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Process Monitoring at a Reprocessing Plant Example of a weighing Cycle:

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Abstract

A software tool to monitor nuclear material during the various unit operations of a reprocessing plant is developed, based on the PI-UDS for the data acquisition. One of the important key measurement points is the final product stage of Pu powder product. Here the dosage of the final Pu powder is for safeguards and safety reasons of high importance. The cyclic behavior of the weighing scale is therefore closely monitored in order to account with high precision for the final product quantity.
The output signal of the weighing scale shows very steep variations. To ensure a correct interpretation by the analyzing software a special data acquisition and compression algorithm was applied. This algorithm collected in a triggered manner a sufficient amount of data points at each steep variation, while it reduced sufficiently the number of registered points in the smooth slope region. The data acquisition and compression algorithm was successfully implemented as NT-service and validated at the reprocessing plant in La Hague. An example of a complete weighing scale cycle is presented.

1. Situation of the weighing monitoring problem

Safeguarding nuclear material has taken on ever increasing importance with the increasing throughput of bulk handling facilities and none more so than in the back-end area of the nuclear fuel cycle. Monitoring is becoming a key issue in all reprocessing plants. Both Euratom inspectors at the La Hague reprocessing plant and in the near future IAEA inspectors at Rokkosho reprocessing plant [1] are confronted with process monitoring. In the reprocessing plant of La Hague the filling of a recipient, typically of 4 kg with the Pu powder had to be followed closely by monitoring the weighing scale. The accuracy of the weighing measurement has an important effect for the accountancy in this material balance area of final Pu product. As the weighing scale is utilised several times a day a certain cycle of the signal profile can be observed. However the duration of such a cycle as well as the time between succeeding cycles is not fixed, so that the total profile of the weighing signal is not strictly periodical. Therefore the pattern matching technique is not applicable here.
The signals in a weighing cycle show a very irregular profile with very steep slopes at the positioning on the scale and at the lifting of the recipient. These steps in the profile are to be registered with a dense data rate in order to obtain very accurate values of the real weight value.
Between these steps the profile may be flat, representing a stagnant signal or smoothly increasing, representing a slow filling of the recipient. The filling of the recipient takes time, yielding a noisier signal with a more or less constant slope. A flat or smoothly increasing profile is less interesting in comparison to the steps in the profile, as it does not affect the accuracy of the final weight value. Here a collection of measurement points at dense data rate is disadvantageous and the registration of data points has to be limited.
During one weighing scale cycle – an example is shown in Fig. 1 - the following sequential sub-regions in the profile are to be identified:

- offset test with zero reading (A)
- check of the linearity of the weighing scale (with 3 certified weights, B-C-D)
- offset test with zero reading (E)
- the weighing of the empty recipient (F)
- the positioning of the loader (G)
- the filling of the recipient with the product (H)
- the lifting of the loader (I)

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- the lifting of the recipient (J)
- offset test with zero reading (K)
- final weighing of the filled recipient (L)
- offset verification of the zero reading (M)

This weighing cycle has to be followed in conformity with the daily procedure strictly prescribed for the final Pu product stage at La Hague. It should be noted that a linearity check of the weighing scale with three different certified weights, covering the range up to the weight of the final Pu powder quantity, is performed before each weighing of a batch with several recipients, several times per month. Of course a complete check with recalibration of the weighing scale if necessary is additionally performed during the shutdown for physical inventory taking on a yearly basis. In the envisaged reprocessing plant the accountancy of the product is of high importance. Therefore each final weight value is to be registered with high accuracy and therefore at high data acquisition rate. However during the filling a high acquisition rate is useless and even inefficient. A classification between interesting and non-interesting sub-regions is needed to distinguish a way of compressing the data.

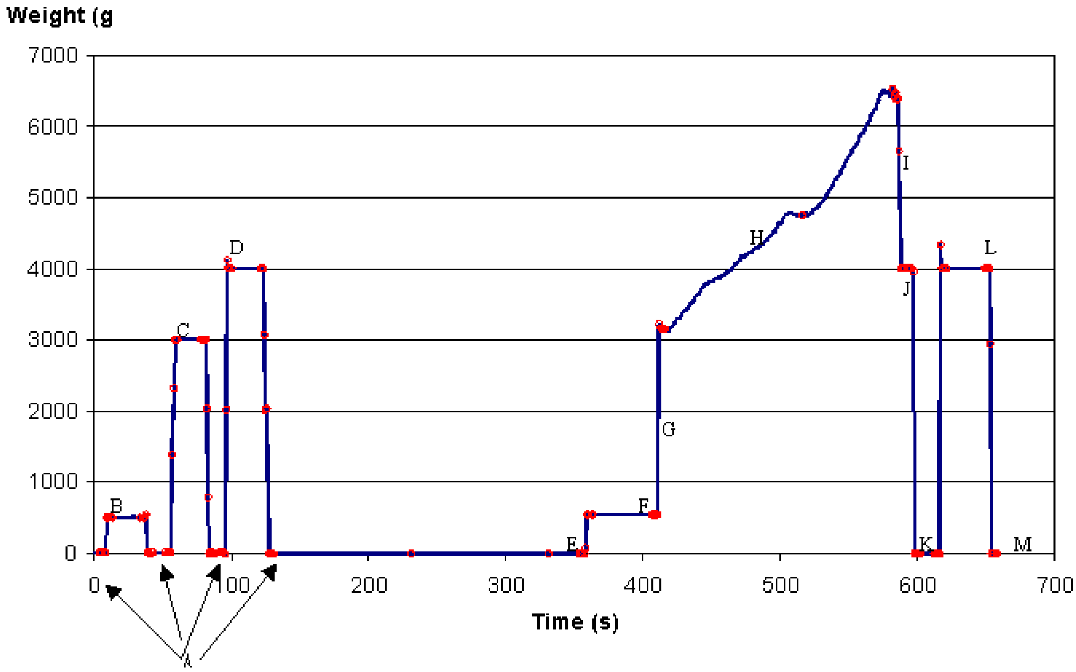

Fig. 1: Example of a weighing cycle (blue: measured signal, red: collected and stored data measurement points, letters: indicate the important events in the different sub-regions).

2. New methodology for monitoring a signal cycle

An intelligent process monitoring software system is developed, which neither supervises nor controls but analyses the measured data points and interprets the required coherency for safeguards purposes without intervening in the process by a feedback function. The monitoring software system is based on the commercial PI-UDS for the data acquisition and on the newly developed analysing kernel DAI for interpreting and evaluating the data. The analysing kernel DAI (Data Analysis and Interpretation) directly supports the inspector in verifying the coherence in material flow and especially allows near real time accountancy. A similar tool has been applied by Howell [2] for near real time accountancy.

The approach followed here for DAI is somewhat different as it decomposes the specific signal in abstract functional behaviour blocks, which is a graphical representation of a sub-region in the cycle and which corresponds to a well-defined elementary function. For the weighing cycle the following functional behaviour blocks are defined:

- incremental step with predefined weight
- plateau at zero reading
- plateau for weight reading
- increasing linear function for filling
- decremental step for lifting

The innovative element in the software algorithm is the formalisation, which allows to describe the signal cycle by means of functional behaviour blocks and to make abstraction of the signal. The reasoning and analysis on the coherency of the material flows in the system and on the conformity of the process procedure is performed on a symbolic level by means of the functional behaviour blocks. The design of the weighing cycle (taking into account the instrumentation and procedure) is given in Fig. 2. A more detailed description of the methodology with functional behaviour blocks is given in [3].

The DAI analysing kernel has three important tasks:

1. to detect the important events in the cycle by means of identifying the start/end of the functional behaviour blocks
2. to verify by means of auto-correlation if the succession of functional behaviour blocks in the cycle conforms to the prescribed procedure
3. to verify by means of cross correlation if the signals of correlated events have the required similar or complementary behaviour.

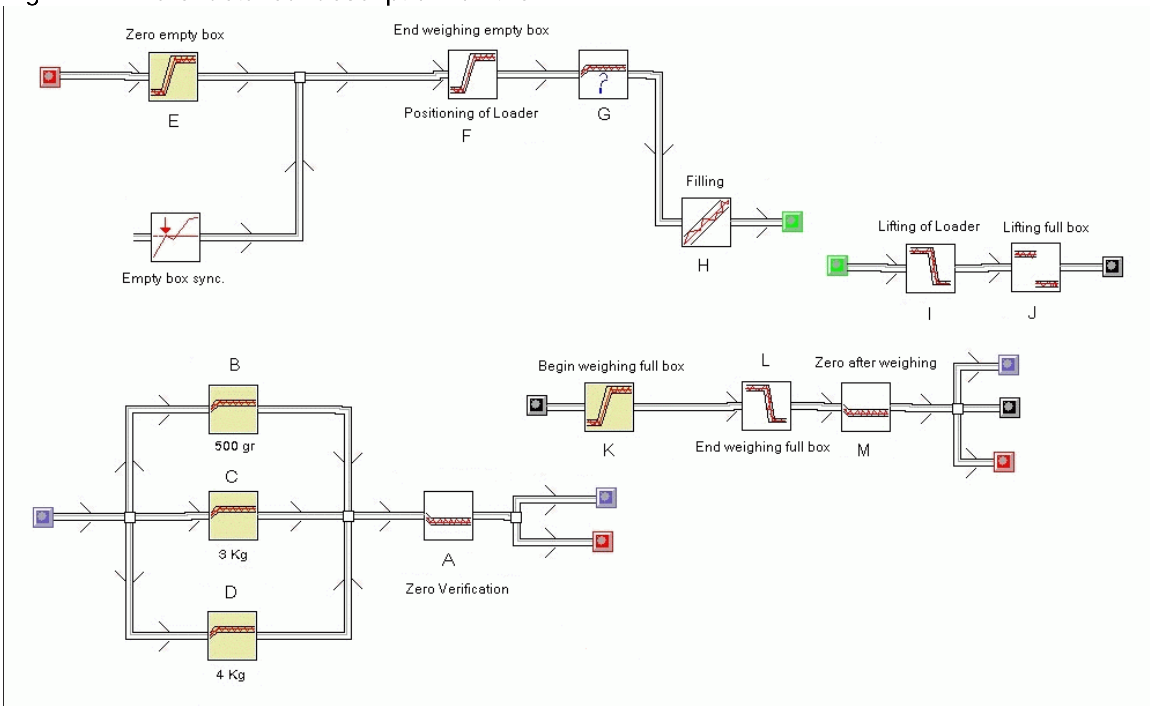

Fig. 2: symbolic representation of the weighing scale operations in one cycle.

3. Appropriate monitoring of the weighing scale

3.1 The algorithm for monitoring the weighing scale

A special data acquisition and compression algorithm was developed and implemented by means of the PI-API interface tool.

The swinging door compression algorithm, offered in the PI software was not appropriate, because the raw data signal can not be analyzed with the same accuracy in all sub-regions. With a small half-width of the deviation blanket a high number of data points were collected for the important start/end points of a sub-region with a special tank functional behaviour (such as

filling or emptying) but also for some sub-regions with noisy signal during the complete region (e.g. during the filling). The registering of the complete filling is only memory and time consuming, without any interest. On the other hand no swinging door compression with large half-width of the deviation blanket could be applied, in order not to loose accuracy in the detection of the real start/end points and so in the final weight value.
Instead a new algorithm was created, which recognized the interesting sub-regions with a profile of steep slope based on a high value of the prescribed minimum slope parameter. In the latter sub-regions the measured data are compressed according to the prescribed parameter of maximum time between two collected points.
For the interesting sub-regions with a step in the profile, the standard deviation was applied to switch on the trigger for collecting all data points in the buffer. With the prescribed size parameter of the buffer N, each step is registered with N points before the steep slope and N points after the steep slope. After implementation on site a sensitivity analysis on the real process resulted in an optimal value of 5 for N.

3.2 Implementation on site of the weighing cycle algorithm

The PI-UDS System Base Package with all subsystems was installed on three separate servers (for each treatment facility and for the development and maintenance platform) and was connected with multiple clients. The PI-API based interfaces have been included to cope with the special data treatment of some signals. At each plant the PI System allows for the inspector a global monitoring of the industrial process with all kind of signals.

4. Results

The return of the small investment was very high. Considering that per month 500 recipients are exiting, an enhancement in accuracy of 1 g leads to a detection of 0.5 kg/month.
As a reprocessing plant is submitted to extensive safeguard inspections the accountancy of nuclear material in the plant is of major concern. The benefit for the plant at La Hague is therefore mainly composed of the following advantages:

- The inspection of the weighing scale signal is less time consuming and therefore enhances the monitoring of the filling process.
- A remarkable enhancement in the accountancy of the weighed end product was achieved
- Material unaccounted for is also to be avoided as much as possible because of the constraints under the Euratom treaty.

5. Perspective and future applications of the software

The dosage of a valuable products is commonly encountered in industrial processes. Not only liquors but also powders are often filled in small recipients. A high accuracy in the dosage is for industry of high economic benefit. On the other hand a robust software is needed for monitoring, as fall out periods are to be avoided as much as possible.
The La Hague reprocessing plant showed satisfactory results and demonstrates the usefulness of a simplified approach to follow-up the integer transfer of a material flow. This validated, highly accurate and robust software tool may be considered for application in other process facilities, such as petrochemical plants, milk or sugar production facilities and chemical plants, dealing with precious solutions or powders.

Literature

[1] Johnson, S. (1997), Safeguards Improvement Plan for the Tokai Reprocessing Plant, 8th Symposium on International Safeguards, by IAEA

[2] Howell, J. and Scothern, S. J. (1997), A Physical-Model-Based Diagnostic Aid for Safeguarding Nuclear Material In a Liquor Storage Facility, *J Nucl. Mat. Man.* **25**(4)

[3] Thevenon, J.B., Janssens-Maenhout, G., Dransart, P. and Dechamp, L., (2003) Une approche du monitoring d'une installation industrielle, submitted to *ClubAutomation*