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Fuzzy set implementation for controlling and evaluation of factors affecting multiple-effect distillers

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Abstract

Multiple-effect (ME) distillation was the first process used to desalt a significant amount of seawater. This process takes place in a series of effects (stages) and uses the principle of reducing the ambient pressure in the various stages in order of their arrangement. In this work, a fuzzy logic is used to evaluate the factors affecting the ME distillers. The fuzzy logic detection was performed to assess three rules; i.e., "Increase", "Decrease", or "No Change" in distillation system in Jordan. We considered the factors that affect the detection of yield. There are many factors affect the ME distillers include: top brine temperature (TBT), concentration factor (CF), seawater temperature (T_{SW}), seawater pH (pH_{SW}), seawater salinity (S_{SW}), scale formation (SF), and CO_2 release. The various characteristics for the case study was synthesized and converted into relative weights w.r.t. fuzzy set method. The fuzzy set analysis for the case study reveals increase as confirmed by the experimental data. The application of the fuzzy set methodology offers reasonable prediction and assessment for detecting yield in distillation system in Jordan.

Keywords: Fuzzy control; Option-factors-fuzzy decision; Multiple-effect distillation; Distillation system

1. Introduction

Multiple-effect (ME) distillation was the first process used to desalt a significant amount of seawater. This process takes place in a series of effects (stages) and uses the principle of reducing the ambient pressure in the various stages in order of their arrangement. This causes the feed water to boil in a series of stages without supplying additional heat. Vapor generated in the first stage gives up heat to the second stage for evaporation and is condensed inside the tubes. This continues for several stages. The seawater is either sprayed, or otherwise distributed onto the surface of horizontal tubes in a thin film to promote rapid boiling and evaporation. The condensate

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from the boiler steam is recycled to the boiler for reuse. The larger the number of stages, the less heat that is required as heat sources. There are many factors affect the ME distillers include: top brine temperature (TBT), concentration factor (CF), seawater temperature (T_{SW}), seawater pH (pH_{SW}), seawater salinity (S_{SW}), scale formation (SF), and CO_2 release.

Scale formation and CO_2 release have mutual effect on each others and this strongly depends on temperature, pH as well as on the concentrations of HCO_3^-, CO_3^{2-}, Ca^{2+}, and Mg^{2+} ions. Al-Rawajfeh et al. [1–4] have modeled the CO_2 desorption rates in ME distillers. Recently, Al-Rawajfeh [5] has developed this model to simulate the simultaneous desorption of CO_2 with the deposition of $CaCO_3$ and investigate their mutual effect.

This paper presents a fuzzy control method which is used to estimate the load of different essential factors (i.e. designs, climate and operational parameters on the productivity) affecting the performance of ME distiller productivity. The fuzzy control is widely accepted as a technology offering an alternative way to tackle complex problems. It is able to deal with nonlinear problems, and can perform predictions and generalisation at high speed. It has been used in diverse applications in control, power systems (Mamlook et al. [6]), and manufacturing. It was tested by Mamlook et al. [7] for the field of solar systems implementation, and water leakage predictions (Mamlook et al. [8]). More detail on fuzzy logic theory and applications are outlined in (Mamlook et al. [6–12], Zadeh [13–14]).

2. Proposed methodology

The fuzzy method presented here was presented in [8] for detecting leakage in water distribution systems in Jordan, also to detect the yield of solar distillation systems in Jordan [12], and is used here to detect the yield in ME distillation systems in Jordan.

Synthetic evaluation is an important application of the fuzzy transform used in developing the extension principle. The term synthetic is used here to connote the process of evaluation whereby several individual elements and components of an evaluation are synthesized into an aggregate form: the whole is a synthesis of the parts. The key here is that the various elements can be non-numeric, and the process of fuzzy synthesis is naturally accommodated using synthesis evaluation. An evaluation of an object, especially an ill-defined one, is often ambiguous and vague. Since a numerical evaluation is often too unacceptable, too complex, and too ephemera (transient), the evaluation is usually described in natural language terms.

To formalize the fuzzy synthesis evaluation, let F be a universe of factors and P be a universe of evaluations, so

$$F = \{F_1, F_2, \ldots, F_N\} \text{ and } P = \{P_1, P_2, ..., P_M\}$$

Let $R = \{r_{ij}\}$ be a fuzzy relation as in Table 1, where $i = 1, 2, ..., N$ and $j = 1, 2, ..., M$. Suppose we introduce a specific ME distillation system into the evaluation process on which the expert engineer has given a set of "weights" (w_i) for each of 7 factors as listed below:

- Top brain temperature (TBT)
- Concentration factor (CF)
- Seawater pH (pH_{SW})
- Seawater salinity (S_{SW})
- Seawater temperature (T_{SW})
- Scale formation (SF) or $CaCO_3$ precipitation
- CO_2 release

Table 1
Sample matrix for fuzzy pairwise relation

	P_1	P_2	. . .	P_M
F_1	r_{11}	r_{12}		r_{1M}
F_2	r_{21}	r_{22}		r_{2M}
.	.	.	.	.
F_N	r_{N1}	r_{N2}		r_{NM}