Are there alternatives to an expensive overhaul of a bottlenecked flare system?

Changes in regulation or the revamp of an existing plant need not require an upgrade to a refinery's flare system configuration

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There are various situations in which it is necessary to re-evaluate the capacity of a site's existing flare system. In general, re-evaluation follows a potential increase in flare load; for instance, when:
- Relief valves that currently blow to air need to be connected to the flare header
- Changes in regulation redefine the scenarios for which the flare system has to be designed
- A new plant is connected to the existing flare header
- An increase in throughput or a revamp of an existing plant might increase the flare load through higher hold-up or higher heat load.

There are other situations that are unique to specific sites, but all of them seem to have only one solution when the capacity of the site's flare system is reaching its limit: a capital project to increase its capacity.

Nevertheless, an effective alternative is available before an increase in the site's flare capacity is considered. This alternative is based on the fact that most flare systems are designed on over-conservative assumptions and steady-state calculations for determining the flare load from the process units. Therefore, these flare systems might show additional capacity when analysed with a more adequate method that considers the dynamic effects of any release to the flare system. This alternative method is dynamic process simulation, which has also been recommended in the latest API guideline:[1]

"Conventional methods for calculating relief loads are generally conservative and can lead to overly sized relief and flare system designs. Dynamic simulation provides an alternative method to better define the relief load and improves the understanding of what happens during relief."

This article gives an overview of the advantages of the approach, guidance on when and where to apply it, and describes a case study of a recent study at BP's Lingen refinery in Germany.

Simplified methods for complex phenomena

Most events inside process units that lead to the opening of a relief valve are of a dynamic nature and lead to a relief load profile that shows a peak when the relief valves open and a more or less pronounced settling curve. This curve, as well as the pressure curve inside the process unit, is the result of many overlaid, non-linear phenomena inside the process unit. Any attempt to linearise these phenomena underrates the dynamic aspects of the event. Conventional calculations use such a linearised approach and apply large safety factors to counteract the effects of simplification. This, in return, leads to the over-design mentioned in the API guideline cited above.

Dynamic process simulation

When applying dynamic simulation, it is possible to create a detailed model of the process unit and the dynamic phenomena that occur during the relief event. Therefore, it is possible to develop a realistic understanding of the overall relief behaviour of the process unit. The advantages of applying dynamic process simulation for relief load studies compared to the conventional mass and energy balance approach are:
- Better estimation of maximum flare load
- Better assessment of simultaneity of different peaks
- Analysis of effectiveness of planned measures, such as control and SV resizing.

Better estimation of maximum flare load

Applying dynamic simulation generally leads to a more realistic estimation of the maximum flare load from a process unit in an emergency situation; for instance, fire or power failure. This is due to the fact that dynamic simulation considers many phenomena that are not considered in the more conventional methods. Examples of these phenomena are:
- Thermodynamics of the system during each step of the scenario, and not only at the beginning and the end. Therefore, complex phenomena that have a significant effect on the results, such as evaporation of lighter components and its effect on physical properties, are considered
- Time-dependent effects of contributors to the pressure increase, such as valve closing times, control system action and limited steam availability
- Effect of cascade relief valves on the maximum flare flow.

As the API guideline states, in general, applying dynamic process simulation will result in lower estimates for the maximum flare

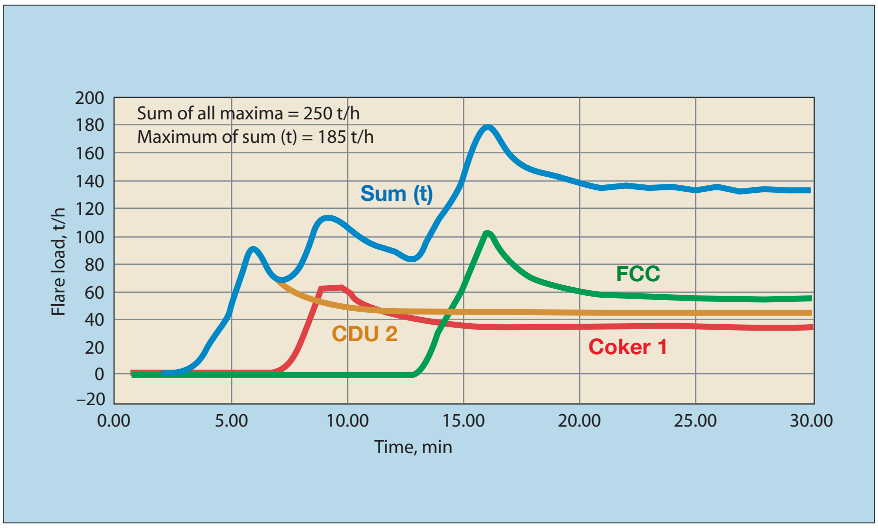

Figure 1 Simultaneity effects of a number of process units

load compared to conventional methods. Nevertheless, there could be situations where dynamic simulation could lead to a higher maximum peak flare load than the maximum average flare load calculated with conventional methods. This is an important aspect to consider when authorities base their operating permission for the plant on the maximum peak flare load.

Better assessment of simultaneity of different peaks

By estimating the flare load entering the flare system as a function of time, it is possible to predict potential simultaneity effects from different flare units. This information could be used to calculate cumulative flare load curves from different flare units. The application of simultaneity factors can therefore be omitted. Figure 1 shows the cumulative flare load curve from three process units. The maximum value of the cumulative curve is significantly lower than the sum of the maximum flare loads of each of the process units.

Analysis of effectiveness of planned measures

Measures to reduce the flare load in an emergency situation can be tested using the dynamic model of the process unit. Therefore, it is possible to test different safety concepts and to understand what is the maximum time allowed for control actions to take place.

When to apply dynamic simulation

As a result of the potential benefits of reducing investment in the flare system compared to the relatively small investment in the dynamic simulation project, this type of approach should be applicable to most flare projects. In order to ensure its feasibility, it is appropriate to analyse the potential benefits that a more accurate estimation of the flare loads during emergency scenarios could bring. These benefits could come from different sources. Examples include:

- Remove the need for a flare system extension when the flare system is bottlenecking plant extensions
- Reduce the cost of measures for flare load reduction. For instance, use standard control circuits instead of high-speed controllers
- Remove the cost of demanding new operating permissions.

Investment in the dynamic simulation study can be assessed by adding up the efforts that are involved in collecting plant data, developing the dynamic model, carrying out the validation of the model, and running and analysing the test scenarios — all in all, an easily predictable cost with relatively low risk.

Case study

In 2008, BP Lingen Refinery carried out a successful dynamic simulation study to determine the flare load of its Rohöldestillation 2 (RD2) crude unit for the case of a general power failure. For this study, BP Lingen selected BP Refining Technology for technology advice and Inprocess Technology and Consulting as the dynamic simulation experts to carry out the study.

The objective of this study was to analyse the effects of a planned increase in throughput on BP Lingen's RD2 crude unit on the maximum flare load, in the event of a general power failure. The throughput for this study entailed an increase of almost 6%, and the necessary crude furnace fired duty assumed an increase in parallel by 33%, including provision for a fouled preheat train.

The maximum flare load of the RD2 had been calculated in previous studies by engineering contractors, based on a simplified conventional approach, including the application of steady-state mass and energy balances, and security factors.

Project description

In this study, a dynamic model of the RD2 crude unit was developed using Aspen HYSYS, mostly utilising the standard HYSYS unit operations library. All of the relevant equipment design data, pipe fitting details and plant operating conditions were used while developing this model.

The greatest challenge in this project was the formulation of a fit-for-purpose dynamic representation of the residual heat transfer to the crude in the furnace, located upstream of the column, after the occurrence of the general power failure. A bespoke model was developed to represent the flow and duty dynamics of the furnace. This dynamic model was validated using the available plant data measured during three previous emergency shutdowns in 1999 and 2000.

The steady-state behaviour of the developed dynamic HYSYS model was validated against data from a previous test run, which was accomplished by converging the dynamic model to the required steady-state conditions and comparing the key process variables against the plant data.

After validation, the model was moved to a new operating point with the increased throughput. From this new steady-state operating point, the general power failure scenario was executed. A number of case studies were carried out to study the dynamic pressure rise in the column and to understand transient and settle-out flaring loads.

Results and conclusions

The main results of the dynamic study at BP Lingen were:

- The predicted flare load after the general power failure for increased throughput and increased furnace duty was >50% lower than the flare load estimated by conventional methods for lower throughput and duty
- The stripping steam reduction flow profile to the column after the general power failure has a significant impact on the study results.

In addition, a comparison of the general power failure scenarios with the fouled preheat train (requiring higher furnace heat duty and lower furnace crude inlet temperatures) against the functioning preheat train (requiring lower furnace heat duty and higher furnace crude inlet temperatures) indicated that the proportion of residual furnace heat utilised to vapourise the accumulated crude in the furnace is higher after the general power failure for a fouled preheat train (higher duty). Consequently, the observed furnace exit temperature is lower, indicating a margin for a further increase in throughput without increase in flare load.

BP Lingen is presenting the dynamic study results to the local authorities to prove that the current flare system configuration has sufficient capacity even after an increase in throughput and furnace duty. This study, therefore, will remove the need for any flare system extension, and BP Lingen is now carrying out a similar study for the other crude unit at the refinery.

Reference

1 *ANSI/API Standard 521*, 5th ed, January 2007, ch 5.22.

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