ON LINE MONITORING TO MAXIMISE CONVEYOR PERFORMANCE

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1. INTRODUCTION

Modern conveyors are becoming more complex with increased power requirements, multiple drives and longer centre distances. The trend towards reduced manning levels with increased productivity has led to the use of Real Time On Line Monitoring or SCADA (Self Contained Automatic Data Acquisition) systems to manage the operation of conveyor systems. This paper will review the SCADA system in use at South Bulga Colliery and how it is utilised to manage the conveyors.

2. PAPER CONTENTS

3. OVERVIEW OF SOUTH BULGA COLLIERY.

3.1. Operation of Mine.

South Bulga Colliery is a 'State Of The Art' Longwall Mine located in the Hunter Valley of New South Wales, Australia. It is located in the heart of the Hunter Wine growing area 140 km north of Sydney and 70 km west of the seaport of Newcastle. It is one of the most productive underground mines in Australia and is one of the youngest in the Hunter Valley having commenced production in 1994. The mine produced 4.1 Mt of ROM Coal with a total workforce of 181 in the 1997/98 reporting period. The Mine is managed by the Cyprus Australia Coal Co. for the Oakbridge group, with the Mine's production being marketed into the international seaborne trade.

The mine and associated surface activities are located in a worked out section of the Bulga Open Cut Mine, with the Underground Mine entries being driven straight into the

Coal Seam from an existing highwall. Two JOY 12CM30 Continuous Miners and JOY 15SC Shuttle Cars are used in mine development work. Their primary role is to develop the coal blocks for longwall extraction and to create the roadways to service the overall mine. These roadways are used for ventilation, to accommodate the materials handling conveyors and for personnel and material transport. The primary method of coal extraction is the Longwall System of mining with Longwall Blocks of 250 metres width and up to 3 kilometres long, being extracted. The Longwall equipment consists of a JOY Stage Loader, Armoured Face Conveyor and Roof Supports and an Anderson Electra 1000 Shearer for coal cutting.

3.2. Conveyor system.

The materials handling conveyor system has been designed to match the production of the high capacity Longwall Mining equipment. The main trunk conveyors are rated at 4,000 tph and panel conveyors at 3,000 tph. Individual conveyor specifications are listed below in Table 1. To minimise the requirement for installation labour, conveyor flight lengths have been kept as long as possible. This has resulted in a minimum number of conveyors between the Coal Face and the ROM stockpile; see Sketch **1** for a diagrammatic layout of the system. One multiple motor Drive-Head is used to power the trunk conveyors and a dual motor Drive-Head and two dual motor Tripper- Drives power the panel conveyors. Panel conveyors are installed during development and utilise the equipment required for longwall operations, only operating at half speed, 2 mps, by using 8 pole motors to power the Drive-Head. For longwall operations these motors are replaced with 4 pole motors and the two Tripper-Drives are installed at their predetermined locations along the conveyor. The conveyor is shortened and the Tripper-Drives removed as the longwall retreats during mining operations. Panel conveyors have to be re-located every 10 to 12 months to keep up with mining operations.

4. OVERVIEW OF MONITORING SYSTEM.

4.1. What is monitored?

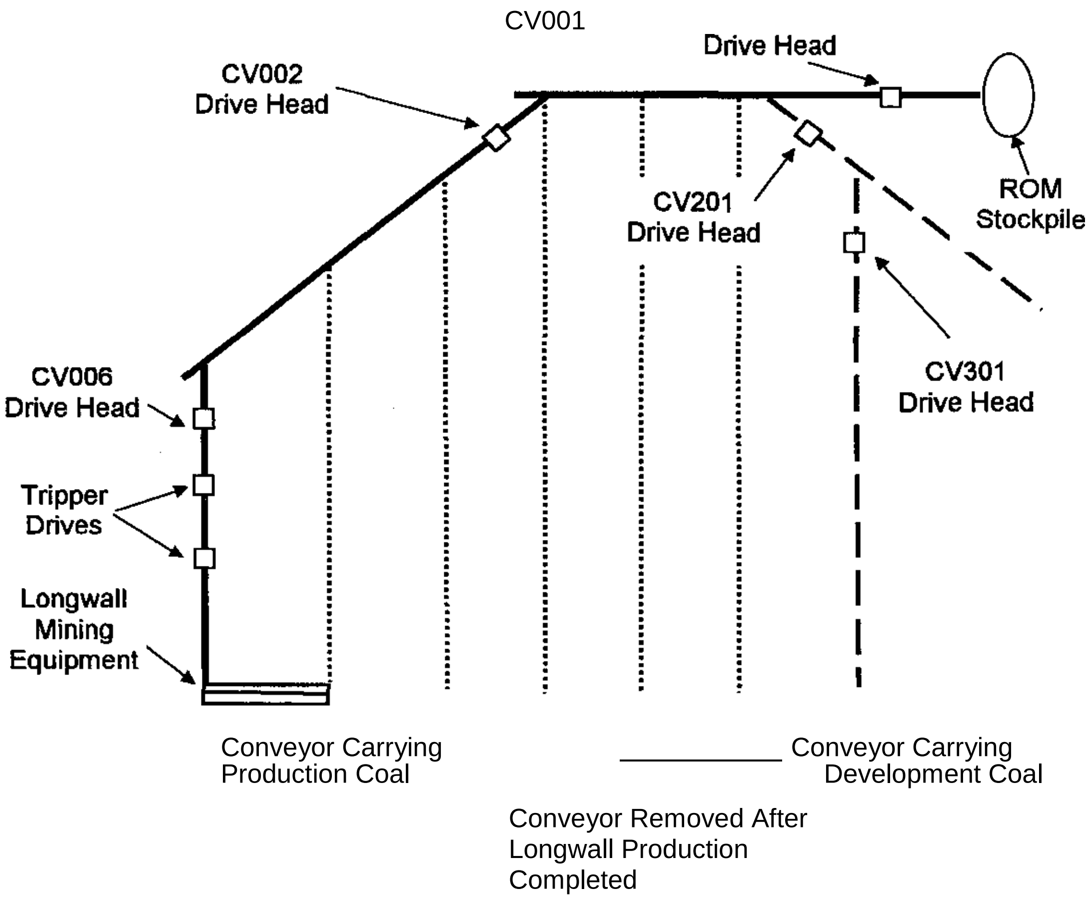
The SCADA system in use at South Bulga Colliery is a total Mine Monitoring System, which can present information as Real Time, Historical Tables or as Trend Graphs. The monitoring covers everything from the services to the mine, electricity, water and compressed air, through to the mine ventilation system and the underground atmospheric environment. It also covers the operation of the Longwall Shearer, Roof Supports, Mine production and of course the Conveyor System.

South Bulga Colliery has specified that PLCs be fitted to carry out all control functions, and that they be capable of being connected to a data-highway. In some instances were PLCs are not required for control, such as electrical power distribution, PLCs have been fitted to provide monitoring via the Data-Highway. The SCADA system via the Data-Highway, monitors between 5,000 to 5,500 points, with some 3,500 of these points connected to the PLC network. The use of the Data- Highway, which is by fibre optics from the surface, also allows for the remote monitoring and programming of the PLCs from the Mine's surface control room.

Trunk conveyors have up to 150 points monitored to give either trending or alarm information in the SCADA system. A longwall panel conveyor may have double this number of points when the Tripper-Drives are added. All information recovered from the SCADA system is recorded in computer memory. The memory is capable of holding just over one months information, it is then archived on to disc for future use.

Conveyor	Width mm	Length m	Lift M	Power kW	Starting Mechanism	Controller
Trunk 1 CV001	1800	1100	30	4 x 320	Head NM BOSS	PLC
Trunk 2 CV002	1800	1450	36	2 x 500	Dodge CST	PLC
L/W Panel CV006	1500	2500	84	Head 2 x 320	Head NM BOSS	PLC
				Tripper 1 2 x 500	Tripper 1 Dodge CST	PLC
				Tripper 2 2 x 500	Tripper 2 Dodge CST	PLC
E1 Trunk CV201	1800	1350	38	2 x 500	Head Dodge CST	PLC
E1 Dev. CV301	1500	3150	112	2 x 200 8 pole	Head NM BOSS	PLC

Table 1
South Bulga Colliery - Conveyor Specification March 1999



Sketch 1 South Bulga Conveyor Diagram March 1999

4.2. Information recovered from the system.

The system records information that can be transmitted as a digital signal or a normally acceptable analogue signal (i.e. 4 to 20mA). This allows for the display of information such as, Longwall Roof Support leg pressures, the Shearer position on the Face, through to the number of times the remote Borehole Pump has stopped and started.

The general information presented on the conveyor system is shown in the screens, which have been downloaded, from the SCADA system. Screen 1 is the overview screen for all Mine operations. It shows the status of the conveyor system and longwall, with all conveyors in green when operating, yellow when isolated and red when faulted. The Icons beside the message bars in the top half of the screen indicate the status of individual systems using the same colour sequence to display their status. These Icons give quick access to further system information screens by mouse operation. Highlighting and clicking on Maingate No 6 Conveyor Icon will bring up Screen 2.

Screen 2 is the Maingate No 6 Conveyor Mimic. This presents the current status of this conveyor showing motor currents, belt speed and belt tensions. In this case the conveyor is operating and Tripper 2 is not installed. The readings for Tripper 2 motor currents and tensions are the last known valid readings retained in the system. If the conveyor is turned off a message is displayed in the Message Bar just below the Mimic Diagram. At present it reads 'Pullkey Operated at - All Healthy' and the conveyor is operating. If a drive is faulted it flashes red and further information can be obtained by clicking on the Drive Status Icon. Clicking on the Drive Status Icon under the Head Drive will bring up a drive status screen, as seen in Screen 3.

Screen 3 is Head-Drive, Winch and General Status and Alarms screen. In the screen shown we see in the Head-Drive Status area, Conveyor Belt Stopped, General Safety Status Fault and in the General area, Sequence Fault. The conveyor is stopped due to a loss of sequence signal from the receiving conveyor. The message bar right at the top of the screen shows the message, Trunk Conveyor No 1 Pull Key North Side Cut Thru 3. The opening of the signal line on Trunk Conveyor No 1 has stopped that conveyor and the conveyors feeding onto it have then stopped in sequence. This is one of the ways faults on the system can be accessed quickly. This message bar displays the last alarm signal recorded in the system.

On screen 2 by clicking on the Startup Performance Icon we can review the performance of the conveyor during the last start. Clicking on the Icon will bring up Screen 4, Startup Performance Details.

The Startup Performance Details shown on Screen 4 is the information recorded during the last start of the conveyor. It shows the maximum motor currents, clutch pressure and temperature reached during the acceleration ramp. Other information displayed is the breakaway clutch pressure, the pressure required to start the belt moving and the time to start the conveyor, 190 seconds for this start. The 190 seconds is the time to bring the belt up to full speed. Of this 47 seconds was required to break the belt away after clutch pressure was applied and another 55 seconds to accelerate the belt. The 88 seconds not reported is taken up with Safety Checks, Motor Starting, Tensioning the Loop and insuring Clutch Hydraulic Systems are up and running ready for the start.

Screen 5 is a trend overview of the conveyor involved in Longwall Production. It is used as a quick review of the conveyor performance during recent production shifts and picks up the motor currents from the longwall conveyor drives and flow rate from the belt weigher. This gives a ready reference to the performance of each drive on the conveyor and to the production rates being achieved. Any anomalies can be readily identified for further investigation by using the SCADA screens covering the conveyor drive in question.

4.3. Operational and alarm information.

Operational information is provided in shift, daily and weekly production reports developed from signals received from the belt weigher. This covers both production from the Mine and Coal recovered from the stockpile by the Preparation Plant Reclaim System. The main operational benefit of the system is the continuous monitoring of the Longwall Roof Supports. The Support leg pressures are continuously monitored. The rate of increase in leg pressure after 'Legs Set' is achieved is an indication of stability of the roof above the longwall. South Bulga has experienced several interruptions to production due to 'Weighting Events'. The present solution to this is to keep the longwall in production until it has passed the area of roof instability and leg pressures are again showing no pressure rise after Leg Set.

Alarm information is maintained by having all changes of state of digital inputs recorded in an event log. This log is updated as the events occur, both on a VDU screen and on hard copy. As well as this, the last alarm is displayed at the top of each system display screen, as seen in screen 3 above. Access to the main alarm screen is available by clicking on the 'Alarm Icon' at the bottom of all screens. All the current alarms are then displayed until they have been acknowledged or reversed. A typical Alarm Screen is displayed in Screen 6. The information displayed on the screen consists of the input register designation, its description, the state of the input and the date and time the change occurred. Some of the alarm information contained in the log is shown in the Table 2 below.

Register	Description	State	Date	Time
2204STOP	Washery Reclaim Conveyor	STOPPED	11/27/98	09:23:32am
LWSULP3PC	Longwall Pump Station	Pump No 3 Unloader Fault	11/27/98	04:15:07am
T2WLVLT	Trunk Conv. No 2 Winch	Line Voltage Low Trip	11/11/98	10:17:29pm
T2WM1GFT	Trunk Conv. No 2 Winch	Motor 1 Ground Fault Trip	11/11/98	11:17:28pm
T2WMAN	Trunk Conv. No 2 Winch	Manual Mode Selected	11/05/98	10:41:03am
T2WSEQ	Trunk Conv. No 2 Winch	Not in Sequence Mode	11/04/98	03:40:05pm
CB8 LMSC	66/11 kV Substation	CB 8 Local Mode Selected	11/02/98	10:01:49am
MCB1 LMSC	66/11 kV Substation	MCB 1 Local Mode Selected	10/12/98	02:01:46am

Table 2

Sample of SCADA Alarm Information Contained in Screen 6

5. SOUTH BULGA'S EXPERIENCE.

5.1. Commissioning without monitoring.

South Bulga was Fast Tracked into production and not all systems were completed before Longwall Production was commenced. It was always planned to have a total Mine Monitoring System in operation, but as it was seen as not being essential to production it was given a low priority. The first Longwall Panel Conveyor was subsequently commissioned without the SCADA system in operation. The three PLCs, Head Drive and two Tripper Drives, were all interconnected via a limited Data-Highway. Information from the three drive control panels was available at each PLC station by the use of Panel View Screens. The conveyor was commissioned successfully empty and put into production with each drive apparently operating as designed. As Longwall Production was ramped up after the commissioning period, a problem developed with starting the conveyor under loaded conditions. Aborted starts and broken belt (clip pullouts) became a common event when starting the loaded conveyor. Unloaded starts did not present any problems. A complete review of the PLC programs did not reveal any anomalies with the control system or the operating philosophy.

In a final attempt to solve the Loaded Start problem each drive location was manned during starting. Observers were placed to monitor the physical actions of the belt and hydraulic control systems, as well as the individual PLCs. It was still impossible to determine the problem preventing consistent starting of the loaded conveyor. Once the conveyor had started everything operated to design, but starting the conveyor in a loaded condition had become a lottery. The Mine introduced procedures to ensure the conveyor was run empty before it was turned off. If a stop occurred when loaded and the conveyor did not start the first time, Coal was to be shovelled off to reduce the load before another start was tried. All this resulted in lost production.

5.2. Success with monitoring.

It was only after the SCADA system was commissioned that the cause of the starting problem became apparent. It was only when the analogue trend graphs could be overlaid on each other and studied, the problem with the starting philosophy was found. The problem was exacerbated by South Bulga's Panel Conveyor installation having a major difference to other Tripper operations in use at the time. All South Bulga drives were similarly powered, with one third of the required power being applied at the Drive-Head and an extra third being applied at each of the Tripper- Drive sites. This meant that two thirds of the power input was being controlled by the measured tensions in the conveyor belt. This worked quite well when the conveyor was running, but was not performing during the starting ramp. The Trippers at times were lazy during loaded starts, their operation depended on the distribution of the load along the conveyor and at times the Trippers did not deliver any power to the conveyor. On the last aborted start before changes were made to the system the belt at the Drive-Head had reached 18% belt speed with no belt movement or tension change at either Tripper, and yes we broke the belt.

The PLC programs were modified to turn the Trippers on earlier during starting and return to normal operation at the end of the starting ramp. This modification was only an interim measure and required continuous monitoring to reset the parameters as the conveyor retracted. This monitoring was carried out in the Surface Control Room by reviewing the trends over the last 24 hours, and making adjustments in the PLC programs as required.

The mine also made the decision at this time to fully vulcanise the belt to remove ail clips as the clips that had not pulled apart had also been exposed to the same starting tensions that had caused failures and were considered suspect.

5.3. Use of information in future conveyor design.

Optimising Tripper Drive Location. The trends recorded during the operation of the first three Longwall Panels, designed before the start of Longwall Operations, showed the original Tripper-Drive locations were not the optimum to achieve maximum load on the conveyor. They also showed the original assumptions covering conveyor friction factors were in error, too low. The increase in friction was traced to increased Rim-Drag of the idlers caused by the use of double lip grease seals for the bearings. This plus having five roll trough sets and three roll returns sets was responsible for an increase in the No-Load friction on the system. This affected the calculated power required for individual sections of the conveyor and ultimately the Tripper locations. In the original design the Trippers where located so they were fully loaded with the conveyor operating at rated capacity and at full length. With the increase in friction factor this resulted in the Trippers being positioned to far inbye, towards the Longwall Face. The Drive-Head and Tripper No1 where overloaded with the conveyor operating at rated capacity.

The Tripper locations must take into account any production restrictions that may be required such as, at the start of the Panel longwall commissioning, and the conveyor installed power after the removal of Tripper-Drives. The long Panel Conveyors at South Bulga Colliery have their capacity restricted for a short period at the start of the Panel, with the conveyor is at full length, and after a Tripper is removed to prevent the conveyor drives from being overloaded. The time required for these restrictions has to be reduced to maximise production. It was only after the trends of motor currents, belt tensions and tonnes per hour could be compared, that the information was available to allow the optimum location for the Tripper-Drives to be determined. It was found that being 100 metres out in location could make a difference of up to 500 tph in capacity. This was the case for Panel 3 where No 1 Tripper was 100 metres further inbye towards the conveyor tail than the optimum position. This resulted in the conveyor having a rating of 2,500tph instead of the designed 3,000tph. This had the effect of reducing operating capacity until after this Tripper was removed or over two thirds of the Panel length.

Timing for removal of Power Modules. Even though the use of the information recovered from the SCADA system allows for the accurate calculation of conveyor power requirements. Continuous monitoring of the motor currents is the best tool in predicting the removal of the power modules from the Trippers.

South Bulga Colliery utilises a Monorail system to supply services to the Longwall Mining Equipment. To maintain maximum conveyor capacity these services must be brought past the Tripper-Drives before they are removed. With the catenary cables and hoses having to be manhandled over the Tripper-Drive power modules the early removal of a power module halves the manual labour involved. The use of the SCADA motor current trends allows this removal to be accurately predicted by taking into account any changes that may have occurred in the local operating conditions of the conveyor. Once the trends indicate each motor is consistently below 50% load one power module can be successfully removed and the Tripper operated with one.

6. SCADA AS A MAINTENANCE TOOL.

6.1. Fault location on multiple drive conveyors.

As shown on Screen 6 and in Table 2 the SCADA system records and displays large amounts of information in the Alarm Log. South Bulga Colliery has expanded this Alarm Log to use it as a maintenance tool. The system has been set up to activate an audible and visual alarm in the maintenance workshop whenever any of the conveyors are stopped due to a fault. Tradesmen can then access information about the fault; by interrogating the particular conveyors Mimic Screen, such as Screen 2 and associated Status Screen, Screen 3. The tradesman can then make arrangements to have the fault corrected and direct response to the location of the fault. On the Panel Conveyors, which have six separate power modules located up to two kilometres apart, knowing which power module or its controls is faulted saves substantial time in addressing the fault.

6.2. Monitoring drive performance.

Having the parameters from each power module available as Trend Graphs allows for the individual drive performance to be assessed. The Panel Conveyors have the two power modules at each location programmed to share the load equally between them. When the motor current trends indicate load is not being shared equally the trends of the control system inputs and outputs can be reviewed to find out which signal is in error. Clutch actuation pressures can be compared one to the other, as can the signals to each control valve and the associated motor current. A different signal to the control valves indicates a problem with the load sharing control circuitry. The same signal strength with a different actuation pressure indicated would indicate a fault with the control valve, while same actuation pressure with a different motor current may indicate a clutch or some other mechanical problem.

A mechanical failure of one of the four drives on Trunk 1 Conveyor (CV001) was found when the trend of one motor current fell to the No-Load level. With all control signals at normal levels and comparable one with another, a mechanical problem was expected and found with the drive, a gearbox fault. Steps were taken to limit the load on the conveyor before it stopped on motor overload. A stop on overload would have caused a production delay for Coal to be shovelled off the conveyor to allow it to be restarted. By controlling the peak load on the conveyor production was maintained until the conveyor could be removed from service to effect repairs.

6.3. Fault finding on control system.

Fault finding on control systems is not as straightforward as above. The monitoring of the conveyor signal line pull switches is easy as each pull switch is fitted with an identification chip. This chip is used to identify the location of each switch and can be used to indicate if the switch is off or the signal line is faulted at or inbye of this location. At South Bulga the location of all signal line switches for Trunk 1, CV001, are displayed as part of the conveyor Mimic Screen. The switch icon is green when healthy and flashes Red when turned off. The panel conveyor signal line switches have been programmed to display the Cut Through number, in which they are located, in the message bar on the conveyor mimic screen.

Fault finding throughout the rest of the control system can be accomplished from the Surface Control Room using the Data-Highway to access the individual PLC programs. This saves the time required to transport a programming computer underground and connect to the system. This is an operation, which is not allowed by regulations in hazardous zones of the mine. The use of the Data Highway, being Fibre-Optic from the surface, allows the computer to be connected to PLCs in these hazardous zones, as well as to equipment while it is operating. The permanent connection of the Data-Highway into the control panels allows computer connection to be made without having to go through the electrical isolation procedures required to gain access.

7. CONCLUSION

To optimise the performance of multiple drive long flight conveyors an efficient SCADA system is a necessity. South Bulga Colliery could not have overcome its starting problems or been able to optimise the Panel Conveyors without the information obtained from the SCADA system. The ability to be able to compare Trend Graphs from all monitoring points on a conveyor and have them presented on the same synchronous time scale is far superior to using paper charts from pen recorders. The synchronisation of which is hard to determine and the information is only available from the points connected for the time the recorder is operating. The information recorded by the SCADA is ongoing from all points, for the total time the conveyor is operating and covers all events, even the unexpected. The information that can be recovered is invaluable for managing the ongoing performance of a conveyor system. Especially one that is forever changing, such as the Longwall Conveyor, which in operation, is continually changing in length and then being relocated into a new area.

For the Conveyor Engineer, having the SCADA information available on his Desktop Computer makes the Job a lot easier. With information at the fingertips the Engineer has 'Online' access to data for analysis. This data coming from a conveyor operating under the exact conditions in which the next conveyor is to be installed, or for a new conveyor, allows assumptions used in the design calculations to be checked. A comprehensive SCADA system has the effect of turning the conveyor installation into an operational Test Bed' for the Conveyor Engineer. It allows actual performance to be checked against design and the maximisation of productivity by fine-tuning the operational parameters. (Conveyor length, load carried - peak or average, or even the strength of replacement belting)

For the Maintenance Engineer the SCADA system is an invaluable maintenance tool. The system gives access to operational and fault information online in the quest to reduce downtime. By providing accurate fault information as it occurs the Engineer can respond quickly, allocating the appropriate resource required to correct the problem. The SCADA also gives operational personnel accurate information on where conveyors have been isolated, or turned off, reducing the down time incurred searching for the isolation point if the location is not known.

With the Longwall Panel Conveyors at South Bulga Colliery operating at the limits of the installed power and belting strength, the location of the Tripper Drives is critical to maximising the performance of the conveyor equipment. Without the information made available by the SCADA system it would not have been possible to fine-tune the design to optimise the Tripper Drive operation. South Bulga's conveyor system would be operating at something less than full capacity, or would have required more capital investment to achieve the same tonnage ratings. The commissioning of the SCADA system gave access to information, which triggered the change in starting philosophy and allowed for the fine-tuning of the Tripper Drive locations. Taking the information from the early Longwall Panels into account, South Bulga has been able to maintain the conveyor capacity without extra capital investment.

I would like to thank the Cyprus Australia Coal Company, Oakbridge Pty Ltd. and South Bulga Colliery for allowing me to present the information contained in this Paper. The presented screens have been downloaded from the SCADA system in operation at South Bulga. All comments are based on the personal observations of the author from experience gained working with the system while employed at South Bulga Colliery.

About the Author

Alex McHarg has been employed In the Coal Mining Industry in the Hunter Valley of New South Wales for 27 years. Holding qualifications in both Electrical and Mechanical Engineering, he has been employed in both capacities at both Underground and Surface Mining Operations. In 1992 he transferred form Bulga Coal Management's Open Cut Operations to join a team to develop an Underground Longwall Operation in the southern area of the Mining Lease, South Bulga Colliery. Alex stayed at South Bulga after the commencement of Longwall Operations as Mechanical Engineer, and has subsequently finished employment at the Mine, establishing his own company consulting to the Mining Industry and is still heavily involved with the ongoing design of South Bulga's conveyor system.

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Employment History

1992	1998	South Bulga Colliery - Engineer in Charge
1990	1992	Bulga Coal Management - Chief Engineer (Electrical)
1990	1982	BHP Minerals Saxonvale Mine - Chief Engineer & Electrical Engineer in Charge
1982	1978	C & A Wallarah Colliery - Mechanical Engineer in Charge

Qualifications

Mine Electrical Engineers Certificate of Competency MINE

Mechanical Engineers Certificate of Service Electrical

Engineering Certificate - TAFE Mechanical Engineering

Certificate - TAFE

Current Study

Master of Engineering Practice in Business and Technology