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An expert system for improving the gamma-ray scanning technique

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Abstract

The gamma-ray scanning technique is widely used in the diagnosis and identification of industrial installations, in general and, in particular, of distillation columns considered as the most critical components in petrochemical plants. It provides essential data to optimise the performance of columns and identify maintenance requirements.

Due to the various difficulties that can arise while analysing a scanning profile and in order to benefit from the continuous advent of new technologies in the field of electronics and data processing, the team of the Division of Instrumentation and Industrial Applications of CNESTEN have conducted a project aiming the elaboration of an expert system for acquisition, processing and interpretation of the scanning results. This system consists of two main modules: the first one is devoted to the preparation and control of the scanning operation conditions, while the second module has been developed to carry out easily and effectively the automatic (on-line) analysis and interpretation of the scan profiles.

Keywords: Distillation columns; Expert system; Gamma-ray scanning; Scan profile

1. Introduction

The diagnosis based on gamma-ray scanning technique plays an important role in the resolution of industrial installations and process problems. In comparison to other non-destructive control techniques used in practice, gamma-ray scanning provides, in real time, the clearest vision of the production conditions inside a reservoir of process. This powerful diagnosis tool being used since about 40 years ago is cost-effective, fast and effective. It provides essential data to optimise the performance, track the deteriorating effects and identify maintenance requirements of a distillation column so that it reduces significantly repair downtime. It is worth noting that there is an increasing demand from countries having petrochemical installations to gamma-ray scanning as an efficient means of identification of the process-related problems in distillation columns without aborting the production process.

The continuous advent of new technologies in electronics and data processing fields lead us to conduct a project with the main objective to improve the reliability and effectiveness of this technique. The corresponding research work is focused on the elaboration of an expert system for acquisition, processing and interpretation of the data delivered by the gauge used in gamma-ray scanning. The first step to fulfill the objectives of the project has been the conception of a software which allows real-time control of the whole devices directly or indirectly linked to the scan conduct. On the other hand, a data acquisition module has been developed to obtain the measures with high precision.

In this paper, we present a full description of the elaborated expert system used in gamma-ray scanning technique.

2. Measurement and physical principles of gamma-ray scanning

In performing a scanning of a distillation column or a similar reservoir, a small and adequate sealed source of gamma-ray with an appropriate collimator is placed on one side of the column and a sensitive radiation detector is placed on the opposite side [1]. The source and detector are

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synchronously moved down along the column in small increments (Fig. 1). The transmitted radiation intensity is measured and recorded via an interfaced portable computer which allows data storage and analysis.

The interaction of gamma radiation will produce changes in the intensity of the beam that can be correlated to the property of the irradiated column according to the following fundamental relationship:

$$I = I_0\,e^{-\mu\rho x} \quad (1)$$

where I_0 and I are the initial and transmitted intensities of gamma beam, x the thickness of the traversed material of density ρ and μ is the coefficient of absorption which is constant for a given gamma-ray energy and material composition. Eq. (1) shows that an increase in material density will reduce the radiation signal and vice versa. These variations can be analysed and correlated to the properties of the medium inside a closed reservoir. By applying these physical processes to the practical case of a distillation column, the following statements can be derived:

- When gamma radiation goes through a medium containing a tray filled of aerated liquid, a good part of the incident beam is partially absorbed and the radiation quantity reaching the detector is relatively small.
- When a radiation beam goes through a non-aerated liquid, the most part of this radiation is absorbed and the detected signal is weak.
- When a radiation beam goes through steam there is only a small amount of suspended material to absorb radiation, this causes the transmission of high radiation intensity to the detector.

To sum-up, a scan using gamma radiation of a column [2–4] can differentiate between liquid and steam regions within the column. It can also make the discrimination between liquid aeration and can detect levels of foam and aerosol in steam regions. The correlation of the changes in density recorded in the scan profile with the inner part of the column lead, therefore, to an accurate picture of performances and physical conditions. Every tray and the space extended above reflect its working state. For instance, a tray functioning correctly has a reasonable level of aerated liquid, showing a fast decrease of the corresponding density gradient until reaching a clear steam space just below the following tray.

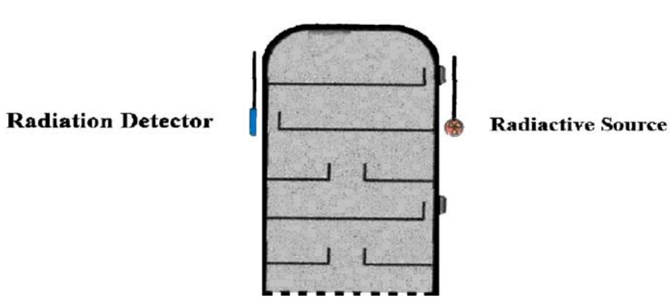

Fig. 1. Principle scheme of the gamma-ray scanning of a distillation column.

3. Expert system for the gamma-ray scanning

The interpretation of a scan profile is not always easy and depends, in a large way, on the experience and competence of the technical staff in charge of the control. This is due to the diversity of phenomena related to the process and to different mechanical components of the column that are quite dissimilar from the standard elements usually used during the interpretation of the obtained profiles. These components, which affect the radiation crossing the column, complicate the profile obtained when correlating them to the results directly linked to the process. Whence the necessity to have a system able to take into account the maximum information that the team in charge of the control dispose before the start-up of the scanning operation.

The system we have developed, consists of an expert system for acquisition, processing and interpretation of data delivered by the gauge used in gamma-ray scanning. This system is composed of the following two main modules:

- A module devoted to the preparation and control of the scans' progress conditions.
- A module dedicated to the automatic analysis and interpretation of scans.

The conceived software allows the real time control of all elements directly or indirectly bound to the conduct of the scan. A module for data acquisition has been elaborated to carry out the measurement's recording with high precision, taking into account corrections due to detector's shift according to the sampling time. The different blocks of the system developed are depicted in the synoptic scheme of Fig. 2.

The acquisition module consists of an advanced electronic card of eight layers and having a dimension of 100×46.9 mm. It is a multichannel card endowed with an in situ programmable microcontroller. This card, implanted in the radiometric gauge, is used to achieve the following tasks:

- to record the nuclear counting [5],
- to control the detector bias supplies,
- to calibrate the gauge,
- to record some possible additional physical parameters such as (temperature, etc),
- to communicate with the software through the RS485 connection.

The microcontroller [6–8], of type Dallas DS89C51PLCC, allows the independent programming of