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Evolving a prediction model based on machine learning approach for hydrogen sulfide removal from sour condensate of south pars natural gas processing plant

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ABSTRACT

In present study Support Vector Machine (SVM) is employed to develop a model to estimate process output variables of stabilizer column of an industrial natural gas sweetening plant. The developed model is evaluated by process operating data of south pars natural gas processing plant in Asalouyeh/Iran. A set of 6 input/output plant data each consisting of 660 data has been used to train, optimize, and test the model. Model development that consists of training, optimization and test was performed using randomly selected 80%, 10%, and 10% of available data respectively. Test results from the SVM based model showed to be in better agreement with operating plant data. The minimum calculated squared correlation coefficient for estimated process variables are 0.97 for H_2S concentration and 0.94 for Reid vapor pressure (RVP). Based on the results of this case study SVM proved that it can be a reliable accurate estimation method.

1. Introduction

Gas condensate is a valuable liquid hydrocarbon mixture, generated during transmission in rich gas gathering pipelines, which could be utilized as a diluent to heavy crude oil or converted to different petroleum products such as gasoline, jet fuel, etc (Scott and Stake, 2013). The challenge of condensate in its natural form is a design that processes the condensate to a commercially accepted form by decreasing its water, salt and acid contents (i.e. H_2S, CO_2, mercaptans, etc) to the required standards for storage and transportation (Karimkhani and Khorrami, 2009; Ghanbari and Khoshandam, 2014). The vapor pressure of the processed condensate must meet a range within which light components don't evolve as a separate gas phase in pipelines or storage tanks. Thus some sort of condensation stabilization should be considered for the raw condensate in order to comply with the specifications (Moghadam and Samadi, 2012; Davoudi et al., 2014).

Stabilization of condensate refers to the stripping of the light ends content (methane and ethane) from the heavier hydrocarbon gases in order to prevent the production of vapor phase upon flashing the liquid to atmospheric vessels by increasing the dew point pressure of the condensate liquids (Bonyadi et al., 2014). There are two methods to accomplish stabilization of condensate streams: flash vaporization and fractionation. Flash vaporization, a simple operation similar to stage separation, achieves flashing of large amount of lighter ends at the temperature and pressure of separation utilizing the equilibrium principles between vapor and condensate phases. On the other hand, stabilization by fractionation is a more comprehensive process capable of producing liquids of suitable vapor pressure, meeting any kind of specifications with the proper operating conditions in a single tower process that requires external energy source (Mokhatab and Poe, 2012; Bernhardsen, 2012).

Since in condensate are also present volatile sulfur containing molecules, mostly hydrogen sulfide, leading to significant corrosion and appreciable discharges of such lethal gas into atmosphere, the stabilization process includes desulfurization to lower the H_2S content to safe levels (Jensen and Webb, 1995; Chandra Srivastava, 2012; De Angelis, 2012). The main objective of efficient desulfurization of sour condensates is the improvement of environmental

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and safety standards performed several experiments by considering various scenarios to propose a practical procedure for removal of sulfur species. They concluded that the oxidation process which used sulfuric acid as the oxidative agent provided the most efficient procedure (Moaseri et al., 2013; Ghorbani et al., 2014). Deterministic modeling of H_2S removal of condensate requires accurate thermodynamic property prediction of overall process variables whereas statistical models require rich operating database instead.

Reliable accurate models of H_2S removal of condensate allows one to optimize operating conditions thus minimizing operational costs. This is a necessity due to inherent seasonal variations in feed stream and temperature. Attempts to develop such models include those that are based basic principles and those that are data-based using input/output plant data (Ding et al., 2012). Models based on detailed mass and energy balance equations proved to be very complicated and hard to solve especially when coupled with optimization computer routines (Mehdizadeh and Movagharnejad, 2011; Haghbakhsh et al., 2013). Available commercial simulation softwares that are not open-source can be used to perform accurate simulations, however coupling them with optimization procedures is a difficult task to manage. Moreover, the proprietary nature of these softwares is another discouragement to their industrial application. Operating plant data is an invaluable information source that is readily available through programmable logic control systems that most plants are already equipped with.

In this work a SVM based model is developed to determine the output variables of the south pars natural gas processing plant. Section 2 of this paper is dedicated to process description of the stabilization process of condensate in an industrial natural gas sweetening plant. In the third section, the principle and the equations of the support vector machine have been discussed in detail. Section 4 presents preprocessing and normalization of operating plant data. Input/output operating plant data, model parameters and model validation are included in Section 5 that is followed by conclusions in the sixth section.

2. Process description of condensate stabilization

A schematic representation of condensate stabilization process is illustrated in Fig. 1. The gas from offshore enters the inlet receiving facilities at the slug catcher where the primary gas/liquid separation takes place. The liquid from the slug catcher flows to the separator which provides three phase separation: gas, condensate and water. The condensate brought from the inlet separator is preheated in the exchanger and enters the feed drum to provide the feed of the stabilization tower. Depending on whether it is sour, the condensate is fed to the stripper at approximately 50–200 psi. (The low end of this range is required for sour stabilization and the high end of the range for sweet stabilization). The stabilization is carried out in a tray-type reboiler absorber. However, a refluxed distillation tower is preferred to a top feed reboiler absorber in cases of need for better separation. Heavy ends get stripped out of the gas as it goes up from tray to tray and the liquid becomes leaner in light components and richer in heavy components as it falls into the column. Circulation of the liquid through the reboiler provides a series of stage flashes at ever-increasing temperatures by adding heat to the bottom of the tower. The liquids leaving the bottom of the tower must be cooled to a sufficiently low temperature to prevent flashing of vapors to atmosphere in the condensation storage tanks. For large atmospheric tanks, adequate pressure control and venting and vapor recovery systems should be considered. Overhead gas exiting the top of the tower which contains light components is sent to the low-pressure fuel gas system through a back pressure control valve that controls the tower pressure.

3. Support vector machine (SVM)

Support Vector Machine introduced first by Vapnik (Vapnik, 1995), like Artificial Neural Networks (ANN), is a supervised learning method with associated learning algorithm that analyzes data and recognizes patterns of input/output data. In recent years, ANN has been demonstrated to be a substitute for deterministic modeling and estimation methods with good potentials to be explored. However, in some cases it may lead to random initialization of the under development networks and variation of the stopping criteria during optimization of model parameters (Eslamimanesh et al., 2012). Other problems and limitations that ANN approach generally has are also presented as follows (Balabin and Lomakina, 2011):

- Extrapolation is not recommended for ANN approach;

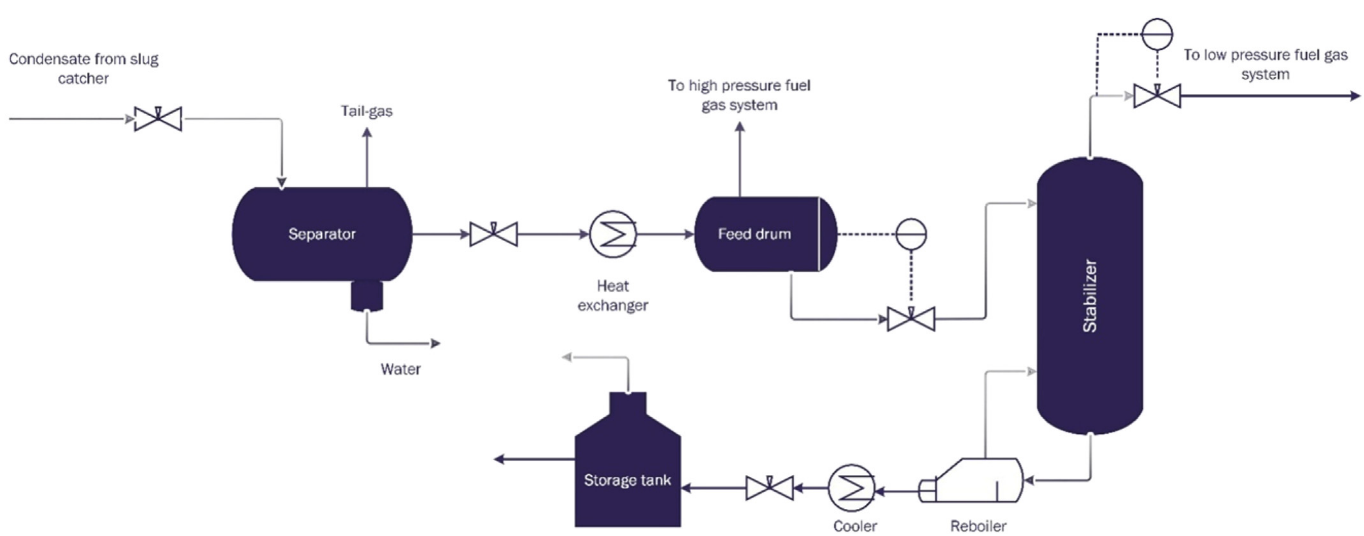

Fig. 1. Schematic of a condensate stabilization process.