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STEAM AND CONDENSATE ADVISOR*

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ABSTRACT

This paper describes a collaborative project to develop an operational expert system prototype that will help mill operators and engineers to troubleshoot and optimize the steam and condensate portion of paper machine dryer sections. The objectives of the collaborating organizations and the functionality of the prototype are presented. The prototype's life cycle and prospects for further development are discussed.

INTRODUCTION

The purpose of this paper is to describe a collaborative expert system (ES) development project. The global objective of this one-year project is to apply the capabilities of expert systems to a paper machine, through the development of a practical operational prototype that will assist operators to increase productivity and efficiency. Specifically, it will help them to troubleshoot and optimize the steam and condensate (S&C) system.

This project is the result of a series of meetings, beginning with an open Workshop on November 14, 1991 and culminating in a meeting on October 5, 1992, that included three pulp and paper companies and two software vendor/consultant companies. The Workshop, organized by NRC (National Research Council) with the collaboration of PAPRICAN and CRIM (Centre de Recherche Informatique de Montreal), was well attended by

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many representatives of the pulp and paper sector. A project proposal to develop an operational prototype for a Paper Drying Expert System (PDES) was then prepared by NRC and submitted to these companies for their approval and commitment. This application (specifically, the steam and condensate sub-system) was selected from several alternatives based on: (a) return on investment, (b) scope for a one-year project, and (c) general applicability.

SIMCON (Software for Integrated Manufacturing Consortium, an umbrella organization that facilitates the management of projects done jointly by groups of companies in collaboration with NRC) is the organization representing the partner companies. In a meeting of June 18, 1993, between the SIMCON partners and NRC representatives, the project proposal was agreed upon as the basis for an NRC/SIMCON agreement. The one-year project would deliver an operational prototype to two specified pulp and paper mills within 9 months of the starting date (September 1, 1993). The last three months would consist of well-defined validation and acceptance tests. These tests, along with more detailed technical specifications, would be defined and agreed upon in the early stages of the project.

The partners currently consist of Abitibi-Price, Stone Consolidated, EDS of Canada Ltd. (software developer), and KanEng Industries, Inc. (manufacturer for the pulp and paper industry). One more pulp and paper company is under consideration. The work is being done at NRC with the participation of a person from EDS. A paper machine consultant is employed by SIMCON, and an expert system consultant from PAPRICAN is under contract to NRC.

The PC-based prototype will be tested and validated in at least one mill, over a three month period, following its implementation (scheduled for May 1994). It will be designed for portability to other paper machines and computer platforms. The pulp and paper partners expect to realize a return on their investment by using the prototype in their mills. The developer company will benefit from its investment by converting the prototype into a commercial product with enhanced capabilities. The prototype will allow the consulting company's clients to more easily and quickly identify performance problems requiring its services.

LIFE CYCLE

Installation and Testing

The system will be installed, tuned and tested by NRC with the assistance of EDS, KanEng, Stone and Abitibi. Each of the two installations will take approximately two weeks. Testing and tuning at both sites will continue for 3 months. The PDES project will ensure that adequate, dedicated hardware is available on site. The mills will supply personnel to assist in these tests. Data will be acquired from the S&C system and entered into the PDES an average of once per day during the test period.

One of the objectives of the installation and test period is to allow plant personnel to become familiar with the PDES. At the conclusion of this period, plant personnel should be capable of both running the PDES and configuring the PDES for other paper machines.

Acceptance tests will be performed at one of the two mills during this period.

Normal Use

Once installed and tested, KanEng, Stone, Abitibi will continue to use the PDES. In the mills, the level of usage may vary. For example, the PDES may be used as follows: (a) on a regular schedule, (b) when an operator perceives a problem, (c) when the operating mode of the S&C system changes significantly, or (d) when the paper machine's configuration changes. In some mills the PDES may get used once per month, while in others it may be used daily. One significant determiner of frequency of use will probably be how easy it is to acquire the necessary data. KanEng's usage of the PDES may involve both internal use and installation at clients' sites.

Adaptability

The operating companies intend to use the PDES on most or all of their paper machines. They expect to be able to make the appropriate modifications to the PDES' knowledge base without outside assistance.

Upgrade and Adjustment

During the test phase, the PDES project team is responsible for maintenance of the system. During normal use, any upgrading or adjustment of the PDES is the responsibility of the developing companies. They may choose to engage one of the other PDES collaborators to provide support.

Further Development

The main goal of KanEng in upgrading the PDES would be to improve its value relative to its consulting engineering practice. This would most likely involve extending the knowledge base to handle a wider range of equipment types, machine layouts, and diagnostic tests. Further development by EDS most likely will involve customization or extension of PDES capabilities for specific in the P&P sector. NRC could collaborate in follow-on projects which explore extensions or other applications involving technical risk. An example might be extension of the PDES' capabilities to encompass diagnosis of ventilation sub-systems. Regardless of extensions, it is expected that the PDES will eventually be transformed into an on-line diagnostic tool.

TECHNICAL DESCRIPTION

This project deals with the dryer steam and condensate system of paper machines. Although steam and condensate does not represent all the potential energy savings associated with the dryers, it is at least as important as the ventilation system (including economizers) in this regard. Furthermore, it can be made to satisfy the project's time constraint while yielding an acceptable return on invested effort.

The prototype will be PC-based (to satisfy the pulp and paper partners) and off-line, i.e., there will not be hardware connections to sensors or other computers. All required information may be entered manually. The short project time frame (9 months) for installation of the prototype does not allow for on-line data acquisition. The choice of development software takes into consideration the desire for portability to other platforms (e.g., VAX and UNIX based platforms) expressed by the vendor partners.

The prototype will demonstrate functionality. A subsequent project aimed at on-line data acquisition may be considered. It would relieve the operator from some manual data entry, and an annunciation feature to alarm the operators when the steam and condensate system is operating sub-optimally could be considered.

Phases of Operation

From a user's perspective, the operation of the PDES can be decomposed into three logical phases: (a) system configuration, (b) data acquisition and analysis, and (c) fault diagnosis. The user of the system will progress from one phase to the next, allowing for iterations at each stage.

System Configuration

The initial interaction between a user and the PDES in the context of a new S&C system application is the configuration phase. During this interaction, the user will be guided through the new S&C system's specification. The PDES will be capable of managing descriptions of many S&C systems. This phase will allow a user to create a new description or select and modify an existing description. It will guide the user through the specification process, providing defaults where appropriate.

The configuration of the S&C system can be broken down into the following main areas: (a) general information about the dryer system, (b) detailed information about each dryer steam section, (c) detailed information about each drive section, (d) detailed information about each condensate drainage section, (e) information regarding a size press (if used), and (f) information about each coater station (if used).

Data Acquisition and Analysis

During normal use of the PDES, there is an initial data acquisition phase in which the operating state of the S&C system is determined. The PDES will guide a user through this phase, providing information on how the data should be acquired.

The PDES will perform several numerical calculations. These calculations will provide a quantitative description of the current operating state of the S&C system. Some of the calculated values will be compared to a Base Line standard, and these comparisons will be used as the basis for determining whether or not a fault exists in the system. The data required for the calculations consists of previously entered configuration data as well as current operating data provided by the user. The configuration data consists of dryer sizes and the presence (or absence) of a size press and/or coater stations.

Interpretation will involve the comparison of calculated data (as described above) and current operating parameters provided by the user, with Base Line values derived from: (a) the literature, (b) a comprehensive field study of the machine, (c) the historical database of the S&C system, and (d) the user.

The Base Line values describe an acceptable state of the S&C system. All comparisons are made to this Base Line using thresholds configured by the user. If it is determined that the S&C system is currently operating more effectively than the Base Line state (i.e., the amount of water evaporated per amount of steam consumed is above the Base Line value), then the user will be prompted to reset the Base Line values to this current operating level. If the S&C system is operating below the Base Line, then the result of the interpretation will be an appropriate symbolic representation of the state of the S&C system and an expression of the certainty (reliability, accuracy, etc.) of that knowledge. This knowledge identifies symptoms for consideration in the fault diagnosis phase of operation.

Fault Diagnosis

In the third and final phase of normal operation, the PDES will examine the symptoms identified in the previous phases and hypothesize on possible faults or problems in the dryer section. It will then engage in a diagnostic session with the user.

A diagnosic session will consist of a series of system questions and user answers aimed at acquiring more information on the operating conditions of the paper machine. The answers given by the user will be used to confirm or refute the possible hypotheses. The diagnostic session will terminate with a list of possible faults and corresponding recommendations for alleviating the problem. The user will have the ability to question the system as to why a particular operating parameter is needed or why a certain conclusion was reached.

User Interface

The user interface will be a windows based graphical user interface (GUI) which conforms to the "look and feel" of the Microsoft Windows operating system. It will provide typical GUI entities (eg. pull-down menus, pop-up dialogs, push-buttons, ...) for ease of use of the interface. It will be able to display a simple schematic of the S&C system and will have the ability to display graphs similar to the TAPPI graphs of drying rate versus steam temperature. It will provide help facilities in the form of Windows help files, that will explain the various user interface elements, and conclusions drawn during diagnosis. The user interface will support both imperial and metric units on input and output.

Validation and Acceptance

Validation will be performed in two distinct stages, namely, before and after installation of the prototype. The post-installation stage is expected to take approximately 3 months. All tests and conditions of acceptance will be defined and agreed upon by the collaborating partners and the project team during the course of development.

During the pre-installation stage, actual case studies will be used (if appropriate ones are available from the domain expert's records); such studies will reflect real life practicality. In addition, improvised case studies will be designed for more complete testing of the prototype's functionality.

Mill cooperation for testing during the validation phase will be essential. The prototype will be used at prescribed frequencies (e.g., every 48 hr) and a log will be kept of prescribed observations regarding its use. For example, the log will record the effectiveness of conclusions and recommendations from the prototype relative to reality and established mill practices. When recommendations were implemented, how effective were they? Otherwise, why were they not implemented? Suggestions for improvement will be recorded. The development team will have regular access to the log for fine-tuning and evaluation purposes during validation.

EXPECTED BENEFITS TO PARTNER ORGANIZATIONS

Economic Benefits

The main economic benefit perceived by the partner organizations is from reduced steam inefficiencies in dryers. In a standard newsprint mill, the excess steam requirements due to various inefficiencies in operation and design could amount to 10% of the overall dryer steam usage on average. A good drying system would have a loss of 5% or less, but there are other machines with steam losses in excess of 20%. Actual savings would vary from mill to mill depending on the cost of steam, the speed and capacity of the machine, and the current state of health of the dryer system.

Other Benefits

Several other benefits will be available to the partner organizations, including: (a) liberation of internal and external experts for more challenging work, (b) faster restoration of machine efficiency after grade changes and maintenance shutdowns, (c) training tool, and (d) modular design facilitating possible inclusion in a larger decision support system (DSS) in the future.

CONCLUSION

A collaborative project for the development of a diagnostic expert system in the steam and condensate area of paper machine dryer sections was described. The one-year project will culminate in an operational prototype that will be used in the mills of the collaborating pulp and paper companies. Subsequent versions featuring improved functionality will be developed by the collaborating software company.

Further development following a successful completion of this project (circa September 1994), is likely to include an extension to the ventilation sub-systems of dryer sections. Regardless of extensions, it is expected that the system will be transformed eventually into an on-line diagnostic tool. This would relieve the operator from some manual data entry, and an annunciation feature to alarm the operators when the steam and condensate system is operating sub-optimally could be considered.

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