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STATE ESTIMATION PROBLEM FOR THE DETECTION OF A SHUTDOWN VALVE CLOSURE IN GAS PIPELINES WITH MULTIPLE VALVES

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The undesired and uncontrolled closure of Shutdown Valves in a gas pipeline is among the critical failures that can compromise the supply of gas to consumers, incurring not only on large financial losses, but also on increasing risks in industrial and power plant installations. Shutdown Valves are used in order to isolate parts of gas pipelines if, for example, maintenance is required.

This work presents the solution of an inverse problem for the detection of undesired and uncontrolled closures of Shutdown Valves in gas pipelines, in sections containing several valves. This is an extension of reference [1], where the analysis was restricted to pipeline sections containing one single valve. Remote measurements of pressure, temperature and gas flow rate, taken at two or more measurement stations, are used in the inverse analysis. The inverse problem is solved in terms of a non-linear state estimation problem, by utilizing the Sampling Importance Resampling (SIR) algorithm of the Particle Filter [2-6].

The compressible flow of the gas in the pipeline was considered as one-dimensional and numerically simulated with a software developed in this work, based on the WAF-TVD method [7]. This code was verified with the analytical solutions of different physical problems, including the Rayleigh and Fanno lines, as well as the shock-tube. The numerical solution of the gas flow in the pipeline served as the evolution model for pressure, temperature and velocity of the gas. Uncertainties in such quantities, for the evolution and observation models, were taken as additive, Gaussian, uncorrelated, with zero mean and with standard deviations of 0.6% for pressure, 4% for velocity and 1% for temperature, with respect to their current values. The evolution model for the variable that describes the valve opening ($0\% \leq opening \leq 100\%$) was taken as a random-walk, with a standard deviation of 10%.

The application of the present methodology was examined for test-cases involving 3 or 5 valves, in a natural gas pipeline section with length of 90 km. Figure 1 presents the configuration tested involving three valves in the pipeline section. Figure 2 shows the results for the valve opening, obtained with 1000 particles in the SIR algorithm of the particle filter, for a case where valve 1 was suddenly closed but the other valves remained fully open. Such results were obtained with measurements from two stations near the pipeline ends. This figure shows that, even for large uncertainties in the evolution and observation models, the closure of valve 1 could be accurately predicted. On the other hand, the detection of the closure of valves far from the measurement stations, like valve 2, might not result in a unique solution. In order to overcome such difficulty, measurements of an additional station within the pipeline were required. Such aspects are discussed in the paper, as well as test-cases with 5 valves.

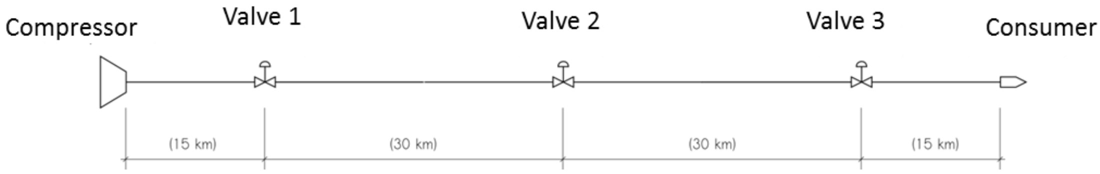

Figure 1. Configuration of the test-case with 3 valves

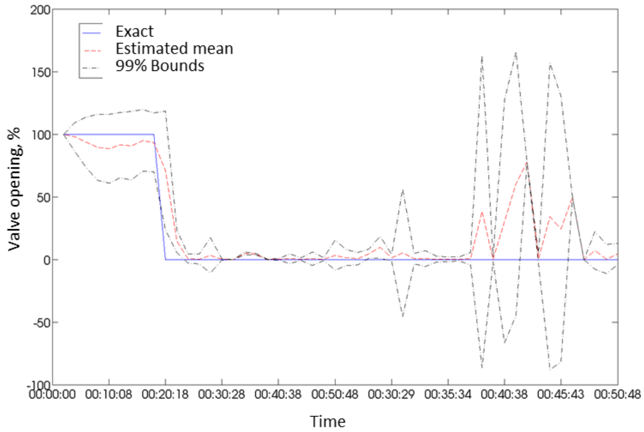

Figure 2. Detection of the closure of valve 1

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