Stabilizing slug flow at large valve opening using active feedback control

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Abstract— The threat of slugging to production facilities has been known since the 70's. This undesirable flow phenomenon continues to attract the attention of researchers and operators alike. The most common method for slug mitigation is by choking the valve at the exit of the which unfortunately could negatively production. The focus therefore is to satisfy the need for system stability and to maximize production simultaneously. Active feedback control is a promising way to achieve this. However, due to the complexity of multiphase flow systems, it is a challenge to develop a robust slug control system to achieve the desired performance using existing design tools. In this paper, a new general method for multiphase flow system stability analysis was proposed. Active feedback control was observed to optimize slug attenuation compared with manual choking.

Keywords- Choking, active feedback, slugging, stability analysis, multiphase flow

I. INTRODUCTION

Oil and gas activities in many oil producing nations of the world have shifted to deep offshore. Many of the fields are too small to accommodate a standalone offshore processing facilities. Also many of the existing fields are either in plateau production phase thus it becomes very popular tying production pipelines from satellite fields to an existing pipeline to use common offshore processing facility. The transportation of the produced crude is usually done in multiphase pipelines. In so doing, one of the challenges encountered is slugging. Slugging in oil and gas pipelines is a cardinal problem for all oil and gas producers. It is characterized by large pressure and production fluctuations.

One of the ways of suppressing or eliminating fluctuation due to slugging is by choking. In practice, oil and gas industry have used this method for many years to eliminate severe slugging by manipulating the valve opening at the exit of the riser which unfortunately could negatively affect production [1; 2]. The use of controller however has been reported to be able to help alleviate this problem by stabilizing the system at larger valve opening [3]. Significant efforts have been concentrated on modelling and understanding the slug attenuation mechanism for choking [2; 4] and active slug control [5-9]. These models can be used to gain insight into the mechanism and control design. Nevertheless, these models may not accurately represent real systems due to the complexity of multiphase flow [10-12]. This leaves the robustness of slug control systems designed based on these models questionable. There is therefore the need for a simple but yet robust methodology that can be used for system analysis and controller design. The aim of this study is to develop an approach to slug flow stability using feedback control. To achieve this aim, we propose a new method that can be used for slug flow stability analysis and design a controller for stabilizing the unstable slug flow. A theoretical analysis was attempted to show the slugging mitigation potential of active feedback control at larger valve opening compared with traditional manual choking. This paper is organized as follows: in section II, the new approach to slug flow stability analysis is presented; in section III numerical case study was performed and the work is concluded in section IV.

II. STABILITY ANALYSIS OF SLUG ATTENUATION WITH FEEDBACK CONTROL

In the co-current flow of gas-liquid mixtures through pipeline-riser system, slugging is frequently encountered for wide range of pipe inclinations and flow rates. Severe slugging is a flow regime which can be described as a four stage transient cyclic phenomenon shown in Fig.1. At low flow rate, the liquid accumulates at the riser base blocking the gas flow while the riser column get filled with liquid (slug formation stage), the gas is compressed in the upstream pipeline causing a pressure buildup which later becomes sufficient to overcome the hydrostatic head in the riser thereby forcing the liquid slug out of the riser (slug production stage). This is followed by a gas surge (gas blow out) and the remaining liquid in the riser fall back to the riser base (liquid fall back stage) which again starts the cycle [2]. Severe slugging usually manifests in significant fluctuation of flow and pressure. This instability is as a result of the upward multiphase flow in the riser and compressibility of gas. Due to these two factors, any increment of gas flow can cause two opposite effects on the riser base pressure, positive and negative. The negative effect can make the system unstable if it is dominant.

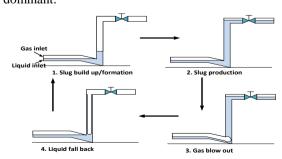


Figure 1. Severe slugging mechanism