Advances in computer-based, multimedia training provide significant opportunities to improve results

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ABSTRACT

Current conditions in the copper market demand that mine and plant operators make budgeted production targets at the lowest possible unit costs. For those companies bringing new production capacity on-line, achieving budgeted production levels as quickly as possible after start-up is vitally important to minimize unit costs and to begin a positive cash flow. Whether the objective is to simply improve unit costs or successfully start-up a new, complex plant, success will be strongly influenced by the skill levels of the operators and supervisors. The only way to assure return on plant investment, and to survive during depressed metal prices, is to ensure that plant operators have the knowledge to effectively run the plant. Technology available in computer-based, multimedia training systems, including: interactive animation, videos, voice-overs, schematics, and text can now be used to train operators at their own pace using plant-specific information. Additionally, it has been shown that learning through multimedia provides a higher degree of long term retention than more traditional learning methods.

WHAT OPERATORS NEED TO KNOW

Performance Associates has been in the business of assisting mining companies to effectively start up and operate minerals-related processing plants for the past 16 years. During this time it has become apparent that certain key information must be known by the operators and front-line supervisors if the plant is to be operated effectively.

This key information consists of several elements. First, it is essential that the operators have a conceptual understanding of the process and the principle of operation of each major unit operation in their area of responsibility. Conceptual knowledge allows for more effective reasoning when process upset conditions occur. Rather than attempting to provide a recipe covering any conceivable upset, the operator's conceptual knowledge will enable the operator to draw the appropriate conclusions based on the situation at hand.

In addition to understanding the process and its equipment, the following information is also vital. To ensure that each employee works safely, information on the correct methods for performing potentially hazardous jobs must be understood. Each plant operation will contain potential hazards that must be understood by every employee. These hazards include working with various reagents, such as sodium cyanide, caustic, sulfuric acid, etc. They also include working around various types of moving equipment.

Each operator must also fully understand each control loop in his area of responsibility. This understanding includes the variable being controlled, the instruments and control strategy employed, how to recognize when control problems occur, the backup options available, and when it is appropriate to exercise those options. This understanding has become more difficult over the recent past since control strategies have become increasingly complex with the advent of more and more powerful process control software.

In addition to the control loops, all interlocks must be thoroughly understood, including how interlock logic is effected by various operating parameters, such as remote operation, local operation, maintenance operation, etc. There has been a very significant increase in the complexity of plant interlocks during just the past few years.

Once the process and its critical variables are understood, along with the controls and interlocks, the operator must then learn the fault, cause, and remedy associated with each alarm—a daunting task since many of today's new plants have literally hundreds of programmed alarms in each plant area.

Each operator must also learn the correct steps to start up and shut down the plant under various conditions. These conditions normally include: start-up from complete shutdown, start-up from standby shutdown, start-up from power failure, and start-up from emergency shutdown. Additionally, each operator must know how to manipulate the distributed control system (DCS) to determine what is happening in the process, to take control of a particular controller, to adjust set points, etc. Operators must also know how to effect control using any local control panels in the plant. These panels are typical for packaged boilers, samplers, and solution heaters. The new complexity of metallurgical plants makes all of these procedures much more involved than they used to be.

Finally, each operator must learn a host of other operating procedures. These procedures include such tasks as taking samples, measuring slurry density, conducting routine inspections, and ensuring that the plant operates within permit requirements.

Operators having any limitations in the above-described knowledge will operate the plant at less-than-optimum conditions, resulting in higher than necessary unit costs. The more the knowledge gap, the more it will cost.

In plant start-up situations where very little of this knowledge has been transmitted to operators, the start-up can be nearly disastrous. In a typical start-up scenario, personnel react inappropriately to process upset conditions, causing further upsets. These upsets result in a new series of inappropriate reactions, sometimes including physical plant changes. Many times, a never-ending cycle occurs in which operator reactions cause problems that cause different reactions, in turn, causing more and more serious problems. Once this cycle has started, it can quickly get out of hand. Just getting back to the base plant condition can be virtually impossible.

The problems begin to multiply; since everyone is working extra hours to deal with the problems, there is no chance to catch up. Operators are left to absorb the necessary information by trial and error while dealing with the start-up problems. In some cases, more complex plants never do successfully start up. Simpler plants may eventually operate at production capacities approaching design, but only after long, arduous start-up periods.

Our observations are that operators of plants started under these conditions, as well as operators of many plants that have been operating for some time, have their own pet methods for controlling the operation. We have observed many plants where critical variables are controlled with entirely different home-grown strategies on each shift. In some cases, even the target values are different.

AN ALTERNATIVE APPROACH

Introduction

Few people would dispute the necessity of transmitting literally thousands of pieces of information about a metallurgical plant to the operator. Historically, we have recommended writing a series of custom plant operating manuals specifically designed for an education level of about the average high school graduate. These manuals are then used in a formal classroom training program, complete with graphic support, workbooks, and tests. With this method, training must occur prior to mechanical completion. Ideally, the trained operators complete the class work and then assist with the final stages of preoperational testing. Only then are they ready to introduce feed and perform their normal operating functions. However, for an already-operating plant, conducting training classes is sometimes not practical since the operators and supervisors are busy running the plant. It is usually impossible to assemble all of the operators in a classroom for instruction.

However, with the advent of computer-based, multimedia training programs, all of the necessary information can be imparted to the operators at their own pace, working on their own in front of a computer. Additionally, computer-based training allows for learning devices that are not possible in the traditional classroom. For instance, interactive animation approach the training effect of a full-blown simulator. Videos provide visual reinforcement of concepts and procedures described by narrators and text. The multifaceted nature of the computer interface makes learning interesting—almost like playing a video game. Testing is also provided to ensure that the student is progressing. An added advantage is that the huge amounts of information can be stored on just one CD.

Computer-Based, Multimedia Training

<u>Hierarchy</u>

The computer-based, multimedia training system is organized in a multi-level hierarchy. When the user enters the program, it opens with a summary flowsheet of the whole plant. A bar menu at the top of the screen indicates each of the areas of the plant. The user can then click on the applicable bar menu choice using the computer mouse to enter the desired plant area. Alternatively, the system can be programmed to allow the student to simply click the mouse in the desired area of the summary flowsheet.

When the user enters the desired area, the screen displays a detailed flowsheet of the selected plant area. The user can then enter a system within a plant area. Some systems are further divided into subsystems, depending on the complexity of the system and the level of detail required.

When the user enters a particular system within a plant area (for instance primary grinding) the system flowsheet is displayed on the screen. The user is presented with several buttons to allow for selecting various types of information. These buttons include: process description, process variables, control loops, interlocks, and alarms.

<u>Process Description</u>

When the user clicks on the process description button, a scroll box containing a written description of the process associated with that system is displayed on the left side of the screen. Hyperlinks are provided in the text to allow the user to connect to various schematic diagrams, videos, and glossary definitions as the text is read. For example, as the user reads about the SAG mill, a hyperlink might be available to allow the user to link to a video clip of a SAG mill in operation. Users can scroll up or down in the box as they read the text, or want to return to an earlier paragraph. Generally, the hyperlinks to schematic diagrams also have a written principle of operation to amplify the information on the particular unit operation being described. Alternatively, the user, having entered a process system, can click on a narration button. A narrator then describes the same information that is contained in the text box. Additionally, as the narrator describes the various unit operations, schematics, photographs, etc., are displayed at the appropriate time during the narration.

The purpose of the process description is to provide the operator with a conceptual understanding of how the process functions, along with the fundamental principles for each of the unit operations in the system.

Process Variables

After the user becomes familiar with the process and its equipment and unit operations, the process variables button can be selected. The screen then illustrates each of the key process variables in a box. The user clicks on the desired variable (for example, cyclone feed slurry density). A box then presents the variable, the target range, a summary description of the method of control, and a written description of the impact this variable has on the process. In other words, what the effect on the process is if the variable is not controlled within the target range. In addition to the written description, an arrow on the system flowsheet points to where the process variable is measured.

Control Loops

When the user clicks on the control loop button, a box showing each control loop in the system is displayed. The user then clicks on the desired control loop. A box is presented containing a written description of the control strategy for that loop, including automatic remote set point, automatic local set point, ratio, and manual, as applicable. In addition, a graphic that shows standard P&ID instrument symbols on the flowsheet illustrating that loop is presented on the screen. The user can toggle between the P&ID schematic and a simple block diagram, which also illustrates the control loop.

The user can also click on a narration button. When this button is selected, a narrator describes the information contained in the text box. As with the process description, the user can both read and listen to the description of how the loop functions.

Interlocks

When the user clicks on the interlock button, a box showing each interlock in the system is displayed. The user then clicks on the desired interlock. Next, a box is presented showing the equipment for which the interlocks and/or permissives must be satisfied and each of the input conditions. A flowsheet diagram for that interlock, graphically illustrating each of the input conditions using standard P&ID symbols, is also displayed.

Alarms

When the user clicks on the alarms button, two boxes are displayed. The first box contains a list of alarm groups, while the second displays each alarm in the selected group. The user selects the desired alarm group (for instance, SAG mill lubrication alarms). When the alarm group is displayed on the screen, a flowsheet with an alarm overlay is presented. The overlay shows alarms using standard P&ID symbols on a flowsheet diagram. The user can either click on the P&ID alarm symbol on the flowsheet or directly select the alarm tag shown in the second box. The selected alarm symbol shows a halo, while three text boxes that describe the fault, the cause, and the steps to take to remedy the alarm are displayed.

Safe Job Procedures

Safe job procedures are selected from the bar menu at the area level of the hierarchy since they apply to multiple systems. The safe job procedures are presented on screen in the form of written procedures instructing the user in how to handle any potentially hazardous job functions, such as making up sodium cyanide solutions.

Operating Procedures

The operating procedures are selected from the bar menu at the area level of the hierarchy. These procedures are divided into three sections: start-up, shutdown, and operator tasks.

When the user selects start-up, the area flowsheet is displayed along with a text box showing each start-up procedure. As the user selects each procedure in the start-up sequence, a second box that shows any observations, warnings, cautions, or notes associated with that start-up step is displayed when applicable. As each motor is started, the motor on the flowsheet can be programmed to turn from red to green. Any group starts show each motor in the group turning green in turn after the group start is selected.

Shutdown works in the same way as the start-up, except that as each shutdown procedure is selected in turn, motors turn from green to red. Observations, warnings, cautions, and notes are also displayed in a second box as each step is selected.

Operator tasks are organized in the same way as safe job procedures and describe procedures required to operate the plant. An operator task procedure is important whenever consistency is critical. These procedures always include preoperational inspections necessary to set up the plant for start-up. They also include procedures necessary for the operator to perform the job function. They may also include any steps the operator must take to manually control key process variables. Typical operator tasks for various job functions are:

- Manual boiler blowdown.
- Measuring pH.
- Preparing a batch of flocculant.
- Operating a column flotation cell.
- Shift inspection.

Interactive Animation

One of the major advantages of computer-based training is that interactive animation’s can be developed that provide the training advantages of a process simulator without the high cost of such simulators. For example, Performance Associates has developed SAG mill, thickener, and cyclone interactive animations.

For example, the SAG mill interactive animation provides the user with controls for establishing a ratio of water-to-new mill feed, along with sump water and trim water. As the user adjusts these variables, the effect on cyclone overflow size distribution is shown. With the thickener interactive animation, the operator can vary underflow pump speed and flocculant addition rates. A computerized strip recorder shows the effect over time on slimes level, underflow density, and rake torque. As the torque increases an alarm sounds, and ultimately, the thickener rakes raise if the user does not take appropriate corrective action.

Knowledge Assessment Tests

Multiple choice tests are available in each system for the user to test his knowledge. A tracking database is also available to log how much time each user spends in each system, as well as how much time is spent taking the tests. Additionally, the score each operator achieves is logged each time a test is taken. The user may take the test as many times as desired.

Multimedia Content Development

Developing the information contained in the multimedia system is a tedious and involved process. The following source material is needed:

- Flow diagrams.
- Piping and instrument diagrams.
- Equipment operating and maintenance instructions.
- Interlock logic diagrams.
- Motor control schematics.
- Design criteria.
- Equipment list.
- Instrument list.

Initially the text is written using a word processor in the form of a hard-copy operating manual. Graphics are initially developed in AutoCAD and translated into bit maps, where color is added. Color photographs are scanned. Animation can be developed with a number of software tools, depending on the nature of the animation. Voice-overs are read by a professional narrator using a previously-developed script. Videos are taken in the plant as necessary to illustrate equipment and procedures.

Material development writers must be experienced in plant operation and should be good writers; this is often a difficult combination to find. Typically, several months must be dedicated to the writing and development process. In start-up situations, engineering changes may still be occurring as the materials are being prepared; this adds to the complexity.

Training

In an operating plant, each operator can use the computer-based training system at his own pace, as scheduling permits. There is no need to schedule several operators into a classroom, as would be the case with more traditional training.

For a start-up situation, there is the opportunity to assemble all of the operators and front-line supervisors in a classroom environment. There are advantages to this approach since questions can be asked of an instructor and simulation drills can be conducted between teams of trainees. Therefore, we have normally recommended doing hard copy manuals that can be used in the classroom for start-up training. However, another option would be to use the computer-based, multimedia approach using a computer projector. A combination of both would be ideal for start-up training.

For start-ups, once the formal training sessions are completed, additional time can be spent in the field tracing pipelines, identifying every control valve and instrumentation element, and generally marking up P&IDs as instruments, equipment, and pipelines are identified.

The final phase of training is trainee participation in preoperational testing prior to introduction of feed. Operators, having completed training, are extremely knowledgeable about the new plant. They make ideal personnel to walk the plant and prepare punch lists of discrepancies.

When functional testing of completed plant systems occurs, operators can also participate in that testing. Ideally, the new operators can use the distributed control system or local PLC controls to operate the equipment necessary under the direction of appropriately qualified engineering personnel. As problems are identified during the testing phase, the new operators and supervisors can participate in problem solving teams investigating the problems.

SUMMARY AND CONCLUSIONS

There are literally thousands of specifics that must be learned by each operator involved in running a plant. In addition to facts concerning the plant, operators must also learn principles and theory associated with the equipment, controls, and methods. No matter how carefully the plant has been designed, or how well the new equipment works, the plant will not be optimized until the operators have completed this training.

There are only two ways for operators to learn the material necessary: the right way and the wrong way. They can learn it in a controlled environment as has been discussed in this paper, or they can learn it by trial and error as they are attempting to operate the plant. The cost of the former approach, while certainly not inexpensive, is very low compared to the lost production and high unit costs usually associated with the latter approach.