An Expert System for Monitoring and Control of an Oil Production Facility

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Abstract: This paper presents the development of an expert system for monitoring and control of an oil production facility. The objectives of developing an expert system for the oil production facility are to monitor the important processing parameters in different sections of the facilities and to control battery operations in real time. By providing consistent, fast, and reliable decision support to operators, the expert system can be used for automated monitoring and control of a petroleum production facility located south of Regina in Saskatchewan, Canada.The system was implemented in Visual Basic 6.0*.

1. Introduction

Monitor of oil batteries can be difficult because they are often located in remote locations that are difficult to access in severe weather. Delayed responses to problems occurring in oil batteries could result in financial losses. With the development of more oil fields, there is a need to reduce production cost by operating the production facilities more efficiently. The propose of this project is to develop and implement a knowledge-based expert system for intelligent monitoring and control of battery operations in real time to increases the efficiency of the process and reduces the need for physical visits to oil production facility sites. Hence, implementing such an expert system will enhance both efficiencies of the batteries and cost-effectiveness of their operations.

2. Oil Production Facility

The surface production equipment in an oil production facility (also called an oil battery) consists of a wellhead, oil production pipes, separators, treaters and tanks. The schematic flow diagram for the battery is shown in figure 1. Currently, there are two production wells connected to this facility. In the future when the field development plan materializes, more wells will be connected. The output oil from the production wells is passed first to the header, a controller that decides which of the production well output flows enters the gas-liquid-separator. The decision depends on what measurements are needed. The gas-liquid-separator separates different phases of oil into gas and liquid, which consists of water and oil. This is the first stage of the separation process on the oil produced from a reservoir. Based on the output of gas and liquid from the gas-liquid-separator, the gas-liquid ratio, which is an important parameter to indicate oil quality, can be calculated.

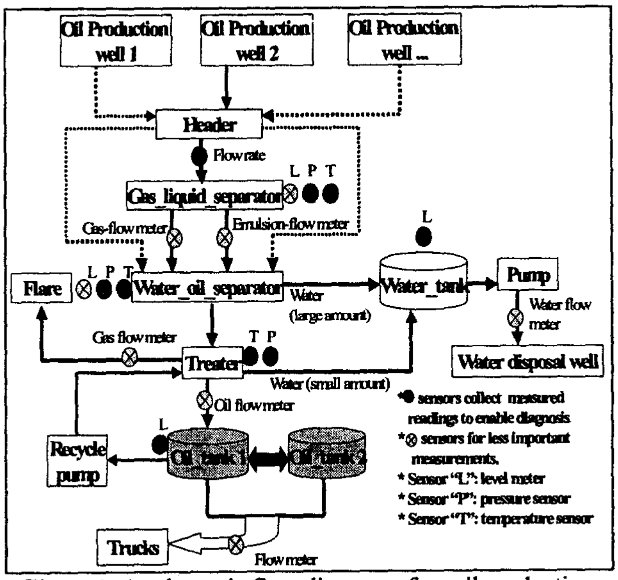

Figure 1. A schematic flow diagram of an oil production facility (Oil battery)

3. Problem Domain

The production facilities used for the initial stages of crude oil separation (also called batteries) are usually located in remote areas close to production wells. Operators often have to travel long distances at severe weather conditions to make routine checks on battery operations. Occasionally, this oil treatment facility run into some problems due to machine failure or process malfunction that halts the entire system for hours before the problems can be investigated. If there should be an operational malfunction, it usually takes some time for the field operators to locate it, which translates to financial losses for the company involved.

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To deal with this situation and to operate the batteries more efficiently, some oil companies have installed Supervisory Control and Data Acquisition (SCADA) systems that include a series of sensors integrated into a data gathering facility. The main function of a SCADA system is to gather the data needed to remotely monitor the operation of production facilities. Currently the company sends data acquired through the SCADA data through the World Wide Web so that customers can download the operating information. Coupled with a SCADA system, a knowledge-based expert system can monitor the operating conditions of a production facility by continuously comparing the measured values with normal or desired values. If there are deviations, the expert system can set off an alarm to advise the operator on where and what the problem is, and makes suggestions on how to solve the problem.

Expert system developments in different areas of chemical engineering such as process design and control, manufacturing, and production has been under study for many years. Despite the vast amount of research and study conducted on expert system in chemical engineering, application of expert system techniques in petroleum engineering is still in its early stages. The majority of expert systems developed for the petroleum industry are focused on decision support and/or screening purposes. Khan et al. [1] developed a prototype expert system for preparing appropriate input data sets to design miscible gas floods using the University of Texas compositional simulator. Gueríllot [2] developed an expert system to assist in the selection of an enhanced oil recovery process. Several literatures support on using expert system for monitoring and control. Szladow et al [5] described the application of intelligent system in heavy industry. They mentioned that the expert system could help manage production workflow and training of new operators. Ramesh et al [4] used an expert system as an advisory system to monitor polyethylene plants. Kritpiphat et al [3] introduced an expert system as a supervisory and decision support system for monitoring and control of a water pipeline network. Wu et al [7] discussed that expert could usefully control the leaching process in zinc hydrometallurgy.

4. System Development

First, the development begins with a knowledge acquisition process with experts by interviewing. This knowledge was analyzed and represented in the knowledge base of the expert system. The expert system design was completed. An overview of the system design that includes six modules is shown in figure 2.

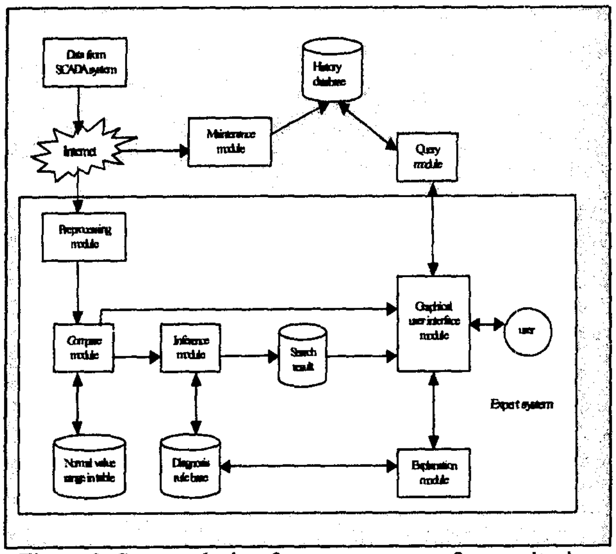

Figure 2. System design for expert system for monitoring and control of oil production facility

The six modules are: preprocessing module, comparison module, inference module, graphical user interface module, explanation module, maintenance module and query module. The six modules together can ensure control and monitor of the oil production facility. The Supervisory Control and Data Acquisition (SCADA) system collects the sensor readings from the oil production facility and stores them in data files (obtained as a history.csv file) that can be accessed by the preprocessing module on the Internet through the Sitelinkdata website at www.sitelinkdata.com. The preprocessing module downloads the data files and converts them into MS Access database files that can be obtained by the expert system. The comparison module monitors the battery operation parameters by comparing readings in the data file with the normal or standard value ranges stored in a system table. According to the domain expert, there are three categories of problems:

(1) Minor problems are caused by small deviations from standard values and are indicated by yellow warnings in the system;
(2) Serious problems are caused by larger deviations and are displayed with red warnings in the system and;
(3) Even larger deviations from standard values indicate emergency problems, which trigger an alarm bell. The yellow warnings that indicate minor problems are displayed on the graphical user interface module. When an emergency problem occurs, the inference module is invoked to determine the causes of the problem.

The knowledge base contains rules that relate causes of problems with their symptoms. The inference module interacts with the diagnostic rule base to determine causes of problems and possible solutions. The graphical user interface module displays causes of problem and possible solutions as system output. The explanation module interacts with the diagnostic rule base and provides responses to the user's queries of *How* and *Why*. The developer can also use it to uncover errors in the knowledge base of the system, and the user can better understand the system's reasoning. The maintenance module and query module that access the history database facilitate building a corporate database for the company. Currently, all sensor readings are obtained manually during field checks, so most of the operation data are not kept in long term storage. The maintenance module addresses this problem by updating the history database as soon as new data is available. At the same time, the user can inquire about the operation during a specific period of time and in a particular field. The query module executes query requests from the user by searching the history database.

5. System Output

The prototype of an expert system for monitoring and diagnosis of the oil production facility has been implemented with Visual Basic 6.0 on Windows 98 based on the design. The main screen of the expert system is shown in figure 3. The 'start' button can trigger the expert system to read a new line of data from the data file and the 'stop' button terminates input. An alarm that flashes on the gas_liquid_separator indicates the gas_liquid_separator has a serious problem, and the operator can obtain detailed information on the problem by clicking on the 'magnifier' button.

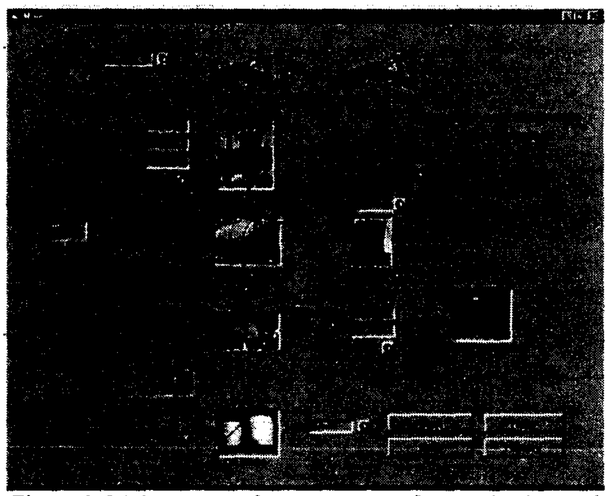

Figure 3. Main screen of expert system for monitoring and control of oil production facility

After triggering the 'magnifier' button, detailed information about the gas_liquid_separator is displayed as shown in figure 4. It shows that at this time, the flow rate of inlet to gas_liquid_separator is 75 m^3 /day, the working pressure in the gas_liquid_separator is 42 KPa (kilo Pascal) and the level in meters in the gas_liquid_separator is 1. The expert system has identified the problem that caused the alarm to be 'low pressure in gas_liquid_separator' and the possible causes to be 1) the exit valve of gas_liquid_separator is opened more than it should be, and 2) the production rate is too low. The recommended solutions in this case include 1) check if the valve of the gas_liquid_separator is opened more than it should be, and 2) check if the production rate is too low.

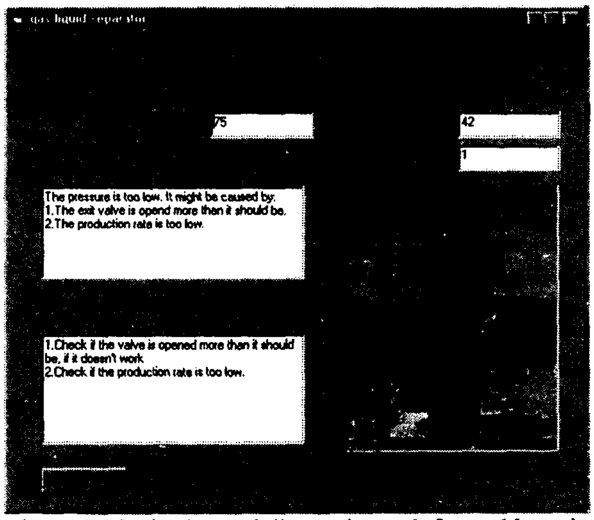

Figure 4. Monitoring and diagnosis result for problematic facility

6. Conclusions

Some advantages of developing an expert system for control and monitoring of an oil production facility include the following:

1. Development and implementation of knowledge based expert system for intelligent monitoring of battery operations increases the efficiency of the process and reduces the need for continuous monitor of these facilities by human operators. The system allows users to work on their desktop computer or notebook computer so that they can operate the system wherever and whenever they wanted. Through the graphical user-interface, users can obtain information quickly and easily. An expert system can provide users with pictures and tables which can support enhanced visualization of the system and can improve upon the displays of SCADA data provided on the web. The displays from the SCADA system only provide users with operating information at different period of times in the form of data in excel files.
2. With implementation of an expert system, the expertise that has been encoded in the system is a valuable resource for the organization.
3. The expert system can be integrated with an existing SCADA system, and provide intelligent decision support based on the data obtained from the SCADA system. Once the user can download the SCADA data from the web, the expert system obtains the data and interprets the data to obtain an understanding of the state of the system and gives recommendations on the system future state, and determines and executes needed operational controls.

However, The prototype expert system developed does not currently have direct control over the sensors and valves in the battery. If connected to a control system, the expert system can issue the necessary corrective measures to resolve a diagnosed problem. In the future, the system needs to be validated by the experts from the company involved.

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