Drive actuation in active control of centrifugal compressors

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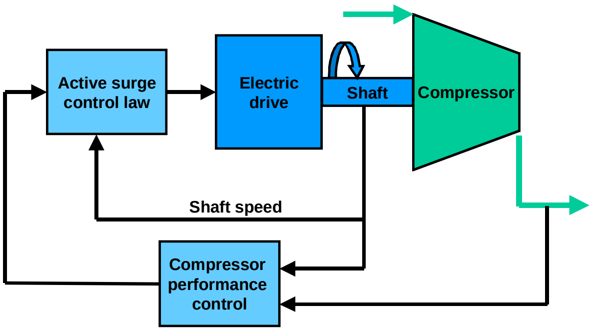

Figure 1: Active surge control using drive

1 Introduction

Traditionally, centrifugal compressor surge has been avoided using surge avoidance schemes that use various techniques to keep the operating point of the compressor away from the surge line. Typically, a surge control line is drawn at a specified distance from the surge line, and the surge avoidance scheme ensures that the operating point does not cross this line. Usually a recycle valve around the compressor is used as actuation. This method works well, as has been proved by numerous installations. However, due to the presence of the surge margin, the method restricts the operating range of the machine, and achievable efficiency is limited. In this study, which is on compressors with electrical drives, we propose to use the electrical drive as a means of active surge control, as depicted in Fig. 1. The advantage of this is that the drive is already present, and no additional actuation device is required. This means that the compressor can be operated at low flows without recycling, and there is a potential for reduced energy consumption of the compressor.

2 Modeling

A Greitzer model with varying speed [1] is used:

$$\dot{\hat{p}} = a_{01}^2 V_p^{-1} (\hat{m} - \hat{m}_t) \quad (1a)$$

$$\dot{\hat{m}} = A_1 L_c \left(\widehat{\Psi}_c (\hat{\omega}, \hat{m}) \, p_{01} - \hat{p}_p \right), \quad (1b)$$

$$\dot{\hat{\omega}} = J^{-1} (\widehat{\tau}_d - \widehat{\tau}_c) \,. \quad (1c)$$

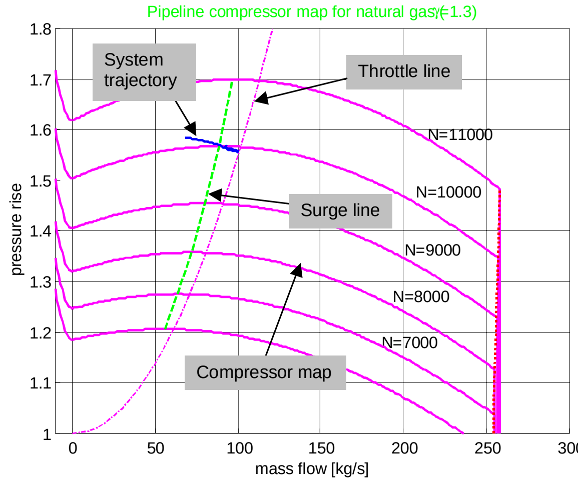

Figure 2: Stabilized operating point using torque.

3 Control

The control is derived in two steps. First, the angular speed, $\hat{\omega}$, is used as control, and then the drive torque $\widehat{\tau}_d$, with its additional dynamics (1c) is used.

Theorem: Using the speed as control, the control law

$$\hat{\omega} = -c\hat{m}, \quad (2)$$

where the gain c is chosen according to $c > \frac{\partial \Psi_c / \partial m}{\partial \Psi_c / \partial \omega}$ makes the origin of (1a) and (1b) globally exponentially stable.

Sketch of proof: Consider the Lyapunov function candidate $V = \frac{V_p}{2a_{01}^2}\hat{p}^2 + \frac{L}{2A}\hat{m}^2 > 0, \forall (\hat{m}, \hat{p}) \neq (0,0)$ .Using (2) it can be shown that $\dot{V} < -k_p\hat{p}^2 - k_m\hat{m}^2 < -kV, \forall (\hat{m}, \hat{p}) \neq (0,0)$ and the result follows.

A simulation of active surge control on a industrial size natural gas pipeline compressor using drive torque is shown in Fig. 2. The complete analysis and additional simulations can be found in [2]

References

[1] J.T. Gravdahl and O. Egeland, *Compressor surge and rotating stall: modeling and control*, Advances in Industrial Control. Springer-Verlag, London, 1999.

[2] ," http://www.itk.ntnu.no/ansatte/Gravdahl_Jan.Tommy/papers/automatica2002.pdf.