Murdoch University

School of Engineering and Energy

FINAL REPORT

FOR

ENG450 - ENGINEERING INTERNSHIP

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A report submitted to the School of Engineering and Energy, Murdoch University in partial fulfilment of the requirements for the degree of Bachelor of Engineering
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ABSTRACT

The culmination of a Bachelor of Engineering is signified by a body of work highlighting the student’s knowledge and capabilities in their chosen field. For this I have chosen to pursue an Engineering Internship at Proteus EPCM Engineers with the aim of getting exposure to engineering design through workplace employment under the direction of engineers experienced in the field.

The primary component of this internship work placement was providing engineering assistance to prepare a definitive feasibility study for Stage 2 of Karara Mining’s Iron Ore Project located in the Mid-West region of Western Australia.

Through the internship period, the projects offered significant technical experience and challenges providing additional depth to the knowledge already established during the tenure at Murdoch University.
DISCLAIMER

All of the work discussed in the report is the work of the author unless otherwise referenced.

I declare the following to be my own work unless otherwise referenced, as defined by Murdoch University's policy on plagiarism.
ACKNOWLEDGEMENTS

Without the support, encouragement and assistance of several key persons, the internship and the Bachelor of Engineering qualification it is culminating would not have been possible.

I would like to thank my family, especially my parents Neil and Cath but also my siblings Tenielle, Kellie and Ben as well as their respective partners for their unconditional support and encouragement they have provided throughout my tertiary and non-tertiary education.

I would also like to thank my friends and fellow students, with particular mention of Ash Jenkinson and Luke Morrison for their friendship and assistance both educational and otherwise, throughout our studies, initially at Challenger TAFE and finally at University.

Recognition must also be made to the selfless contribution of the teaching staff at Murdoch University – especially Dr Graeme Cole and Dr Gareth Lee. Their patience, dedication and motivation over the course of my studies has always been inspiring. It is their commitment to education and the improvement of others that has facilitated my degree and I, like others will be proud to say that I am a Murdoch Engineering graduate.

Finally, I would like to thank my employer of the last five years, Proteus EPCM Engineers, in particular Lachlan Walker and Lance Rattigan whom have provided unprecedented opportunities for personal development for which I am truly grateful.
1.0 INTRODUCTION

1.1 General

The culmination of a Bachelor of Engineering is typically signified by a body of work highlighting the student’s knowledge and capabilities in their chosen field. For the majority of university students this is a thesis, a project that typically involves specification, design and implementation in a field relative to their studies.

In addition to the thesis option, Murdoch University’s School of Engineering and Energy offer a unique industry based alternative in the form of an Engineering Internship. A similar process of specification, design and implementation is also applied, but is performed external to the university at placement within industry.

The practical experience and exposure offered by the placement allows the student to expand and provide valuable context to the knowledge they have gained during the university studies. This is achieved by assisting with engineering activities both at an individual level, and part of a larger engineering team.

The purpose of this report is to document these activities and the Engineering Internship undertaken by Chris Holloway during the second semester of 2012. This internship was conducted within the offices of Proteus EPCM Engineers providing engineering support to Karara Mining Ltd and BHP Billiton Pty Ltd.

While the primary purpose of this document is to facilitate formal assessment towards fulfilment of an engineering degree, the report also provides personal benefit to the author in the form of a record of the personal development and lessons gained during the period.

The intention is to capture the milestone events, documenting the activities that were completed and highlight the experience gained over the 16 week internship period. Particular focus is given to the technical challenges encountered and the approach and methodology applied to identify, consider and resolve these complications.

To provide context to the internship topic, an introduction to the parties involved and what the projects entail, commences the body of the report. Further is a thorough discussion of the project activities focussing on the elements mentioned above, before concluding with an analysis of the project outcomes and demonstration of work experience.
# Abbreviations and Terms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AWA</td>
<td>Aluminium Wire Armoured</td>
</tr>
<tr>
<td>CCE</td>
<td>Capital Cost Estimate</td>
</tr>
<tr>
<td>CMS</td>
<td>Cleaner Magnetic Separator</td>
</tr>
<tr>
<td>DFS</td>
<td>Definitive Feasibility Study</td>
</tr>
<tr>
<td>DlgsILENT</td>
<td>Power system modelling and analysis software package</td>
</tr>
<tr>
<td>DOL</td>
<td>Direct On-Line</td>
</tr>
<tr>
<td>DSO</td>
<td>Direct Shipping Ore</td>
</tr>
<tr>
<td>EDS</td>
<td>Engineering Design System Database</td>
</tr>
<tr>
<td>EEL</td>
<td>Electrical Equipment List</td>
</tr>
<tr>
<td>EHV</td>
<td>Extra High Voltage</td>
</tr>
<tr>
<td>HDPE</td>
<td>High Density Polyurethane</td>
</tr>
<tr>
<td>HPGR</td>
<td>High Pressure Grinding Roll</td>
</tr>
<tr>
<td>HV</td>
<td>High Voltage</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation and Air Conditioning</td>
</tr>
<tr>
<td>IFQ</td>
<td>Issued for Quotation</td>
</tr>
<tr>
<td>IMS</td>
<td>Intermediate Magnetic Separation</td>
</tr>
<tr>
<td>KIOP</td>
<td>Karara Iron Ore Project</td>
</tr>
<tr>
<td>KML</td>
<td>Karara Mining Limited</td>
</tr>
<tr>
<td>kVA</td>
<td>Kilo Volt Amperes</td>
</tr>
<tr>
<td>LRS</td>
<td>Liquid Resistance Starter</td>
</tr>
<tr>
<td>LV</td>
<td>Low Voltage</td>
</tr>
<tr>
<td>MCC</td>
<td>Motor control centre</td>
</tr>
<tr>
<td>MEL</td>
<td>Mechanical Equipment List</td>
</tr>
<tr>
<td>Mtpa</td>
<td>Million Tonnes Per Annum</td>
</tr>
<tr>
<td>MV</td>
<td>Medium Voltage</td>
</tr>
</tbody>
</table>
1.3 Project Aim

The goal of this engineering internship is to expose Chris Holloway, to the principles of engineering design through a period of workplace employment at a professional level in a typical Engineering firm, in this case Proteus EPCM Engineers.

A successful internship period involves applying engineering theories learnt at Murdoch University to the real life challenges experienced within a typical engineering project.

1.4 Parties Involved

1.4.1 Murdoch University – School of Engineering and Energy

Murdoch University is a public university whose primary campus is located in the suburb of Murdoch, south of the city of Perth in Western Australia. Named after Sir Walter Murdoch, it was established in 1973 as the second university in Western Australia after the University of Western Australia. In 2012, Murdoch is comprised of over 18,000 students and 1,400 staff and offers over 200 undergraduate degrees across five faculties.

Operating within the Faculty of Science and Engineering, the School of Engineering and Energy is lead by Dean Parisa Bahri, providing undergraduate and postgraduate courses across multiple disciplines including engineering, physics and nanotechnology, and energy studies.

1.4.2 Chris Holloway
Chris Holloway is the author of this report, and the subject of the Engineering Internship. After graduating from Willetton Senior High School in 2002, Chris experimented with a number of full-time roles working in a number of diverse fields, before finally settling into a role in internal sales at the specialist distributor of local and wide area network communication products, Page Data.

This grassroots involvement in the Electrical and Communications industry triggered a desire to gain a greater depth of knowledge in the field and prompted enrolment in full-time study at Challenger TAFE in a Diploma of Electrotechnology.

Just prior to completion of the 24 month program, the pending qualification secured employment at Proteus Engineers working as an Electrical and Instrumentation draftsman.

At the conclusion of the TAFE program, a desire to obtain qualifications at a professional engineering level prompted enrolment in full-time study at Murdoch University, pursuing a Bachelor of Engineering.

In 2012, the degree will be completed coinciding with 5 years of continuous employment with Proteus, both as a Draftsman/ Designer and finally as an Undergraduate Engineer.

**1.4.3 Proteus EPCM Engineers**

Proteus EPCM Engineers is a provider of engineering services to the resources and energy sectors of Western Australia engaging in all phases of a project life cycle from identification to operations. Key strengths are study, design and EPCM project execution services for the mining, mineral processing and infrastructure sectors across a wide range of commodities.

Proteus was acquired by Tetra Tech Inc in August 2011. Tetra Tech is a U.S. based public company with 13,000 employees worldwide and USD $2.6bn revenue (FY2011). Tetra Tech provides consulting engineering and project management services for mining, water resources, groundwater, watershed management, geotechnical and environmental management projects, including mine closure.

**1.4.4 Karara Mining Limited**

The Karara Mining Ltd is a 50-50 joint venture between Gindalbie Metals Limited and the Chinese state owned Anshan Iron and Steel Group, established in 2007. Karara’s operations are located in Mid-West Western Australia and consists of an open pit mine, processing plant and supporting infrastructure located on site and at the export terminal at the port of Geraldton.
The sole operation of Karara is the Karara Iron Ore Project (KIOP) located in the Mid-West region of Western Australia. The project located approximately 250km inland from Geraldton, Western Australia has a total resource potential of 30Mtpa over an expected mine life of 30+ years.
2.0 THE PROJECT

The project engineering activities to be completed during the internship period relate to the expansion of mining operations of Karara Mining Ltd.

2.1 Karara Iron Ore Project – Stage 1

Established for Stage 1 of the Karara Iron Ore Project was a 10Mtpa iron ore mine processing 2Mtpa as a direct shipping ore (DSO) hematite and an additional 8Mtpa of magnetite though a dedicated processing facility.

Significant infrastructure required to support the mine was also completed at the completion of Stage 1 including a 1300 room accommodation village for site personnel, 140km water pipeline from the Parmelia aquifer for process water requirements and an 85km rail spur connecting the mine site to Brookfield Rail’s WestNet Rail operations at Tilley Siding near Morawa.

In addition, electrical infrastructure required included a 180km, 330kV overhead power line from the locality of Eneabba, through Three Springs and to Karara, connecting the mine to the South West Interconnected System (SWIS) (Gindalbie Metals Limited, 2007).

Works were also completed at the port location of Geraldton, the export terminal for the Karara project in the form of a 16Mtpa ore storage and ship loading facility.

Figure 1 - Infrastructure for KIOP (Gindalbie Metals, 2012)
2.2 Karara Iron Ore Project – Stage 2

Karara Mining Limited (KML) has engaged Proteus Engineers to prepare a Definitive Feasibility Study (DFS) for the Stage 2 expansion of their Iron Ore project. The intention of KML is to expand beyond the initial facilities that provide 8Mtpa Magnetite towards 16Mtpa total magnetite production.

To achieve this, the Stage 2 study is concerned primarily with the construction of a new 8Mtpa magnetite process plant, with some consideration given to two additional 8Mtpa Stage 3 and 4 expansions towards 32Mtpa total Magnetite production. The business case for completing Stage 2 is compelling as it would allow KML to fully utilise the 16Mtpa port facility capacity constructed at Geraldton for the project. Should Stages 3 and 4 be completed, additional port facilities would be required to handle the additional capacity – such as the proposed Oakajee Port and Rail project (Gindalbie Metals Ltd, 2010).

With the existing 8Mtpa process plant only recently approaching commissioning and final construction, there is a significant quantity of recent, accurate engineering data available to use as basis for the new expansion. It is the intention of Proteus and KML to make use of this data to produce a cost estimate for the proposed process plant. This cost estimate will then be presented to the KML Board for consideration.

The use of the existing data has allowed preliminary engineering activities to proceed over the past few months with Proteus engineers developing process flow sheets (P&ID, PFD) based on new process improvements and a revised, more effective site layout for the new process plant installation.

These preliminary works have been beneficial to the Electrical department, as they provide a solid base to begin production of the engineering design and cost estimate documentation, the basis for this internship.

2.3 Hematite and Magnetite

The Karara project produces Iron Ore, a commodity primarily used in the production of steel, common to Western Australia. In recent years, the Chinese demand for Australian Iron Ore has resulted in record exports, growth and prosperity, primarily originating from the Pilbara region of North-West Australia. This demand has been served by large resource companies such as BHP Billiton, Rio Tinto and Fortescue Metals Group (FMG) supplying unprecedented quantities of hematite product. (Department of Mines and Petroleum, 2011)

As a direct shipping ore (DSO), hematite has a relatively simple crushing, screening and blending process performed locally before being stockpiled and shipped. It is non-magnetic with an iron content of between 56-62%. A combination of the simple
processing, existing infrastructure and the abundance of this ore in the Pilbara region has meant hematite forms the majority (approximately 96%) of Australian Iron Ore exported.

Where the Karara project differs to these major iron ore operations is that its primary product is magnetite. Also an Iron Ore product, Magnetite in its raw form has a much lower Iron content of between 25-40% requiring an additional and complex processing phase that utilises its magnetic properties to produce a concentrate product of between 65-70% iron.

In addition to the primary crushing, secondary crushing and screening stages required in hematite iron ore mining, the processing facility includes a multistage grinding process (HPGR, Ball and Tower Mills), three stages of magnetic separation (RMS, IMS and CMS) as well as final concentration of product through a reverse froth flotation stage.

In addition to its significantly higher iron content, the final concentrated magnetite product has lower impurities and superior smelting characteristics, requiring less energy and hence generating less overall greenhouse emissions compared to hematite. These benefits see magnetite attract a price premium over hematite, offsetting the additional processing costs of ore.

2.4 Internship Activities

The primary focus of the engineering internship was to develop an electrical distribution design for supply of electrical loads within the stage 2 process facility in sufficient detail that an accurate estimation for the supply and installation of such a facility could be calculated. This activity would be performed under the direction of the Karara project Lead Electrical Engineer Chris Davy.

This would then be included in the capital cost estimate prepared for the definitive feasibility study report for presentation to the Karara Board.

In order to perform this task, the following activities were completed:

- Review of Karara Design Parameters
- Identification of Process Facility Electrical Power Demand
- Development of Distribution Network to Service Process Loads
- Preparation of Electrical Packages for Capital Cost Estimation

Key steps to complete these tasks will be covered in detail in the body of this report.
3.0 THE APPROACH

Before engineering activities contributing towards the DFS could commence, a project timeline had to be established to ensure that the parties involved would sufficiently meet not only the deadline and budget requirements of Karara, but also satisfy the resource scheduling requirements within Proteus.

In order to satisfy the obligations to Karara and the Proteus resource demand, it was determined that in addition to the author, the core team would consist of the Lead Electrical Engineer (overseeing the Electrical design of the project), Chris Davy and the lead Electrical Designer, John Duncan. Also available on a part-time basis were an additional two engineers and two designers if or when required. Using these project resources the design was commenced.

3.1 Design Parameters

The initial task was to ascertain the client specific design parameters that the electrical distribution would be required to meet, considering Karara’s requirements, preferences and expectations – both stated and implied. The former was well covered in formal documentation issued to Proteus, including the electrical basis of design (BOD) and additional specifications. The latter was established via client meetings attended by Chris Davy and communicated via meeting minutes to the project team.

3.1.1 General Design Considerations

The primary consideration for the proposed electrical design was to ensure the safety of maintenance and operations personnel is maintained at all times – this includes engineering hazards out of the design where practical.

In addition, the electrical system was to be designed to be self-protecting, allowing the rapid isolation of a faulted component whilst confining power interruption to the smallest area practicable.

3.1.2 Preferred Equipment Suppliers

Specification of the equipment makes, suppliers and models was to be standardised as much as practical where standardisation would not compromise the design technically or financially. Applying preferred equipment suppliers specifications was of particular importance due to the wealth of experience gained during commissioning, as well as the physical components on hand from the initial Stage 1 development.

3.1.3 Distribution Voltages and Methodology

The primary point of supply for the Stage 2 processing plant would be via a 330kV connection to the South West Interconnected System, as established during Stage 1. A
dedicated switchyard would be allowed for the project, with consideration given to either indoor or outdoor options.

The incoming 330kV supply would be stepped down via power transformers to 33kV – the primary reticulation voltage for the processing facility, and distributed to localised electrical switchrooms for tertiary reticulation via localised switchboards.

33kV switchboards supply local step down transformers for tertiary reticulation at either 6.6kV or 415V. Distribution of these tertiary voltages is to be achieved via Motor control centres (MCC) containing drive starters for supply to process loads directly, or via external components such as variable speed drives (VSD) or soft starters.

In addition to the above primary and tertiary reticulation, emergency generation for critical loads occurs via diesel generators at 11kV, stepped up to 33kV for distribution on the primary reticulation network.

3.1.4 Switchrooms

In accordance with Karara requirements, electrical distribution infrastructure is to be installed within buildings designed and installed on site for that sole purpose. Equipment to be accommodated includes motor control centres, variable speed drives (VSD), uninterruptable power supplies (UPS), marshalling panels (MP) and programmable logic controllers (PLC) with a 20% spare capacity for expansion of equipment. This spare provision requires an allowance of both physical space for installed equipment, as well as electrical capacity in the cabling and electrical infrastructure.

A heating, ventilation and air conditioning system (HVAC) sized for 100% redundancy is to be installed to allow for heat dissipation of said equipment. Internal temperature shall be maintained at a suitable level with all equipment operational.

Installation of switchrooms is to be approximately 2100mm above ground level to allow for connection of external cabling to switchrooms, permissible by cable entry through the floor of the building.

3.1.5 Equipment Sizing

As specified in Karara’s BOD document - equipment used for electrical distribution, including transformers and switchgear is be sized and quantified from the calculated maximum demand plus an additional provision of 20% spare capacity. Power distribution cabling is also to be sized to the maximum demand, with the exception of transformer cabling which is to be sized to the equipment rating.

The maximum demand forming the basis of these calculations is derived from the installed power of the equipment considering its electrical efficiency, power factor and
utilisation factor. If the absorbed power cannot be accurately defined, a default 90% peak load factor of the installed power is to be used. Furthermore, in the absence of motor data, motor efficiency of 95% and an electrical power factor of 0.85 and 0.95 are to be used for DOL and VSD motors respectively. Standby motors shall not contribute to the electrical power consumption, unless specific information considering the changeover can be determined.

3.1.6 Motor control centre Drive Methods

Up to a specified installed power, selection of motor control centre drive methods is generally dictated by the process requirements. These requirements should they be, speed control, high torque starting, or current limiting operation for instance can be satisfied through a number of different methods - the preferred selection of which is specified by the client in their basis of design documentation.

Selection options include direct on-line (DOL), variable speed drive (VSD), electronic soft starting (SS), liquid resistance starting (LRS), auto transformer starting (AutoTF), star-delta or Hydraulic as summarised in Table 1 below.

<table>
<thead>
<tr>
<th>Table 1 - Preferred Drive Method for Process Requirements</th>
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<tbody>
<tr>
<td>DOL</td>
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<tr>
<td>-----</td>
</tr>
<tr>
<td>Default</td>
</tr>
<tr>
<td>Speed Control</td>
</tr>
<tr>
<td>Current Limiting</td>
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<tr>
<td>High Torque Start.</td>
</tr>
</tbody>
</table>

As detailed, drives marked as "preferred" are the clients default selection. Specification of drives outside of these choices are to be made in exceptional circumstances only, and/or require the written approval of a client representative.

3.1.7 Drive Voltage Selection

Similar to the motor drive method specification, the voltage for motors specified on the project is also selected based on client requirements. The argument for selecting LV or MV motors is weighted depending on the cost benefit of each installation. At a lower range of installed power, HV motors and drive modules are more expensive than LV, but at higher ratings the trend reverses. Selection must also consider the cabling length and installation; costs for HV are smaller due to the lower operating currents and smaller cables.

While it is important to consider these factors, especially for unique installations, Karara had completed a cost-benefit analysis and issued their standard preferences as captured in Table 2 below. These figures will be used when selecting drive type and drive voltage during the preliminary engineering design.
3.1.8 Emergency and Critical Loads

Due to the high electricity consumption of the process plant, and the nature of the interconnection of the Karara and the South West Interconnected System, a power management system (PMS) is implemented across the site. The PMS provides feedback on the status of the power system, capacity of the Western Power supply, and the onsite generation as required by the power supply contract.

The PMS is required to allow for proactive load shedding if required to protect connected equipment, and potentially the SWIN. To assist with this operation, Karara requirements specify that all process and non process loads supplied by the plant-wide electrical system are required to be categorised as one of the following: Emergency, Critical, Reduced Throughput and Non Essential.

Critical loads have the highest priority and are the last loads to be shed. In addition they are the first to be initiated upon return of power. Critical loads are typically process equipment that would sustain damage or cause significant downtime via a power outage of a significant duration.

Emergency loads have the second highest priority. Subject to available reserve power, these loads are to be manually connected and supplied from the process plant power station. Connected emergency equipment is generally required to assist with fault finding, plant cleanup and restoration of overall mains power.

Reduced Throughput loads include process equipment that is required to maintain reduced plant production should full supply power be unavailable. These loads are further categorised to enable various stages of load shedding depending on the electrical network requirements.

Finally, Non Essential loads are those which can be shed to maintain reduced plant production throughput – these are the lowest priority loads that can be shed with minimal disruption and inconvenience.

Application of these categories to the Stage 2 expansion requires input from all disciplines and client representatives to properly ascertain the implications of a power loss. Where

<table>
<thead>
<tr>
<th>Rating</th>
<th>DOL</th>
<th>LRS</th>
</tr>
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<tbody>
<tr>
<td>0 to 250kW</td>
<td>415V</td>
<td>-</td>
</tr>
<tr>
<td>250 to 450kW</td>
<td>6.6kV</td>
<td>415V</td>
</tr>
<tr>
<td>450kW+</td>
<td>-</td>
<td>6.6kV</td>
</tr>
</tbody>
</table>
possible, loads fitting the above categories are grouped to common switchgear to assist with load shedding.

3.1.9 Cabling Specifications

Due to large variations in cable type, construction and installation method – Karara dictate the required specifications for installation at the mid-west site.

As a minimum, all power cables require copper conductors and cross linked polyethylene (XLPE) insulation. This specification is used as an alternative to polyvinyl chloride (PVC) due in part to its greater mechanical strength, but primarily due to the higher conductor temperature it permits. Where PVC insulation begins to degrade at a conductor temperature of greater than 75 degrees Celsius, XLPE insulation maintains its insulating properties up to a conductor temperature of 90 degrees Celsius. This higher temperature rating allows same size cable to carry larger currents for the XLPE insulation.

The remaining variations between cable specifications relate to the mechanical protection applied to the cable. Cabling installed underground is prone to damage from construction equipment and the like - hence to protect the cable and potential equipment operators, protective metallic armour surrounds the insulation. For three core cabling, this protection is steel and is abbreviated SWA, however in single conductor cables aluminium is used (AWA) to prevent the conductor’s magnetic field inducing electrical currents into the armour.

The final cable variation in the cable construction specification is the requirement for either a chemical impregnated High Density Polyurethane (HDPE) or Nylon sheath for underground cabling. This is an additional protective layer required to prevent insulation damage by termites, a common problem in the warmer climates of Australia.

3.2 Electrical Power Demand

With design parameters established, consideration was given to confirming the electrical power demands of the processing facility, in terms of size, geographical location and other special load requirements. As this component of the design is handled by engineers of other disciplines, maintaining good communication and flow of information with peers, in particular the process and mechanical counterparts was essential.

Assisting the transfer of information, the engineers working on the project utilised the Engineers Design System Database or EDS – a Microsoft Access based software tool developed in-house by Proteus EPCM Engineers.

EDS is the central hub for Proteus designers providing a data management tool for all projects, systematically organising, publishing and sharing engineering detail across multiple disciplines.
This permits the efficient communication of data between engineers working on a single project; for instance Mechanical Engineers will enter Mechanical Equipment into the database such as conveyors, chutes, pump motors and the like which is published to a Mechanical Equipment List (MEL) with parameters such as Equipment Numbers, Descriptions, Associated Equipment, Capacities and Manufacturers.

An identical process is also conducted for Electrical Equipment via the Electrical Equipment List (EEL), with equipment identifiers, descriptions and key technical information recorded.

The relationship between the items providing electrical distribution recorded on the Electrical Equipment List and requiring electrical power on the Mechanical Equipment List, is captured via the Electrical Load List.

### 3.2.1 Electrical Load List Development

Developing and maintaining the Electrical Load List document was the primary role during the initial phase of the internship period, working under the direction of Lead Engineer Chris Davy.

The load list is the fundamental electrical document prepared for the Karara DFS, representing the electrical distribution of the Stage 2 process plant development. The list encompasses all electrical loads from 0.55kW cooling fans to 5500MW HPGR Variable Speed Drives across all voltages from 110VDC battery chargers to the site’s main 330/33kV incoming supplies.

As previously mentioned, Mechanical Engineers enter data for items requiring electrical power, and hence of relevance to the Electrical Engineers including drive type and load (kW). Once a piece of mechanical equipment has either a Drive Type (DOL, VSD etc) or a load, it then appears on the Electrical Load List waiting to be allocated to a MCC or Switchboard. This enables a ‘live’ and seamless transfer of information.

This live transfer of data permits the review of electrical loads even while MEL and EEL are still in development. This parallel operation is beneficial as the allocation of loads is a time consuming and detailed process requiring careful consideration of a number of factors, including electrical parameters such as load size (kW), voltage, method of starting/drive type (DOL, VSD etc).

The geographical location of electrical loads is also influential as indicated in Figure 2 below. Here supply to the HPGR unit operation is separated due to the significant distance between the Screening and Crushing operations. Regular review of plant layouts is required to capture these design intricacies.
Other client initiated operational concerns relate to redundancy and/or separation of process streams. Addressing these more complex concerns require careful review of engineering documentation such as Process Flow Diagrams (PFD), Piping and Instrumentation Diagrams (P&ID). An example of this is shown in Figure 3 below where the stockpiling conveyor (yellow) is supplied from a different supply to the stock pile reclaim conveyor (pink).
This process separation is required to allow the primary crushing, screening and stockpiling operations to continue even if the downstream processing facility is offline or vice versa.

As an understanding of the distribution of electrical loads is developed, a regular review of the required number of Switchboards and MCC’s allocated to the project is performed. The review requires the addition of boards according to major process groups, in order to prevent highly loaded boards with impractical bus current and transformer capacities.

The load list development is by no means a once through engineering process. As the process plant evolves, the associated documentation is under frequent review. However, throughout the later stages of the design the Process and Mechanical Engineers had finalised their designs. As such the changes were less significant, and the documentation more closely reflects how a finished process plant would appear.

### 3.2.1.1 Background Information for Mechanical Loads

Interaction with the Electrical Load list and indeed EDS in general, is designed to be as intuitive as possible, utilising common database functionality to reduce the quantity of repetitive data entry required by operators as much as possible. An example of this design methodology is the storage of electrical parameters for a range of standard motor sizes within a table in the database background. A lookup function then allows for the population of default values for calculation variables such as motor efficiency and power factor.

As the Karara project specified Teco high efficiency motors almost exclusively, a review of manufacturer’s motor datasheets was performed and the parameters listed above were extracted and formatted in the EDS format. From this point forward, as the MEL was populated with the installed power of motors, the load list automatically updated the motor efficiency and power factor accordingly.

Special installations, such as the MV variable speed drives that supply the ball mills, had a manual data entry override function provided on the load entry screen allowing the specification of known parameters.

A similar process also applies to the drive-type variable selectable by mechanical engineers on the MEL, and by electrical engineers on the EEL. In the interests of consistency and to prevent alternate representations of the same information (For instance, DOL, Direct On-Line or D.O.L.), this selection is locked to a client job-specific range of options. This list was populated with the Karara standard drive options detailed in 3.1.6 providing an additional benefit of ensuring conformance with client standards.
3.2.1.2 Load List Structure and Electrical Parameters

To represent the electrical loads within EDS, a load list report is published. This report details all loads within the mechanical and electrical equipment lists that had either a kW or drive type specified, whether allocated or not.

This list is grouped and sorted sequentially according to the load groups that the equipment is allocated to, subsequently listing all connected loads, an excerpt of which is shown in Figure 4 below, detailing Rougher Magnetic Separator (RMS) feed pumps allocated to the RMS 415V Motor control centre, designated 2304-MC-002.

<table>
<thead>
<tr>
<th>EQUIPMENT NUMBER</th>
<th>DESCRIPTION</th>
<th>DRIVE TYPE</th>
<th>Rating [kW]</th>
<th>Eff. Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2304 PU 108</td>
<td>RMS Feed Pump</td>
<td>VSD</td>
<td>400.00</td>
<td>0.960</td>
</tr>
<tr>
<td>2304 PU 109</td>
<td>RMS Feed Pump</td>
<td>VSD Standby</td>
<td>400.00</td>
<td>0.960</td>
</tr>
</tbody>
</table>

Figure 4 - Load List MCC Allocation
Sorting of the load list in this manner allows for easy line by line review of all connected loads for comparison against process flow diagrams and other documentation.

Also shown on Figure 4, are key electrical parameters including the drive type field (column 5) detailing the drive type or starting methodology, as well as specifying whether a motor is duty or standby. The specification of duty / standby arrangement is important when considering the electrical loading as by default standby motors do not contribute to the electrical consumption unless specific changeover characteristics are known.

Column 6 lists the rating of the load item - this is the installed mechanical (or shaft) power delivered by the equipment in kW. This figure is also commonly referred to as nameplate, the absorbed or shaft power.

The final value shown in column 7 is the motor efficiency, a value typically less than 1 representing the ratio of electrical input power to mechanical output power (or rating). As previously discussed, this figure is extracted from tables within EDS, but originates on manufacturers’ datasheets when available. In the absence of verified values, 0.90 is substituted in accordance with Karara standards.

Continuing immediately right of Figure 4 and shown in Figure 5 below is the ½ (half) hour demand calculation, also commonly referred to as the short term or peak demand. This calculation considers the intended use of the installed equipment making allowances for the fluctuating or intermittent use by virtue of a diversity factor shown in column 8 (Div. Factor) below.

<table>
<thead>
<tr>
<th>DRIVE TYPE</th>
<th>Rating [kW]</th>
<th>Eff. Factor</th>
<th>1/2 hr Maximum Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>VSD</td>
<td>400.00</td>
<td>0.960</td>
<td>0.83</td>
</tr>
<tr>
<td>VSD Standby</td>
<td>400.00</td>
<td>0.960</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Figure 5 - Half Hour Demand Calculation
This diversity, or utilisation factor, is a figure between 0 and 1 specifying the expected load maximum utilisation of the equipment over a half hour period. This figure along with the efficiency factor is used to calculate the true half hour electrical power consumption, or Peak Demand titled Power [kW] in column 9 according to the formula shown in Equation 1 below.

\[
0.5hr \text{ Power (kw)} = \frac{Mech. \text{ Power (kw)}}{Efficiency} \times Utilisation
\]

Equation 1 - Peak Electrical Demand Calculation

Also included under the half hour maximum demand is the power factor in column 10, extracted from within EDS based on manufacturers’ data and used to calculate the Reactive Power [kVAr] and apparent power, or Load [kVA] shown in columns 11 and 12 respectively in accordance with the relatively common power calculations shown in Equation 2 and Equation 3 below.

\[
Apparent \text{ Power (kVA)} = \frac{0.5hr \text{ Power (kw)}}{Power \text{ Factor}}
\]

Equation 2 - Apparent Power Load Calculation (Proteus Engineers, 2012)

\[
Reactive \text{ Power (kVAr)} = \sqrt{Apparent \text{ Power (kVA)}^2 - 0.5hr \text{ Power (kw)}^2}
\]

Equation 3 - Reactive Power Calculation (Proteus Engineers, 2012)

The fundamental role for the 0.5hr maximum demand is for sizing of distribution equipment including transformers, switchboards and associated cabling, to be discussed in further detail in 3.3.3 - for this purpose it is the adjusted apparent power referred.

Also included on the load list calculation, immediately to the right of the Figure 5 is the 24 hour average demand calculation shown across columns 13 to 17 in Figure 6 below.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.80</td>
<td>333.33</td>
<td>0.98</td>
<td>67.69</td>
<td>340.14</td>
<td></td>
</tr>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.98</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6 - 24hr Demand Calculation
Alternatively referred to as the average long term demand, this calculation also uses an additional longer period diversity or utilisation factor to provide an estimate over a 24 hour nominal period. Where the 0.5hr demand serves to calculate the maximum demand that the network will be subject to, the 24hr demand is primarily used to provide a guide to the expected power consumption of the network.

The calculation method for 24hr demand uses the same process as the half hour maximum demand method detailed above, and will not be repeated here.

The final column on the load list calculation is the Emerg/Critical field – a Karara requirement detailed in 3.1.8 that was included for the Definitive Feasibility Study. This serves as a visual guide only, with calculation of Emergency and Critical demand performed separately within EDS.

The final key function of the load list of particular importance to the Karara design is the load group subtotal which appears immediately below the final load item on the load list. Whilst this cannot be shown here for formatting reasons, an example is included in Figure 7 below, or alternatively in the full load list included in Appendix C.

### Figure 7 - Load Group Subtotal

<table>
<thead>
<tr>
<th>Subtotal: 2304-MC-002</th>
<th>0.5hr Maximum Demand</th>
<th>24hr Average Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rating [kW]</td>
<td>Power [kW]</td>
</tr>
<tr>
<td></td>
<td>1600</td>
<td>1383</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1333</td>
</tr>
</tbody>
</table>

The load group subtotals are used to sum the connected load of the load group in question. This is especially useful when confirming the loading on Motor control centres and Switchboards are within their stated capacity, as well as within the capacity of supply transformers.

A final total is also included at the end of the report which serves to sum the connected load of all load items across the process plant.

### 3.3 Distribution Design

Developing an efficient, logical and cost effective electrical reticulation design to suit the process loads was the next step in the DFS process, applying a systematic approach to ensure the design was in accordance with the design parameters. This portion of the work best utilised the technical skills developed over the course of the university studies, specifically the units relating to electrical power engineering.

In the majority of cases there were several different options for supply, each with different advantages and limitations. It was important to remain conscious that the overall project is

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for a feasibility study, rather than a detailed design. With this in mind, the preference was given to designs that were the most flexible, such that the overall electrical design could be adaptable to design changes that could not have been foreseen at this preliminary stage.

3.3.1 Switchroom Locations

Process loads had been carefully allocated to motor control centres according to process and physical requirements. However the physical location for electrical infrastructure required is to be allocated within the processing facility. As previously mentioned, motor control centres and associated drive equipment are required to be installed in dedicated temperature controlled switchrooms in accordance with Karara standards.

The design and allocation of switchrooms within the process plant requires significant deliberation. In general, the preference is to minimise the number required as the price per item is substantial for both the supply and installation. However, the benefit gained from minimal switchrooms is then offset by the expenditure required for the additional cabling, cable ladders and installation labour required to service the electrical loads connected.

With these considerations in mind, isolated motor control centre loads were tentatively accumulated and allocated to switchrooms such as the HPGR loads shown in Figure 8 below, and multiple MCC loads accumulated into common switchrooms as demonstrated by Switchroom 003 servicing the RMS, IMS and HPGR screening loads in Figure 9. As shown, both Switchrooms are segregated into separate buildings - a shipping requirement that will be discussed in further detail in 3.3.6.

This process was continued across the plant - locating switchrooms to service all electrical loads, the result being ten switchrooms located within the process facility shown on the partial site layout in Appendix B. An additional three switchrooms were located outside the process plant perimeter servicing remotely located loads including tailings stacking, train loadout and concentrate filtering facilities.
3.3.2 Transformer and Motor control centre Selection

Prior to finalising the distribution design, consideration had to be given to the specification of electrical infrastructure, specifically the transformers and motor control centres.

To maintain conformance with Karara's equipment standardisation design philosophy, a decision was made to use the same switchboard and transformer specifications as those provided for the Stage 1 project wherever possible.

The Stage 1 distribution transformers installed were standardised to 2MVA for the 33/0.433kV 415V low voltage tertiary supply and either 7.5, 15 or 20MVA for the 33/6.6kV medium voltage tertiary supply.

As the distribution transformers would be directly connected to the motor control centres, it was important to ensure that switchboard bus ratings were within the current ranges these transformers were capable of supplying, both in terms of the full connected load rating and the prospective fault currents permissible.

The full connected load current (FLC) to be carried by the motor control centre was calculated based on utilising the transformer at 100% of its nameplate capacity as shown in Equation 4 below.

$$TF\ Sec.\ FLC = \frac{\text{Transformer Rating (VA)}}{\text{Secondary Voltage (V)} \times \sqrt{3}}$$

The prospective fault current possible for a switchboard installation is a more complex calculation and considers a number of factors, many of which are not known at a definitive feasibility level. However, a comprehensive DlgSILENT model is to be developed for the overall system at a later stage which will satisfy those requirements.

Hence, calculations conducted at this stage were required to be conservative estimations – realistic enough that an error would not significantly impact the ultimate design, but not as comprehensive as those performed later by the modelling software.

With these considerations in mind, the fault calculation performed is the infinite bus method, assuming a limitless supply under fault conditions. Furthermore supply cable impedances were neglected, using only the transformer suppliers’ minimum impedance in the circuit. These conservative assumptions were offset by neglecting the motor contribution to the short circuit current, which under fault conditions acts as a generator capable of supplying between 4 – 6 times its full load current, again neglecting its own supply cables.

The subsequent equation for this method is shown below (Equation 5).

\[
\text{Fault Current} = \frac{TF \text{ Sec. FLC (A)}}{\text{Transf. Impedance} \%}
\]

Equation 5 - Transformer Fault Level Calculation (ABB Switchgear Manual, 2012)

These calculations were performed on the four transformer / motor control centre combinations that were available, the results of which are shown in Table 3 below, the values of relevance being the full load current – secondary and fault current – secondary.

<table>
<thead>
<tr>
<th>Transformer</th>
<th>Voltage</th>
<th>Full Load Current</th>
<th>Fault Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVA</td>
<td>Imped.</td>
<td>Primary</td>
<td>Secondary</td>
</tr>
<tr>
<td>2</td>
<td>kVA</td>
<td>6.5%</td>
<td>33 kV</td>
</tr>
<tr>
<td>7.5</td>
<td>kVA</td>
<td>8.5%</td>
<td>33 kV</td>
</tr>
<tr>
<td>15</td>
<td>kVA</td>
<td>8.5%</td>
<td>33 kV</td>
</tr>
<tr>
<td>20</td>
<td>kVA</td>
<td>8.5%</td>
<td>33 kV</td>
</tr>
</tbody>
</table>

With an idea of the expected full load current and fault current established, confirmation that the motor control centres to be selected will be within specification was required. In accordance with the standardisation principles, a review of the stage 1 installation was again completed, focussing on motor control centres. This review resulted in the preferred supplier being confirmed as Siemens and Plummer's for the 6.6kV and 415V motor control centres respectively.
Review of the datasheets supplied for equipment resulted in the current ratings shown in Table 4 below. Comparing these figures with the transformer current ratings in Table 3 above shows that both bus current and bus fault current ratings are well within the manufacturers’ specification for the preferred equipment.

<table>
<thead>
<tr>
<th>Karara Reference</th>
<th>Manufacturer</th>
<th>Product</th>
<th>Bus Current</th>
<th>Bus Fault Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.6kV MCC</td>
<td>Siemens</td>
<td>SIMOPRIME</td>
<td>3600A</td>
<td>40kA for 3 Seconds</td>
</tr>
<tr>
<td>415V MCC</td>
<td>Plummers</td>
<td>Pi INSULSAFE</td>
<td>3000A</td>
<td>80kA for 3 Seconds</td>
</tr>
</tbody>
</table>

The fact that the client specified equipment is well within the preliminary estimations provides confidence in the current design, providing an assurance that in future, more thorough, power modelling is also likely to come within specification.

3.3.3 Motor control centre Loading

Whilst plant electrical loads had been tentatively allocated to motor control centres, consideration now had to be given to the connected electrical load of these boards, whether high or unnecessarily low.

To ensure conformance with Karara design requirements, 20% spare allocation for switchboards and motor control centres was required. Hence, using the preferred transformer selections mentioned earlier, the revised limit for connected capacity was calculated and is shown as available capacity in Table 5 below.

<table>
<thead>
<tr>
<th>Karara Reference</th>
<th>Connected Transformer</th>
<th>20% Spare Provision</th>
<th>Available Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>415V MCC</td>
<td>2,000 kVA</td>
<td>333 kVA</td>
<td>1,667 kVA</td>
</tr>
<tr>
<td>6.6kV MCC</td>
<td>7,500 kVA</td>
<td>1,250 kVA</td>
<td>6,250 kVA</td>
</tr>
<tr>
<td>6.6kV MCC</td>
<td>15,000 kVA</td>
<td>2,500 kVA</td>
<td>12,500 kVA</td>
</tr>
<tr>
<td>6.6kV MCC</td>
<td>20,000 kVA</td>
<td>3,333 kVA</td>
<td>16,667 kVA</td>
</tr>
</tbody>
</table>

With the ideal switchboard loading now quantified, a review of the load list was performed to rationalise the MCC allocations such that the 0.5hr demand for load groups met the available capacity calculated above.

This process was aided by the switchroom allocations as it allows for the amalgamation of multiple lightly loaded MCC’s, or the addition of new boards to spread the load where required.

This was a time consuming process requiring an iterative approach and several passes of the design to consider viability of different options, including moving entire MCC’s across
switchrooms where necessary. When this development was complete, a milestone issue of the load list was issued. This was a key step in the project, as while it was understood that the design would still evolve further – at that snapshot in time a realistic and comprehensive electrical design was complete and could form basis for pricing by equipment vendors in the form of electrical packages.

3.3.4 Producing the Electrical Equipment List (EEL)

Supporting the other design documentation produced, such as drawings, datasheets, calculations and the like, the electrical equipment list is an EDS deliverable used to track the Electrical Equipment proposed to be installed on the project.

Key parameters included on the equipment list include equipment designations, descriptions, ratings and specifications, as well as drawing and datasheet cross references.

While it is a deliverable that can be filtered and issued when required, its primary use during the DFS design phase was the allocation and tracking of equipment numbers to prevent duplications, as well as providing data for producing Cable Schedules.

3.3.5 Single Line Diagrams

While the Load List provides the basis for the Electrical Distribution of the process plant, electrical drawings are required as they more coherently represent the overall power flow and provide a preferable method for determining HV reticulation.

For this reason, an overall Single Line Diagram was produced and routinely reviewed and updated through the changing iterations of the load list. This allowed the intern and the supervising engineer to develop and modify the 33kV distribution to switchrooms from one A3 drawing covering the whole process facility.

Typically this resulted in a radial distribution from the main 330kV/33kV substation, with some exceptions made for isolated and/or lightly loaded switchrooms such as the Tailings Stacking Switchboard which were subfed from other switchrooms.

The other exception is the switchrooms such as the train load out substation which due to process requirements required a redundant supply. These overall distribution concepts can be seen on the overall single line diagram attached in Appendix G.

More detailed switchboard and MCC drawings were produced for HV and MV distribution as they provided an opportunity to display the technical detail for circuit protection, metering and earthing systems. This detail is necessary even at the preliminary feasibility stage in order to gain accurate pricing information from potential switchgear suppliers.
As the drafting work was performed by others, the engineering role is to provide mark-ups for changes as the site-wide distribution changed, and follow up with an engineering check for consistency with the revised load list, and other documentation including the equipment specifications detailed on datasheets and the electrical equipment list.

### 3.3.6 Switchroom Layouts

Similar to the electrical single line diagrams, switchroom layouts are required so that the physical requirements of the switchgear, variable speed drives and other ancillaries can be estimated. Design of switchrooms is complicated by Karara's preferred method of electrical distribution being via transportable switchrooms – the overall dimensions of which are constrained from both the final site location within the process plant and also transportation regulations.

Considering the switchrooms to be installed are transportable buildings constructed and fitted out in Perth, and shipped to site for permanent installation, these rooms dictate a maximum room length of approximately 30 metres, and a width of approximately 6 metres. Overall room size can be increased by combining sections, however this is generally only done for two sections permitting 60x6m. Rooms longer than two sections require provision for additional emergency exits in the body of the room and can make site installation and functionality cumbersome.

The design of Switchroom layouts was completed by Electrical Designers working on the project with the intern providing feedback on the proposed arrangement.

### 3.3.7 HV Cable Sizing & Scheduling

Due to varying cable specifications, and many insulation and conductor combinations available, procurement of HV cables can be an expensive and time consuming process. Long lead times are often required, especially for the production of specialised or non-standard cables, some of which like chemically treated HDPE are required by Karara specifications as detailed in 3.1.9.

Hence, a preliminary cable schedule was produced to capture expected cost and more importantly, forecast delivery periods for the cabling required for the project. With switchrooms containing process MCC’s and switchboards now located on the process facility and a distribution network established and represented graphically via the overall Single Line Diagram, it was an opportune time to perform this.

#### 3.3.7.1 HV Cable Sizing

In accordance with AS3008, a derating factor was applied to the cabling to reflect the sub-optimal installation conditions, mostly due to the installation method, environment and the
proximity of parallel circuits. These derating methods were calculated and applied to all cables to be sized.

Cabling installed on cable tray were derated by 0.88 as per AS3008 Table 27(1) due to an installed ambient air temperature of 50°C. Contribution of 8 additional parallel circuits did not contribute further, as the Karara installation method for both multi-core and single-core HV cables includes segregation and minimum diameter spacing, equivalent to a derating figure of 1.0 for 8 circuits, as in AS3008 Table 24.

This made the resultant overall derating for both multi-core and single-core cables installed on cable ladder, equivalent to 0.88.

Buried cable installations were subject to more stringent derating. A depth burial of 1.10 metres required by Karara as per installation drawing 1300-EL-DRG-2832 resulted in a derating of 0.95 in accordance with AS3008 Table 28(2).

A ground temperature estimated at 25°C was used, with no effect on the installation from derating of 1.0 due to the XLPE cables have a 90°C conductor rating, refer AS3008 – Table 27 (2).

Likewise, a thermal resistivity rating of 1.20°C.m/W resulted in no derating due to the backfill of resistivity specification installed according to 1300-EL-DRG-2832. The circuit configuration detailed did influence the derating further, with the 0.30m installation spacing between 5 circuits resulting in derating factors of 0.78 and 0.73 for multicore and single core cabling respectively.

The final derating figures were 0.741 and 0.672 for multicore cabling and single core cabling respectively. The final derating figure is shown for buried multicore cables in Figure 10 below.
With derating figures determined for all types of installation, the true current carrying capacity of the cables could be determined by multiplying the calculated figures by the manufacturers’ specified current ratings for the different cable conductor sizes available. However, while this satisfies the normal operating conditions of the cable, additional situations need to be considered, such as the cable’s ability to survive short circuit fault current conditions, and the requirement to meet the client’s minimum volt drop specifications for the length of the cable. Example calculations will be covered in detail.

For the sizing of the 20MVA transformer cables – the full calculation is included in Appendix D.

The minimum cable size for short circuit withstand current is dependent on the fault level at the point of cable connection, and also the operating time of the protective device which dictates the magnitude of let through energy (LTE). Considering the highest transformer fault current was determined to be approximately 20kA as calculated in Table 3, a nominal fault level of 25kA was allowed for, with the true figure to be confirmed by the DIgSILENT model at a later date.

The protective device, in the form of an air circuit breaker was determined to have a maximum operating time of 65ms, resulting in a let through energy or “joule integral” shown in Equation 6 below.
\[ LTE \ (I^2t) = 25,000^2 \times 0.065s = 4.06E^{+7} \]

Equation 6 - Let through Energy Calculation
(Joint Standards Committee, A1-2011)

In accordance with the maximum XLPE temperature rise of 250°C specified in Table 53 of AS3008, the unit-less constant K for copper conductors is equal to 143 for 90°C XLPE (Table 52). Hence, the cross-sectional area of the current carrying component \( S \) is equivalent to 44.6\( mm^2 \) as calculated in below.

\[
S = \frac{I^2t}{K^2} = \frac{4.06E^{+7}}{143^2} = 44.6\ mm^2
\]

Equation 7 - Minimum Cable Size for Short Circuit Withstand
(Joint Standards Committee, A1-2011)

Similar to the process applied for the Motor control centre bus fault calculations, a conservative fault estimate of 25kA has resulted in a relatively small cable size, well within the size required to sustain the operating currents. Therefore, a similar assumption can be made, that even in the event that a greater fault potential is calculated by the DIgSILENT model, the cables are sized to sustain the subsequent increase in let-through energy and hence short circuit withstand.

The final calculation for the HV cabling specification is the maximum volt-drop between source and final connection due to the circuits current and impedance. The upper limit for voltage drop is expressed as a percentage and stated by the client specifications, as well as section 3.6 of Australian Standard AS3000, and is equal to 1% in this case.

To calculate this, the current carrying requirement of the cable, its resistance, impedance, length, supply voltage and load power factor were considered as shown in Equation 8.

\[
\text{Volt Drop (\%)} = \frac{\sqrt{3} \times I \times (R_{\text{cable}} \times PF + X_{\text{cable}} \times sin(cos^{-1}PF)) \times L}{V_L} \times 100
\]

\[
= \frac{\sqrt{3} \times 1750 (0.0198 \times 0.85 + 0.02925 \times sin(cos^{-1}0.85)) \times 0.2}{6600} = 0.0296\%
\]

Equation 8 - Maximum Voltage Drop Calculation
(Joint Standards Committee, A1-2011)

With a maximum voltage drop of 1%, the cable selected for this purpose is more than satisfactory. This was observed for all HV cables that were sized: once the cable met the current carrying capacity requirements, the voltage drop and fault current requirements were also more than satisfied.
3.3.7.2 HV Cable Scheduling

With cables sized, a rationalisation process was performed to minimise the quantity of cables required for procurement to roughly 10 different types. The benefit of this was a simpler procurement process, with no surcharges for not meeting minimum order quantities. In addition, management of cable stocks on site is easier. A sample cable schedule produced in EDS is included in Appendix E.

3.4 Capital Cost Estimation

Following a subsequent review by senior engineers to ensure correct process had been followed, the final stage of the DFS design commenced and involved the electrical design being separated into distinct packages and issued to preferred suppliers for pricing. Considering it is the feasibility of the project that is being considered; an accurate estimation of the expected investment will be a key indicator of Proteus’ performance on the project.

3.4.1 Procurement Packages

With the electrical design complete, issuing of procurement packages for quotation became the sole focus of the internship. Separation of the overall electrical design into distinct packages for quotation was necessary so that prospective equipment suppliers were quoting on the items that they were the preferred supplier for.

In line with Karara requirements, packages were required to be issued with substantial documentation to best translate the requirements of the prospective supplier. Typically this included a cover letter, specifications, scope of works/supply, supplier data requirements list, equipment datasheets and drawings where applicable.

The cover letter was the first point of reference for the tenderer. It introduced the parties involved, including Proteus and Karara, and the nature of their relationship. There was a brief overview of the Karara iron ore project and description of the item to be quoted, as well as a summary of the electrical package’s documentation. Also stated are a brief overview of the technical requirements including a review of the confidentiality agreement and the conditions of quotation and client obligations.

The specifications provided are a corporate document prepared, supplied and owned by Karara, defining the minimum technical requirements for the item or service being supplied. These documents specifically written for the item to be supplied but will typically define the requirements of the design considering factors such as materials, manufacturing tolerances, testing, documentation, packaging and delivery.

The scope of supply, or the scope of works document, identifies and defines the work activities and deliverables required for the supply and/or installation of the package being...
considered. Preparing a clear and coherent scope document is critical due to the varying technical background of those who will be required to read and understand the document, as well as the contractual implications of the document interpretation.

The Supplier data requirements list provided is a matrix document that outlines the contractual obligations for the form and submission timeline for project documentation. Documentation includes, but is not limited to, document, plans test results and drawings, and is adjusted according to the package or equipment to be supplied or installed.

The Equipment Datasheets prepared for the electrical packages are a key technical document in the overall package as they provide a method of communication between the engineering party (Proteus) and the prospective supplier. To achieve this, they are supplied in a native format with blank cells for key equipment parameters.

To provide a comparison and to ensure conformance, project design parameters from the client specifications are also shown where meeting a specification is a requirement of supply. For instance, the transformer datasheet will provide the design parameters for the range of primary and secondary voltages (ie 33kV and 6.6kV +/- 5%), alongside the provision for manufacturers data, as shown on the far right column of Figure 11. This allows the manufacturer to quote their figures which may meet or exceed this range, but allows the reviewer to confirm compliance. A completed datasheet returned from the transformer supplier to Karara is included in Appendix H for reference.

![Figure 11 - Excerpt from Transformer Datasheet](image)

Parameters for which there is little or no client preference, such as transformer dimensions or weight, for the example considered above, are left blank. This allows the value to be recorded and either compared with competing tenders, or if selected, allowed for in the design of the transformer compound and footprint.

As the type of information contained varies from equipment to equipment, datasheets are prepared specifically for the individual equipment items to be supplied; hence multiple datasheets are often required to capture the equipment within the package.

The final items contained within the tender package documentation are electrical design drawings which are also specific to the equipment and/or package being issued. As an item that requires significant preparation and contains substantial intellectual property,
they are usually only provided where they can be of use to the tenderer, providing clarification or better understanding of the design.
4.0 FUTURE WORKS

4.1 Finalising the Capital Cost Estimate

The purpose of the Karara DFS is to produce an estimate of the costs associated with the proposed expansion; hence the fundamental document to be issued to the client is the Capital Cost Estimate. This comprehensive document will capture the supply and installation of all equipment required for the expansion across all disciplines of engineering.

The role of the internship to date has been to work with the Proteus electrical engineering team to calculate costs for the supply and installation of electrical equipment.

To do this, the overall engineering design documentation has been separated into packages that can be issued to vendors who specialise in particular components such as Variable Speed Drives (VSD), Transformers, HV/MV Switchgear or LV MCC and Switchrooms. These packages have been Issued for Quotation (IFQ), and at the time of writing all clarifications have been answered and budget pricing is being received.

Estimation of the installation of electrical infrastructure is following a similar approach but uses rates based quotation method – vendors familiar with performing electrical installations of this magnitude with the scope of work have been approached with documentation detailing activities to be completed.

These vendors have provided an estimate of both time and the hourly rate of the individual performing a multitude of diverse and different tasks, such as cable installation/terminations, cable tray installation or erection of light poles with fittings.

This raw information will eventually be included in in the capital cost estimate as unit “rates”. When Material Takeoffs (MTO) are completed by the designers, the bulk quantities will be applied to each area within the plant electrical installations, the total of these providing an idea of the time and cost required for the installation.

With these steps, remaining installation costs completed, and supplemented with the electrical packages, an accurate estimation of the total electrical cost should be established. This will be compiled with the work performed by other disciplines and the estimate will be finalised for issue to the client in early 2013.
5.0 CONCLUSION

The internship at Proteus and specifically the project role undertaken has provided great engineering experience over the period. The Karara role was unique in that it provided a wealth of engineering experience on a project of significant size and complexity and streamlined within the timeline of the internship period.

To perform the detailed design on a project as large and complex as Karara would be such a significant undertaking, that the engineering resources required would be well outside Proteus' current capabilities from both a project wide and an electrical engineering viewpoint. In addition, the detailed design period for such a project would easily eclipse the 16-week internship period.

However, as the project was at feasibility level only, and heavily utilised existing stage 1 design data, the internship period allowed for the development of a distribution network encompassing an entire process plant, servicing over 1,000 process loads at three voltages. This task was primarily performed by the single graduate engineering intern under the direction of a lead engineer.

The valuable experience considering design options and their implications at a site-wide level would not be typically available to an intern at the beginning of their career, and provided a great opportunity to apply the concepts of power system operation and control established during the later stages of the Power Engineering major.

These higher level distribution concepts were well complimented by design at a process level. Daily interaction selecting and reviewing motors, variable speed drives and soft starters well utilised the background developed in earlier Power Engineering units studying the concepts of electromechanical energy conversion and power electronic converters.

Experience gained was not limited to the Power Engineering discipline. Informal discussions with colleagues about proper utilisation of fieldbuses for plant and MCC control purposes and the interaction between the power system and the process control system, not covered in the detail of the report, fundamentally relied on the experience the intern gained in the Industrial Computer Systems Engineering laboratories under the direction of Associate Professor Graeme Cole.

Other more general skills the intern applied during the internship period were gained, or developed during the tenure at Murdoch. For instance, personal accountability for decisions or actions performed both in a general sense, but also when specifically considering the safety of oneself and others. More than corporate rhetoric, these safety conscious attributes developed through first-hand experience in potentially hazardous
laboratory environments provided necessary context when applying Karara’s safety first methodology.

Finally, the application of effective communication skills, written and oral, both formal and informal developed in part via group projects and presentations at university, proved invaluable when required to work in a team environment, and provided the intern with the confidence to represent Proteus in public speaking roles such as client meetings.

The Engineering Internship now acts to formally finalise the intern’s personal transition from a drafting/designing role to an engineering role. It presents the intern with new and exciting challenges enabling the intern to apply a wealth of knowledge gained from engineering experience gained in an educational and in a workplace environment.
6.0 REFERENCES


Plummers Industries Pty Ltd. (2010, October 1). Pi INSULSAFE Modular System. Modular Switchgear and Control System. Perth, Western Australia, Australia: Plummers Industries Pty Ltd.


APPENDIX A: Industry and Academic Supervisor Proforma
We are satisfied with the progress of this internship project and that the attached report is an accurate reflection of the work undertaken.

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APPENDIX B: Plant Layout– Switchrooms Highlighted
(Omitted)
APPENDIX C: Electrical Load List (12016-CE-501)
(Omitted)
APPENDIX D: 6.6kV Cable from 20MVA Transformer (Omitted)
APPENDIX E: CABLE SCHEDULE
(Ommitted)
APPENDIX F: Electrical Equipment List – TF Filtered (Omitted)
APPENDIX G: Overall Single Line Diagram
(Omitted)
APPENDIX H: Completed Transformer Datasheet
(Omitted)