

Avoiding Compressor Surge When Operating Multiple Centrifugal Compressors - Case Study

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The risk of a compressor surge event is higher when there are multiple centrifugal compressors operating in parallel and/or series. This example illustrates how a fast stop in one compressor will cause other compressors to go into surge, something the operators want to avoid.

The typical surge simulation analysis conducted by EPC, or others, does not address the interaction between units, or adequately consider important details in the piping system. For example, the detailed characteristics of Emergency Shutdown (ESD) valve and anti-surge valve must be incorporated in the transient study, since they play a critical role in avoiding surge events.

A valid surge simulation study will identify problems associated with the proposed piping and component selection. It will also guide the facility design team in selecting the right valve size, trim, and locations in the system, and can highlight operating limitations required to avoid damaging upset conditions.

Three Centrifugal Compressors in Parallel

At an existing compressor station, the owner refurbished two existing centrifugal compressors (units 6 & 7) and added one new compressor (unit 8) to a common header having each unit set up to run in parallel. In this case the two existing units were refurbished by one OEM and have a slightly narrower operating map compared to the completely new unit by a different OEM.

The design team defined the piping layout, valve location, and the specific ESD and surge valves; while the OEMs completed a basic surge analysis to verify the transient surge characteristics and surge control components required.

Since the owner was aware of the potential risks associated with possible compressor interaction, Beta Machinery Analysis (BETA) was retained to conduct a dynamic surge simulation of the three units and the related piping system. The scope of work included:

1. Evaluation of recycle system capacity with respect to the compressor wheel map
2. Evaluation of normal start-up and shutdown protocols, along with slow transient analyses
3. Evaluation of ESD/fast stop events on compressor surge, which includes:
 - Fast stop of all units
 - Fast stop of Unit 6 Only, or 7 only, or 8 only
 - Evaluate different valve options and the impact on the system performance

The results from BETA's analysis verified that individual compressor shutdowns (one unit running), and group compressor shutdowns (all three stop at same time) would satisfactorily avoid surge events as the compressors wound down in speed. Figure 1 illustrates the compressor wind down characteristics of each compressor on its respective wheel map; note that the operating point on the respective wheel map does not penetrate the surge line in a station ESD event.

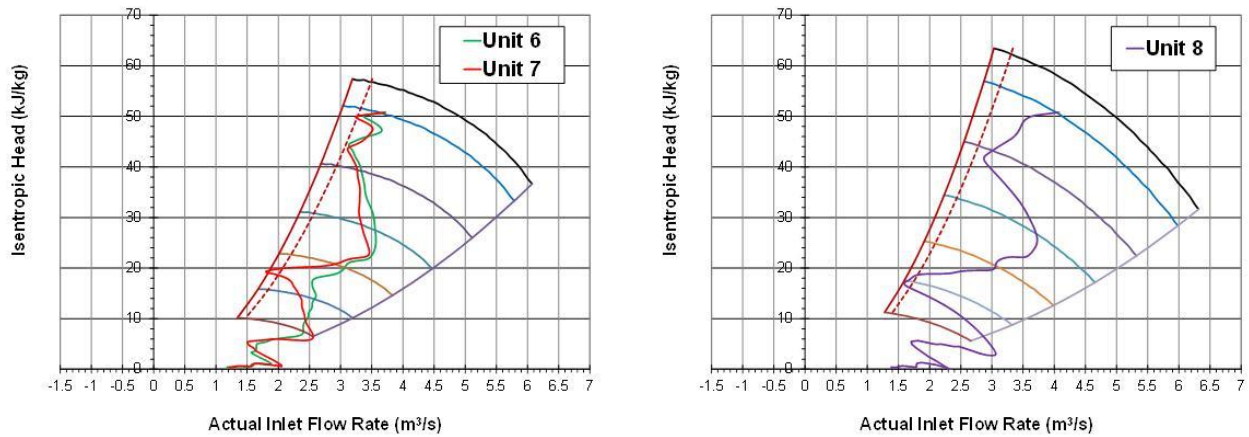


Figure 1: ESD of all 3 units at the same time

However, when BETA simulated the scenario of a unit 8 trip (or fast stop) while all three compressors were in operation, an important design risk with the system design was identified. When unit 8 experienced a fast stop, the resulting effect caused units 6 and 7 to go into multiple deep surge cycles. See Figure 2, which indicates unit 6 and 7 going into surge.

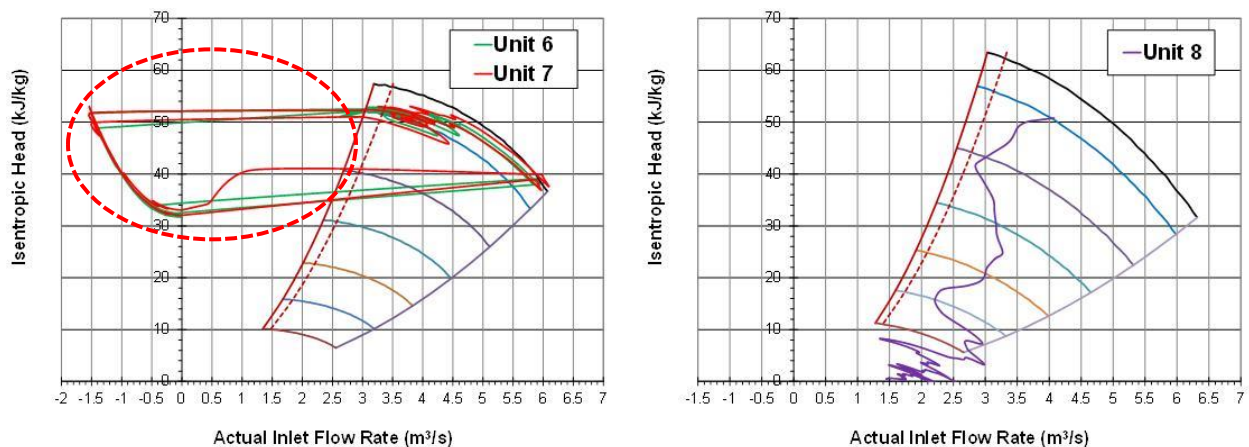


Figure 2: ESD of Unit 8, while Units 6 and 7 are Running (area in circle shows units in surge).

The reason for this specific problem is due to the recycle and surge control valve trim characteristics and differing operating points on each wheel map. BETA evaluated different valves and system modifications to improve the design. Surprisingly, the problem could be resolved with a smaller/cheaper valve than what was previously selected with the original surge design. This change provided improved reliability and operability across all the scenarios.

Conclusions

Simplified transient surge studies are commonly performed for centrifugal compressors. As shown in this case study, the results from these studies do not provide the accuracy required nor do they capture the true dynamics of fast stop events, and can create reliability problems with multiple unit systems. Unfortunately, equipment owners and EPCs are not aware of these accuracy limitations – given the highly technical nature of stability and transient analysis.

To properly assess transient events in the piping system, an accurate transient study scope is required that considers the interactions between units (in parallel or in series). The study should be initiated during the preliminary design stage and then fine-tuned during the detailed design stage. The cost of an accurate transient study is quite low and a minor expense compared to the potential impact associated with poor component selection, and damaging surge events. BETA's experts use a field-proven transient solver (CENTRAN) that offers superior results due to its distributed parameter-based model that incorporates partial differential equations (PDEs) as opposed to ordinary differential equations (ODEs).

BETA Machinery Analysis is a global machinery and piping integrity consultant specializing in vibration design, troubleshooting, and machinery performance.

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