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Measurement of Multiphase Flow of Oil and Gas Using Soft Sensor

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Abstract

This paper presents soft sensor as a multiphase flow meter. Nonlinear observer with Ensemble Kalman filter (EnKF) by Navier Stocks equations for in line flow is used to estimate the oil and gas flow. Finite element method and EnKF are used along two scenarios; in addition, in the first scenario, the estimation is done with the refinery output measurement, and in the second scenario, this estimation is done with the production unit output measurement. In this article, we don't use primary element for multiphase flow measurement, instead of that flow will be estimated using some secondary variables (like pressure, temperature, output single phase flow, phase fraction and etc that can be measured directly with high accuracy). Results of comparison between two mentioned scenarios show that also the estimation with output measurement is not accurate, but the accuracy and repeatability of second scenario (estimation with production unit measurement) is in the acceptable standard range. Thus we can conclude that this soft sensor can be used as a backup for primary system and also as a primary system for multiphase flow measurement.

Keywords: Measurement System, Multiphase Flow, Oil and Gas, Soft Sensor, Nonlinear Observer.

Introduction

Increasing population and limitation of hydrocarbon sources of the world cause more command, and this fact has direct effects over the price of these products. The high price of energy-producing sources such as oil and gas reveals the need of increase in measuring precision of these products [1–3].

The variables and process parameters that are considered by the operators are not always readily available, or for some reasons such that measuring their cost and equipment, or because they are currently not directly measurable due to the weakness of the technology. In this regard, a solution to measure the arbitrary variables is to use the soft sensors to accurately estimate them from measuring other variables. Due to the fact that direct measurement of multiphase flow using existing systems with sufficient accuracy is not cost effective, or in some cases, impossible soft sensors are used. One of the important tools which can be used in this area is the Kalman filter. After the extraction of oil and gas from well, they will receive from the platform which may have preliminary production or be directly sent to gas refinery or petrochemical. Based on the content of outlet flow of well and due to many temperature and pressure change in long distances, the flow will be multi-phase and measuring either in well or the entrance of refinery must measure a multi-phase flow.

Operational System

Most of the gas producing sources are in seas, and due to various numbers of tools, lines volume and several tanks, requiring large area and producing safety in the land these gas refinery are in a great distance from the source of gas producing source and for this reason pressure changes and flow temperature will receive as multi-phase flow and after passing from tools and various processes this multi-phase flow will become two products which are dry gas and Condensate Stabilization and come out of the refinery. A schematic of the multi-phase has flow entrance plus liquid, division of refinery various units an existed measurement are shown in Figure 1.

In this section, the comparison of the simulation results (estimated state variables) and the received information from the actual process is presented. As mentioned earlier, in this paper two scenarios have been used:

In the first scenario: measuring variables based on the input of the refinery. In this method, in addition to the pressure at the various sections of the pipeline, the quality analysis of the input flow is measured.

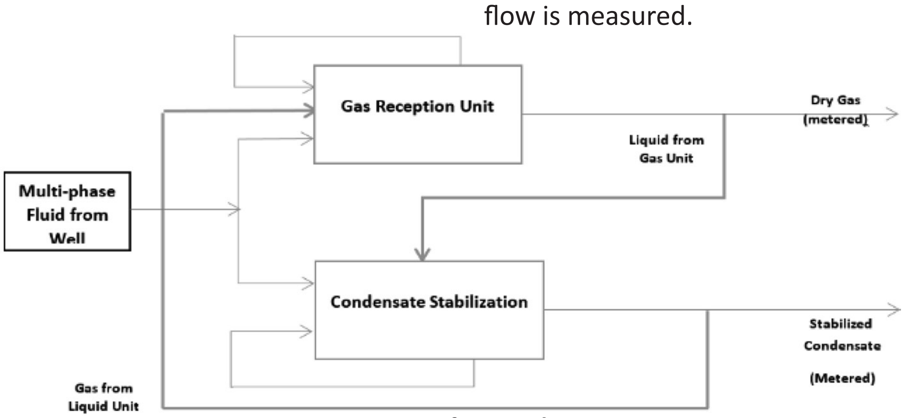

Figure 1: Gas refinery schematic.

The second scenario: measuring variables based on the refinery output which consist of single-phase gas measurements and applying a coefficient greater than 1 that multiplies the output measurements. This coefficient covers the quantities sent to the flare, the fuel of the furnaces and the equipment inside the discharged water, etc.

Dynamic model of this system is extracted from Navierstokes equation [4].

Discussion and Results

In this article, measuring and existed numbers the acquired numbers of one of the gas refineries which obtain its need from POGC platforms are utilized in real and their simulation are performed by Matlab where he results of these simulations are in the following figures. As shown in Figure 3, the velocity based on the soft sensor is equal to 20.08 m/s which corresponds to a volume equals to 171600.09 m^3/day.

The reading of the meter at point meter 2 which measures the dry gas, is 144265.56 m^3/day and the shrinkage factor is (1.13) that covers the fuel consumption, the gas flare, LPG, water content and so on which corresponds to output measurement 163020.08 m^3/day. Figures 2 and 3 illustrate the gas speed, liquid volume fraction and time base liquid volume fraction in node 10. The noise was considered for the Kalman filter is measurement noise and model noise that was considered as white noise with a zero mean average. The variance for model noise (R) is 0.001 and for measurement noise (Q) is 0.005.

Conclusions

In this paper, the EKF was applied to the Navier Stokes model and a comparison was made between the mode of using the whole product measurement in the production unit and the dry gas measurement mode at refinery output. The figures and diagrams are evidence that the simulation results track the actual process and the difference and error is within the aceptable standard range. It is observed that the mean squared error based on the input is about 0.00022 and based on the output is 0.1, which has a very large difference. The mean squared error velocity and volume fraction, both based on the input, are 0.00005 and 0.00065 respectively.

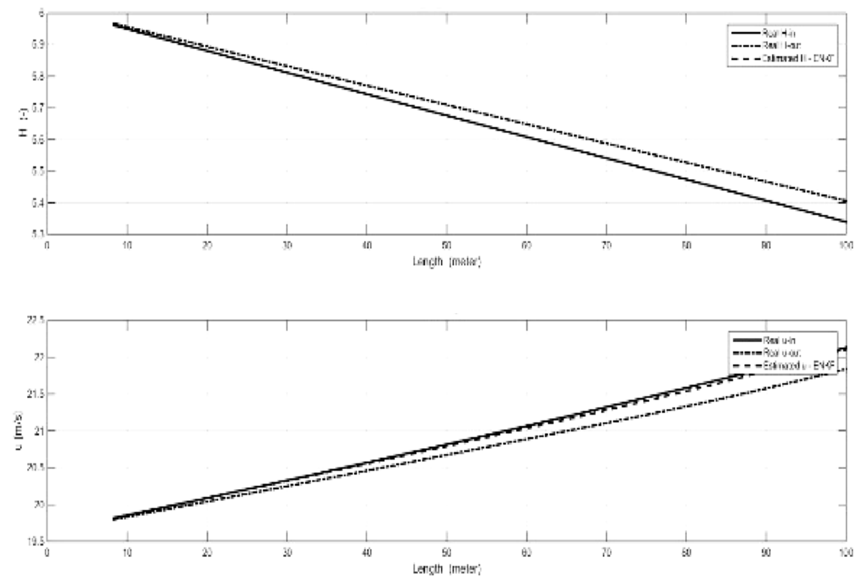

Figure 2: gas speed and liquid volume fraction.

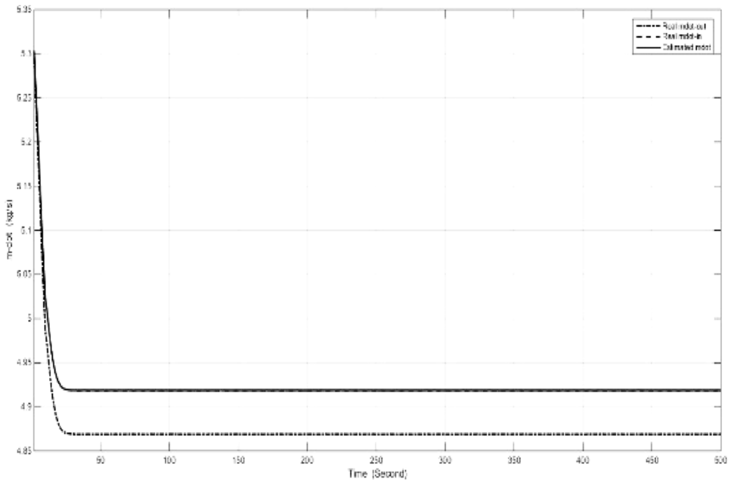

Figure 3: liquid fraction at node 10.

More important, it is a fact that even in reality, the method of measuring the output and applying the coefficient of loss to it and obtaining the delivery amount in the refinery has a high range of uncertainty.

The source of the difference in the results obtained from soft sensor with the actual operational information includes one or more of the following:

1. Correlation of friction factor,
2- Change the characteristics of the fluid,
3. Uncertainty in mathematical model,
4- Inaccuracy in direct measurements, and
5- Incorrectly choosing the correct matrix Q and R correctly.

This means that by reducing the effects mentioned above, we can obtain more precision in the measurement than before. For example, by reducing the uncertainty in direct measurement of parameters and fluid specifications, or the precision in determining the existing matrix, the measurement error can be greatly reduced.

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