Chaotic dynamic induced by PI control in offshore oil production plants.

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Abstract. Several dynamic behaviors exhibited in a representative model of a Petrobras offshore oil production plant were studied, considering both, open-loop operation and closed-loop operation when using a feedback PI control scheme. The present work evaluated three different SISO control scenarios taking into account three controlled variables in order to determine the suppression effect of the oscillatory dynamic behavior raised due to the slugging flow phenomenon. It was observed that in the PI anti-slug control scheme when the pressure at the top of the riser was considered the controlled variable, the dynamics exhibited chaotic oscillations as a function of the PI tuning parameters. The chaotic behavior was characterized and it was determined the control scenarios and tuning conditions that favor the appearance or impression of complex dynamics behaviors.

Introduction

Frequently, floating facilities used for offshore oil and gas production consist of tubing-pipeline-riser systems. Despite this production technology being widely used, it has been observed these production systems are susceptible to exhibiting slugging, a common and undesirable multiphasic flow pattern phenomenon that causes periodic blockage of gas flow due to a large liquid slug accumulation through the riser and pipeline section. These slugging flow instabilities can generate harmful operating conditions leading to process safety losses, process production drop, and even plant shutdown [1].

Several approaches have been developed in order to avoid or remediate problems in pipeline-riser systems due to the slugging phenomenon, including automatic control strategies aimed to change the operating condition that favors the arise of the slugging flow. It is worth mentioning that the major part of slugging behaviors observed in industrial-scale processes and the corresponding phenomenological models described periodic oscillatory dynamics, and more complex dynamics have not been observed in these production scales [2].

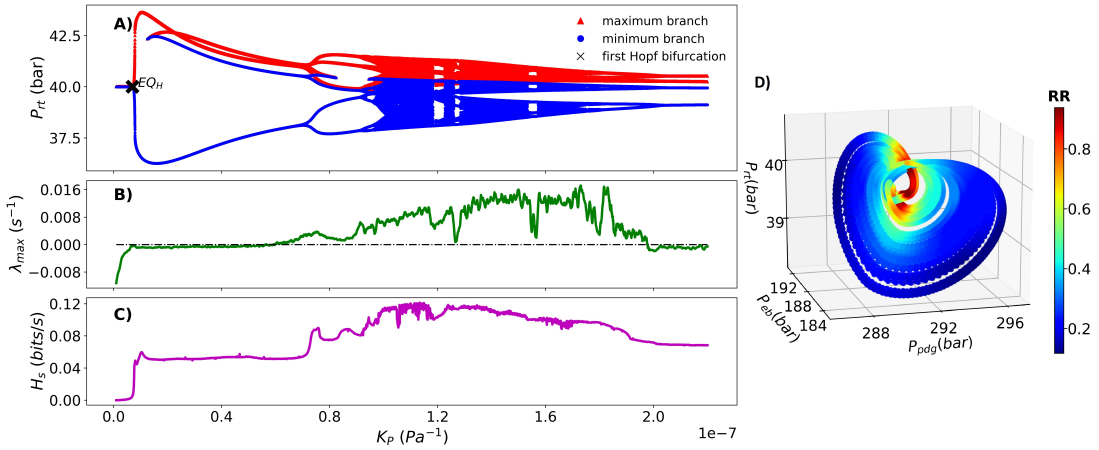

Figure 1: Chaotic behavior characterization induced due PI control action.

Results and discussion

The PI control scheme, applied to the upstream production system represented by the FOWM model [3] aimed to change or suppress the operational conditions that lead to slugging dynamics by manipulating the oil production valve opening. The PI controller suppression effect was measured as the capacity to shift the born location of the Hopf bifurcation to higher valve openings, i.e to higher production conditions. Fig1A shows the bifurcation diagram corresponding to the PI control scenario when the pressure at the top of the riser was the controlled variable. As one can see, the local extrema of the pressure oscillations describe the arising of chaotic behavior as a function of the PI tuning parameter Kp. Furthermore, the characterization of the chaotic behavior is determined by the largest Lyapunov exponent Fig(1B) and the Shannon entropy Fig(1C) criteria. In addition, Fig1D offers a qualitative characterization from a recurrence analysis.

References

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