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A Computerized Dispatch System for Underground Production Machines at Finsch Mine

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The dispatch system described consists of infrared beacons mounted in strategic positions, which report the locations of passing load–haul–dump units (LHDs) to a base computer on the surface via a complex but reliable communications network. LHD operators receive their instructions on on-board computers that communicate over a VHF leaky-feeder radio system based on a leaky feeder. The system monitors and dispatches the LHDs on the production levels according to the priorities set for loading drives and tips in the production plan. The LHD operators interact with the on-board computers to notify the dispatch operator of delays, breakdowns, and changes in the status of tips or loading drives. The dispatch operator then re-assigns the LHDs according to the changing production variables.

Most of the commissioning problems have been addressed, and the system has become a useful aid to the production and management staff. In addition, the system is making a valuable contribution to the achievement of production goals at Finsch Mine. Development is proceeding on a smaller, more rugged computer to better meet the harsh underground conditions, and on a UHF token-ring data radio, which is less capital-intensive than the leaky-feeder radio system.

Introduction

Finsch Mine is a diamond mine situated 160 km west of Kimberley in the northern Cape Province. It was operated as an open-cast mine from 1963, and started to produce ore from the underground workings in October 1990, when the open-cast operation was terminated.

The production call from underground is 4,5 Mt of ore and 250 kt of waste per year. The Mine is producing ore from two levels, utilizing eighteen 12 t load–haul–dump units (LHDs) to load and transport the ore from a total of 110 loading ends to 8 ore passes. Each ore pass is 6 m in diameter, with a storage capacity of 8 kt, and has two tips, thus providing thirty-two tipping points distributed over two levels.

The Mine installed a PLC-based system to monitor all the underground operations, and to control some operations from surface. The PLCs and computerized supervisory system are connected by a fibre-optic ethernet network. The system currently handles about 6000 inputs and outputs distributed between 8 PLCs and covering 6 levels in the mine.

Requirements of the System

Before starting the production underground, it was calculated that it would be very difficult to obtain the daily call, even under ideal conditions of totally uninterrupted operation. The rapidly changing variables like the availability of vehicles, loading ends, tips and passes, and the traffic congestion would impose further constraints on the achievement of the production call.

Extensive research work by the Mine indicated that a computer-based LHD-dispatching system was required to meet the production goals. The object of such a system would be to maximize the production with the available equipment by monitoring the real-time production requirements, the availability of loading ends and equipment, and the status of tips and passes; and by assigning the LHDs accordingly. Finsch believed that such a system was feasible with the technology existing at that time.

Selection of a Dispatch System

The development of the underground system began in 1988 with an informal meeting between personnel of Modular Mining Systems (MMS) and De Beers at Finsch Mine. MMS has a proven track record, having installed open-pit dispatch systems world wide. The initial discussions led to a formal feasibility study, which was reported by MMS in the middle of 1990.

The study concurred with the Mine's conclusion, and laid the groundwork for a proposal and contract for a computerized system for monitoring and dispatching the LHDs.

Where possible, components of the proven MMS open-pit system were incorporated intact or modified to meet the needs. However, several components of the communications system had to be developed and brought into production in a short time in order to meet the requirements of the underground application. The planning and testing paid off in that the new components generally proved to be trouble-free.

Major Components of the System

Figure 1 shows the major components of the system. The actual configuration includes backup components for all the major components.

The Underground Computers

The underground applications runs on Sun Microsystems SPARCstation 1 + workstations running under the UNIX operating system. The real-time, backup, and engineering workstations are located in the control room on surface, and a conventional ethernet local-area network connects the three workstations. The workstations on surface are linked to the grand master controller by means of a fibre-optic cable.

The function of the underground system is to route location-detection transactions from the infrared beacons, and operator transactions to and from the LHD on-board computer to the application tasks on the workstation.

The Underground Grand Master Controller

The underground network consists of several components under the control of the grand master controller. The network utilizes synchronous data-loop communications (SDLC) protocol, in which the components are arranged in nested loops or token rings. The grand master directs traffic to the communication interface processors and five loop controllers on the master loop, and to the workstation on the surface.

The CIP Processors and Loop Controllers

The communication interface panel (CIP) handles communications with the leaky-feeder data-radio network, which passes information back and forth to the LHD on-board computers. Each of the five loop controllers handles communications with a remote loop of between thirty and forty roof-mounted infrared beacons, which detect the moving LHDs.

The loop controller has the ability to detect a break in the cable connecting the beacons. If that occurs, the loop controller terminates the loop at the location of the break and all the beacons upstream of the break remain active on the loop.

The Roof-mounted Infrared Beacons

The roof-mounted infrared beacons are suspended on chains that are anchored to the tunnel roof by rockbolts. The interconnecting cable between these beacons provides a power supply to recharge the beacon battery, and provides error-free communications at 19 200 baud (bits per second) with the loop controller. The roof-mounted beacons report to the loop controller each time an LHD passes by.

In the event of a damaged loop cable, the roof-mounted beacons beyond the break revert to a stand-alone mode (not connected by wire), and the activities of the LHDs are transmitted via the leaky-feeder radio system because the beacon has lost communication with the loop. The stand-alone operation allows the beacons to continue to function for approximately a day while the damaged cable is being repaired.

A battery-powered stand-alone beacon operating in the microwave bandwidth that transmits data on LHD movements via the leaky-feeder radio system was considered initially. However, MMS estimated that the radio traffic for LHDs passing the two hundred beacons in the mine could easily exceed the capacity of the radio network.

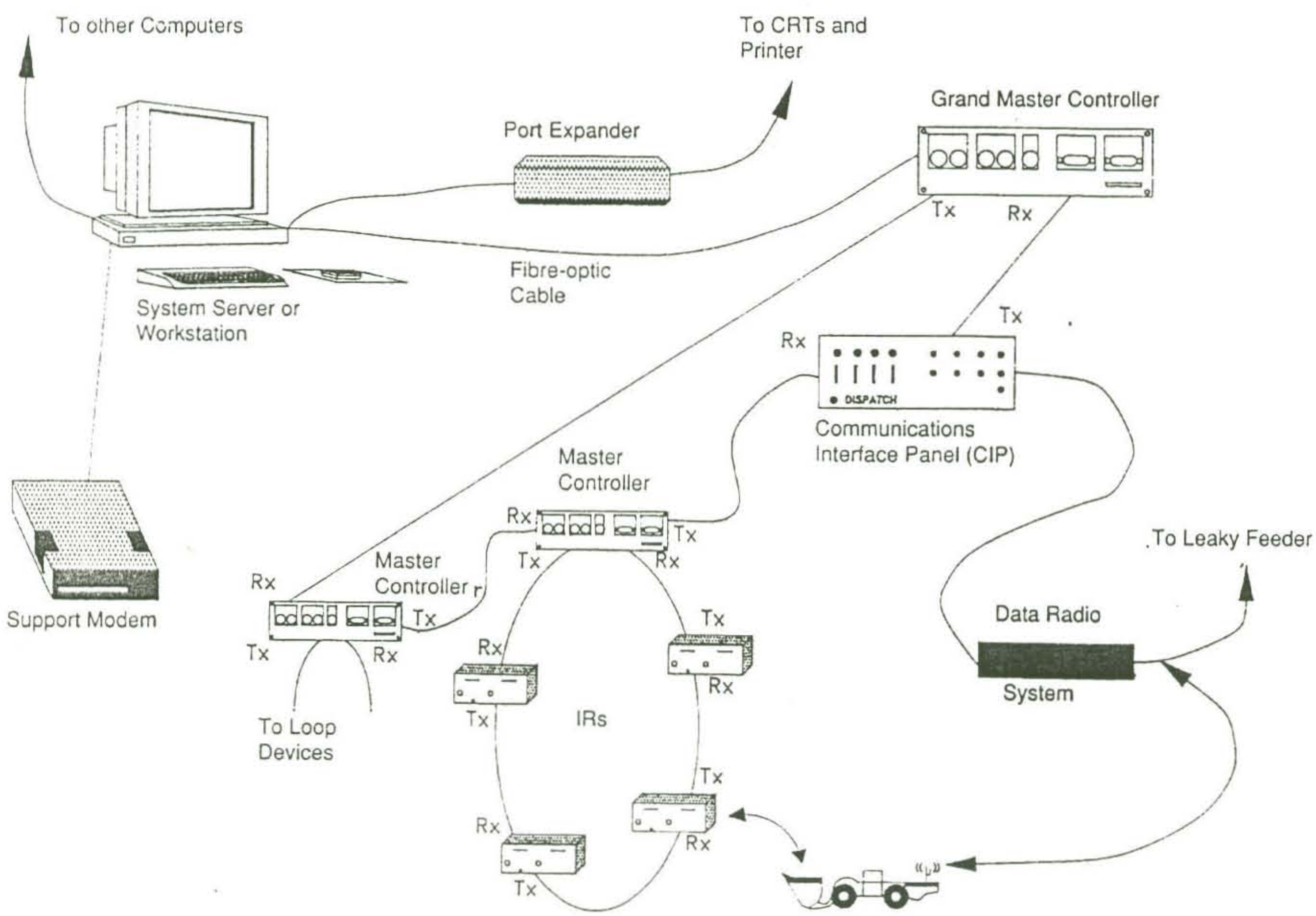

Figure 1. Configuration of the underground hardware

As an alternative, MMS proposed directional infrared beacons, which were undergoing testing on trucks and shovels in open-pit mines. These beacons have a range of approximately 5 m, and provide very accurate information on the location of LHDs.

The requirement for an interconnecting cable has not become as much of a problem as expected because the cabling for the infrared beacons is typically mounted adjacent to other utility cables and as close as possible to the hangingwall. The beacons are standing up very well to the concussion caused by blasting activities.

The Leaky-feeder Radio System

Any vehicle-dispatch system requires a communication link with the vehicles so that instructions can be issued to the operator, or data can be received from the vehicles regarding operator activities and vehicle status. Finsch Mine, after testing various underground radio systems for voice communication, eventually selected the FD4 system, which is based on a leaky feeder and is manufactured by Tunnel Radio in the United Kingdom.

The system operates in the VHF band, and standard radio equipment can be used. Owing to losses in the leaky-feeder cable, the system requires amplification of the signal in the cable about every 300 m and remote transmitters to return the outgoing signal from the end of the different spurs.

The FD4 radio system was selected for data transmission on the production levels once tests had shown that the desired baud rate of 1200 could be achieved, which satisfied the requirements of the dispatch system. Line-of-sight communication is possible up to 70 m from the leaky feeder.

Various factors influenced the selection of the radio system.

- The maintenance personnel on the mine were familiar with the system and knew its shortcomings.
- The system is being used in a relatively small area, which reduces the cost of the cable, and standard radio equipment can be used.
- All the components including the leaky-feeder coaxial cable are now manufactured locally under licence by EMCOM, which reduces the cost considerably.

The LHD On-board Computers

The LHDs are equipped with on-board computers whose components have seen several years of reliable operation in haulage trucks in open-pit mines. The main components of the on-board computer are the black box, data radio, operator interface panel (OIP), and vehicle infrared beacon. The computers are mounted in a smaller version of the industrial enclosures used for the haulage trucks on surface.

The black box is the main computer processing unit (CPU) of the on-board computer. When required, software is down-loaded from the main workstation to the black box over the network of the leaky-feeder data radio. The vehicle infrared beacon is mounted on the cover of the enclosure, and faces upwards towards the roof of the tunnel. A steel frame fitted with a Perspex top effectively protects the lens of this beacon from rock damage, while still allowing the signal to penetrate. The operators routinely clean the covers.

The vehicle infrared beacon 'handshakes' with the roof-mounted beacons when passing by, and the encoded signal identifying the LHD is sent to the loop controller by the beacon connected to the loop.

The OIP for the on-board computer is positioned so that the operator can read the 32-character display when travelling in either direction. The operator presses buttons on the OIP when arriving at a destination and leaving it.

These buttons and the infrared-beacon detections provide the system with timing information for loading, travelling, and tipping. Additional OIP buttons allow the operator to log in, answer 'yes' and 'no', and report downs, delays, and changes in tip and tunnel status.

One interesting start-up problem was caused by water that became trapped in the OIP when the LHD was being washed with a high-pressure hose during steam cleaning. The current OIP design does not lend itself to total waterproofing, and silicone has been used to seal openings as a temporary measure. The next version of the OIP will feature a waterproof enclosure.

The on-board computer utilizes a VHF radio to transmit OIP-button responses, and to receive messages over the leaky-feeder radio system, thus providing a two-way communication path for the data.

Implementation of Dispatch

Most of the hardware was installed during the first two quarters of 1991 by De Beers Finsch personnel and contractors under the supervision of MMS technicians. In May of 1991, the system became operational on the 350 m production level, while the installation of the hardware continued on the 430 m level.

During the first days, attention was focused on the testing of the infrared beacons and communications network, and on the monitoring of LHD movements. During the following weeks, LHD operators and dispatch operators were trained, and allocated dispatching began on the upper production level.

At the same time, the installation of beacons and the leaky feeder continued on the lower production level. The final beacons were installed in the fourth quarter of 1991, and the system then became fully operational on both production levels.

Monitoring of LHD Position

The accurate determination of LHD locations is of great importance in the constrained underground environment, and location monitoring of the LHDs was therefore emphasized as the primary concern in the initial implementation of the system. With that in mind, MMS developed display screens for each production level to show the LHD movements.

The level displays show the position of the LHDs with respect to the rim tunnels, loading drives, tips, and workshops. Each time an LHD passes a tunnel infrared beacon, the system decodes the transmission, the display detects the new data, and the icon representing the LHD moves to the proper position on the display screen. The screen also displays the current status of the LHDs, e.g. down, ready, delay, standby, or parkup.

The monitoring of LHD locations will become increasingly important when the Mine completes the development on the production levels and limits access by light vehicles. The next phase in LHD dispatching is optimization, which will require accurate LHD location to minimize LHD interaction.

Allocated Dispatching

LHD assignments are based on tip and loading-drive allocations as specified by the dispatch operator according to the production plan for the shift. The application software locks the LHD to the loading drive and tip, and the LHD travels back and forth between the destinations.

The system requires the status of the loading drive and tip so that LHDs can be assigned, and disallows assignments when that is not the case. If the tip or loading drive becomes unavailable, then the dispatch operator modifies the assignment and the LHD proceeds according to the new allocation. The system is in constant contact with the LHDs so that re-allocations are instantaneous and idle time is minimized.

The dispatch operator can send messages to the LHD operator at any time, thus saving the supervisory personnel the time they would need to locate the LHD and pass on the message. The system monitors the progress of each LHD, and notifies the operator of any LHDs that are late in arriving at a destination, the dispatch operator thus giving an early indication of breakdowns or delays.

When more tips and loading drives become available, each LHD will be allocated to a loading district, which consists of one or more tips and a few loading drives. Allocations will be calculated ahead of real time, and will be assigned automatically according to the priorities set by the mining personnel.

The Benefits of the System

The benefits of the MMS computerized open-pit dispatching system are well-documented in the mining literature. Most of these benefits, including the current shift and historical reporting, also apply to the underground system. Further, while allocated dispatching rarely optimizes open-pit production, it offers a very efficient mode of operation underground, where the dispatching options are more limited.

LHD-location monitoring offers immediate benefits to the production and maintenance personnel. The dispatch operator can assist the maintenance personnel in finding an LHD; thus they can spend their time repairing LHDs, rather than trying to locate them.

Shift bosses can ensure that LHDs are loading in high-priority areas, and that they are not wasting time loading in the wrong loading drives, which can lead to a blasting delay and translate into lost production.

Soon after the implementation of the system, Finsch realized that a shift boss could make many production-enhancing decisions using the information available from the dispatch system. As a result, a shift boss was moved into the control room on surface on a full-time basis to assist in changing the production plan in the event of major deviations such as passes not being available or breakdowns on LHDs loading in priority ends.

Ongoing Development

Token-ring UHF Radio

Finsch Mine's positive experience with the leaky-feeder led to its selection as the data-radio system to transmit instructions to the LHD on-board computers. The system has proved to be reliable despite the hazardous environment in which it has been installed, but represents a sizable capital expenditure.

As a result, MMS has developed a prototype UHF-based radio that could eliminate the need for the leaky-feeder in future implementations. This radio system is loop-based, and consists of a radio transceiver that is attached to the beacon loop like the roof-mounted infrared beacons.

Approximately six transceivers will be adequate to cover one production level. Data from the LHD will be received by the token-ring transceiver and relayed via the loop to the application software. Likewise, messages from the main computer will travel down the loop and be transmitted by the token-ring radio to the LHD radio. Improved radio coverage and reduced capital cost are the primary reasons for the development of the new radio system.

New On-board Computer

The next generation of on-board computers will address the issues of size reduction and weather-proofing of the OIP for the underground environment.

Finding a location for the on-board computer that does not interfere with servicing of the LHD is not an easy task. Further, the open cab of the LHD makes a weather-proof OIP a necessity.

The new on-board computer will also offer improved functionality because the OIP will utilize a programmable touch screen in a weather-proof enclosure. New buttons and functions can be added at any time. The current OIP uses custom-designed keypad for which the button labels are specified prior to installation and cannot be changed without changes in the overlay.

Conclusion

The time spent on careful planning and up-front engineering before the installation of the dispatch system paid dividends in that few problems were experienced during start-up. The dispatch system has played a major role in the rapid build-up to full production at Finsch Mine.

The system has been in operation for almost a year without any major problems, and the results achieved have been very encouraging, especially the system's ability to monitor and direct the activities of the LHDs. This ensures a high level of productivity from the LHD fleet.

It is almost certain that new problems will arise in the near future, but solutions will actively be sought. The encouraging results to date provide sound evidence of the value and economic viability of a system of this type, and support the belief that high technology will play an increasingly important role in underground mining operations in the future.

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Bibliography

LUKE, R.A. Computerized vehicle dispatching goes underground. 94th CIM Annual General Meeting. Montreal, Apr. 1992.

MARTIN, D.J.R. Radio systems for underground mines. *Min. Mag.*, vol. 158, no. 2. Feb. 1988. pp. 123-127.