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Abstract. This paper presents the model of a decisional system for $^{13}$C Isotope Separation column, which is used to detect mission critical situation. The start model was a model of one distributed control system of critical situations that may arise in the operation of the distillation column. The research work it is proposed a model of decision system which implement a temperature sensor inside of liquid nitrogen level in the condenser. The condenser is a part of column where take place the cryogenic process using nitrogen liquid. The work temperature is very low about -192°C, and because the temperature can grow or go down more than 2 degrees is a very critical location inside the column. In this way the column has a deeply monitor and supervised and it take a decision in a proper time when the temperature is grow up or getting down and became a critical situation. For monitor and supervised it was used MatLAB SimuLink. The model, the decision system gives a signal to one sensor when something is wrong in the condenser which is the most critical place of the isotopic column. In this way it creates an alarm that something is getting wrong in the isotopic column.

1. Introduction

In the last 15 years, the availability of increasingly powerful computers at a decreasing cost, on one part, and advances in operations research science that have resulted in improved algorithms, on the other part, have given the possibility to solve larger and more complicated problems than ever before [1]. The need of an optimisation-based decision support system, which can also be viewed as an application-specific delivery system for an industrial process [1], arises when one technology can be used to support highly repetitive decisions.

The level of continue increasing of complexity in industrial processes causes a corresponding growth in the complexity of control algorithms. Similarly, the structure of controlled technological objects and process control requirements is affecting the control of the system and its software architecture and system—wide quality requirements.

The column, in simplified scheme, separates the carbon isotopes based on the cryogenic distillation of pure carbon monoxide, which is fed at a constant flow rate as a gas through the feeding system.

Most of the systems are simultaneously control and real-time systems, since their proper functioning is directly dependent on the satisfaction of certain time restrictions. For time restrictions should adopt a way of planning tasks.

In time with technological progress, monitoring systems for remote control and distributed control systems has proven their value through some contribution, to increasing the effectiveness and efficiency of the activities of the industry processes.
2. Model of $^{13}$C isotope separation column

The column separates the carbon isotopes based on the cryogenic distillation of pure carbon monoxide, which is fed at a constant flow rate as a gas through the feeding system [2].

Take in consideration the very-low operating temperature, an efficient thermal isolation vacuum jacket is necessary. Since the “elementary separation ratio” [2] is very close to unity in order to raise the $(^{13}\text{C})$ isotope concentration up to a desired level, a permanent counter current of the liquid-gaseous phases of the carbon monoxide is created by the main elements of the equipment: the boiler in the bottom-side of the column and the condenser in the top-side.

The gaseous carbon monoxide upstream (from boiler and from the feeding system) condenses on the “coldwall” of the condenser, cooled with liquid nitrogen by atmospheric pressure and falls, in small drops, downstream to the electrically heated boiler [3].

The $(^{13}\text{C})$ isotope, slightly heavier than the predominant $(^{12}\text{C})$ isotope, accumulates in liquid phase and will be extracted as end product at the bottom of the column, while the $(^{12}\text{C})$ component accumulates in vapours phase and will be extracted as waste at the top of the column. The column operates with two zones: the stripping zone, from the feeding point to the top of the column and the enriching (rectifying) zone, in its lower part [3].

The characteristics of the carbon cryogenic separation column, presented, needs a necessity and modern control strategies.

The counter current cryogenic distillation column related is a highly complex plant, nonlinear, multivariable, with many time constants that overcomplicate the control solutions. The control system is to maintain the column operation parameters constant, by eliminating the effects of disturbances while keeping the overall system stable, despite the uncertainties that may arise [4].

The main parameters that need to take in use for monitoring and control are:

- The liquid nitrogen level in the condenser of the column. The drop of the liquid nitrogen level below a critical value would lead to the impossibility of efficiently condensing the vapours upstream and thus would compromise the entire separation process.
- The electrical power supplied in the boiler part. High variations of the power supplied would affect the separation by modifying the upward gaseous stream.
- The vacuum pressure of the column. Variations in the vacuum pressure bring about the loss of the efficient thermal isolation and cause the increment of the inner column temperature.

It is very important to know the material and energetic column equation to establish the mathematic model of the separation process [3].

The material equation for the separation column is [8]:

$$\frac{d(N \cdot x)}{dt} = F_a x_a - F_v y - F_b x$$  \hspace{1cm} (1)

Where: $N$ is the number of moles of liquid from the column, and $F_a$, $F_v$, $F_b$ are the molar flow of feeding at the top and base of the column.

Energy balance equation for separation column will determine the enthalpy of the liquid and vapour in the system and is [3]:

$$\frac{d(N\lambda)}{dt} = F_a \lambda_a - F_v \lambda_v - F_b \lambda - a_p + Q_{ag}$$  \hspace{1cm} (2)

Because the $^{13}\text{C}$ isotope separation column is a critical process I try to make a model of one decision system which will be able to monitor the column and make one decision when some critical situation appear.

In these simulations, a wireless communication network is used, to transmit data. It was taken as study case, two critical situations that may arise due to increasing pressure parameter:

- a) increasing the pressure parameter inside the column;
- b) increasing the pressure parameter in the vacuum cover of the column.

In the first case it is necessary the action of an electro-valve which will open pipe connecting the column and a vacuum container, resulting in pressure drop in the column to the reference value. To
automatically adjust the electro-valve's position and implicit the flow rate of pipe on which it is acting, it is used a PI controller. In the second case it is necessary the consecutive start-up and in parallel of two vacuum pumps.

For proper operation of the distillation column is required thermal insulation from the outdoor environment. Thermal insulation is achieved by ensuring a high vacuum values in column casing. On the occurrence of an alarm that signals the increase of pressure in casing of column, first of all is turned on high vacuum pump.

If pressure in casing does not drop for a specific time, in parallel with the first, the second pump is turned on.

The transfer function of the electro-valve is obtained using the relation:

\[ H_{\text{Ev}}(s) = \frac{10}{(0.005s + 1)(0.11s + 1)} = \frac{10}{0.0005s^2 + 0.115s + 1} \]  \hspace{1cm} (3)

To automatically adjust the position of electro-valve and the flow pipeline which it acts, it is use PI regulator (Kessler method) which transfer function is:

\[ H_{\text{PI}}(s) = 0.22\left(1 + \frac{1}{0.11s}\right) \]  und \( K_P = 0.22 \), iar \( T_I = 0.11 \) sec. \hspace{1cm} (4)

In the figure 1 it is shows the simulation scheme of distributed control system for critical situations afferent to column.

Figure 1. Simulation scheme of distributed control system for critical situations afferent to column.

3. Generalised Model of critical situation-tolerant Control Systems

In the community control, the most used technique to describe a control system is based on logical function blocks. This approach is also supported by most generic and custom design tools for control processes. Each function block can have several inputs, performs some function, and produces a number of outputs.

Several function blocks can be combined in different topologies, each function block can be decomposed into more primitive blocks.
This model is used for theoretical system analysis and to design and implement on control processes. Moreover, this model-based approach becomes more and more popular for dealing with all kinds of industrial processes.

There are further benefits of using function blocks. When designing distributed systems, the innermost function blocks represent basic units of allocation to processing elements. A composite function block, on the other hand, can be executed in distributed mode. Furthermore, on the top (system or context) level and entire control system – distributed or not- can be considered as a single function block.

A generalised model of a control system needs to take critical situation tolerance and real-time issues into account that are typically not integrated in the traditional development methods for control applications. The model considered has been designed for easy implementability on diverse general distributed architectures [4, 5].

Furthermore this model is use for control the liquid nitrogen level in the condenser of separation column. Its basic idea is to combine control functions (composed of function blocks) with a monitoring function and reconfiguration capabilities, and to include the notion of system resources.

The monitoring function supervised the behaviour of input and output signals that control the nitrogen level in the condenser which is critical for column functionality. For this it used the model Decisional Critical Situations System (DCSS).

A DCSS combines both the algorithmic part of a control application and all resources needed to perform the task given. The algorithmic part is represented by a set of function blocks [6]. In addition, a DCSS encloses also the critical situation tolerance and temporal features of the encapsulated blocks [7].

In the context level, an entire control system is considered as a single global DCSS that contains all hardware resources and program code. Its objectives are expressed generally (e.g., “control one process”).

This DCSS can be decomposed into a set of more primitive DCSS that perform a number of subtasks of the primary objective.

Instead of running the control application code, the global DCSS is managing its sub-blocks. Each sub-block owns a subset of resources and a part of program code allocated to the superior block. On this level, the objectives are more specific (e.g., “maintain the temperature of a mixture”). This decomposition can be applied recursively, i.e., DCSS can be decomposed hierarchically.

On the lowest level of the hierarchy, application code of control functions is executed. Since a specific objective can be accomplished in different ways, it is not necessary that all sub-blocks are active at a specific point in time. Selecting alternative function blocks and/or alternative DCSS also provides for both critical situation tolerance and timeliness [7].
The internal configuration of a DCSS at a specific instant is selected by configuration control signals provided by higher levels in the DCSS hierarchy, or by the operator on the top-most level. Each configuration also inherently performed. In the case of hard real-time tasks these parameters are firm. For soft real-time tasks, some of its can be given in ranges, or by some fuzzy rules. This allows for better flexibility in cases that only limited resources are available or of transient overloads.

If there are not enough local resources available to perform a selected configuration status information is generated to the upper levels in the DCSS hierarchy and, eventually, to the operator. Consequently, at an upper level, alternative scenarios can be chosen, the general objective can be degraded, or the system can be shut down in a controlled manner. If a DCSS can handle hardware, software, and timing critical situations locally, a higher level of hierarchy is not notified.

A conversion function (e.g., from an acquired raw integer to a physically correct floating-point temperature value) may be defined within the DCSS, together with bounds and/or other plausibility control. For an alternative sensor, a different function may apply. Similarly, DCSS is influenced the plant through changing some physical properties (e.g., by heating the liquid in a tank, or by increasing/decreasing fuel flow). This approach allows for a higher degree of flexibility and for better critical situation tolerance [8, 10].

4. Description of DCSS
A complete DCSS is composing of:

Local resources. Any DCSS is associated with a set of resources: processing capabilities, input/output interfaces, sensors and actuators, etc. Some of the resources are available exclusively to a single DCSS, and some can be shared among several DCSS. For example, more than one DCSS can be executed on a single processing element, or sensor data can be read by several DCSS.
However, an actuator will most likely be associated with one single DCSS, only. A set of resources available can change during local or global reconfiguration of a system. The resources allocated to a specific DCSS are available in all its sub-blocks as well. There can be no resources locally assigned to a sub-block, which are not part of superior block, too. Therefore, the DCSS on the context level owns all resources of the control system [7].

Monitoring, reconfiguration and mode control (MRMC). The module manages the DCSS. Based on external configuration control signals, the MRMC allocates and configures available resources and other components of the DCSS to perform a requested task. According to the configuration selected, the programs performing the control algorithm are invoked.

The MRMC also monitors all associated resources and traces any malfunctions in them. If a critical situation is detected by MRMC during the execution of the executive DCSS, the MRMC firstly, tries to deal with it locally by using redundant or alternative components, by reconfiguring the local sub-blocks, etc. If a critical situation cannot be dealt with locally, the MRMC immediately notifies the superior entity by means of appropriate status information.

Input data mapping and pre-evaluation. This module receives all input data signals needed by the DCSS to perform a given task. The inputs originate either from the local resources of from external information paths. It maps external data values into the data domain used by the DCSS. For example, it can map integer values produced by an A/D converter into floating-point quantity that represents the actual control parameter [7, 9].

The module can check the plausibility of input data and inform the MRMC if anomalies are detected. It also serves as a multiplexer if alternative information sources for some input exist.

For instance, several redundant sensors may by allocate to the DCSS. After start-up, one of them serves as actual data input. If this sensor fails, the MRMC can transparently switch to the next available one without the need to restart the primary control function. In some cases, if no alternative for some input is available, the MRMC can activate an auxiliary module that will provide the missing information by an approximation based on other sensorial inputs. This information is then delivered to the same data input as if it came from the sensor. Not all input data needs mapping and probably not every signal is tested.

Executive. The executive performs the DCSS control functions according to the configuration parameters set by the MRMC. On non-leaf levels of the block hierarchy, the executive consists of several subordinate DCSS [8].

The MRMC controls which subordinate DCSS should be activated, and how they interact with each other. On the elementary level, the executive executes program code of control functions on the processing element, some dedicated hardware component, etc., which are part of the local resources. In either case, the executive provides also some information on the MRMC if required. As noted before, sometimes the MRMC should know if subordinate DCSS cannot execute their tasks within required deadlines, or if subordinate DCSS do not have the capability to perform the tasks at all.

5. Conclusion and future work
In this paper it is propose a model DCSS use to deeply monitor the $^{13}$C isotope separation column the most important part of column being the liquid nitrogen level in the condenser. In this condenser the temperature has to be deeply monitoring because it can’t have fluctuations more the 2 up or down degrades.

The DCSS has rolled to make a decision in the column when some critical situation appears at condenser level.

In the future it is wanted to implement this model inside the condenser of the$^{13}$C isotope separation column, more then that to apply this model inside of vacuum column.

References


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