Coal Mining Application Requirements for Distributed Computer Control and Monitoring Systems*

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1. Introduction

This paper has indicated the requirements for distributed microcomputer control for underground application in coal mines. It was considered unlikely that any revolutionary change would occur over the next 10 to 20 years in current mining equipment and techniques. Therefore, only evolutionary changes were considered.

These changes will involve the introduction of many more sensors to monitor underground equipment; this is essential for the advancement of computer control. There should be a gradual progression from comprehensive monitoring and computer aided manual control, to remote monitoring and control, and finally to full automatic control. In fact, the use of distributed microcomputers will allow localised activities to be automated without necessarily being connected to a minewide communication system.

The system architecture which meets the above general requirements will consist of stations interconnected by serial communication lines to form a network. The serial communication is necessary because the physical distribution could be over distances of up to 10 km. The station itself will consist of one or more microprocessors and will have sensors, actuators or some other form of input/output (eg. operator interface) connected to it. A simple station may be an intelligent sensor or a more complex one might be a conveyor controller. A complex function could either be performed by multiple stations or by multiple processors within a single station, ie. there is modularity at two levels.

2. System software and station architecture

The application software is decomposed into component modules, one or more of which may be assigned to a particular station. System modification/reconfiguration

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is controlled by commands to a command interpreter, Except for system modification/reconfiguration each module will remain at a particular station. Each station must provide system software (kernel) for the following:

- To support the applications software (ie. device handling communications interface).
- To manage the modules (ie. linking and loading modules).
- To control module execution (ie. scheduling parallelism, stopping / starting / initialising modules).

The system software is thus composed of the kernels of the station and a system command interpreter to control modules. The requirements of the station architecture are:

Communication - a station must have a communication capability to enable plant to be controlled and monitored by a remote operator and to allow co-ordination of the activity of a number of items of plant. It must be able to exchange information with the operator and with other stations. To ensure reliable communication the station must provide a protocol for exchanging messages. It is likely that a micro-computer will be incorporated in the station with the sole task of implementing this protocol.

Control - the control function for individual items of plant is generally not complex. For these 'simple' functions, the station must be able to monitor about 10-50 digital (two state) inputs and up to 10 analogue inputs. It must also be able to control a small number of digital (two state) and analogue outputs. However, there are instances where the control function implemented by the outstation is considerably more complex, as in the coalcutter. Therefore, there is a requirement for the station design to cater for a range of control complexity. The design which handles the 'simple' control must have the capability to be extended, in terms of its processing power and input output, to handle the complex control applications. The obvious way of meeting this requirement is to have a modular design for the station. In a particular station, the number of micro-computers and input/output modules will match the needs of the control application.

Maintenance - in common with all electronic and electrical equipment used in coalmines, the maintenance of control equipment is complicated by the lack of test gear available for use underground. Consequently, the station design must facilitate easy maintenance using little or no test equipment. Again, this requirement can be met by having a modular station design. Faulty hardware modules can be replaced underground and taken to the surface for repair. The repair by replacement philosophy ensures a minimum of a down-time for the station. The use of microcomputers further alleviates the maintenance problem by allowing stations to include diagnostic facilities.

The station diagnostics should be capable of remote and local operation and should be able to identify the faulty modules for the maintenance personnel. Obviously, to minimise maintenance, a design objective for the outstation must be high reliability.

Safety - in coalmining, an overriding requirement for control equipment is the safe operation of the controlled plant. A station must implement 'fail-safe' operation. Failure of the station must always result in the controlled plant being put into a safe state. For the majority of plants this safe state is isolation from the power supply. To ensure fail-safe operation, the station design may incorporate some hardware logic for safety, in addition to the microcomputer/s which perform the primary control function.

Stand Alone Operation - a station should have the capability to continue with its local control function when isolated from the rest of the control network. Stand alone operation is also required for local operator control, maintenance and provision of local automation before the mine-wide communication network has been installed. Stand alone operation means that the outstation must provide a local operator interface

Physical - as with other mine electrical equipment, the station must be intrinsically safe or flameproof and physically rugged. It must be capable of running from a battery backup for essential functions, such as environment monitoring, which must continue operation when the main plant power has been cut.

Physical robustness is particularly important for outstations which are frequently moved (eg. stations at gate-ends) or integral with moving machinery (eg. coal-cutter).

3. Communications system

Standardisation - there is a need for standards within the communication system. This is essential if components used for different activities are to communicate, particularly if the components are supplied by different manufacturers. This would then allow a mine to buy and interconnect equipment from differen manufacturers to form a mine wide distributed control system. There are two aspects which must be standardised:

1. Protocols - the rules governing the exchange of informatic between equipment. This includes the format of the information, the acknowledgements, or responses to use in case of error, etc.
2. Interface - the mechanical electrical and logical specification of an interface (eg. plug and socket) to allow components to be connected to the communication system.

Extensibility - it is difficult to estimate the accurate quantitative information transfer requirements as much of the automation suggested in this report is conjecture at present rather than specifying a single communication system with adequate handwidth to cater for all foreseeable applications, it is better to specify a modular system which can be enhanced to cope with future traffic. This would also allow a mine to install a small system and expand it gradually.

Transmission Medium - the communication system design must, to a large extent, be independent of the particular transmission medium, eg. the technique specified should not depend on, say, the use coaxial cable. There is already a large investment in installed twisted pairs. It is acceptable for the maximum transmission rate to depend on the medium used, and so it should be possible to match the medium to the information transfer rate requirements between stations. For example, local communication between the shearer and gate end might have a transfer rate high enough to warrant the use of coaxial cable or even fibre optics.

Types of Information - the communication system must carry the following types of application information:

- Commands - from an operator or controller to an item equipment, eg. start, stop, send all sensor readings.
- Responses - to the above commands, eg. performed OK.
- Alarms - from equipment controller to system controller operator, eg. bearing temperature = 100 degrees.
- Status reports - it is necessary to check the status of equipment at regular intervals to determine that no failure the control system or communication system has isolated to equipment and so it is unable to report an alarm, eg. all working OK or values of particular sensor readings.
- Logging Messages - lists of readings of sensors over a period to allow off line trend analysis.
- Programs - it is likely that an operational system would have programs in ROM, but the communication system should still allow programs to be transmitted, eg. for diagnostic, or for development purposes.

Message formats are design decisions, but a typical command would contain fields to indicate:

Device identifier,
Command Code, and
Parameters.

Commands would require about 3-10 bytes, other messages (eg. logging messages) and programs are likely to be longer, ie. there is a requirement for a variable length message

The communication system must allow arbitrary bit patterns in the application information as it may contain binary or coded data.

Information Transfer Rate - it is very difficult to estimate the information transfer rate requirements for a typical mine. This would depend on the amount of remote control or local automatic control, what plant is being controlled etc. To a large extent, it is future control systems which will require communications, and technology or cost changes can make a dramatic difference. For example, present mines have about 10-15 environmental sensors per district, but if they become cheap enough a district may use 100 or more.

It is possible to derive a very rough estimate of the information transfer requirements of a single item of plant, eg. a pump controller based on the following assumptions:

The plant controller contains intelligence which monitors all sensors and makes decisions to switch on/off.

Readings from most sensors are not reported to the surface. Selected readings are reported on an event basis, ie. when a significant change occurs.

Normal Transfer rate: status reports of 20 byte message every 15 minutes in response to a 5 byte command, ie. average transfer rate is less than I bit/sec.

Peak rate: request for all sensor readings at 30 sec intervals,. assume 100 bytes message, ie. approximatively 27 bits/sec.

Local intelligence, on the whole, reduces the information transfer rate requirement.

Communication Response Time - as mentioned in section III, the reaction time of mining plant is typically tens of seconds. It can be assumed that any sensors requiring fast scanning (eg. pick force sensors) will have local intelligence to perform this function. A response time in the order of 0.1 seconds to transfer a 10 byte message and receive a reply should be adequate for most applications. This will allow multiple messages to be transferred to perform sequence starts. Shorter response times may be required in a localised system, eg. for shearer steering controller.

Reliability - we were unable to obtain Quantitative reliability requirements but the following figures seem reasonable.

Undetected Error Rate - the IEC requirements for commands carried over a communication system is that there should be less than

message with an undetected error per 1000 years continuous operation, ie. there should be no undetected errors in the information carried by the communications systems during it operational life. The undetected error rates reguired for logging messages and cyclic updates could be less stringent.

The system should not contain a single component (eg. a "master station") whose failure would halt all communications throughout the system, all communication.

Parts of the communication system, eg. for environmental monitoring will have to operate continuously, ie. it should have an availability in excess of 98% over a 7 day week.

Error Control - the communication system should perform automatic detection and correction of errors due to corruption. Any fault from which it is unable to recover must be reported. The inability to deliver a message must be reported to the sender, and any fault due to failed components or persistent erros must be reported to a operator.

Remote Diagnostics - the system should be designed so that diagnostics performed from the surface would allow failed components to be determined down to the board or transmission line level. It must also be possible to monitor communication to or from module within stations for testing purposes particularly for system development.

Error and Performance Monitoring - the system must contain facilities for monitoring performance and errors so that intermittent faults or bottlenecks can be identified.

4. Conclusions

One of the main benefits from an extensive use of sensors and microcomputers will be to make more information available on the state of equipment, eg. machine status and health monitoring. The microcomputers could help to continuously monitor equipment, to report when limits are approached and succeeded. and to aid in the diagnosis of machine faults. This should reduce stopping (by improved preventative maintenance and fault diagnosis) and hence improve production. Other benefits include improved safety and manpower savings in some activities (eg. comprehensive remote monitoring of the environment could allow mines to be unmanned over weekends).

Despite the reduction of information flow to the surface from a particular functional area by the use of local microcomputer monitoring and control, there will be an overall increase in the amount of information available at the surface. Care must be taken to decide where this information goes and how it is presented to operators, engineers and managers.

In general it was not possible to quantify the requirements for distributed control in mines as most of the computer control activities identified in the report are still conjecture. However, control in mines is not dissimilar to process control in other applications eg. petrochemical industry. The environment is slightly harsher but there are similar requirements for Intrinsic Safety or Flame Proofing. Most mine activities do not require very fast response times nor high information transfer rates. One of the main differences from other control applications is that equipment is moved more frequently and hence the systems must be easily reconfigured.

One of the most important qualitative requirements identified was that of modularity. Most of the other requirements - such as reconfiguration, reliability, ease of maintenance, etc. depend on a suitable modular design for the distributed computer control system. Also, to allow the gradual introduction of additional computer control into mining activities, the modularity of the computer system must be consistent. This leads to the need for standards and common practices at various levels:

Language standards for specifying the control system requirements, the system configuration and programming the system.

- Standard protocols for communication between activities or modules within an activity.

- Standard interfaces to modules and to the communication system.

The station architecture need not be standard as it may be incorporated into equipment produced by different manufacturers. However it must support the other standards.

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