FULL SCOPE SIMULATOR FOR TRAINING OF SUGAR MILL CONTROL ROOM OPERATORS

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Summary

This work contains a short description of the use of the simulation for the training of control room personnel. The operator training methodology developed in the *Centro de Tecnología Azucarera* (CTA - Sugar Technology Centre) is set out, and a description of the simulator is included. This description focuses especially on the hardware and software structure, and more specifically on the simulation and modelling tools and methodology applied.

EcosimPro was used to model the various unitary operations produced in the sugar industry.

Key Words: Operator training. Training simulators, EcosimPro, OPC.

1   INTRODUCTION

1.1 Motivation

Sugar production is a complex process. It includes several production sections and many production units are involved, both for continuous and batch operation. Hundreds of process variables must be monitored and controlled, so a distributed control system (DCS, fig. 1) must be used. This control system receives process data directly as well as results from the analyses carried out in the plant laboratory, generating a set of control signals that allow controlling the plant's behaviour.
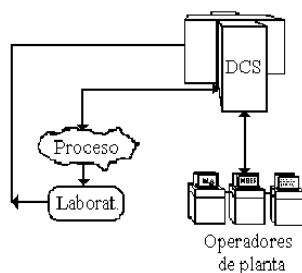
Fig. 1

However, the problem involves not only the control of the production process (which the DCS does), but also its monitoring. This smart monitoring process is performed by the operator by interacting with the process through the DCS (Fig. 2). It can be divided into two clearly differentiated tasks: (a) detection of anomalies in the production process and (b) process operation.

Fig. 2. Plant operator in a control room

In some cases the plant operator does not know enough about the process he/she is supervising or actuating upon, so operation is inappropriate. A way to help prevent these problems is to use advanced monitoring and control techniques so that there exists a level between the DCS and the operator that allows automation of many of the tasks performed by the operator. These techniques include the use of expert systems for failure detection and diagnostics and the application of advanced control algorithms such as the GPC with restrictions.

These techniques may be considered an aid to the operator to facilitate his work because they reduce the effort he must make to supervise the process. However, they do not eliminate the need to improve operator knowledge of the production process, as any enhancement of this knowledge would result in better productivity and product quality. The best way to enhance operator knowledge is to train them using simulation techniques.

1.2 Process simulators for the training of control room operators

When people think of a process simulator, the image that generally springs to mind is that of a replica of the control room, full of displays and connected to enormous computers where very detailed process simulations are being executed. This kind of simulator has been used for years in critical industries such as nuclear power plants or oil refineries, both for personnel training and to improve the production process. However, its cost, both in human and economic terms, has hindered extending its use to other process industries.

Now, however, this situation is changing thanks to the significant progress made in aspects related to the hardware that supports the simulator and to the software that allows the process simulation. This is having a big impact in many industrial applications. Furthermore, the use of simulation models for the design of production processes has allowed these models to be reused and updated for training purposes at a low cost.

Two types of simulators can be identified in the process industry:
- Simulators for the design of installations (DS, Design Simulators)
- Training simulators (PTS, Process Training Simulators).

There are two types of PTS:

- The FSS (Full Scale Simulators) or full scope simulators, which reproduce the whole operating environment. These simulators are associated to a replica of the control room (CCR, Central Control Room), both in appearance and functions
- The MFDS (Model Forward for Design Simulators) are simulators that reproduce the behaviour of the process but not the CCR. They can, however, actuate on the simulation in execution time

Despite the advantages provided by FSSs in the process industry, their use is not as widespread as would be desired due to their high manpower needs and economic costs. This owes to the difficulty of developing a model of the plant, the need to develop sophisticated user interfaces and the limitations brought on by the fact that the hardware and software are developed for a specific application, which makes their updating and maintenance difficult.

Consequently, the development and maintenance of an FSS requires many man-hours and it would be desirable to develop tools to provide automation for many of the tasks associated to the development and maintenance of an FSS. Furthermore, the development of an FSS is not the final aim of a computer-based training, but only the beginning. This is because once the training simulator has been developed, a strict training scheme must be developed as a function of the simulated plant. This program may require various training and evaluation strategies.

2 THE TRAINING SIMULATOR FOR THE CONTROL ROOM

The Centro de Tecnología Azucarera (CTA - Sugar Technology Centre) has spent several years training personnel for the control rooms of sugar mills. In this sense, its main focus has been on the development of a training simulator for control room personnel. This project involves the following tasks:

- Modelling and simulation of the production process

- Development of interfaces for the handling of the simulation and the emulation of the control room

- Execution of the simulation in real time

- Development of the communications between simulations and the interfaces that support its handling

The simulator developed in the CTA is of FSS type and emulates the control room of a sugar mill (Fig. 3). From a functional point of view, there is a simulation in real time that emulates the behaviour of the process, an interface for the instructor to control the training and an image projection system controlled by the instructor and used to project the mimic displays, photographs or videos the instructor may deem relevant.

Fig. 3

2.1 Hardware and Software Architecture

There are currently two different architectures (*Fig. 4*):

- The first and older architecture uses a *distributed control system* (*SICODI*), developed in the CTA

as an operator console. It runs on both UNIX and Windows NT machines

This control system relies on several Local Control Units (LCUs) that can share information. There is a link program, supported by a UNIX machine, used to control the execution in real time and communicate the control system with the dynamic simulation (ACSL program, run on a UNIX workstation) and with a console for the instructor (developed with G2 and executed from a UNIX workstation).
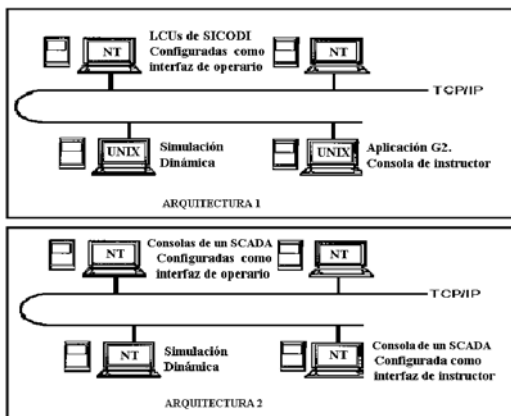

Fig. 4

- The second architecture only uses machines with the WINDOWS NT operating system. A *SCADA* developed by the CTA is used, actuating either as operator or instructor interface, and communications are based on the OPC (OLE for Process Control) standard.

An OPC server is generated as follows: EcosimPro generates the C++ fonts corresponding to the simulation classes and the experiment. The OPC server is created automatically by means of a program on the basis of these fonts, and it is later configured with the variables for which access is required (fig. 5) and recorded. The server can be located on a local or remote machine.
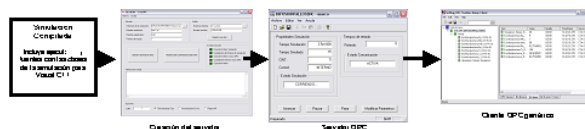

Fig. 5

Once the OPC server has been generated with the simulation, it can be connected directly to a SCADA (fig. 6). In order to make this connection, the SCADA has to be configured with the data of the simulation that need to be accessed, the mimic displays, tables, etc, have to be created and configured, etc.

Furthermore, if the instructor capability is to be used, the Instructor Console module has to be configured.
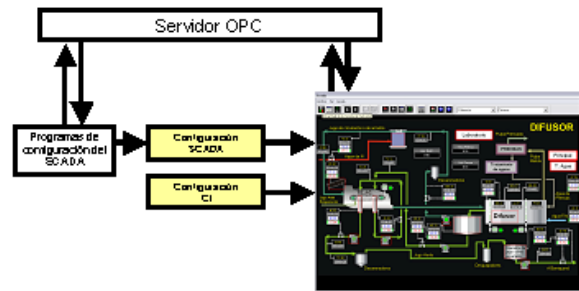

Fig.6

The resulting architecture for the simulator is shown in fig. 7. There is a simulation in a PC within a Windows network and a series of operators accessing it. Also connected to the system is an instructor who can suggest exercises.
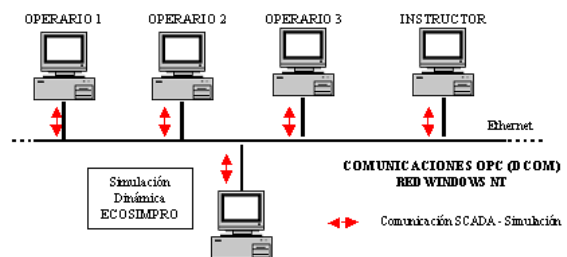

Fig.7

If there are several simulations, the only element that changes in the diagram is that there will be several simulations in communication with each other, and the operating ports will access them in the same way as with a single simulation.

2.2 Dynamic simulation

The simulation engine is a computer program that solves a system of ODES and events that model the dynamic behaviour of the system simulated. These models must provide a reliable representation of the sugar manufacturing process, so first principle models or knowledge models are employed.

It is obviously possible to develop a simulation program using a high-level programming language plus a set of routines to integrate differential equations. However, it is not the most adequate methodology because of the elevated human cost (knowledge of programming and numerical calculation) and time cost it entails. For this reason, the choice was made to use a simulation language that allowed the simulation model to be written with as

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close a syntax to the set of equations that describe it and avoid the problems that arise from programming and use of the integration routines. The language selected initially was ACSL (Advanced Continuous Simulation Language).

ACSL is a good simulation language that structures the mathematical model monolithically in three regions (initial, dynamic and terminal) with a very simple syntax. However, its biggest problem is that it does not allow the modular decomposition of the modelled system, so models cannot be reused. Being able to reuse the models is crucial to obtaining a flexible training tool that allows easy modification of the simulation program so as to adapt it to different mills.

The modelling tool chosen must therefore fall within the group of the OOML (Object Oriented Modelling Languages), and, within this group, EcosimPro was chosen. OOML tools allow a hierarchical breakdown of the model to generate a simulation code on the basis of the symbolic manipulation of the equations that describe the component models and of the equations associated to the connection elements. This hierarchical decomposition of the model allows libraries of component elements to be developed (Fig. 8). These may be used to describe various productive processes.

A series of libraries has been developed and used as a basis for the modelling of the following parts of a sugar mill:

- Diffusion.
- Evaporation.
- Purification.
- Sugar room.
- Boilers.
- Dryer.
- Liquor storage.

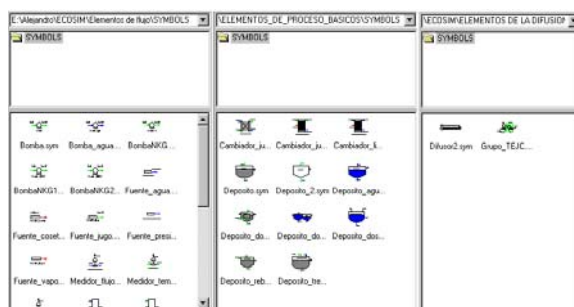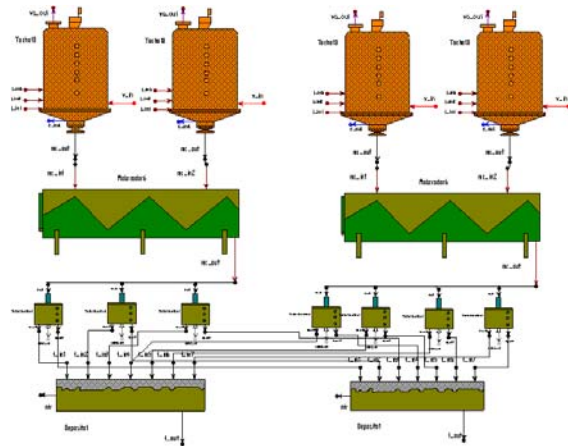As an example, fig. 9 shows the crystallisation section of a sugar mill.

Fig. 8

Fig. 9

EcosimPro has been selected as the simulation tool because it allows the development of libraries and the reuse of models, and the simulation model is generated as a C++ class, which, together with the integration routines, is easy to include in a different software application. This feature allows the development of executable files that simulate the system behaviour in real or accelerated time and have the capability to operate as OPC (OLE for Process Control) data servers. The use of the OPC standard allows communication between the simulation and any generic OPC client, be it a distributed control system, a SCADA, a controller, another simulation, etc, facilitating the reuse of the simulation code in multiple applications.

2.3 Operation and Supervision Environment

The operator consoles allow actuation in the same mode as in the real process:

- Browsing through mimic displays
- Display of results, both graphically and in tables
- Operator actuation (changing commands or manually manipulating control signals) and sometimes change in the value of the parameters of the regulators

The instructor console allows:

- The same functions as the operator
- Manual actuation on the process. Selection of process units both through mimic displays (Fig. 10) and user menus (Fig. 12), where these units are organised hierarchically by production sections and type of unit.
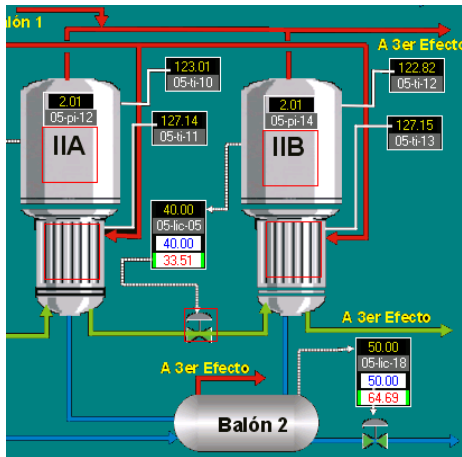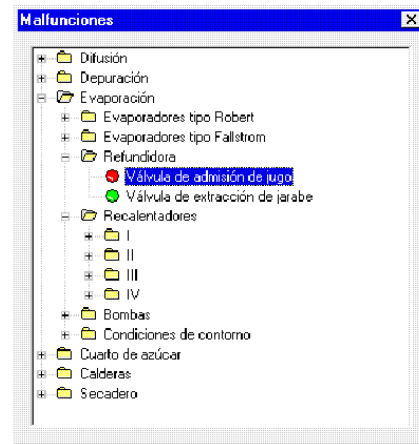
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Fig.10

- The selection, creation and recording of training sessions where several faults and changes in the boundary conditions are linked

Figure 11

- The activation and projection of videos and mimic displays to supply the operator with additional information or establish a guideline within the training

At the end of the training session the results are available in the historic file of the control system for their analysis and comments by the instructor and the operator.

Figure 12

2.4 Development Equipment and Current and Future Courses of Action

The project has been developed in the CTA (Valladolid University) by a multidisciplinary team. The courses of action taken are the following:

- Develop a library of dynamic models of process units and sugar products in EcosimPro
- Build models of the sections of a reference mill. Validation of these models with experimental data and expert knowledge
- Provide an OPC interface and real time execution capabilities to the simulation of each section
- Develop and configure the SCADA for the various productive sections, both for the operator console and the instructor console
- Establish communication between the simulations of each section so that they cooperate in a distributed mode
- Develop the training sessions and their corresponding manuals

3. CONCLUSIONS

A full scope simulator emulating a control room has been developed for sugar mills for the purpose of training personnel.

This simulator can have two architectures: one uses the distributed control system developed in the CTA (SICODI) and the other uses a SCADA, also developed in the CTA, with communications based on the OPC standard.

As regards the modelling language, EcosimPro has been selected for the dynamic simulation of all the processes of a sugar mill because it allows a hierarchical breakdown of the model and the development of reusable component model libraries.

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