Advance control application in crude distillation

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Distillation columns are designed to separate their feed to its components-based on their boiling points variance. For example, methanol/water separation, separation of different alcohols and/or separation of different acids.

The working conditions of the distillation tower are the outcome of the physical properties of the materials to be separated.

The working pressure governs the boiling temperatures of the components which form the temperatures profile within the column.

In the Crude Oil case, the time gap between the changes in process conditions (pressure, temperature profile and products flow rates) to the actual feed back of these changes on the products quality, is measured in many minutes or even hours. The reasons for this long time gap are the size of the items involved, the measuring elements in real time and/or the human factor, if the results are produced by off-line laboratory tests. The special problems involved in the Crude Oil distillation are the results of:

1) The crude oil is a mixture of many components with many similar properties. The products are cuts, different in their boiling ranges and usually there is an overlap between neighbor cuts ("Distillation Tails") .
2) The composition of the mixture called "Crude Oil" and hence various products quantities, is not always the same and depends strongly on the crude origin. In addition to this, we have to consider the fact that the crude unit feed is very seldom a "pure" one kind of crude and it usually is a mixture of whatever is available from the tank farm.

The main task of the crude unit is to produce products that comply with certain codes and specifications such as "summer gas oil", "winter gas oil", "kerosene", "light naphtha", etc.

Each property appearing in the specification was matched with the appropriate controlling force and the dynamics of the process were studied. Among other things, the time lag in the processes and the gain of these were measured, using known identification techniques.

The control targets are properties such as "cloud point", "freeze point", "90% Distillation point" and any other property which is measurable. For all of these properties on-line analyzers were installed.

The following targets to control forces were chosen:

1) The amount of heat supplied to the tower is controlled by altering the furnace outlet temperature. This also influences the "distillation tails".
2) The pressure level determined the boiling ranges and the temperatures along the

column.

3) The temperature profile is controlled by the pump around (P.A.) streams.
4) The quality control of the products is made by changing the off take rates. Higher rate leads to heavier product and vice-versa.

The control policy is carried out in two levels:

1) the basic level which involves data acquisition and continues control like approach on:
   A) Inlet temperatures to the column.
   B) Pressure level in the column.
   C) Pump around flow rates.
   D) Products off take flow rates.
   This is done in the TDC2000 system
2) On the higher level, a cascade control is applied by a process control computer (PMX II) and is involving advance control missions and optimization tasks such as:
   A) Controlling the percentage of products off-take based on the crude feed.
   B) Changing the products percentage Set Points' as required, in order to keep the relevant trays at desired temperatures.
   C) Changing the temperatures on the trays to make the analyzers outputs match the specifications of each and every product (see detailed discussion).
   D) Changing the proportional heat load per pump-around loop to make the separation better.
   E) Minimizing the furnace outlet temperature according to the crude type and known practical assays to achieve just enough overflash.
   F) Changing the pressure level in the column with the changing weather conditions and changes in the crude feed properties.

Adaptive control of plate temperature to meet the specifications.

While studying the dynamic behavior of the process, very long lags were observed. The time from change in off-take flow rate to first change in product quality, is in the order of magnitude of an hour. Total time to steady state is like two hours.

From the beginning it was obvious, that using usual "PID algorithm" would be pointless.

Besides the long dead times, there are the problems of constantly changing process and environmental conditions and in particular the changing of crude type.

To overcome these problems, the product quality (analysis) is related to the plate temperature as a polynom of n^{th} order. (First degree is being used):

$$Y = F(T)$$

Where

Y - Current analysis (at the sampling point)

T - The plate temperature when the current product "was there".

A long vector (more than two hours in timed intervals) of temperatures is kept in the computer memory and the appropriate one is used. The time lag is estimated from the product flow rate.

$$\Delta t = \frac{V}{F} \times 60$$

Where

Δt - Time lag (min)

V - Volume of system (m3)

F - Product flow rate (m3/hr).

The polynom coefficients are recalculated using new information gathered and dropping the old. This way the model is being adapted to the actual changing conditions of the process.

When the polynom coefficients are available, the Set Point for the temperature controller is found by solving for:

$$x = f^{-1}(Y)$$

Where

Y - The quality set point (the desired analysis).

X - The temperature Set Point.

Validity checks are applied and the rate of change is limited.

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