Real time Prediction of Evaporator Circuit Performance Using ML Based Soft Sensors

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Abstract

In alumina refineries, evaporation is the critical process used to concentrate spent liquor to achieve desired caustic concentration for the digestors and to maintain the process water balance. The evaporation circuit contributes to ~ 20–25 % of the total energy requirement; this is third highest energy consuming process after calcination and digestion. The energy or heat source is live steam which demands are as high as 40–50 % of total refinery steam requirement. Therefore, this process needs special attention to control the steam input and maintain consistent performance of the evaporator steam economy. To optimize and control the evaporator performance, soft sensors have been developed to predict quality parameters such as the concentration of strong evaporated liquor (SEL), and steam economy. This will help to minimize the variation in evaporator steam economy while maintaining consistent product quality. An advanced machine learning (ML) algorithm i.e., random forest, is used to develop predictive models based on historian data base for both SEL concentration & steam economy (SE). These models are optimized with hyper parameter tuning to achieve higher accuracy. The model accuracy for the prediction of SEL concentration is obtained in the acceptable range of ± 2–3 g/L. The minute-wise prediction dashboard has been developed for the area concerned to take prompt decisions to achieve consistently high steam economy which is utmost important towards saving energy. The predictions were validated using real-time DCS (distributed control system) plant data on a minute-wise basis. Through a web-based GUI (graphical user interface) platform, real time predictions from the model and actual plant measurements were pulled, displayed, and compared to showcase the critical parameters for the prediction accuracy.

Keywords: Soft sensor, Machine learning model, Spent liquor, Strong evaporator liquor, Steam economy.

1. Introduction

The evaporator is the second highest energy intensive section in the liquor circuit of the Bayer process. It plays a key role to concentrate spent liquor caustic to the desired level; this liquor is circulated to the digester to minimize the loss of caustic and maintain the plant water balance. Considering the energy efficiency, a multi-effect falling evaporator having steam economy ranging 3–4 is widely used in alumina refineries. Obtaining reduced steam consumption while maintaining the quality of product liquor i.e. SEL (Strong Evaporated Liquor) is crucial for improving the efficiency of the evaporator circuit.

Many researchers have made efforts to model the industrial-scale evaporator; one approach follows an empirical correlation using residence time distribution to model the falling film evaporator [1]. However, due to the complexity involved in the process because of simultaneous evaporation and condensation, the empirical correlation may not provide an appropriate description of the process. The dynamic behavior of multi-effect evaporators was investigated by disturbing the input parameters as a different approach [2]. A generalized mathematical model, which could be applicable to any number of effects was also attempted. This lumped and distributed mathematical models were developed for four effects falling film evaporator [3]. The results indicated that the distributed model had better prediction than the lumped model. Thereafter, combined model of lumped and distributed was used to predict the outlet liquor concentration for the evaporator circuit [4]. The simulated values of concentration were close to the measured values. From the perspective of energy consumption point, it was investigated for multi-effect evaporators with and without mechanical vapor recompression (MVR) [5]. The evaporator integrated with MVR consumed one-third of the energy compared with the conventional one. Although MVR technology seems promising, it requires further evaluation to be implemented in the alumina refineries.

Despite having the advantages with mathematical modelling, the online prediction of desired parameters through advanced data analytics resolves the issues related to offline analysis. Since process data is a direct reflection of the performance of the evaporator, the development of an online predictive model through soft sensing method seemed to be a reliable approach for accurate representation.

The technological development in the alumina industry has aided in developing approaches and algorithms to predict certain physical or quality parameters through soft sensors. A stepwise linear regression approach was used to predict the strength of alumina crystal conglomerates from alumina refinery [6]**.** Another approach, where-in comparison between different methods such as artificial neural network and multiple linear regression method was made for prediction of the alumina recovery efficiency. The amount of red mud produced, red mud settling rate and bound-soda losses in the red mud were studied [7]. The Radial Basis Function under the neural network function turned out to be the best-fitted approach for the considered data set. A predictive model using Support Vector Machine (SVM) was developed for predicting the leaching rate [8]**.** Leaching rate of alumina in the digestion process obtained through laboratory analysis delays the course of action. This causes less control of the process creating problems such as a low leaching rate and excess energy. Distributed support vector machine-based soft sensor to predict the quality of the digested slurry online was developed [9]. Based on expert knowledge and the mechanism of the blending and digestion process, a hybrid expert control system for supervisory control of the blending process was developed to optimize the raw material proportioning.

Limited attempts have been reported on developing soft sensors in the evaporator section with industrial validation. This present work is aimed to fill this gap by finding optimum independent parameters which can open opportunities for steam reduction. The development of a soft sensor would be beneficial to predict SEL (g/L) to take proactive actions to maintain desired SEL (g/L) and achieve consistent steam consumption.

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6. References

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