COMPLETED AND ONGOING R&D PROJECTS

Modeling and advanced control of amine treating unit (Completed)

Refinery gases are treated in the Amine Unit to remove acid gases such as H2S and CO2 as a pollution control measure. These gases react with Alkanolamines (MEA, DEA etc.) in the Absorber column and the regenerated amine from the Stripper column is recycled. The stripped H2S is further treated in a Claus unit for production of elemental sulfur.

· Steady state models have been developed for both the Absorber and Regenerator columns following a transport phenomena based analytical approach. The models have been validated against plant data. These models are good for rating the performance of the columns and also for optimization. These models also provide the initial conditions for integration of dynamic models.

· Dynamic models for the two columns suitable for controller design and rating have also been developed.

· A single variable Quadratic Dynamic Matrix Controller (QDMC) has been developed which also takes into account constraints on manipulated and controlled variables. The controlled variable is H2S content in sweet gas with amine flow rate as the manipulated variable and sour gas composition, its flow rate and temperature as disturbances for the Absorber column. For the regenerator, H2S content in lean amine was the controlled variable to be manipulated with steam flow rate to the reboiler.

· The entire software package has a GUI (Graphics User Interface) which is user friendly. The package can be implemented online as well as used for training.

Simulation and online optimization of a crude distillation unit (CDU) (Completed)

A GUI (Graphics User Interface) supported package was developed which has the following:

(i) Steady State Simulator including

An equilibrium stage based steady state nonlinar analytical model with an efficient and robust solution procedure.

A thermodynamics package for estimation of VLE data empirically. A single correlation allows accurate prediction of equilibrium constants in the entire range of boiling points. This allows a drastic reduction in computations required to solve the model equations. Use of analytical derivatives further reduces computation time while using Newton-Raphson type of algorithm.

Numbering of the stages in the side strippers vis-à-vis the main column in a certain fashion was found to reduce computations significantly as compared to the conventional numbering.

(ii) Model Tuning

For using the steady state model for online applications the following are required:

Nonlinear estimation of model parameters, which, for the present case are stage efficiencies. These must be evaluated before embarking on the use of the model for any online application.

The parameters estimation itself is a nonlinear constrained optimization problem. This ensures that the model is in “tune” with the plant.

For crude petroleum, the exact composition is seldom known in terms of its constituents and usually a representative True Boiling Point (TBP) curve which is a boiling point vs volume percent distilled plot is used to characterize it. However, the crude composition and hence TBP curve is known to vary because of contamination with other crudes, and stratification in storage tanks etc. This requires that the TBP curve should also be “tuned” in order to be able to predict the product properties correctly.

An online TBP backcalculation procedure has been developed and built into the tuning algorithm. This makes use of some easily measurable operating column temperatures and other conditions similar to those required for efficiency tuning.

(iii) Product Properties Prediction

In order to exercise effective feedback control of CDU, it is important to know, online, the “quality” of the products. The quality is usually specified in terms of certain properties such as specific gravity, Reid vapor pressure, Flash point, Pour point, Recovery at 366oC and some ASTM temperatures etc. None of these properties are measured online, mostly because of lack of availability of hardware sensors suitable for online measurements. Most refineries, therefore, resort to “cut point” control which is a unsatisfactory measure of the said product properties.

In the present investigation “software sensors” were developed, semi-empirical or blackbox (Artificial Neural Network based) type which have the capability to predict the desired properties online thus facilitating true feedback control. This package has been used for online optimization at the supervisory level.

(iv) Supervisory online optimization

An economic objective function was constructed to be maximized subject to all the operating constraints and model equations using a chosen set of operating parameters as manipulated variables. Product withdrawal rates from the side-strippers, pumparound flow rates, coil outlet temperature (COT) and steam flow rates formed a typical list of manipulated variables. The lower and/or upper bounds on the product properties within which those were desired were suitably incorporated into the objective function. The optimization results (manipulated variables) provided the set points for the advanced control layer in the hierarchy. The objective function value was a measure of additional profit that will accrue if the optimized conditions were implemented. It simultaneously ensures that the product quality will be within prescribed bounds when the column is operated at optimized conditions.

On-line Estimation of Product Properties for Crude Distillation Unit (CDU)

The stringent quality requirement of petroleum products in a highly competitive market makes on-line monitoring and control of product properties essential. But unfortunately few on-line hardware sensors are available and these are also difficult to maintain. It is, therefore, necessary to develop ‘software sensors’ to predict the product quality using other easily measurable secondary variables.

An algorithm has been developed that uses the crude true boiling point (TBP) curve and other routinely measured flow rates, temperatures and pressures in the CDU to predict the product properties. The measured top distillate and side-stripper draw plate temperatures are corrected for hydrocarbon partial pressures to obtain equilibrium flash vaporization (EFV) temperatures. These product EFVs are converted to TBPs and are superimposed on the crude TBP curve. An assumption, that the initial boiling point (IBP) of the next heavier product lies vertically below the final boiling point (FBP) of the product under consideration and the two points are equidistant from the crude TBP curve, allows estimation of the IBP and FBP temperatures of all the distillate products. A straight line approximation of the product TBP curve is used to obtain intermediate temperatures.

These TBP temperatures are converted to product ASTM (American Society for Testing Materials) temperatures which are correlated with the desired product properties.

Several properties have been predicted using the above procedure. These include densities of all the CDU products, Flash points for all the side-stream products, Reid Vapor Pressure (RVP) for the distillate, Freeze point for kerosene, Pour point and the recovery for the gas oils etc. It is possible to complete all the calculations in 30 to 40 secs on a PC which means that this algorithm can predict these properties repeatedly every minute as long as steady state conditions prevail in the CDU. The algorithm ha been applied off-line with the available on-line data from two different refineries. A satisfactory match between the predicted and the measured properties validated the developed soft sensors. However, extensive testing is recommended before the implementation of this soft sensor on the actual process.

Online steady state Identification, Gross Error Detection and Data Reconciliation for Industrial Process Units

Steady state is one of the basic assumptions in the model development for process monitoring and optimization. It is equally important that any gross error that may creep in the data is detected and corrected. The random measurement errors also need to be accounted for through data reconciliation before online data can be used for process monitoring and/or online optimization.

Various steady state detection techniques are available in the literature and one amongst them, which suits online application, is by Cao and Rhinehart. This method is based on computationally efficient way of calculating variances by two different methods and checking the ratio of the two for steady state identification. This technique requires judicious selection of three filter constants. The present study exploits the interplay between these three constants to obtain the estimate which would help in reducing both Type I and Type II errors and at the same time facilitate earlier detection of both steady as well as unsteady states. The factors which affect selection of the filter constants such as sampling frequency, the extent of autocorrelation present between successive data, the number of data averaged, the variance associated with the measurements and the extent of the process drift which should be considered in the steady state regime are included in the algorithm to get the optimal set. For systems where conventional gross error detection methods such as generalized likelihood ratio are not applicable, a simple algorithm has been developed which makes use of past measurements and Kalman filter to detect the presence of gross error and estimate its magnitude. This algorithm simultaneously reconciles the data for random measurement errors without having to use an optimization technique.

This method has been applied to a crude distillation unit (CDU). Some of the tray temperatures, which are sensitive to all sorts of disturbances, were chosen for steady state detection. The algorithm was able to track all unsteady state efficiently and at the same time small drifts remained undetected and undisturbed. If one assumd that the initial steady state measurements are free of gross errors, then the present algorithm was able to detect gross errors in all the measurements in the CDU.

Online inferencing and optimization of diesel blending operations

The objectives of this work are as follows:

I. to estimate the required properties online for all the input streams using software sensors. The properties are

· density

· flash point

· pour point

· recovery at 366oC

· sulfur content

· total sediment

Typically 12 to 15 streams are blended into the diesel pool withdrawn from atmospheric and vacuum crude distillation units, fluid catalytic unit etc.

II. to develop blending correlations to predict the properties of the diesel pool from individual stream properties.

III. to carry out online optimization of the blending operation (maximize profit) subject to the product meeting all the prescribed specifications· constraint of availability of each stream blending correlations