Eskom	Scope of Work	Kriel Power Station

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PART 3: SCOPE OF WORK

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C3.1: *Employer's* WORKS INFORMATION

Contents

1 Description of the works

1.1 Executive overview

The upgrade of the Kriel Power Station excitation system project includes and mainly concerns the replacement/ upgrade of the excitation controllers for unit 1, 2, 3 and 5. This will be limited to the excitation system panels, and will exclude the excitation transformers, busbars, generator stator current CTs, generator VTs, slip ring as well as the brushgear. The scope therefore includes but is not limited to the engineering, design, manufacturing, testing, delivery to site, offloading, erection, installation, commissioning as well as training of Eskom Engineering, Maintenance and Operating personnel; this work also includes cabling.

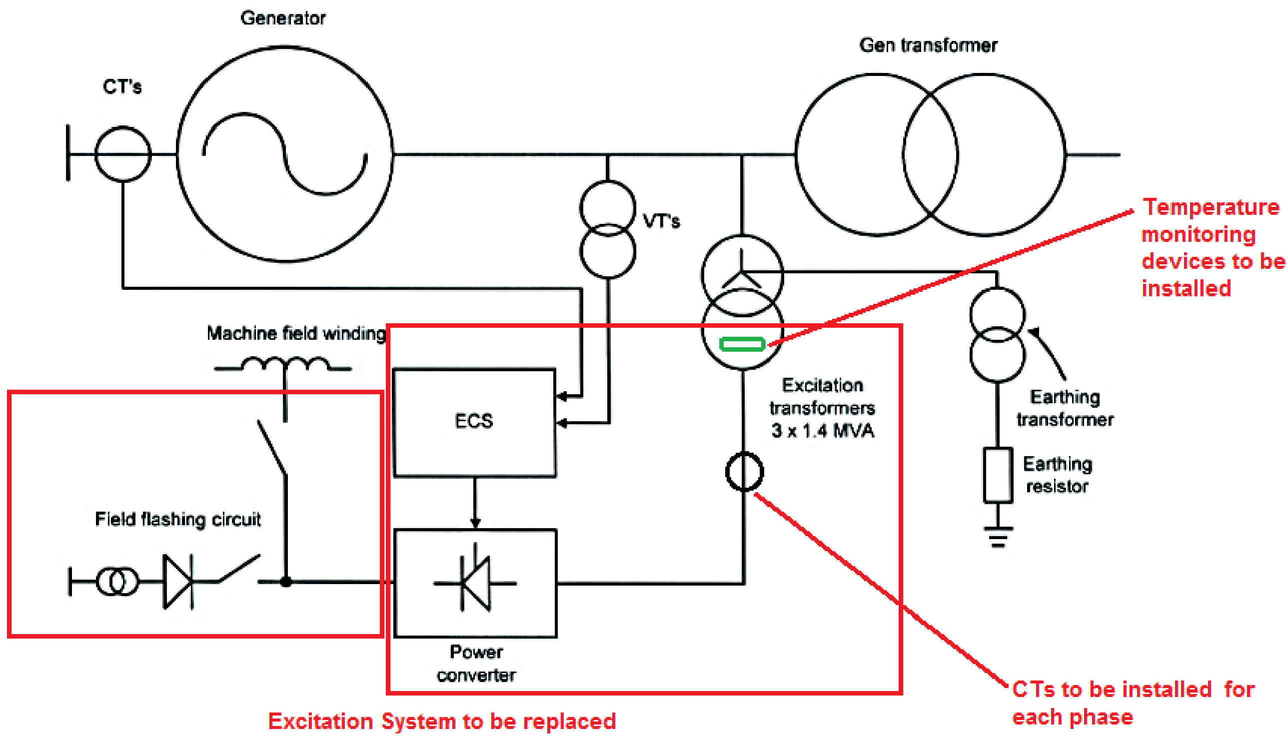


Figure 1: Project boundary

1.1.1 Scope

Through this project, the *Employer* seeks to receive the following from the *Contractor:*

1. The *Contractor* provides al the design services for the works, including design of plant, materials layout, all interfaces and additional cabling requirements. These include but are not limited to general arrangement, single lines, AC and DC key diagrams, cabling terminations, cable block diagrams, cable schedules and input-output (IO) lists.
2. Manufacturing is at the *Contractor*'s premises, local or abroad, while the factory acceptance testing is to be carried out in South Africa at a properly equipped testing facility. Local engineering and panel construction support shall be available should panel/ software configuration changes be required.
3. A complete design in accordance with the *Employer*'s specifications as listed.
4. Sizing of all components including providing all calculations to support the design.
5. The procurement, manufacturing and assembly of a complete tested system .
6. Shipping, transport, delivery and offloading of equipment to Kriel Power Station including final placement of equipment.
7. Decommission and remove existing excitation system components and cabling to a designated area as indicated by the *Employer*.
8. Scanning for rebar and core drilling for cable access as required by the design and layout of panels.

9. Complete installation if the excitation assembly on site as well as providing the necessary floor preparations and repairs including repainting of floor areas worked on.
10. Design, supply and complete installation of any additional cable racking as required by the design and layout of the new system.
11. Design, supply, delivery, preparation, routing, decommissioning, installation, testing, termination, numbering, glanding and lugging of cabling.
12. Removal and re-installation of any cabling fire proofing barriers where holes were created or barriers were removed during decommissioning or installation.
13. Interfacing of all hardwired excitation interfaces as per the agreed detail design to the generator protection scheme, synchroniser, AC & DC voltage supplies, station earth mat, VT junction boxes, CT junction boxes, station control desk.
14. Testing which consists of type tests (where type test certification is not available), function tests, factory acceptance tests, site acceptance testing, cold commissioning tests. Hot commissioning tests, post commissioning optimisation, Grid code compliance testing and guarantee testing.
15. Complete commissioning of the excitation system assembly.
16. Provision for all documentation in the specific format as requested by the works.
17. All plant drawings and equipment type tests and datasheets to be compiled and provided.
18. Provide spares as well as maintenance and operating manuals.
19. Formal training of Engineering, Maintenance and Operating personnel. All training material and presentation of training sessions is included in the works. This training is supplied in South Africa, operating and maintenance training needs to take place at Kriel Power Station.
20. Active interfacing with the *Employer*'s system engineers is required to complete a fully functioning unit.
21. Provide Engineering and maintenance tools for purpose of accessing and maintaining all electronic and mechanical components where recommended by the *Contractor*.
22. Compilation of excitation settings document for the excitation system and power system stabiliser as required by the South African Grid Code. This include the supply of the excitation system models

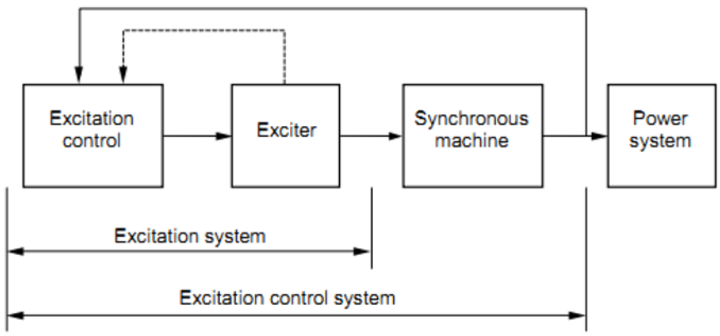
1.2 *Employer*'s objectives and purpose of the *works*

The purpose of this works is to install a new excitation system in each of the four units at Kriel Power station. This new system needs to provide safe and reliable operation for a minimum of 15 years.

1.3 Interpretation and terminology

The following definitions apply:

Definition	Meaning given to the definition
Excitation Control	Control of excitation system modifying the excitation power, responding to signals characteristic of the state of the system encompassing the synchronous machine, its exciter, and the network to which it is connected [IEC 60034-16-1 definition 2.3]. Usually a single integrated assembly, it includes the automatic voltage regulator (AVR), field current regulator (FCR), excitation limiters that contribute to the machine capability, and even protection functions. IEEE defines this functionality as that of the "synchronous machine regulator".
Excitation System	Equipment providing the field current of a machine, including all regulating and control elements, as well as field discharge or suppression equipment and protective devices [IEC 60034-16-1 definition 2.1]
Excitation system	Feedback control system that includes the synchronous machine operating in the power system and its excitation system [IEC 60034-16-1 definition 2.4].

	
Generator transformer	The 18kV/ 400kV step up transformer that connects the generator to the transmission system.
Machine	The term ‘machine’ is used throughout this document and is understood to refer to the main synchronous generator.
Unit Control System	This is a distributed control system (DCS) with a computerised control system for a process or plant usually with many control loops, in which autonomous controllers are distributed throughout the system, but there is no central operator supervisory control

The following abbreviations are used in this Works Information:

Abbreviation	**Meaning given to the abbreviation**
AC	Alternating Current
AKZ	Anlangen Kenn Zeichnung
AVR	Automatic Voltage Regulator
UNIT CONTROL SYSTEM	Control and Instrumentation
CT	Current Transformer
DC	Direct Current
DCS	Distributed Control System
EMDAS	Energy Management Data Acquisition System
ES	Excitation system
ESVD	Excitation System Validation and Documentation
FAT	Factory Acceptance Test
FCR	Field Current Regulator
GCB	Generator Circuit Breaker
IPB	Isolated Phase Busbar
HMI	Human Machine Interface
HV	High Voltage > 1000 V AC/DC

HVCB	High Voltage Circuit Breaker
IEC	International Electro Technical Commission
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LV	Low Voltage < 1000 V AC/DC
OEM	Original Equipment Manufacturer
PC	Personal Computer
PID	Proportional-Integral-Derivative
PSS	Power System Stabiliser
QCP	Quality Control Plan
QMP	Quality Management Plan
RTS	Return to Service
SAT	Site Acceptance Test
VDSS	Vendor Documental Submittal Schedule
VT	Voltage Transformer

2 Management and start up.

2.1 Management meetings

Regular meetings of a general nature may be convened and chaired by the *Project Manager* as follows:

Title and purpose	Approximate time & interval	Location	Attendance by:
Risk register and compensation events	As agreed between the Project manager and the *Contractor*	Kriel Power Station	*Employer, Contractor, Supervisor,*
Overall contract progress	As agreed between the	*Contractor*'s workshop/	*Employer*, *Contractor*,

and feedback	Project manager and the *Contractor*	Kriel Power Station	*Supervisor*, and ___

Meetings of a specialist nature may be convened as specified elsewhere in this Works Information or if not so specified by persons and at times and locations to suit the Parties, the nature and the progress of the *works*. Records of these meetings shall be submitted to the *Project Manager* by the person convening the meeting within five days of the meeting.

All meetings shall be recorded using minutes or a register prepared and circulated by the person who convened the meeting. Such minutes or register shall not be used for the purpose of confirming actions or instructions under the contract as these shall be done separately by the person identified in the *conditions of contract* to carry out such actions or instructions.

2.2 Documentation control

2.2.1 Document Management

All documents supplied by the *Contractor* shall be subject to Eskom's approval. The language of all documentation shall be in English. The *Contractor* shall include the *Employer*'s drawing number in the drawing title block. This requirement only applies to design drawings developed by the *Contractor* and his Sub*Contractor*s. Drawing numbers will be assigned by the *Employer* as drawings are developed. All equipment to be coded, AKZ codes to be supplied by the *Employer*.

2.2.2 Document Identification

The *Contractor* is required to submit the Vendor Document Submission Schedule (VDSS) as per agreed dates to the delegated Eskom Representative. Eskom will pre-allocate document numbers on the VDSS and send back to the *Contractor* through the delegated Eskom Representative. The VDSS is revisable and changes must be discussed and agreed upon by all parties. Changes in the VDSS can be additional documentation to be submitted, changes in submission dates or corrections in documentation descriptions, document numbers, etc. The *Contractor*'s VDSS shall indicate the format of documents to be submitted. In Appendix A the *Employer*'s VDSS is attached to indicate minimum documentation required.

2.2.3 Document Submission

All project documents must be submitted to the delegated Eskom Representative with transmittal note according to Project / Plant Specific Technical Documents and Records Management Work Instruction (240-76992014). In order to portray a consistent image it is important that all documents used within the project follow the same standards of layout, style and formatting as described in the

Work Instruction
The *Contractor* is required to submit documents as electronic and hard copies and both copies must be delivered to the Eskom Representative with a transmittal note.
In addition, the *Contractor* shall be provided with the following standards which must be adhered to:

- Documentation Management Review and Handover Procedure for Gx Coal Projects (240-66920003).
- Project Documentation Deliverable Requirement Specification (240-65459834).
- Technical Documentation Classification and Designation Standard (240-54179170).
- Excitation control system project handover documentation checklist (240-156104699)

Email Subject
The *Contractor* shall submit all documentation to the Eskom Representative as well as the Project's Documentation Centre in the following media:

1. Electronic copies shall be submitted to Eskom Documentation Centre through generic email address (drmsharedservices@eskom.co.za). The email subject shall as a minimum have the following: (Project Name_Discipline_Subject). Electronic copies that are too large for email will be delivered on CD/DVD, large file transfer protocol and/or hard drives to the Project Documentation Centre. A notification email, with the transmittal note attached, shall be sent to the project generic email address. The Representative will be copied on the email as well.

2. Hard copies shall be submitted to the Eskom Representative accompanied by the Transmittal Note.

2.2.4 DRAWINGS FORMAT AND LAYOUT

The creation, issuing and control of all Engineering Drawings will be in accordance to the latest revision of 240-86973501 Engineering drawing Standard. Drawings issued to Eskom will be a minimum of one hardcopy and an electronic copy. All *Contractor*s are required to submit electronic drawings in Micro Station (DGN) format, and scanned drawings in .pdf format. No drawings in TIFF, AUTOCAD or any other electronic format will be accepted. Drawings issued to Eskom may not be “Right Protected” or encrypted.

2.2.5 Operating

Procedures and manuals for the operation of all modified systems shall be provided/ updated by the *Contractor*.

2.2.6 Maintenance

1. Manuals for the maintenance of all modified systems shall be provided/ updated by the *Contractor*.
2. A list of recommended spares and their technical specifications are to be provided.
3. A list of special tools and drawings are to be provided. Drawings are to be provided as both hard and soft copies.

2.2.7 Engineering

1. A system operating description is to be provided.
2. Technical manuals detailing the implemented modifications are to be provided.
3. All OEM datasheets are to be provided.
4. All existing P&ID’s, layout, general arrangement, line diagrams, logic diagrams and associated technical documentation affected by the modifications are to be updated to reflect the new/modified systems. Drawings are to be provided as both hard and soft copies (3 hard copies per drawing).
5. All new drawings and documentation to be uploaded and registered on the Kriel Power Station Documentation System by the *Employer*.
6. The *Contractor* provides all applicable documentation listed in the Vendor Documentation Submission Schedule in Appendix A for acceptance by the *Employer*.
7. All functional logic diagrams are submitted by the *Contractor* to the Project Manager for acceptance before activation of logic on the control.

2.2.8 As Built Drawings And Documents

It will be the responsibility of the *Contractor* to revise the drawings and to update all the existing documentation to reflect the “as build” status of the Kriel units and forwards these drawings to the Project Manager 15 working days prior the Completion Date.

2.3 Health and safety risk management

The *Contractor* undertakes to take all reasonable precautions to maintain the health and safety of persons in and about the execution of the service. Without limitation the *Contractor:*

- accepts that the *Employer* may appoint him as the "Principal Contractor" (as defined and provided for under the Construction Regulations 2003 (promulgated under the Occupational Health & Safety Act 85 of 1993) ("the Construction Regulations") for the Affected Property;
- warrants that the total of the Prices as at the Contract Date includes a sufficient amount for proper compliance with the Construction Regulations, all applicable health & safety laws and regulations and the health and safety rules, guidelines and procedures provided for in this contract and generally for the proper maintenance of health & safety in and about the execution of the service; and
- undertakes, in and about the execution of the service, to comply with the Construction Regulations and with all applicable health & safety laws and regulations and rules, guidelines and procedures otherwise provided for under this contract and ensures that his Subcontractors, employees and others under the Contractor's direction and control, likewise observe and comply with the foregoing.

The *Contracto*r, in and about the execution of the service, complies with all applicable environmental laws and regulations and rules, guidelines and procedures otherwise provided for under this contract and ensures that his Subcontractors, employees and others under the Contractor's direction and control, likewise observe and comply with the foregoing.

Radiographic Examinations
When radiographic tests are carried out in the plant the danger area is barricaded. Workers are made aware of this fact and the Radiographic technicians ensure that no person is within or enter the danger area prior to commencing of or during the tests by public announcement according to the procedure.

2.4 Environmental constraints and management

All spillages (whether oil, grease, diesel, chemical, etc.) are prevented at all times and where accidents occurred in line with any spillages, immediate remedial actions are taken to clean-up the affected area using the appropriate spill-cleaning chemicals/absorbents.

It is the responsibility of the *Contractor* to ensure that the *Contractor* obtains copies of the Environmental Policy of oil spillages,

The non-adherence to the rules will result in a non-conformance, hence immediate termination of the contract.

Rules are as follows:

1. Provide sufficient storage containers, labelled depicting general or hazardous waste and store in a designated storage area.
2. No hazardous waste may be stored for a period of more than 90 days at Kriel Power Station premises.
3. Ensure that all hazardous waste is disposed of at a licensed class H disposal site. A copy of the hazardous waste disposal certificate is submitted to the *Project Manager*.
4. Ensure that all other general waste is disposed of at the local municipal waste dump.
5. Ensure that your site complies with the general good housekeeping practices

2.5 Quality assurance requirements

1. The *Contractor* shall adhere to the Eskom Supplier Quality management Specification, 240-105658000.
2. QCP's shall be supplied by the *Contractor* for all work to be done.
3. No work shall commence before the QCP's have been approved by the *Employer*.
4. The QCP's shall make provision for Hold and Witness point to be included by the *Employer*'s representative.
5. There shall be signature pages in the QCP's that captures the detail of the people who is authorised to sign off activities on the QCP's.

2.5.1 Quality Plans

The Quality Plan manages the overall quality of the project's main activities/milestones. It lists detailed activities in order of execution where each activity is described and references the associated work packages or specifications with witness-, hold- and verification points. The QCPs make provision for signatures indicating completion by the *Contractor* and acceptance by the *Employer* at the end of each activity.

2.5.2 Work Packages

For all site related work the *Contractor* is required to submit a work package before any type of work can commence on Eskom plant. The required format of the work package is accordance with template 167A/158-A and a signed copy is provided by the *Contractor* after the *Employer* has reviewed and accepted the Work Package as final prior to any work.

2.6 Programming constraints

2.7 *Contractor*'s management, supervision and key people

The *Contractor* makes arrangements for the use of the available workshop Equipment and Site specific tools.

The *Contractor* does not modify any plant or materials unless accepted by the *Employer* prior to implementation.
The *Contractor* notifies the *Employer* at least two days in advance of a Hold or Witness point on the *Works*.

The *Contractor* informs the *Employer* of any defect found and notify the *Employer* at least two days in advance of a Hold or Witness point on the Works.

The *Contractor* does not operate any Equipment on Site, unless specific authorisation is obtained from the *Employer*.

2.8 Invoicing and payment

Within one week of receiving a payment certificate from the *Project Manager* in terms of core clause 51.1, the *Contractor* provides the *Employer* with a tax invoice showing the amount due for payment equal to that stated in the *Project Manager's* payment certificate.

The *Contractor* shall address the tax invoice to Eskom Holdings SOC Ltd and include on each invoice the following information:

- Name and address of the *Contractor* and the *Project Manager;*
- The contract number and title;
- *Contractor*'s VAT registration number;
- The *Employer*'s VAT registration number 4740101508;
- Description of service provided for each item invoiced based on the Price List;
- Total amount invoiced excluding VAT, the VAT and the invoiced amount including VAT;
- (add other as required)

Add procedures for invoice submission and payment (e. g. electronic payment instructions)

2.9 Insurance provided by the *Employer*

2.10 Contract change management

Contract change management is managed in accordance with clause 6 of the core clauses in ECC3. In summary, in the event that the *Employer*/*Contractor* notices a change, an event register is issued. If the event/change has cost implications then a quotation is submitted with the event register. The *Project Manager* assesses the quotation and gives an instruction in writing to the *Contractor*.

2.11 Provision of bonds and guarantees

The form in which a bond or guarantee required by the *conditions of contract* (if any) is to be provided by the *Contractor* is given in Part 1 Agreements and Contract Data, document C1.3, Sureties.

The *Employer* may withhold payment of amounts due to the *Contractor* until the bond or guarantee required in terms of this contract has been received and accepted by the person notified to the *Contractor* by the *Project Manager* to receive and accept such bond or guarantee. Such withholding of payment due to the *Contractor* does not affect the *Employer*'s right to termination stated in this contract.

2.12 Records of Defined Cost, payments & assessments of compensation events to be kept by the *Contractor*

2.13 Training workshops and technology transfer

Formal training is conducted as part of this contract before completion of the works. The *Contractor* trains the *Employer*'s personnel as per details in section 5.2.9. The *Contractor* is responsible for providing a training register in order to keep as proof of training provided. The signed off training register by all participants is also to be supplied by the *Employer*.

3 Engineering and the *Contractor*'s design

3.1 *Employer*'s design

3.1.1 Operating philosophy

Kriel Power station is a base load coal fired power station located 15 km outside of Kriel town in Mpumalanga province, South Africa. The power station was first commissioned in 1975 and it comprises of 555 MVA Hydrogen and water cooled generators in each of its 6 units. These generators utilise a full Static Excitation System with dual redundant control electronics. The control electronics have full redundancy with respect to power supplies and analogue processing but not all digital inputs and outputs. The power electronics have four bridges in parallel of which three are capable of supplying full excitation. The control electronics are digital type with personal computer user interface for setting alterations. The local control and display panel cannot be used to alter any settings, apart from normal operational parameters i.e. channel selection, mode selection, raising/lowering etc.

The ES taps its power from three single phase excitation transformers rated at 18kV/605V, which taps its 18kV from each of the Isolated Phase Busbars (IPB) on the generator stator terminals. The 605V AC is fed to the four sets of converters which are connected in parallel to each other. The converters are controlled by one of two digital regulators through a gate control unit, which sends the required firing pulses to the converter electronics coupled to each converter.

From the converters, the power goes through a set of two single pole field breakers in parallel, which break the positive leg of the DC circuit to the rotor slip ring. An electronic crow bar together with resistors acts as a field suppression during de-excitation or field breaker tripping commands.

A field flashing circuit is used to excite the generator for a brief moment during initial excitation as the generator is unable to self-excite at that moment. The field flashing is supplied from the 380V Unit Board C, through a 380/40V step down transformer and to a rectifier. It is then connected to the DC bus bars through a field flashing contactor.

3.2 Parts of the *works* which the *Contractor* is to design

3.2.1 Functional Requirements for the *Works*

The following are descriptions of devices that are to be built into the works or that the works is capable of doing:

1. The upgraded ES shall employ a split system with the EC (regulator) panel located in the Equipment room (12m) and the thyristor bridge panels in the AVR room on 9m level.
2. The control system needs to be digital. This includes sampling of analogue values up to the generation of firing pulses.
3. All settings need to be digital. Analog to digital conversion of potentiometers as setting adjusters shall not be allowed.
4. The control system must not introduce voltage oscillations and the machine terminal voltage is to remain within the limits.
5. The voltage regulator must be continuously acting with adjustments for all gains and time constants, with no dead-band or zone of insensitivity.
6. The regulator must be easily operated, maintained and repaired; ensuring continuous operation of the unit by means of redundancy.
7. Regulator redundancy is provided in the form of two identical automatic voltage-regulating channels, Channel 1 and Channel 2. Both these channels need to be able to act as master while the other follows. This includes the converters if a 1+1 or N-1 configuration is chosen.
8. To minimise the risk of common mode failure, the two channels must not share any power supplies or input or output cards.
9. The voltage control system shall consist of at least a lag-lead-lead-lag controller (similar to a PID controller). The frequency response characteristic shall be adjustable. The variable parameters shall be considered as settings applied to the AVR.

10. Both channels shall include a field current regulator of the proportional plus integral type and constantly following their respective voltage-regulating channels.
11. Each channel shall make provision for a test function, where control of the field current can be done manually without being reliant on any feedback signal from the control system.
    a. This mode shall be available for test purposes only; software interlocking shall be required to activate this function.
    b. The control system must prevent the test mode from being engaged by the operator under normal operating conditions.
    c. The test mode allows for open circuit and short circuit tests to be carried out on the synchronous generator as well as feed-back loop checks of the excitation system prior to engaging any of the regulation loops.
12. The excitation control shall start-up in Auto mode (Voltage Regulator Mode) and preferably to channel 1 when power is recycled, provided all signals that may cause a transfer is healthy. It is therefore important that the boot sequence is set-up correctly to allow proper settling of disturbance signals before the channel and modes selection are applied.
13. Voltage sensing circuits in the voltage-regulating mode shall respond to the three-phase line-to-line machine terminal voltage. Sensing of only one line-to-line or a line-to-neutral voltage is not acceptable due to high resistance earthing arrangement on the generator.
14. The machines shall be capable of operating in parallel with stable reactive power. Cross-connection of ES circuits between machines shall not be acceptable
15. The regulator must ensure that there are no oscillatory operations before synchronising, on load and after load rejection.
16. All control and communication cables are the responsibility of the *Contractor*. The *Contractor* shall provide detailed cable requirements to interface with all other systems as required. Correct terminations on both panel and plant side thereof is done by the *Contractor* and witnessed by the *Employer* to ensure correct terminations are done.
17. The system shall have a transient/fault recorder.
18. The system shall have a built in sequence of events recorder with all logged data time stamped at the source when data originates within the excitation system. All binary inputs originating from external sources are time stamped when the inputs on the I/O cards are activated.
19. An excitation-on interlock must be provided by the unit control system to prevent excitation from being switched on either from remote or local.
20. A field flashing circuit is part of the works to allow reliable excitation build-up upon initial excitation. The field flashing current is supplied from a 400 VAC supply with a suitably sized transformer rectifier and contactor arrangement. The field flashing components must be able to handle three consecutive field flashing attempts based on the longest field flashing times.

3.2.2 Interface requirements

3.2.2.1 General

1. The *Contractor* allows enough time in order to achieve proper interfacing between all the *Employer's* Engineers and the *Contractor*. The *Contractor* is involved in clarifications and technical queries regarding interfacing and be actively involved during interfacing sessions.
2. The following systems will be affected:
    a. Generator Protection
    b. Excitation transformer protection and monitoring
    c. Synchroniser
    d. Generator CT's and VT's
    e. Excitation transformer AC converter supply
    f. Station and unit AC/DC supplies
    g. Local plant HMI
    h. Floor plans, cable entries and dimensions
    i. AKZ requirements
    j. Unit Control System
    k. Control room operating desk
    l. Grid Code requirements

3.2.2.2 Interface details

1. All alarms, events and analogues generated from the ES must be available for display locally as well as relayed for display to the unit control system. The interface must provide data in the form of a value and time and that replicates the exact attributes and values from the generated source.
2. The *Contractor* shall provide all networking components and cabling for all internal network requirements. This includes network switches, network interface cards, device driver software and software licenses.
3. The *Contractor* provides any fibre optic cables, connections, splices, splice boxes and fibre optic fly leads between the ES recording equipment and Unit Control System where required.
4. The following communications setup requirements must be met:
   a. No single point of failure for internal control communications for the ES
5. Interface principle between the ES and external plant is:
   a. All control signals are hardwired. The ES has high impedance opto-couplers to interface with these signals. “Wetting voltage” is from the Unit Control System. No control is done via the communication link.
   b. All trip signals are hardwired. No tripping is done via the communication link.
   c. All selected alarm signals are to be interfaced to the unit control system via bus communication (PROFiBUS DP- CM104 communication module), except the alarms that have been strategically selected to be hardwired
   d. Status information is hardwired only for a few selected signals. All other status information is sent via communication link to the Unit Control System .
   e. Analog quantities are hardwired 4-20mA for only a few selected analogue quantities. The rest are published via communication link to the Unit control system.
   f. All I/O interfaces are wired two wires per signal. If needed, bridging is only allowed on the terminal rails and not on the I/O cards or devices themselves.
   g. All hardwired ES binary inputs are supplied by its own control supply. All external plant binary consist of dry contacts only.
   h. All binary inputs do not energise for values up to 60% of nominal value.
6. As part of commissioning activities, a temporary trip facility is provided for direct connection to the excitation system. This interface is permanently available on a terminal strip for commissioning personnel to wire the external emergency trip button to the excitation system without disturbing any other wiring. It trips the field breaker directly. This input is also monitored by the excitation monitoring system.

3.2.3 Control and Monitoring Requirements

1. The control circuit shall be of a digital system to allow versatility thereby minimising hardware configuration when changes are required. It shall have extended ability for self-diagnosis, testing and fault finding.
2. The *Contractor* shall provide a reliable, easy-to-use data input facility which will facilitate local operation in terms of controlling, testing, displaying as well as resetting of alarms. This shall be in the form of a local control panel or industrial PC permanently installed at the excitation control panel.
3. The *Contractor* shall provide a notebook computer with the appropriate operating system as an easy-to-use data input facility which will also facilitate local operation in terms of controlling, testing, commissioning, displaying as well as resetting of alarms. It shall also be uses for configuration changes and any download of configurations for back-ups as well as data logger and any oscillography data for further analysis.
4. Power and control circuits shall be galvanically isolated from each other.
5. A self-monitoring function shall be part of the excitation control to monitor the Plant and Material associated with each channel. Any failure of the active channel must initiate a smooth automatic change over to the other channel with minimal change nominal stator voltage.
6. A failure in the inactive channel inhibits change over to the failed channel. In the event of an inactive channel failure, no trip signal is issued, rather an alarm is initiated and captured in the built-in fault logger/recorder.
7. A fault occurring in the voltage transformer circuitry and a sudden drop in machine voltage are automatically discriminated against each other. The excitation system detects a VT fuse failure during

start-up and normal operation. The *Contractor* shall indicate to the *Employer* during the tender stage how this philosophy shall be implemented.

8. Lack of voltage sensing upon initial excitation being applied to the machine is detected by the excitation system to prevent prolonged over fluxing under such start-up conditions. Such a condition causes de-excitation and appropriate alarming of the condition to aid speedy rectification of the fault. A system where individual phase voltages and field current measurement, interlocked with a timer are monitored has proven to provide the only acceptable solution in voltage regulator mode. This is a very important issue . A simple yet very effective alternative to detect such condition is to start the excitation in field current regulator mode and to monitor the stator voltage. As soon as the voltage reaches a predefined setting (90% typically) a transfer to voltage regulator mode can be done and the ramp function takes over.
9. The following input signals from the external plant are required as digital inputs to the excitation system. All external binary signals are dry contacts.

Table 1: AVR Binary inputs

Signal to Excitation	Field Interface	Signal type from Field	Comments
Excitation ON	Unit Control System	Pulsed DO	FCB closes and excitation switches on. Field flashing will also be initiated by the excitation from this command if field flashing is required.
Excitation OFF	Unit Control System	Pulsed DO	Excitation system switch pulses off while FCB stays closed. This command cannot be executed by the excitation while the machine is online/ synchronised to the network.
Excitation ON speed Interlock	Unit Control System	Latched DO	Closes when the rotor speed > 95% of rated speed
Excitation Trip Main1	Gen Prot	Latched DO	ESD Conditions Main 1 trip. The FCB is also directly tripped from Main 1.
Excitation Trip Main2	Gen Prot	Latched DO	ESD Conditions Main 2 trip. The FCB is also directly tripped from Main 2.
Excitation OFF Main1	Gen Prot	Pulsed DO	Only switches off excitation, FCB remains closed
Excitation OFF Main2	Gen Prot	Pulsed DO	Only switches off excitation, FCB remains closed
Set-point raise block	Gen Prot	Controlled DO	Gen protection blocks set point raise when over flux is detected.
Excitation Active Mode set-point raise and lower	Unit Control System	Pulsed DO	Raise and lower signal from control desk/ HMI to change the set point of the active mode that is selected.
Voltage set-point raise and lower	Synchroniser	Pulsed DO	Synchroniser raise and lower pulses.
18 kV Breaker closed	Gen Prot	Latched DO	GCB status for excitation on interlocking and superimposed regulator FCR.
18 kV Breaker open	Gen Prot	Latched DO	GCB status for excitation off interlocking and superimposed regulator FCR. Double bit logic for security.
400kV Breaker closed	Gen Prot	Latched DO	Status for excitation on interlocking.
400 kV Breaker open	Gen Prot	Latched DO	Status for excitation off interlocking.
AVR Mode On	Unit Control System	Pulsed DO	Ensure regulation is selected to AVR mode when doing any run-up.
Force Channel Changeover	Independent protection device	Pulsed DO	Forces a channel changeover in the event of sustained field over current.
Channel 1 ON	Unit Control System	Pulsed DO	Selects regulation channel 1

Signal to Excitation	Field Interface	Signal type from Field	Comments
Channel 2 ON	Unit Control System	Pulsed DO	Selects regulation channel 2
PSS ON	Unit Control System	Pulsed DO	Selects PSS to ON
PSS OFF	Unit Control System	Pulsed DO	Selects PSS to OFF
Alarm acknowledge	Unit Control System	Pulsed DO	Acknowledge excitation system alarms and reset alarm if alarm condition has cleared.
H2 Pressure	Unit Control System or Gen Monitoring	Latched DO	Invoke second parameter set for maximum field current limiter
Rotor Earth Fault	Gen Prot	Latched DO	
Stator Cooling Water Temperature	Unit Control System	Latched DO	
Note: All signals are preliminary and will be finalised during the detail design phase			

10. The following remote hardwired digital outputs from the excitation are required. All outputs are dry contacts:

Table 2: AVR Binary Outputs

Signal from Excitation	Field Interface	Signal Type	Comments
Excitation is ON	Unit Control System	Pulsed DO	Confirms that excitation is ON (close contact) open contact is regarded as the inverse i.e. excitation is OFF
Excitation is OFF	Unit Control System	Pulsed DO	Confirms that excitation is OFF
AVR mode ready	Unit Control System	Sustained DO	AVR mode selected and no auto fault
AVR mode active	Unit Control System	Sustained DO	Excitation on and AVR mode active
Field Breaker open	Unit Control System	2xN/O and 2xN/C auxiliary contact for FCB	FCB switch drop out philosophy
Field Breaker closed	Unit Control System	Latched DO	FCB is closed
Excitation ready	Unit Control System	Sustained DO	All local conditions are ready to switch on excitation. Not in local, AVR mode selected, all doors closed, field flashing supply healthy, etc.
Excitation system tripped	Unit Control System	Pulsed DO	Excitation has tripped
Excitation system tripped to Main 1	Gen Prot	Pulsed DO	Excitation has tripped. If excitation was tripped by Main 1 protection, this DO will not go high.
Excitation system tripped to Main 2	Gen Prot	Pulsed DO	Excitation has tripped. If excitation was tripped by Main 2 protection, this DO will not go high.
Common alarm	Unit Control System	Unit Control System	Only hardwired alarm, all other alarms via communication bus.
Note: All signals are preliminary and will be finalised during the detail design phase			

11. The following hardwired 4-20 mA analogue output signals are required:

Table 3: Analog Outputs from the ECS

Signal from Excitation	Field Interface	Signal Type
Field voltage	UNIT CONTROL SYSTEM / Gen Fault Recorder	4-20 mA
Field current	UNIT CONTROL SYSTEM/ Gen Fault Recorder	4-20 mA
Rotor temperature	UNIT CONTROL SYSTEM/ Gen Fault Recorder	4-20 mA

12. Local controls include:
    i. Channel changeover/select from Channel 1 to Channel 2 and vice versa.
    j. Regulation mode selection. (AVR.FCR)
    k. Field breaker close/open commands
    l. Excitation ON/OFF.
    m. Set-point raise and lower of the active channel.
    n. Local alarm acknowledge.
    o. Local alarm resetting.
    p. Power System Stabiliser (PSS) ON/OFF (the default position of the PSS is on).
    q. Local/remote selection via HMI shall be password protected or via external key switch

13. Local control signals and remote control signal shall be interlocked with a local/remote mode to ensure that a command from only one particular source is executed at any particular time. All signals from either local or remote shall be interlocked to ensure that two buttons are pressed simultaneously to prevent accidental operation, except for the alarm acknowledge and set point change controls

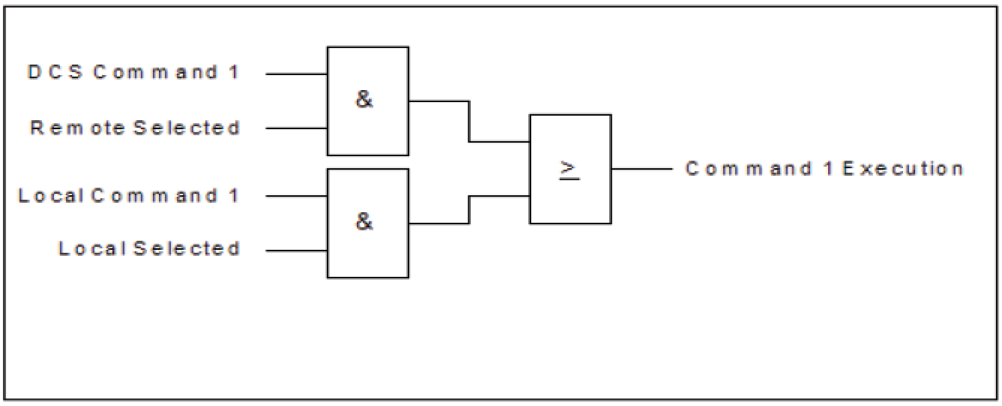


Figure 2: Local/ remote command interlock

14. Provision shall be made by the *Contractor* for a pre-set reference value to which the machine is to be excited once the excitation is switched on. This reference value shall be adjustable in the range specified for the operation of terminal voltage. The pre-set function is present in AVR, FCR and test mode.
15. During application of initial excitation, a ramp function overrides any regulation loop except for over fluxing which always has priority. The generator voltage therefore rises according to a set ramp rate, which is adjustable. This is present in voltage regulator mode.
16. The permission to close the field breaker signal input from the unit control system is used to prevent excitation being switched on if the speed is less than a certain percentage of nominal as well as other unit conditions.
    a. Loss of this signal does not switch off the excitation while the unit control is synchronised to the electrical grid.
    b. The excitation-ON command is enabled via the unit control permission to close signal.
    c. The permission to close signal is used for execution as a level triggered event and not an edge triggered event.
    d. When the machine is not synchronised, the loss of this signal allows de-excitation to take place in the form of an excitation-OFF command and not a field breaker-OFF command.
17. Provision shall be made for a step function and frequency sweep signal for testing and commissioning purposes.

e. Should this not be a build-in function, allowance for such an external analogue disturbance signal shall be provided.
f. A means of interlock or prevention of this function is provided so that it can be active only in a test mode.
g. The step function and/or the frequency sweep functions have user adjustable limits to prevent commissioning personnel from accidentally applying too big a value in either positive or negative directions.

18. The converter bridges are to be equipped with conduction and pulse monitoring supervision. Conduction monitoring not only monitors pulses but the actual switching of the semiconductor devices as well.
    h. The faulty bridges and the faulty element in the bridge are indicated locally.
    i. Bridge conduction monitoring with current feedback may be interlocked until field current is more than 60% of open circuit field current.
    j. The importance of this signal is to allow a properly functioning monitoring part to detect loss of conduction and to take the necessary action to keep the machine excited.
19. The full and uncontrollable rectification of a bridge can lead to generator field over heating with serious damage and very expensive repairs. A controller could be measuring it correctly but due to a voltage being imposed on the control signal going to the thyristors, it cannot reduce the field current. This is a classic example of “what if scenario” if the controller that is supposed to annunciate or control the transfer to the other channel cannot do that. In such a scenario the internal controls do not necessarily indicate a fault and allow the standby channel to take over. It is therefore very important that a sustained high field current be **independently** monitored and that control be transferred to another healthy channel should the condition arise. The importance of this cannot be over emphasized. This is the only protection against sustained field over current.
20. An independent AC over current device is used to detect such sustained over current conditions and have two adjustable definite time functions and at least one adjustable IDMT function with a sustained fault timer. The SFT may be replaced with a second IDMT function. The first IDMT function allows transfer of channels to take place and then if the conditions still sustain, the unit shall be tripped by either the SFT or second IDMT function via the generator protection system.
21. This independent monitoring is done by a separate protection IED powered from 110VDC batteries directly (no additional power supply in between) and interfaces directly to the field circuit breaker, the generator protection system as well as the excitation system. It has its own disturbance recording capability complying to a set number of recordings it can keep in non-volatile memory, time stamping, sampling rate, number of analogue and binary signals as determined by *Employer* in the technical schedule.
22. The reference setting is adjustable from the following places:
    a. Local at the AVR control panel.
    b. Remote control panel at the unit control desk
    c. Automatic synchronising system

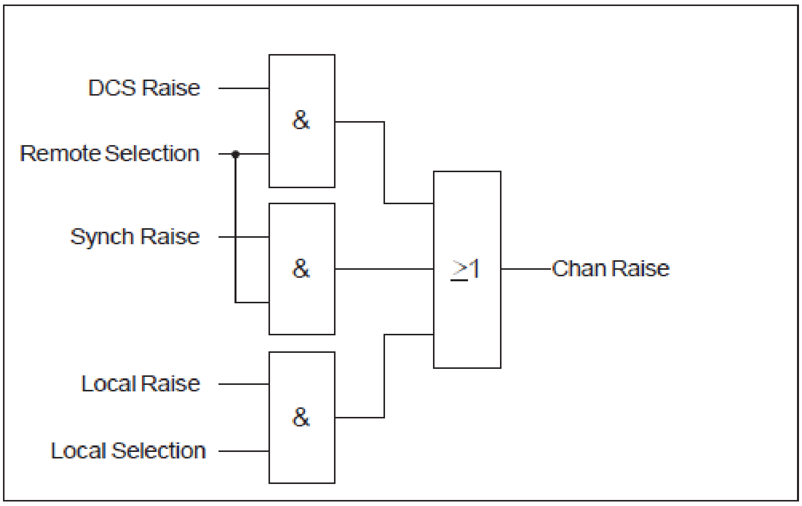


Figure 3: Reference setting adjustment logic (Channel Lower is also applicable)

23. Although the FCR mode is not a preferred operating mode, it forms part of the redundancy configuration of the excitation system. When the machine is on load and FCR mode is active (due to automatic transfer or deliberately selected), there exists a danger that the machine (and auxiliaries) may be subjected to severe over voltages when the GCB/HVCB opens whilst the machine is operating at more than 30% power and exporting MVArs at the time. The higher the field current requirements for the particular load condition, the higher the potential over voltage. To alleviate/minimise the risk of such an overvoltage, the excitation system monitors the GCB/HVCB status and stator current to detect such delta I_{gen} to signal a breaker opening. This then reduces the field current set point to a pre-set level where the amount of flux does not cause over voltages to the machine and connected auxiliaries. It is appreciated that the FCR is only a PI type regulator so the time to reach safe values of voltage levels are dependent on the PI settings too. Although the GCB/HVCB status may be used to initiate the required field current reduction routine, it needs to be supervised by power and/ or stator current. The use of only a binary signal from the breakers' statuses is acceptable. Depending on the operating point of the machine, the loss of the breaker status (undue reduction of the field current) with subsequent unnecessary tripping from the generator protection. The *Contractor* describes in his tender how this function is implemented.

3.2.4 Alarm and status indications

1. Alarms that have been initiated by the ES while in service are not to reset automatically when the alarm condition clears. These alarms shall only be cleared by accepting or resetting the system.
2. All alarms and statuses which are sent to the Unit Control System shall also be available on the local HMI.
3. As a minimum, the following alarms are made available on the *Employer's* Unit Control System via communication link:
    a. AVR Mode active
    b. FCR mode active
    c. PSU failure Ch1
    d. PSU failure Ch2
    e. AVR AC Supply fail
    f. AVR DC Supply fail
    g. AVR Channel 1 fault
    h. AVR Channel 2 fault
    i. Converter Bridge x fault: (temp high, pulse loss, fan fail, fuse fail, tripped, etc.)
    j. Over excitation limiter active
    k. Under excitation limiter active
    l. Field flashing time out
    m. Excitation transformer over current trip
    n. Excitation transformer temperature high alarm (per phase)
    o. Excitation transformer temperature very high alarm (per phase)
    p. Rotor temperature high alarm
    q. Sensor signal fault (e.g. PT100)
    r. Channel change over initiated.

4. As a minimum, the following statuses are made available to the *Employer*'s Unit Control System via communication link:
    a. AVR Channel 1 selected.
    b. AVR Channel 2 selected.
    c. Field Breaker open
    d. Field Breaker closed
    e. PSS ON
    f. PSS OFF
    g. Set point minimum reached
    h. Set point maximum reached
    i. Field flashing active
    j. Discharge circuit active

5. As a minimum, the following local alarms are made available on the ES HMI:

a. Channel 1 VT fuse failure
b. Channel 2 VT fuse failure
c. Channel 1 AVR not ready
d. Channel 2 AVR not ready
e. Channel 1 manual mode trip
f. Channel 2 manual mode trip
g. Channel 1 AC/DC power supply faulty
h. Channel 2 AC/DC power supply faulty
i. Channel 1 24 VDC supply faulty
j. Channel 2 24 VDC supply faulty
k. Channel 1 internal failure
l. Channel 2 internal failure
m. Channel 1 synchronising (input) voltage failure
n. Channel 2 synchronising (input) voltage failure
o. Channel 1 field current failure
p. Channel 2 field current failure
q. Field breaker position unhealthy
r. Converter Bridge * temp high alarm
s. Converter Bridge * temp high trip
t. Converter Bridge * air flow low alarm
u. Over excitation limiter active
v. Under excitation limiter active
w. Excitation external trip received
x. External sustained over excitation channel transfer (per channel)
y. External sustained over excitation channel trip
z. Positive/Negative field over voltage
aa. Rotor temperature alarm level 1 and 2
bb. Emergency change over initiated
cc. Conduction monitoring alarm and trip condition indicating which bridge/bridges and element are faulty

6. As a minimum, the following local statuses are made available on the ES HMI and should be displayed on default home screen:
   a. Active channel in operation (Channel 1 or Channel 2)
   b. Active mode in operation (Auto/Manual)
   c. Excitation OFF
   d. Excitation ON
   e. Field breaker is closed
   f. Field breaker is open
   g. PSS ON
   h. PSS OFF
   i. Local operation selected
   j. Remote operation selected
   k. Active converter in operation (if it’s a 1+1 configuration)
7. Additional alarms/statuses of the plant that the *Contractor* deems necessary are to be provided and will be reviewed by the design team.

3.2.5 Local analogue indication requirements

1. Permanent indication of all machine quantities is required.
2. The following panel mounted indicating instruments are provided:
   a. Generator stator voltage
   b. Generator stator current
   c. Generator active power
   d. Generator reactive power
   e. Generator field current
   f. Generator field voltage
3. All the indicating instruments are analogue instruments with sizes, accuracy, full-scale deflection angle etc. If a LCD panel with analogue instruments is provided, its time response emulates that of true analogue indications. Bar graph type displays are not allowed.

4. Instrument displays are consistent, i.e. all instruments have the same face size, similar scale markings and the same full-scale deflection angle.
5. Transducers/isolating amplifiers for all quantities are provided by the *Contractor*.
6. Requirements for the transducers to be specified by the *Employer* and *Contractor*.
7. Requirements for the indicating instruments to be specified by the *Employer* and the *Contractor*.

3.2.6 Software and licensing

1. The *Contractor* provides the latest version of all proprietary or open source software and licenses where applicable, including PC operating systems and licenses. The *Employer* cannot accept hardware with the *Contractor*s corporate operating system software.
2. The firmware, software and licensing updates are provided to the *Employer* for the duration of the support period of the specific equipment. The support period required for the equipment far outlasts any operating systems life expectancy. The *Contractor* therefore puts contingency plans in place when operating systems become obsolete to ensure that their own applications are either migrated to a new platform and that the necessary software drivers are compatible with new hardware as well. The *Employer* is responsible for maintaining the operating system licences throughout the lifetime.
3. All required software, including operating systems and device drivers with their respective licenses and installation files, in order to do maintenance and configuration changes and system recovery, are supplied by the *Contractor*.

3.2.7 Special hardware requirements

1. All computer based systems have a solid state drive installed that is utilised by no more than 50% of the full capacity.
2. An equivalent solid state drive is replicated after final commissioning to serve as a one-to-one replacement in the case of an SSD failure.
3. All hardware needed to connect with the system needs to be pre-configured and supplied by the *Contractor.*
4. All required software, including operating systems and device drivers with their respective licenses and installation files, in order to do maintenance and configuration changes and system recovery, are supplied by the *Contractor* and form part of the *Works*

3.2.8 Engineering and special tools

1. The *Contractor* provides any special tools, test handles or keys that are required for maintenance or affecting adjustments.
2. A detailed list of tools is supplied by the *Contractor* to the *Project Manager* before delivery.
3. Should any special interfaces for connection to PCs be required it is regarded as special tools.
4. Notebook PCs are generally not regarded as special tools but the *Contractor* has to provide at least **two** such devices and these are available during FAT. Notebook PCs are dedicated to the ES and due to driver compatibility issues and rigorous testing by the *Contractors* to choose the right hardware, they are regarded as special tools for this project. Notebooks are to be supplied with licensed operating system software and disks. The *Contractor* provides a fully functional engineering tool to commission and modify all intelligent electronic devices supplied as part of the Works. The engineering tool includes the necessary software and hardware required to access the intelligent electronic devices.
5. If proprietary software is used, five licensed copies of such software are provided as part of the special tools requirement for the project.
6. There are a minimum of two special tools for all other special tools supplied to this project.

3.2.9 Fault/ transient recorder

The fault or transient recorder has many interpretations causing ambiguity. It is also known as pertography or oscillography devices. This device, or built in functionality, shall be capable of recording pre-event and post event data where the data to be recorded and the trigger event/s descriptions to follow below

1. These fault or transient recorders shall be configurable to record pre-selected “analogue” data and may record binary data or events with appropriate time stamping too.
2. Transient recorders shall have a fast enough sampling rate to record analogue value disturbances that may trigger events like converter voltage failure or machine voltage failure. It will be allowed to have separate functionalities with fast sampling and slower sampling to provide the best of both worlds.
3. When analogue values within the excitation controllers are recorded the sampling shall not be less than the fastest interrupt signal generated by the electronic controllers. This way a true representation of what the controller detects or measures to base its decision making algorithm on, is recorded. This applies to fast changing signals too.
4. Any event internal or external that will cause a change to the excitation control mode or “normal” operating conditions shall be deemed a triggerable event and shall be selectable as a trigger for the transient recorder, immaterial if this will a cause a trip or not.
5. External signal that shall be selectable as triggers include but are not limited to are:
    a. Channel change over from remote (DCS/SCADA/Unit control)
    b. Operating mode change from HMI
    c. Generator protection trip
    d. External protection like internal arc or over current devices
    e. Emergency trip (EPB)
    f. Signals that will be specified by the technical specification
6. Internal signals that shall be selectable as triggers shall include but limited to are:
    a. Any event causing a change over from one channel to another, either operator selected or due to a forced change (by internal fault)
    b. Any event causing a change in the operating mode, either operator selected or due to a forced change.
    c. Any excitation system generated trip.
7. Time stamping of every recording and trigger event shall be done.
8. Several analogue type signal are important for disturbance analysis and therefore at least eight analogue quantities (user selectable) shall be recorded simultaneously by the transient recorder and these shall include any 8 of the following, but not be limited to:
    a. Generator/Machine voltage.
    b. Generator/Machine stator current
    c. Generator/Machine excitation voltage
    d. Generator/Machine excitation current
    e. Generator/Machine active power
    f. Generator/Machine reactive power
    g. PSS influence signal
    h. Converter control voltage (equivalent to firing angle control)
9. If the recorder is capable of being triggered by analogue values, it shall be possible to disable analog triggers due to its notoriously over functioning and then recording memory is compromised.
10. The transient recorder shall provide a recording buffer to adjust the pre-trigger up to 80% of the time window and a post trigger of up to 80%. Both pre and post trigger not be able to be settable to maximum at the same time.
11. Minimum time window at the fastest interrupt to accurately record the abovementioned analog values is 10 seconds.
12. Fast sampling to detect disturbances in the converter voltage that could lead to trips due to converter voltage disturbances, shall have a time window of at least 100 cycles of the AC converter supply.
13. At least six disturbance records shall be stored in non-volatile memory on the excitation equipment or recording device for later retrieval via appropriate software. The transient recorder shall be user selectable to either stop the recorder once the memory is full or to start over-writing the first recording to allow the most current recording to be last in the memory.
14. The data may be recorded in any digital format. Either free ware or proprietary software shall be supplied as part of the excitation for retrieval and analysis of the data. For the purpose of data retrieval

and data analysis, a laptop computer with most current Windows operating system for interfacing with the recorder hardware shall be provided.

15. The laptop can be used for local (at the excitation panel) or remote (still in the confines of the power station) downloading of the information from the recorder hardware. This will in most cases require additional data switches and media converters to be supplied. Remote communicating with the recorder hardware is provided through Ethernet for remote down loading. The technical specification will define the scope of supply.
16. An extra data converter that can convert the disturbance records to COMTRADE format as specified by IEEE C37.111, IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems shall be provided as this format allows easy analysis and data integration with other disturbance recorders in the protection system.
17. Time stamping of all events must be provided.

18. Time synchronization is provided by an external GPS clock.
    a. A polling system must be utilized between the ES and the GPS clock

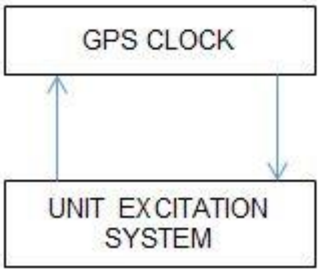


Figure 4: Polling system

    b. The system is compatible to Network Time Protocol (NTP).
    c. The GPS based master clock is provided by the *Employer.*
    d. Contractor to provide an RTC that does not deviate by more than 1 minute in 30 days for the ES. This is equivalent of almost 20ppm accuracy.
    e. All items required to realise a fully operational system for all four units to be time synchronised to the same time is included in the *Contractor*'s supply.

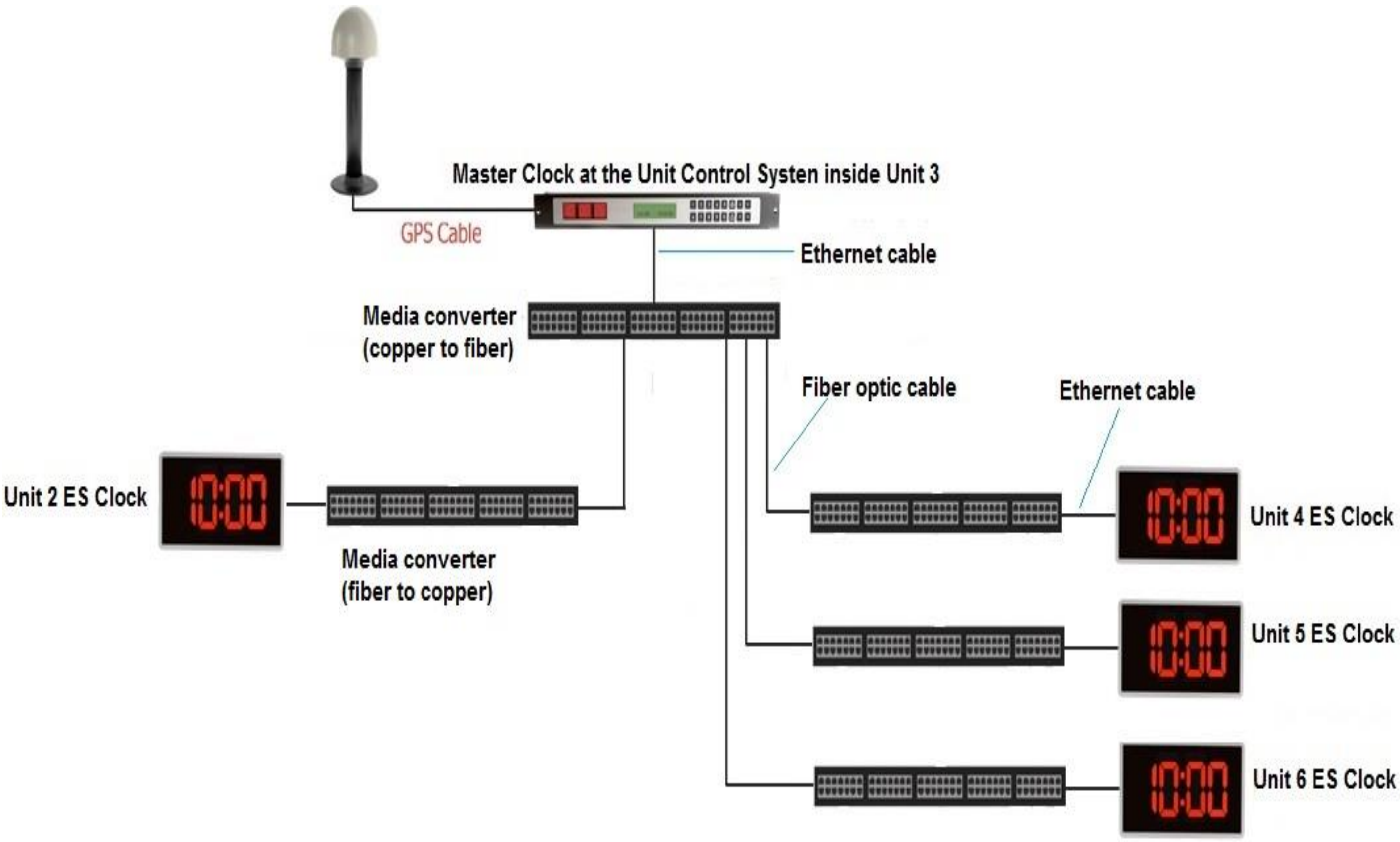


Figure 5: GPS Clock Distribution to the ES Concept diagram

Event logging facilities

1. Event logging describes the action and time stamping of any event (alarm, trip or a status change) and storing it into a rolling buffer in chronological order. The size of the buffer with regards to number of event shall be listed by the *Employer* in the technical schedule.
2. All events logging apparatus is time synchronised with the master clock as described under section 3.2.9
3. All alarms and trip events form part of the event logging by default.
4. All signals logged in the event log indicates when it becomes active and when it clears, either automatically or via HMI reset function.
5. Further events like limiters or commands from local or remote are configurable as events as well.
6. Field breaker status change shall by default be recorded as an event too.
7. It shall be possible to retrieve the event log/s from the ES and save it to proprietary and non-proprietary formats like comma separated value, text files or ASCII files

3.2.10 Follower circuits

1. Circuits in the inactive channel follow the operation of the active channel, such that when a sudden changeover is carried out from the active to the inactive channel, the transient change and steady change in the machine terminal voltage is within limits, as specified by the *Employer* in the technical schedule.
2. Figure 6 below explains the steady state and transient changes

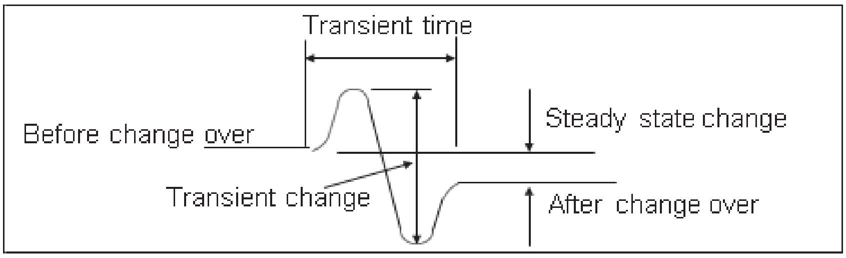


Figure 6: Transient and steady state change

3.2.11 Limiter and protection requirements

The limiters listed below form part of each automatic channel and their limits are adjustable. Upon intervention of the limiters on the voltage regulator, no sudden changes in excitation levels are observed nor should it be oscillatory.

3.2.11.1 Flux limiter

1. The flux (V/Hz) derived from the output terminal voltage is used to control the ECS output to operate within the flux levels specified.
2. The limiter is supplemented with an adjustable time delay as specified by the *Employer* In the technical schedule
3. The limiter characteristic is user selectable between inverse time characteristics and definite time.

3.2.11.2 Under Excitation limiter

Under excitation limiter refers to a collection of limiters ensuring that enough excitation is delivered to the machine to maintain synchronism with the system.

3.2.11.2.1 Load angle limiter or P-Q limiter

1. The control circuit calculates the synchronous machine's active and reactive power to control the operation of the machine within the safe operating pre-set limits by influencing the excitation as per *Employer's* specification in the technical schedule
2. The limiter characteristic on the operating capability chart of the synchronous machine have adjustable MVArs offset and slope parameters or a piece-wise linear P-Q type limit.
3. The limiter is dependent on the machine stator terminal voltage and automatically changes its characteristics to maintain a constant margin of safety with the generator protection.

3.2.11.3 Over excitation limiter

Over excitation limiter is also collective to limiters that prevent over excitation.

3.2.11.3.1 Maximum field current limiter

1. The maximum field current limiter is measuring, supervising and controlling the main generator field current if it exceeds set thresholds.
2. The maximum field current limiter limits the machine rotor field current within the permissible levels as specified by the *Employer* in the technical schedule and Grid Code.

3. The limiter has a maximum level parameter, which is not exceeded at any time and another parameter, which is either fixed time adjustable or dependent on the I^2t heating characteristics of the rotor.
4. This is a maximum continuous permissible setting, which acts on the regulator circuit and has priority over all other regulating or limiter functions as long as it is active.
5. When the thermal capacity of the field winding has been fully consumed, the limiter will restrict the field current to the maximum continuous rated value. As time passes the cooling effect of the field winding is emulated by a cooling down algorithm or back integration function to calculate the thermal capacity of the field winding for a subsequent field forcing event. Once the total thermal capacity has been reached, a new full field forcing window will be available.
6. In addition, it provides for a binary input to switch over to a second set of settings if any additional limitation needs to be imposed. This limitation could for instance originate from an external H2 alarm condition, Stator Coolant temperature or rotor ground fault alarm. Any condition that the *Employer* requires to switch to this second parameter set needs to be captured individually but the action for the switch over to the second parameter set is the same i.e. any one condition activation needs to switch over to the second parameter set. This signal is latched and can only be changed back via human/operator intervention. A sustained alarm status will be generated for any of these conditions by the excitation system.

3.2.11.4 Protection requirements

The protection of the excitation system is highly selective in its functioning and offers the correct discrimination. The following protection is provided:

1. Protection of the converters against over current and DC short circuit.
2. Over temperature of converters are permanently monitored.
3. The excitation transformer is also fitted with a redundant set of temperature sensors (PT100). Provision is made by the new ES to accept these signals and act accordingly. All temperature trips are time delayed to ensure stability.
4. Detection of internal arcing in the power electronics cubicles with the exception of DC field breaker cubicle. Internal arc tripping is supervised by a settable over current function measured on the HV side of the excitation transformer.
5. Protection of the converters against AC and DC over voltages.
6. Protection of the field winding against over voltages.
7. Rotor temperature monitoring is calculated using the field voltage and current as primary variables. Any other parameters required by the algorithm used by the Contractor needs to be specified so that the most accurate values can be provided. The rotor temperature value is displayed on the local control panel as well as be transmitted to the unit control system via 4-20mA signal. It has two warning stages available as external alarms.
8. All protection relays to be used are either part of 240-56227589 (latest revision) (available on request) or are tested by the *Employer* for compliance to its requirements. The cost of testing is for the account of the *Contractor*.
9. Detection of internal arcing in the ES busbar cubicles is to be provided.
10. Internal arc detection devices uses an overcurrent check from the HV side of the excitation transformer to supervise any arc detection and does not issue a trip unless an over current condition has been confirmed via a settable threshold. It is appreciated that the excitation arrangement is such that the power source cannot be isolated via a breaker, but having this protection can reduce damage and improve safety under arcing conditions. HRC fuses, when used can dramatically reduce the arc energy. When fuses are used as input protection

3.2.12 Power System Stabiliser

1. The PSS is of the 2B type as specified by IEEE 421.5–2005.
2. The PSS includes an adjustable filter on the speed signal to further reduce the potential of exciting shaft torsional modes.
3. Both phase and gain settings are variable.

4. A mechanical load change does not affect the voltage control of the ES.
5. The PSS includes limiters, which prevent the excessive degradation of the excitation voltage.
6. These limits are adjustable and cannot be exceeded under any circumstances.
7. The PSS has active power level detection and can switch the stabiliser on and off when above or below a certain setting respectively.
8. The PSS also monitors the machine voltage and switches itself off when this exceeds the specified values and after a time delay as specified by the *Employer*.
9. On recovery of the machine voltage, the PSS switches back on after a set time delay.
10. In addition, the PSS is switched on/off from the remote Unit control desk.
11. The *Contractor* supplies the preliminary PSS settings and model before commissioning as well as the final optimised settings during commissioning.
12. The PSS indication to the control room is linked to whether it has been selected to the on position or not (PSS enabled or disabled). The active state of the PSS is power system dependant and indications to the control room can be confusing when PSS status indication appears and disappears haphazardly if the status is linked to the PSS "stabilizing" signal.
13. The selection of FCR mode de-selects the PSS (switches it off) and does not automatically switch on when AVR mode is activated. Switching the PSS on, is then a conscious action by operating personnel.
14. The PSS must however be automatically selected when the ES is in AVR mode at start-up/initial excitation.

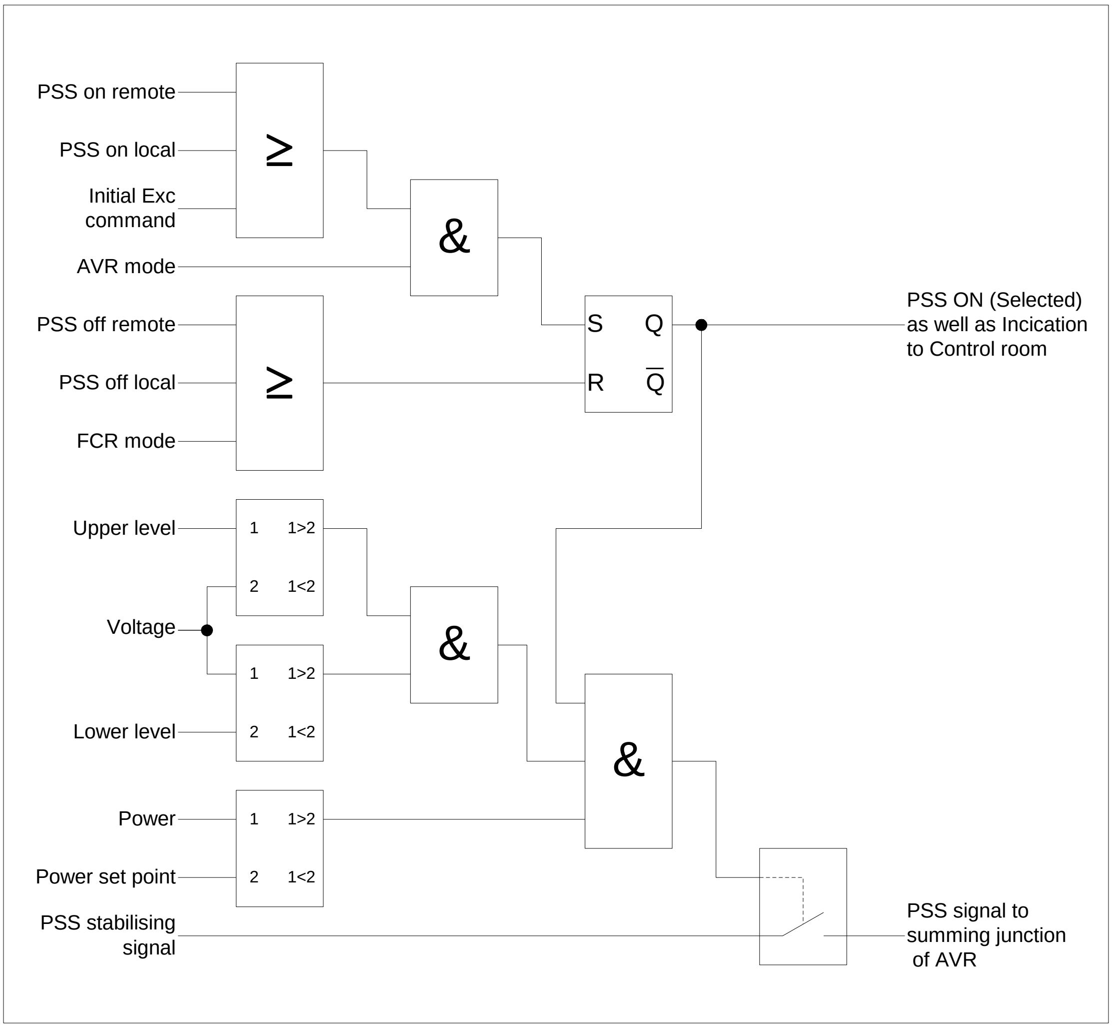


Figure 7: PSS switch on logic

3.2.13 Field flashing

1. Field flashing is a requirement and attention to the breaking capacity of the field flashing contactor is given especially if the supply voltage is higher than the rated field voltage for open circuit conditions. This is to prevent over excitation that can lead to over voltages on the machine.
2. Protection with the aid of a timer is used to stop the field flashing should the machine not self-excite within a predetermined time.
3. The *Contractor* indicates exactly the application of field flashing and proves that it can withstand all the requirements in the proposed arrangement. .
4. The existing field flashing supply comes from the 400V AC supply.

Table 4: Field flashing circuit details

CIRCUIT	PROTECTION DEVICE TYPE	MCCB /MCB SIZE	AC VOLTAGE	ENTRY POSITION	CABLE SIZE	CABLE CORES	EST CABLE LENGTH	CIRCUIT TYPE
AVR FIELD FLASHING BREAKER	MCCB	80 A	400 V	BOTTOM	16 mm^2	3	105 m	FIXED

3.2.14 Initial excitation and soft start

1. Although this requirement is not strictly speaking a limiter, it is a form of superimposed regulation.
2. Provision is made so that initial excitation is activated from an operator or control system command from the unit control desk that is also interlocked with a speed signal from the control system.
3. A soft start function prevents the machine voltage from rising at a rate faster than that specified by the *Employer*.
4. The time to reach the pre-set machine voltage is adjustable.
5. The flux limiter has priority over the soft start function.
6. Although the soft start or ramp function is primarily to prevent stator voltage over swing, the lack thereof has caused bridge failures on start-up for the *Employer*. An additional requirement is that under such start-up condition the field voltage never exceeds nominal field voltage. It would be even better if it never exceeds open circuit field voltage thereby creating a natural stator voltage rise with no overshoot.
7. An acceptable alternative is to use the field current regulator as ramp function during starting to ensure slow build-up of excitation in the machine.

3.2.15 Field suppression requirements

1. The field suppression circuit is accomplished by means of a combined electronic crowbar system.
2. The field suppression circuit is designed to dissipate the magnetic energy stored in the exciter field as rapidly as possible and is capable of handling the highest exciter field currents possible under fault conditions while in service, without undue temperature rise or damage.
3. The discharge resistor and associated components comply with the latest revision of IEEE 421.6.
4. The de-excitation process ensures minimum wear on the field circuit breaker.
5. Overlapping time between inverter operation and field breaker tripping signal is adjustable at least in the range as specified by the *Employer*.

3.2.16 Field Breaker control

1. The field breaker control is to be carried out by the ECS when selected to “remote”.
2. With the field breaker control selected to “local”, only local electrical control is permitted. Only electrical operation of the field circuit breaker is permitted and no operation from the control interfaces is allowed once the unit is synchronised to the grid.
3. Auxiliary contacts are provided for status monitoring and interlocking functions. Each field breaker has one tripping and closing coil.
4. The field circuit breaker should not be allowed to re-close after a breaker trip within a specified time.

3.2.17 Power Supplies

1. The main source of auxiliary power is supplied by the excitation transformer and dry type auxiliary transformers. This is to allow the excitation system to be as autonomous as possible.
2. The power supply transformers are adequately sized to allow the primary source of control power to be derived from this source.
3. Suitable filtering is installed so that the connected power supply modules are not affected by any commutation interference from the power electronics.
4. The *Employer* provides protection in the form of fuses/circuit breakers for all station supplies at the supply points.
5. Any internal fuses or MCBs are monitored and any open or tripped conditions shall be alarmed, where possible.
6. The dual outlet wall socket supply in the ES panels has earth leakage protection as required by SANS10142-1 and complies with the 16A, 250 V South African socket outlet requirements(SANS 164-1 and SANS 164-2)
7. The secondary source of power for internal power supplies comes from two 110VDC supplies from the Unit and station DC boards respectively. VA requirement of the supply is provided by the *Contractor*.
8. This 110VDC supply is also used as a tripping supply.
9. Two independent power supplies per channel supply the control system’s “Channel 1” and “Channel 2” as a primary source of power.

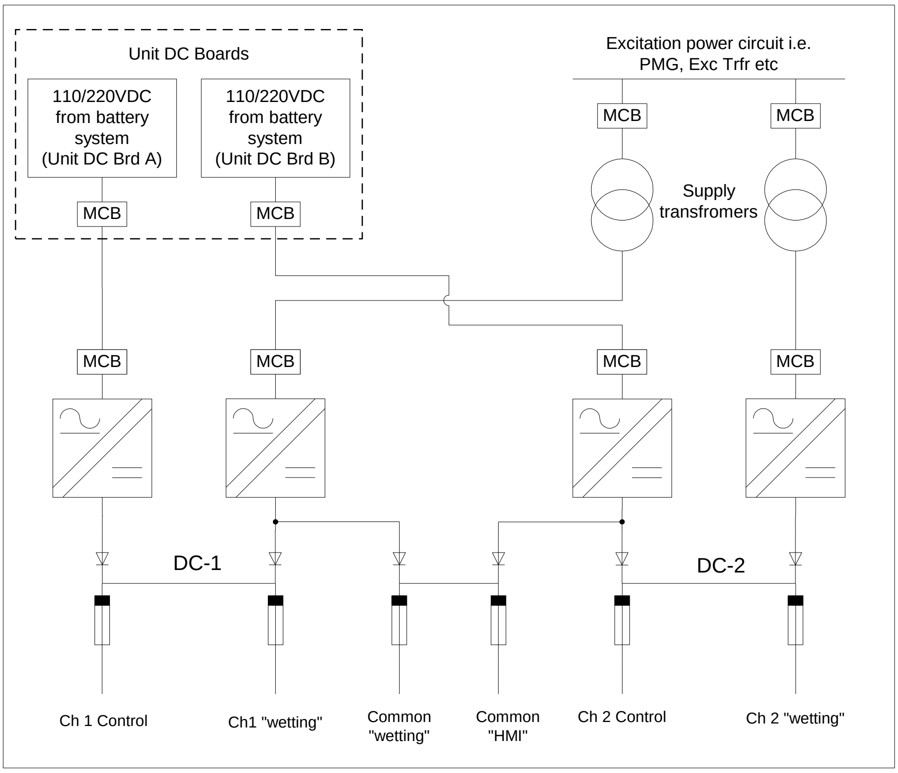


Figure 8: Channel power supply

10. Please note that power can only be diode decoupled after galvanic isolation of the primary sources i.e. only the secondary side of the power supplies. Diode decoupling on the primary side is completely unacceptable.
11. Supplies available for the ES panels are:
    a. 400V 4 wire AC supply
    b. 220V AC supply from non-essential boards
    c. 110V DC Unit supplies
12. The contractor specifies the VA requirement for each supply to be used and how many circuits should be available.

3.2.18 Auxiliary Transformers

1. All new transformers supplied are of the dry type.
2. The use of toxic insulation materials is not allowed.
3. The leakage flux produced by any magnetic component is kept as low as possible to avoid heating of its mountings and surrounding components.
4. Transformer nameplate data shall be fixed to the transformer with screws, bolts or rivets in such a way not to damage any insulation or be a safety hazard to personnel.
5. Nameplates shall not be metallic stickers but be engraved or punched on heat resistant material like aluminium or stainless steel.
6. Regulation range should be such that at maximum current the output voltage shall still be sufficient for whatever load is dependent on it and will operate satisfactory.
7. Transformers supplied by frequencies other than standard power frequency shall not build up heat due to the higher supplied frequencies. Design details and test results to support such a design shall be carried out prior to acceptance of the transformer/s and where possible these transformers shall be tested as part of either type tests or FAT at the design frequency.
8. Redundant transformers for power supplies are required; one transformer per control channel.

9. Auxiliary transformers are normally fused or MCB protected with subsequent alarming to the Local HMI and alarm circuitry. Unhealthy voltage values or phase voltage failures on some circuitry can be detected by monitoring software to detect if synchronising supplies are healthy.
10. All auxiliary transformers shall be protected by suitable MCBs or MCCBs. These protection devices then also doubles as isolation points

3.2.19 Converter Bridges

1. The converter bridges shall have at least 1+1 or N-1 redundancy.
2. Each rectifier element is permanently marked with its make, rating and manufacturer's type number.
3. The plant and material are rated to achieve continuous maximum field forcing excitation even under N-1/1+1 configuration.
4. The *Contractor* ensures that all Plant and Material is rated to withstand the highest possible surge current and surge over-voltage.
5. The surge calculations are submitted to the *Project Manager* for acceptance.
6. The converters are rated to be installed and operated with forced air cooling in an environment with an ambient temperature of 35 °C.
7. Air is taken in from the bottom of the panel and exhausted at the top.
8. The *Contractor* shall provide a dual fan system per converter with front access for testing and replacement, and also for quick and easy replacement of the fans during operation.
9. The *Contractor* shall furthermore describe in detail in the tender document the type of monitoring and control used for the cooling mechanism.
10. Proper filtering with easily removable filter elements for cleaning is provided. It is known that the filters get clogged up quite frequently due to PF and dust, filter design caters for these environmental conditions. Quick replacement is required to minimise contaminants to enter the cubicles while filter changes takes place.
11. The cooling fan motor assembly shall be readily available in South Africa.
12. Each converter has fan redundancy in the design. To ensure that all fans are operative, fans selection/change-over is performed and monitored immediately after initial excitation to give the assurance that the redundant fans are operational/serviceable. This automated check is a prerequisite for the excitation system ready signal to the control system to allow the synchroniser to be switched on.
13. The cooling fans have separate internal supply transformers for the "main" fans and the "back-up fans". Both fan sets also have an external test supply input and can be selected to either main supply or test supply. The switch positions shall be monitored by both controller channels as part of the excitation ready signal.
14. The *Contractor* provides the dimensions on the drawings and confirms the position indicated as acceptable.
15. The panels are exposed to high and low temperatures, high and low humidity and therefore be rated as IP52Cin terms of SANS IEC60529.
16. No water-cooled converter stacks are allowed.
17. If any part of the cooling systems fails, an alarm is activated both locally and remotely.
18. Temperature monitoring of the converters are supplied as well as air flow sensors.
19. Each cubicle door for the cubicles installed has a lockable handle to open and close the door.
20. The locking mechanism for the handle is external to the handle to accept padlocks.
21. Each excitation cubicle door is equipped with a high quality limit switch. These switches are required as an interlock for all doors to be closed before excitation can be switched on and generates an alarm in the event list. Post excitation on, these switches only generates an alarm in the event list and does not trip the excitation system.
22. The polarity on the slip rings needs to be swapped around about from time to time. The converter or field breaker cubicles make provision for a bus bar design to incorporate polarity changes. It is possible to make these changes without dismantling any part of the cubicle or other parts of the bus bar or field breaker. These links are also easily accessible within the panel including torque wrenches.

23. A new shunt for field current measurement is fitted to the DC bus bars in the converter/field breaker cubicles.
24. Studs or bolts that are part of insulators used to support bus bar or shunts do not form part of any conduction path bolted joint. Insulators only support the conductors for mechanical rigidity and insulation purposes.
25. All bus bar support insulators are rigid enough to withstand the electro-mechanical forces of the bus bar and or cabling under short circuit conditions. Design calculation of any cable or bus bar supports are provided to the *Project Manager* for approval.
26. All cubicles are adequately earthed to the station earth. The station earthing point is provided by the *Employer*. The *Contractor* supplies the earth connection material and connects the panels to the supplied earthing point. Minimum copper square area is as per *Employer's* specification.
27. Please consider the provision of a converter test supply for outage related maintenance. Feedback from this supply needs to go to the controllers. Any connection to a test supply must also isolate the normal supply to prevent back energising of the excitation transformer.

3.2.20 Excitation Regulator panel

1. The existing regulator panel is located in a room together with the converter bridges. This introduces safety, reliability and operational challenges due to heat dissipation and fault currents.
2. This panel shall be relocated from the excitation equipment room to the Equipment room, right next to the generator protection panels. The *Employer* shall provide floor layout diagrams to the *Contractor* detailing the current and proposed locations of the regulator panel.
3. This relocation of the panel introduces some known challenges in adequately achieving Grid code model validation tests due to the longer distances of the field voltage and current signals. The *Contractor's* design needs to make provision for achieving these requirements in the most practical and safe manner, The *Contractor* displays this during the tender stage.

3.2.21 Protection device requirements

1. All protective relays/IEDs and circuits comply with 240-64685228.
2. The relays/IEDs do not malfunction should the DC auxiliary supplies be switched on and off permanently or repeatedly at a random rate.
3. Refer to specification 240-64685228 for the required apparatus performance under electrical disturbances.

3.2.22 Civil requirements

1. The height, width and total length of the installed panels are designed to fit the available space. Any additional space requirements are clarified with the *Employer* during the basic design phase.
    a. The current excitation system (ES) is housed in a room below the turbine floor at a height of about 9.5 m from the ground floor. The equipment where the excitation regulator panel is to be relocated is on the turbine floor at a height of about 12m from for the ground floor.

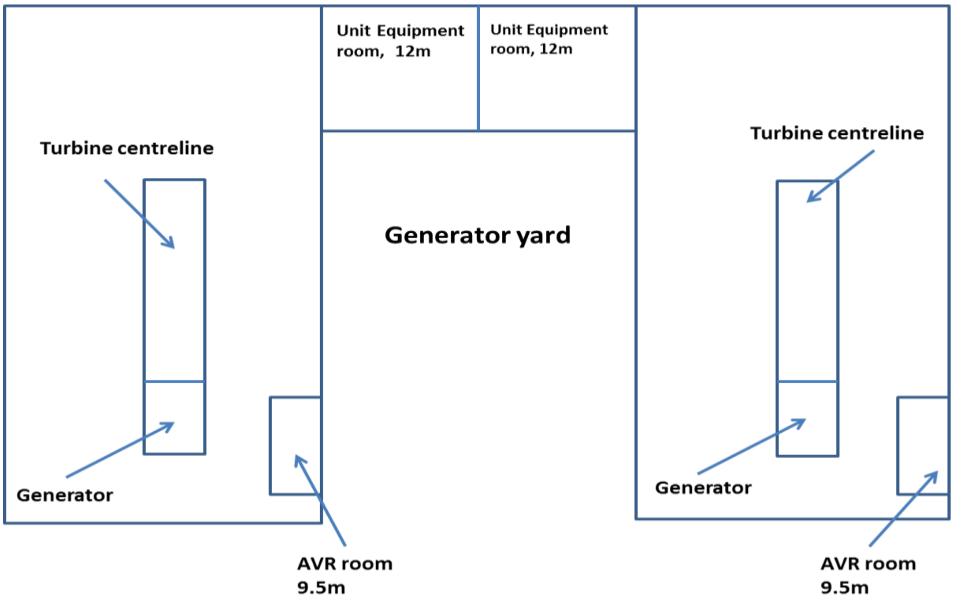


Figure 9: Excitation system converter room and regulator room locations

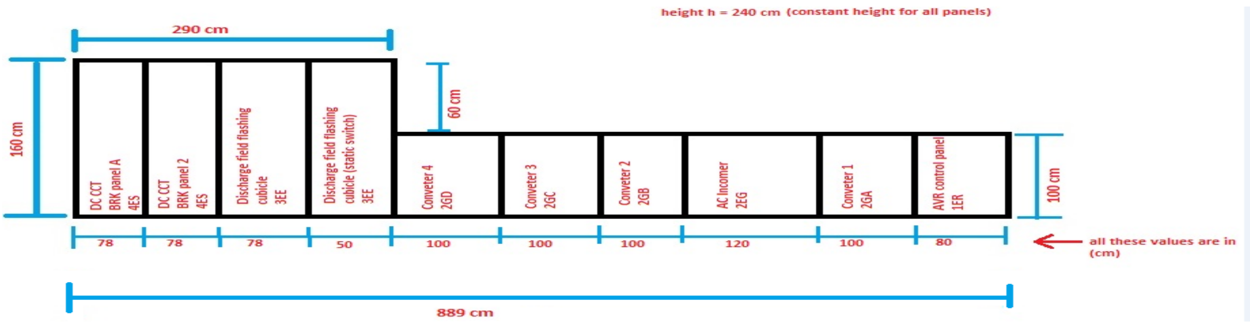


Figure 10: Existing excitation system dimensions

The current excitation system (ES) inside the AVR rooms is composed of boards made up of 10 panels in a row as shown in Figure 10

The inside of the new panels must be marked with the mass of the panels once all components are mounted and wiring is completed.

Contractor ensures that load carrying capability of the floor is not exceeded. The *Employer's* civil engineer provides load bearing capabilities. Should the *Contractor's* submission not comply to the given load-bearing capacity, the project will be halted for an adequate period so that the *Employer* may pursue the construction and/or installation of additional load-bearing structures or investigate suitable changes to the design requirements.

3.2.23 Excitation transformer requirements

1. EMDAS requirements
   a. The Contractor shall supply and install CTs for measuring current on each excitation transformer; the CTs shall adhere to 240-56359083, Metering and Measurement Systems for Power Stations in Generation Standard [52] (minimum 5VA) for monitoring of . It is allowed to use two cores within one CT block to minimise space requirement.
   b. The insulation level of CTs supplied by the excitation provider shall match the installation.

2. Thermal protection
    a. The *Employer* provides thermal monitoring equipment at the excitation transformer/s. Each phase of the transformer is monitored by two temperature sensors. Associated sensor processing units are installed and two contacts per phase are made available to which the ES must interface.
    b. The two alarm contacts per phase are in parallel.
    c. The trip contacts are arranged in 2oo2 system per phase.
    d. The concept design is depicted in **Figure 2**Figure 11 below. A detail design will be provided to the *Contractor*.
    e. Each phase shall be separately monitored for its alarm and trip contacts. The alarm and trips shall have adjustable delays to prevent nuisance tripping.

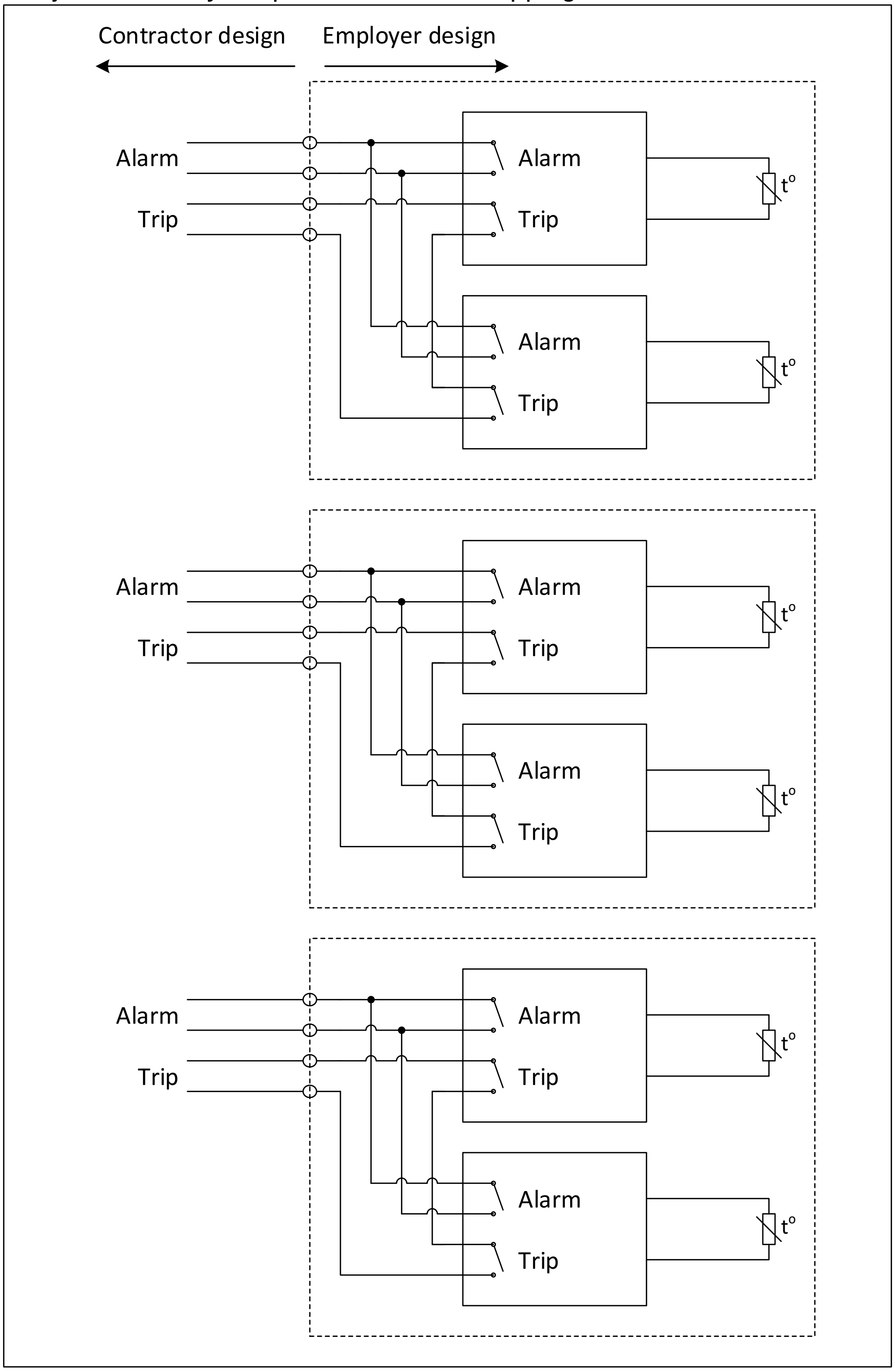


Figure 11: Excitation transformer temperature monitoring concept

3.3 Procedure for submission and acceptance of *Contractor*'s design

This is a mandatory requirement of core clause 21.2 and must be addressed. Identify the extent of detail (the particulars) of the *Contractor*'s design which is to be submitted to the *Project Manager* for his acceptance. This procedure may also include a design stage activity matrix or requirements for co-operation with Others on a multi party project. State requirements for drawings to be prepared by the *Contractor*.

The Detail design is submitted in a hard copy and soft copy format. Drawings to be submitted in Bentley Microstation version 8 format and text documentation to be at least in PDF or Microsoft Word 365 is the preferred format for ease of review and commenting. The *Employer* reviews the submitted designs and provides comments back to the *Contractor* within 21 working days. After approval of the Detail design, the *Contractor* proceeds with manufacturing of the system based on the approved designs.

3.3.1 Design phases

The process requires two distinct design phases:

3.3.1.1 Basic design

1. Full system technical and functional descriptions
2. Transfer functions of the system in the time and frequency domain
3. System philosophies finalised
4. Single line diagram of the proposed solution.
5. Block diagram of the system and system plant interface points
6. General layout drawings and cubicle dimensions to allow the *Employer* to evaluate if the installation can be accommodated, both in terms of rigging and space.
7. Approval of the final cubicle layout and designs
8. Floor plans and dimensions and all civil requirements
9. Bill of proposed materials/components including datasheets of all components
10. Type tests of components and/or assembly
11. Test certificates and datasheets of cabling
12. Samples of the termination schedules
13. Cable racking routes and additional racking identified
14. Pre-FAT communications integrity checks/tests
15. Conceptual proposal is submitted by the *Contractor* outlining the product offered, the features and how it will be applied to the Kriel plant setup.
16. A reference list is submitted indicating similar applications to plant.

3.3.1.2 Detail design

1. The final drawings (electrical and mechanical) of the complete excitation system including plant interfaces updated on the excitation drawings.
2. Panel internal wiring diagrams with numbers, AKZ, component descriptions, etc.
3. Termination schedules and cabling block diagrams
4. Cable racking designs for any additional racking.
5. Documented ES application software and any necessary viewing application to review the software
6. All calculations and specifications of the proposed equipment
7. Design calculations of all power cable requirements.
8. List of all cables to be installed (Cabling Schedule)
9. Design calculations of de-excitation equipment
10. Field suppression design
11. AC & DC short circuit calculations
12. Preliminary system and PSS settings for commissioning
13. Factory acceptance testing procedures

3.3.2 Implementation Approval

1. Completed & signed off FAT defects lists
2. Two identical sets of marked up drawings to be used for site installation.
3. Completed & signed of FAT test reports
4. Long lead items delivered to site, especially cabling
5. Site establishment completed. (containers, tools, scaffolding, printers, etc on site)
6. A complete on-site inspection check list to be completed right after delivery (Panels & cabling checks)
7. Authorised site acceptance testing procedures
    a. Panel decommissioning work package
    b. Cabling decommissioning work package
    c. Panel installation work package
    d. Cabling installation & testing work package
    e. Cable racking work package
    f. Civils work package
8. A complete cold commissioning testing procedure (Live loop checks & function tests with machine at standstill)
9. A complete hot commissioning testing procedure (Function tests with machine running). The *Employer* will integrate the program to the overall commissioning program.
10. All relevant QCP steps signed off by the *Contractor* where applicable at the time.

3.4 Other requirements of the *Contractor*'s design

1. All plant and materials shall be new
2. All electrical installations shall be carried out by a qualified electrician.
3. The new electrical cabling is certified by the *Contractor*'s electrician issuing a certificate of compliance (COC) before it is allowed to be connected.
4. All components comply with the Eskom standard 240-64685228 as well as associated international standards, unless otherwise stated.

3.4.1 Configuration management

1. Kriel Power Station subscribes to the AKZ codification system
2. All AKZ numbers or codes shall be submitted to the Project Manager for approval.

3.4.2 Control cubicle requirements

1. The excitation control electronics shall be housed in separate self-contained cubicles.
2. Access to all electronic cards, control and indications shall be from the front of the panel. The exact mechanical layouts and cable slot dimensions shall be confirmed by the *Contractor* during the first site visit.
3. Rigging of equipment of all cubicles to the correct level and location to be done by the *Contractor*. The *Employer*s crane can be used.
4. The cubicles shall be designed to prevent the ingress of dust.
5. The cubicles shall be vermin-proofed.
6. Any additional safety measures to be provided by the Contractor.
7. All access doors and covers to live apparatus are adequately marked with warning signs to warn of live parts behind them.
8. All doors equipped with voltage and current carrying plant and materials are earthed to the main frame of the cubicles by means of a braided earth strap.

9. Internal panel lighting is provided with a door-mounted switch enabling the light to switch on automatically when opening the door.

3.4.3 Wiring and wiring identification requirements

1. All wires to be provided with alphanumeric ferrule codes. All panel wiring to be marked with Graphoplast wiring markers or equivalent (subject to Project Manager acceptance).
2. Wires to be marked on both ends with the same number.
3. A wire adopting its termination point in a terminal rail as its wire number is not acceptable. When one wire has to move from one terminal to another the complete philosophy fails.
4. Ferrules with wire identification numbers read from left to right and from top to bottom on vertical terminal strips.
5. For control wiring, each wire tail is of sufficient length to reach the allocated apparatus plus an additional length of 100 mm to facilitate changes in wiring.
6. The slack is as close as possible to the component in the form of a loop.
7. Wiring is presented in a neat appearance, it is braced and placed in PVC trunking to prevent vibration and the possibility of forces being exerted on termination arrangements, no stick on plastic bracing supports can be used.
8. Wires to plant and material on swing doors are so arranged as to give a twisting motion and not a bending motion to wires. It is required that robust wiring looms at doors are used with clamps on both ends (Clamp on the door and a clamp inside the panel).
9. Where wiring is connected to current transformers, the termination shall be protected adequately.
10. Control and power panel wiring sheaths are coloured as follows:
    a. Black for single phase AC circuits.
    b. Grey for DC circuits.
    c. CT and VT wiring are colour coded as per the phase – red, white, blue and black (neutral).
    d. Power 3 phase AC circuit wiring is colour coded as per the phase – red, white, blue and black (neutral).
11. Panel wire terminations to electronic cards from the back are permissible.
12. All cable cores are terminated on a terminal strip with panel wiring completing the circuit to the relevant interface.
13. Wiring in trunking occupies no more than 75% of the cross sectional area of the trunking.
14. Any wiring connected to AC and DC busbars has an insulation withstand capability of 10 times the rated voltage with a minimum of 2.5 kV over one minute (IEC 60034-1 and IEC60255)

3.4.4 Panel/cubicle labelling

1. Eskom standard 240-62629353 – Specification for panel labelling, applies to panel labels.
2. Conductive labels or backing plates are not allowed on the inside of any electrical cubicles unless attached to components such as auxiliary transformers with rivets..
3. All warning labels on panels, doors or other structures are pre-approved before printing and application by the *Contractor*.

3.4.5 Fuse links and carriers

1. Fuses are of industrial high breaking capacity type as per IEC 60269.
4. Fuse links and fuse bases for bolted connections are used for power fuse applications.
5. Fuse links and fuse bases with blade contacts are not acceptable for high power circuits (converter bridges)
6. Fuse links and fuse bases with blade contacts are acceptable for small current circuits (e.g. VTs or power supplies)
7. All other fuses for DC and AC supply and VT fuses and fuse holders are of the F1 offset tag blade connector fuse
8. No screw type fuse holders are permitted.

3.4.6 MCBs

If MCBs used for stator voltage isolation have to be graded with VT fuses upstream. Proof of such grading is supplied to the *Project Manager* for acceptance. “Z-curve” MCB has proved to grade with fuses in most cases.

All MCBs shall have at least once auxiliary contact for status monitoring if it is dedicated to a channel. When an MCB is common to both channels dual auxiliary contacts are required.

3.4.7 Signalling lamps

1. Indicating lamps are of the LED type and are easily replaceable from the front of the panel without the use of special tools.
2. The voltage of the lamps is as per the circuit served.
3. The mounting of the lamp and resistor facilitates adequate ventilation.
4. Visual indication of alarms might also be served via scrollable LCD display or other type of visual display.

3.4.8 Auxiliary relays

1. Auxiliary relays comply with Specification 240-56227589.
5. Special notice should be taken if such auxiliary relays are to perform tripping functions. All relays should be of the demagnetising type.
6. All plug in type relays have bases where the termination of wires up to 1.5mm2 can be connected and up to a maximum of two wires per termination point.
7. Plug in relay bases do not cause wires entering the outermost terminals to interfere with an adjacent relay base.
8. All plug in type relays have metal, rust resistant retaining clips to prevent the relays from dislodging either accidentally or due to vibrations. Spacing between relay/relay bases are adequate to allow for individual relay removal without disturbing adjacent devices.
9. It is customary to use auxiliary relays with a mechanical forcing plunger. Such plungers are removed before final commissioning and the holes plugged with a suitable plug to prevent dust ingress into the relay contact area.
10. All auxiliary relay type tests or OEM certificates/specifications are submitted to the project manager for approval prior to ordering the components. Specifications include the contact’s DC breaking capability.

3.4.9 Output contacts

1. All output relays are to be fitted with self-resetting contacts.
2. Each tripping relay shall have at least two output contacts.
3. Contacts are rated in accordance with specification 32-333 (20MΩ at 500Vdc).
4. Output contacts of any relay, auxiliary or binary output card is able to carry the maximum load of the circuit it is used for without any damage.
5. In cases where large coils need to be energised with a high closing current but a much lower holding current, an “economising” resistor is typically inserted by the very same device through its own auxiliary contact. When such auxiliary contact fails to open to insert the resistor in series with the coil, a suitable MCB protects the initiating relays output contacts from being damaged. The preferred solution is rather to use an appropriate mini contactor as interposing device that can carry the closing current of the large coil continuously or a combination of the two.

3.4.10 Earthing requirements

1. The excitation apparatus is adequately earthed.
2. All non-current carrying conductive parts including the entire panel frame, all removable covers, relays, meters, gland plates, etc., are effectively connected to the earthing conductor by means of their mounting arrangement on the panel or by a separate earthing conductor.

3. This is done in such a way that the touch potential at any point on the panel due to a full phase to phase or phase to earth fault is limited to earth potential.
4. The earthing conductor is connected to the station earth mat at the designated earthing point of the panel.
5. The earthing conductor is pre-drilled to allow for connection to the station earth mat.
6. Should additional earthing conductors be required to meet the above requirements and specifications, the Contractor provides and installs such material
7. All cable screens and spare cores are earthed one side only.

3.4.11 Shrouding

1. All exposed terminals and cable terminations including test block terminations are shrouded using a transparent non-flammable material to prevent accidental contact.
2. All transducers connected to any field winding/busbar or shunt shall have proper shrouding over the terminations to prevent accidental contact to the terminal and shall be clearly marked where high voltages or a high risk of accidentally earthing the measuring point exist.
3. Acrylic sheeting is unacceptable as a shrouding material. Non-flammable, transparent, poly-carbonate or poly-propylene is the preferred material.
4. All cover designs are submitted to and approved by the Project Manager.

3.4.12 Terminals

1. Neither insulation displacement type connectors nor spring type connecter without screws are allowed.
2. Provision is made for printed circuit boards to be modified if this is a preferred type connector by the *Contractor*.
3. The use of “fast-on” or push on connectors are not allowed on power circuits, voltage transformer circuits, current transformer circuits or earth connections.
4. The terminals are spring retained on the assembly rail complying with DIN EN 50045 and when mounted and wired in service, is closely fitted to avoid the accumulation of foreign matter between adjacent terminals.
5. End barriers or shields are provided for open sided patterns.
6. It is possible to replace any terminal in an assembly without dismantling adjacent units; it is permissible, however, to loosen any clamping device.
7. Screw retention of any component from the rear of the mounting rail is not acceptable.
8. All terminal blocks are readily accessible.
9. The terminals are of the rail mounted screw clamp spring-loaded insertion type where terminations or lugs are compressed between two plates by means of terminal screws.
10. Terminals are spring loaded such that the actions of the springs are independent of the action of the terminal screws.
11. Terminal screws are captive within the mouldings and their heads do not project above the mouldings when fully released.
12. Each terminal accepts up to two hooked blade type lugs.
13. Terminal entries are shrouded such that no current carrying metal is exposed when hooked blade lugs are fitted.
14. Springs withstand corrosion that might affect performance during their working life.
15. Springs do not carry any current.
16. Cross connection required for connecting two or more adjacent terminals are via wire loops. OEM supplied bridge pieces screwed down by the cage clamp is submitted to the Project Manager prior to use. Bridging from the top of the terminal to connect adjacent terminals invariably requires terminal insulation to be mechanically modified and bridging materials are not plated after punching and bending and allows for high resistance connections to develop over time. Should this be a preferred connection method it is submitted for approval prior to use on this project.

17. When used in current transformer circuits, the terminals are capable of accepting hooked blade lugs on 6mm² wires.
18. The terminals are sized to provide for pre-insulated lugs to fit after being crimped with the ‘flat’ crimp lying parallel with the rail.
19. The insulation impulse level and isolation requirements between individual terminals are guaranteed.
20. For stud type terminals two terminal studs are provided for each “way”, and are of sufficient length to accommodate two ring tongue terminations in addition to a full nut and a locking device.
21. Loose links, where provided, are secured by a nut and washers, and are of tin plated copper or brass. Barriers are provided between terminal “ways”.
22. These barriers project at least 3mm above the studs.
23. All types of commonly used terminals as shown on the drawing 18.48/5695 sheet 4. However the type of terminal in which the screw bears directly onto the termination or the conductor, i.e. “pinches the conductor”, is not acceptable.
24. All control system interface terminals are spring loaded link type terminals.
25. Terminals are numbered sequentially from left to right.

3.4.13 Lugs

1. No bare wire connection to any terminal is allowed.
2. All lugs are of the compression type.
3. Control lugs and their application with different types of terminals are as detailed on the drawing 18.48/5695 sheet 4.
4. Crimping on power lugs is in accordance with IEC 61238-1.
5. Crimping tools are calibrated according to their manufacturer’s specifications. The crimped area is at least equal to 1.5 times the conductor square area.
6. Documented proof of conformance to IEC 61238-1 specification requirements for tensile force heat cycling, resistance and temperature measurement may be requested by the Project Manager.
7. Controls wiring using bootlace ferrules are crimped with a crimping tool compressing the ferrule from four sides. Single sided indent type crimping is not allowed.
8. Push on/fast on lugs are not the preferred lug. Any uses of push on lugs in the entire system are declared in the tender document for approval of the Project Manager. After judgment on merit and if allowed, only nickel plated steel lugs are allowed and no tin plated brass or copper lugs are allowed due to their inferior longevity and contact resistance.
9. All lugs crimped onto wires of 6mm2 and above are of the hex crimped type. Indent (dimple) type crimping is not permitted.

3.4.14 Noise emission and electromagnetic compatibility

1. The ECS shall not exceed the electrical noise interference limits as stated in 32-333.
2. The ECS is not damaged and does not mal-operate when operated under conditions described in 32-333.

3.4.15 Test points

1. For testing and commissioning purposes, the following signals are available as scaled analogue values for recording purposes with an instrument with a 1MΩ input impedance.
2. These signals are available in both channels.
3. At least six are to be available simultaneously.
4. The following analogue test points are provided for external measurements/recordings:
    a. Machine stator voltage
    b. Machine stator current
    c. Field voltage
    d. Field current
    e. Rectifier Control voltage
    f. Active power
    g. Reactive power

h. Frequency
i. PSS Output signal

5. Two additional, permanently mounted, fused measuring points for direct measurement of field voltage and field current are available. Due to the fact that shunts develop a very small voltage any resistance in series with the measuring point could lead to inaccurate results when fuses create high resistance connections. Fuses are therefore not recommended where measurement shunts are used in general. If commissioning measurements require direct access to the shunts from a remote location, then fuses are required that can be locked in the open position. Fuse holders need to be of a high quality and have a wiping action when the fuse is inserted or the fuse holder is closed. One fuse per connection is required. (i.e. 2 fuses per filed voltage connection and two fuses per shunt connection) Fuses shall be of the HRC fuses rated to cater for the voltages in IEC 60034-1 table 16.

   Consider the use of high quality “operate behind close door”/extended operating handles like shown below. These disconnector can then be fused.

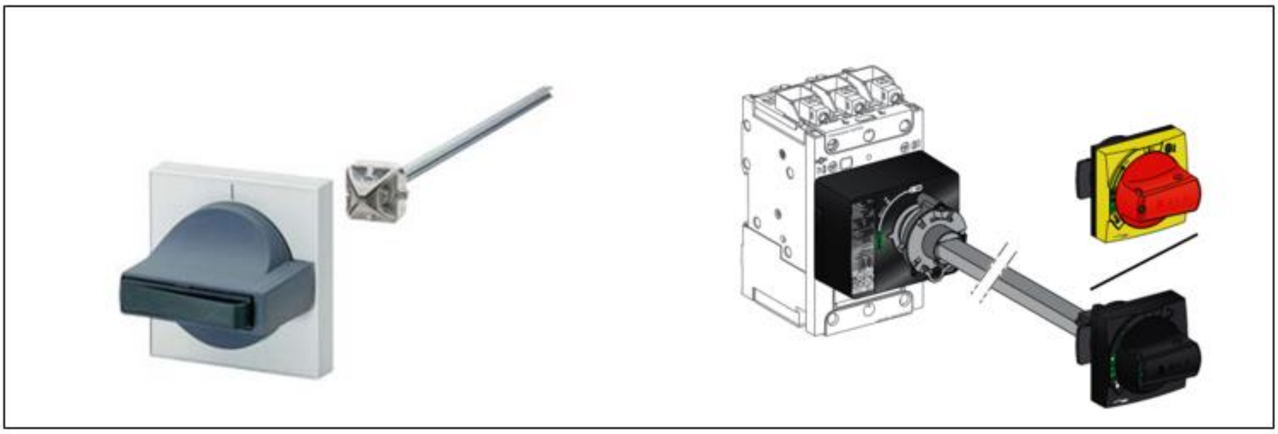


Figure 12: Fused switch disconnector (courtesy of Havells)

Shafts can be extended as shown in the examples above for example

3.4.16 Test blocks

1. Each channel is supplied with a set of voltage transformers and therefore each channel is supplied with its own test block situated at an easy accessible place for measurement and testing purposes on the front panel door.
2. Both channels shall be connected to different sets of current transformers as shown in Figure 13 below. All wiring interface to the CTs and VTs shall be provided by the *Contractor*; the CTs and VTs shall be tested by the *Contractor* before being used. The wiring must be arranged in such a way that each channel is supplied with its own test block situated at an easy accessible place for measurement and testing purposes on the front panel door. The removal of a test block on one channel does not influence the other channel.

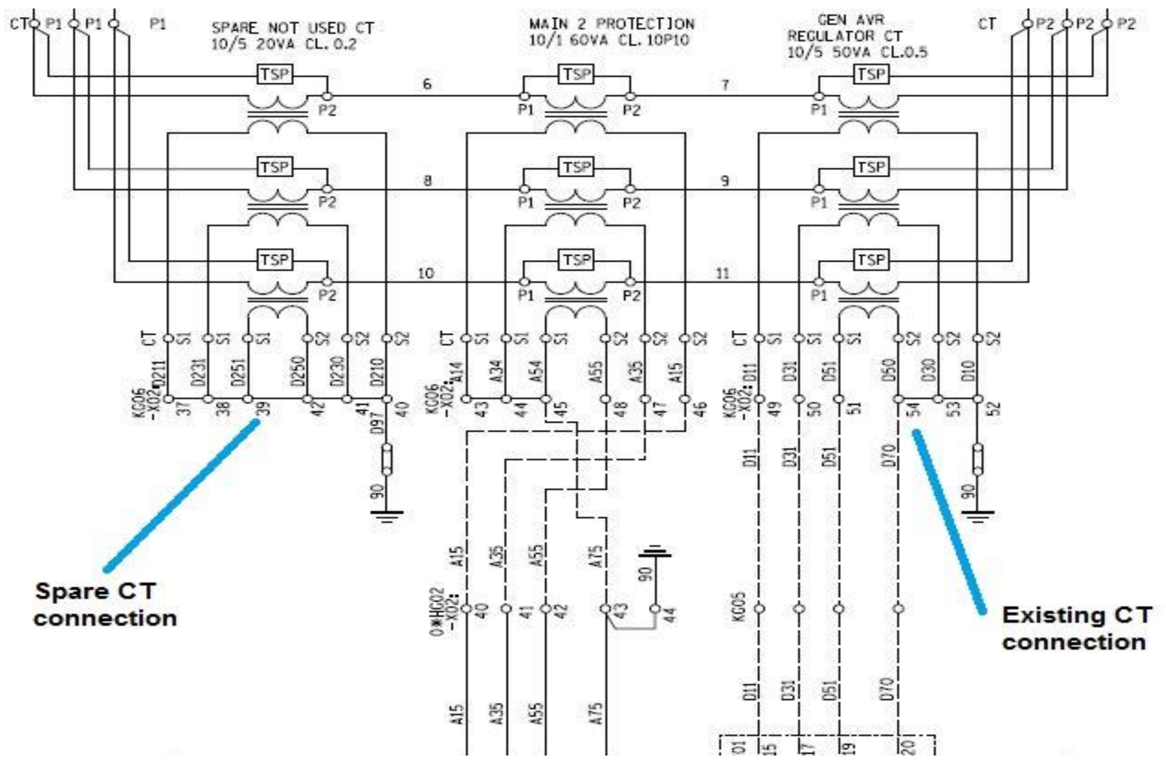


Figure 13: Excitation system CTs

3. The test block for the excitation transformer over current device is wired according to conventional protection circuits where the field side is shorted out when the test block cover is removed.
4. Approved test blocks are in accordance with 240-70975231
5. One test handle of each type of test block is provided as part of the testing equipment.

3.4.17 Cabling scope

The *Contractor* provides goods and services to meet the following requirements:

1. Testing of all power cables,
2. Replacement of damaged cables,
3. Cable joining and termination,
4. Cable numbering,
5. Installation of cable racks from excitation equipment room to the Equipment room
6. Decommission of existing ES.
7. Core drill if required by Employer.

8. Fire sealing of all cable entry points and floor slots.
9. Connection of earth conductors for switchgear assembly to existing earth.

3.4.18 Cabling requirements

1. The *Contractor* supplies and installs all cables required for the ES upgrade project.
2. Cabling to other systems must be specified, supplied and installed by the Cabling *Contractor*.
3. The *Contractor* may re-use the existing cabling.
4. Cables that are not long enough may not be joined. They should either be replaced or connected via a junction box; the *Contractor* provides and installs such material.
5. All electrical installations of 220V and above are carried out by a qualified electrician.
6. The new electrical cabling is done in accordance with the following standards:
   a. 240-56227443: Requirements for Control and Power cables for power station standard SANS 10142-1- Wiring Premises
7. The following templates issued by the *Employer*, must be used during the design and works section of the project. These are (but are not limited to):
   a. Template 240-56176097: Electrical Cable Schedule
   b. Template 240-56227927: Electrical Load List Template
   c. Template 240-77301384: Electrical LV Load Schedule Template
8. Cable schedules are supplied by the *Contractor* indicating the following minimum data:
   a. Cable number
   b. Cable type
   c. Cable length
   d. Plant/interface description
   e. Plant destination AKZ
   f. Core ferule numbers
   g. Route identification
9. After delivery of cabling to site, the cable drums must be inspected and the insulation tested by the *Contractor*. The results must be supplied to the *Employer* and it must be indicated whether the drum has passed or failed.

3.4.19 Cable installation

1. Cables may enter panels from the bottom or top as prescribed in the technical schedule
2. During installation of the cables, extreme care is to be exercised to avoid kinking or bending which may damage the cable insulation or sheath.
3. Cables which are accidentally damaged during installation are to be repaired or replaced to the satisfaction of the *Employer*. In no case is a cable, on which the outer sheath has been punctured, installed.
4. The Cabling *Contractor* is responsible for storage of all cable and is to suitably protect it from weather and damage during storage and handling.
5. The Cabling *Contractor* installs the cables onto the existing cable racks where applicable or where new racks are installed after approval of the project manager.
6. Power and control cable are not be routed on the same rack.
7. No tee offs nor jointing of wiring is to be done, other than at the terminals.
8. The *Contractor* shall use optic fibre cables with metal armouring for fiber cables that are leaving the ES cubicles to another distant location

3.4.20 Cable identification

All cables are identified by a cable number at termination points.

1. The Cabling *Contractor* applies to the Project Manager for cable numbers in Excel format indicating the following:
   a. Type of cable e.g. Armoured PVC
   b. Number of conductors e.g. 2

c. Voltage e.g. 24V
d. Description of Purpose e.g. Eastern Substation 400V Main Distribution Board Supply B.
e. Origin and destination

3.4.21 Cabinet and Junction Box Identification

1. All cabinets panels and junction boxes are identified by a permanent number fixed to the cabinet/box.
2. The *Contractor* applies to the Project Manager for cabinet/junction box numbers in Excel format indicating the following:
    a. Location e.g., Unit 1 AVR room
    b. Number of cables e.g., 4
    c. Voltage e.g., 400 V
    d. Description of Purpose e.g., Unit 1 AVR Converter 1.

3.4.22 Product support

1. The OEM clearly states, in writing, the warrantee period on their product and the components covered.
2. It must also be clearly stated in writing what the limitations in product support are beyond the specified warrantee period and what options there are to be considered as well as the cost involved regarding support beyond the warrantee period.
3. Beyond the warrantee period the *Contractor* still have the ability to do repairs on faulty components. If this is not possible then the *Contractor* provides an exchange policy to the *Employer* where faulty electronic modules can be exchanged and a discount provided by the *Employer* for the new component.
4. During and beyond the warrantee period the faulty modules are to be investigated by the *Contractor* and a failure report provided to the *Employer* stating the reason for failure.
5. The *Contractor* offers a 12 month guarantee on the supplied equipment from the date of commissioning. The *Contractor* offers a standard 12 month warranty on quality and workmanship.
6. The *Contractor* plans for a visual inspection at a time suitable to the *Employer*, approximately one year after completion.
7. The *Contractor* inspects each unit on or before the defects date and provides the *Employer* with an inspection report.
8. The *Contractor* liaises with the *Employer* three months prior to the defects date to confirm machine availability.
9. The *Contractor* corrects all defects identified before the defects correction period

3.5 Use of *Contractor*'s design

The *Employer* may use the *Contractor*'s design for any purpose in relation to the excitation systems at Kriel Power Station.

3.6 Design of Equipment

None.

3.7 Equipment required to be included in the *works*

The *Contractor* shall provide all equipment needed for the works.

3.8 As-built drawings, operating manuals and maintenance schedules

3.8.1 General

1. The original as built approved version of all documents and drawings shall be handed to the *Employer*. The *Contractor* shall provide documentation in electronic media using Microsoft Office or "searchable" PDF format. The *Employer* allocates numbers to the documentation and drawings which the *Contractor*

indicates on the documentation and drawings. The *Contractor* shall use pre-approved templates provided by the *Employer* for all documentation and drawings required.

2. The *Contractor* shall submit all technical documentation and drawings for acceptance to the *Employer* prior to manufacture. The *Contractor* submits two sets of hardcopy files plus an electronic copy of information on CD of all documentation indicated in the paragraphs to follow

3.8.2 Drawings

1. All drawings are created electronically and 100% compatible with Microstation software in a DGN file format.
2. In conjunction with the electronic DGN copies, the *Contractor* shall provide a merged set of PDF copies upon first issue and each time drawing updates are required. All drawings shall be signed and revisions noted as per the *Employer*'s specifications.
3. The basic design is also to be submitted in this format to evaluate both the design and the electronic format.
4. The electronic file shall conform to the Eskom standard 240-86973501.
5. The detail design drawings have the pre-approved title blocks and borders as provided by the *Employer*.
6. Graphical symbols are used in accordance with the NRS002 standard.
7. All drawings shall be submitted to the Project Manager for acceptance.
8. The *Contractor* shall produce as built drawings within 4 weeks of each site acceptance test and submit them to the Project Manager for his acceptance.
9. The *Contractor* shall be produced in the following types of drawings:
    a. Cover sheet
    b. Index sheet
    c. List of symbols
    d. List of components with values, tolerances, ratings, type numbers, purchasing specification numbers, manufacturer and circuit reference numbers
    e. General layout drawing of the proposed panels and floor plan
    f. Singe line diagram
    g. Block diagram of the system
    h. Panel internal wiring drawings, including cross referencing and wire numbers
    i. Cable block diagrams with termination points
    j. Transfer functions of the system in the time and frequency domain.
10. The *Contractor* is liable for updating drawings until final commissioning when the *Employer* has signed off and approved the final "As Built" state of the drawings. After commissioning the Contactor shall supply two sets of drawing hardcopies in two separate files and in A3 format.

3.8.3 Technical, maintenance and operating manuals

1. All manuals shall be specific to Kriel Power Station.
2. Documentation includes transfer functions of each part of the regulation system.
3. The technical, maintenance and operating manuals also contain the information and course material of the training manuals.
4. All design information forming part of the Works Information is to be included in the manuals.
5. All documentation including drawings and operating and maintenance instruction manuals are uniquely identified and cross-referenced with all related documents.
6. The manuals are complete with:
    a. Power Station name and order number
    b. Content list
    c. List of reference drawings, and
    d. Details of all components
7. Manuals are of good quality prepared by suitably experienced personnel. The *Contractor* ensures that the manuals/files are complete with the following information represented as a minimum:
    a. Details and descriptions of all hardware and software
    b. Design calculation sheets
    c. Settings and configuration
    d. Detailed product descriptions and features

   e. System control philosophy
   f. System parameters and models
   g. Datasheets of all components used
   h. Recommended spares lists
   i. Operating, maintenance and testing requirements
   j. Full system maintenance program
   k. Installation procedures of each component
   l. Isolation procedures
   m. Alarm descriptions and responses
   n. Type test certificates
   o. Certificates of compliance to international standards
   p. Routine test results reports
   q. Commissioning test results reports
   r. Training information
   s. Technical tender submission information
8. Any special instructions pertaining to storage of spare parts or to their shelf life are included in the manual.
9. All drawings required for component location, dismantling, and re-assembly for maintenance is provided in the manual.
10. All special tools required for maintaining and operating the plant and material are identified in a schedule and described in the manual.
11. Manuals are produced such that a Synopsis is first presented, followed by a First Draft, then a pre-print proof and finally be the Final Manual.

3.8.4 Settings and device configurations

1. The *Contractor* shall provide the settings data for each configurable device supplied.
2. All settings, configurations, alarm, and tripping matrixes are configured as per recommendation by the *Contractor* and are reviewed by the *Employer* for final acceptance.
3. The *Contractor* is responsible for the calculation of all settings and the calculations are provided to the *Employer* for acceptance. The applied settings within the excitation system are provided to the *Employer* by means of active Windows or configuration files containing the settings which can easily be copied to a work document.
4. The excitation system settings contain mathematical Laplace models of the individual control loops in the controllers including the PSS. The settings information also contains an overall mathematical Laplace model of the entire system. The *Contractor* provides detailed calculations showing how the settings for each of the systems were calculated. All system settings and data supplied comply with the *Employer*'s standards as listed and as per the South Africa Grid Code requirements.

4 Procurement

4.1 People

4.1.1 Minimum requirements of people employed on the Site

4.1.2 BBBEE and preferencing scheme

4.1.3 Accelerated Shared Growth Initiative – South Africa (ASGI-SA)

The *Contractor* complies with and fulfils the *Contractor's* obligations in respect of the Accelerated and Shared Growth Initiative - South Africa in accordance with and as provided for in the *Contractor*'s ASGI-SA Compliance Schedule stated below
.
[Insert the agreed ASGI-SA Compliance Schedule here]

The *Contractor* shall keep accurate records and provide the *Project Manager* with reports on the *Contractor*'s actual delivery against the above stated ASGI-SA criteria. [Elaborate on access to and format of records and frequency of submission etc.]

The *Contractor*'s failure to comply with his ASGI-SA obligations constitutes substantial failure on the part of the *Contractor* to comply with his obligations under this contract.

4.2 Subcontracting

4.2.1 Preferred sub*Contractor*s

4.2.2 Subcontract documentation, and assessment of subcontract tenders

4.2.3 Limitations on subcontracting

4.2.4 Attendance on sub*Contractor*s

4.3 Plant and Materials

4.3.1 Quality

All inspections and testing to be performed in accordance with the Quality Control Procedure developed by the *Contractor*. The specified Materials and Equipment are to be new, unused, and free from defects and imperfections. Reconditioned Materials and/or Equipment are not regarded as new under any circumstances. The *Contractor* will not use Materials or Equipment which are generally recognised as being unsuitable or Otherwise to be avoided for the purpose for which they are intended.
Only components of high reliability will be utilised, with a proven operating history, to enable the Plant to achieve required reliability and availability. Equipment design, engineering and manufacture will be done in accordance with the best modern practice applicable to high-grade products of the type to be furnished, so as to ensure the efficiency and reliability of the Works and the strength and suitability of the various parts for the Works.
Materials and equipment withstands ambient conditions and the variations of temperature arising under working conditions without distortion, deterioration or undue strains in any part. All parts and components are made accurately, and where practicable, to acceptable standards so as to facilitate replacement and repairs. Repair of defective material and/or equipment will be done only with the *Employer*'s approval and any such repair, if approved, will be carried out to the satisfaction of the *Employer*.
The *Contractor* ensures that co-ordinated and formally documented management system is in place for the assurance of quality. The *Employer* is to specify intervention (hold and witness) points during the manufacturing, installation and on site testing stages of the project. The *Contractor* issues preliminary notification of such intervention points by ten working days in advance to the *Employer*, and confirms such hold and witness points at least five working days prior to the activity.

4.3.2 Plant & Materials provided "free issue" by the *Employer*

None

4.3.3 *Contractor*'s procurement of Plant and Materials

N/A

4.3.4 Spares and consumables

The *Contractor* supplies the *Employer* with a detailed list of all spares required in order to maintain the new Excitation system. The list of spares is supplied three months before the delivery of the items for the installation. The *Contractor* further supplies all basic maintenance spares, in accordance with the *Contractor*'s maintenance schedules, such as filters and fuses to the *Employer* before installation. The *Contractor* shall keep all critical spares at hand, as needed during commissioning, to prevent extended delays caused by failure of any of the components; these spares will remain the property of the *Contractor*. Furthermore, the *Contractor* shall provide a detailed spares management plan with projection on spares obsolescence and end of life management for electronic modules, power electronic devices and other assembly modules.

The complete recommended spares list includes the following details:

1. Description
2. Part number
3. Special storage requirements
4. Replacement part or routing maintenance part
5. Quantity
6. Cost
7. Lead time
8. Supplier full contact details and address.

4.4 Tests and inspections before delivery

4.4.1 Factory acceptance test (FAT)

1. The *Contractor* will perform pre-checks and tests before the *Employer* is notified to be involved with FAT.
2. Before FAT will commence, a complete Factory Acceptance Test Procedure will be submitted by the *Contractor* to the *Employer*. The *Employer* will review the procedure and make updates where necessary.
3. The *Contractor* supplies two copies of all test certificates and data sheets prior to the commencement of the factory testing.
4. The *Contractor* gives the *Employer* at least two months' notice of the date on which the ES is ready for inspection and testing when these tests are to be done in South Africa and four months' notice if it is to be done outside the border of South Africa.

5. The *Employer* is provided with access to the *Contractor*'s premises for the purpose of establishing compliance with the contractual requirements by means of inspections, surveillance's, audits and witnessing the performance of any tests.
6. Communications testing will be conducted during the basic design phase. This will also be regarded as a pre-FAT test.
7. This inspection entails a full system check (functional and wiring checks) to ensure compliance with this specification, contract drawings and other applicable standards.
8. Allowance is made in the delivery time to cater for this requirement.
9. The system functionality is to be demonstrated by the *Contractor* to the Project Manager/Supervisor during Factory Acceptance Tests at the *Contractor's* facility for one ES system. Only if non critical defects are picked-up that cannot be rectified before the first unit's commissioning, will additional FAT continue on subsequent units on the same basis.
10. A complete Factory Acceptance Testing procedure is included in the design package.
11. The following tests (checks) are conducted by the *Contractor* as a minimum requirement and witnessed by the Project Manager/Project Supervisor, lead Engineer and site representative:
    a. Dielectric test of current transformers, auxiliary wiring and control circuitry;
    b. Dielectric tests of power circuit, bus bars and cables.
    c. Current transformer test to prove the ratio, polarity, resistance and magnetising curves;
    d. Check the nameplates, connections, torque all bolts and nuts on power cabling that will not require loosing and refastening on site;
    e. Functional tests on circuitry, and the indication circuitry (checks include fuse ratings, labelling, ferrule numbers, crimping and tightness of all connections including lugs);
    f. Calibration checks of all voltmeters and ammeters to prove their operation and accuracy class;
    g. Power Supply checks
    h. Control Function Tests (Limiters, step responses on a simulator, firing angles, control, etc)
    i. Alarms and indication checks
    j. Power electronics checks and tests
    k. Breaker/contactor tripping and closing under off-nominal voltages.
12. The Factory Acceptance Testing of the ES is completed at the manufacturer's works and accepted by the Project Manager, before dispatching the complete unit to site.
13. A defects list needs to be kept as a live working document to capture any deviation from the works information. These could be simple wiring errors or more serious functional requirements that are not met.
14. The *Contractor* is given a reasonable time to rectify wiring without delaying the completion of the FAT. When more serious defects are encountered, the *Contractor* needs to inform the Project Manager immediately about it, with an estimated time to resolution and testing of the function/requirement.

4.5 Marking Plant and Materials outside the Working Areas

N/A.

4.6 ***Contractor*'s Equipment (including temporary works).**

N/A.

5 Construction

5.1 Temporary works, Site services & construction constraints

5.1.1 *Employer*'s Site entry and security control, permits, and Site regulations

5.1.2 Restrictions to access on Site, roads, walkways and barricades

5.1.3 People restrictions on Site; hours of work, conduct and records

5.1.4 Health and safety facilities on Site

5.1.5 Environmental controls, fauna & flora, dealing with objects of historical interest

5.1.6 Title to materials from demolition and excavation

5.1.7 Cooperating with and obtaining acceptance of Others

5.1.8 Publicity and progress photographs

5.1.9 *Contractor*'s Equipment

5.1.10 Equipment provided by the *Employer*

5.1.11 Site services and facilities

5.1.12 Facilities provided by the *Contractor*

5.1.13 Existing premises, inspection of adjoining properties and checking work of Others

5.1.14 Survey control and setting out of the *works*

5.1.15 Excavations and associated water control

5.1.16 Underground services, other existing services, cable and pipe trenches and covers

5.1.17 Control of noise, dust, water and waste

5.1.18 Sequences of construction or installation

5.1.19 Giving notice of work to be covered up

5.1.20 Hook ups to existing works

5.2 Completion, testing, commissioning and correction of Defects

5.2.1 Work to be done by the Completion Date

On or before the Completion Date the *Contractor* shall have done everything required to Provide the Works except for the work listed below which may be done after the Completion Date but in any case before the dates stated. The *Project Manager* cannot certify Completion until all the work except that listed below has been done and is also free of Defects which would have, in his opinion, prevented the *Employer* from using the *works* and Others from doing their work.

	Item of work	**To be completed by**
	As built drawings of	Within days after Completion
	Performance testing of the *works* in use as specified in paragraph of this Works Information.	See performance testing requirements.

5.2.2 Use of the *works* before Completion has been certified

N/A

5.2.3 Materials facilities and samples for tests and inspections

All components will be in line with approved list of components as supplied by the *Employer*. Samples of components may be requested by the *Employer* for pre-approval where deemed necessary.

5.2.4 Commissioning

The activities forming part of live testing, live commissioning or power up of any component is not embarked on until the Project Manager's acceptance (safety clearance certificate) has been obtained for construction and erection work performed in this stage.

5.2.4.1 Commissioning documentation

Commissioning does not start until the following documents, which are required for the commissioning of the plant, is accepted by the Project Manager:

1. All relevant drawings as-built.
2. All relevant site acceptance test reports completed and signed.

3. All QCP's signed at the relevant steps.
4. Draft Technical Maintenance and Operating manuals supplied.
5. All installation related defects are cleared.
6. All safety clearance certificates signed.

5.2.4.2 Site acceptance tests

1. Site acceptance tests are carried out by the *Contractor* and witnessed by the Supervisor and/or *Employer*.
2. The test procedures are prepared by the *Contractor* and accepted by the Project Manager.
3. The purpose of the Site acceptance test is to ensure that all the Plant and Materials are correctly installed, checked and that no malfunction or damage occurred during the transportation and / or erection.
4. The *Contractor* provides all the test equipment for testing the individual functional units/components.
5. When the site acceptance tests are completed, the ECS is safety cleared (safety clearance certificate) and the *Contractor* issues a COC for acceptance by the Project Manager.
6. The *Contractor* is the signatory to this certificate (240-156104699)

5.2.4.3 Cold / pre commissioning tests

1. Site cold commissioning tests are carried out by the *Contractor* and witnessed by the *Employer*.
2. The test procedures are prepared by the *Contractor* and accepted by the Project Manager.
3. The purpose of the cold commissioning is to ensure that all the Plant and Materials are correctly installed, prove live loops and test basic functions with the machine at standstill.
4. The *Contractor* provides all the test equipment for testing the individual functional units.

5.2.4.4 Hot commissioning

Hot commissioning starts after cold commissioning is complete.

1. The plant is commissioned by running the system fully manual and testing each piece of Plant and Material for full functionality in each mode of operation.
2. The *Contractor* in conjunction with the *Employer* performs the commissioning of the Excitation system and allows for the following tests to be completed:
   a. Full function tests as per this specification
   b. ESVD testing offline and online
   c. GCR4 Grid Code compliance testing as per Grid Code requirements
3. Due to possible constraints from the *Employer*, the *Contractor* allows for his commissioning engineer to be available continuously during each hot commissioning activity.
4. The commissioning engineer is officially certified by the *Contractor* as being qualified and experienced to commission the excitation system and be able to make the necessary software updates as may be required onsite during hot commissioning.

5.2.5 Start-up procedures required to put the *works* into operation

The *Contractor* is on site when the first live operation of the plant commences. All switching to get the plant ready is done by the *Employer* to obtain the status for start-up as per agreed commissioning program.

5.2.6 Take over procedures

Take-over is when all testing, inspections and commissioning as specified in sections 5.2.1, 5.2.4, 5.2.5 are completed successfully.

5.2.7 Access given by the *Employer* for correction of Defects

5.2.8 Performance tests after Completion

Commissioning results are sent to the system operator for evaluation and results can be requested to be readjusted to meet system requirements.

5.2.9 Training and technology transfer

5.2.9.1 General

1. The *Contractor* provides training on the Plant and Material and systems included as part of the *works* to the various categories of the *Employer's* technical staff for the duration of the *works*.
2. Training provided by the *Contractor* is directly applicable to the actual Plant and Material supplied for the works.
3. Generalised training based on similar Plant and Material is not acceptable.
4. Engineering training is provided prior to the Factory Acceptance Testing of the ECS.
5. All pre-FAT training is conducted at the *Contractor's* local test facility and all operating and maintenance training is conducted at Kriel Power Station.
6. The local facilities for training provided by the *Employer* are a suitably sized air-conditioned room, to accommodate 35 trainees as well as trainee and trainer desks, an overhead projector and flipchart or white board.
7. The *Contractor* submits to the *Project Manager* for acceptance a detailed training programme as well as a prospectus for each course one month before each training session.
8. The number of participants that are to be trained is as indicated by the Project Manager.
9. The *Employer* bears the cost of salaries, accommodation, travelling expenses and other allowances of his personnel during the training, but all other training costs are borne by the *Contractor*.
10. The *Contractor* provides 3 additional (repeat) training courses as and when instructed by the *Project Manager*.
11. Practical hands-on training for each individual trainee forms an integral part of each of the following courses:
    a. Operating Training
    b. Maintenance Training
    c. Engineering / Commissioning Training
12. The Engineering / Commissioning training are of such a standard that experienced staff are able to commission and re-engineer some parts of the system after such training has been obtained.

5.2.9.2 Operating

The training includes the following aspects:

1. Familiarise with documentation including drawing configuration logic.
2. Operator interface familiarisation e.g. operational functions, alarms etc.

5.2.9.3 Maintenance

The training includes the following aspects:

1. Familiarisation with documentation (maintenance plan, procedures etc.)
2. Operator interface familiarisation e.g. operational functions, alarms etc.
3. Hardware familiarisation
4. Hardware maintenance
5. Maintenance of control and instrumentation
6. Remote interrogation and analysis of information from the ECS and data recorders

5.2.9.4 Engineering

The training includes the following aspects:

1. Familiarisation with documentation (maintenance plan, procedures etc.)
2. Operator interface familiarisation e.g., operational functions, alarms etc.
3. Hardware familiarisation
4. Hardware maintenance
5. Maintenance of control and instrumentation
6. Changes and addition of function blocks
7. Time stamping protocols
8. Interfacing to the future control system
9. Bus system fault finding and engineering
10. Full commissioning understanding

5.2.9.5 Training documentation

1. The *Contractor* incorporates all necessary technical data, design data literature and drawings into his training manuals.
2. The course material is in English and includes all third-party documentation.
3. A copy of the training documentation is supplied for each trainee.
4. The supply of drafts, pre-print proofs and printed copies of training documentation is planned by the *Contractor* in such a way that the required training is complete before FAT of the unit commences.
5. Training manuals are continuously updated by the *Contractor* up to the date of issue of the Defects Certificate for the whole of the *works*.

5.2.10 Operational maintenance after Completion

None

6 Plant and Materials standards and workmanship

6.1 Investigation, survey and Site clearance

N/A

6.2 Building works

N/A

6.3 Civil engineering and structural works

6.4 Electrical & mechanical engineering works

Doc Identifier	Description
ISO 9001	Quality Management Systems
32-727	Eskom Safety, Health, Environment and Quality (SHEQ) Policy
240-105658000	Supplier Quality Management: Specification
240-56227589	List of Approved Electronic Devices to be used on Eskom Power Stations
240-56227443	Requirements for Control and Power Cables for Power Stations Standard
240-53114026	Project Engineering Change Management
240-53114186	Document and Record Management Procedure
240-66920003	Project Handover Documentation Management Procedure
240-71432150	Plant Labelling Standard
240-86973501	Engineering Drawing Standard

6.5 Process control and IT works

6.6 Other [as required]

N/A

7 List of drawings

7.1 Drawings issued by the *Employer*

This is the list of drawings issued by the *Employer* at or before the Contract Date and which apply to this contract.

Note: Some drawings may contain both Works Information and Site Information.

Drawing number	Revision	Title

8 Appendix A – Vendor Document Submittal Schedule

DOCUMENTION REQUIREMENTS AND SUBMISSIONS

Document	Description	-	-	TOTAL PROJECT PHASE WHEN DOCUMENTATION IS REQUIRED						
		Reference	Format of presentation	ENQUIRY	TENDER RETURNABLES	CONTRACT AWARD + months (ENGINEERING)	MANUFACTURING ACCEPTANCE	BEFORE INSTALLATION	BEFORE COMMISSIONING	PROJECT COMPLETION
Electrical Documents Submission										
General	Index and Register of Documents - Preliminary	N/A	Soft / Hard Copy		x					
	Index and Register of Documents - Final	N/A	Soft / Hard Copy							x
	System Design Preliminary	N/A	Soft / Hard Copy		x					
	Philosophies	N/A	Soft / Hard Copy		x					
	System Design Final	N/A	Soft / Hard Copy			x				
Scope of work	Cabling Scope	Works Info	Soft / Hard Copy		x					
	Earthing & Lightning Protection Scope	Works Info	Soft / Hard Copy		x					
	ECS Scope of work	Works Info	Soft / Hard Copy		x					
Switchgear Interfaces	Electrical Interfaces, Schematics & Drawings - Preliminary	N/A	Soft / Hard Copy		x					
	Electrical Interfaces, Schematics & Drawings - Detail Design	N/A	Soft / Hard Copy			x				
	Electrical Interfaces, Schematics & Drawings - Revisions	N/A	Soft / Hard Copy					x		
	Electrical Interfaces Commissioning Procedure	N/A	Soft / Hard Copy						x	
	Electrical Interfaces, Schematics & Drawings - Final	N/A	Soft & Hard Copy							x

Cabling	Cable Design - Preliminary	240-56227443 / Works Info	Soft / Hard Copy		x					
	Completed cable tables in accordance with 240-56227443 - Preliminary	240-56227443 / Works Info	Soft / Hard Copy		x					
	Cable Schedule - Preliminary	240-56227443 / Works Info	Soft / Hard Copy		x					
	Cable Routing - Preliminary	240-56227443 / Works Info	Soft / Hard Copy		x					
	Cable Detail Design Pack	240-56227443 / Works Info	Soft / Hard Copy			x				
	Cable Routing and Termination Drawings (For Review)	240-56227443 / Works Info	Soft / Hard Copy					x		
	Cable Tests and Procedures (For Review)	240-56227443 / Works Info	Soft / Hard Copy					x		
	Cable Commissioning Procedures (For Review)	240-56227443 / Works Info	Soft / Hard Copy						x	
	Cable Routing and Termination Drawings - FINAL AS BUILT	240-56227443 / Works Info	Soft & Hard Copy							x
	Cable Tests Reports as per 240-56227443	240-56227443 / Works Info	Soft & Hard Copy							x
	Cable Handover Pack (including all terminations, schedules, Test Reports and procedures - signed)	240-56227443 / Works Info	Soft & Hard Copy							x
	Completed cable tables in accordance with 240-56227443	240-56227443 / Works Info	Soft & Hard Copy							x
	Completed Technical Schedule A and B in accordance with 240-56063805 for LV cables	240-56227443 / Works Info	Soft & Hard Copy			x				
	Cable schedules	240-56227443 / Works Info	Soft & Hard Copy		x	x				
	Cable servitude drawings	240-56227443 / Works Info	Soft & Hard Copy		x					
	Cable rack loading calculations	240-56227443 / Works Info	Soft & Hard Copy			x				
	Cable rack design drawings	240-56227443 / Works Info	Soft & Hard Copy			x				
	Cable pull cards	240-56227443 / Works Info	Soft & Hard Copy						x	
	Cable drum delivery schedule	240-56227443 / Works Info	Soft & Hard Copy							x

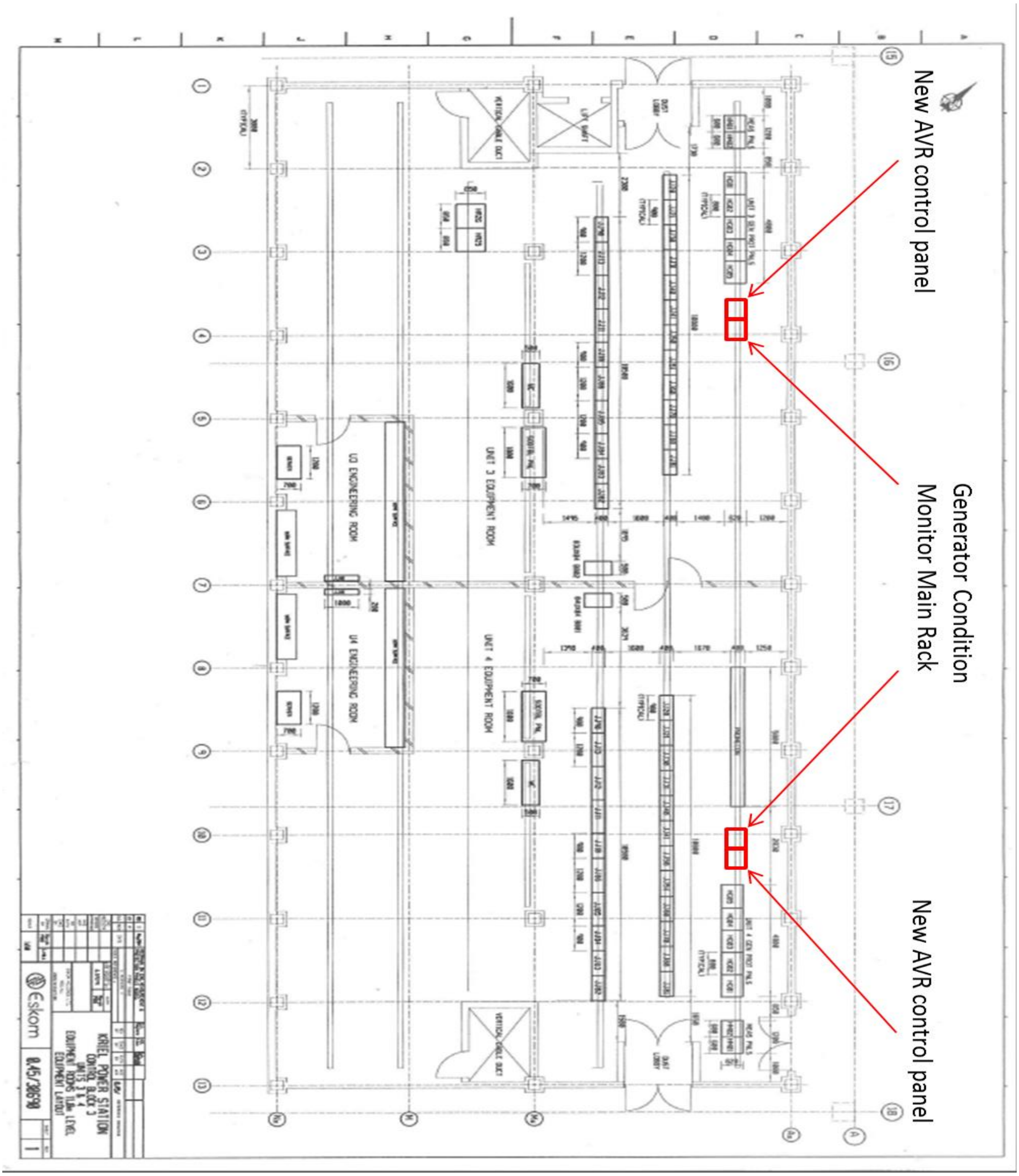
	Cable block diagrams	240-56227443 / Works Info	Soft & Hard Copy			x				
	Fire barrier datasheets	240-56227443 / Works Info	Soft & Hard Copy			x				
	Fire barrier test certificates	240-56227443 / Works Info	Soft & Hard Copy							x
	Completion Certificate	240-56227443 / Works Info	Soft & Hard Copy							x
Earthing & Lightning Protection	Earthing Layouts / Drawings - Preliminary	240-56356396	Soft / Hard Copy		x					
	Earthing Layouts / Drawings - Detail Design	240-56356396 / Works Info	Soft / Hard Copy			x				
	Earthing Tests and Procedures (For Review)	240-56356396 / Works Info	Soft / Hard Copy					x		
	Earthing Layouts / Drawings - FINAL AS BUILT	240-56356396 / Works Info	Soft & Hard Copy						x	
	Earthing Test Reports as per 240-56356396	240-56356396 / Works Info	Soft & Hard Copy							x
	Earthing Handover Pack (including all test reports & procedures signed)	240-56356396 / Works Info	Soft & Hard Copy							x
	As built drawings	240-56356396 / Works Info	Soft & Hard Copy						x	
	Completion Certificate	240-56356396 / Works Info	Soft & Hard Copy							x
Excitation system	Excitation system Technical Schedule A and B	Works Information	Soft / Hard Copy		x					
	Type test reports and certificates	Works Information	Soft / Hard Copy		x					
	Switchgear load schedules - Preliminary	Works Information	Soft / Hard Copy		x					
	ECS protection philosophy, list of alarms and trips	Works Information	Soft / Hard Copy			x				
	Detailed equipment list (material list) for each circuit	Works Information	Soft / Hard Copy			x				
	ECS general arrangement drawings	Works Information	Soft / Hard Copy		x					
	ECS schematic drawings	Works Information	Soft / Hard Copy			x				
	ECS logic drawings	Works Information	Soft / Hard Copy			x				
	ECS input/output drawings and signal	Works Information	Soft / Hard Copy			x				

	descriptions									
	Full sets of drawings	Works Information	Soft / Hard Copy			x				
	Detailed design review documentation	Works Information	Soft / Hard Copy			x				
	Design-verification certificates of all functional units	Works Information	Soft / Hard Copy			x				
	Technical details of all the components	Works Information	Soft / Hard Copy			x				
	Routine test reports	Works Information	Soft / Hard Copy							x
	Routine test certificates	Works Information	Soft / Hard Copy							x
	ECS handover file index	Works Information	Soft / Hard Copy							x
	Engineering handover file index	Works Information	Soft / Hard Copy							
	As built package for design (which contains the cover sheet, general arrangement, bus-wiring arrangement, summary sheet and applicable schematic drawings)	Works Information	Soft / Hard Copy					x		
	As built package for functional unit (which contains the schematic drawings, material list, punch list (signed-off), mechanical and electrical inspection checklist, functional and operational tests)	Works Information	Soft / Hard Copy					x		
	Training course outline (topics/curriculum)	Works Information	Soft / Hard Copy					x		
	Summary or preliminary version of training manuals	Works Information	Soft / Hard Copy					x		
	Engineering training manual	Works Information	Soft / Hard Copy					x		
	Operating training manual	Works Information	Soft / Hard Copy					x		
	Maintenance training manual	Works Information	Soft / Hard Copy					x		
	Operating, installation and maintenance manuals	Works Information	Soft / Hard Copy					x		
	(with work instructions)	Works Information	Soft / Hard Copy					x		
	Equipment guarantee certificates	Works Information	Soft / Hard Copy							x
	Calibration Certificates for test equipment used	Works Information	Soft / Hard Copy							x

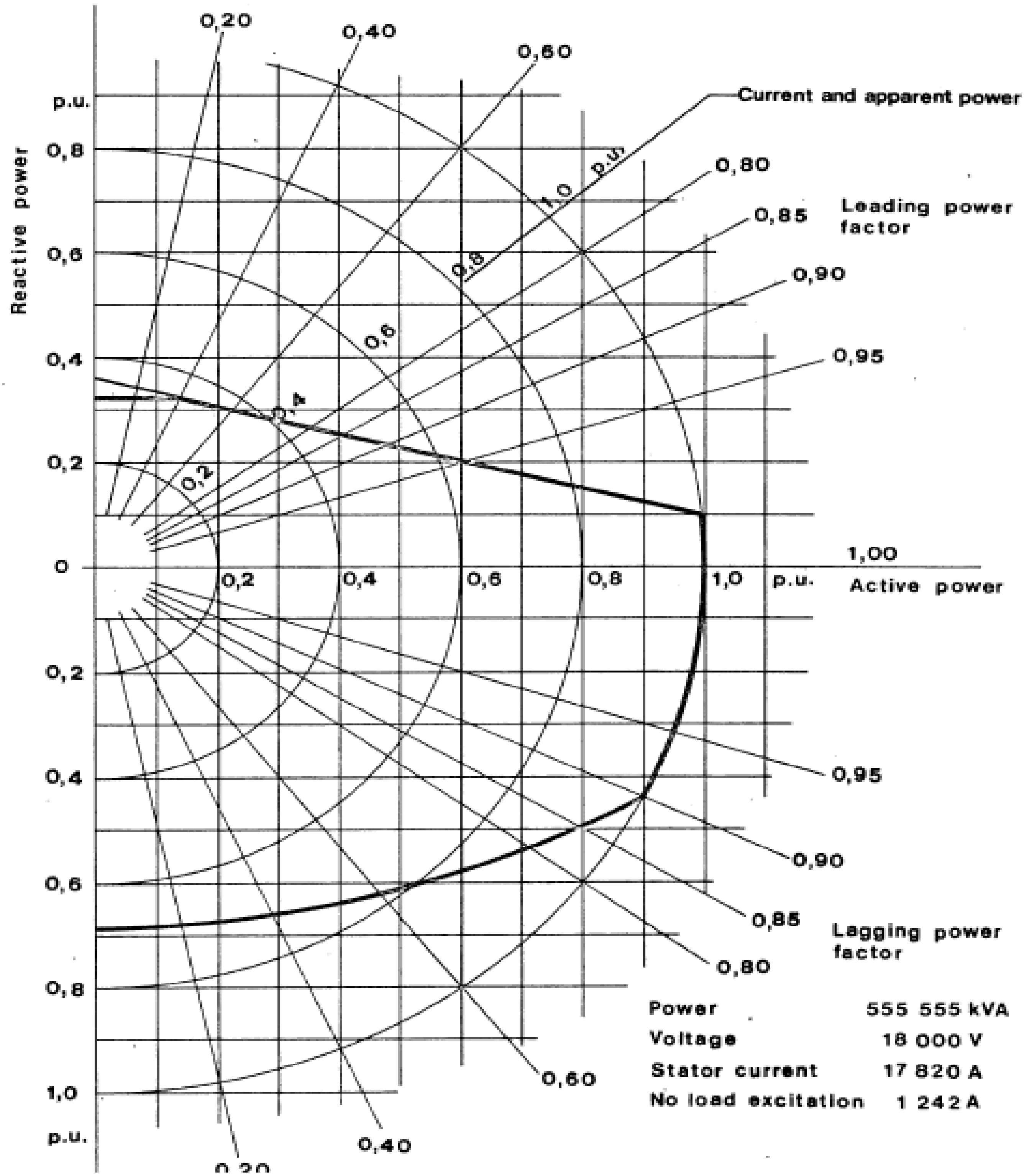
	Maintenance plan for ECS life of 30 years	Works Information	Soft / Hard Copy					x		
	Recommended list of spares	Works Information	Soft / Hard Copy					x		
	Quality Control Plan (QCP) or Inspection and Test Plan (ITP)	Works Information	Soft / Hard Copy				x			
	Factory Acceptance Testing (FAT) Plans and Procedures	Works Information	Soft / Hard Copy				x			
	FAT Report	Works Information	Soft / Hard Copy					x		
	FAT File	Works Information	Soft / Hard Copy					x		
	(e.g. Routine test certificates, verification check list, test equipment calibration certificates, instrument transformer calibration certificates, manufacturing drawings, functional checks report)	Works Information	Soft / Hard Copy					x		
	Factory Clearance Certificate	Works Information	Soft / Hard Copy					x		
	Site Acceptance Testing (SAT) Plans and Procedures	Works Information	Soft / Hard Copy					x		
	SAT Report	Works Information	Soft / Hard Copy							x
	SAT File	Works Information	Soft / Hard Copy							x
	(e.g. Routine test certificates, verification check list, test equipment calibration certificates, construction drawings, functional checks report)	Works Information	Soft / Hard Copy							x
	Completion certificate	Works Information	Soft / Hard Copy							x

9 Appendix B: Power System and Interface Information

9.1 Equipment Room Floor Layout



9.2 Installed Kriel Generator Capability Diagram



9.3 Excitation Transformer Data

Transformer Type	DTE 1400/24
Norms	IEC 60076-11
Nominal Power	1400 KVA
Insulation class	H
Temperature Rise	125 K
Frequency	50 Hz
Rated Primary Voltage	10392 V
Rated Secondary Voltage	605 V
Vector Group	Yd11
No load loss	3100 W
Load loss	11500 W
Short circuit voltage	6%
Total Weight	2865 kg

9.4 Unit 4,5 &6 Kriel Generator Data

Generator and related data		
Description	**Symbol and value**	**Unit**
Rated generator VA	$S_{GN} = 555$	MVA
Rated Generator stator voltage	$U_{GN} = 18.0$	kV
Rated Generator power factor	Pf :=0.9	pu
Nominal frequency	$f_n = 50$	Hz
Rated Generator stator current	$I_{GN} := \frac{S_{GN} \times 10^3}{\sqrt{3} \times U_{GN}}$ $I_{\ GN} := 17801.6$	A
Field resistance @20.5˚C	$R_f = 72.3$	mΩ
Open circuit field voltage at nominal stator voltage	$U_{fO} = 130$	V
Open circuit field current at nominal stator voltage	$I_{fO} = 1252$	A
Rated field voltage	$U_{fN} = 425$	V
Rated field current	$I_{fN} = 4280$	A
Continuous permissible field current	$I_{fN} = 4450$	A
Calculated ceiling field voltage positive($\alpha_{min} = 10°$)	$+U_{fmax} = 817$	V
Calculated ceiling field voltage negative($\alpha_{max} = 150°$)	$-U_{fmax} = -707$	V
Unsaturated direct axis reactance	$X_d := 2.74$	pu
Unsaturated transient direct axis reactance	$X'_d := 0.41$	pu
Unsaturated sub transient direct axis reactance	$X''_d := 0.24$	pu
Quadrature axis synchronous reactance(unsaturated)	$X_q := 2.67$	pu
Quadrature axis sub-transient reactance(unsaturated)	$X''_q := 0.275$	pu
Negative Phase Sequence reactance	$X_2 := 0.272$	pu
Zero sequence reactance	$X_0 := 0.16$	pu
Direct axis transient open circuit time constant	$T'_{do} = 7.35$	s
Direct axis transient short circuit time constant	$T'_d = 1.1$	s
Direct axis sub-transient open circuit time constant	$T''_d = 0.03$	s
Machine voltage transformer ratio	$VTR_G := \frac{18000}{110}$	
Current transformer ratio	$CTR_G := \frac{18000}{1}$	
Earthing resistance	REF1 := 0.55	Ω
AVR first current transformer ratio	$CTR_{G2} := \frac{18000}{10}$	
AVR second current transformer ratio	$CTR_{G2} := \frac{10}{5}$	

9.5 Unit 2 Kriel Generator Data

Generator and related data		
Description	**Symbol and value**	**Unit**
Rated generator VA	$S_{GN} = 555$	MVA
Rated Generator stator voltage	$U_{GN} = 18.0$	kV
Rated Generator power factor	Pf :=0.9	pu
Nominal frequency	$f_n = 50$	Hz
Rated Generator stator current	$I_{GN} := \frac{S_{GN} \times 10^3}{\sqrt{3} \times U_{GN}}$ $I_{\ GN} := 17801.6$	A
Field resistance @20.5˚C	$R_f = 72.3$	mΩ
Open circuit field voltage at nominal stator voltage	$U_{fO} = 130$	V
Open circuit field current at nominal stator voltage	$I_{fO} = 1252$	A
Rated field voltage	$U_{fN} = 425$	V
Rated field current	$I_{fN} = 4280$	A
Continuous permissible field current	$I_{fN} = 4450$	A
Calculated ceiling field voltage positive($\alpha_{min} = 10°$)	$+U_{fmax} = 817$	V
Calculated ceiling field voltage negative($\alpha_{max} = 150°$)	$-U_{fmax} = -707$	V
Rated impedance	$Z_n = 0.58$	Ω
Unsaturated direct axis reactance	$X_d := 2.75$	pu
Unsaturated transient direct axis reactance	$X'_d := 0.35$	pu
Unsaturated sub transient direct axis reactance	$X''_d := 0.27$	pu
saturated transient direct axis reactance	$X'_{dv} := 0.32$	pu
saturated sub transient direct axis reactance	$X''_{dv} := 0.21$	pu
Negative Phase Sequence reactance(unsaturated)	$X_2 := 0.26$	pu
Zero sequence reactance(unsaturated)	$X_0 := 0.12$	pu
Negative Phase Sequence reactance(saturated)	$X_{2V} := 0.20$	pu
Zero sequence reactance(saturated)	$X_{0V} := 0.096$	pu
Potier reactance	$X_P := 0.35$	pu
Leakage reactance	$X_σ := 0.22$	pu
Stator resistance per phase at 20˚C	$R'_a := 2.22$	mΩ
Direct axis transient open circuit time constant	$T'_{do} = 7.34$	s
Direct axis transient short circuit time constant	$T'_d = 0.93$	s
Direct axis sub-transient open circuit time constant	$T''_{do} = 0.014$	s
Direct axis sub-transient short circuit time constant	$T''_d = 0.011$	s
Quadrature axis transient open circuit time constant	$T'_{qo} = 0.51$	s
Quadrature axis sub-transient open circuit time constant	$T''_{qo} = 0.022$	s
Short circuit time constant of the armature winding	$Ta = 0.17$	s
Machine voltage transformer ratio	$VTR_G := \frac{18000}{110}$	
AVR first current transformer ratio	$CTR_{G2} := \frac{18000}{10}$	
AVR second current transformer ratio	$CTR_{G2} := \frac{10}{5}$	

Earthing resistance	REF1 := 0.55	Ω

9.6 Generator Transformer Data

Generator Transformer and related data		
Description	**Symbol and value**	**Unit**
Rated generator transformer VA	S_{GT} := 590	MVA
Rated generator transformer high voltage	U_{GTHV} :=420	kV
Rated generator transformer low voltage	U_{GTLV} := 18	kV
Rated current (HV side)	$I_{GTHV} := \frac{S_{GT} \times 10^3}{\sqrt{3} \times U_{GTHV}}$ $I_{GTHV} := 811.0$	A
Rated current (LV side)	$I_{GTLV} := \frac{S_{GT} \times 10^3}{\sqrt{3} \times U_{GTLV}}$ $I_{GTLV} := 18924.3$	A
Vector group	YNd1	
Positive sequence impedance @ nominal tap	Z_{GTn} := 14.92	%
Zero sequence impedance at nom tap calculated by OEM	14.09	%
Number of taps	5	
Nominal tap number	3	
Typical operational Tap number	3	
% change in voltage per tap	1.25	%
HV voltage at tap 1 (kV)	430.5	kV
Voltage transformer ratio	$VTR_{HV} := \frac{400 \times 10^3}{110}$	

9.7 Fault Level on the 400 KV System

Description	Nominal L-L Voltage	Ik''(1-phase) 2020/2021	Ik''(3-phase) 2020/2021	Lowest Rated Breaker	Possible Breaker Exceedance	Busbar Rating	Possible Busbar Exceedance
	kV	**kA**	**kA**	**kA**		**kA**	
Kriel 400 BB1A	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BB1B	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BB1D	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BB1E	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BB1F	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BB2A	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BB2B	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BB2C	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BB2D	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BB2E	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BB2F	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 BBC	400	49.79	49.86	50	NO	64.4	NO
Kriel 400 Transfer BB	400	49.79	49.86	50	NO	64.4	NO

C3.2 *Contractor'*S WORKS INFORMATION

This section could also be compiled as a separate file.

SCHEDULES A AND B

a. SCHEDULE A: PARTICULARS OF EMPLOYER'S REQUIREMENTS
b. SCHEDULE B: GUARANTEES AND TECHNICAL PARTICULARS OF PLANT AND MATERIAL OFFERED
c. Notes with regards to the completion of the schedule:
d. Where there is insufficient space provided in Schedule B, particulars must be furnished on a separate sheet marked with the number of the Schedule A item referred to.
e. If a blank space is left in Schedule B next to the Employer's requirements listed in Schedule A it is assumed that the Tenderer does comply with this requirement.
f. Where the Tenderer does not comply with the Employer's requirements these deviations must be clearly stated on Schedule B.

DESCRIPTION			**Schedule A**	**Schedule B**
1.	**EXTERNAL PLANT CONDITIONS** (*Section 1 does not need to be filled in by the Contractor*)			
1.1	**NORMAL SYSTEM CONDITIONS**			
(Extremes of these parameters can occur simultaneously)				
I.	Voltage range	V	95 to 105	
II.	Frequency range	%	97.5 to 102.5	
III.	Voltage imbalance – Negative sequence voltage as a percentage of normal positive sequence voltage	%	2	
IV.	Wave form - maximum amplitude deviation from sine wave	%	5	
1.2	**SUSTAINED ABNORMAL SYSTEM CONDITIONS**			
(Up to six hours unless otherwise indicated)				
I.	Voltage range	%	90 to 110	
II.	Voltage depressions per unit (for up to ten seconds)	%	75	
III.	Frequency range (continuous)	%	95 to 105	
IV.	Voltage imbalance - Negative sequence voltage as a percentage of normal positive sequence voltage	%	3	
1.3	**220VDC NORMAL SUPPLY CONDITIONS**			
I.	Voltage range	%	85 to 110	
II.	Maximum r.m.s ripple voltage	%	2,5	
III.	DC earthing		High resistance	

1.3	**24VDC NORMAL SUPPLY CONDITIONS**			
I.	Voltage range	%	87.5 to 125	
II.	Maximum r.m.s ripple voltage	%	2,5	
III.	DC earthing		High resistance	
2.	**FLOOR REQUIRMENTS**			
2.1	**CABLE OPENINGS**			
a)	List dimensions of cable openings required for excitation panels			
b)	Number of cable openings required			
2.2	**FLOOR LOADING**			
a)	Mass of completed excitation power panels with cables	kg		
b)	Mass of completed excitation control panel with cables	kg		
3.	**PANEL DESIGN AND CONSTRUCTION**			
3.1	**GENERAL**			
a)	Manufacturer of panels			
3.2	**SIZE OF EXCITATION POWER PANELS**			
a)	Length	mm		
b)	Width	mm		
c)	Height (including base frame)	mm		
3.3	**SIZE OF EXCITATION CONTROL PANEL**			
a)	Length	mm		
b)	Width	mm		
c)	Height (including base frame)	mm		
3.4	**SPACE ALLOCATED FOR PLACING EXCITATION POWER PANELS**			
a)	Length	mm	8890	
b)	Width	mm	1600	
3.5	**SPACE ALLOCATED FOR PLACING THE EXCITATION CONTROL PANEL**			
a)	Length	mm	140	

b) Width		mm	100	
3.6	**MINIMUM MATERIAL THICKNESS**			
a)	Base plates	mm	5	
b)	Gland plates	mm	5	
c)	Supporting structures	mm	2.5	
d)	Cover plates	mm	2.5	
e)	Removable covers	mm	2.5	
f)	Doors	mm	2.5	
g)	Equipment mounting panels (Chassis plate)	mm	2.5	
3.7	**PANEL ACCESS**			
a)	Front panel access		Yes, doors	
b)	Rear panel access		Yes, doors	
c)	Excitation power converter cubicle cable entry		Bottom	
d)	Excitation Regulator cubicle cable entry		Bottom	
3.8	**COMPARTMENT SEPARATION**			
a)	Separate switching devices compartment		Yes	
b)	Separate control electronics compartment		Yes	
c)	Access restriction to live parts when doors are open		Transparent low flammability polycarbonate sheeting	
3.9	**C U B I C L E DOORS**			
a)	Door locking mechanism		Door handle to accept padlocks	
b)	Minimum latching points (Doors >800mm)		2	
c)	Minimum hinges		3	
d)	Door over-swing protection		Yes	
e)	Door reinforcement required		Yes	
f)	Excitation cubicle door is equipped with a high quality limit switch		Yes	
3.10	**CORROSION PROTECTION & FINISHING**			
a)	External colour		Ivory or grey G29	

	b) Surface finish	SANS 175 SANS 1274	
	c) Internal mounting plates/chassis plates colour		
	d) Framework/support structures		
	e) Gland plates		
3.11	**MINUMUM DEGREE OF ENCLOSURE PROTECTION (TO IEC 60529)**		
	a) Excitation cubicles	IP52C	
4.	**EARTHING**		
4.1	**C U B I C L E MAIN PE CONDUCTOR**		
	a) Connections	Bolted	
	b) Earth conductor position	Rear of panel	
	c) Earth conductor material	Copper	
	d) Min earth conductor size mm²	150	
	e) Earth conductor rated short-time fault withstand time s		
4.2	**METAL COMPONENTS/FRAMES**		
	a) Connections	Bolted star stud connection	
	b) Material	Multi-strand conductors	
	c) Colour coding	Green and Yellow	
	d) Min material thickness mm²	6	
4.3	**DOORS**		
	a) Connections	Stud/bolted connection	
	b) Material	Braided conductor	
5.	**EXCITATION CONTROL SYSTEM**		
5.1	**GENERAL**		
	a) Manufacturer		
	b) Model number		
	c) Type	Digital	

d)	Configuration		Fully redundant dual channel.(AVR, and field current control per channel)	
e)	Test mode		Open loop, user selectable (Yes/No)	
5.2	**COMMUNICATIONS PROTOCOL TO EMPLOYER'S SCADA**			
a)	Protocol: First option (Most preferred)		Profibus DP	
b)	Protocol: Second option			
c)	Protocol: Third option			
d)	Time synchronization		Network Time Protocol (NTP).	
e)	Time synchronization method		External GPS clock *(Provided by Employer)*	
5.3	**PERFORMANCE INDEX**			
a)	Transient gain	pu	≦ 20	
b)	Nominal response	s^{-1}	At least 2	
c)	Voltage over shoot	%	≦ 30 % of step size	
d)	Rise time (From 10%Ugn to 90%Ugn)	ms	Up to 500	
e)	Maximum voltage reached after disconnection from grid at rated field current	pu	1.4	
f)	Minimum stator voltage at which rated excitation field current can be maintained	%	80	
g)	Positive ceiling voltage (α=15^o, U_{gen}=80%)	pu	1.6	
h)	Channel changeover steady state deviation	%	1 U_{gn}	
i)	Voltage control accuracy (AVR Mode)	%	Within 0.5 of U_{gn}	
j)	Open loop regulator accuracy	%	Within 1 of I_{fn}	
5.4	**VOLTAGE CONTROL LIMITS**			
a)	Upper limit	%	$U_{gn} + 10$	
b)	Lower limit	%	$U_{gn} - 10$	
5.5	**FIELD CURRENT CONTROL RANGE**		105%	

a)	Upper limit	%	105	
b)	Lower limit	%	0	
5.6	**STEP FUNCTION**			
a)	Amplitude (adjustable)	%	IEEE421-2	
b)	Resolution	%	IEC 60034-16	
5.7	**FREQUENCY SWEEP FUNCTION**			
a)	Amplitude (adjustable)	%		
b)	Resolution	%		
c)	Frequency range	Hz		
d)	Frequency resolution	Hz		
5.8	**OVER EXCITATION LIMITER (Maximum Field Current Limiter)**			
a)	Operating mode		I^2t thermal capacity	
b)	Max ceiling value adjustable	pu	1.6 pu	
c)	Thermal value adjustable	pu	1.05 pu	
5.9	**STATOR CURRENT LIMITER**			
a)	Operating mode		Selectable between definite time and IDMT/I^2t type characteristic	
b)	Operating in capacitive or inductive region		Selectable	
5.10	**FLUX LIMITER**			
a)	Operating value	pu	1.09	
b)	Time to operate	s	Shall be graded with the generating unit's protection	
c)	Operating mode		User selectable between inverse time and definite time	
5.11	**UNDER EXCITATION LIMITER**			
a)	Reactive power offset range	pu	5-10%	
b)	Limiting incline	deg	80^0	
c)	Resolution	deg	At least 0.01	
d)	External reactance	pu	0 to 1 in steps of 0.01	

e)	Resolution of Q setting when limiter is Q(P)	pu	At least 0.01	
f)	If the UEL is a Q(P) limiter then at least 4 points be available for setting the characteristic in both import and export quadrants	pu		
5.13	**SOFT START FUNCTION**			
a)	Time to reach pre-set	s		
b)	Resolution	s		
c)	Range of control	%	From approximately 10% less than no-load field current to approximately 5% above maximum required field current.	
5.14	**EXCITER FIELD WINDING OVER VOLTAGE PROTECTION**			
a)	Positive bar		Yes	
b)	Negative bar		Yes	
5.15	**DC SHORT CIRCUIT PROTECTION**			
a)	Range	pu	0 to 5 I_{fn}	
b)	Resolution	pu	0.01	
5.16	**POWER SYSTEM STABILISER (PSS)**			
a)	Damping ratio local mode		> 0.1	
b)	Frequency operating range	Hz	0.1 to 3	
c)	Active power switch-on level	pu	0.1 to 0.3	
d)	Active power switch-on time delay	s	0 to 10	
e)	Timer resolution	s	0.1	
f)	Active power switch-off level	pu	0.2	
g)	Active power switch-off time delay	s	0 to 10	
h)	Stator voltage switch off (low level)	%	$U_{gn} - 10$	
i)	Stator voltage switch off (upper level)	%	$U_{gn} + 10$	
j)	PSS switch-off time delay due to PSS output out of bounds	s	0 to 10	
k)	PSS switch-on time delay due to PSS output recovery	s	0 to 10	
l)	PSS output Low limit	%	0 to 10 U_{gn}	

m)	PSS output Upper limit	%	0 to 10 U_{gn}	
6.	**CONVERTOR OPTIONS**			
a)	Model number			
b)	Type		6 pulse, full wave, thyristor controlled	
c)	Redundancy		1+1 or N-1	
d)	Continuous rating of one converter at ambient of 35ºC	A		
7.	**DC FIELD BREAKER**			
a)	Number of main poles		1 or 2	
b)	Coil nominal operating voltage (DC)	V	110	
c)	Coil operating voltage min range (trip and close)	%	80% of nominal value	
d)	Normally open auxiliary contacts for use other than by the ECS		5	
e)	Normally closed auxiliary contacts for use other than by the ECS		5	
f)	Number of mechanical operations		≥ 10 000	
g)	Operating counter		Breakers must have mechanical counters installed	
h)	Trip coils		2	
i)	Time to block breaker operation switch from opening to closing	s	5-30	
8.	**FIELD FLASHING**			
8.1	**AC FIELD FLASHING SUPPLY**			
a)	Nominal voltage	V	380	
b)	Voltage range	%	±10	
c)	Supply VA requirement	VA		
9.	**FIELD SUPPRESSION**			
a)	Overlapping time	ms		
b)	Nominal voltage	V		
10.	**RECORDING DEVICES**			
10.1	**EVENT RECORDER**			
a)	Minimum number of stored events			
b)	Sampling rate			

c) Type of event display			
10.2 TRANSIENT RECORDER			
a) Minimum digital quantities			
b) Contact voltage			
c) Minimum analogue quantities			
d) Sampling rate for non-instantaneous signals (i.e. voltage converted to DC value)	ms		
e) Minimum recording time window	s		
f) Triggering criteria			
g) Pre-trigger	s		
h) Digital trigger			
i) Analog trigger			
j) Export file types			
k) Minimum number of records stored in memory			
11. PROTECTION IED'S			
a) Manufacturer			
b) Type		Digital	
c) Connection		3 phase	
d) Nominal current (In)	A	1	
e) Current setting range			
f) Time multiplier			
g) Error of settings	%		
h) Overload capability			
i) Curve/characteristic			
j) High set			
k) High set time	s		
l) Number of IDMT curves simultaneously active			
m) Logic functionality to add sustained fault timer			
n) Sustained fault timer range	s		
o) Setting resolution	ms		
12. AUXILLIARY ELECTRICAL & MISCELLANEOUS COMPONENTS			

12.1	**INTERNAL POWER SUPPLY UNITS**		
a)	Manufacturer		
b)	Input voltage range to maintain nominal output voltage %		
c)	Maintain rated output voltage in case of supply loss ms		
d)	Overload indication and protection	Yes	
12.2	**MCB'S FOR CONTROL CIRCUITS**		
a)	Manufacturer		
b)	Rated breaking current kA		
c)	Rated voltage VAC/VDC		
d)	Curve selections		
12.3	**FUSES POWER ELECTRONICS**		
a)	Manufacturer		
b)	Type	IEC or equivalent	
12.4	**CONTROL CIRCUIT FUSES**		
a)	Manufacturer		
b)	Type		
c)	Rated voltage V		
d)	Rated breaking current kA		
12.5	**SIGNAL LAMPS OR LIQUID DISPLAY**		
a)	Manufacturer		
b)	Type	LED	
c)	Supply voltage V		
12.6	**LABELS**		
a)	Language	English	
b)	Colour (General Labels)		
c)	Colour (Warning Labels)		
d)	Letter print: Internal labels		
e)	Letter print: External labels		

12.7 FERRULE NUMBERING		
a) Manufacturer		
b) Material		
c) Size mm		
d) Type		
e) Font		
f) Colour		
12.8 CABLE NUMBERING		
a) Manufacturer		
b) Material		
c) Size mm		
d) Type		
e) Font		
f) Colour		
g) Placement		
12.9 TRANSDUCERS		
a) Manufacturer		
b) Type mA	4-20	
c) Accuracy		
d) Power supply Vdc		
12.10 CT TEST BLOCKS		
a) Manufacturer		
b) Type		
c) Mounting		
d) Supply test handles	Yes	
12.11 VT TEST BLOCKS		
a) Manufacturer		
b) Type		
c) Mounting		
d) Supply test handles	Yes	

12.12	**INDICATING INSTRUMENTS**			
a)	Manufacturer			
b)	Type	mA	4-20	
c)	Size	mm		
d)	Full scale deflection angle	deg		
e)	Accuracy			
f)	Mounting			
g)	Generator stator voltage range	kV	0 to 18	
h)	Generator stator current range	kA	0 to 20	
i)	Generator active power range	MW	0 to 500	
j)	Generator reactive power range	MVAr	-400 to 400	
k)	Generator field current range	A	0 to 5000	
l)	Generator field voltage range	V	0 to 500	
13.	**CABLING**			
13.1	**PROCESS CONTROL AND INSTRUMENTATION CABLING (<1 AMP SIGNALS)**			
a)	Manufacturer			
b)	Code			
c)	Type			
d)	Core identification			
e)	Minimum voltage rating	V		
13.2	**LV POWER & CONTROL CABLING**			
a)	Manufacturer			
b)	Code			
c)	Type			
d)	Core identification (2-4 cores)			
e)	Core identification (>4 cores)			
f)	Minimum voltage rating	V		
13.3	**ROTOR CABLING**			
a)	Manufacturer			
b)	Code			
c)	Type			

d)	Minimum voltage rating V		
13.4	**EXCITATION TRANSFORMER HV CABLING**		
a)	Code		
b)	Type		
c)	Core identification		
d)	Minimum voltage rating kV		
13.5	**EXCITATION TRANSFORMER LV CABLING**		
a)	Code		
b)	Type		
c)	Core identification		
d)	Minimum voltage rating V		
14.	**HV INSULATION**		
a)	Tests on power plant and material		
b)	Tests on electronic plant and material		
15.	**SUB-CONTRACTORS**		
a)	Subcontractor engaged in delivery of assembly		
b)	Subcontractor engaged in erection of assembly		
c)	Subcontractor engaged in commissioning of assembly		
d)	Other subcontractors		
16.	**MANUALS & SOFTWARE**		
16.1	**OPERATING AND MAINTENANCE MANUALS**		
a)	Number of copies of all instruction/O&M manuals required	5	
b)	Electronic submission required	Yes – CD/DVD	
c)	Format	At least searchable pdf	
16.2	**SPECIAL TOOLS**		
a)	Number of each special tool set required for maintenance	2	

b) Software packages Windows compatibility	Windows 10 upwards	
17. TRAINING		
17.1 NUMBER OF STAFF TO BE TRAINED Engineering/Commissioning staff Maintenance personnel Operating personnel	Total 35	
17.2 LOCATION		
a) Engineering /Commissioning staff		
b) Maintenance personnel	Kriel Power Station	
c) Operating personnel	Kriel Power Station	