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Troubleshooting of crude oil desalination plant using fuzzy expert system

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ABSTRACT

This paper investigates fuzzy troubleshooting of a complex crude oil desalination plant. First, probable plant faults and all the related information were investigated. Then, based on the collected data, proper membership functions and consistent rules were prepared. In the next step of study, the Mamdani fuzzy inference system was utilized. Finally, the proposed expert system was employed to recognize faulty performance of the plant. Comparing the proposed model with plant data, it was found that the proposed system is capable of fast and accurate trouble shooting of the plant. In addition to the trouble shooting, the system can also be used for operator training.

1. Introduction

The difficulty in troubleshooting chemical plants increases with increasing plant complexity. Major damages and negative impacts on both plant's performance and human factors can occur when there is delay in plant decision making. Henceforth, creating an automated supervision that can identify faults precisely in an efficient manner is necessary for safe and economic operation of complex plants. Systematic and consistent troubleshooting reduces operator errors and consequently, decreases maintenance and repair time.

A crude oil desalination process is a complex plant which includes large, multipart and complex stages. Therefore, performing a correct troubleshooting method is an essential matter to prevent any unpredicted shutdown.

Fuzzy troubleshooting (FT) provides a systematic method for diagnosing by incorporating expert knowledge acquired from experts or plant manual. The use of fuzzy expert system provides a means for dealing with an uncertain situation when existing knowledge is ill-defined [1]. A fuzzy expert system is also protected from all human emotions, like stress, and exhaustion, that can cause deficiency while troubleshooting [2].

Fuzzy troubleshooting was recently utilized in trouble shooting of chemical plants. Tarifa and Scenna, [3] presented an efficient method for identifying faults in large chemical processes. The whole chemical plant was divided into segments by using structural, functional or causal decompositions. For each segment, a signed directed graph model was used. The model outputs were used to develop a troubleshooting system of the multi-stage flash (MSF) desalination plant.

Tarifa and Scenna, [4] represented a fault diagnostic system for an MSF desalination plant which prepared drinkable water in Argentina. For this purpose, they applied a real time expert system. The diagnostic system was developed in order to verify the process state (normal or abnormal). The system output was 0(abnormality) and 1 (normality) for each potential fault.

Venkatasubramanian et al. [5], investigated fault diagnosis methods that were based on historic process knowledge. They compared and evaluated the various methodologies in terms of the set of desirable characteristics.

Morgan et al. [6], in their study represented an expert system which was able to troubleshoot the source of milling problems. The expert system utilized a fuzzy logic-based process to take the signals and information, and recommended possible alternatives to the process to achieve high-performance milling operations. They concluded that fuzzy logic is a satisfactorily robust method to deal with the variety of dynamic analysis data encountered within the milling process.

Abdul-Wahab et al. [7], developed a fuzzy logic-based expert system in order to provide real time troubleshooting advice. They particularly worked on the brine heater of the MSF plant. They found that the system was able to perform troubleshooting tasks and could be used for either on-site trouble shooting or off-line operator training.

Fuzzy expert systems also have many other applications like manufacturing, decision problem, controlling and modeling [8–11]. Following a review on the oil desalter process, this paper provides a brief introduction on fuzzy logic. In the next part, membership functions for troubleshooting of the plant are presented. Finally, the validity of proposed system is proven using off-line data and plant operator experiences. Based on our literature survey, the proposed

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troubleshooting method on the crude oil desalter plant has not been proposed in previous studies.

2. Process description

Oil desalination is a process of removing dissolved salt from oil. Salt in oil may crystallize in equipment causing blockages, or may result in catalyst deactivation in refinery reactors. In addition, salt can cause corrosion in instruments and transportation pipes. In order to prevent these major problems, the salt content of crude oil must be reduced to a certain level.

The crude oil treatment method can vary from simple techniques like gravity settling to complicated method such as high voltage desalination. Selection criteria for the desalination method depend on the amount of water and salt to be removed.

In this study, an industrial refinery complex crude oil desalination plant was selected for troubleshooting purpose. This plant includes several instruments and sections, and utilizes different desalination techniques [12]. Fig. 1 shows the schematic of the plant.

As demonstrated in Fig. 1, at point No. 1, the crude oil emulsion, which contained water and dissolved salt, flowed to a wet tank. The emulsion may contain up to 25% water. Typically, a desalting plant should treat crude oil until the water and salt contents are reduced to 0.10% by volume and 5.0 pounds per thousand barrels (PTB), respectively. To eliminate such a large amount of water from the oil stream, a two-stage desalting system was used. In the wet tank, some of the water was separated gravitationally. The separated water flows to a waste water treatment plant or is disposed off to a disposal pit. Then, at point No. 2, an emulsifier is injected into the stream. The mixture then entered a heat exchanger (Point No. 3), where heat is recovered from the treated crude product stream (stream No. 10). The stream then flows to a water bath indirect heater (point No. 4). At point number 5, recycled water from the second stage vessel is injected into the emulsion flow. The aim of recycling water application was to minimize freshwater consumption at the mixing valve (No. 6), (an induced shearing force disturbs recycled water and emulsion). A simple globe valve performs the function of a mixing valve, where an operator would set the differential pressure across the valve to be as high as possible to assure better mixing of the two fluids. Stream No. 7 leaves the mixing valve to enter the first stage desalter vessel. In the first stage desalter, the emulsion was exposed to a high voltage electrostatic field. The application of the electrostatic field caused coalescence of the dispersed water phase. As a result, the enlarged coalesced water dropped gravitationally and accumulated at the bottom of the vessel. Effluent water from the first stage (stream No. 1) left the system to a wastewater treatment plant or the disposal pit. This stream contained various impurities and salts.

Treatment of the emulsion was improved in the second stage desalting vessel. Crude oil passed through a mixing valve at the entrance of the second stage vessel (Stream No. 8). The emulsion that contained residual salt was once more blended with fresh water (stream No. 9). The differential pressure across the mixing valve is usually maintained about 15 psia. Then, incompletely treated emulsion flowed into the second stage near the bottom of the vessel and, moved upward through the electrical voltage field.

The recovered water was collected at the bottom of the vessel and recycled to the first stage desalter (stream 5), while the treated crude flowed from the top of the vessel (stream No. 10) and into an analyzer (stream No. 12). If the treated crude is within the desired specification, a signal was sent to the diverting valve to open the dry tank. Otherwise, the flow is directed back to the wet tank. A more detailed description of the process can be seen in [12].

2.1. Fuzzy logic

This section presents the basic concepts of fuzzy set theory introduced by Zadeh [13,14]. Fuzzy sets are development of classical sets. In contrast to the classical set, or crisp set, the boundary of a fuzzy set is not precise. That is, the gradual change from nonmembership to membership. This gradual change is expressed by membership

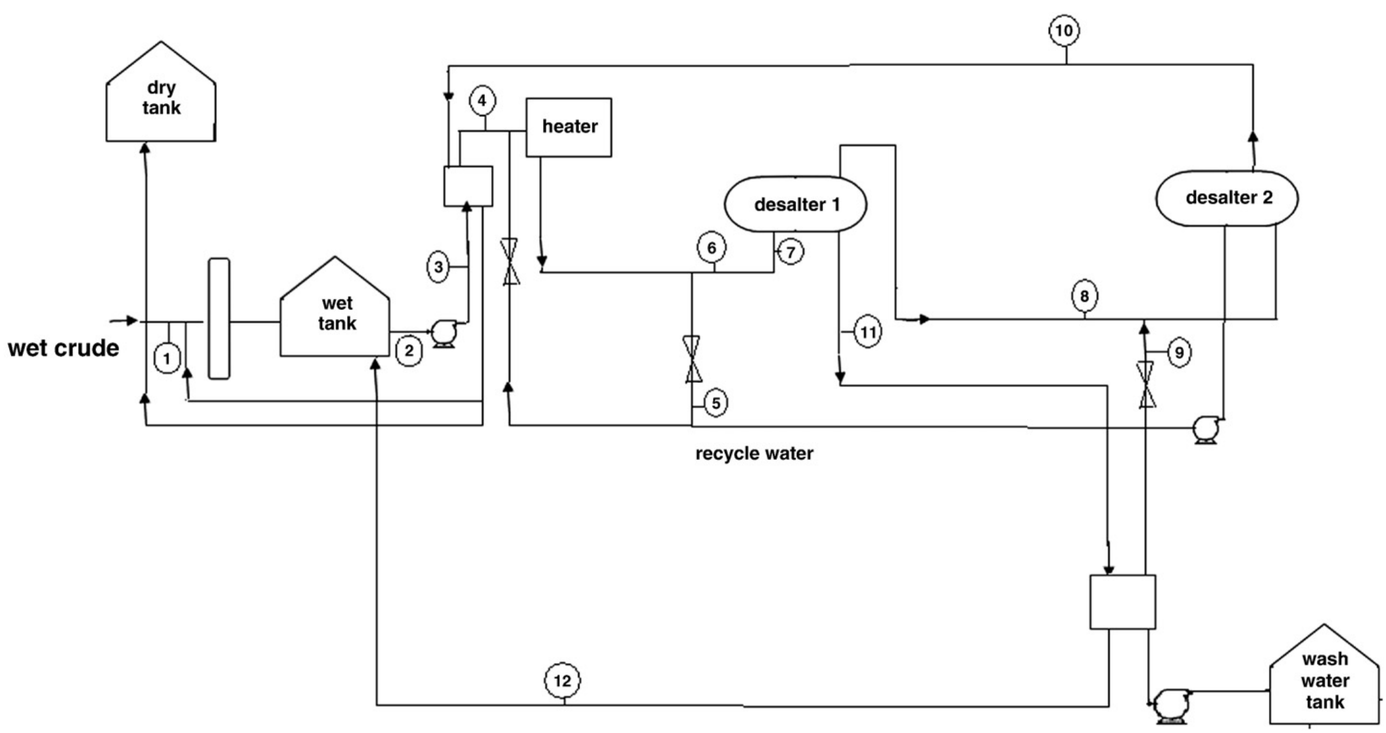

Fig. 1. Schematic of desalination process.