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INTERNATIONAL MATERIALS HANDLING CONFERENCE

1989

Instrumentation Control and Monitoring
of an Overland Conveyor System

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THE CONTROL AND MONITORING OF LARGE OVERLAND CONVEYORS IN THE MINING INDUSTRY

by

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SYNOPSIS

This paper describes aspects of the electrical, control and information technologies used for the control, protection and monitoring of large overland conveyors in the mining industry, with particular reference to a waste and over-burden dump system with which the writer has been involved. The paper concludes that multi-disciplinary skills are required from the electrical engineers involved with modern conveyor systems, and that these skills need to be carefully co-ordinated and integrated with the other engineering activities of the overall conveyor system design. Advances in low cost SCADA systems have enabled managers and engineers to make effective decisions to improve conveyor availability and performance.

1. INTRODUCTION

The control and monitoring of large overland conveyors in the mining industry involves a wide variety of electrical disciplines, which need to be carefully integrated and interfaced in order to achieve a successful, reliable and efficient end result. These disciplines may include: medium voltage distribution switchgear; medium voltage motor control gear; rotor resistance starters; distribution transformers; low voltage distribution switchgear and motor control gear; programmable controllers and associated software; conveyor on-board safety devices and associated telemetry; PLC to PLC, and PLC to computer communications; computer based supervisory, control and data acquisition systems, and associated software; lighting; erection and cabling; plus several others. This paper illustrates these multi-disciplinary activities with some reference to a project at Iscor's Grooteluk Coal Mine, in which the writer's company was the main electrical contractor of a turnkey project for the conveyor electrics of a waste and over-burden dump system. However, not all the items discussed necessarily apply to this particular project, and these have also been adapted from other projects in which the writer has been involved.

2. THE WASTE AND OVER-BURDEN DUMP SYSTEM

The project involved the control, monitoring and protection of four large overland conveyors, each with a capacity of 7000 tonnes per hour. Refer to Figure 1 for a diagrammatic representation of the waste and over-burden dump system.

Waste material from a stock pile from a coal washing and separating plant can be fed onto the "L", "L + U", or "U" conveyor systems via a bi-furcating transfer chute. Similarly, over-burden from a mobile crusher at the open cast pit, can be fed onto the "L", "L + U", or "U" conveyor systems, via a second bi-furcating transfer chute.

Both the "L" and "U" conveyor systems comprise a fixed conveyor (L1 and U1) and a movable conveyor (L2 and U2). The movable conveyors are able to be lengthened and rotated, in order to allow for growth of the dump system.

A tripper car, on both the L2 and U2 conveyors, enables material on these movable conveyors, to be fed onto the L and U system stackers, at any point along the L2 and U2 conveyors.

The commands for the control of the conveyors and transfer chutes, signalling to the stackers, monitoring of the complete system, and all interlocking, is performed at a central control room. The control and protection of each conveyor and its associated auxiliary drives, start up and shut down sequencing, and local alarm annunciation, is performed at the drive station of the associated conveyor. A conveyor may be started out of sequence at the drive station, in the "maintenance" mode, but must be started at the central control room, in the "normal" mode.

3. THE CONVEYOR DRIVE STATION

Refer to Figure 2 for a single line diagram of the drive station power distribution. Each conveyor drive station comprises an 11kV substation, a transformer bay, and a conveyor control substation.

Due to the growing and changing nature of the waste and over-burden dump system, the substations are in the form of metalclad skid-mounted kiosks, housing the associated switchgear, control gear and instrumentation. The substation kiosks are internally pressurized to reduce the ingress of dust, and air-conditioned to reduce the internal temperature rise.

The transformer bay is fenced, and the transformers are of the oil immersed outdoor skid mounted type.

Concrete plinths and concrete lined cable trenches are provided for all equipment. The conveyor control kiosk is described in further detail hereafter.

4. THE CONVEYOR CONTROL KIOSK

The conveyor control kiosk comprises two sections mounted on a common skid base.

The first section is fully metalclad, with hinged access doors, and houses the 6,6kV switchgear and main motor stator starters, the 400V switchgear and auxiliary motor control gear, and a PLC control panel. A kiosk alarm display, and the conveyor on board safety device control unit, is mounted on the wall of the kiosk, and is accessible from the outside of the kiosk.

The second section houses the rotor resistance starters and associated rotor contactors, and has expanded metal walls, to allow free air flow for ventilation and cooling.

5. 6,6kV SWITCHGEAR

The incomers and transformer feeders comprise metalclad indoor horizontal draw-out vacuum circuit breakers. The stator switches comprise metalclad indoor horizontal draw-out fused vacuum contactor starters. Each starter switches the stators of 2- 875kW conveyor drive motors simultaneously.

Vacuum circuit breakers and vacuum contactors provide hermetically sealed phase segregated interrupters. This is considered an important safety aspect in the prevailing rough environmental conditions. Fused vacuum contactor starters offer a long and virtually maintenance free life for this arduous and frequent switching duty application, and are also therefore considered most suitable. All primary motor protection devices, as well as the output trip contacts of the conveyor on board safety device control unit, are hard-wired to the 6,6kV motor starters.

6. ROTOR RESISTANCE STARTERS

A number of 875kW slipring motors provide the motive power for each conveyor. These are each started by an associated rotor resistance starter, comprising naturally ventilated stainless steel grid resistors, and a number of rotor resistor shorting contactors. This ensures a high starting torque, to cope with the starting of a fully loaded conveyor, while simultaneously reducing starting currents, and therefore volt drops, on the supply system.

Grid resistance type rotor starters have the advantage of a good thermal capacity and an extremely short cooling time constant, making them most suitable for repeated and frequent starting duty. They are also extremely rugged, requiring virtually no maintenance, and are thus considered most suitable for this application.

The torque characteristics of a grid resistance rotor starter may be accurately designed, and it is suggested that the rotor contactors can be controlled from the PLC via a belt speed analog input signal, such as to maintain a virtually constant acceleration during start-up, irrespective of conveyor loading, so as to minimize or avoid belt slip.

A permanently rated rotor slip resistance is left in circuit in each rotor starter, when the conveyor is running at full speed, in order to ensure reasonable load sharing of the various conveyor drive motors.

7. 400V AUXILIARY MOTOR CONTROL CENTRE

A 400V auxiliary motor control centre and small power and lighting distribution board is mounted within the conveyor control kiosk. This controls the conveyor auxiliary motor drives such as:-

- 4 thruster brake motors [DOL starters]
- 4 oil pump motors [DOL starters]
- 1 belt tension winch [reversing DOL starter]

In addition it provides small power for the conveyor for functions such as:-

- conveyor lighting
- drive station lighting
- kiosk lighting
- welding plugs
- switched socket outlets
- PLC control panel
- alarm display
- control unit for conveyor on-board safety devices
- start-up alarm sirens
- kiosk pressurization and air-conditioning

8. PLC BASED CONVEYOR KIOSK CONTROL PANEL

A PLC control panel is mounted on one end of the auxiliary MCC. The functions of the PLC control panel are as follows:-

- receipt of start/stop commands from the central control room, when in the normal mode
- receipt of start/stop commands from the maintenance start/stop pushbuttons, when in the maintenance mode
- communication to the central control room of the conveyor status, i.e. running/stopped, available/fault, restart timer lockout, etc.

- communication to the central control room of all alarm, trip and fault conditions, including the status of the conveyor on-board safety devices
- control of the local alarm display and alarm siren, in a first-up alarm annunciator sequence
- control of the start-up and shut-down sequence of the conveyor drive

The start-up sequence is detailed as follows:-

- sound pre-start alarm siren
- start oil pump motors to establish oil flow, as indicted by the oil flow switches
- start thruster brake motors to release brakes, as indicated by the thruster limit switches
- start the belt tension winch to establish the belt starting tension, as indicated by the belt starting tension signal
- start the first main motor pair
- start the second main motor pair
- control the belt tension winch to maintain the belt starting tension during run-up
- control the rotor contactors to maintain a constant acceleration during run-up
- when the belt is up to speed, as indicated by the belt speed signal, control the belt tension winch, to reduce the belt tension to the running tension
- monitor the belt slip condition by monitoring the belt speed signal
- control the belt tension winch to maintain a constant belt running tension

9. CONVEYOR ON-BOARD SAFETY DEVICES

Mounted on the conveyor structure are a number of conveyor on-board safety devices. These devices are interconnected by the emergency stop pull-rope cable, back to the conveyor on-board safety device control unit, which is mounted on the wall of the conveyor control kiosk. These devices include:-

- about 30 pull rope emergency stop/lock-out devices
- 1 blocked chute detector
- 4 belt rip detectors
- 4 belt run-off detectors

The emergency stop pull-rope acts as a telemetry cable for signals from the conveyor on-board safety devices to the control unit. The control unit is a fail-safe device which provides a relay contact interlock signal to the conveyor starters (indicating the healthy/lock-out status of the conveyor on-board safety system). In addition, the control unit displays a two digit identification number of the locked-out conveyor on-board safety device, which is visible from the outside of the conveyor control kiosk. Finally the control unit provides a BCD output of this two digit identification number, which can be inputted to the PLC for communication to the central control room.

10. TRANSFER CHUTE CONTROL

The control of each bi-furcating transfer chute is performed by a motorized actuator, which moves the chute, and directs the incoming material onto either the L, L + U, or U conveyor systems.

The actual position of the actuator (and therefore the chute position) is indicated by a potentiometric signal from the actuator. A local PLC control panel receives chute position control commands (ie. L, L + U, or U) from the central control room (in the normal mode) or from local control pushbuttons (in the maintenance mode). Depending on the present chute position (as indicated by the potentiometric position signal to the PLC), the actuator is signalled to move either forward or reverse until the desired position limit, as indicated by the potentiometric signal, is reached.

The conveyor feeding the bi-furcating transfer chute is interlocked with the L and U conveyor systems, depending on the position of the transfer chute (i.e. L, L + U, or U). For example, if the chute is in the L + U position, the feed conveyor can only run if both the L and U conveyor systems are running.

11. THE CENTRAL CONTROL ROOM

The monitoring of the complete waste and over-burden dump system is performed at a central control room. In addition the start or stop commands for the various conveyors, and the position commands for the transfer chutes, are given by the plant operator from this central control room.

Pushbuttons and selector switches mounted on the operator's control desk provide signals to a PLC within the control desk for communication to the remote PLC's at the transfer chutes and conveyor drive stations.

A conventional mimic diagram and alarm display is driven by the PLC within the control desk. The PLC receives status and alarm/fault signals, by communication with the remote PLC's at the transfer chutes and conveyor drive stations.

Finally it is suggested that a personal computer based supervisory control and data acquisition (SCADA) system can supervise the entire waste and over-burden dump system, by communication with the central control room PLC, and thereby with all the remote connected PLC's at the transfer chutes and conveyor drive stations.

The advent of relatively low cost industrialized computer hardware, and standardized flexible SCADA software packages, enables sophisticated and comprehensive monitoring and reporting functions to be achieved at a realistic price.

The functions of a computer based supervisory system for this application could include:-

- mimic display, on the EGA colour monitor of the computer, for monitoring the status of the complete waste and over-burden dump system
- alarm annunciation, on the EGA colour monitor of the computer, together with a print out on the printer, of all alarm and fault conditions, together with the date and time of occurrence
- logging on the printer of all normal and abnormal start-up and shut down events, together with their date and time of occurrence
- logging on the printer of the date and time when each alarm or fault condition is acknowledged and subsequently reset
- archiving of all events on non-volatile memory (e.g. hard disc) for future analysis

- generation of shift reports and consolidated monthly reports including:-

  - a report on the totalized quantity of waste and over-burden dumped, together with a detailed energy consumption and power demand analysis and report
  - a detailed consolidated alarm and fault report
  - a detailed availability/down time/operator response time analysis and report

12. CONCLUSIONS

In order to capitalise on advances in electrical, control and information technology, multi-disciplinary skills are required from the electrical engineers involved with the specification, design, manufacture, installation and commissioning of the electrics for modern large conveyor systems.

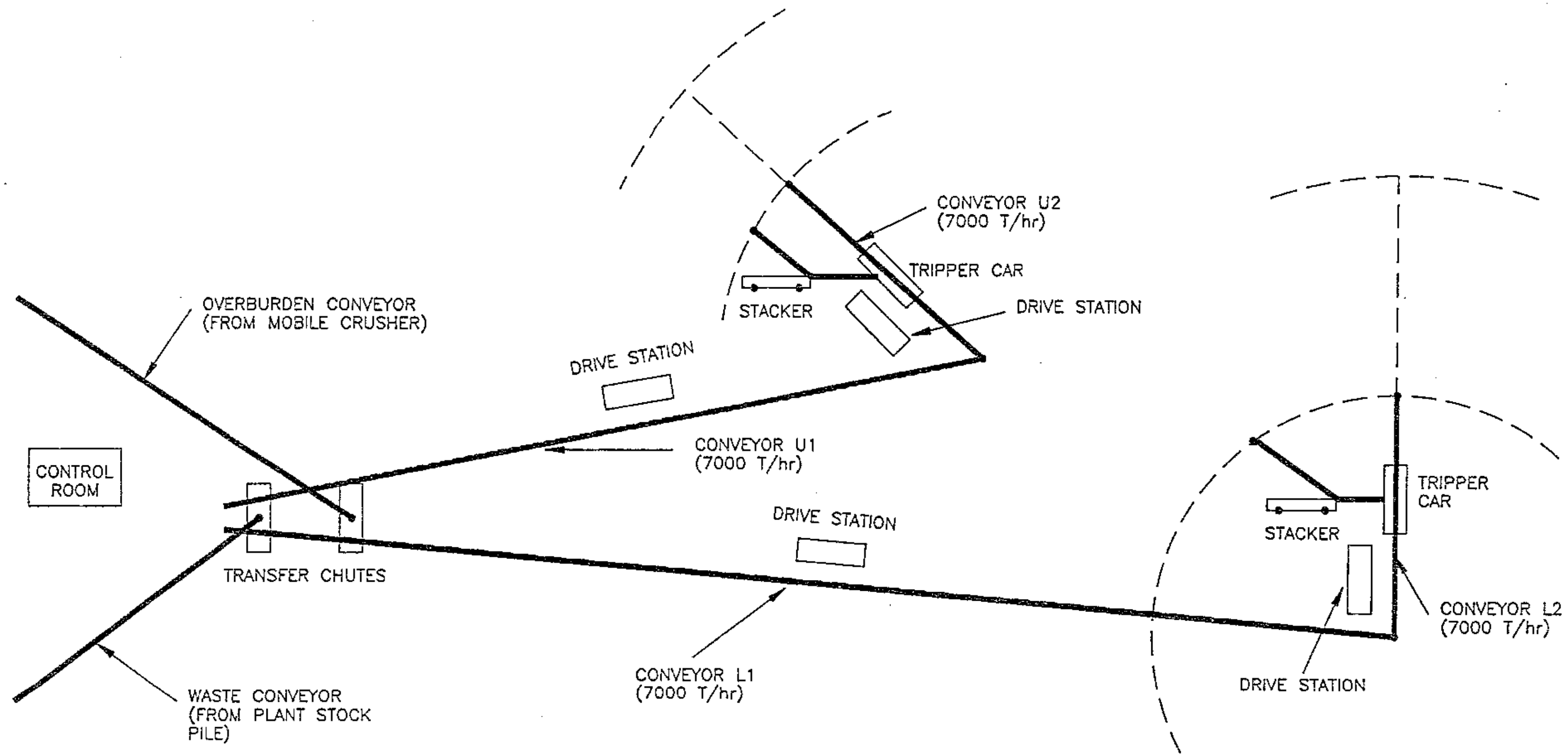
These multi-disciplinary electrical skills also need to be carefully co-ordinated and integrated with the other engineering disciplines (i.e. civil, mechanical and production) of the overall conveyor system design.

Rapid advances, especially in control and information technology, can enable significant improvements to be achieved in performance and efficiency of an overall system.

Effective management information provided by computer and PLC based SCADA systems, can quickly highlight production achievements, energy costs, the causes and production losses of downtime, and the response time of maintenance personnel, in rectifying faults and trip-outs. All of this information enables managers and engineers to make effective decisions to improve conveyor availability and performance.

13. ACKNOWLEDGEMENTS

The writer would like to formally acknowledge the role played by the project section of the ISCOR's Mining Division in the overall design and specification of the waste and over-burden dump system described in this paper.



WASTE AND OVERBURDEN DUMP SYSTEM

FIGURE 1

L1 CONVEYOR DRIVE STATION

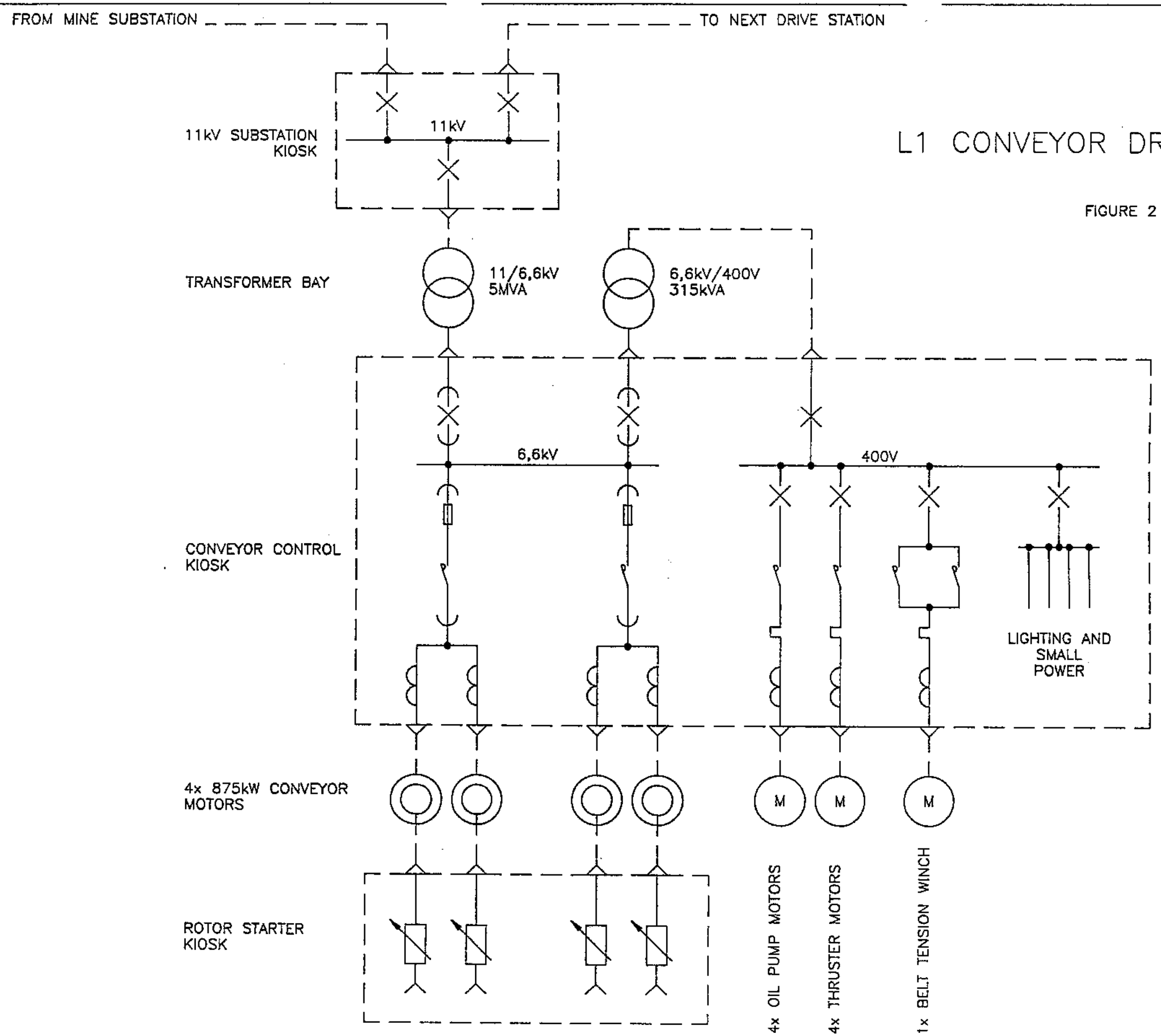
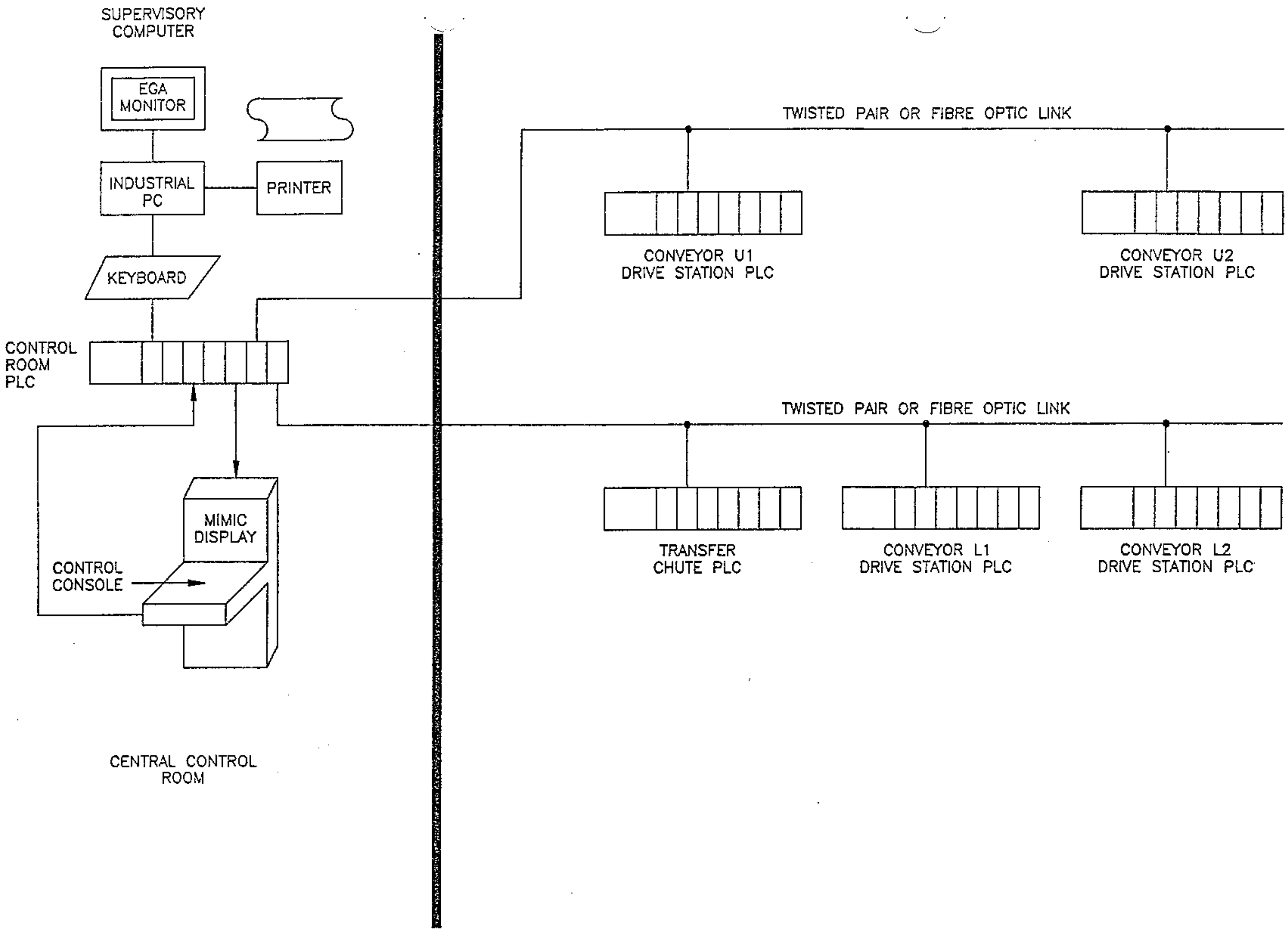


FIGURE 2



PLC TO PLC, AND PLC TO COMPUTER.
CENTRALISED MONITORING AND
DISTRIBUTED CONTROL SYSTEM.

FIGURE 3