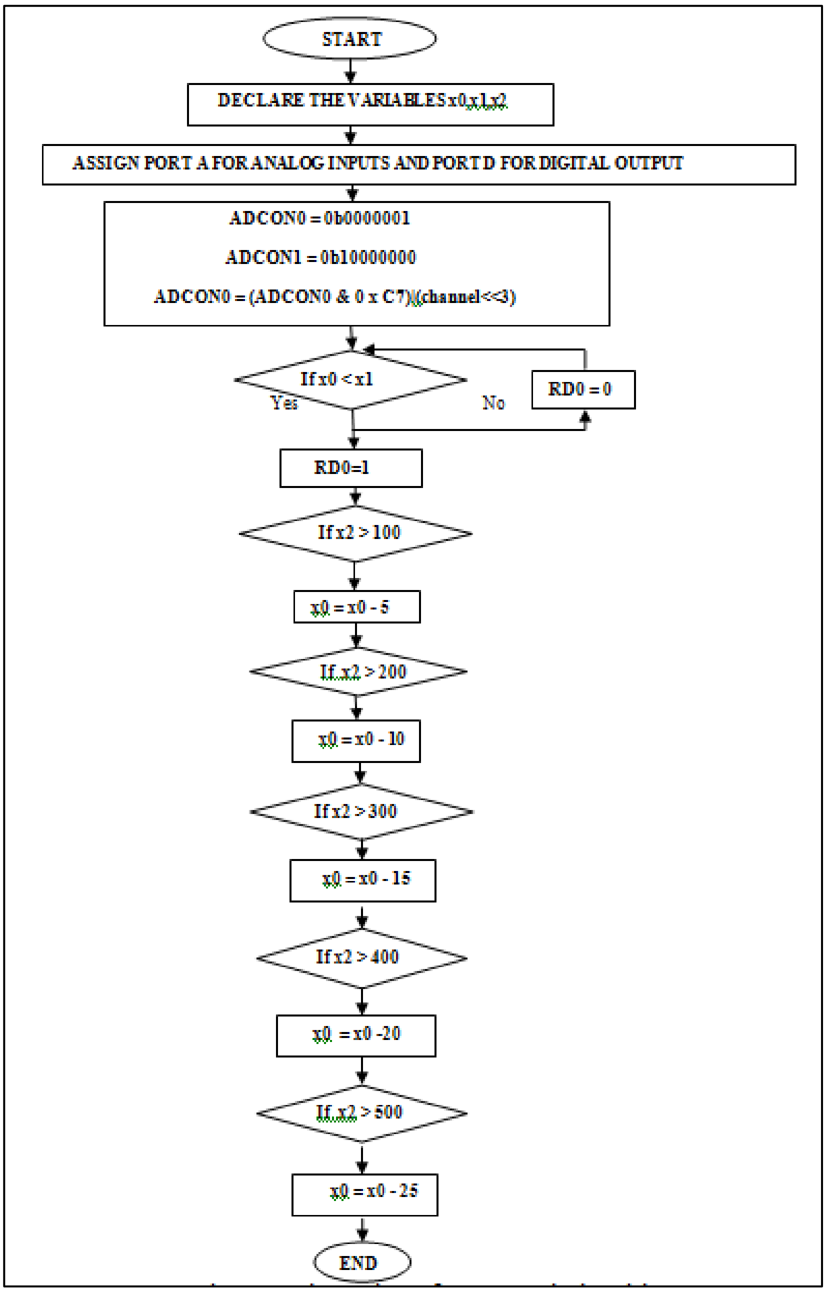


**Fig 9**

The flow chart shown in Fig 9 explains the control program of the PIC microcontroller. The analog values of the Thermocouple sensor, Variable set point of temperature and FSR sensor are assigned to the variables x0, x1 and x2 respectively. Port A is allocated for analog inputs and Port D for digital outputs. The delay function for the program is declared. Also the function for analog to digital conversion is declared.

The conditions for temperature are checked. If the thermocouple output is greater than the set point, then the pin 19 of the Port D will be high (This pin is connected to the switching circuit which controls the power supply to the electric furnace). If the thermocouple output is lesser than the set point, then the pin 19 of the Port D will be Low.

The temperature value is scaled according to the value of the FSR sensor. If the flow value exceeds a certain set value, the temperature is reduced by 20%. Thus the temperature is shown to be in ratio with the flow value.

**VISUAL BASIC PROGRAMMING:**

Visual Basic software v6.0 is used. The whole process diagram is shown as the front panel in the simulation with international standards symbols and colors. The program is written separately for the process and the Database. The channels are assigned to each channel of the ports in the PIC microcontroller.

In the furnace part, the input parameters such as inlet flow, oil flow and gas flow are indicated. The outlet temperature obtained from the electric furnace is indicated. In the distillation part, the tray temperature and tray level are indicated. The set points are given for tray temperature, tray level, boiler temperature and inlet flow. Graphs are plotted for inlet flow, outlet temperature, tray temperature and tray level with respect to time.

When there is a failure in thermocouple, the thermocouple is disconnected from by the electric furnace and it is indicated.

## V. CONCLUSION

Control scheme for furnace and distillation column has been designed and tested using DCS at CPCL. The feedback and cascade control are implemented in the existing control scheme at CPCL. The fluctuations are found to be reduced.

In the prototype, the furnace is turned on when the temperature becomes low and it is turned off when the temperature becomes high. This condition is implemented by using ON-OFF controller. The inlet flow and the outlet temperature of furnace are controlled by a control algorithm which is programmed to PIC Microcontroller using Embedded C language. The fuel oil and fuel gas flow are controlled by a ratio so as it should be complementing each other. The distillation column part is an open loop process which is simulated in Visual Basic. When the tray level of distillation column exceeds a certain level, water is pumped out. When the tray temperature becomes high, the tray temperature is maintained by recycling the water. Thus the tray level and tray temperature are maintained.

## REFERENCES

[1] *Embedded Temperature Monitoring and Control Unit* **Author(s):** Balraj, A., Sch. of Interdiscipl. Sci. & Technol., Int. Inst. of Inf. Technol., Pune, India, Patvardhan, A.; Renuka Devi, V.; Aiswarya, R.; Prasen, V.

[2] *An application of temperature controlling* **Author(s):** Akgun, B.T., Dept. of Control & Comput. Eng., Istanbul Tech. Univ., Turkey

[3] *Chemical Process Control: An Introduction to Theory and Practice* by George Stephanopoulos

[4] *Embedded C programming and the microchip PIC* by Barnett Cox and O'Cull

[5] www.msdn.microsoft.com

[6] www.wikipedia.org