RIO TINTO IRON ORE – ROBE VALLEY – MESA A

MURDOCH UNIVERSITY

SCHOOL OF ENGINEERING AND INFORMATION TECHNOLOGY

Investigation, Elimination and Documentation of VSD Faults Causing Downtime at Mesa A

Rachael Ritchie

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A report submitted to the School of Engineering and Information Technology, Murdoch University in partial fulfilment of the requirements for the degree of Bachelor of Engineering.

Abstract

The final aspect of the Engineering degree at Murdoch University is the Internship project. The Internship is a major project done with a company. In this case the Intern did their Internship project with Rio Tinto, at a mine site in the Pilbara called Mesa A. The role of the Intern was to investigate, eliminate and document the faults that were occurring with VSDs for CV102 Stacker Feed Conveyor. These faults were causing unscheduled downtime for the plant which needed to be kept to a minimum.

There were three projects worked on by the Intern. The first project was termed the Out of Sync fault. An Out of Sync fault is when one of the two motors driving the belt of CV102 is running at or above 100% of its capacity while the other motor is idling. At the completion of the Internship the cause of the Out of Sync fault had not been determined. More information is required before a determination of cause/s can be made. There is at present only one date where the fault has occurred and that alarm information is available. Data from the VSD is not available for this event. To make further progress with the project more information needs to be gathered. The event log in the VSD needs to be downloaded at the time of the fault and the alarm data also needs to be downloaded. The gathered information can then be sent to CSE-Uniserve, the company that installed and commissioned the VSDs at Mesa A.

The second project was called the Crash Stop fault. In this fault a cluster of alarms from the VSD prevent the plant being restarted after a crash stop to the plant has occurred. Consulting with CSE-Uniserve and Electricians on site lead to the cause of the fault being identified as due to the communication between the PLC of Motor 1 and Motor 2 with the PLC of the Sync VSD becoming blocked when the power was cut to the VSD and the VSD controllers. The internal UPS was supplying power to the controllers to enable them to send the alarms. The solution

was to remove the internal UPS. The wiring changes and the procedures were drawn up. The removal of the UPS was done during the shutdown in October. As well as the removal of the UPS some of the information in Citect, the SCADA package at Mesa A and the PLC were changed so there was no reference to the UPS that had been removed. All that remains as part of this project is to monitor to ensure that there are no unexpected negative impacts as a result of the removal of the UPS. At the time of this report no alarms relating to the VSD after a crash stop have occurred. The plant has only been up a few days since the change so it has not yet been confirmed that the cause of the fault has been eliminated.

The final project of the Internship was to improve the information that was available in Citect to enable better fault finding capabilities in relation to the CV102 VSD faults. To improve the information in Citect more information needed to be gathered. Inside the VSD are Siemens S7-200 PLCs. The plan was to connect to these PLCs and use the information in them to improve Citect, and also to be able to view what is happening in the PLC live, which is useful for fault finding. In order to connect to the PLCs inside the VSDs a new network had to be created. There were complications in the development of this network as there are two separate communications protocols being used by the devices at the present moment. By trying to make another connection to the PLC a third protocol is being introduced. After multiple attempts at designing the new network connections a final design has been drafted. At the completion of the Internship the required equipment had not arrived so the changes had not been made. Another issue with this part of the project is that the program in the PLC is written in Chinese and no-one on site is able to read Chinese. Some University colleagues were able to translate some of the code into English but there was not any back up code for one of the VSDs and the password to access the protected regions of code is not known. This part of the project remains incomplete until the equipment arrives and is installed. Once that is done more information may be able to be included in Citect depending on what is accessible from the PLC.

The Intern finished one project and made significant progress in the other two, getting them to the final design stage, awaiting implementation. Many lessons were learnt by the Intern in terms of technical lessons as well as skills such as project planning, communication and similar skills that are required to be an Engineer.

Disclaimer/Declaration

All of the work contained in this report is the work of the author unless otherwise stated and referenced. This document adheres to the Murdoch University Plagiarism Policy. I solemnly declare that to the best of my knowledge that no part of this report has been submitted in previous application for award of a degree.

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Rachael Ritchie

Date:………………………………….

Industrial/ Academic endorsement

As this is the final assessment of the Internship undertaken, this report needs endorsement by the Academic and Industry supervisors. In doing so, both parties have approved this report as being an accurate representation of the works completed by Rachael Ritchie over the Internship period at Rio Tinto Mesa A.

Signed: Linh Vu, Murdoch University – Academic Supervisor

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Date:……

Signed: Janine Obkircher, Rio Tinto – Reliability Superintendent

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Date:……

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I wish to acknowledge the assistance from many people, without their help this project would not have been the success it was. So thankyou to:

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List of Abbreviations

Table 1 Abbreviations used in report

Abbreviation	Meaning
VSD	Variable Speed Drive
PLC	Programmable Logic Controller
SCADA	Supervisory Control and Data Acquisition - Citect
I/O	Input/ Output
TLO	Train Load Out
Sub	Substation
SoW	Scope of Works
CM	Change Management
TCP/IP	Transmission Control Protocol/Internet Protocol
mA	Milli-Amps
AC	Alternating Current
DC	Direct Current
PWM	Pulse Width Modulation
IGBT	Insulated Gate Bipolar Transistor
IP	Internet Protocol
CV102	Conveyor 102 (Stacker Conveyor)
CV101	Conveyor 101 (Secondary Feed Conveyor)
MO1	Motor 1 driving CV102
MO2	Motor 2 driving CV102
Comms	Communications
Cat 6	Category 6 (type of cable)
ROC	Remote Operations Centre
CV102MO1, CV102MO2	Motor 1 and Motor 2 driving the CV102 belt

kW	Kilowatts
kV	Kilovolts
MO1	Motor 1
MO2	Motor 2
Sync	Synchroniser
HVCIL	High Voltage Critical Interlocks
UPS	Uninterruptable Power Supply
SNMP	Simple Network Management Protocol
PC	Personal Computer
IT	Information Technology
PE	Photoelectric

1 Introduction

At the end of the Murdoch University Engineering degree a thesis or internship must be done. The aim of this is to show the cumulative learning and to put that learning into practice. The Internship is a chance to get industry experience at the same time as finishing study. Rio Tinto Iron Ore Mesa A, provided an Internship and the task of the Intern was to determine the cause of the faults that were occurring with the VSD on CV102 drives. The Intern worked independently to investigate, eliminate and document the faults that occurred to the CV102 VSDs that are causing downtime for Mesa A. Another task assigned to the Intern was updating information in relation to the VSDs in Citect to improve fault detecting capability on the site.

The work done at Mesa A will be presented in the report as follows:

- Section 2: Will explain the fundamentals of how a motor works and how a VSD functions. The fundamentals of PLCs are then discussed followed by the basic information on the communications protocols that are used at Mesa A. The report then goes on to describe Citect and the basis of its role at Mesa A. The Drives and the associated equipment that are used to drive CV102 are then explained.

- Section 3: Describes the project work done at Mesa A including
    - Section 3.1 Out of Sync Fault
    - Section 3.2 Crash Stop Fault
    - Section 3.3 Citect Improvements

- Section 4: This finishes the report with the conclusion which includes the lessons learnt by the Intern during the project work.

2 Background

2.1 Rio Tinto Mesa A

Mesa A is a Rio Tinto operated iron ore mine site located approximately 200km south west of Karratha. Mesa A is a straight line plant. The mined ore is transported along a conveyor from the ROM bin to the primary crusher. Dust sprays are used to adjust water content and supress dust, before the crushed ore, via another conveyor is progressed through a secondary crusher. More water is added before the finely crushed ore is deposited on the stockpile to be loaded onto trains to be taken to Cape Lambert. An overview of the plant can be seen in Figure 1. The focus of the Internship was on the Variable Speed Drives (VSD) on Conveyor 102 (CV102). This 1km long conveyor carries the ore from the output of the secondary crusher to the stockpile, from which it is loaded on the train. Two 710kW squirrel cage induction motors drive the CV102 belt. A VSD is used to control the speed and to start the belt at a low speed, but high torque, when fully loaded. One VSD is for each motor and a component named the Synchroniser, is used to keep both motors operating at the same speed.

All VSDs for the conveyors were installed and commissioned by CSE-Uniserve onsite. The company provide engineering and electrical equipment in the areas of Protection, Automation, Power Conversion, as well as ongoing technical support relating to the VSDs installed.

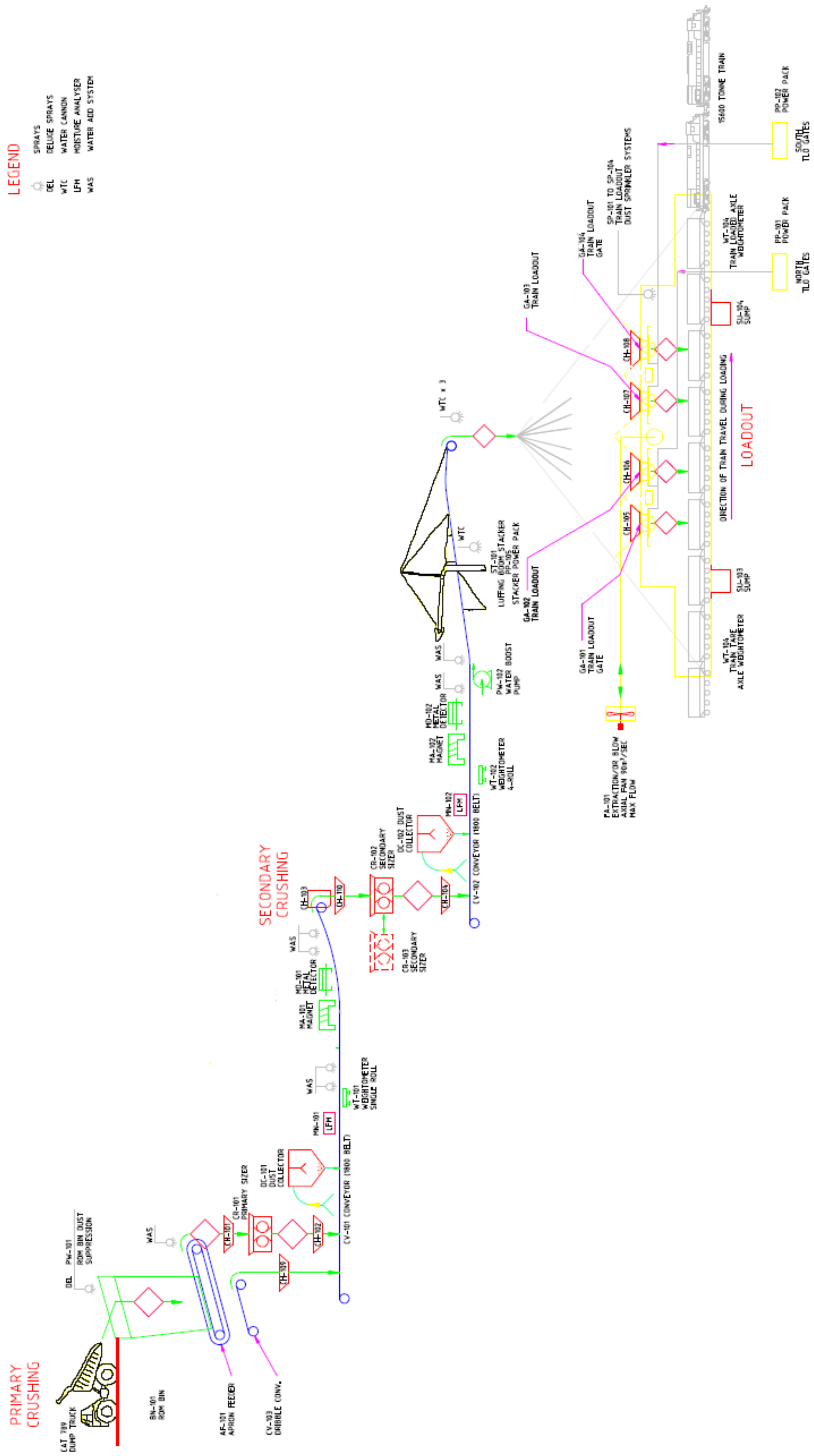

Figure 1 Mesa A Overview of Plant (Rio Tinto 2010)

2.2 VSD Fundamentals

The essential device in the projects undertaken is the Variable Speed Drive. The following section explains the principles of how a motor works and then how the VSD controls the speed of the motor.

2.2.1 Motors

A motor is a device that converts electrical energy into mechanical energy. The motors being used on CV102 are squirrel cage induction motors. Induction motors are also sometimes referred to as asynchronous motors. A representation of the motor is shown in Figure 2. The main components of the motor are the stator, the rotor, the shaft and the bearings. The purpose of the bearings is to reduce rotational friction of the shaft and rotor.

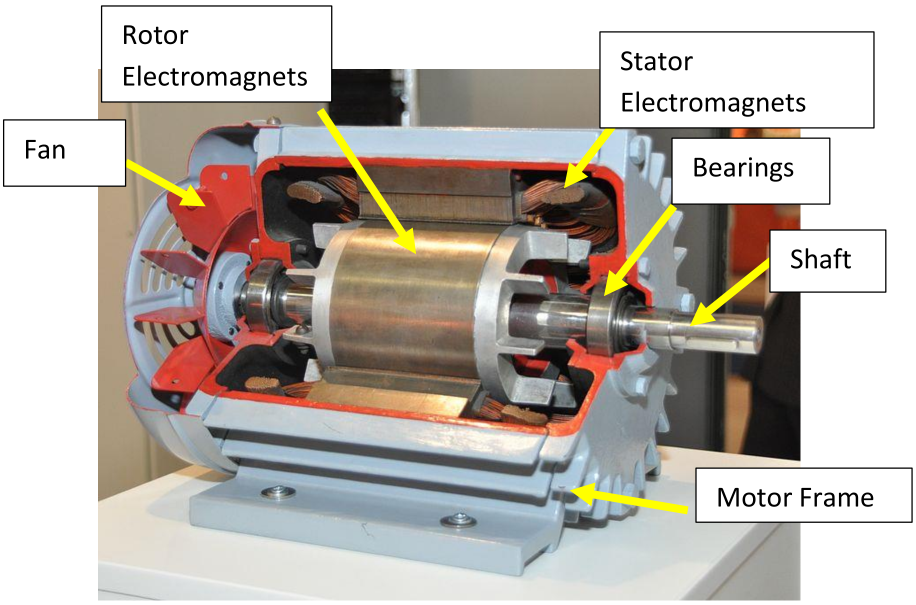

Figure 2 Construction of AC Motor (Waard 2011)

In an induction motor the input power is fed to the stator windings. The current flowing through the stator windings results in the formation of magnetic poles it also induces a magnetic field in the rotor. These poles rotate around the stator (Rizzoni 2006). The magnetic field of the stator rotates as a result of the placement of the windings of each of the phases of the three phase power supply. The input power is sinusoidal and therefore varies with time. Figure 3 shows the input voltage of each of the three phases in the bottom half of the figure and the top half shows the position of the strongest magnetic field. It can be seen that the strongest magnetic field moves around the circumference of the stator due to the changes in the magnetic field and that the rotor will move in an anti-clockwise direction in its attempt to catch up to the magnetic field of the stator (Rizzoni 2006).

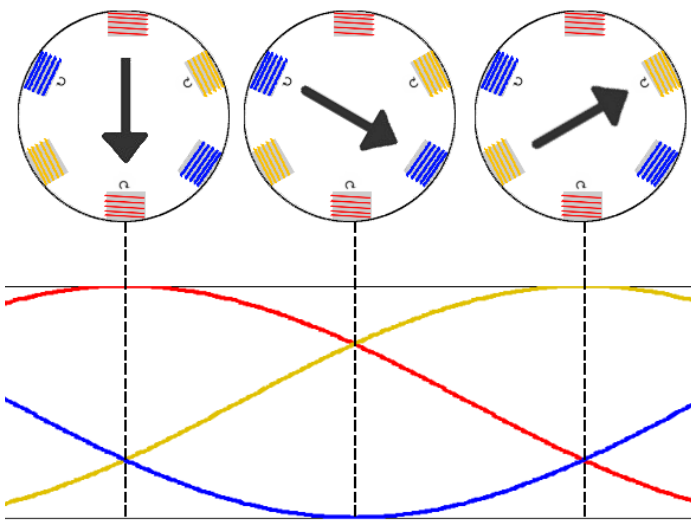

Figure 3 Rotor and Stator Operation of AC Induction Motor (Willplatts 2008)

The torque of a motor is developed due to the magnetic forces of attraction and repulsion between the poles of the stator and the rotor. The poles produce a torque that accelerates the rotor and a reactionary torque on the stator. To ensure continuous and constant direction of rotation the number of poles on the stator and the rotor need to be identical and there also needs to be an even number of poles. The rotation of the rotor is due to the magnetic fields on the rotor trying to align with the magnetic fields of the stator. Because the magnetic fields of the stator are constantly rotating so must the rotor to align its magnetic fields (Rizzoni 2006).

The synchronous speed of an AC induction motor is given by the formula in Equation 1 and Equation 2.

Equation 1 : $n_s = \frac{120f}{P}$

Equation 2: $\omega_s = \frac{\omega}{P/2}$

Where n_s stands for speed (revolutions per minute), f for frequency of the supply in Hertz, and P is for the number of poles of the motor. ω is the supply frequency in radians per second, ω_s is the speed in units of radians per second (Hambley 2011).

As will be explained shortly this synchronous speed represents an upper speed limit for an actual induction motor. As can be seen from Equation 1and Equation 2, the speed of an AC induction motor is related to the voltage, number of poles of the motor and the supply frequency. This speed is called the synchronous speed. In the motor the number of poles is a fixed quantity. Therefore to change the speed of the motor either the voltage or the frequency of the supply needs to be varied. The motors that are used to drive the conveyor belt CV102 are squirrel cage induction motors. This type of motor is the simplest design and is also very rugged. The squirrel cage refers to the construction of the rotor of the motor. It is simply a set of aluminium bars that are joined together by a shorting ring at both ends, shown in Figure 4. The cage is embedded in the iron section of the rotor by casting the molten aluminium into slots in the iron rotor (Hambley 2011). One important feature of the squirrel cage motor is that there are no electrical connections to the rotor (Hambley 2011), which increases the ruggedness of the design.

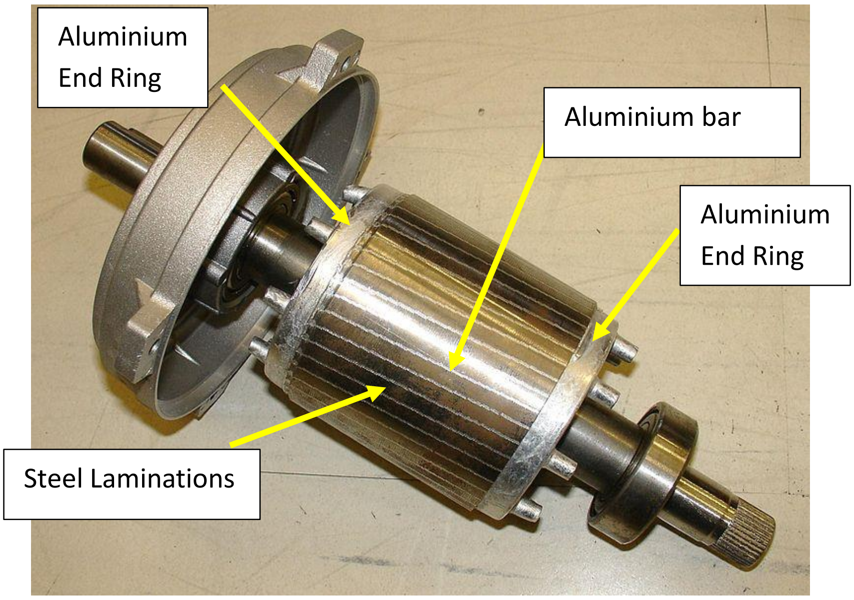

Figure 4 Squirrel Cage Surrounding Iron Core of Rotor (Zureks 2008)

Torque is an important factor in the selection of the motor. Each type of motor has an individual torque-speed characteristic. The characteristic of the squirrel cage AC motor is shown in Figure 5. In order to understand changes in torque as a result of changing speed an understanding of a concept called slip is required.

The mechanical speed (n_m) of the induction motor varies from zero to close to the synchronous speed (n_s). Therefore the speed of the stator field in relation to the rotor is given by n_s-n_m (Hambley 2011). Slip is defined as the relative speed as a fraction of the synchronous speed. It is shown in

Equation 3.

$$s = \frac{n_s - n_m}{n_s}$$

Equation 3 Slip Formula (Hambley 2011):

Another equation is that for the slip frequency of the motor. It is given by

Equation 4. $$\omega_{slip} = s\omega.$$

Equation 4 Slip Frequency (Hambley 2011) :

The slip of the motor varies from being 1 when the rotor is stationary to being 0 when running at synchronous speed. When the mechanical speed of the rotor nears the synchronous speed the frequency of the induced voltage is almost zero (Hambley 2011).

When rotor speed and the stator speed are equal the slip is zero. Because the slip is zero the relative velocity between the conductors of the windings is also zero, this results in the induced voltage being zero and subsequently the induced current is zero. As a result of zero current the torque of the motor is zero. As the slip increases the currents increase along with the induced voltage with the effect of this being an increase in torque. In general for small amounts of slip the developed torque is proportional to the slip (Hambley 2011).

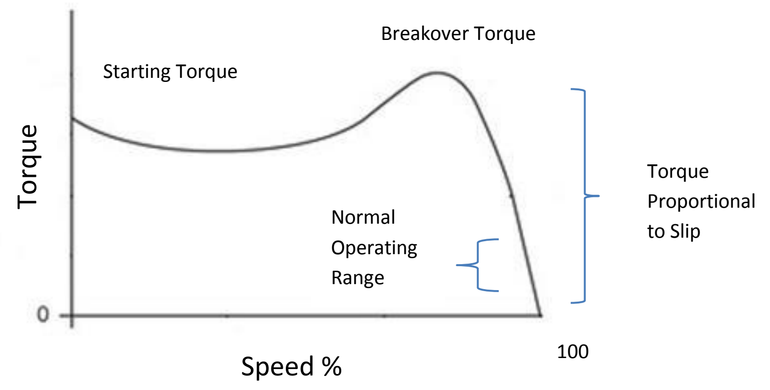

Figure 5 Torque Speed Curve of AC Induction Motor

The torque speed curve in Figure 5 is the typical curve for an induction motor. By changing properties of the motor it can be altered somewhat but still retains the same basic properties.

This profile may not be the ideal profile for all situations. One of the ways to change the curve to get more torque from the motor, especially at both the low speed and high speed ends of the curve are by using a Variable Speed Drive (VSD). The operation of which will be explained in the following section.

The current that is required by an induction motor during start up is typically six to seven times its rated current, MO1 and MO2 are rated at 200A. In the case of the motors used on CV102 this would result in the starting current being 1200-1400A. This is one of the reasons for using a VSD to start a motor. The high start-up current can cause problems, such as a large voltage drop in the network that the motor is connected to. This affects other equipment on the same network. Another issue with the large starting current is that the protection systems for the motors and the network have to be oversized to provide adequate protection, additionally the cables to carry the large currents, lead to a significant rise in costs.

2.2.2 VSD

A Variable Speed Drive (VSD) is a device that is used to control the speed or torque of a motor. These quantities cannot be directly controlled. They are manipulated however by the changing of the voltage and frequency that are seen by the motor. There are two fundamental methods of control, one is torque control and the other is speed control. When the torque is controlled the speed of the motor is determined by the load of the motor and when speed is controlled the torque is determined by the load (ABB 2002).

Originally only DC motors were able to have their speed or torque controlled due to their construction, Figure 6 shows a simplified diagram of a DC motor with torque control, which is known as a shunt connected motor. In the figure the subscript F indicates the field parameters, and A stands for the armature parameters.

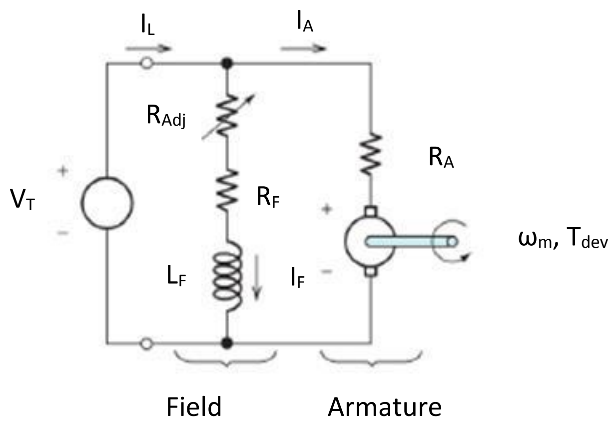

Figure 6 Shunt Connected DC Motor-Rheostat (R_{adj}) for speed/torque control (Hambley 2011)

The control loop of the DC motor speed control is shown in Figure 7. The magnetic field of the motor is created by the field current winding which is in the stator. Due to the construction of the DC motor with the brushes and commutator, the armature winding is always at right angles to the field winding. This arrangement enables the generation of the maximum torque. The arrangement of the field and armature windings fields being at right angles to each other is known as the field orientation.

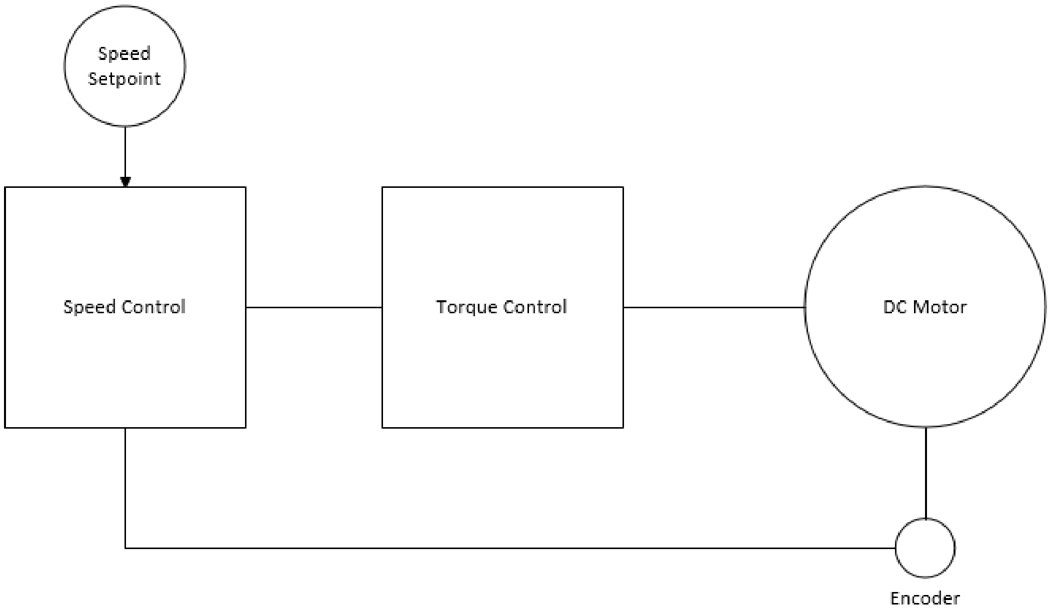

Figure 7 DC Motor Speed Control Loop (ABB 2002)

When the motor has its field orientation set up, the control of the torque is a matter of varying the armature current but keeping the magnetising current constant (ABB 2002). The use of this method of torque control has the advantage that the torque is in direct proportion to the armature current enabling accurate control, the response of the motor to the change in armature current is rapid and it is also a very simple way of controlling the torque, requiring only mechanical parts to control the torque (ABB 2002). This method of speed control also had its drawbacks, as the brushes would need replacing (common problem with DC motors) which reduced the reliability of the motor. DC motors are also more expensive to purchase and the need for an encoder to provide the speed and position of the shaft as feedback to the control loop also added to the cost of the motor.

When it comes to AC motors there are two main methods of control. The first method is frequency control, the second way is flux vector control. Bothe using Pulse Width Modulation (PWM) (ABB 2002). An explanation of each follows.

Frequency control using PWM is based upon changing two variables, voltage and frequency to control the speed of the motor. These variables are not obtained directly from the motor, they come from the incoming power supply. The values of the frequency and voltage are fed into a modulator which then simulates an AC waveform by pulses from the inverter (modulator) which is fed to the motors stator windings. In Figure 8 presents a block diagram showing how the frequency control with PWM operates. It can be seen that there is no feedback from the motor supplied to the modulator, this means that this is an open loop type of control.

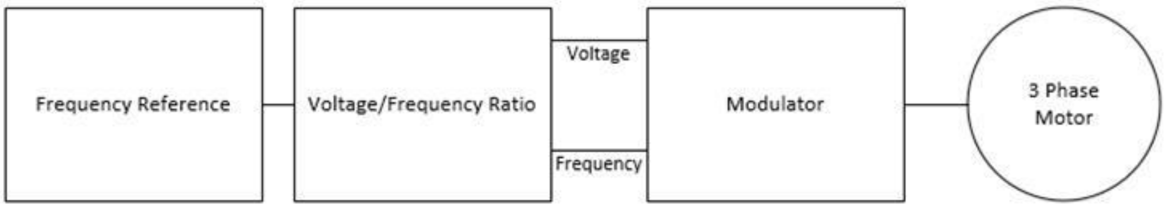

Figure 8 Control Loop Diagram of Frequency Controlled VSD (ABB 2002)

There are both advantages and disadvantages of this type of control. The advantages are that it is simple as there are no feedback devices required and also low cost for the same reason. The disadvantages are that there is not a high level of accuracy in the speed control due to the lack of feedback. The use of the modulator delays the input, as it acts like a filter so the response is slower, and the torque of the motor is not controlled. This type of control method is good for devices that don’t need to be very accurate or precise in terms of speed control. Some useful applications are for pumps and fans.

Flux vector Control using PWM is the second method used to control the speed of AC motors. It works on a principle similar to that of the DC motor. The control loop is shown in Figure 9. It is a field oriented control method, this means it simulates a DC drive. The control emulates the field orientation of the DC motor with the field and armature fields at right angles to each other. This is done by measuring the spatial angular position of the rotor flux and the rotor speed. This information is sent to the controller via pulse encoders. The measurements are used to add to a mathematical model of the motor inside the controllers. The output of the controller is a variety of properties including voltage, current and frequency. These go to the modulator which is then fed to the motor itself (ABB 2002).

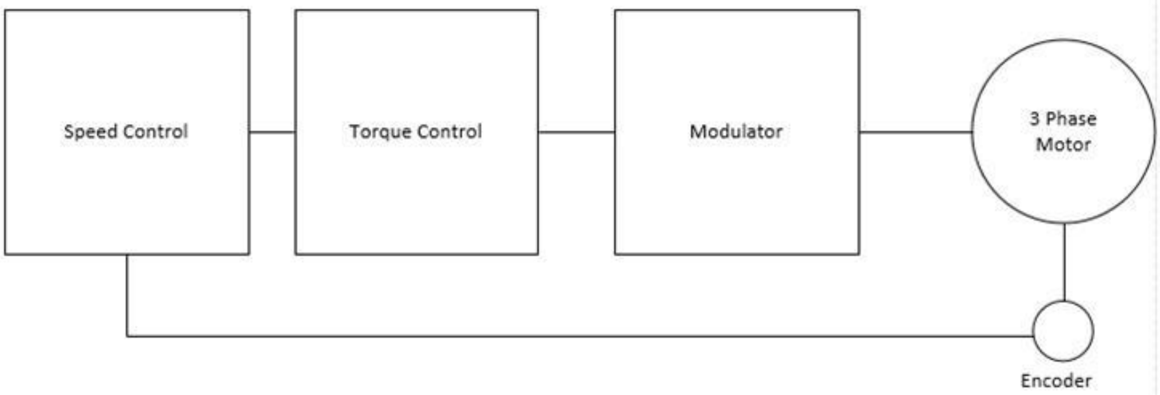

Figure 9 Flux Vector Control Loop Diagram (ABB 2002)

The advantages of this type of control is that there is some control over torque although indirectly. The control of the speed is reasonably accurate and full torque is available when the motor is stationary (so at start-up full torque will be available). The drawback of this type of control is the cost, the need for encoders and modulators add to the cost. The controller is also complex as it is done through electronic means rather than mechanical as in a DC motor (ABB 2002). This method is useful when high torque at low speeds is required and when precise control of speed is required.

2.3 PLC Fundamentals

A very important part of a plant is the equipment that is used to monitor and control the plant equipment such as conveyors, motors and monitoring equipment. A common device that performs this task is the Programmable Logic Controller (PLC). The PLC is an industrial computer. It monitors the inputs and depending on the program that is loaded in the PLC, decisions are made that alter the outputs of the PLC. The method of operation of a PLC is shown in Figure 10. The state of the inputs are read, an image of the inputs is stored in memory, the program code runs. Based on the results of the program an output image is created in the PLC's memory. The status of the outputs are then updated to the external devices.

Figure 10 PLC Operation

The time taken to perform these steps is known as the scan time of the PLC. The scan time is an important consideration when selecting a PLC. The PLCs used at Mesa A were made by Schneider, a model line called Modicon M340 (see Figure 11). The advantage of this model is that it comes in a series designed for harsh environments with dust and higher normal operating conditions, which makes it suitable for mine site use. The Modicon series is also expandable. This means that if more inputs or outputs are needed they can be added to the limit of the main processor module, these are given in the specification of the PLC and it usually relates to memory availability and processor capabilities, (the module that executes the program). Additional modules exist for analogue I/O, which outputs a signal 4-20mA or 0-5V depending on the module, this is useful for devices which are not just on/off devices, such as valve positioning. It may be desired that the valve be opened to 25% of full. This can be done by the output generating an 8mA signal.

Figure 11 Modicon M340 PLC with I/O Modules (Australia Automation 2013)

Another advantage is when devices are not near the PLC itself. The Modicon series allows for what is called Remote I/O. At Mesa A the Remote I/O used is the Advantys (Figure 12). A remote I/O module is installed near the device to be controlled, all the required inputs and outputs are terminated into the Advantys module. The module is connected via a single cable (usually Cat 6 although sometimes fibre optic) to the PLC. If there were no Remote I/O modules then either more PLCs would need to be installed or the I/O would have to be run back to the PLC which may be a long distance. The long distance presents the problem of cost of the cable and also loss of signal over large distance. The remote I/O module enables the data to be transferred quickly and reliably to the PLC with just one cable. At Mesa A the protocol used between Remote I/O and the PLC is Modbus TCP/IP. As a result the input and output signals can be sent and updated quickly.

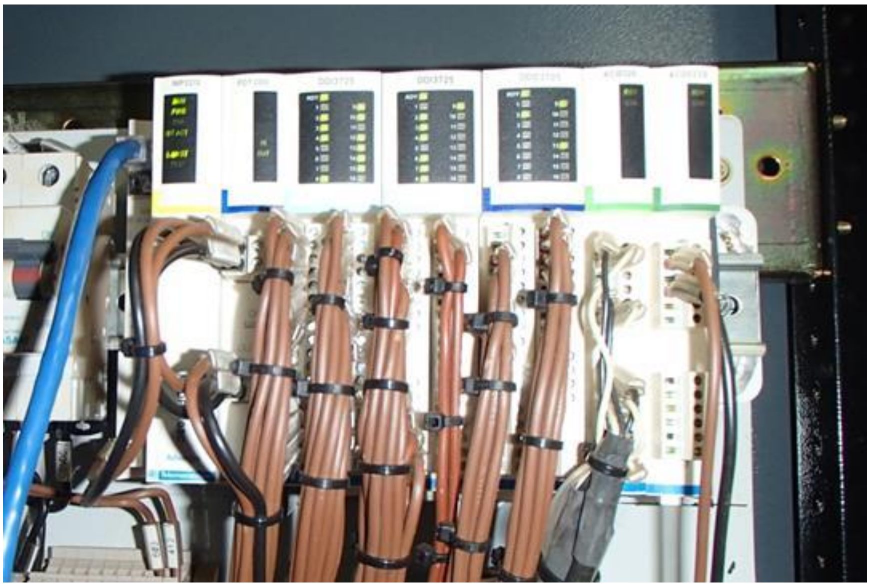

Figure 12 Advantys Remote I/O Module in VSD Sync Cabinet

2.4 Communications Protocols

2.4.1 Communication Protocols

A communication protocol is a set of rules that are used to define how a message is structured and transmitted. It is the rules of the language that a device uses to communicate with other devices. All devices on a network should be using the same protocol to enable effective communication. It is similar to people talking. All people need to be speaking the same language, such as English, to be able to understand each other. On any particular site it is ideal for all devices to use the same protocol to avoid having lots of 'translators'. The main communication protocol used at Mesa A is Modbus TCP/IP. The communication protocol used by the Siemens PLC inside the VSD is Modbus Serial. Each of these will be discussed below.

2.4.1.1 Modbus Serial

Modbus-Serial is the original Modbus. The communication is done using a serial cable, twisted pairs with shielding. The main network structure available for a serial Modbus network is one master and many slaves. The master device is in control of the data communication. The master will send out requests to the slave devices, which will in turn respond with the requested information. In a Modbus network each slave device has a Modbus address, which is a number between 1 and 247. Each device must have an individual address (Modbus.Org 2002). Consequently the master can request specific information from just one device or as many devices as required. The slave devices do not initiate communication on the network, but only respond to requests. The communication is usually done using a RS485 cable, which can be 2-wire or 4-wire. The 2-wire cable means that communication is half-duplex, although three wires are needed, while the 4-wire configuration (uses five wires) is full duplex. An example of each is shown in Figure 13 (2-wire) and Figure 14 (4-wire). The additional, unpaired wire is referred to as the common, it used to ensure that all devices on the communication network are brought to the same voltage potential. It is important to have the same potential across all the devices as the information is transmitted as a voltage signal, if the devices are at different potentials the messages can be misinterpreted or corrupt, being totally unreadable.

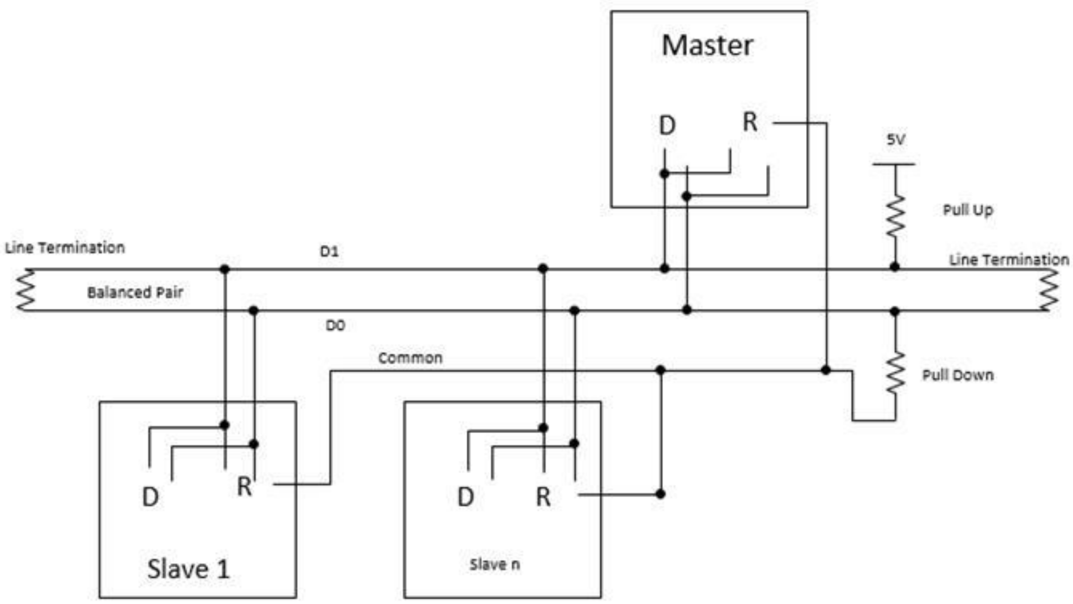

Figure 13 2-Wire Termination of Serial Modbus (Modbus.Org 2002)

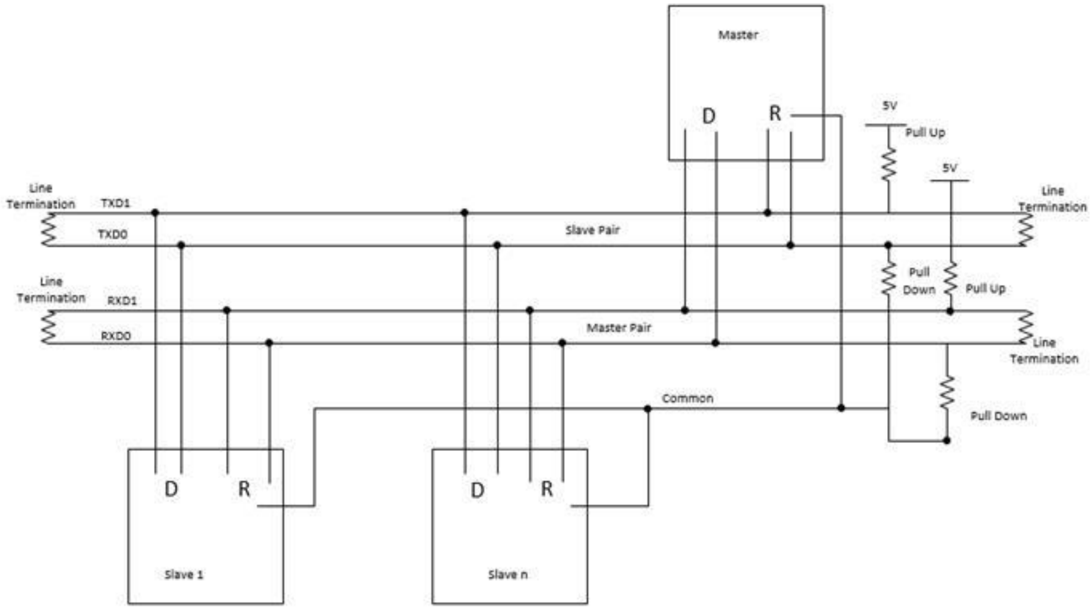

Figure 14 4-Wire Termination of Serial Modbus (Modbus.Org 2002)

Half duplex means that communication can only travel in one direction at a time. That is the master sends a request to a device. After this the device sends its reply back, then a request can be made to another device and so on. In full duplex, while the master is waiting for a reply from device one it can send its request to device 2. This is because in full duplex mode there is one pair of cables is called the master pair. The data on this pair is received only by the slaves, while the other pair is the slave pair and only the master receives the data transmitted along this pair (Modbus.Org 2002). The extra wire in each of the configurations is called the common, it ensures that each device is at the same potential (in terms of voltage) for correct communication.

2.4.1.2 Modbus TCP/IP

This communication protocol is the same as serial Modbus except for some of the following major points. In a TCP/IP network the slave devices are now referred to as Servers and the masters are now Clients. Another significant difference is that each network can now have more than one master (Clients) (Modbus.Org 2002). This enables a wider variety of network models to be configured. The most commonly cable to carry the transmissions is Ethernet cable. It is a 4 twisted pairs cable, the current highest rating is Cat 6, this is used at Mesa A. This protocol is based on an internet model, as a result each device must have its own individual IP address.

2.5 Citect Fundamentals

Citect is the name of the Supervisory Control and Data Acquisition (SCADA) program that is used at Mesa A. It is a computer program that communicates with all the PLCs and other devices for which it has been configured to communicate with. Citect is used by the Operators in the Perth Remote Operations Centre (ROC) to control the plant, e.g. the speed of the crushers, conveyors and train loading can be controlled from ROC. The main overview screen in Figure 15 shows the areas that are under the control of the Citect system. These include Primary Sizing, Secondary Sizing, Stockpile, Train Load Out as well as Power Distribution and Water Distribution.

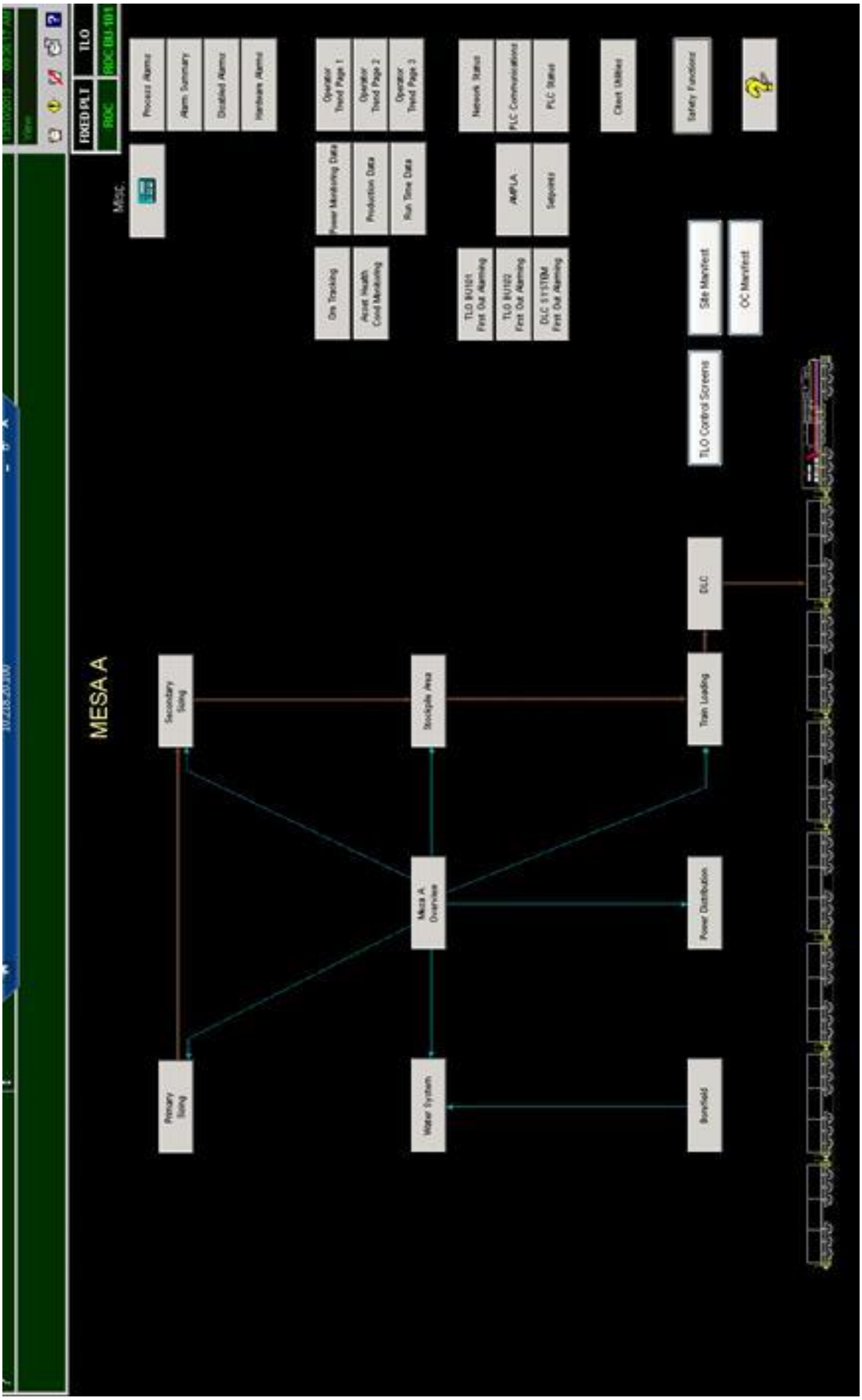

Figure 15 Main Overview Citect Page of Mesa A

Using Citect Operators can perform tasks such as starting the plant and also provides information of the status of the plant. This is useful for the maintainers (Electricians/ Mechanical Fitters) as Citect provides a log of the alarms so that the cause of a fault can be easily found and rectified. The PLC contains most of the safety interlocks but the Citect system also forms a part of the interlocks. The use of Citect enables the plant to be run remotely and also enables changes to inputs such as ore into the primary crusher to be varied so that the plant remains in the optimal operating range.

There are facilities in Citect that allow various inputs or outputs to be trended, the input or output as measured by the PLC can be plotted against time (see Figure 16). These trends are very useful when trying to determine the cause of a fault and also for tracking the performance or wear of various components. The Citect system has a sample time of one second so not all the information that is gathered by the PLCs (which have a much faster scan time) is included in the display. For the Mesa A site a one second refresh time is suitable because there are not any properties that change at an extremely high rate. Properties such as motor speed are controlled by the PLC which have scan times that are at the appropriate speed to maintain control, whereas Citect enables the Operator to get an overall picture of how well the devices are working.

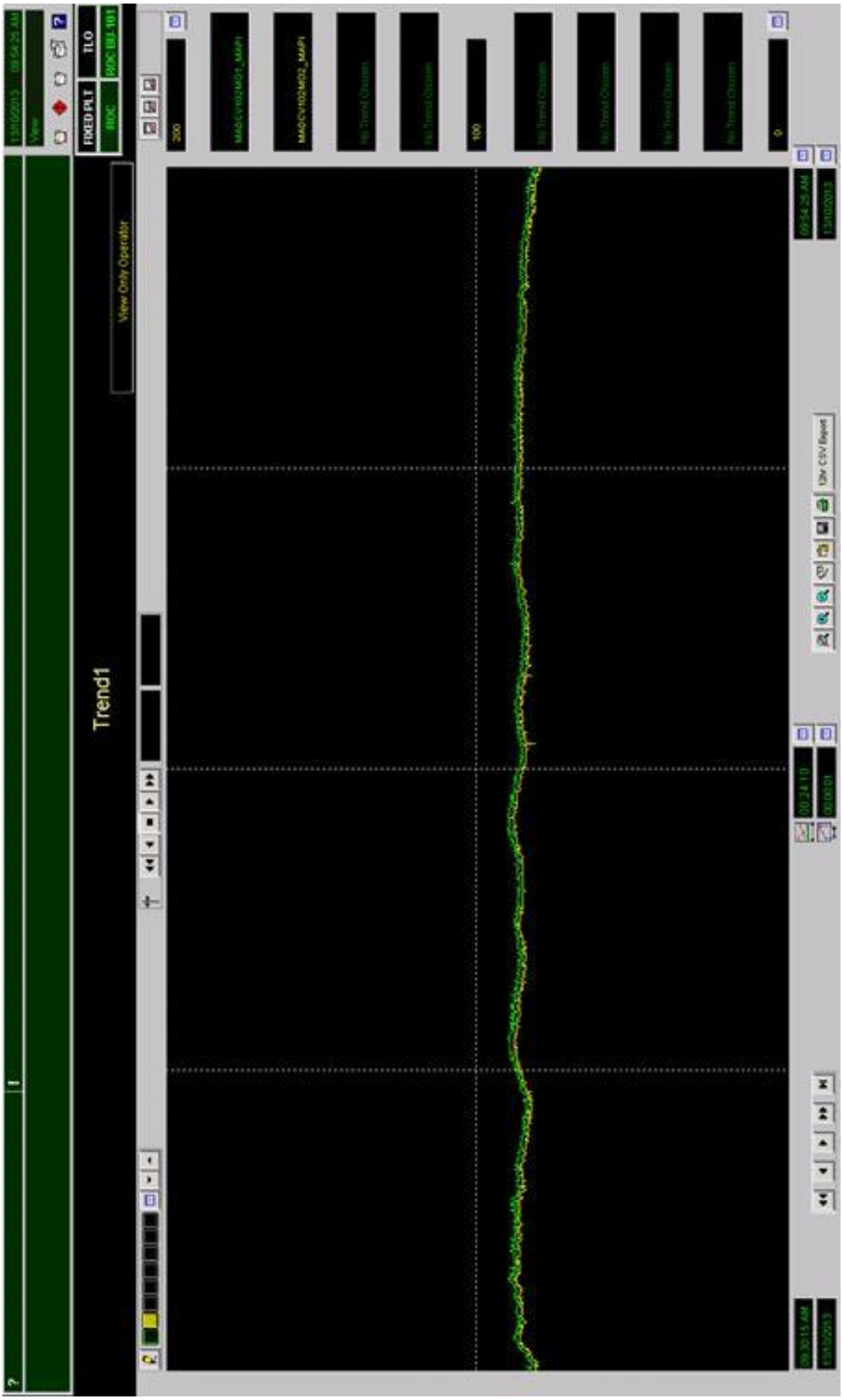

Figure 16 Trend Page – Current of CV102MO1 and CV102MO2

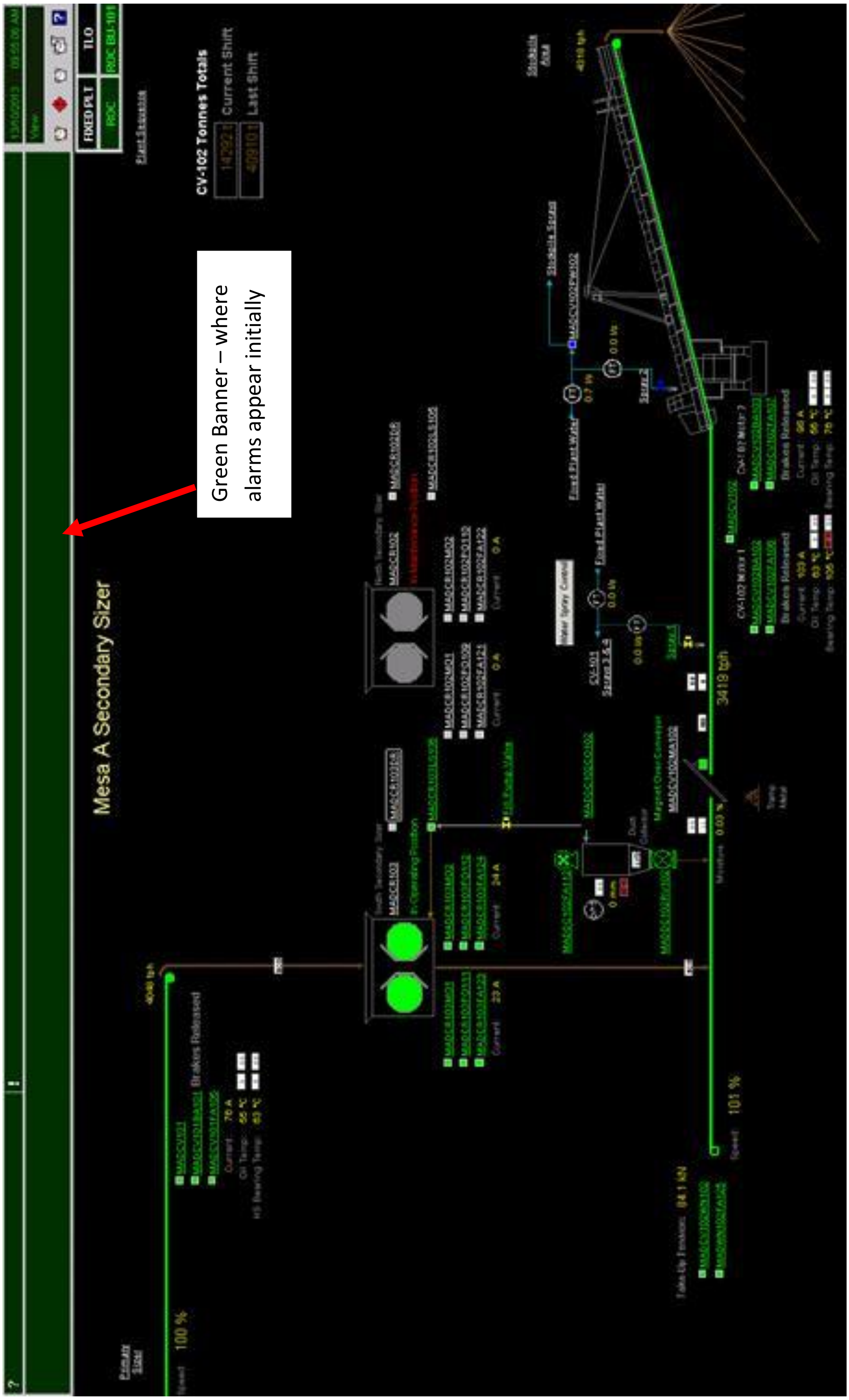

Figure 17 Secondary Crusher Page – Alarms Appear in Green Banner

Alarms appear in various colours depending on severity in the display bar at the top of the screen (Figure 17). There is also a page that is used to show the alarms that have occurred (Figure 18), called the Alarm Summary Page, it is able to be modified to show only desired items. For example in Figure 18, the events have been filtered out. Events are occurrences in the process that are recorded but do not trigger an alarm. One example is the activation of Photoelectric (PE) Cells in the TLO which is used in loading the train.

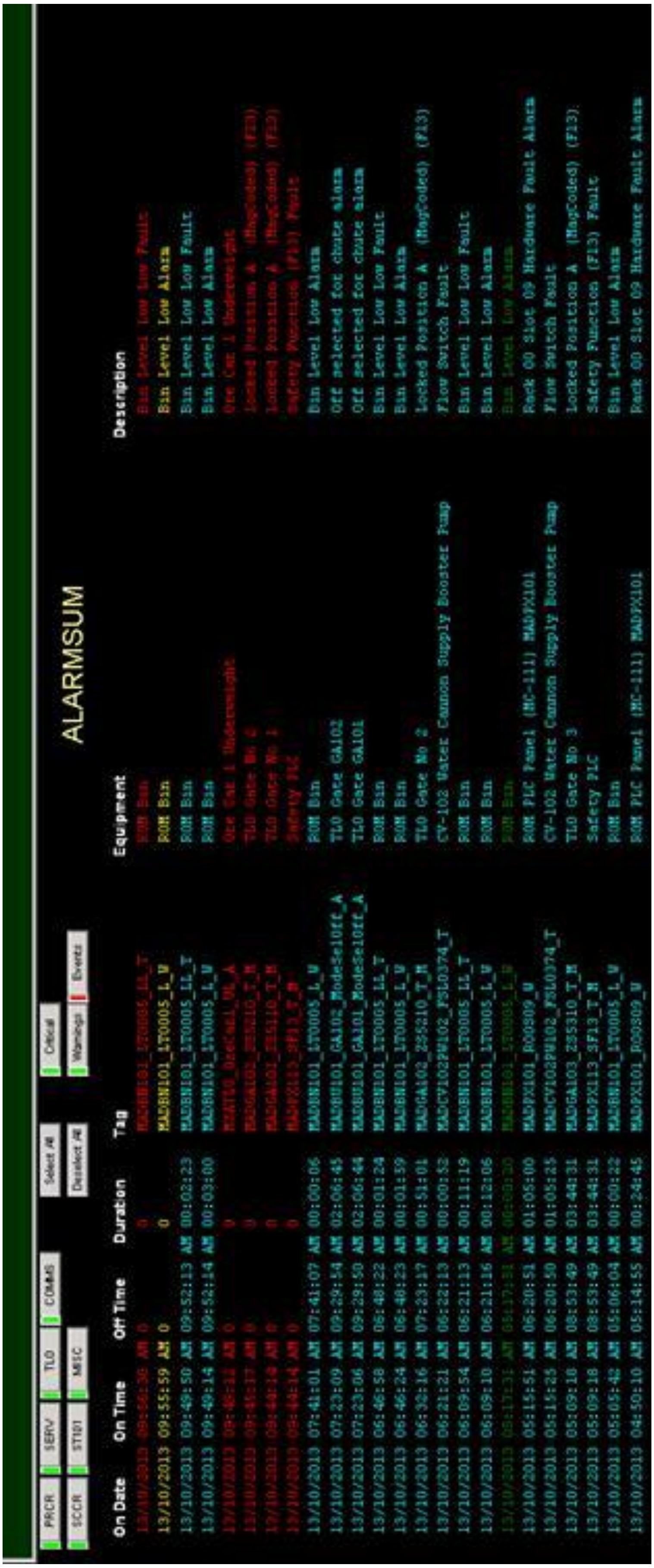

Figure 18 Alarm Summary Page Without Events Showing

The Alarm Summary Page looks like Figure 19 if the events are included. The ability to remove events is of particular use when the train is loading as every PE cell that is blocked is recorded in the Alarms Summary. This makes searching the alarms difficult when trying to determine cause of faults.

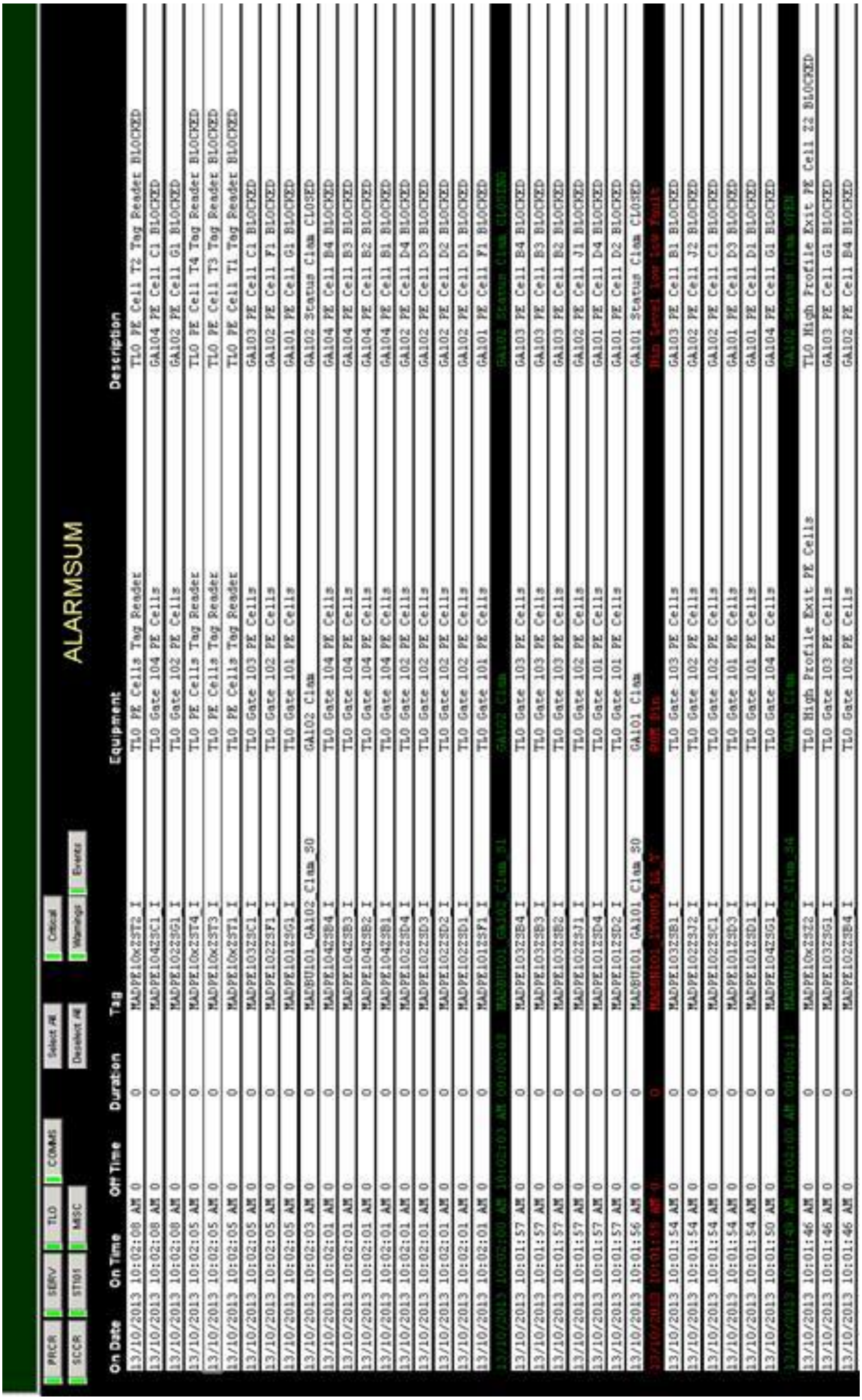

Figure 19 Alarm Summary with Events Showing

2.6 Mesa A CV102 Drive Equipment

The conveyor belt that transports the crushed ore from the secondary crusher to the stockpile is called CV102 and is in part shown in Figure 20. The motors that are visible in the bottom right are the motors that drive the belt. These are called CV102MO1 and CV102MO2 or MO1 and MO2 for short in this report. The motors are 710kW 3.3kV 4 pole squirrel cage induction motors constructed by Falk.

Figure 20 CV102 (Second Half) Including Drive Motors MO1 and MO2

The speed and torque as well as the starting and stopping of the motors is controlled by two VSDs and a Synchroniser. MO1 has its own VSD named CV102MO1VSD, MO2 has its own VSD, named CV102MO2VSD. The synchroniser (CV102VSDSYNC) is not a VSD in the technical sense but throughout the documentation provided by the manufacturer is referred to as a VSD and so this is done throughout the report. The synchroniser plays a vital role in the correct operation of the motors MO1 and MO2. The role of the synchroniser (sync) VSD is to ensure that the load of driving the belt is shared equally between the two motors. By having the load shared equally the wear on the motors is less and the motors are able to run more efficiently. These VSDs were constructed by Leader & Harvest, a Chinese company that specialise in the construction of VSDs. The external cabinets of the VSD are shown in Figure 21.

Figure 21 CV102 MO1 VSD and VSD Synchroniser Cabinet

The VSDs are located in the TLO substation. This is the nearest substation to the drive motors. The first cabinet on the right of Figure 21 is the Synchroniser cabinet. In this cabinet are the Siemens PLC and the Industrial computer that keep MO1VSD and MO2VSD running at the same speed and torque. The VSD has a modular design. The first module (from the left) is the isolation switch and magnetising current cabinet. This is where the 3.3kV enters the VSD and also provides an isolation point for the VSD. The next cabinet to the right is the transformer cabinet. In this cabinet the 3 phase 3.3kV AC power is phase shifted and this power supplies each of the Power Cells in the next cabinet. The 3.3kV AC is put through a series of cells (Power Cells) that create the output sinusoidal waveform with variable voltage to the motor. The controller cabinet is the last of the MO1 VSD cabinets. Its role is to control the functioning of the other cabinets. It contains a touch panel interface to enable the setting up of parameters and also a log to view events in case of faults. The control cabinet also contains an industrial computer and communication to the VSD Synchroniser.

The principle of operation of the VSD is shown in Figure 22. The AC power is converted into DC power. A phase shift is added by the transformer (to reduce harmonics (Leader & Harvest n.d.)).

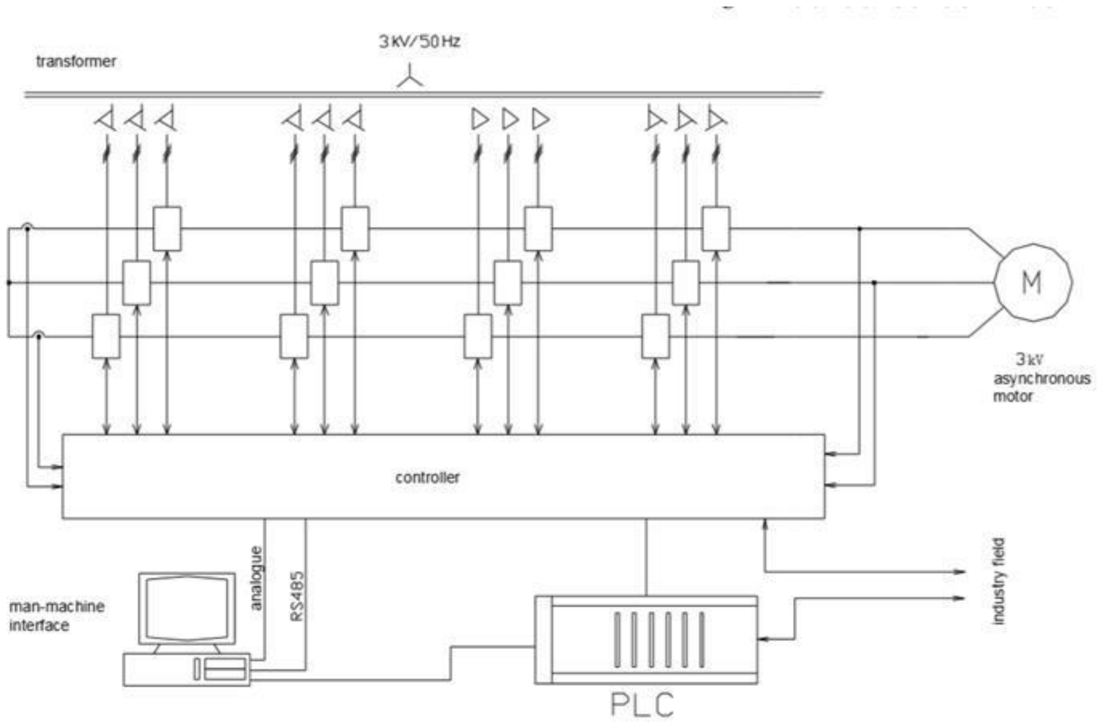

Figure 22 Overview of Operation of VSD (Leader & Harvest n.d.)

The Power Cells are essentially a single phase AC-DC-AC inverter circuit. The structure of the cell is shown in Figure 23. The rectifier converts the AC voltage into DC voltage, while the capacitors and resistors act as filtering/conditioning for the circuit. The inverter then converts the DC into AC, by switching the IGBTs. An IGBT is an electronic component that enables the rapid switching of a circuit. It turns on and off based on the voltage input received. The rapid switching of the IGBTs generates the PWM waveform sent to the motor.

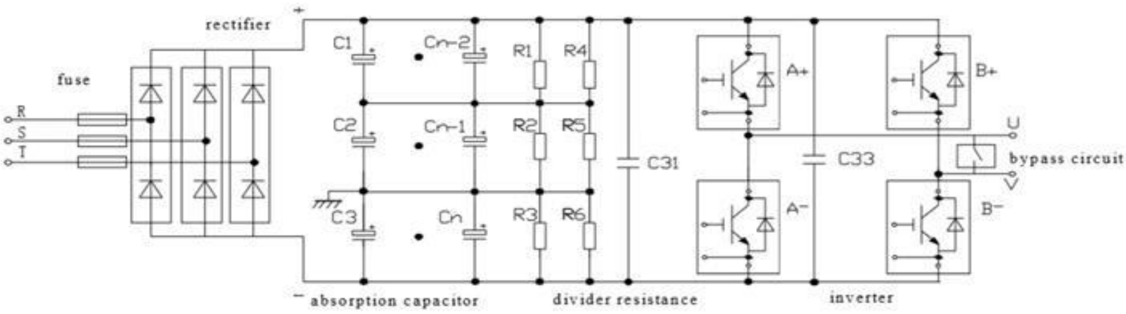

Figure 23 Power Cell Structure (Leader & Harvest n.d.)

The output wave form of each cell is a PWM waveform with a sinusoidally varying duty cycle, as can be seen in Figure 24. All the waveforms of each cell are combined together (under the control of the controller) to produce the final output waveform shown in Figure 25. This waveform is the input for the motor (MO1 and MO2). The variation in the PWM frequency changes the apparent voltage of the input waveform seen by the motor which then determines the speed at which the motor will run.

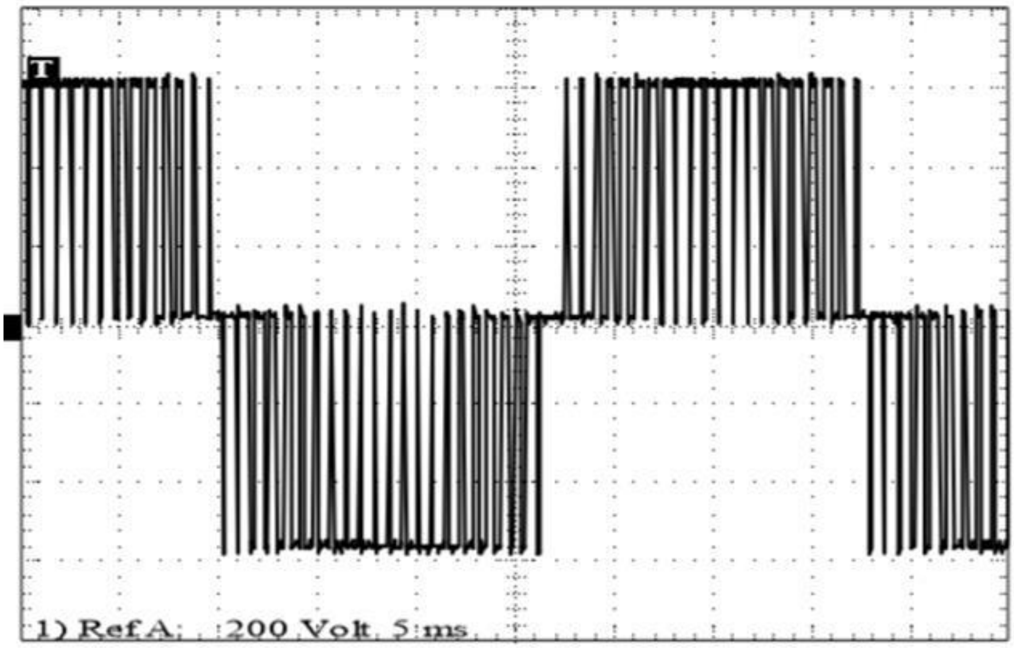

Figure 24 Output of Single Power Cell (Leader & Harvest n.d.)

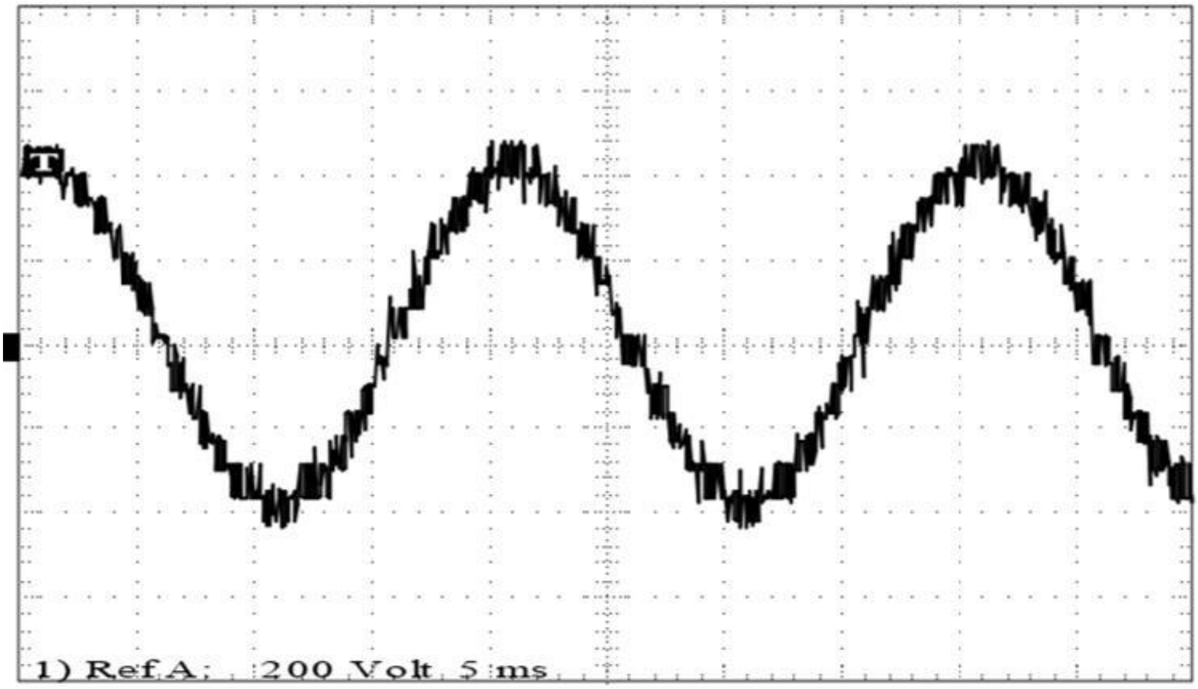

Figure 25 Single Phase Output of Power Cells (Leader & Harvest n.d.)

3 Project Work

3.1 VSD Out of Synchronisation Fault

3.1.1 Description of Fault

The two 800kW VSDs are kept operating at the same torque by the Synchroniser VSD. The role of the synchroniser is to give each of the motors a torque input. There is another system as part of each motor VSD that controls the speed of the motors. Its aim is to keep the belt running as fast as possible without the motor entering a run-away state. There is feedback from the motor VSD to the synchroniser where the speeds are compared to ensure that both motors are running at the same speed (Internal Communication).

Two motors CV102MO1 and CV102MO2 drive the conveyor belt. It is important to control the speed of the belt and the torque provided by the motor, especially when starting the conveyor belt. To overcome the inertia the motor needs to provide a high amount of torque to start the fully loaded belt at a low speed from its stationary status. Once the belt is moving the speed of the motor increases to its normal operating speed, which depends on the feed rate of the ore onto the belt.

An Out of Sync fault occurs when one motor carries all the load of the belt, while the other is idle. This fault might cause serious damage to the motor and the VSDs. For example, as recorded in Anubhav (2011) a serious incident occurred, in which CV102MO2 was carrying the entire load, running at more than 120% of its rated capacity for extended periods of time (twice for over an hour). This running at high current draw led to overheating of the motor and to the VSD (strong smells were detected in the TLO substation). CV102MO1 however was running at just 50A (this is the idle current draw of the motor). As a result of this incident the plant was down for several days to replace the motor and extensively test the VSD to ensure that no long term damage had been sustained.

3.1.2 Scope

One of the major aims of the project is to determine the cause of the Out of Sync fault. Once the cause of the fault is thoroughly investigated and understood a solution should hopefully be found and implemented to completely prevent the fault or reduce its occurrence by at least 50%. All investigations and solutions need to comply with Rio Tinto's regulations in terms of safety, operational security and also at a minimum cost to the company.

3.1.3 Definition and Analysis of Out of Sync Fault

Once the Out of Sync Fault had been understood, The PLC (MADPX103) which controls the running of CV102 was examined. A section of code relating to the Out of Sync fault is shown in Figure 26. It can be seen that an Out of Sync fault might occur when the difference between the frequency outputs of MO1VSD and MO2VSD are different by 20% for a period of more than 300 seconds (5 minutes). The frequency is represented as a percentage with a range of 0-100%, where 100% is the maximum normal frequency supplied to the motor which corresponds to 50Hz, the supply frequency.

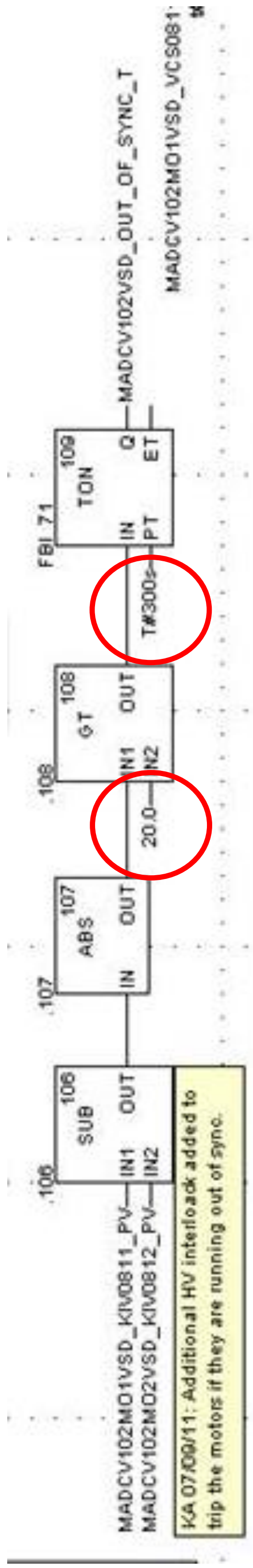

Figure 26 Out of Sync Fault Code

When this occurs the tag MADCV102VSD_OUT_OF_SYNC_T changes state to 1 (on). Because this tag is a part of the High Voltage Critical Interlocks (HVCIL), see Figure 27, any of its conditions would immediately shutdown the plant. The crash stop is done by breaking the 3.3kV circuit breaker that powers CV102 and its controllers. Other sections of the plant are also turned off immediately as their main power source is cut off. The Out of Sync fault is a critical interlock for continuously running the plant because significant damage can be done to the motors of the conveyor if they are overloaded for an extended period of time, as was the case in 2011.

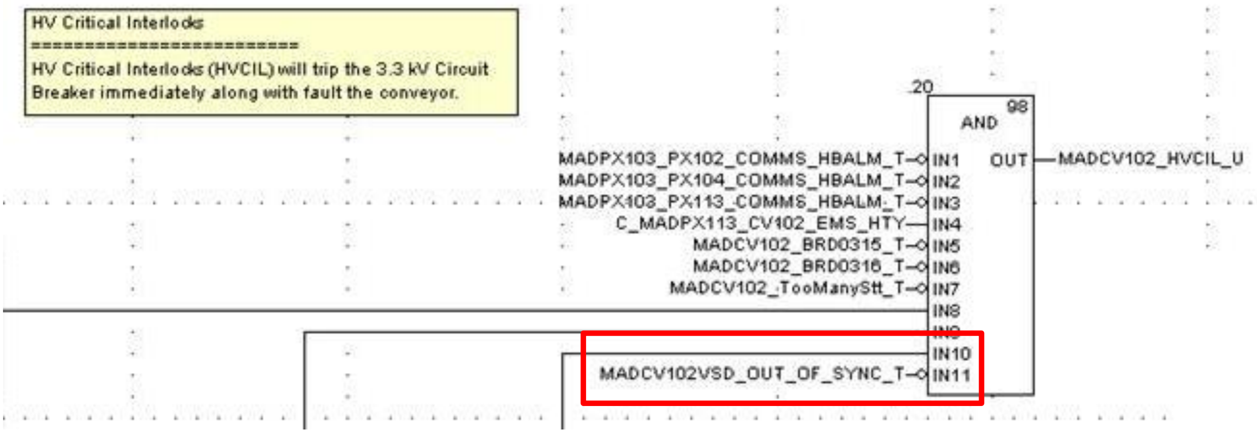

Figure 27 HVCIL- Out of Sync Fault is a Critical Interlock Condition

In an attempt to determine the cause of the Out of Sync fault, data was collected from the SCADA system (Citect) and the alarm historian data base Matrikon. CSE-Uniserve who installed and commissioned the VSDs were consulted. Each of the VSDs are controlled by a Siemens S7-200 PLC, which transfers specific data to the sites Modicon M340 PLC which in turn runs the plant. The code of the Siemens PLC needs to be examined to see if it may be a source of the fault.

The frequency output of both motor VSDs and the differences in their frequency output were plotted against time to identify the date and time when these differences were above 20%

(related to the scaled analogue conversion of the frequency input to the PLC). The corresponding alarm log would then be investigated. If the alarm log had clusters of alarms for the VSD of CV102 or the associated PLC it might be an Out of Sync fault.

3.1.3.1 Analysis of Alarms and Trends

Unfortunately one case of the Out of Sync Fault has been found with available alarm data for investigation. It appears that the cause may be the generation of a “minor fault”, which is believed to be communications related, before the motors start to run out of synchronisation.

3.1.3.1.1 Normal Trends

There were three parameters that might identify an Out of Sync fault. These are listed in Table 2 with a brief summary of property representations and tag names.

Table 2 Properties Used to Determine Out of Sync Fault

Tag	Summary
MADCV102MO1_MAPI	This is the average current that the MO1 is using.
MADCV102MO2_MAPI	This is the average current that MO2 is using.
MADCV102MO1VSD_IIV0811_PV	This is the Output Current from MO1VSD.
MADCV102MO2VSD_IIV0812_PV	This is the Output Current from MO2VSD.
MADCV102MO1VSD_KIV0811_PV	This is the Frequency Output of MO1VSD.
MADCV102MO2VSD_KIV0812_PV	This is the Frequency Output of MO2VSD.

As mentioned earlier an Out of Sync fault is when the Frequency output differs by more than 20% for a period of five minutes. To determine if there was a fault of this type a plot of the difference of the Average Current, of the Frequency Output and the Current Output was created, with a line at 20 to be able to easily see when the condition was reached. For comparison purposes Figure 28 is the plot when the VSD is operating without fault.

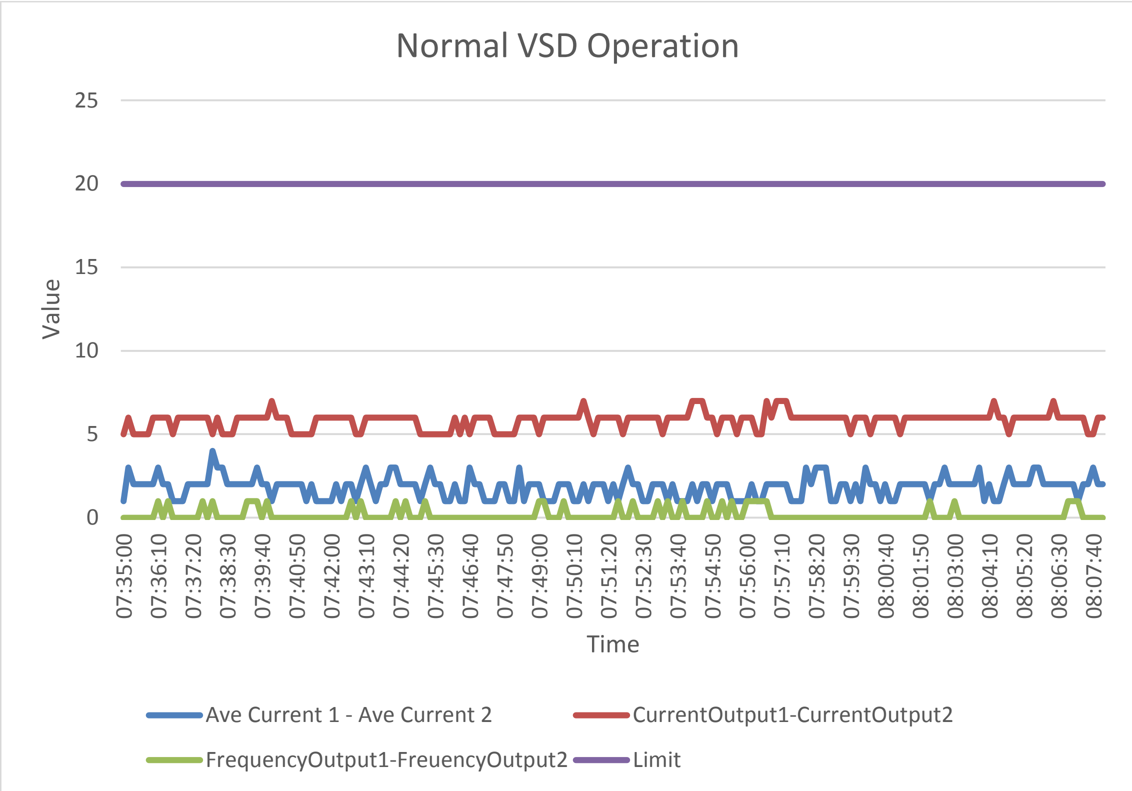

Figure 28 Normal Operation of VSD Plot (Difference of Outputs)

As can be seen from the graph in Figure 28, although there is some difference between MO1 and MO2 outputs the difference is not large and not over the 20 that is required for an Out of Sync fault.

3.1.3.1.2 January 24 2013

The data obtained from January 24 2013 is the only example where an Out of Sync fault has been located and had alarm data available. Figure 29 shows the plot of the data at the time of the fault.

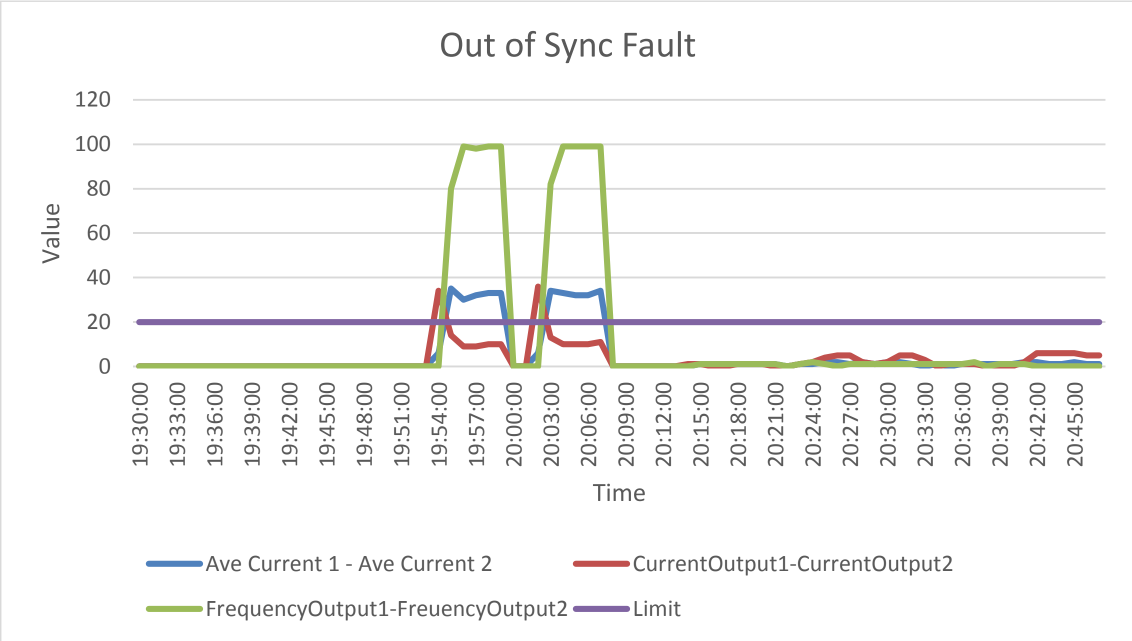

Figure 29 Out of Sync Plot

As can be seen in Figure 29 the difference between the frequency output (green line) of MO1 and MO2 is more than 20, and in fact it is different by 100. It can also be seen by looking at the time stamp that they were different for a period of five minutes. The dip in between the two events is due to the HVCIL status no longer being healthy so the plant tripped and shut down. The plant was restarted but again the motors were running out of synchronisation. Figure 30 shows the actual current drawn by each motor at the time of the fault.

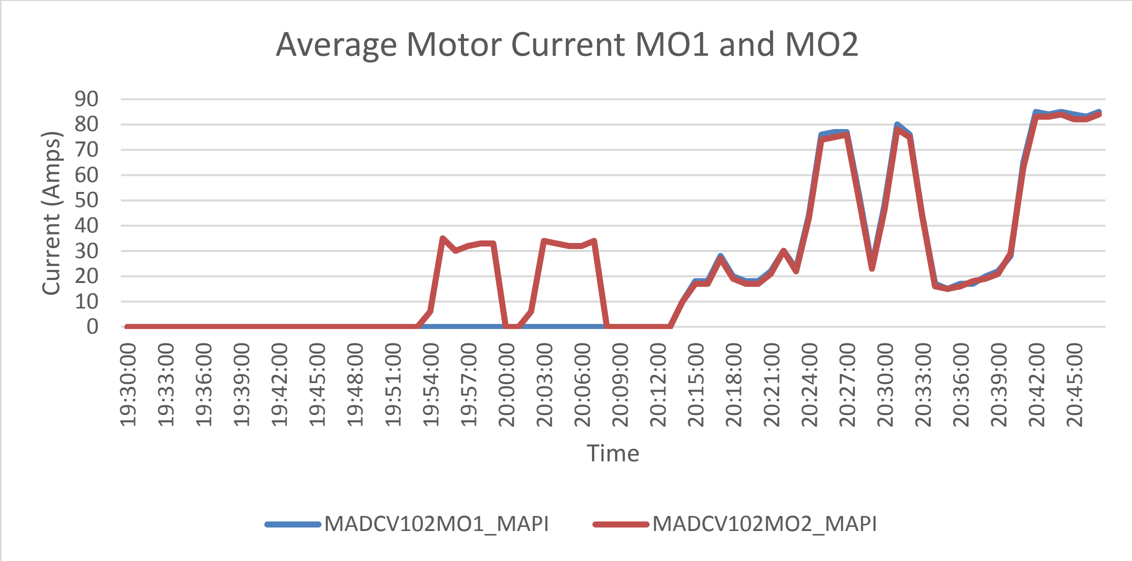

Figure 30 Motor Current at Time of Out of Sync Fault

As can be seen from Figure 30 the current of MO2 is approximately 35A while MO1 is not drawing any current at all. This is an Out of Sync Fault. The next step in trying to determine the cause of the fault was to look at the alarm logs at the time of the fault. The summary of the alarms relating to the VSD are included in Table 3.

Table 3 Alarm Summary at Time of Out of Sync Fault (Matrikon n.d.)

Time	Tag	Tag Description	Priority
19:47:52	MADCV102MO1VSD_FLTM0	CV-102 Motor 1 VSD Minor Fault	Warning Alarm
19:47:52	MADCV102VSD_FLTM0810	Stacking Conveyor VSD Synchroniser - Minor Fault	Warning Alarm
19:47:53	MADCV102MO2VSD_FLTM0	CV-102 Motor 2 VSD Minor Fault	Warning Alarm
19:48:22	MADPX103_CV102MO1VSD	TLO PLC Panel (MC-113) CV-102 MO-1 VSD PLC I/O Scanner Comms Warning	Warning Alarm
19:48:22	MADPX103_CV102MO2VSD	TLO PLC Panel (MC-113) CV-102 MO-2 VSD PLC I/O Scanner Comms Warning	Warning Alarm
19:48:22	MADPX103_CV102SYNC_I	TLO PLC Panel (MC-113) CV-102 VSD Sync PLC I/O Scanner Comms Warning	Warning Alarm
19:48:23	MADPX103_PX103C_AdvM	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Slot 7 (ACI) Fault	Trip Audible Alarm
19:48:23	MADPX103_PX103C_AdvM	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Slot 7 (ACI) Fault	Trip Audible Alarm
19:48:23	MADPX103_PX103C_AdvM	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Slot 7 (ACI) Fault	Trip Audible Alarm
19:48:23	MADPX103_PX103C_AdvM	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Slot 7 (ACI) Fault	Trip Audible Alarm
19:48:23	MADPX103_PX103C_AdvM	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Slot 7 (ACI) Fault	Trip Audible Alarm
19:48:23	MADPX103_PX103C_IOSC	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Scanner Fault	Trip Audible Alarm

19:48:24	MADCV102MO1VSD_IIV08	CV-102 Motor 1 VSD Output Current Bad PV Fault	Trip Audible Alarm
19:48:24	MADCV102MO1VSD_KIV08	CV-102 Motor 1 VSD Output Frequency Bad PV Fault	Trip Audible Alarm
19:48:24	MADCV102MO2VSD_IIV08	CV-102 Motor 2 VSD Output Current Bad PV Fault	Trip Audible Alarm
19:48:24	MADCV102MO2VSD_KIV08	CV-102 Motor 2 VSD Output Frequency Bad PV Fault	Trip Audible Alarm
19:59:05	MADCV102VSD_OUT_OF_S	CV102 Motors Out of Sync CV102 Motors Out of Sync	Trip Audible Alarm
20:07:04	MADCR101MO1_TooManyS	Prim. Sizer North Motor Too Many Starts Fault	Trip Audible Alarm
20:07:04	MADCR101MO2_TooManyS	Prim. Sizer South Motor Too Many Starts Fault	Trip Audible Alarm
20:07:04	MADCR103MO1_TooManyS	Sth Sec. Sizer North Motor Too Many Starts Fault	Trip Audible Alarm
20:07:04	MADCR103MO2_TooManyS	Sth Sec. Sizer South Motor Too Many Starts Fault	Trip Audible Alarm
20:07:04	MADCV102VSD_OUT_OF_S	CV102 Motors Out of Sync CV102 Motors Out of Sync	Trip Audible Alarm
20:08:36	MADCV102MO1VSD_FLTM0	CV-102 Motor 1 VSD Minor Fault	Warning Alarm
20:08:36	MADCV102VSD_FLTM0810	Stacking Conveyor VSD Synchroniser - Minor Fault	Warning Alarm
20:08:38	MADCV102MO2VSD_FLTM0	CV-102 Motor 2 VSD Minor Fault	Warning Alarm
20:09:37	MADPX103_PX103C_AdvM	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Slot 7 (ACI) Fault	Trip Audible Alarm
20:09:37	MADPX103_PX103C_AdvM	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Slot 7 (ACI) Fault	Trip Audible Alarm
20:09:37	MADPX103_PX103C_AdvM	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Slot 7 (ACI) Fault	Trip Audible Alarm
20:09:37	MADPX103_PX103C_AdvM	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Slot 7 (ACI) Fault	Trip Audible Alarm
20:09:37	MADPX103_PX103C_AdvM	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Slot 7 (ACI) Fault	Trip Audible Alarm
20:09:37	MADPX103_PX103C_IOSC	Stacker PLC Panel (MC-113) MADPX103 Advantys Remote I/O Scanner Fault	Trip Audible Alarm
20:09:37	MADPX103_CV102MO1VSD	TLO PLC Panel (MC-113) CV-102 MO-1 VSD PLC I/O Scanner Comms Warning	Warning Alarm
20:09:37	MADPX103_CV102MO2VSD	TLO PLC Panel (MC-113) CV-102 MO-2 VSD PLC I/O Scanner Comms Warning	Warning Alarm
20:09:37	MADPX103_CV102SYNC_I	TLO PLC Panel (MC-113) CV-102 VSD Sync PLC I/O Scanner Comms Warning	Warning Alarm
20:09:38	MADCV102MO1VSD_IIV08	CV-102 Motor 1 VSD Output Current Bad PV Fault	Trip Audible Alarm
20:09:38	MADCV102MO1VSD_KIV08	CV-102 Motor 1 VSD Output Frequency Bad PV Fault	Trip Audible Alarm
20:09:38	MADCV102MO2VSD_IIV08	CV-102 Motor 2 VSD Output Current Bad PV Fault	Trip Audible Alarm
20:09:38	MADCV102MO2VSD_KIV08	CV-102 Motor 2 VSD Output Frequency Bad PV Fault	Trip Audible Alarm

The two sections in Table 3 where the time is in red are the two instances of the Out of Sync Fault. At 19:59:05 the alarm for an Out of Sync Fault was generated. This has been highlighted in red text to be more easily seen. The plant came to a stop at 19:59:05 due to the fault and the “too many starts” alarms after it indicated that there was difficulty in getting the plant started again, which is not unusual for a crash stop. When the plant was started again, the motors again ran out of sync.

Looking at the alarms that occur before the Out of Sync fault, it can be seen that there are Minor Faults from both motors. A warning from the Advantys Remote I/O module is generated, then there is a fault from the Advantys Remote I/O responsible for collecting data from the VSD. Slot 7 is connected to the Ethernet Gateway and to the VSD. The comms fault is an alarm that will trip the plant. Although in the second occurrence the Comms warnings are after the Comms fault it is extremely likely that the warning occurred first, then the fault. Citect only retrieves data each second so it appears that the warning and fault might occur at the same time. Additionally the Citect system and the PLCs have not been set up for first in first out alarms, which means that the alarms are not recorded in the order of which they occur, when the time between the alarms is less than a second.

From this one instance of an Out of Sync Fault it could be thought that the cause of the fault is related to the communications between each of the VSDs and also between the VSD and the Advantys Remote I/O. More information is required to get a more accurate idea of the cause of the fault. It is possible that the Minor Fault that occurs is not a communications fault but another type of minor fault. Unfortunately the type of fault still remains unknown at this point until more information regarding what a minor fault is can be obtained.

3.1.4 Out of Sync Fault Technical Issues/Constraints

One of the main issues in this part of the project which that the Siemens PLC was written in Chinese, the PLC code could not be viewed without Siemens software. The manufacturer of the VSDs (Leader & Harvest) did not provide a translated copy of the code due to the company policy to protect their intellectual property. There was also difficulty in being able to get access the PLC code during the operation of the VSD due to the lack of available communications ports on the Siemens PLC. This issue is dealt with in Section 3.3 Citect Improvements.

Another limitation in the investigation of the Out of Sync fault is that the alarm data is only available for a period of 12 months. This limits the amount of data available for analysis as recently the problem has not been occurring as often as in the past. The current information that is available in the Citect system is not particularly useful in determining the cause of the fault as the information available is only the outputs of the VSD and the average current. It would be useful to be able to have a longer record of the alarms that are raised, such as the communication alarms. Also of use in determining cause of faults would be some way to see if the output of the synchroniser is being received by the motor VSD or if the problem is located within the motor VSD or how the actual motor is responding to the VSD output.

There is also the difficulty of determining when there is an Out of Sync fault. When looking through the Ampla Downtime records it is hard to find what VSD faults are related to the motors being out of synchronisation. This lies in the way that the down times are recorded. It relies on the operator recording the reason and location of the cause of the downtime. Often the Operators do not know the reason of the fault. There is a section of code that determines when the motors are out of sync and this is connected to a critical interlock that will shut down the motors and the plant, when the fault occurs. The difficulty for the Operator is that there is a relatively large set of alarms that occur within a few seconds and due to the workload of the operator, their limited knowledge sorting through the alarms and determining the cause of the downtime. The Out of Sync alarm is not one of the alarms that is passed through to the alarm historian Matrikon so it cannot be used to search for when the fault occurs.

3.1.5 Status of Out of Sync Fault

Investigation into the faults has led to a possible cause of the Out of Sync fault. It could be due to a problem arising from a communications error. No further work has been carried out on this project due to the limitation of time and available data. The data that was available has been sent to consultants at CSE-Uniserve for further their investigation and feedback.

3.1.6 Conclusion and Future Work of Out of Sync Fault

Future work on this project needs to wait until another Out of Sync Fault/s, retrieving the fault data that is stored in the VSD event logger, as well as the alarm logs from Citect. This information would be sent to CSE-Uniserve to look at to provide reasons for the fault. Until this is available no more useful work can be done on this project.

3.2 Crash Stop VSD Faults

3.2.1 Description of Fault

During analysis of the down time due to CV102VSD, clusters of alarms were noticed. An example of the alarm cluster is shown in Table 4.

Table 4 Typical Cluster of Alarms after Crash Stop (Matrikon n.d.)

Timestamp	Tag	Tag Description
2012-06-03 12:01:10.000	MADCV102MO1VSD_FLTS0	CV-102 Motor 1 VSD Severe Fault
2012-06-03 12:01:10.000	MADCV102MO1VSD_VDS08	CV-102 Motor 1 VSD CB Open Request Fault
2012-06-03 12:01:10.000	MADCV102VSD_FLTM0810	Stacking Conveyor VSD Synchroniser - Minor Fault
2012-06-03 12:04:45.000	MADCV102VSD_FLTM0810	Stacking Conveyor VSD Synchroniser - Minor Fault
2012-06-03 12:05:03.000	MADCV102MO2VSD_DC081	CV-102 Motor 2 VSD Door Closed Alarm
2012-06-03 12:05:03.000	MADCV102MO2VSD_FLTM0	CV-102 Motor 2 VSD Minor Fault
2012-06-03 12:05:03.000	MADCV102MO2VSD_FLTS0	CV-102 Motor 2 VSD Severe Fault
2012-06-03 12:05:03.000	MADCV102MO2VSD_HTY08	CV-102 Motor 2 VSD Drive Fault
2012-06-03 12:05:03.000	MADCV102MO2VSD_VDS08	CV-102 Motor 2 VSD CB Open Request Fault
2012-06-03 12:05:03.000	MADCV102VSD_FLTS0810	Stacking Conveyor VSD Synchroniser - Severe Fault
2012-06-03 12:05:04.000	MADCV102MO2VSD_IIV08	CV-102 Motor 2 VSD Output Current Bad PV Fault
2012-06-03 12:05:04.000	MADCV102MO2VSD_KIV08	CV-102 Motor 2 VSD Output Frequency Bad PV Fault
2012-06-03 12:05:05.000	MADPX103_CV102MO1VSD	TLO PLC Panel (MC-113) CV-102 MO-1 VSD PLC I/O Scanner Comms Warning
2012-06-03 12:05:05.000	MADPX103_CV102MO2VSD	TLO PLC Panel (MC-113) CV-102 MO-2 VSD PLC I/O Scanner Comms Warning
2012-06-03 12:05:05.000	MADPX103_CV102SYNC_I	TLO PLC Panel (MC-113) CV-102 VSD Sync PLC I/O Scanner Comms Warning

Investigation of the faults found that each of the occurrences of this cluster of alarms was when the plant had crash stopped and the plant was being restarted. The solution to get the plant up and running again was to turn off each of the UPS that are inside the VSD and after a couple of minutes turn them back on again. This cleared the alarms and the plant was able to start again.

3.2.2 Scope

The aim of this section of the project is to develop and implement a solution to the crash stop faults. Research was done into the cause of the fault, which involved speaking to consultants from CSE-Uniserve. CSE-Uniserve had already been approached by Engineers a few years ago in relation to this issue and the proposed solution was to remove the local UPS inside the VSD cabinet.

3.2.3 Crash Stop Fault Solution Overview

Because the solution had been suggested a few years ago but not implemented it was decided that some investigation should be done to determine if there had been a reason for it not being done. So a few of the past Mesa A engineers and Electricians who were onsite for a number of years were asked if they knew of any reason why the project was not done. As no reason was provided, the project went to the next stage. This involved designing the changes that would need to be done to remove the UPS safely and ensure the correct operation of the VSD after the removal of the UPS. The original circuit is shown in Figure 31. The box labelled GU41 is the UPS. The redesigned circuit is shown in Figure 32. The UPS has to be disconnected from the power supply and the output of the UPS removed from the power conditioning devices. Once the UPS is disconnected the power supply needs to be reconnected to the power conditioning devices.

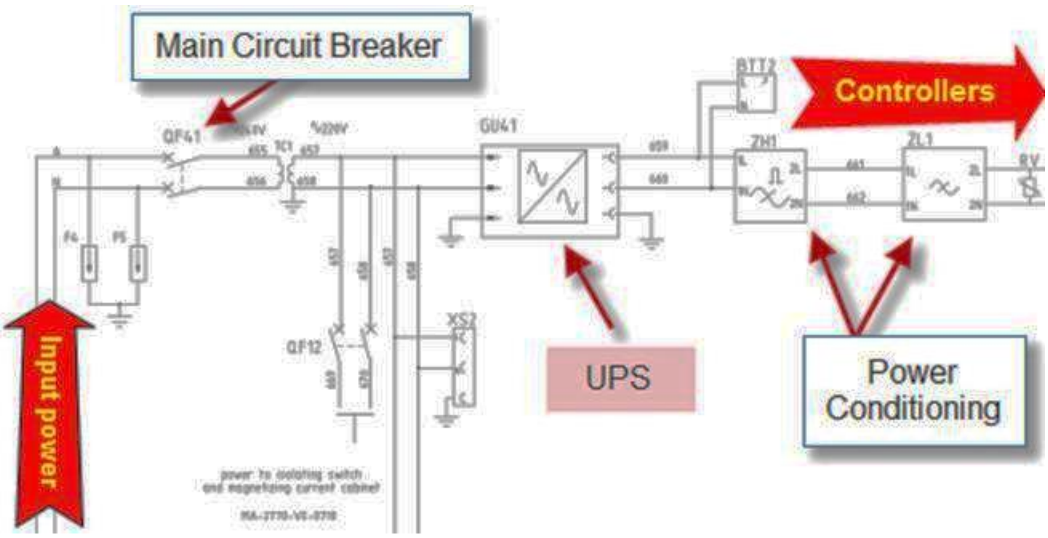

Figure 31 Initial Circuit of VSD

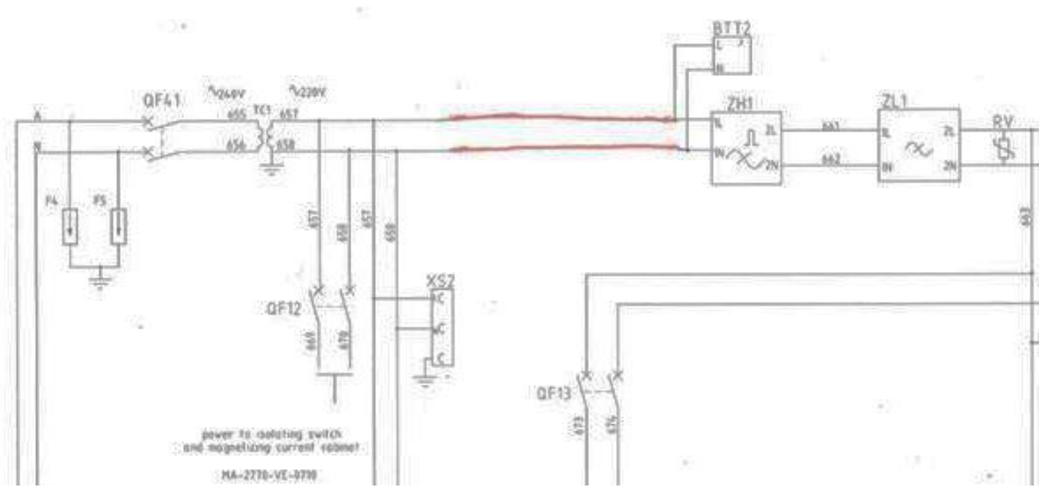

Figure 32 Final Circuit Wiring After UPS Removal

3.2.4 Crash Stop Fault Project Work

There were a few technical issues and constraints associated with this part of the project. Once the changes had been drafted a Scope of Work (SoW) needed to be written up so that the site electricians could perform the job. Due to Rio Tinto's Health and Safety Policy the work would have to be done when the equipment was in a de-energised state. That meant that the motors would not be running and the VSDs would have to be isolated. The VSDs would have to be switched off in any case as the UPS was also used as a power conditioning device as well as a back-up power supply. Needing to have the power off to the VSD presents a constraint as it means the plant will not be producing ore. Therefore the work will have to be carried out in one of the scheduled shut downs.

During the development of the SoW it was discovered that the physical wiring did not actually match what was in the wiring diagrams. This meant that the SoW had to be modified slightly to make sure that the electricians remove the correct cables. This difference in wiring could lead to problems in terms of the functionality, therefore during the changes the Intern would be on site to supervise the work and take note of any other changes that would exist between the actual wiring and the diagrams. When the altered drawings are sent to the drawing office for revision the new drawings will represent what is actually present. This will make any further changes easier and less likely to have problems due to errors in wiring.

During the design phase it was realised that the UPS circuit was an integral part of the control circuit so advice was sought from CSE-Uniserve as to whether the UPS could be removed without negative impact on the control circuits. From the discussion it was understood that the reason for the UPS is that in a lot of the sites where these VSDs are used there is a very low quality of 240V AC power, and as such the computer processors can experience regular fluctuations in power which affected the operation of the VSD. To overcome this issue a UPS was installed to condition the power fed to the processors and supply power through small disruptions in the main power supply. It was decided that the power quality and stability at Mesa A was good enough and that the UPS was not required. The UPS was also not required because when there would be a crash stop on the plant the entire plant should be without power but with the UPS the controllers of the VSD still having power could be a potentially unsafe situation. In consultation with the Statutory Electrical Supervisor and Electrical Engineer it was decided that the VSD would not need to be connected to the sub-station UPS for two reasons. Firstly there would be the chance that the faults would still occur as there was a back-up power supply, secondly when the power went down or there was a crash stop there was no reason to have the controllers powered up as the motors were not going to be run. To stop the belt, brakes were applied in a crash stop. The belt was not brought to stop by lowering the speed with the VSD, therefore power to the VSD was not required.

Comparing drawings and Citect alarms, it was noticed that there was an alarm related to the UPS. This alarm is called UPS Power Off. It is supposed to signal when there is no power to the UPS. Careful analysis of the circuit indicated that the trigger for the alarm, relay K1 was actually connected after the UPS and with the proposed changes to the wiring, the functionality of the alarm was not going to be changed. To avoid confusion in the future the name of the alarm, on the Citect pages, will be changed to Controller Power Off, see Figure 33 and Figure 34, this indicates that the controllers of the VSD are no longer receiving any power. The code in the Modicon M340 PLC MADPX103 tag names will not be changed but a comment (as in

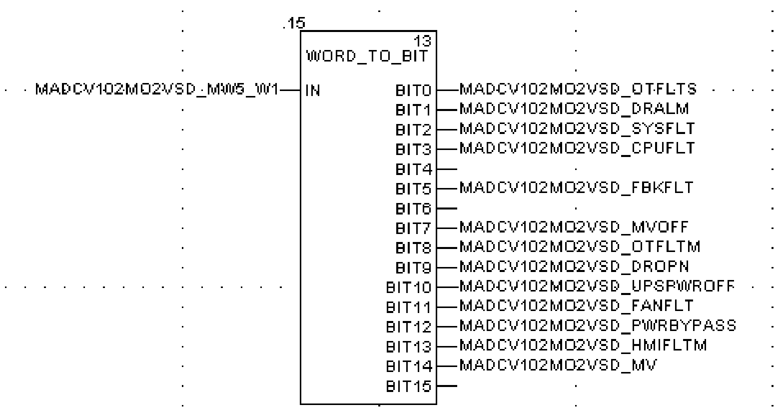

Figure 35 and Figure 36) will be added to each location where the UPS Power Off is mentioned. The comment will explain that the UPS has been removed and that now the alarm means there is no power to the controllers.

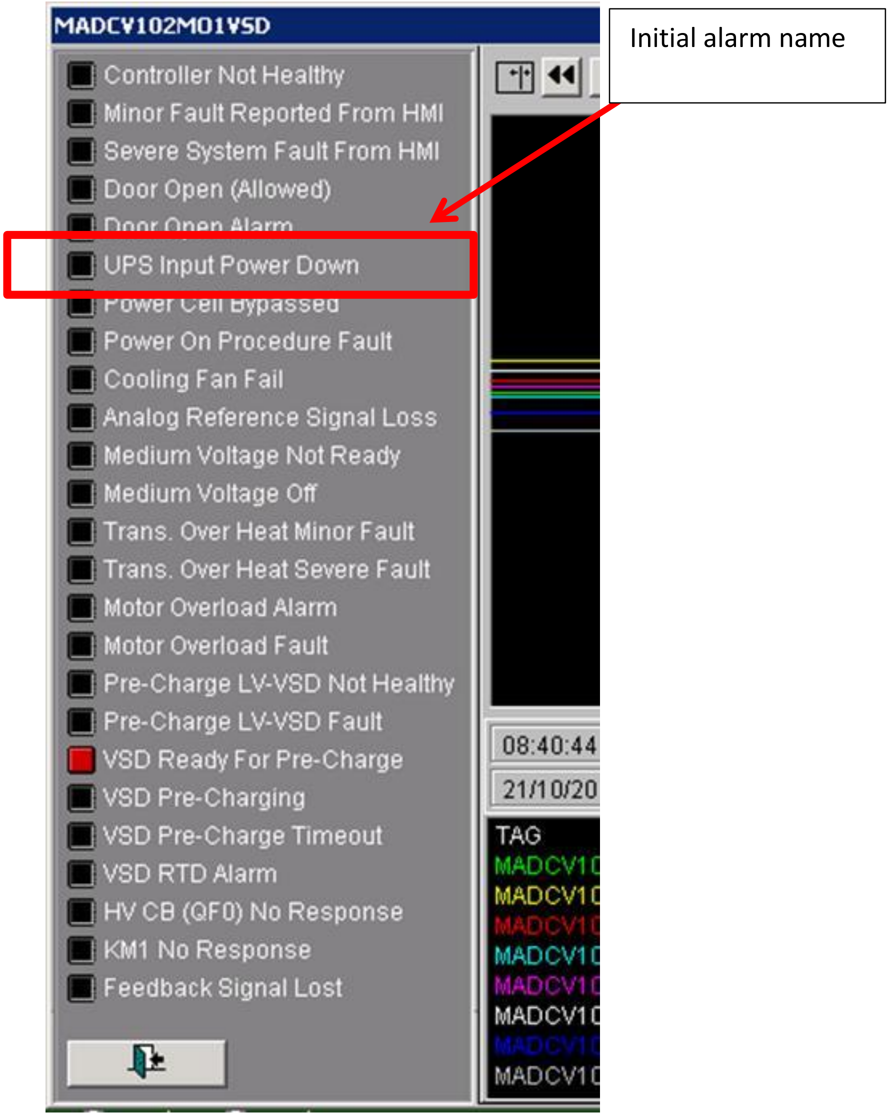

Figure 33 Alarm Page for VSD Before Changes

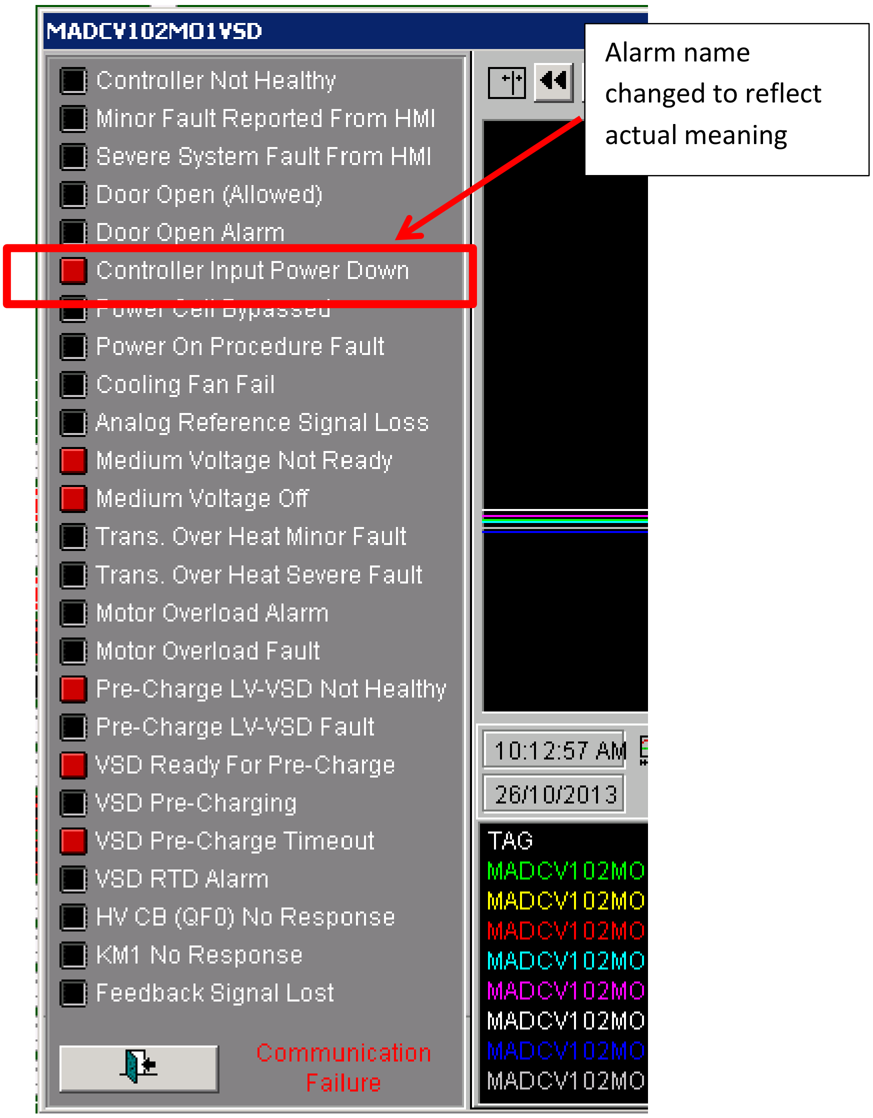

Figure 34 Alarm Page for VSD After Changes

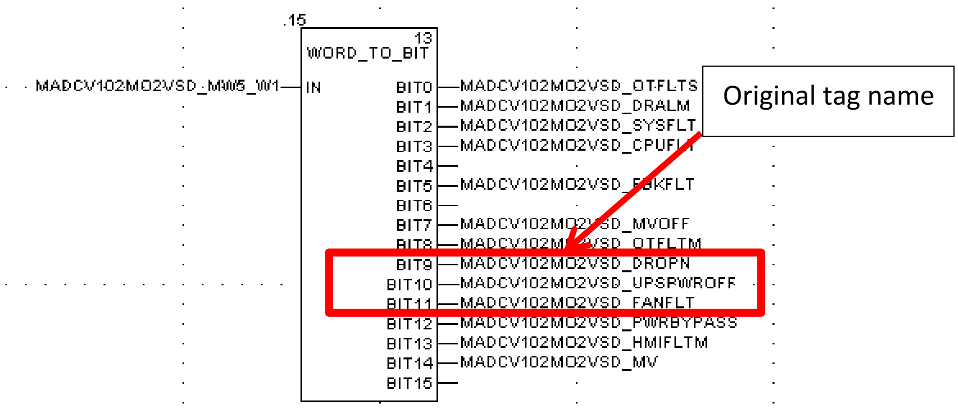

Figure 35 Original VSD Code in PLC

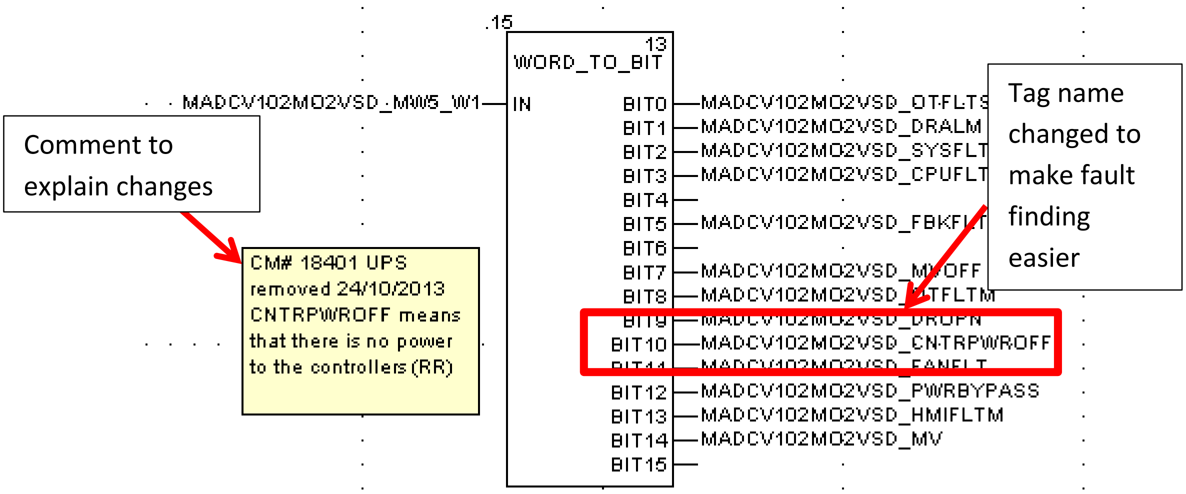

Figure 36 Comment Added to PLC Code to Clarify Changes

The final constraint on the removal of the UPS was in relation to actually performing the task. For safety reasons the power must be removed from the VSD before performing the task. This work should be carried out without affecting the production of the mine. The mine is a single line plant and turning off the VSDs means that CV102 would also be out of service. As a result the crushed ore could not be transported to the stockpile. This meant that the work would have to wait until a scheduled shutdown period. The only one that was available was the shutdown beginning on the 21st October2013. All preparation work was completed and submitted before the shutdown planning was finished to enable it to be included in the list of tasks during the shutdown. As a result of the UPS being removed at a late stage of the Internship the results obtained are not going to be very accurate in terms of indicating if the project was a success.

3.2.5 Crash Stop Fault Testing/Commissioning

The design phase of the project was completed by the end of September. A scope of work was written, which was then given to the Electricians to complete the tasks following appropriate procedure and order. The project was scheduled as a part of the shutdown for October 22nd. The work was done by the Rio Electricians on nightshift. It went well with only minor modifications required. The modifications were a result of the difference between the drawings and the actual wiring in the VSD. The Electricians eventually edited the drawings so that the actual changes could be recorded and sent to the Drawing Office to be updated in the drawings database (Appendix 6.2). Testing of the changes had to wait for a few days until the shutdown was completed before the power could be turned back on to the VSDs. Once the UPS was removed the changes to the PLC and Citect pages could be made. These changes were made following the Mesa A guidelines for making changes to Citect. It was decided that the tag name in the PLC for UPS power off would also be changed to MADCV102MOxVSD_CNTRPWROFF (Figure 36) to reflect the actual function of the alarm. Consequently the variable tags in Citect also changed. All these changes were made and rolled out following the established method in the document Mesa A Citect Architecture and Roll-out Procedure. When the power was returned to the VSD an alarm was present on the MO1 VSD. It was the “Controller Input Power Down” alarm, as seen in Figure 37.

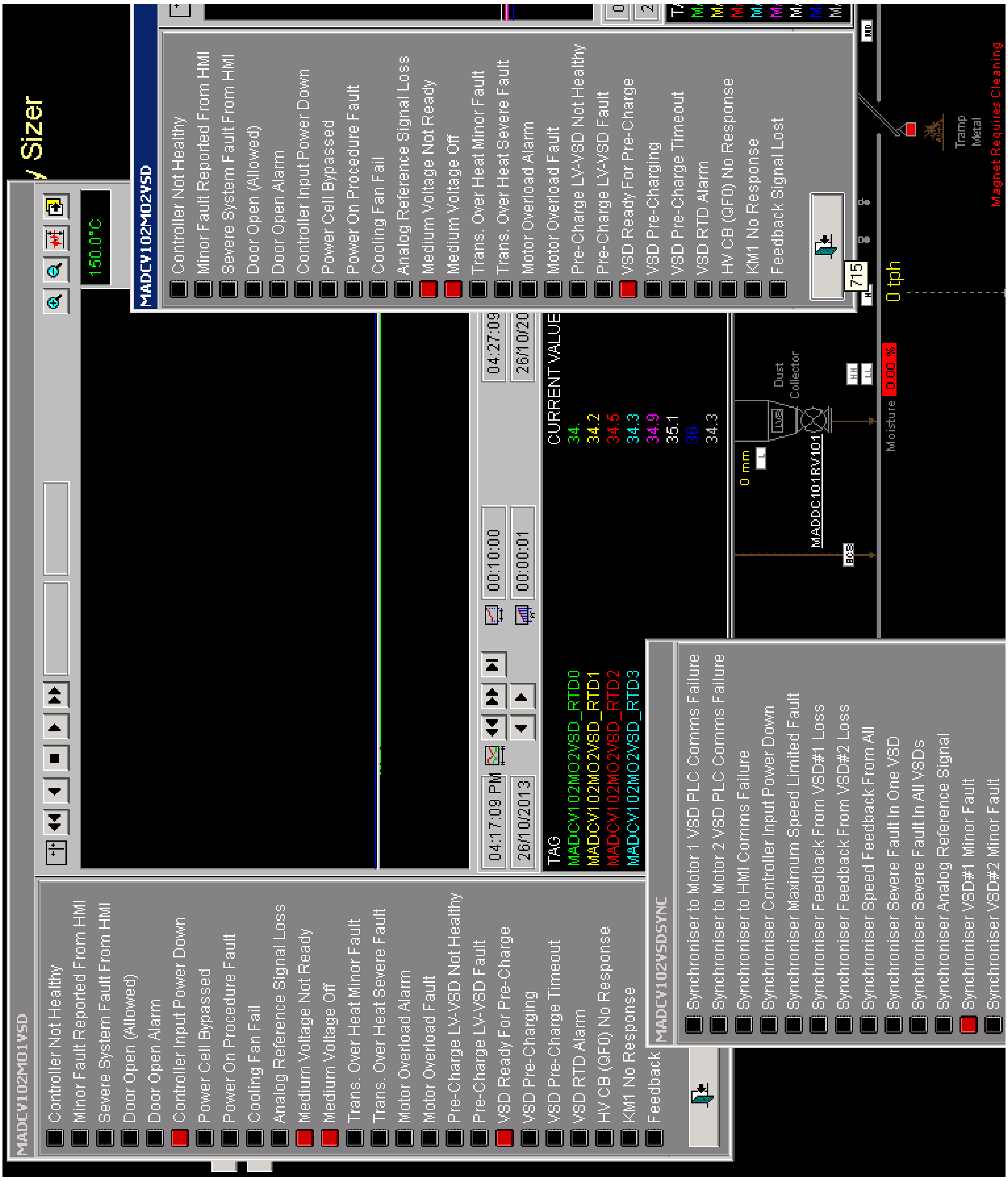

Figure 37 Alarms on Starting VSD After Changes

The fault occurred on only one of the VSD, whereas the changes had been made to all three of the VSDs. Therefore it seemed likely that the fault was related to a wiring issue associated with MO1 VSD. The wiring was investigated, but was done correctly. Then the wires were checked for continuity, by tracing each connection. It was determined that one of the terminal links to connect two points together to form one electrical connection had not been pushed in properly (Figure 38).

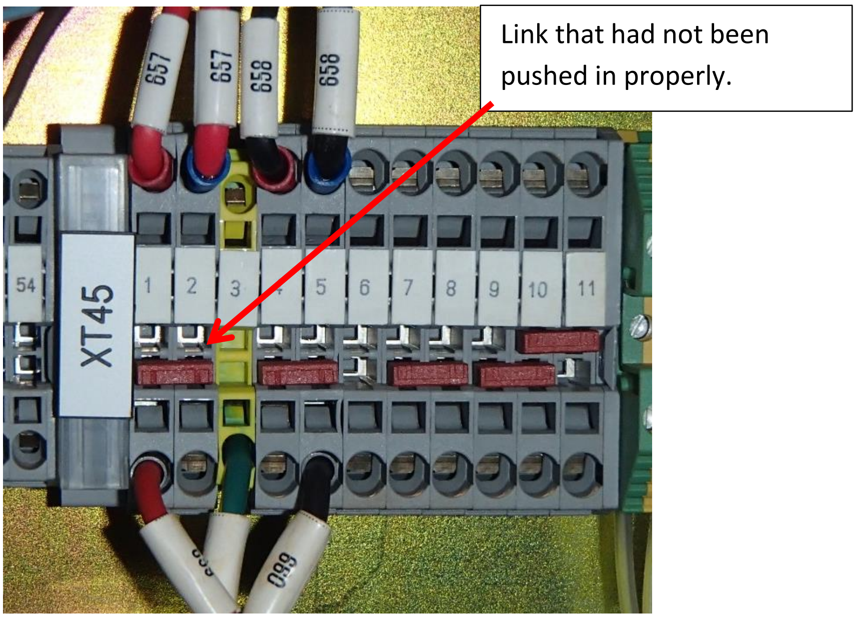

Figure 38 Link That Caused the Initial Fault During Testing

This meant that there was no power getting to the controllers. Once the link was pushed in properly the fault was cleared and the VSD was able to start up. But then it was shut down due to other faults in the system unrelated to the VSD. Full testing of the VSD was not done until 24 hours after the power was returned.

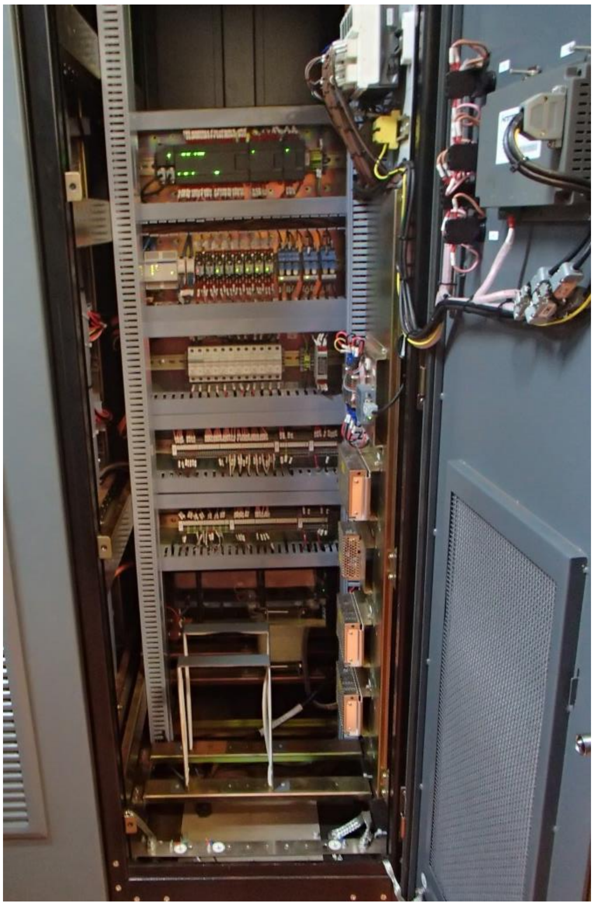

Figure 39 Finished UPS Removal – VSD Sync Controller Cabinet

Figure 39 shows the VSD Sync cabinet after the removal of the UPS. Once the link had been pushed in there were no further problems with the VSD and 24 hours later the plant was running and the VSD was functioning normally. Overall the project was successfully completed.

3.2.6 Crash Stop Fault Conclusion/Future Work

The only remaining part of the UPS removal project that needs to be completed is the monitoring stage. As a part of Rio Tinto procedure, as the plant was being changed a Change Management (CM) process had to be completed. The initial stages have been completed by the end of the Internship up to the point of implementing the change (removal of the UPS). All that remains of the CM process is the monitoring of the change to ensure that there are no negative impacts on the operation or safety of the plant. This monitoring period is typically from six to nine months, after which if there are no negative impacts the CM will be closed and the process is complete.

3.3 Citect Improvements

3.3.1 Description of Current Situation

Mesa A mine site uses Citect, the SCADA system produced by Schneider. Operators and Maintainers of the plant rely on Citect to control and monitor the plant. Information from Citect is used as the first step in fault finding problems with the plant as Citect provides alarm and other information that is useful for determining the cause of problems. At the beginning of the project only some information was available on the VSD as shown in Figure 40. The page provided the alarm summary but did not identify the causes of the alarms.

Figure 40 Alarm Summary Citect Mimic

3.3.2 Scope

The aim of this part of the project is to update Citect pages with the information that has been gathered from the previous parts of the Internship project such as Crash Stop fault and Out of Sync fault, together with information obtained from the Siemens PLC inside the VSD cabinet, and get all that information into the Citect system. The up to date Citect pages will help enable the Operators and Maintainers to better find the cause of the fault when it occurs to the VSDs.

3.3.3 Implementation

In order to update the Citect pages more information is required from the VSD and the PLC. A mini project was designed to enable communication between the Siemens PLC and a computer in the TLO substation. The design phase went through many versions but at the end of the Internship still could not come to the final stage. The design progress is outlined below. The mini project involved considerable collaboration with Siemens representatives and then with Rugged Com representatives as they are the manufacturers of the network switch devices to be used as part of the project.

The first step in locating more information to include in Citect was to identify the information having already been received and readily available to be included in the Citect pages. To do this the drawings of the VSD were inspected and compared to the information available in both the Advantys I/O module and used in Citect. It was seen that all readily available data was shown in Citect pages, shown in Figure 40. As a result of this discovery and the need to have more information available the decision was made that communication with the Siemens S7-200 PLC, which formed a part of the VSD, was required.

Typically when a PLC is installed and communication with it is desired for fault finding and performance reasons, such as modifying code or viewing the code live, a way of connecting to it is part of the design process. In the case of Mesa A all PLCs have one of their communications ports connected to the SNMP network. This is the network for monitoring and configuring devices. It is a low priority network, meaning that essential plant process communications take preference to the network to ensure correct and safe operation of the plant. In the case of the VSD, the manufacturers had only allowed some communication between the VSD and the Plant. There was no ability to view the code running live, and this is one of the major aims of this project. The communications network for the VSD is shown in Figure 41. The S7-200 comes with two communications ports and both of these are being used. One port is communicating via the Ethernet Gateway to the Remote I/O modules to the rest of the plant and the other communications port is connected to what is referred to in manufactures documents as an Industrial Computer. Its role in operation of the VSD is unknown.

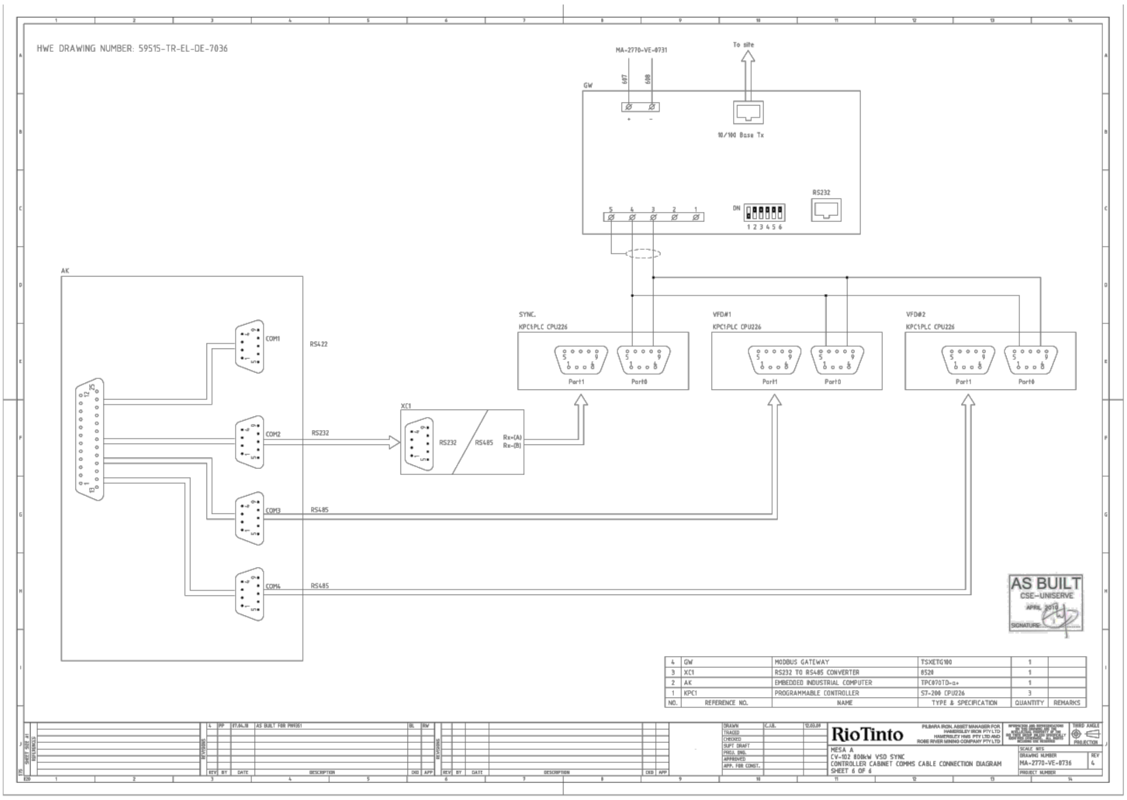

Figure 41 Communication Network of Synchroniser VSD (Rio Tinto 2010)

In the VSD all the communications come to the Synchroniser cabinet where they are then sent to the Ethernet Gateway (GW in Figure 41) which converts the Serial Modbus protocol into Ethernet TCP/IP before the information goes to the Advantys remote I/O module (Figure 42).

The first option was to install an Ethernet switch, RS900, in the VSD Sync Cabinet and connect it to the rest of the network via Cat 6 cable using the TCP/IP communication protocol and the switch would be the same type as the rest of the plant. This would mean spares in case of failure. The conceptual design is shown in Figure 42. The Ethernet Switch would be after the Ethernet gateway and would connect both the Advantys remote I/O module and the PC with the MicroWIN Siemens software to communicate with the Siemens PLC.

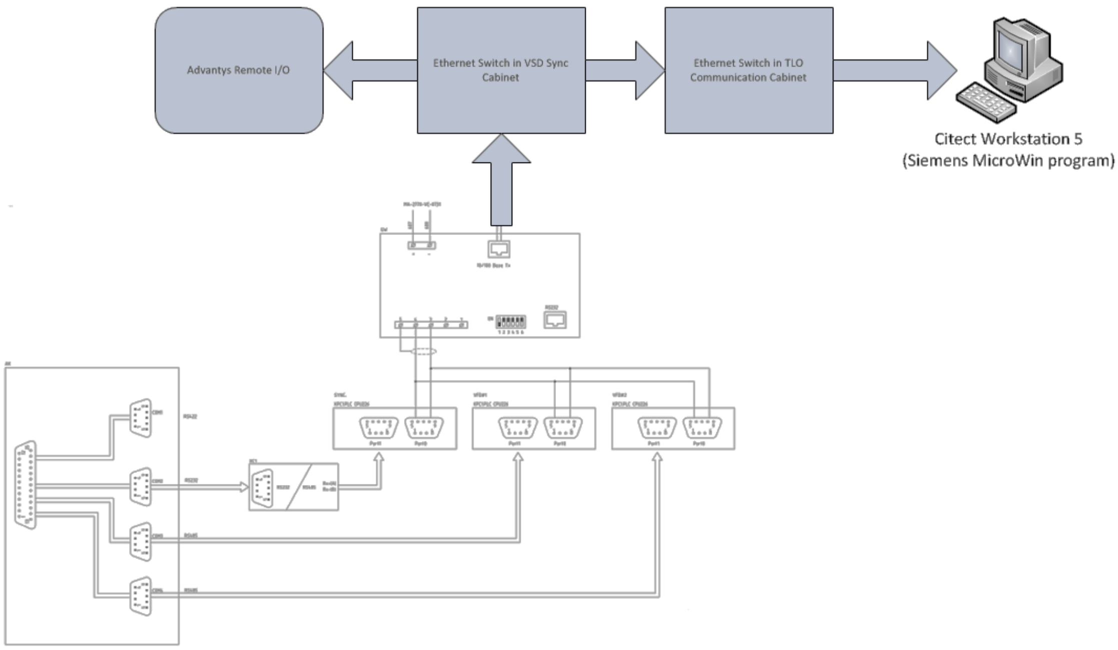

Figure 42 Initial Design to Enable Communication to Siemens PLC

The design was presented to representatives at Siemens to ensure that the design would work. They came back to the engineers stating that the design would not work because of the MicroWIN program. The reason it would not work was that the program needed to know what protocol is being used. The program has only a couple of options that are able to work with the Siemens S7-200. Based on the advice of the Siemens sale representative, the USB/PPI cable was selected, whereas other options required the installation of communication cards to be installed in the PC to enable communication along a serial cable. The installation of cards was required to be done by IT support, and would have added another level of complexity together with further delays to the project. The USB/PPI cable would be slightly more versatile. By installing the software on a laptop or a PC. Then the cable could be used to plug directly into a PLC if required. The problem with the first design (Figure 42) was that the USB/PPI cable does not allow for TCP/IP communication that would then be converted into Modbus via a 2-wire RS485 connection. The Siemens software required the language to remain the same throughout the communication line. This lead to the development of the second design, shown in Figure 43. In this design all the connections were going to be made into the serial ports of a different network switch, this time an RS401. This switch had the advantage of having serial network connections and also has four Ethernet connections. The new design was developed and presented to the Siemens and Rugged Com representatives. Initially they agreed that it would work. As part of writing up the SoW for the Electricians the steps that would be required to be completed by the Intern Electrical Engineer were also being written up. When installing an RS401, as for any network switch, each of the communication ports need to be configured. The user manual was consulted and so were existing configuration files for other network switches that were used on site. The reason for looking at the other configuration files was to try to get a sense of what the main settings would need to be in terms of settings like security, baud rates, communication timeouts, and priority of communication. After reading all the available information it became apparent that the Intern did not know enough about communication networks to be able to configure the switch without further information from the Rugged Com specialist. The Rugged Com specialist had mentioned using RAW Socket as the communication protocol to enable communication with all the required devices. Research revealed that both the PC and the Ethernet Gateway would need to be able to DIAL in a connection, it would need to be able to initiate the communication in RAW Socket protocol. The PLC would be able to respond without any changes, a feature of RAW Socket. The intern was unable to determine if the PC or the Gateway would be able to initiate the communications. During the reading of the user manual the Intern discovered that the serial ports were capable of using Modbus as a communication protocol.

Although Rugged Com were fairly sure that the plan would work, they would not guarantee it so they provided a loan RS401 to trial. If it worked then one could be ordered and the loan returned when the purchased one arrived.

It was decided that all connections could be made to the serial ports and they could all be configured as Modbus devices. The Intern sent this design to the Rugged Com specialist, along with a few questions to ensure that this plan would be successful.

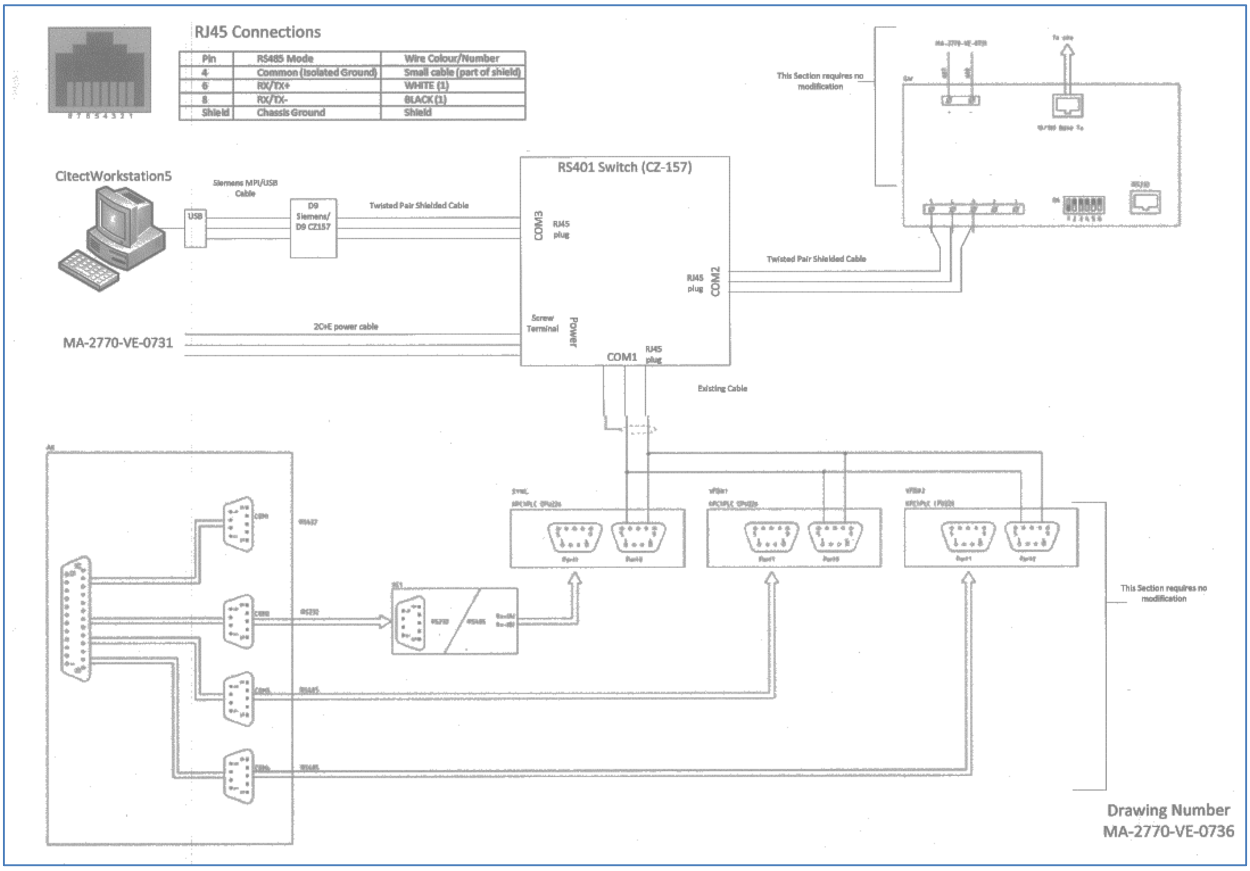

Figure 43 Second Design of Project to Communicate With S7-200 PLC Inside VSD

As the Intern was sure that the plan in Figure 43 was going to work based on information received from both Rugged Com and Siemens equipment was ordered, this included RS485 cable; although only 50m was required due to limitations imposed by the retailer 300m had to be purchased. The RS485 cable is a twisted pair cable with shielding, this provides protection from various sources of interference. After the parts had been ordered a reply was received from Rugged Com.

The Rugged Com specialist revealed that this was not going to work due to the limitations of the Rugged Com switch RS401 (and Modbus serial protocols) there can only be one master device. The above setup required the use of two masters (the PC and the Ethernet Gateway). This required a rethink on the design and the equipment required. This new information came just over a week before the shutdown in October. The suggested modifications to the plan meant that a different type of cable would be required to connect the PC to the RS401. A search of the material database indicated that there was no Cat 6 cable (the cable used on site for Ethernet communications) available, therefore it would have to be ordered. Due to the time for the order to arrive it was not going to be possible to do the job in the October shut. The Intern requested that the Planner remove the job from the shut schedule.

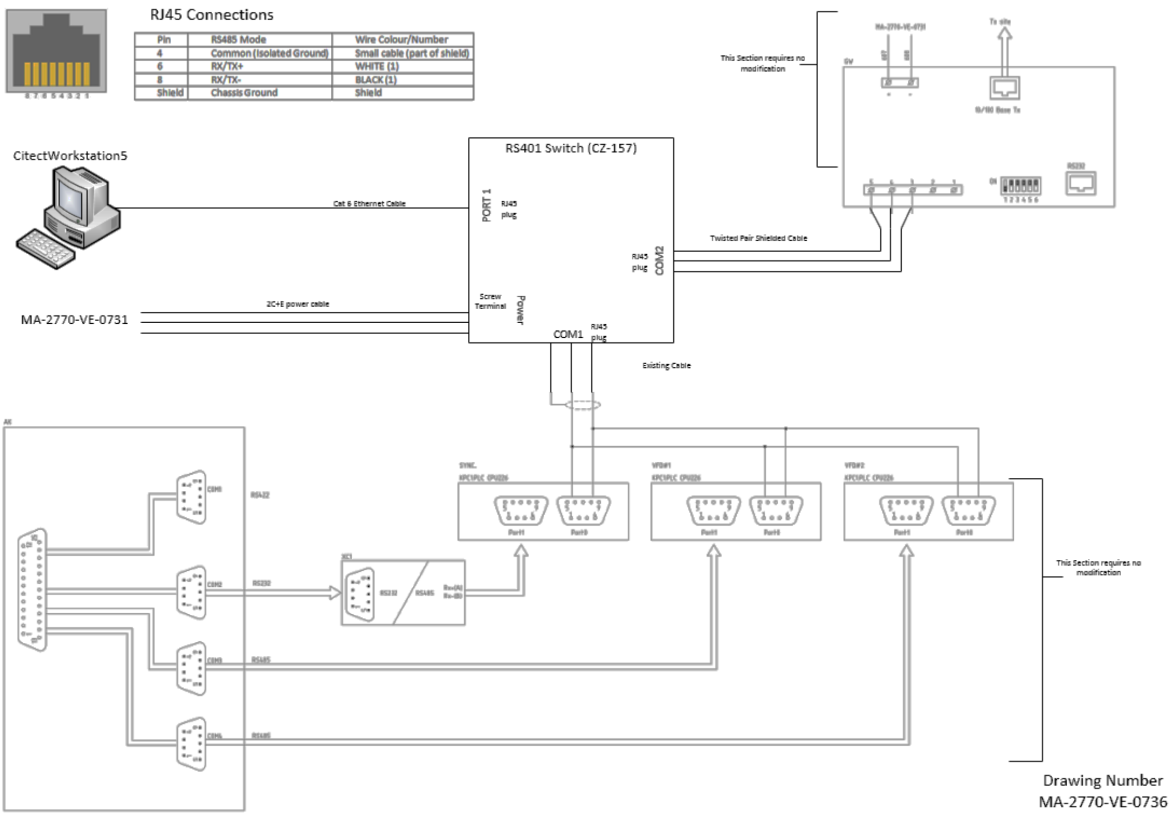

Figure 44 Latest Design of Network Modifications

The latest design is identical in terms of layout except for the connection between PC and RS401. This connection will now be made to the Ethernet port 1, see Figure 44. A piece of software called RuggedDirector installed on the PC will redirect the data that is sent down the Ethernet line into a serial port, which in this case will be serial port 3. The PC would be connected via its Ethernet port. Serial port 3 would be configured as RAW Socket. Investigation of the PC and its ability to have another Ethernet connection is shown in Figure 45. It is noticed that there are no spare Ethernet connection points available on the PC so a way around this is needed.

Figure 45 PC Connection Availability

3.3.4 Citect Improvement Technical Issues and Constraints

This aspect of the project has run into the problem of the Siemens PLC code being in Chinese and also there are no spare communication ports on the Siemens PLC. So another method of communication needs to be developed. The problem encountered is that the rest of the site uses Ethernet TCP/IP while the Siemens uses serial Modbus and the Siemens software will not work through a gateway or switch or in a virtual machine. The Engineering Development Machine is a Virtual Machine that is used to make changes to PLCs, Citect and to monitor various devices onsite for the purposes of fault finding and improvement of the plant.

In relation to the program code being in Chinese, information from Siemens said that to view the code both the PC and the MicroWIN language would need to be changed to Chinese so that the characters could be recognised. It is easy to change the language to Chinese but then there is the problem of changing back as no one on site is able to read Chinese. Discussion of the issue with the Academic Supervisor led to the discovery of another student doing their thesis that is able to read Chinese. They were keen to help. A trial version of MicroWIN was obtained. This was installed on a laptop computer along with the backup versions of the VSD code and taken to the student. They were able to change the language to Chinese and back to English, screen shots were taken during the process so that the same steps could be performed onsite. He was also able to translate some of the comments that were in the code. The memory locations and functional blocks names were already in English when the language changed back. The only time the function block names were not in English were custom made function blocks. The comments were translated and written in English in the code. Not all the code was visible, much of it is protected by passwords, there are two reasons for the passwords, the first is to prevent changing of vital sections of code that could damage the equipment and the second is to protect Leader & Harvest intellectual property.

3.3.5 Status of Citect Improvements

The project is still in the design phase. The end of the loan period of the RS401 is on the 9th of December. The Siemens MicroWIN software has not yet arrived so even if the network modifications were installed the PLC would still not be able to be viewed live. There is also the difficulty of the PLC code being in Chinese. Not all the code has been able to be translate. None of the Synchroniser code has been translated as there is no copy of its code stored outside of the PLC.

3.3.6 Conclusion and Future Work for Citect Improvements

To complete this project the design needs to be completed and if possible tested before actual installation. Ideally this can be done before the loan switch needs to be returned. Once the design has been tested then the RS401 can be purchased and installed. When the MicroWIN software arrives it will need to be installed on the PC. It may be that because the communication is going to occur through an Ethernet port that a Siemens network card may need to be installed. This however would form a part of the design. Once the network changes have been performed and MicroWIN installed the code that has been translated needs to be included in the PLC version of the code and then the Synchroniser code will need to be translated. Once all the available code has been translated the code can be studied to understand what is happening in the VSD and what information can be passed into Citect to help with future fault finding.

4 Conclusion

By the end of the Internship period some parts of the whole project have been completed. Investigation into the Crash Stop Fault (Section 3.2) was completed during the October shutdown, this part is now in the monitoring stage to observe the effect of the removal of the UPS in removing the alarm clusters when trying to start the plant after a crash stop. The other two projects were Out of Sync Fault (Section 3.1) and Citect Improvements (Section 3.3). The Out of Sync Fault project was not completed as there was not enough information available to determine the cause. Moreover, there was only one occurrence where alarm data was available. To continue with this project more information is required. The information will need to be obtained from the VSD event log when the fault occurs and it would be advisable to download the alarm data and save on the local system to ensure it is available for longer than 12 months. More information will also be available when the network modifications are complete for the Citect Improvements project. This part of the project is also not complete due to the complexities of the network and the ability to get parts in time for the shutdown. When the Citect Improvements project is complete the Engineers will be able to view the PLC in the VSD live. The information on Citect will help to improve the fault finding capacity of the Engineers and Electricians in relation to the CV102 VSDs. The final design has been drafted, but the equipment is yet to be ordered. Then an opportunity to install needs to occur before the project can be completed.

Although only one project was completed, many lessons were learnt during the Internship. The most significant one is that planning is vital and to admit that you don't know everything and seek advice from the people that do know. A lot of time can be saved by seeking help from those that have the expert knowledge. The Internship has been very useful in being able to put all the technical skills learnt through University and the 'soft' skills such as time management and communications skills together in one main project. Overall this was a successful Internship.

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6 Appendices

6.1 Out of Sync Fault Data

Table 5 Calculated Data Used in Figure 29

Time	Ave Current 1 - Ave Current 2	CurrentOutput1-CurrentOutput2	FrequencyOutput1-FreuencyOutput2	Limit
19:30:00	0	0	0	20
19:31:00	0	0	0	20
19:32:00	0	0	0	20
19:33:00	0	0	0	20
19:34:00	0	0	0	20
19:35:00	0	0	0	20
19:36:00	0	0	0	20
19:37:00	0	0	0	20
19:38:00	0	0	0	20
19:39:00	0	0	0	20
19:40:00	0	0	0	20
19:41:00	0	0	0	20
19:42:00	0	0	0	20
19:43:00	0	0	0	20
19:44:00	0	0	0	20
19:45:00	0	0	0	20
19:46:00	0	0	0	20
19:47:00	0	0	0	20
19:48:00	0	0	0	20
19:49:00	0	0	0	20
19:50:00	0	0	0	20
19:51:00	0	0	0	20
19:52:00	0	0	0	20
19:53:00	0	0	0	20
19:54:00	6	34	0	20
19:55:00	35	14	80	20
19:56:00	30	9	99	20
19:57:00	32	9	98	20
19:58:00	33	10	99	20
19:59:00	33	10	99	20
20:00:00	0	0	0	20
20:01:00	0	0	0	20
20:02:00	6	36	0	20
20:03:00	34	13	82	20
20:04:00	33	10	99	20
20:05:00	32	10	99	20
20:06:00	32	10	99	20
20:07:00	34	11	99	20
20:08:00	0	0	0	20
20:09:00	0	0	0	20
20:10:00	0	0	0	20
20:11:00	0	0	0	20

20:12:00	0	0	0	20
20:13:00	0	0	0	20
20:14:00	0	1	0	20
20:15:00	1	1	1	20
20:16:00	1	0	1	20
20:17:00	1	0	1	20
20:18:00	1	1	1	20
20:19:00	1	1	1	20
20:20:00	1	1	1	20
20:21:00	1	0	1	20
20:22:00	0	0	0	20
20:23:00	1	1	1	20
20:24:00	1	2	2	20
20:25:00	2	4	1	20
20:26:00	2	5	0	20
20:27:00	1	5	1	20
20:28:00	2	2	1	20
20:29:00	1	1	1	20
20:30:00	2	2	1	20
20:31:00	2	5	1	20
20:32:00	1	5	1	20
20:33:00	0	3	1	20
20:34:00	1	0	1	20
20:35:00	0	1	1	20
20:36:00	1	1	1	20
20:37:00	1	1	2	20
20:38:00	1	0	0	20
20:39:00	1	0	1	20
20:40:00	1	0	1	20
20:41:00	2	2	1	20
20:42:00	2	6	0	20
20:43:00	1	6	0	20
20:44:00	1	6	0	20
20:45:00	2	6	0	20
20:46:00	1	5	0	20
20:47:00	1	5	0	20

Table 6 Raw Data for Out of Sync Fault Figure 29

	RV1.MADCV102MO1_MAPI	RV1.MADCV102MO2_MAPI	RV1.MADCV102MO1VSD_IIV0811_PV	RV1.MADCV102MO2VSD_IIV0812_PV	RV1.MADCV102MO1VSD_KIV0811_PV	RV1.MADCV102MO2VSD_KIV0812_PV
24/01/2013 19:30:00	0	0	0	0	0	0
24/01/2013 19:31:00	0	0	0	0	0	0
24/01/2013 19:32:00	0	0	0	0	0	0
24/01/2013 19:33:00	0	0	0	0	0	0
24/01/2013 19:34:00	0	0	0	0	0	0
24/01/2013 19:35:00	0	0	0	0	0	0
24/01/2013 19:36:00	0	0	0	0	0	0
24/01/2013 19:37:00	0	0	0	0	0	0
24/01/2013 19:38:00	0	0	0	0	0	0
24/01/2013 19:39:00	0	0	0	0	0	0
24/01/2013 19:40:00	0	0	0	0	0	0
24/01/2013 19:41:00	0	0	0	0	0	0
24/01/2013 19:42:00	0	0	0	0	0	0
24/01/2013 19:43:00	0	0	0	0	0	0

24/01/2013 19:44:00	0	0	0	0	0	0
24/01/2013 19:45:00	0	0	0	0	0	0
24/01/2013 19:46:00	0	0	0	0	0	0
24/01/2013 19:47:00	0	0	0	0	0	0
24/01/2013 19:48:00	0	0	0	0	0	0
24/01/2013 19:49:00	0	0	0	0	0	0
24/01/2013 19:50:00	0	0	0	0	0	0
24/01/2013 19:51:00	0	0	0	0	0	0
24/01/2013 19:52:00	0	0	0	0	0	0
24/01/2013 19:53:00	0	0	0	0	0	0
24/01/2013 19:54:00	0	6	58	92	0	0
24/01/2013 19:55:00	0	35	57	71	0	80
24/01/2013 19:56:00	0	30	57	66	0	99
24/01/2013 19:57:00	0	32	57	66	0	98
24/01/2013 19:58:00	0	33	57	67	0	99
24/01/2013	0	33	57	67	0	99

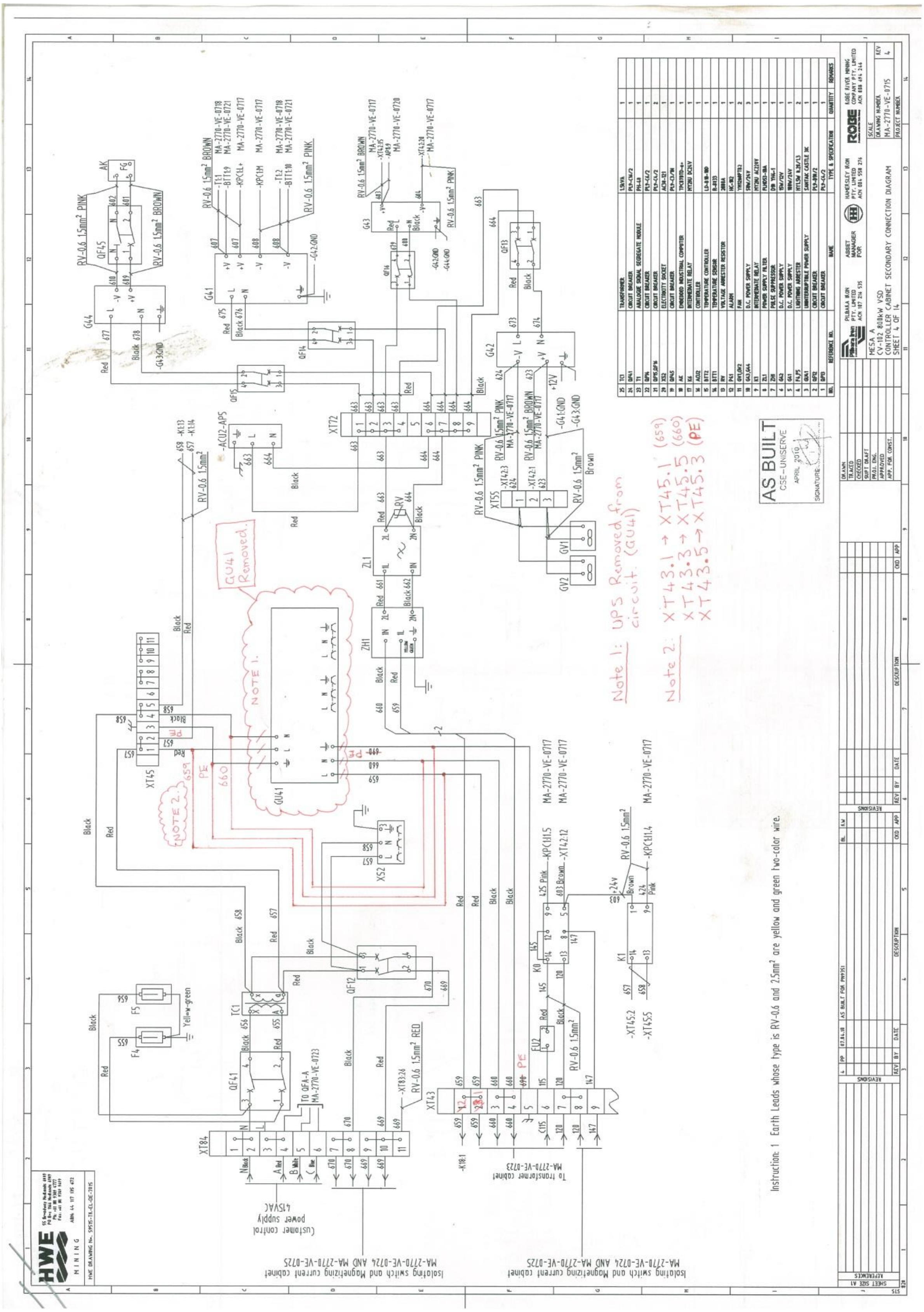
19:59:00						
24/01/2013 20:00:00	0	0	0	0	0	0
24/01/2013 20:01:00	0	0	0	0	0	0
24/01/2013 20:02:00	0	6	57	93	0	0
24/01/2013 20:03:00	0	34	57	70	0	82
24/01/2013 20:04:00	0	33	57	67	0	99
24/01/2013 20:05:00	0	32	57	67	0	99
24/01/2013 20:06:00	0	32	57	67	0	99
24/01/2013 20:07:00	0	34	57	68	0	99
24/01/2013 20:08:00	0	0	0	0	0	0
24/01/2013 20:09:00	0	0	0	0	0	0
24/01/2013 20:10:00	0	0	0	0	0	0
24/01/2013 20:11:00	0	0	0	0	0	0
24/01/2013 20:12:00	0	0	0	0	0	0
24/01/2013 20:13:00	0	0	0	0	0	0
24/01/2013 20:14:00	10	10	60	61	47	47

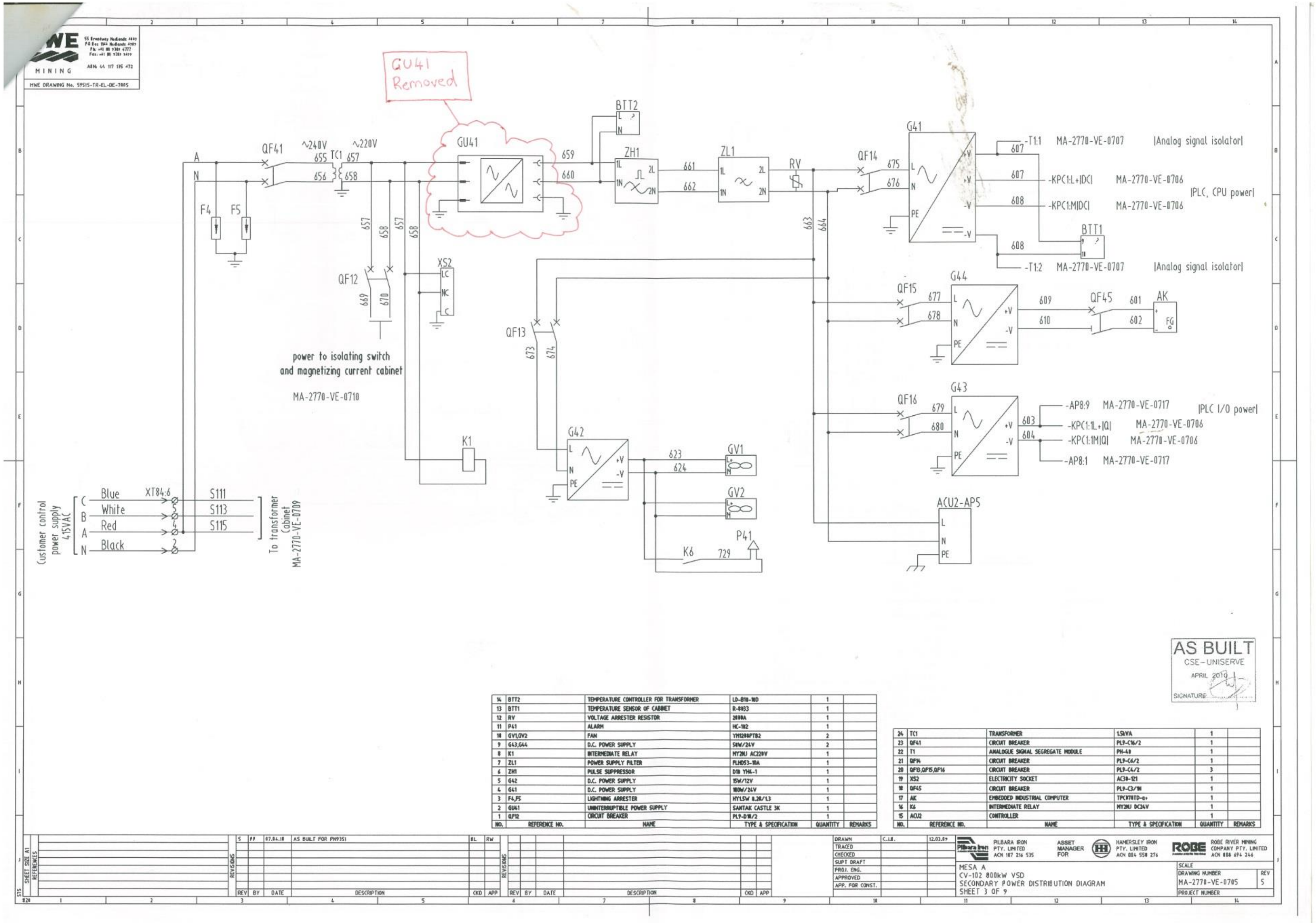
24/01/2013 20:15:00	18	17	60	61	98	99
24/01/2013 20:16:00	18	17	60	60	97	98
24/01/2013 20:17:00	28	27	64	64	97	98
24/01/2013 20:18:00	20	19	61	62	98	99
24/01/2013 20:19:00	18	17	60	61	98	99
24/01/2013 20:20:00	18	17	60	61	98	99
24/01/2013 20:21:00	22	21	62	62	97	98
24/01/2013 20:22:00	30	30	66	66	98	98
24/01/2013 20:23:00	23	22	62	63	97	98
24/01/2013 20:24:00	44	43	73	71	96	98
24/01/2013 20:25:00	76	74	101	97	96	97
24/01/2013 20:26:00	77	75	103	98	98	98
24/01/2013 20:27:00	77	76	104	99	97	98
24/01/2013 20:28:00	52	50	82	80	98	99
24/01/2013 20:29:00	24	23	63	62	97	98
24/01/2013	48	46	76	74	96	97

20:30:00						
24/01/2013 20:31:00	80	78	106	101	97	98
24/01/2013 20:32:00	76	75	103	98	98	99
24/01/2013 20:33:00	44	44	77	74	98	99
24/01/2013 20:34:00	17	16	60	60	98	99
24/01/2013 20:35:00	15	15	59	60	98	99
24/01/2013 20:36:00	17	16	60	61	98	99
24/01/2013 20:37:00	17	18	60	61	97	99
24/01/2013 20:38:00	20	19	61	61	98	98
24/01/2013 20:39:00	22	21	62	62	97	98
24/01/2013 20:40:00	28	29	65	65	97	98
24/01/2013 20:41:00	65	63	89	87	96	97
24/01/2013 20:42:00	85	83	110	104	98	98
24/01/2013 20:43:00	84	83	111	105	98	98
24/01/2013 20:44:00	85	84	111	105	98	98
24/01/2013 20:45:00	84	82	110	104	98	98

24/01/2013 20:46:00	83	82	109	104	98	98
24/01/2013 20:47:00	85	84	111	106	98	98

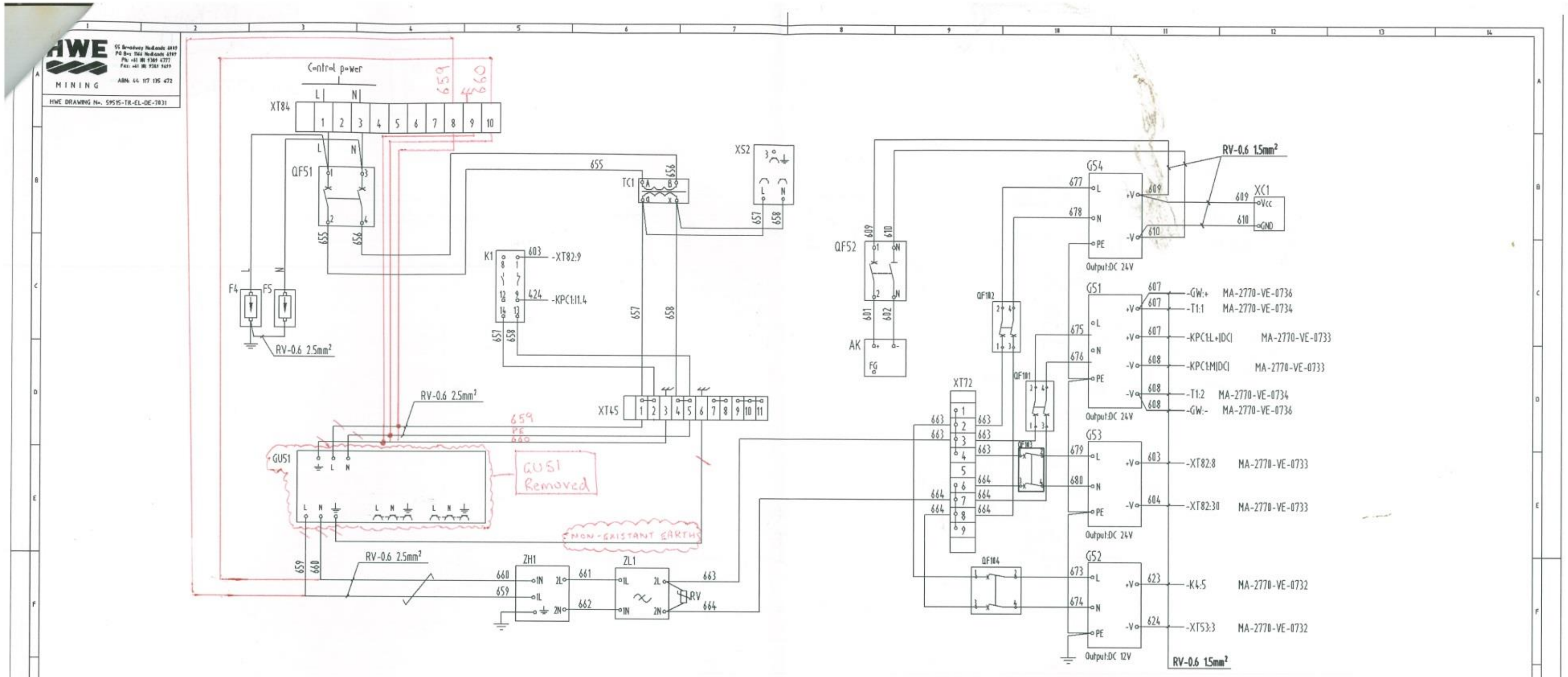
6.2 Red Line Drawings Crash Stop Fault





NO.	REFERENCE NO.	NAME	TYPE & SPECIFICATION	QUANTITY	REMARKS
14	BTT2	TEMPERATURE CONTROLLER FOR TRANSFORMER	LD-B10-10D	1	
13	BTT1	TEMPERATURE SENSOR OF CABINET	R-0033	1	
12	RV	VOLTAGE ARRESTER RESISTOR	2000A	1	
11	P41	ALARM	HC-102	1	
10	GV1,GV2	FAN	YM1200PTB2	2	
9	G43,G44	D.C. POWER SUPPLY	50W/24V	2	
8	K1	INTERMEDIATE RELAY	MY2NJ AC220V	1	
7	ZL1	POWER SUPPLY FILTER	FLHD53-10A	1	
6	ZH1	PULSE SUPPRESSOR	D10 YH6-1	1	
5	G42	D.C. POWER SUPPLY	15W/12V	1	
4	G41	D.C. POWER SUPPLY	100W/24V	1	
3	F4,F5	LIGHTNING ARRESTER	HY1.5W 0.28/1.3	1	
2	GU41	UNINTERRUPTIBLE POWER SUPPLY	SANTAK CASTLE 3K	1	
1	QF12	CIRCUIT BREAKER	PL9-D10/2	1	

NO.	REFERENCE NO.	NAME	TYPE & SPECIFICATION	QUANTITY	REMARKS
24	TC1	TRANSFORMER	1.5kVA	1	
23	QF41	CIRCUIT BREAKER	PL9-C16/2	1	
22	T1	ANALOGUE SIGNAL SEGREGATE MODULE	PH-40	1	
21	QF14	CIRCUIT BREAKER	PL9-C6/2	1	
20	QF13,QF15,QF16	CIRCUIT BREAKER	PL9-C4/2	3	
19	XS2	ELECTRICITY SOCKET	AC30-121	1	
18	QF45	CIRCUIT BREAKER	PL9-C3/1N	1	
17	AK	EMBEDDED INDUSTRIAL COMPUTER	TPC070TD-a+	1	
16	K6	INTERMEDIATE RELAY	MY2NJ DC24V	1	
15	ACU2	CONTROLLER		1	



NO.	REFERENCE NO.	NAME	TYPE & SPECIFICATION	QUANTITY	REMARKS
19	XC1	RS232 TO RS485 CONVERTER	8520	1	
18	AK	EMBEDDED INDUSTRIAL COMPUTER	TPC070TD-a+	1	
17	T1	ANALOGUE SIGNAL SEGREGATE MODULE	PH-40	1	
16	XS2	ELECTRICITY SOCKET	AC30-121	1	
15	QF52	CIRCUIT BREAKER	PL9-C3/1N	1	
14	XT45,XT72,XT84	CONNECTION TERMINAL		3	
13	RV	VOLTAGE ARRESTER RESISTOR		1	
12	QF51	CIRCUIT BREAKER	PL9-C16/2	1	
11	QF102	CIRCUIT BREAKER	PL9-C3/2	1	
10	QF101,QF103,QF104	CIRCUIT BREAKER	PL9-C3/2	3	
9	PS1	ALARM	HC-102	1	
8	GS3,GS4	D.C. POWER SUPPLY	50W/24V	2	
7	ZL1	POWER SUPPLY FILTER	FLHDS3-10A	1	
6	ZH1	PULSE SUPPRESSOR	D10 YH4-1	1	
5	GS2	D.C. POWER SUPPLY	15W/12V	1	
4	GS1	D.C. POWER SUPPLY	100W/24V	1	
3	F4,F5	LIGHTNING ARRESTER	HY1.5W 0.28/1.3	2	
2	K1	INTERMEDIATE RELAY	MY2NJ AC220V	1	
1	GUS1	UNINTERRUPTIBLE POWER SUPPLY	SANTAK CASTLE 3K	1	

AS BUILT
CSE-UNISERVE
APRIL 2010
SIGNATURE:

REV	BY	DATE	DESCRIPTION	CKD	APP
4	PP	07.04.10	AS BUILT FOR PN9351	BL	RW

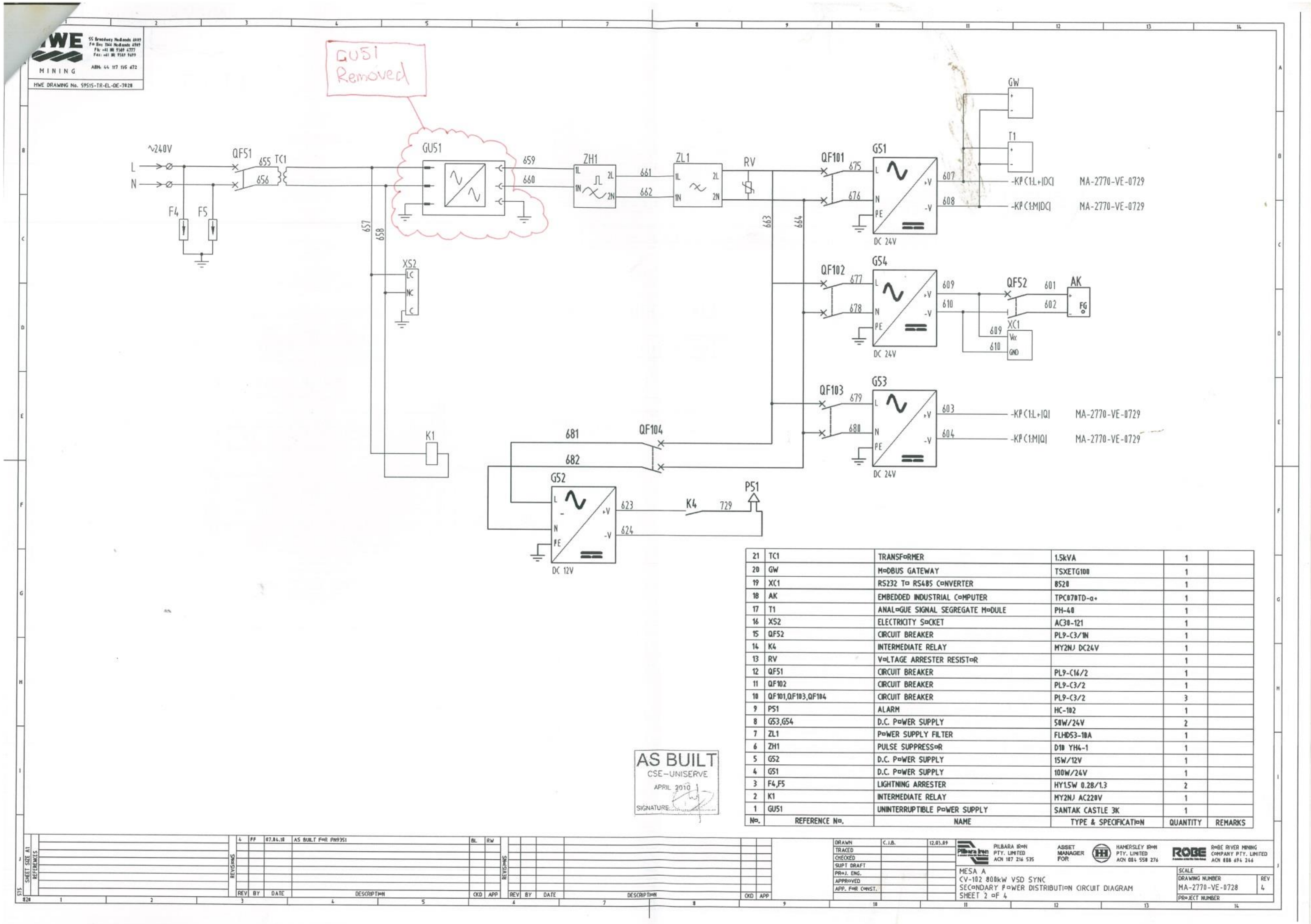
DRAWN	C.J.B.	12.03.09
TRACED		
CHECKED		
SUPT DRAFT		
PROJ. ENG.		
APPROVED		
APP. FOR CONST.		

PILBARA IRON PTY. LIMITED ACN 107 216 535
ASSET MANAGER FOR:
HAMERSLEY IRON PTY. LIMITED ACN 004 558 276
ROBE RIVER MINING COMPANY PTY. LIMITED ACN 008 694 244

MESA A
CV-102 800kW VSD SYNC
CONTROLLER CABINET SECONDARY CONNECTION DIAGRAM
SHEET 1 OF 6

SCALE
DRAWING NUMBER: MA-2770-VE-0731
REV: 4
PROJECT NUMBER

SHEET SIZE A1



No.	REFERENCE No.	NAME	TYPE & SPECIFICATION	QUANTITY	REMARKS
21	TC1	TRANSFORMER	1.5kVA	1	
20	GW	MODBUS GATEWAY	TSXETG100	1	
19	XC1	RS232 TO RS485 CONVERTER	8520	1	
18	AK	EMBEDDED INDUSTRIAL COMPUTER	TPC070TD-a+	1	
17	T1	ANALOGUE SIGNAL SEGREGATE MODULE	PH-40	1	
16	XS2	ELECTRICITY SOCKET	AC30-121	1	
15	QF52	CIRCUIT BREAKER	PL9-C3/1N	1	
14	K4	INTERMEDIATE RELAY	MY2NJ DC24V	1	
13	RV	VOLTAGE ARRESTER RESISTOR		1	
12	QF51	CIRCUIT BREAKER	PL9-C16/2	1	
11	QF102	CIRCUIT BREAKER	PL9-C3/2	1	
10	QF101,QF103,QF104	CIRCUIT BREAKER	PL9-C3/2	3	
9	PS1	ALARM	HC-102	1	
8	G53,G54	D.C. POWER SUPPLY	50W/24V	2	
7	ZL1	POWER SUPPLY FILTER	FLHDS3-10A	1	
6	ZH1	PULSE SUPPRESSOR	D10 YH4-1	1	
5	G52	D.C. POWER SUPPLY	15W/12V	1	
4	G51	D.C. POWER SUPPLY	100W/24V	1	
3	F4,F5	LIGHTNING ARRESTER	HY1.5W 0.28/1.3	2	
2	K1	INTERMEDIATE RELAY	MY2NJ AC220V	1	
1	GU51	UNINTERRUPTIBLE POWER SUPPLY	SANTAK CASTLE 3K	1	