	Report	**Technology**

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EXECUTIVE SUMMARY

Kriel Power Station utilises Dip Proofing Inverters (DPIs) 54L version 2 which are fitted on 380V Unit Boards A-D. These DPIs activate when their input supply voltage drops to 0.75 V_n; during this moment the capacitor discharges, sustaining the DPI output voltage to keep the contactors for the 220V AC motor control circuits energised thereby keeping the motors in operation. Should a voltage dip last for more than 1 second in a system, the contactors will de-energise, cutting the supply to the motors and therefore affecting plant operation. The currently installed DPI technology proves to have a design deficiency such as sensitivity to harmonics on the input supply which can result in DPI activation and failure to re-synchronise thus interrupting the supply to the low voltage motor contactors. The DPI design deficiency is detailed in 474-11302 – Investigation on Different Technologies for AC Control Supply for Gx Plant report. This project addresses this DPI design deficiency by ensuring that a more reliable technology (control supply UPS) is used instead and will therefore prevent production losses at Kriel Power Station which may be due to DPI malfunctioning.

The project has exempted the concept design phase due to the designs being already completed and implemented on some power stations as a pilot project. Furthermore, the product has been approved for use as an alternative technology to the currently installed DPIs as proven from the pilot projects and as recommended by 474-11302 – Investigation on Different Technologies for AC Control Supply for Gx Plant report. For this reason, the technology selection is no longer required.

This basic design report details the design information for the equipment to be used in replacing the currently installed DPIs. Control supply modular UPSs will be employed; this technology proves to be more reliable with regards to voltage dip immunity for the motor control circuits from the studies performed. The proposed reticulations, equipment ratings, interfaces, equipment layouts and risks have been detailed in this report.

1. INTRODUCTION

The currently installed DPIs on the 380V Unit Boards A-D have an inherent design deficiency which results in the supply voltage to motor contactors being compromised and leads to tripping of motors; consequently, causing a disturbance in plant productivity. These DPI malfunctions have contributed to a large number of Unplanned Capability Loss Factor (UCLF) within the Generation division and will therefore be replaced with control supply UPSs and batteries.

The configuration of the control supply UPS is of modular design with (n+1) configuration on the rectifier and inverter modules; which means that for a three rectifier module system, two modules are operating under normal conditions and one extra module which is on standby for redundancy purposes. This configuration adds an advantage of reducing the probability of having a single point of failure in the system and these modules are hot-swappable. The batteries will provide back-up to the loads in case there are multiple rectifier module failures or power interruptions. The control supply UPS is also equipped with a bypass line which will ensure continuous supply to the motor control circuits during multiple rectifier and inverter module failures; and battery outages. The control supply UPS is an online device i.e. whenever there is voltage interruptions that are within the predefined duration, the output voltage will remain uninterrupted. This eliminates any switching transient when a voltage dip occurs.

Replacement of DPIs with control supply UPSs will require additional space to house the UPS panels and battery cabinets due to the bigger dimensions. Different locations for the UPSs are listed in Appendix A-6. A structural assessment has be carried out. This reports aims at detailing the design information to make the project implementation possible.

1.1 SYSTEM IDENTIFICATION

The system covered by the project is the DPIs on the 380V Unit Boards A-D listed in Appendix A-6.

- Identification/codification number of the system – 0*CA, 0*CB, 0*CC, 0*CD where * indicates a unit.
- System name – Unit * 380V Unit Board A-D Dip Proofing Inverters (for 380V boards listed in Appendix A-6) where * indicates a unit.
- Official abbreviation of the system name – DPI.
- Version number of the system – 54L version 2.0.

1.2 SYSTEM OVERVIEW

The project covers Kriel’s critical 380V Unit Boards A-D listed in Appendix A-6. The control supply UPSs will replace the currently installed DPIs and will provide reliable supply to motor control circuits. The UPSs will ensure the supply voltage to the circuits is sustained during normal conditions and when there are voltage dips in the system. The control supply UPSs will interface with the 380V Unit Boards A-D listed in Appendix A-6; the 3 phase supply to the UPS will be from each respective board’s busbars and the UPS output will supply the motor control circuits of that respective board.

2. SUPPORTING CLAUSES

2.1 SCOPE

The scope for the project includes decommission, removal of the installed DPIs and power cables to dedicated area, as per site requirements. Design, manufacturing, FAT, supply, install, SAT, commissioning and handover to site of the control supply UPS system to be installed on the 380V Unit Boards A-D at Kriel Power Station. Furthermore, structural integrity and UPS space allocation, control and instrumentation assessment and requirements have been conducted and addressed; this is covered by this report. As per the ROC and SRD, the system covered by this project are the 380V Unit Boards A-D DPIs which are to be replaced by control supply UPSs. Other areas of the plant are excluded from this project.

This document provides an overview of the engineering processes followed and the system design overview and design outcome at the end of the basic phase. This document includes the results of technical assessments to determine the ability of the design to meet technical requirements, technical risks and lessons learned during the design process. It also describes any outstanding issues from this design phase and provides references to the design output documentation.

2.1.1 Purpose

This document summarises the status and outcome of the basic design phase related activities and describes the achievement of the design goals in terms of meeting the stakeholder requirements. This document, together with the applicable design output documentation of this design phase, will be submitted to a project design review team for technical assessment.

2.1.2 Applicability

The document applies to all Kriel Power Station affected personnel and to all affected disciplines at CoE.

2.2 NORMATIVE / INFORMATIVE REFERENCES

2.2.1 Normative

[1] EEP1054-2 - Engineering Change Root Cause Analysis for DPI Replacement Project Report
[2] EEP1054-1 - Required Operational Capability for Dip Proof Inverter Deficiencies Report
[3] 377-KRL-AABB-D00139-74 Kriel Replacement of DPIs with UPS EMAP (Rev 1)
[4] 474-11302 – Investigation on Different Technologies for AC Control Supply for Gx Plant (Rev 1)
[5] 240-53113685 - Design Review Procedure
[6] 377-KRL-AABB-D00139-75 Kriel DPI Replacement with UPS Project SRD (Rev 1)
[7] 240-53114248 –Thyristor and switch mode charger converter inverter power supply standard
[8] 240-56360086 - Stationary Vented Nickel Cadmium Batteries Standard
[9] 240-137465740 - Standby Battery Storage and Commissioning in Engineering
[10] 240-56364545 - Structural Design and Engineering Standard
[11] 240-56356396 – Earthing and Lightning Protection Standard

2.2.2 Informative

[12] 474-11302 - Investigation on Different Technologies for AC Control Supply for Gx Plant

[13] 240-87040162 – Testing of Hydrogen Emission of Vantex Type Ni-Cad Batteries Installed in Battery Cabinets

[14] Drawing No. 0.45/5322

[15] Drawing No. 0.45/2028

[16] Drawing No. 0.45/1487

[17] Drawing No. 0.45/814

[18] Drawing No. 0.45/1485

[19] Drawing No. 0.45/4979

2.3 DEFINITIONS

2.3.1 Classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.3.2 Malfunction

The termination of the ability of an equipment to carry out intended functions or the execution of unintended functions by the equipment.

2.3.3 System

An integrated set of constituent pieces that are combined in an operational or support environment to accomplish a defined objective. These pieces include people, hardware, software, firmware, information, procedures, facilities, services and other support facets.

2.3.4 Voltage dip

A sudden reduction of the voltage at a particular point of an electricity supply system below a specified dip threshold followed by its recovery after a brief interval.

NOTE 1: Typically, a dip is associated with the occurrence and termination of a short circuit or other extreme current increase on the system or installations connected to it.

NOTE 2: A voltage dip is a two-dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

2.4 ABBREVIATIONS

Abbreviation	Description
AC	Alternative Current
Ah	Amp Hour
AHU	Air Handling Unit
AKZ	Anlagenkennzeichnungssystem

Abbreviation	Description
C&I	Control and Instrumentation
CoE	Centre of Excellent
CS	Control Supply
CW	Cooling Water
DC	Direct Current
DPI	Dip Proofing Inverter
ECM	Engineering Change Management
EMAP	Engineering Management Plan
ENC	Eskom National Contract
EWR	Engineering Work Request
FAT	Factory Acceptance Testing
FTA	Field Termination Assembly
HMI	Human Machine Interface
HVAC	Heating Ventilation Air Conditioning
I/O	Input/ Output Module
LP	Low Pressure
LV	Low Voltage
MV	Medium Voltage
NEC 3	New Engineering Contract
NiCd	Nickel Cadmium
PCM	Process Control Manual
PVC	Polyvinyl Chloride
ROC	Required Operational Capability
SANS	South African National Standard
SAT	Site Acceptance Testing
SRD	Stakeholders Requirements Definition
SWA	Steel Wire Armoured
UCLF	Unplanned Capability Loss Factor
UPS	Uninterruptible Power Supply
V	Voltage
Vn	Nominal Voltage

3. BASIC DESIGN INFORMATION

The basic design phase covers the details of the interface design for the new control supply UPSs to be installed, replacing the existing DPIs. The replacement of DPIs will be done on the 380V Unit Boards A-D listed in Appendix A-6. The basic design outcome will be used as input to technical specification for the project. The details of the basic design for the control supply UPSs with batteries and cabling are included in the following sections.

3.1 KEY DESIGN ASSUMPTIONS

- The UPS system to be installed should exceed the reliability of the existing DPI technology.
- The UPS recorder will have as a minimum, voltage and current recording capabilities.
- Provision should be made to alarm all critical alarms to the EOD.
- Existing DPI circuits on the 380V Unit Boards A-D will be modified and re-used as far as possible for the control supply UPSs.
- New cabling to be supplied for UPS alarms from the UPS to the EOD.

3.2 DESIGN APPROACH

3.2.1 Design Inputs

The design inputs of the project are as follows:

- Control supply UPSs shall sustain the control supply voltage to motor control circuits under normal operating conditions and under voltage dip conditions for 1 second when the voltage drop to 0.75 Vn. This has been proven to be successful from the pilot projects conducted on various power stations. 474-11302 – Investigation on Different Technologies for AC Control Supply for Gx Plant report details the findings and the recommendations with regards to the control supply UPSs to be installed.
- The UPS shall interface with the 380V boards with regards to the rectifier power supply circuits and UPS output termination to the 380V boards.
- The UPSs will be replaced with the same rating as that of the installed DPIs. The UPS ratings to be used on each board are listed in Appendix A-6.
- Cabling for power supply to the UPS and batteries; and from UPS to the board shall be catered for.

3.2.2 Design Process

The design process followed for the project is the ECM process with the exemption granted to exempt the concept design phase due to the technology to be used being known and have already been piloted on other power stations. The ECM process overview is shown in Figure 1; further details can be obtained from Engineering Change Management Procedure 240-53114002.

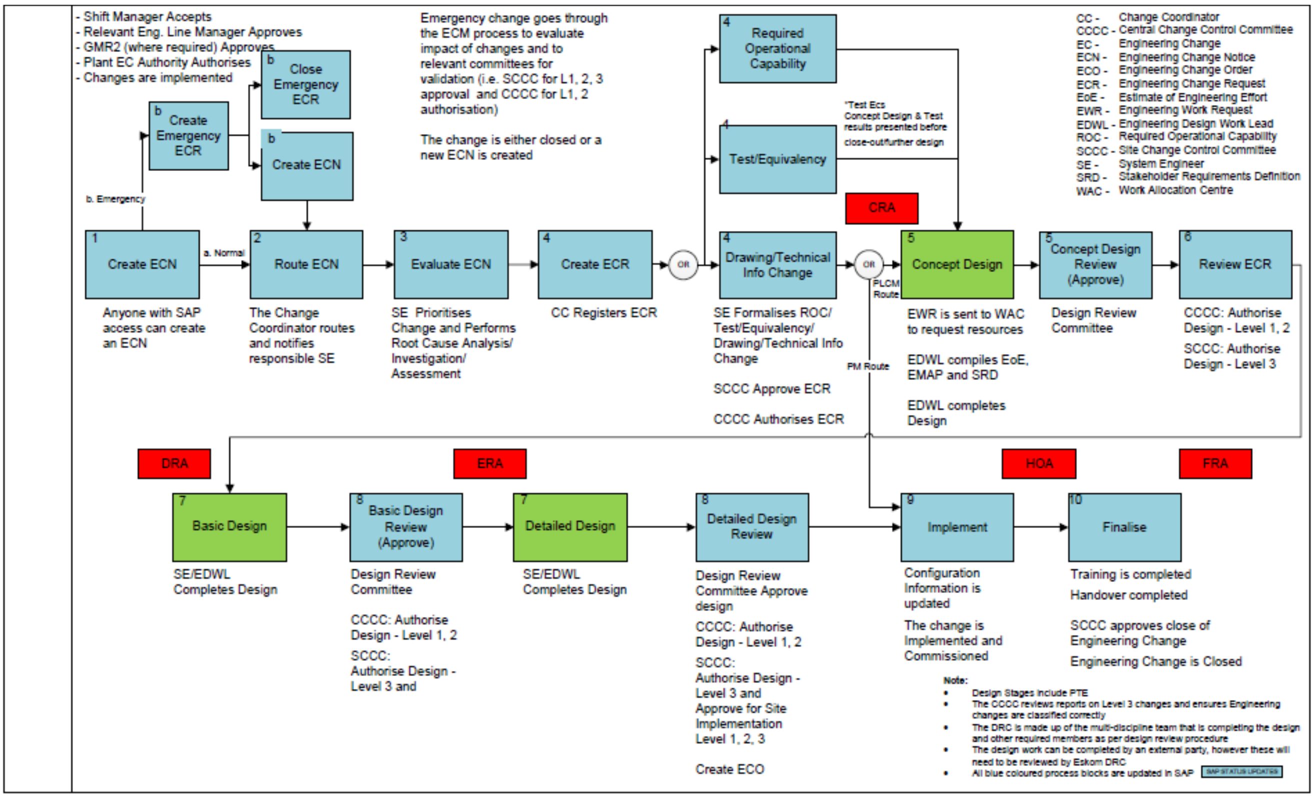

Figure 1: ECM Process overview

The following documents have been submitted as per the ECM process requirements:

- ROC received and approved.
- EWR received and approved.
- EMAP developed and approved.
- SRD developed and approved.
- SRD end of phase design review developed and approved.
- Risk Assessment has been conducted.
- Concept Design Exemption letter has been compiled and approved.

3.2.3 Design Verification

Electrical basic design reviews have been conducted in a form of a formal end of phase internal design review with all electrical relevant stakeholders to ensure the proposed engineering solutions are technically sound, complete and in line with applicable standards. Furthermore a multidisciplinary review will be conducted at the end of the basic design phase and outcomes will be detailed in the 377-KRL-AABB-D00138-40 Kriel DPI Replacement with UPS Project End of Phase Design Review Report.

The equipment to be used has been type tested as witnessed from the pilot projects conducted from other power stations. The pilot project conducted at Matla Power station also proved the operation and reliability of the units on both FAT, SAT and operational pilot stages. The required tests (FATs and SATs) to be conducted during this project execution phase which will be performed.

3.2.4 Design Criteria

For the interface design, the control supply UPS basic design will be analysed with respect to the following site specifications:

- MCB and fuse grading of the UPS system.
- Providing a secure supply to UPS subcomponents.
- Implementation of the under voltage philosophy.
- UPS functional design redundancy and reliability.
- UPS measuring and recording capability.
- Supply feed from 380V Unit Board to UPS.
- UPS rating capability to supply the required control output current.
- UPS to have a self-supervision monitoring capability.

3.2.5 Codes and Standards

- South African Grid Code – Network Code
- SANS 10142-1 - The wiring of premises Part 1: Low-voltage installations
- 240-56227443 - Requirements for Control and Power Cables for Power stations Standard
- 240-56360086 – Stationary Vented Nickel Cadmium Batteries Standard
- 240-137465740 - Standby Battery Storage and Commissioning in Engineering
- 240-53114248 - Thyristor and Switch Mode Chargers, AC/DC to DC/AC Converters and Inverter/Uninterruptible Power Supplies Standard
- 240-56356396 – Earthing and Lightning Protection Standard
- 240-56364545 - Structural Design and Engineering Standard
- 240-83539994 - Eskom NDT Personnel Approval (NPA) for Quality Related Special Processes on Eskom Plant Standard
- 240-83540088 - Requirements for Non-Destructive Testing (NDT) on Eskom Plant Standard
- SANS 10162-1: The structural use of steel Part 1: Limit-states design of hot- rolled steelwork
- SANS 10160-1: Basis of structural design and actions for buildings and industrial structures Part 1- Basis of structural design
- SANS 10100-1: The structural use of concrete Part 1: Design

3.3 KEY DESIGN DRIVERS

The key design drivers of the project were technical constraints i.e. risks involved with the currently installed DPIs which impact on production and hence cost.

3.4 PROCUREMENT STRATEGY

3.4.1 Packaging of Contracts

The project includes different scopes to be executed by different stakeholders. The proposed scope packaging is as indicated in Table 1.

Table 1: Proposed scope packages

Item	Scope	Scope Description	Proposed Stakeholder
Electrical			
1	Control Supply UPSs	Decommissioning, design, manufacture, FAT, supply, install, SAT, commission and handover	National Contract
2	Power Cabling	Decommission, design, supply, install, test, commission and handover	Cabling Contractor
3	Batteries and battery cabinets	Design, manufacture, FAT, supply, install, SAT, commission and handover	Battery Contractor
4	Power Supply	Provision and decommissioning of circuits	Employer
		Supply of components and modification of circuits	Awarded Contractor
5	Electrical Bonding	Electrical bonding of UPS and cabinet enclosures	Cabling Contractor
6	SCADA Modification	Modify the RTUs and EOD SCADA with the new alarms	SAS Contractor
Civil and Structural			
7	Structural Design	Structural assessment with modifications	Civil Contractor

3.4.2 Type of Contract

NEC3 contract is proposed to be used.

3.4.3 Selection Supplier Strategy

The procurement process will be followed which will issue an open tender for the scope not covered in the existing UPS National Contract. The Battery National Contract will not be utilised for this project as there is a design deficiency identified with the Vantex NiCd batteries used, as advised by PEI. This will instead be included as part of the open tender scope.

The open tender scope will be awarded to a contractor specialising in the major scope of the project (and meeting the criteria as set out in the tender evaluation strategy to be developed) which will then appoint the specialised services out of his expertise.

3.5 SYSTEM DESCRIPTION

3.5.1 Electrical Power Reticulation Philosophy

The power reticulation philosophy is depicted in Figure 2. Control supply UPSs will be employed in the 380V Unit Boards A-D listed in Appendix A-6. These UPSs will get supply from the 3 phases of each respective board's busbars. The bypass line will be from the same board as seen in Figure 2. The mains recorder monitors all three phases of the 380V Unit Board and maintain 2 out of 3 phases for under-voltage to determine a real under-voltage and will interrupt the output in the event of 2 phases experiencing a voltage dip for more than 1 second. This is required as the aim is not to interrupt the supply in the event of a single phase loss to the recorder. Resetting of the under-voltage condition will also be a two versus three condition, whereby two phases need to be above the detection set value (i.e. 75% of Vn).

The single phase output of the UPS will feed the auxiliary busbar of each respective board which is used for motor control circuits. The UPS output will interface with the existing DPI output terminals supplying the auxiliary busbar. The UPS modular (n+1) configuration on the rectifier and inverter presents a level of redundancy in the system. Furthermore the system is also fitted with a bypass line and batteries to provide back up.

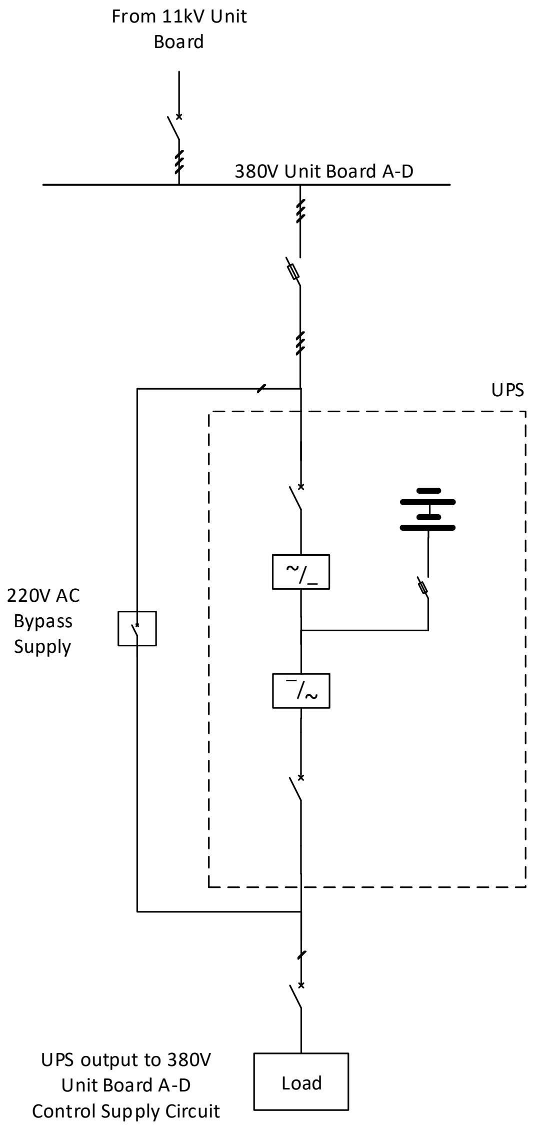

Figure 2: UPS configuration 380V Unit Board A-D

3.5.2 Major Electrical Systems and equipment

The major electrical systems in this project are the UPSs which consist of rectifiers, inverters, batteries. Furthermore, cabling and SCADA (SAS) modification forms part of the major systems with the former summarised as input and output supply cables.

3.5.3 Internal Electrical Interfaces

The interface that the project has with electrical systems is the 380V Unit Boards A-D, control supply UPSs with batteries and cabling. Each board supplies the control supply UPS with 3 phase supply which the UPS also uses to monitor the voltage dip via the mains recorder. The output of the UPS will be terminated on each respective board where the existing DPI output is terminated.

Alarm interface assessment and scope of work was conducted and compiled, respectively to satisfy the requirements. Alarm Interface to the EOD - The UPSs alarms will be monitored at the EOD via the SCADA. The scope of the interface is illustrated in Section 3.11.4.4.

3.5.4 External Interfaces

The installation will be done in the unit LV rooms. In order to perform the installation a civil survey was performed by the respective CoE. Floor loading calculations were performed by CoE and recommendations for the installation of the respective UPS units were made. Alarm interface assessment and scope of work was conducted and compiled, respectively to satisfy the requirements. Multidisciplinary interface requirements are summarised in the following scope of work.

- **Civil and Structural**

  Structural integrity assessment on each affected rooms.

- **Configuration Management**

  AKZ codification for the new system.

3.5.5 Facilities Required

Electrical equipment (i.e. control supply UPSs and batteries) to be used will be housed in the substations listed in Appendix A-6. The UPSs will be remotely monitored and details are as per Section 3.11.4.4.

3.5.6 Maintenance Concept

The UPSs have a modular design, which implies that modules are hot-swappable; allowing the system to be maintained with ease while the UPS is in operation. A bypass line and battery banks are also fitted in the control supply UPSs, making the risk involved with online maintenance to be minimised. The UPS modular design also makes the spares holding easily maintained as one spare module will be standard throughout the installed control supply UPSs.

Planned maintenance of the system will be aligned with the existing switchgear maintenance strategy to ensure that the UPSs are maintained when the 380V Unit Boards are on outage.

3.5.7 Operational Concept

The normal and abnormal operating conditions for the control supply UPSs are as detailed in 474-11302 Investigation on Different Technologies for AC Control Supply for Gx Plant report, Section 6.3. The new control supply UPSs will maintain the current Kriel protection philosophy for sustaining the voltage supply to the contactors for 1 second during voltage dip conditions (0.75Vn).

3.5.8 Safety Concept

UPS design and installation shall be in accordance with all applicable safety standards.

3.6 SITING

3.6.1 Site Selection

The system is located in Kriel Power Station's MV/LV Switchgear Substation of each respective unit.

3.6.2 Site Characteristics

No site characteristics may have an influence on the design and operation of the plant. Temperature conditions will be controlled using the HVAC system.

Kriel Power Station has the following ambient conditions:

Table 2: Ambient Site Conditions

Ambient Condition	Minimum	Average	Maximum
Pressure	80kPa	85kPa	90kPa
Temperature	-10 ºC	35 ºC	40 ºC
Relative Humidity	20%	60%	80%

3.6.3 Site Layout

Appendix A-7 indicates the proposed site layouts for each affected switchgear room. Equipment layout drawings were updated to indicate the position of the new control supply UPS panels and battery cabinets.

3.7 BUILDING OR FACILITY LAYOUT DESIGN

No layout design will be performed within the structural scope of this project. The layout of all additional equipment will be provided by the relevant engineering discipline.

3.8 CIVIL INFRASTRUCTURE AND BUILDING DESIGN

Civil and Structural scope of work includes carrying out structural assessments to evaluate the adequacy of the existing structures to support the additional load that will be added onto the existing structures. The rooms that will be affected by this project are LV switchgear room unit 1 to 6. Civil infrastructures affected by this project are the supporting concrete floor slab, steel I-beams and columns on which the DPI equipment rests.

The information provided below assesses the building for the impacts resulting from the installation of the new UPS system. The layout drawing Appendix A-7 was divided into three areas which were based on the position of the UPS units and Battery banks. The civil analysis entailed assessing the structural resistance of the concrete floor slab.

The concrete floor slab was assessed for bending. The thickness of the floor slab, for the LV equipment room, was 150mm with a compressive strength of 21MPa. QC trays were installed at the soffit of the floor slab. A 50mm thick screed was provided on the surface of the floor slab. The battery banks and

UPS weights were taken as 670 kg and 600kg respectively. The LV equipment room floor slab is supported by steel I-beams which are evenly spaced.

The total dead load applied to the floor slab was calculated to be 4.75 kN/m^2. This includes loading from the self-weight of the floor slab and the screed. The live load exerted onto the floor slab included loading from the battery banks and UPS units. An additional live load of 3 kN/m^2 was applied onto the floor slab to account for the movement of workers and equipment. The analysis did not take into consideration the QC decking.

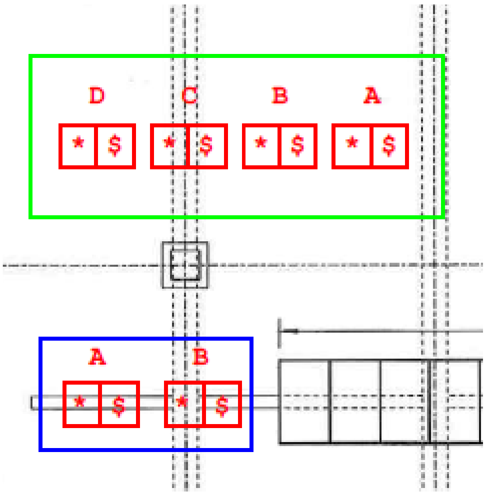

Figure 3: Placement of UPSs and battery banks

The Figure above depicts the placement of four battery banks and UPS units (green block) between Grid lines 6-8. The structural analysis begins by assessing the structural strength for the floor slab of the LV equipment room. Based on the orientation of the QC trays, the slab was classified as one-way spanning in the short direction.

From drawings it can be seen that the maximum applied load which can be applied to the floor is 8 KN/m^2.Taking into consideration that the units will be placed next to each other the worst case applied live load amounts to 11,2 KN/m^2. Thus, the concrete slab cannot resist the bending caused by the battery banks and UPS units.

It is recommended that a detailed assessment be carried out of the floor taking into consideration the QC decking and different arrangements of placement of the battery banks and UPS units. This will help validate the structural integrity of the slab and supporting structures.

3.9 MECHANICAL DESIGN

Not Applicable.

3.10 PIPING DESIGN

Not Applicable.

3.11 ELECTRICAL DESIGN

3.11.1 Design Philosophies

Control supply UPSs will get three phase supply from each respective board and their output is fed to the board’s motor control circuits via the auxiliary busbar. The main objective is to continuously supply the control circuits with single phase supply during normal and voltage dip conditions to keep the motor contactors energised, thereby preventing any interruptions in production. The current Kriel protection philosophy will be maintained.

3.11.2 Power System Studies

Not Applicable.

3.11.3 Sizing of Major Electrical Equipment

The ratings of the control supply UPSs will be the same as the existing DPI ratings which is 5.75kVA. The control supply UPSs will be kept standard at 5.75kVA. Batteries to be used are of NiCad recombination technology.

3.11.4 Basic Design Proposal

3.11.4.1 Control supply UPS overview

The system to be used is configured as depicted by the single line diagram shown in Figure 2. Three phase low voltage supply from each respective board will supply the rectifier modules which converts AC supply to DC supply for charging the batteries while supplying the inverter. The inverter inverts the DC supply to AC supply for supplying the control supply to the 380V Unit Boards. The system is further fitted with a bypass supply which is tapped off from a single phase of the mains AC supply. The bypass supply comes into play during multiple inverter, rectifier and battery outages.

3.11.4.2 Control supply UPS interface with the 380V Unit Boards

The system interface to the 380V Unit Boards is as depicted in Figure 2. The switchgear schedules of each affected 380 V board have been updated to depict the supply to the UPS as per Appendix A-4. The existing DPIs are rated 5.75kVA and the same rating will be applied to the UPSs. Three phase supply to each respective control supply UPS are listed in Table 3. The supply to the bypass line will be tapped off from the main supply. The output from the UPS will also be terminated on the circuits listed in Table 3, which require interface with the control busbar of the 380 V board to be incorporated.

The allocated 380V Unit Boards circuits will be fitted with three phase fuse switch (for rectifier supply). The three phase fuse switch will be supplied from the board’s three phase busbars and the functional unit will require modification as per Kriels standard schematic for a feeder circuit such that the fuse switch is enclosed within the functional unit i.e. the fuse switch shall not be accessible from outside of the functional unit. The output from the UPSs will be terminated on the existing DPI terminals interfacing with the auxiliary busbar.

Table 3: Control Supply feeder circuits

Item	LV Board	380V Unit Board AKZ	380V Unit Board Tier	380V Unit Board Circuit	UPS rating to be used (kVA)
1	Unit 1 380V Unit Board A	+ 05 - 01CA	08	B004	5.75
2	Unit 1 380V Unit Board B	+ 05 - 01CB	10	B004	5.75
3	Unit 1 380V Unit Board C	+ 05 - 01CC	09	B006	5.75
4	Unit 1 380V Unit Board D	+ 05 - 01CD	08	B006	5.75
5	Unit 2 380V Unit Board A	+ 05 - 02CA	08	B004	5.75
6	Unit 2 380V Unit Board B	+ 05 - 02CB	10	B004	5.75
7	Unit 2 380V Unit Board C	+ 05 - 02CC	09	B006	5.75
8	Unit 2 380V Unit Board D	+ 05 - 02CD	08	B006	5.75
9	Unit 3 380V Unit Board A	+ 05 - 03CA	08	B004	5.75
10	Unit 3 380V Unit Board B	+ 05 - 03CB	10	B004	5.75
11	Unit 3 380V Unit Board C	+ 05 - 03CC	09	B006	5.75
12	Unit 3 380V Unit Board D	+ 05 - 03CD	08	B006	5.75
13	Unit 4 380V Unit Board A	+ 05 - 04CA	08	B004	5.75
14	Unit 4 380V Unit Board B	+ 05 - 04CB	10	B004	5.75
15	Unit 4 380V Unit Board C	+ 05 - 04CC	09	B006	5.75
16	Unit 4 380V Unit Board D	+ 05 - 04CD	08	B006	5.75
17	Unit 5 380V Unit Board A	+ 05 - 05CA	08	B004	5.75
18	Unit 5 380V Unit Board B	+ 05 - 05CB	10	B004	5.75
19	Unit 5 380V Unit Board C	+ 05 - 05CC	09	B006	5.75
20	Unit 5 380V Unit Board D	+ 05 - 05CD	08	B006	5.75
21	Unit 6 380V Unit Board A	+ 05 - 06CA	08	B004	5.75
22	Unit 6 380V Unit Board B	+ 05 - 06CB	10	B004	5.75
23	Unit 6 380V Unit Board C	+ 05 - 06CC	09	B006	5.75
24	Unit 6 380V Unit Board D	+ 05 - 06CD	08	B006	5.75

3.11.4.3 Cabling

3.11.4.3.1 Power Cabling

- The existing cabling used for the existing DPIs (to be replaced with control supply UPSs) will be decommissioned. The circuits are listed in Table 3.
- New PVC insulated, SWA, stranded copper conductor cable from the 380V Unit Board allocated circuit (Table 3) to the UPS will be installed.
- The output cable from the UPS will make use of PVC, SWA cables since the UPS output is 230V AC. The cables will be terminated in the allocated circuits listed in Table 3 supplying the auxiliary busbars of each respective board. The terminal points for auxiliary busbar supplies are the same points as the currently installed DPIs.
- All cabling and routing to be in accordance with 240-56227443 - Requirements for Control and Power Cables for Power stations Standard.

3.11.4.3.2 Control Cabling

- The existing alarm cables are of the UVG type consisting of eight cores and an estimated cable length of 50m, 65m, 75m, 80m for 380V Unit Boards A, B, C, D respectively. These cables will be assessed for reusability.
- If the existing cables cannot be reused then new cables are to be installed and terminated from the UPS to the RTU.
- All cabling and routing to be in accordance with 240-56227443 - Requirements for Control and Power Cables for Power stations Standard.

3.11.4.4 Alarms

The existing DPIs have four alarms going to the EOD via the SCADA. The new UPS controller has nine alarm relays (N/O & N/C dry contacts) within the controller that can be configured by software. The common alarm description for the UPSs have nine alarms and three spare alarms. Alarms that are redundant will be grouped as seen in Table 4.

Table 4: UPS Alarm grouping methodology (alarms to be monitored remotely)

Item	New Control Supply UPS Alarm Description (as per National Contract schematics)	Description for new UPS remote alarm
1	Mains Alarm	Mains Failure
2	Charger Fail	Rectifier Failure
3	Charger Abnormal	Charger Facility Abnormal
4	Inverter minor Inverter major	Inverter Output Failure
5	DC system fail	DC System Failure
6	DC system abnormal	DC System Abnormal
7	Phase fail/under voltage fail System major alarm	System fault

From Table 4, it shows that seven alarms are required. Together with the existing four alarms going to the EOD, an additional three alarms are to be catered for at the EOD.

3.11.4.5 EOD SCADA

The DPIs form part of the electrical reticulation hence its monitoring (alarms and indications) interfaces with the EOD SCADA and not the DCS. The same philosophy will be maintained for the UPS alarms where alarms will be sent from the UPSs to the EOD SCADA via the RTUs.

These RTUs and SCADA will be modified to include the alarms listed in Table 4.

3.11.4.6 Electrical Bonding

The existing earthing and interfaces to the earth mat and earth tails will be maintained. New earthing will be installed for new equipment and will be bonded to the station earth mat.

Earthing will be done in accordance to the Eskom standard 240-56356396 Earthing and Lightning Protection.

3.11.4.7 Batteries and Battery Cabinets

The batteries to be employed in this project are semi-sealed Nickel Cadmium with recombination technology, which does not release significant amount of hydrogen gas on different stages of charging i.e. float charge, boost charge and equalise charge. A study/test was conducted to prove the adequacy of the battery cabinet ventilation and to determine the hydrogen release from this battery technology. Eskom report (240-87040162 – Testing of Hydrogen Emission of Vantex Type Ni-Cad Batteries Installed in Battery Cabinets) details the findings and the conclusions. This therefore implies that no hydrogen ventilation is required on these affected areas. Furthermore, the UPSs have a feature that monitors the DC bus overvoltage to ensure that the battery charging voltage is within the safe limits.

The design of the NiCad batteries and battery cabinets are to be in accordance with the Eskom Standard 240-56360086 - Stationary Vented Nickel Cadmium Batteries Standard.

3.11.5 Layout Plans of Major Equipment

Equipment layouts are as detailed in Appendix A-7 where the proposed positioning and spacing of the equipment is highlighted.

3.12 CONTROL AND INSTRUMENTATION DESIGN

The existing Siemens T3000 unit control system was proposed to be utilised to achieve all functionality required to interface to the UPS for alarm display in the unit control room and archiving of the alarm for investigation purposes.

However, the electrical design has indicated that there will be no requirement to interface the UPS to the control system.

3.12.1 Control System Architecture

There will be no scope with regards to the control system architecture as there will be no interface between the Siemens T3000 control system and the UPS.

3.12.2 Power Supply Distribution

There will be no power supply requirements.

3.12.3 Field Equipment

There will be no scope for the field design.

3.12.4 Plant Layout

There is no scope related to existing or new plant layouts.

3.12.5 C&I Assumptions & Risks

There are no C&I assumptions & risks at this phase.

3.13 PRIMARY PLANT DESIGN

Refer to section 3.11.

3.14 SECONDARY PLANT DESIGN

Not Applicable.

3.15 LINES DESIGN

Not Applicable.

3.16 UTILITIES REQUIRED

Not Applicable.

3.17 WASTE MANAGEMENT

3.17.1 Water Purification

Not Applicable.

3.17.2 Waste Storage and Transportation

Not Applicable.

3.18 MAINTENANCE REQUIREMENTS

The UPSs have a modular design, which implies that modules are hot-swappable; allowing the system to be maintained with ease while the UPS is in operation. A bypass line and battery banks are also fitted in the control supply UPSs, making the risk involved with online maintenance to be minimised. The UPS modular design also makes the spares holding easily maintained as one spare module will be standard throughout the installed control supply UPSs.

Planned maintenance of the system will be aligned with the existing switchgear maintenance strategy to ensure that the UPSs are maintained when the 380V Unit Boards are on outage. However, the maintenance strategy for the UPSs will be included in the existing Maintenance Execution Strategy for Protection Plant, replacing the DPI maintenance strategy where applicable.

3.19 DESIGN ASSESMENT

3.19.1 Operability Assessment

All alarms and alarm response procedures shall be documented and/or updated and made available to Operating department at Kriel power station. All training requirements shall be included in the design package.

3.19.2 Reliability, Maintainability, Availability Assessment

The new control supply UPSs will ensure improved plant reliability. The system availability is also improved as the UPSs are of modular design with (n+1) configuration which also makes it maintainable as the modules are hot-swappable.

3.19.3 Procurability Assessment

The equipment to be used will be procured through the existing national contracts in place for control supply UPSs and batteries.

3.19.4 Constructability Assessment

Modular design, manufacturing and assembly techniques have been and/or will be applied to optimally reduce overall system cost, risk and project schedule. The project execution is to be done with the plant off and isolated; which can be aligned to philosophy outages where necessary.

3.19.5 Inspectability and Testability Assessment

The equipment to be used is designed and configured in such a way that there is redundancy built-in in the system. The rectifier and inverter are of modular type with (n+1) configuration which allows for redundancy and are hot-swappable. This implies that there is provision to replace modules online while trouble shooting the defected one. Furthermore, the bypass line is available for providing supply in case there is multiple rectifier, inverter modules and battery outages.

The system is also easily inspectable online as the front of the UPS panels can be opened without affecting the UPS components; there are indications on the components that allow one to identify any abnormalities without tempering with the system.

3.19.6 Sustainability Assessment

The configuration and design changes will be implemented following the design change procedures to maintain sustainability design objectives.

3.19.7 Expandability Assessment

The existing system is being replaced with the control supply UPS technology of the same rating as the currently installed DPIs. This caters for future expansions which have already been catered for in the 380V Unit Boards' spare circuits. New 380V Boards that need motor control circuit supplies will be procured with control supply UPSs depending on the criticality of the board.

3.19.8 Life-Cycle Cost Assessment

The life-cycle cost for the project is as described in Table 8. Cost comparison of the currently installed DPIs and the control supply UPSs have already been conducted and highlighted in 474-11302 Investigation on Different Technologies for AC Control Supply for Gx Plant report.

Table 5: Control supply UPS life-cycle cost

Item	Cost Description	Cost	Interval
1	Capital Cost	R23.2M	Once off
2	Major component replacement (UPSs)	R286k	10 yearly
3	Battery component replacement	R5.67M	17 yearly
4	Maintenance Cost	R245k	Yearly

3.20 SAFETY ASSESSMENT

3.20.1 Industrial Safety Assessment

The anticipated hazard associated with the project is hydrogen emission and electrolyte from the batteries to be used which is nickel cadmium type with recombination units. The batteries will be located in non-hazardous areas i.e. in the substations. The amount of hydrogen emitted from these types of batteries does not amount to explosive levels that could impact on safety.

3.20.2 Fire Safety Assessment

The substations are equipped with smoke detectors which will raise an alarm in case a fire.

3.21 INVESTMENT PROTECTION

All the equipment forming part of this project will be registered on the Kriel asset register and listed under insurance cover where necessary.

3.22 SECURITY

Kriel Power Station applicable security procedures will be followed, relating to physical equipment, information management etc.

3.23 TEST AND COMMISSIONING STRATEGY

Testing and commissioning of the UPS system will be done by the contractor and witnessed by Eskom representatives at Kriel sites. The UPS contractor will test the functionality of the entire system after each individual supporting subsystems have been tested.

3.24 RISK REGISTER

No risks identified at this stage.

3.25 OTHER DESIGN ISSUES

Not Applicable.

3.26 LESSONS LEARNED

Not Applicable.

4. AUTHORISATION

This document has been seen and accepted by:

Name & Surname	Designation
Busi Green	Chief Engineer - Electrical CoE
Dyke Monyane	Chief Technologist - Electrical CoE
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Santhesh Naicker	LDE Civil & Structural CoE
Niloshen Moodley	Civil & Structural CoE
Wesley Els	System Integration Plant EDWL
Mafu Maseko	Kriel Electrical System Engineer
Bayanda Phindela	Kriel PTM
Manie Van Staden	Chief Engineer: Electrical PEI

5. REVISIONS

Date	Rev.	Compiler	Remarks
October 2019	0	S. Marion	First Draft
January 2020	0.1	S. Marion	Updated with comments
April 2020	0.2	S. Marion	Updated with comments from BG and supporting disciplines
April 2020	0.3	S. Marion	Updated Electrical section
July 2020	0.4	S. Marion	Updated Civil Section
September 2020	1	S. Marion	Final Document

6. DEVELOPMENT TEAM

The following people were involved in the development of this document:

- Sashan Marion
- Thokozani Msibi
- Santhesh Naicker

7. ACKNOWLEDGEMENTS

- Jonathan Magano
- Busi Green
- Manie Van Staden

APPENDIX A: DESIGN OUTPUT DOCUMENTS

1. UPS General Arrangement
2. Control Supply UPS Single Line Diagram
3. Typical UPS Schematic
4. Typical Battery Cabinet
5. 380V Switchgear Schedules
6. List of Affected Boards and UPS locations
7. Room Layout Drawings
8. Risk Assessment

Link to Attachments - DPI Replacement Basic Design - Appendix A

APPENDIX B: CIVIL ASSESSMENT CALCULATIONS

KRIEL POWER STATION - DPI REPLACEMENT WITH UPS PILOT PROJECT

LV EQUIPMENT ROOM 0M LEVEL - ANALYSIS OF CONCRETE FLOOR SLAB

DESIGNER: S NAICKER DATE: 12/03/2020

CHECKED BY: NILOSHEN MOODLEY REVISION: 0

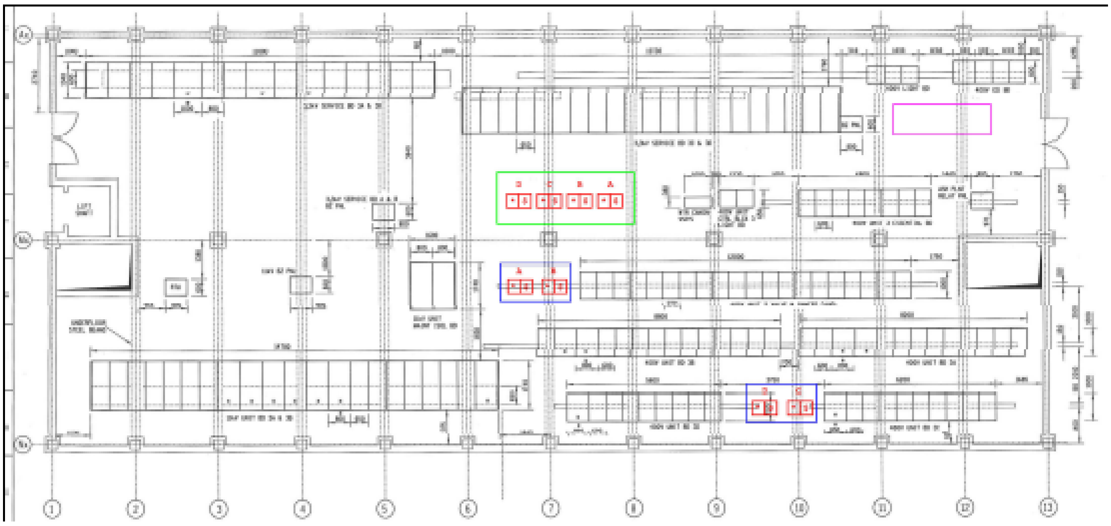


FIGURE 1: UPS UNIT AND BATTERY BANK PLACEMENT WITHIN THE LV SWITHCHGEAR ROOM
(LAYOUT OF EQUIPMENTS WERE OBTAINED FROM THE ELECTRICAL BASIC DESIGN REPORT)

1. PROPOSED EQUIPMENT

BATTERY BANKS

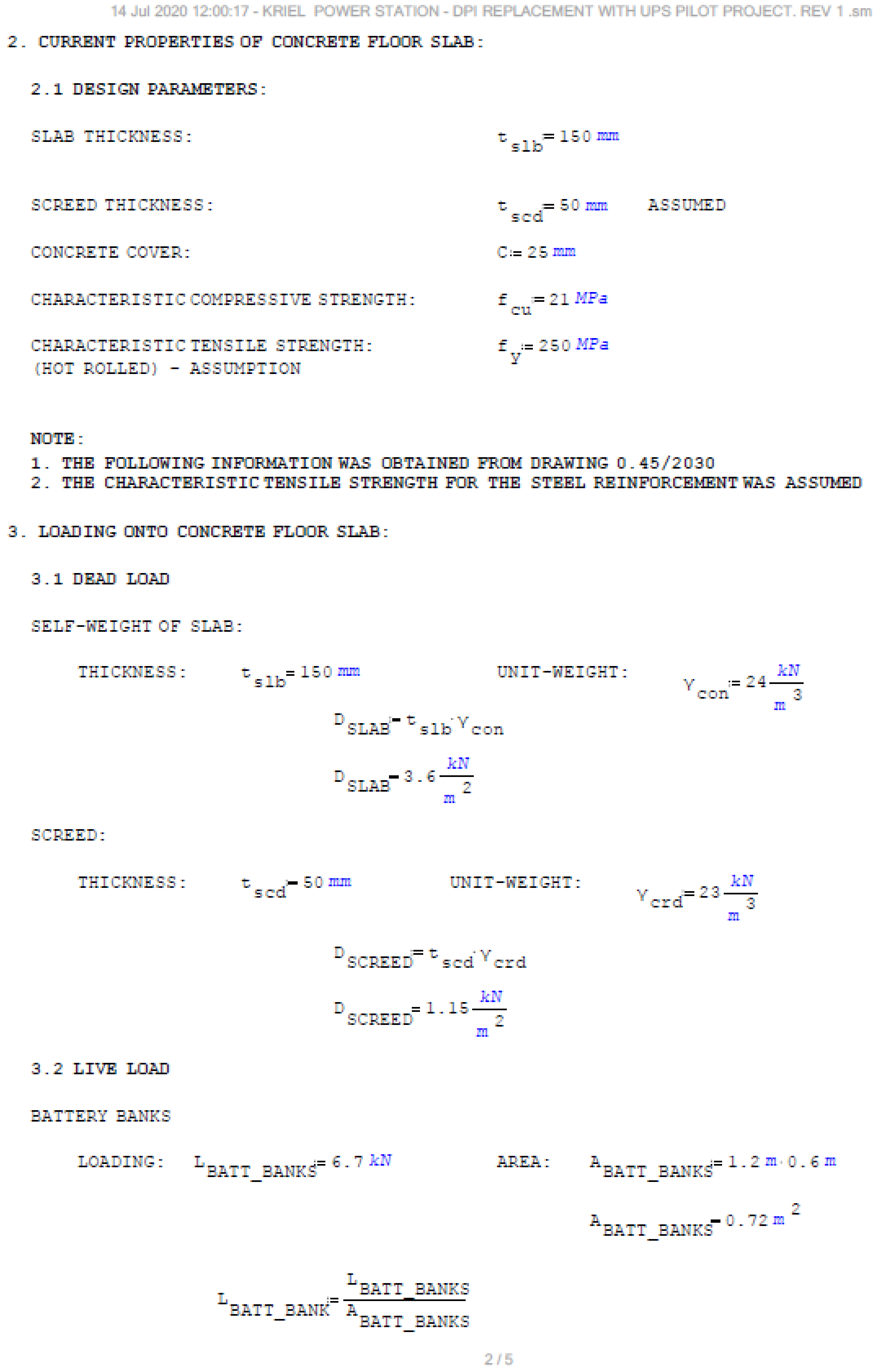
DIMENSIONS: 1200 x 600 mm LOADINGS PROVIDED BY DRAWINGS

LOADING: $L_{BATT\_BANKS} = 6.7\ kN$

UPS UNITS

DIMENSIONS: 600 x 600 mm LOADINGS PROVIDED BY ELECTRICAL DEPARTMENT

LOADING: $L_{UPS\_UNITS} = 3\ kN$



2. CURRENT PROPERTIES OF CONCRETE FLOOR SLAB:

2.1 DESIGN PARAMETERS:

SLAB THICKNESS: $t_{slb} := 150\ mm$

SCREED THICKNESS: $t_{scd} := 50\ mm$ ASSUMED

CONCRETE COVER: $C := 25\ mm$

CHARACTERISTIC COMPRESSIVE STRENGTH: $f_{cu} := 21\ MPa$

CHARACTERISTIC TENSILE STRENGTH: $f_y := 250\ MPa$
(HOT ROLLED) - ASSUMPTION

NOTE:
1. **THE FOLLOWING INFORMATION WAS OBTAINED FROM DRAWING 0.45/2030**
2. **THE CHARACTERISTIC TENSILE STRENGTH FOR THE STEEL REINFORCEMENT WAS ASSUMED**

3. LOADING ONTO CONCRETE FLOOR SLAB:

3.1 DEAD LOAD

SELF-WEIGHT OF SLAB:

THICKNESS: $t_{slb} = 150\ mm$ UNIT-WEIGHT: $\gamma_{con} := 24\ \frac{kN}{m^3}$

$$D_{SLAB} := t_{slb} \cdot \gamma_{con}$$

$$D_{SLAB} = 3.6\ \frac{kN}{m^2}$$

SCREED:

THICKNESS: $t_{scd} = 50\ mm$ UNIT-WEIGHT: $\gamma_{crd} := 23\ \frac{kN}{m^3}$

$$D_{SCREED} := t_{scd} \cdot \gamma_{crd}$$

$$D_{SCREED} = 1.15\ \frac{kN}{m^2}$$

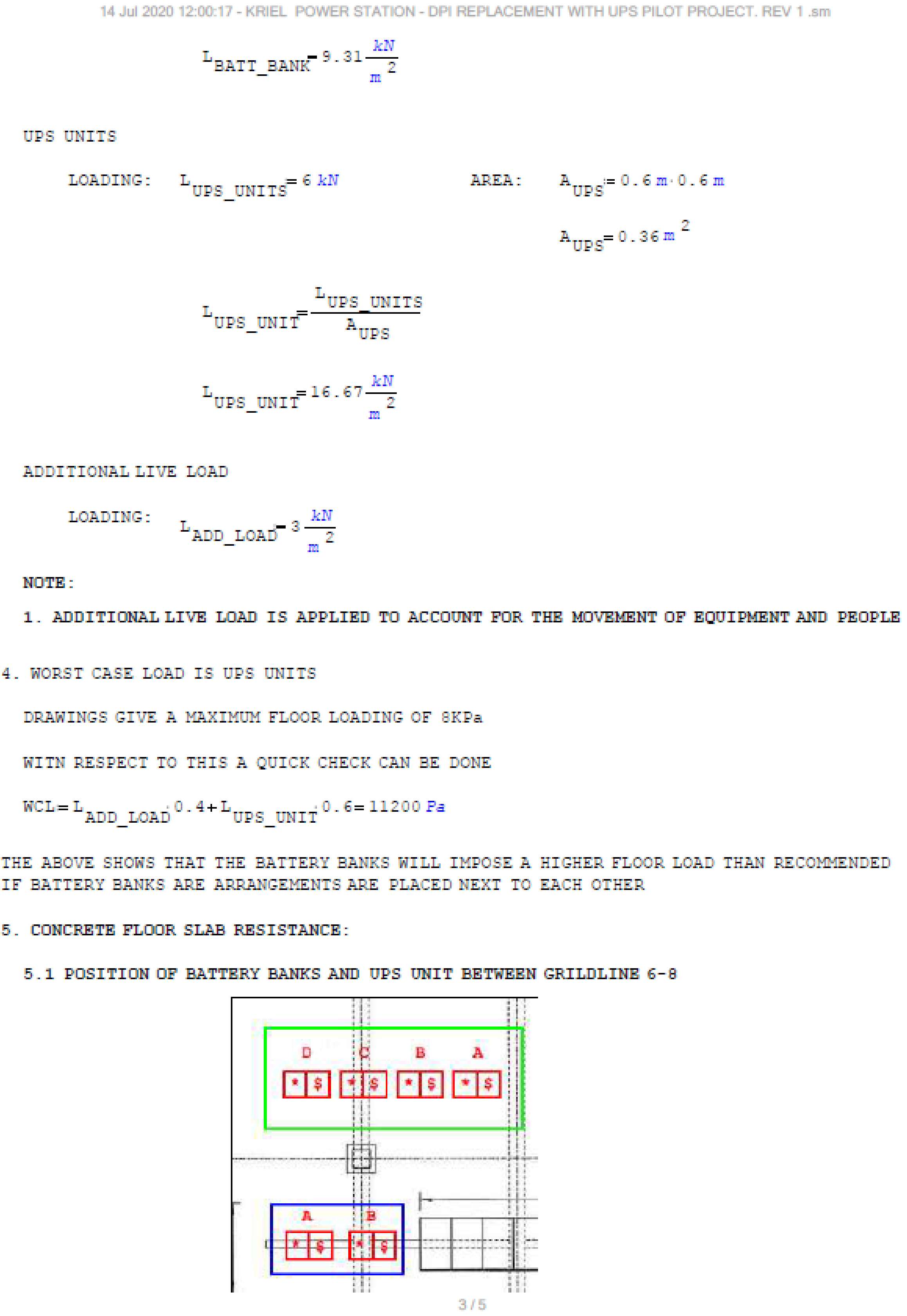
3.2 LIVE LOAD

BATTERY BANKS

LOADING: $L_{BATT\_BANKS} := 6.7\ kN$ AREA: $A_{BATT\_BANKS} := 1.2\ m \cdot 0.6\ m$

$A_{BATT\_BANKS} = 0.72\ m^2$

$$L_{BATT\_BANK} := \frac{L_{BATT\_BANKS}}{A_{BATT\_BANKS}}$$



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$$L_{BATT\_BANK}=9.31\frac{kN}{m^{2}}$$

UPS UNITS

LOADING: $L_{UPS\_UNITS}=6\ kN$ AREA: $A_{UPS}:=0.6\ m\cdot 0.6\ m$

$$A_{UPS}=0.36\ m^{2}$$

$$L_{UPS\_UNIT}=\frac{L_{UPS\_UNITS}}{A_{UPS}}$$

$$L_{UPS\_UNIT}=16.67\frac{kN}{m^{2}}$$

ADDITIONAL LIVE LOAD

LOADING: $L_{ADD\_LOAD}=3\frac{kN}{m^{2}}$

NOTE:

1. ADDITIONAL LIVE LOAD IS APPLIED TO ACCOUNT FOR THE MOVEMENT OF EQUIPMENT AND PEOPLE

4. WORST CASE LOAD IS UPS UNITS

DRAWINGS GIVE A MAXIMUM FLOOR LOADING OF 8KPa

WITN RESPECT TO THIS A QUICK CHECK CAN BE DONE

$$WCL=L_{ADD\_LOAD}\cdot 0.4+L_{UPS\_UNIT}\cdot 0.6=11200\ Pa$$

THE ABOVE SHOWS THAT THE BATTERY BANKS WILL IMPOSE A HIGHER FLOOR LOAD THAN RECOMMENDED IF BATTERY BANKS ARE ARRANGEMENTS ARE PLACED NEXT TO EACH OTHER

5. CONCRETE FLOOR SLAB RESISTANCE:

5.1 POSITION OF BATTERY BANKS AND UPS UNIT BETWEEN GRILDLINE 6-8

3 / 5

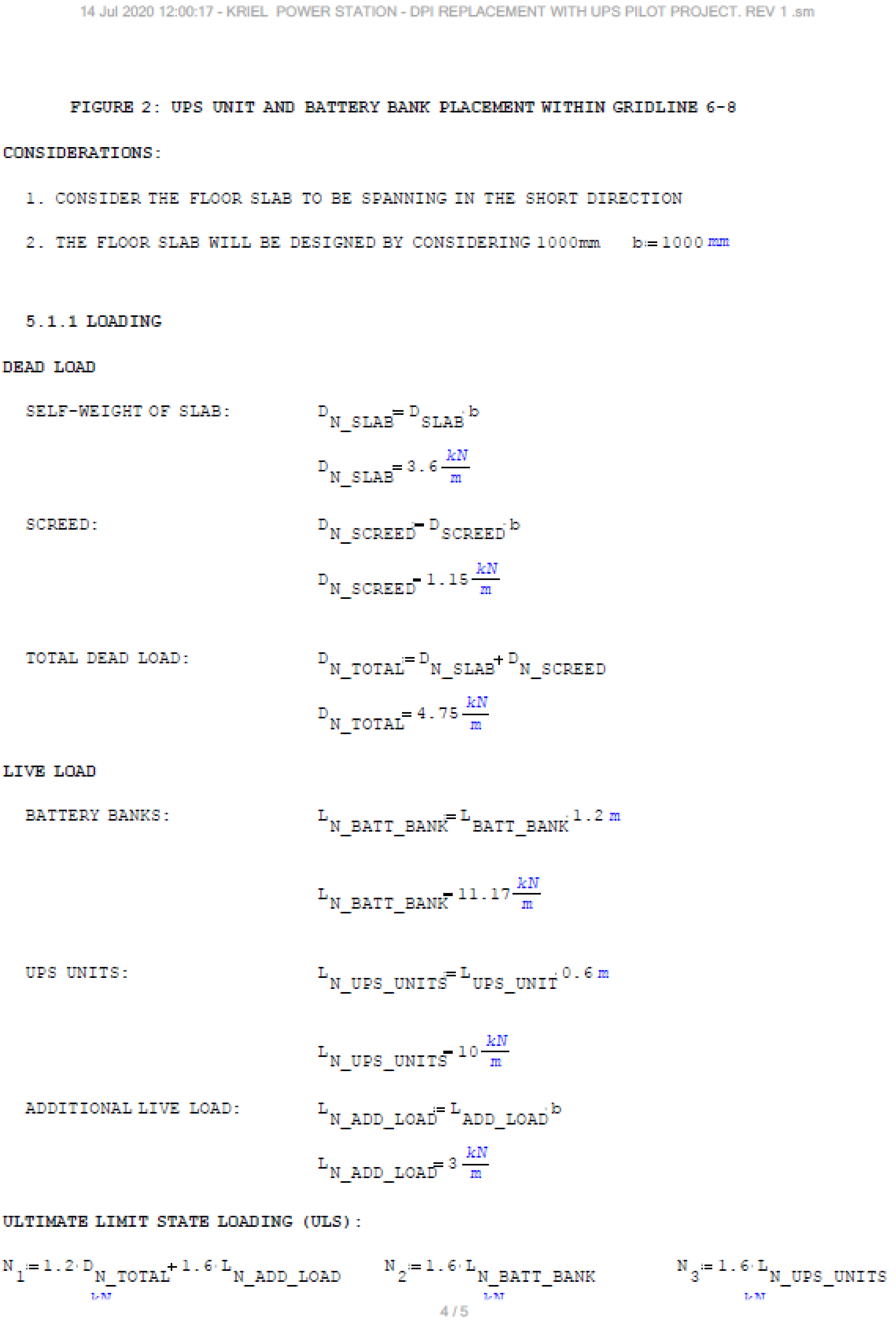

FIGURE 2: UPS UNIT AND BATTERY BANK PLACEMENT WITHIN GRIDLINE 6-8

CONSIDERATIONS:

1. CONSIDER THE FLOOR SLAB TO BE SPANNING IN THE SHORT DIRECTION
2. THE FLOOR SLAB WILL BE DESIGNED BY CONSIDERING 1000mm $b := 1000\ mm$

5.1.1 LOADING

DEAD LOAD

SELF-WEIGHT OF SLAB: $D_{N\_SLAB} := D_{SLAB} \cdot b$

$D_{N\_SLAB} = 3.6\ \frac{kN}{m}$

SCREED: $D_{N\_SCREED} := D_{SCREED} \cdot b$

$D_{N\_SCREED} = 1.15\ \frac{kN}{m}$

TOTAL DEAD LOAD: $D_{N\_TOTAL} := D_{N\_SLAB} + D_{N\_SCREED}$

$D_{N\_TOTAL} = 4.75\ \frac{kN}{m}$

LIVE LOAD

BATTERY BANKS: $L_{N\_BATT\_BANK} := L_{BATT\_BANK} \cdot 1.2\ m$

$L_{N\_BATT\_BANK} = 11.17\ \frac{kN}{m}$

UPS UNITS: $L_{N\_UPS\_UNITS} := L_{UPS\_UNIT} \cdot 0.6\ m$

$L_{N\_UPS\_UNITS} = 10\ \frac{kN}{m}$

ADDITIONAL LIVE LOAD: $L_{N\_ADD\_LOAD} := L_{ADD\_LOAD} \cdot b$

$L_{N\_ADD\_LOAD} = 3\ \frac{kN}{m}$

ULTIMATE LIMIT STATE LOADING (ULS):

$N_1 := 1.2 \cdot D_{N\_TOTAL} + 1.6 \cdot L_{N\_ADD\_LOAD}$ $N_2 := 1.6 \cdot L_{N\_BATT\_BANK}$ $N_3 := 1.6 \cdot L_{N\_UPS\_UNITS}$

$N_1 = 10.5 \frac{kN}{m}$ $N_2 = 17.87 \frac{kN}{m}$ $N_3 = 16 \frac{kN}{m}$