Automatic malfunction diagnosis by on-line expert system for underground mobile machines

Philippe Villeneuve de Janti, Jean-Paul Malet, Marc Lefevre

AUTOMATIC MALFUNCTION DIAGNOSIS BY ON-LINE EXPERT SYSTEM FOR UNDERGROUND MOBILE MACHINES

P. VILLENEUVE de JANTI, JP. MALLET, M. LEFEVRE
INERIS
(Institut National de l'Environnement Industriel et des Risques)
B.P. 2
60550 VERNEUIL-EN-HALATTE, FRANCE

ABSTRACT

In many underground workings, either for mineral production or for creating lines of communication, mobile machines have to operate under conditions that are very difficult for personnel and equipment. Problems such as excessive dust, rock falls, high temperature and humidity, or the presence of an explosive atmosphere are not uncommon. Today, it is possible to monitor such machinery from a surface station, in real time, using a highly reliable digital transmission system (developed by INERIS), at distances of up to 10 km from the working. Similarly, difficulties arising from in-situ maintenance have led to the development of an on-line malfunction diagnosis system that can detect such malfunction and halt operation by a conditionnal programmed stop. The software has been developed using Expert System techniques with GENESIA 1 (EdF-STERIA) and the hardware is compatible with IBM PC-AT. On-line communication is under JBUS protocol. Full analysis (data acquisition - processing - output) takes 20 seconds. The system can be interrupted at any moment to obtain correct status of operation.

INTRODUCTION

The mining environment in general, the working face in particular, is a hostile medium in which traditional industrial equipement has no place. Because the atmosphere may be explosive, all electrical equipment must either be protected against the risk of explosion or else must be intrinsically safe. Every installation requires adaptations to withstand rock falls, water, dust etc. On coal winning machines such as shearers, one must allow for vibrations and impacts, difficult access to components, lack of space in housings and high temperatures (up to 100 C).

Also, the risk of firedamp prohibits the use of live equipment, with open casings, for testing or repair work. In these conditions, it is all too easy to appreciate the importance of accurate, on-line diagnosis.

The developments described here are concerned with shearers, very powerful machines of 40 to 80 tonnes, 12 m long, fitted with two electric motors, each of 300 to 500 kW and the speed of which can be as high as 10m/min. In 1988 these machines provided 40% of the total coal production in France. It is easy to imagine the losses involved when such a machine breaks down.

In normal operation, the machine is radio-controlled (Figure 1). In automatic operation, with computerised on-line monitoring control from the surface, the personnel in the working may intervene to override and correct certain automatic instructions by means of radio-operated remote control.

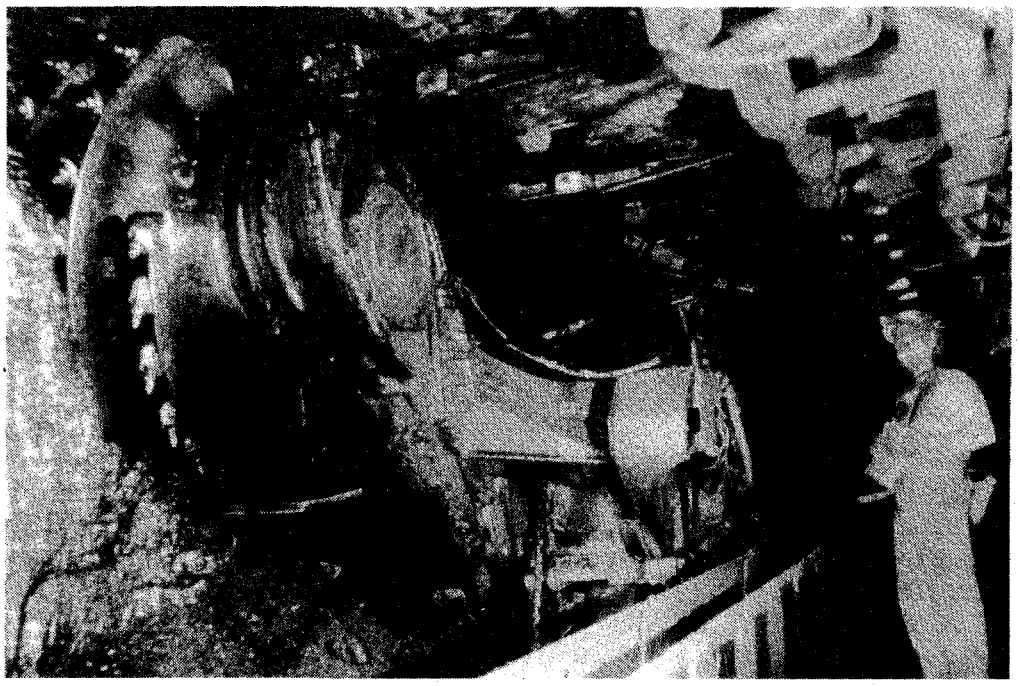

Figure 1 Radio controlled coal-winning machine

TELETRANSMISSION SYSTEM

Teletransmission is by the TELSAFE DV-CA system. This allows exchange of information between a mobile machine powered by an electric cable and a fixed point in the roadway or on the surface. It contains two independent groups working either simultaneously or separately on :

- a "tele-measurement" and "tele-signalling" channel for the acquisition of data on the state, position, functioning of the machine and the transmission to the micro-computer.

- a "remote-control" channel, allowing the transmission of messages formulated by the micro-computer for a monitor to be installed on the machine.

The shearer is also equipped with a series of transducers for obtaining the principal parameters characterising its functions. These data are collected in the machine, codified in digital form, then put into the power supply cables of the coalcutter via a coupler.

The power cable is necessarily in good state when the machine is running. So, we are sure that data can be transmitted. In the vicinity of the district transformer, the data are extracted from the power circuit, amplified and transmitted to the surface via a telephone pair.

The teletransmission capacity is 2550 useful bits per second (47 ms cycle) divided into 12 analogous measurements and 48 "all-nothing" data.

ON LINE DIAGNOSIS

A preliminary data-processing system for the on-line diagnosis of faults has been developed on a VME system under the MOTOROLA VERSADOS real-time operating system. The software, written in PASCAL, occupies 100k octets and is a sort of decision table which identifies what each particular group of data signifies as regards the state of the machine. A diagnosis as to the probable cause of malfunction is written and displayed in real time (Figure 2).

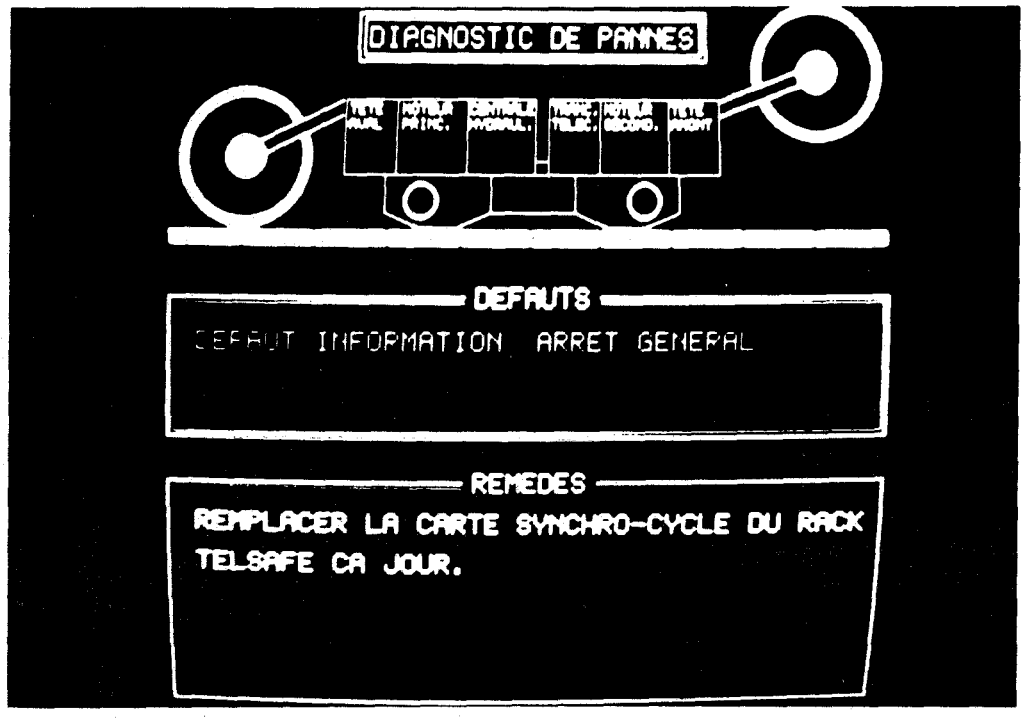

Figure 2 display of diagnoses with the PASCALprogram

The limitations of such software are the difficulties involved in parametering (considerable readjustment of the software in order to adapt it to the type of machine or to modifications in its instrumentation) and its unsuitability for treating cases of breakdown, where the diagnosis depends on the moment, the time or the sequence in which the events occur.
This software maintenance demands data processing services and limits the chances of success when applying the system to industrial operations.
In order to mitigate these disadvantages, the use of software of the "Expert System" type was decided on.

EXPERT SYSTEM ARCHITECTURE

Progress of data

The data transmitted by TELSAFE are sent via an on-line interface to the surface (frontal TELSAFE) ; this ensures the filtering and pre-treatment of certain data, which are then loaded into a JBUS letter box.
A serial link can be added to a real time VME computer for the monitoring and control of the movements and functions of the mobile machine underground. By a second serial link, the calculator, bearing a diagnosis of the operation (PC-AT compatible) consults the letter box of each inference (Figure 3), possible via modems.

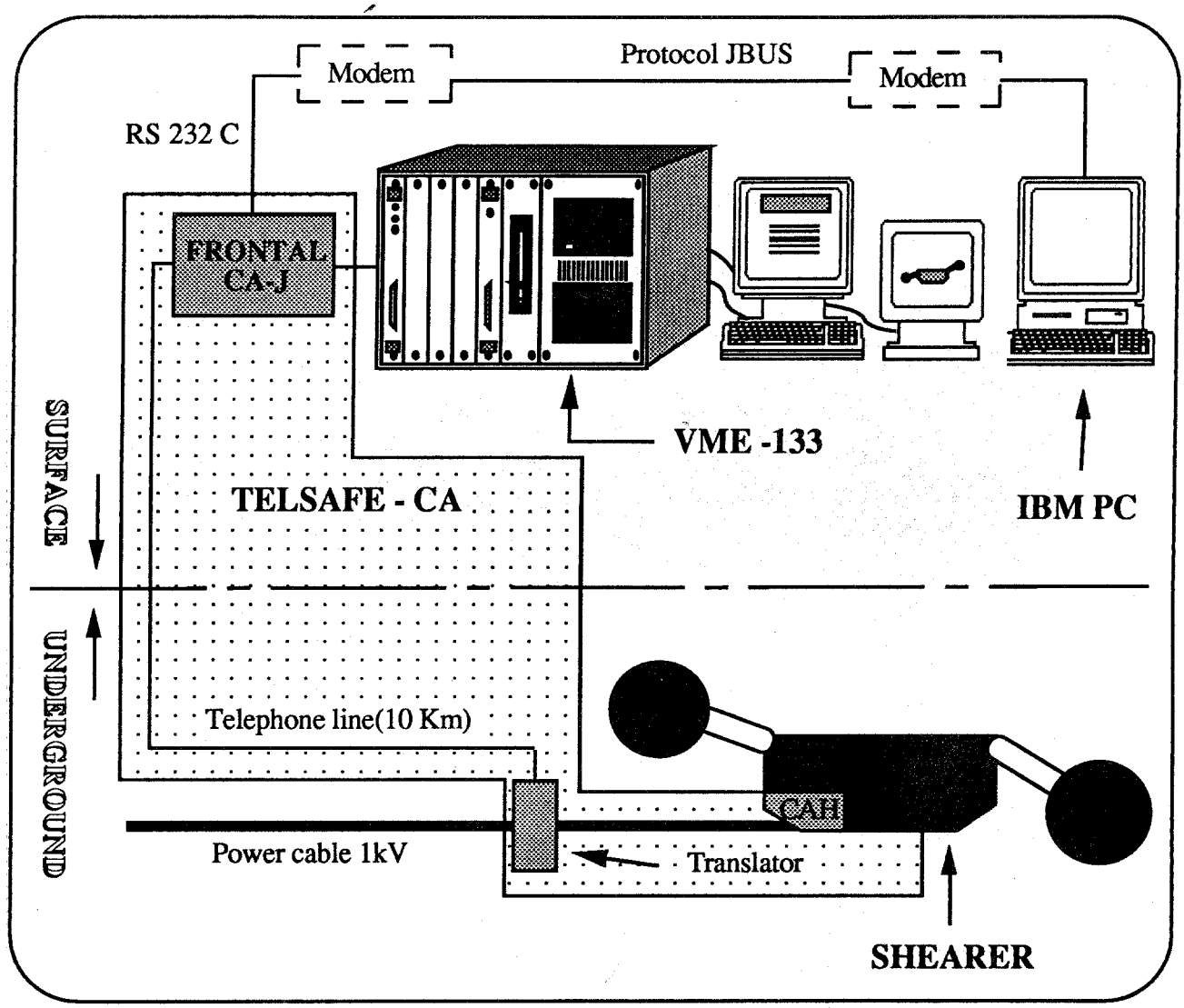

Figure 3 Progress of data

Hardware and software configuration

At present the machines used are COMPAQ 286 or 386 with 20 or 25 MHz of clock. The size of the group of files for the application is almost 1 Mo.

The generator

The generator of the GENESIA 1 expert system was adopted, for the following reasons :

- possible use, on-line, with the TELSAFE frontal which decodes the data from the shearer and manages the series link under the JBUS protocol ;
- the price is reasonable for a model for a feasibility study before extending the system to take in several mines ;
- consequent functioning on PC ;
- inference processing time is no more than a few seconds ;
- system of order 0+ ;
- possible explanation of diagnoses in order to facilitate development and give users confidence in this device ;
- it gives mechanical experts (who are familiar with the language used by automation specialists) a tool for development not requiring advanced training in data processing.

This Expert System generator functions with forward chaining. Programming is carried out by production rules of the kind IF...THEN,... The units processed may be of the chain,whole, real, unknown type.

It is possible to start an inference with the demonstrator. One may thus get to know :

- the rules involved ;
- the associated comments ;
- the reason why the premises were valid ;
- the original facts.

Special functions added to the generator

A certain number of special functions were incorporated, at INERIS's request :

- starting, without loading, a new inference with the same basis of rules, but operating on a new basis of facts ;
- acquisition of the variable CONVERGENCE, which changes to 1 when the inference is at an end ;
- writing in a file available at the end of the inference, without leaving GENESIA 1.

APPLICATION

Generality

The application consists of procedures written in Pascal and in C, files of data processing systems, by lots, starting DOS functions, with GENESIA run-time and basis of rules compiled.
The system is designed to work autonomously, without human intervention. The diagnoses are put on the screen of the PC, keeping pace with the inferences, every 15 to 45 seconds according to the processor used.
Each new diagnosis (occurrence of fault or return to normal) is recorded, with date and time, on a hard disc, in files peculiar to the machine inspected. These data can, likewise, be printed continuously.

Starting

It starts with a menu (Figure 4), which makes it possible :

- to select which machines one wishes to connect ;
- for central technical services, to compose, automatically, the telephone number to reach the corresponding modem ;
- to start the diagnosis (or other applications) ;

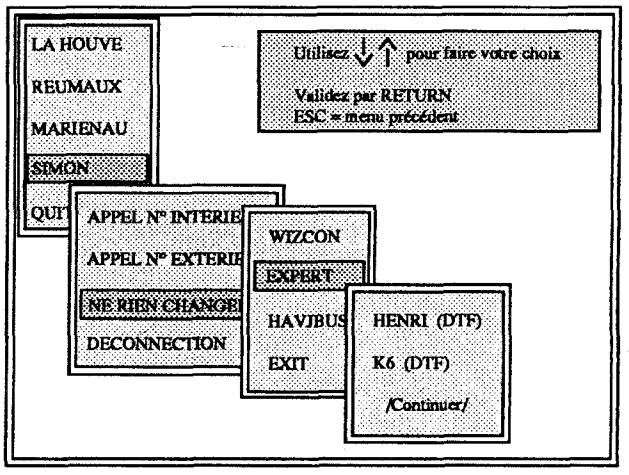

Figure 4 Main Menu

Another menu (Figure 5) gives an access, for each selected machine, to its related list of informations. This list can be edited and any information described in it can be inhibited. So, it is possible to tell the system not to consider an information if a sensor is disconnected or failing.

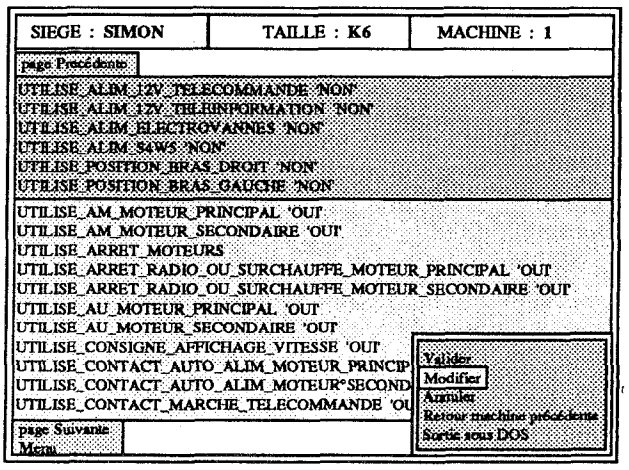

Figure 5 Sensor select Menu

Cyclic diagnosis

When this preliminary work is done, cyclic diagnosis can be launched :

- machine #i information reading,
- fact base construction,
- inference start on the basis of 200 rules, diagnosis elaboration,
- results printing (Figure 6),
- diagnoses edition (on disk or printer),
- if there is a new default, fact base saving for a future explanation,
- iteration for machine #i+1.

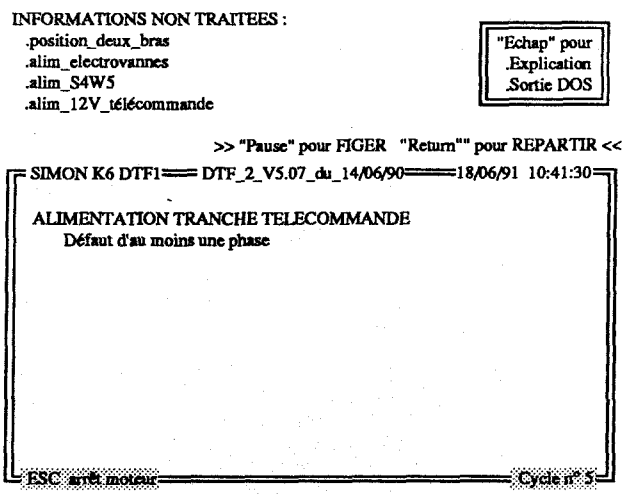

Figure 6 Diagnosis screen

Explanation of the diagnosis

It is possible, at any moment, to stop the system in order to ask to follow the reasoning on which the diagnosis was based. This procedure enables one to visualise each of the rules validated, with its commentary, and to return, step by step, to the premises of the fact base (Figure 7).

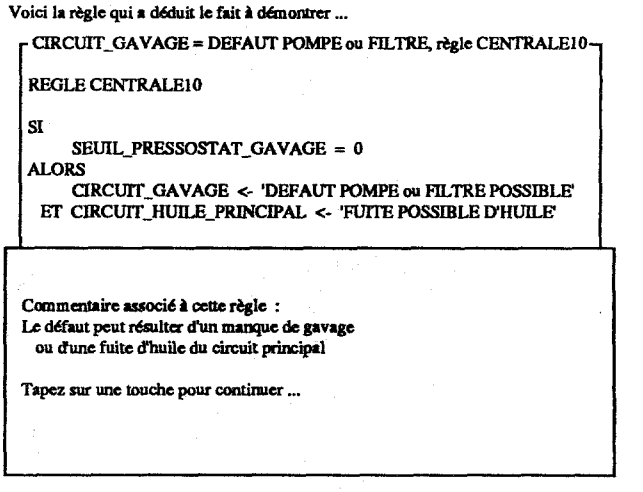

Figure 7 Diagnoses Explanation

Utilisation

The system has been is use at the Unite d'Exploitation REUMAUX of the Houilleres du Bassin de Lorraine since April 1990. The principle qualities recognised are :

- accuracy of diagnosis permitting emergency repairs without proceeding by trial and error ;
- possibility of keeping the system in service even if a transducer is faulty ;
- explanation given as to the manner in which the diagnosis has been established.

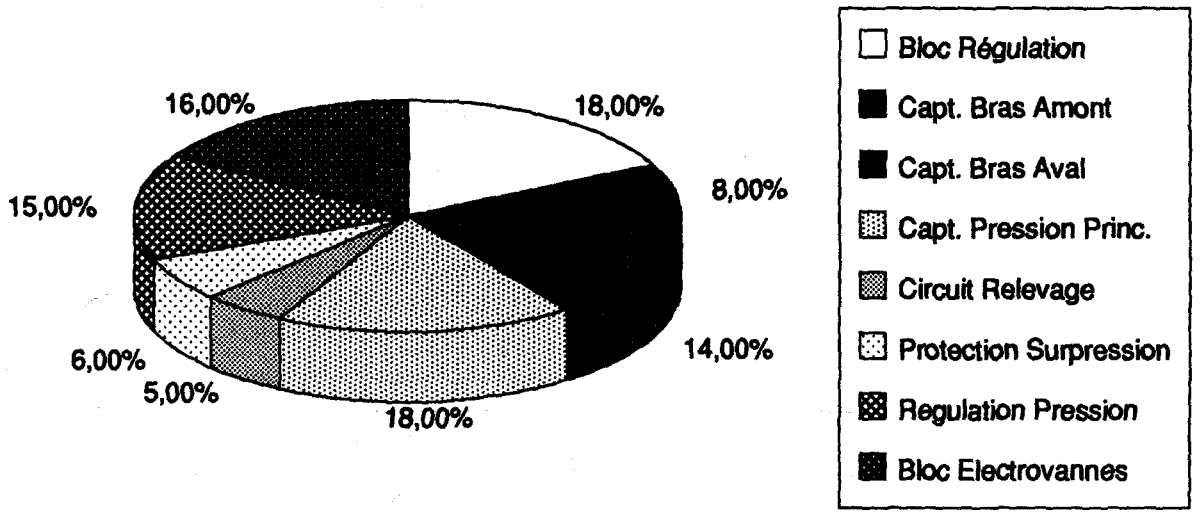

Figure 8 Frequencies of occurrence of faults classified by types of affected devices

CURRENTS DEVELOPMENTS

An application has been developed to consult the file of diagnoses by the shift, the week, month or operational cycle (5 months to 1 year or more), in order to get to know the most frequent and long-term faults etc. Statistical information on frequencies of occurrence of faults, classified by types of affected devices, can be displayed automatically (Figure 8).
The use of files over a long term will make conditional and preventive maintenance possible.

Extension to all types of machines

The rules written for the DTF shearer may be partly adopted for other types of machine. Even now the system is ready to select rule bases corresponding to the different machines working in a mine.

Spending-up the scanning cycle

Modification of the structure of application and better use of the resources of the PC should halve the time necessary for establishing a diagnosis.

Transfer to machines

INERIS's current improvements to the TELSAFE CA transmission system will extend the present possibilities of surface-to-underground. It will soon be possible to use a display unit on the machine, in order to bring the diagnoses as close as possible to the site.

Consideration is also being given to the installation, on the machine, of a sufficiently powerful and robust computer, in order to process the data at source. Such an installation which would no longer be limited by the rate of transmission over a distance, could deal with rapidly developing values (vibrations, starting power etc.) containing very important information as regards maintenance.

EXTENSION TO OTHER APPLICATIONS

The architecture of the system developed can, even now, be easily applied, to monitor any industrial process having development times of the order of a few seconds.