KENDAL POWER STATION

BLACK START FACILITY

TECHNICAL SPECIFICATION

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1. INTRODUCTION

A Gas Turbine is in the process of being installed at Kendal Power Station This Gas Turbine will be used for black start purposes in the event of a power failure on the national grid. The Gas Turbine will be controllable from the Station Control Room A Simatic PLC shall be installed at the Gas Turbine. The PLC shall be connected to the existing station control *Redundant H1 bus.*

1.1. Scope of Work

The contractor shall be responsible for the engineering, supply, delivery, off loading, installation, wiring, and commissioning of the specified system so that it is a fully workable system. *Commissioning shall be in conjunction with Eskom personnel.* See **fig. 1** for limits of supply

It is shown that ESKOM will supply all the electrical signals to the SAE marshalling terminals of the PLC cubicle. The contractor will be responsible to complete these loops to the PLC and for the connection via the *Redundant H1 bus* to the Station Control Room. The marshalling terminals will be housed in the same enclosure as the PLC

1.2. Technical Requirements

The Simatic PLC required should be able to support the following:

- 64 digital inputs (24 V dc).
- 64 digital outputs (24V dc)
- 4 analogue inputs (0-20 mA) **Signal ranges of 4 - 20mA will be used**
- 12 analogue inputs (±500 mV).
- Full communication with the Kendal Station Control *Redundant H1 bus.*
- An E490 oscillostore sequence of events recorder for 96 real inputs and 32 virtual inputs.
- The above equipment shall be wired into a panel and all I/O shall be terminated at the specified marshalling terminals (Sae's)
- The I/O count includes at least 10% spare capacity No spare channels need to be provided for the E490 hardwired inputs

The PLC shall accept analogue and digital I/O and the status of the I/O shall be displayed on the COROS SCADA system following the format detailed in the Station Control Upgrade Operating / Control Philosophy Revision C dated 22 February 1993. The Gas Turbine shall be controllable from the existing STN COROS system under normal conditions. In the event of a failure of either the STN COROS station or the STN co-ordinator PLC, the Gas Turbine shall be controlled from the Unit COROS system in accordance with the requirements of the Station Control system. (ref. to Station Control Upgrade Operating / Control Philosophy Revision C dated 22 February 1993)

In terms of the Station Control Coordinator PLC backup Proposal dated 6 October 1995, the gas turbine displays can be viewed and controlled from both the Unit and STN COROS systems simultaneously. For the sake of simplicity operator prompting during the monthly and black start sequence programs should occur only on the STN COROS

2. OVERVIEW OF PLC SOFTWARE REQUIREMENTS

The PLC shall allow for the following:

- Full communication with the following PLCs via the *Redundant H1 bus*. Unit 1 to 6 Satellite PLCs, STN satellite, HV Yard satellite, Unit, STN, HVY and alarm (stn/unit) co-ordinator PLCs. Communication with the Unit, STN and alarm (stn/unit) COROS systems via their respective co-ordinators.
- Updating the status of digital inputs displayed on the COROS SCADA system according to status in the plant.
- Triggering hardware, software and system alarms for display on the alarm (stn/unit) COROS.
- Updating of the analogue values displayed on the COROS SCADA system according to their values measured in the plant.
- Control of digital outputs according to remote commands issued from the COROS SCADA system and interlocks processed in the PLC.
- Processing of sequence control programs for the start-up of the Gas Turbine under black start and monthly start conditions
- Full interface to other satellites and co-ordinators for the transfer of commands, statuses, and interlocks as described in the interface areas and the sequence control program
- The principal of the special interlocking is shown in **fig. 2** and the programming of these interlocks forms part of the scope of work. The actual interlocks are shown in section 14.1 5

3. OVERVIEW OF COROS SOFTWARE REQUIREMENTS

New graphic displays (pages) shall be created within the COROS system. These layouts are shown in **fig. 3** and **fig. 4** and page 9 and 10 of this document. These displays shall have control and indication functions. In addition there shall be pop-up menus informing the operator of the status of the sequence and prompting him where necessary to perform manual operations. These pop-up menus are shown in **fig. 5a, 5b, and 5c.** Alarms from the PLC shall be displayed on the alarm screen and printed on the alarm printer. The existing Station Control overview displays (**fig. 6a and 6b**) must be modified to incorporate the Gas Turbine reticulation into the existing system layout.

4. STANDARDS

All standards applicable to the current Kendal Station Control contract OPJ11891 will apply to this specification unless otherwise specified.

5. ENCLOSURE

The supply of a panel suitable for housing the PLC, the marshalling terminals as well as one additional 19" rack (free-issue) also forms part of the scope of work. The panel shall be to ESKOM's approval. The doors of the panel shall be easily removable. The panel shall be installed in the Harmonic Filter Substation. A proposed panel layout is shown in **fig 7.**

6. POWER SUPPLY

ESKOM will provide a 24V dc power supply which will supply a minimum of 18A at 24V and provide 40 Ah of backup. The power supply will be dedicated to this system. The contractor shall ensure that the equipment is compatible to this supply.

7. CABLING AND WIRING

The existing Kendal Station Control standards shall apply. (As per OPJ11891)

8. DOCUMENTATION

Full documentation shall be provided for the hardware, installation and software including a flow chart of the monthly and black start process.

9. COMMISSIONING

NWS 1007/P shall be completely complied with. In addition ESKOM shall approve, test and commission the system in conjunction with [redacted]

10. ACCEPTANCE TEST

An actual monthly start-up sequence must be performed. A complete black start sequence must be simulated on each unit at site. Software shall comply to the general standards and formats used in the existing station control PLC's. All special configuration software and documentation must be given to Eskom. When the system operates according to ESKOM's functional specification, acceptance will be given.

11. QUALITY ASSURANCE

All work must comply with OPS 3450.

12. TAKE OVER

Take over of these modifications by ESKOM shall be governed by GCC: clause 46. During this period the contractors responsibilities and liabilities shall be the same as those applying during official maintenance period GCC: clause 47. The take-over of the Gas Turbine-station control interface shall be as per **fig. 8** for all interfaces.

13. SIGNAL LIST

The following documents describe all signals and their wiring

- **fig. 9** C & I Schedules
- **fig. 10** Detailed Signal List.
- **fig. 11** Cable Schedules.
- **fig. 12** Interface Drawings.
- **fig. 13** Help Overlay Descriptions
- **fig. 14** Interfaces with other PLC's
- **fig. 17** Plant Overview Diagram

14. OPERATING PHILOSOPHY

14.1. Cyclic Program

14.1.1. Time Update

Time will be received from the master clock via the *Redundant H1 bus* time broadcast. This time is used to update the PLC's real time clock, which in turn should update the E490. The E490 time is updated whenever a change is made to the PLCs real time.

14.1.2. Alarming

The E490 should perform both real and virtual channel processing of all alarm signals detailed in the C & I schedule. The conversion of time from milliseconds to hours, minutes, seconds, and milliseconds should take place in the Gas Turbine PLC as per the Unit satellite PLCs.

14.1.3. Status and Analogue monitoring

All statuses and analogues required for monitoring purposes on the COROS displays are indicated on the C & I schedule (**fig. 10**). Raw analogue values are sent up to the co-ordinator for scaling. Only power factor conversion is performed in the Gas Turbine PLC This signal must be converted from an angle to a power factor (Cos ϕ) in the range 0-1-0, for maximum leading, unity, and maximum lagging power factors respectively. Status and Analogue signals must be marshalled and sent up in the same format and fashion as from the other Station Control satellites

14.1.4. Command Processing

All signals which are commands from the COROS / co-ordinator level should be marshalled to the appropriate outputs as per the other Station Control satellite PLCs. The command signals are indicated on the C & I schedule (**fig. 10**). The description of these commands follows below.

14.1.4.1. Breaker Open/close

Command processing as per other switchgear of Station Control system (for details refer to Station Control Upgrade Operating / Control Philosophy Revision C dated 22 February 1993)

14.1.4.2. Gas Turbine start/stop

Command outputs are interlocked so that only start or stop should be active at any given time. If the correct status feedback is not received in a reasonable time, then the output is reset and a fault generated Command requests will be ignored until the fault is reset

14.1.4.3. Base/Peak/"no mode" mode selection

Command outputs are interlocked so that only base or peak should be active or both can be off at any given time. If the correct status feedback is not received in a reasonable time, then the output is reset and a fault generated Command requests will be ignored until the fault is reset

14.1.4.4. Droop/Isoch mode selection

Command outputs are interlocked so that only droop or isoch should be active at any given time. If the correct status feedback is not received in a reasonable time, then the output is reset and a fault generated. Command requests will be ignored until the fault is reset.

14.1.4.5. Raise/Lower Governor

Command outputs are interlocked so that only raise or lower should be active at any given time There is no status feedback for these signals. For operator commands, the outputs are set high for a pre-set time each time the command request is received. When the sequence program controls the governor, the program determines the time that the output is kept high.

14.1.4.6. Raise/Lower Voltage

Command outputs are interlocked so that only raise or lower should be active at any given time. The status feedback is taken from the MVAR and voltage signals of the system The outputs are set high for a pre-set time each time the command request is received. When the system is synchronised, the VAR limits are used for control For single mode when the system is not synchronised, the voltage limits are used for control.

14.1.4.7. Emergency Stop

If an emergency stop request is received by the PLC, the emergency stop output is set high until feedback is received that the machine has stopped If the feedback is not received in a given time then the output is disabled and a command failure alarm is generated.

14.1.4.8. Synchroniser Select

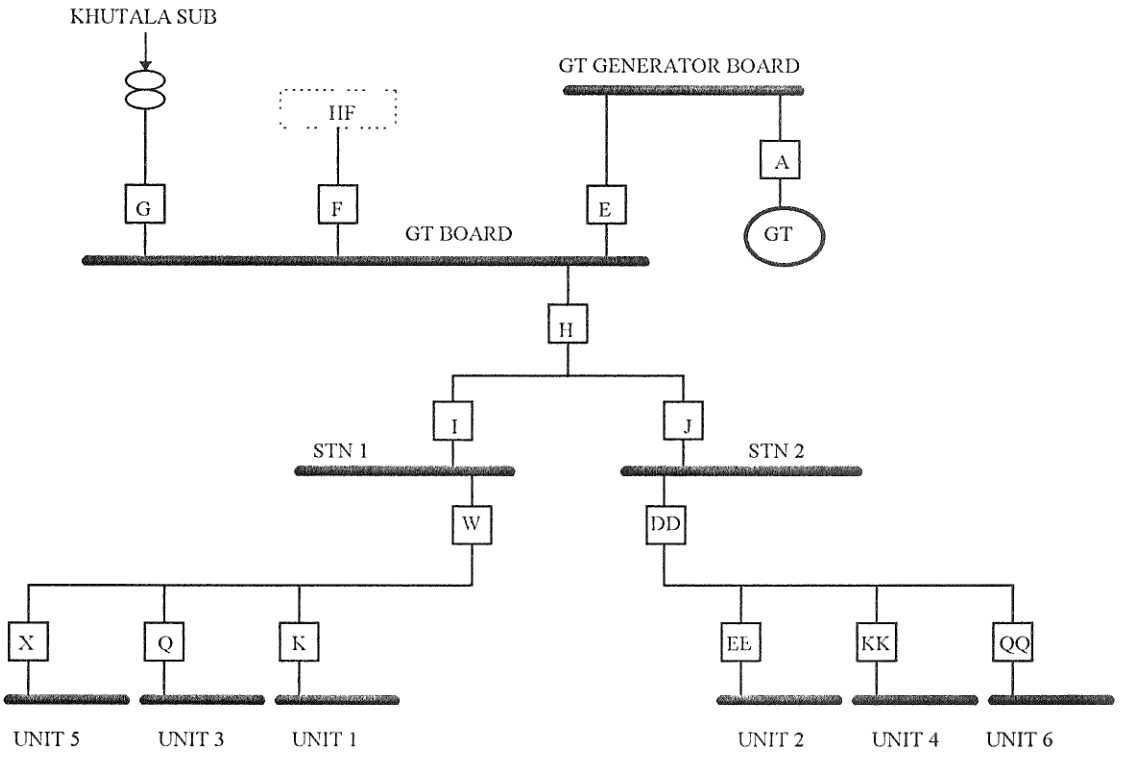
If a synchroniser is selected and the synchroniser "on" feedback is received, then the enable output is set until feedback is received that the relevant breaker is closed If the synchroniser "on" feedback is not received in a pre-set monitoring time then the output is reset by the timer. If the synchroniser is already on it cannot be selected again until it is disabled

14.1.5. Interlocks

All command and interlock signals from the Gas Turbine PLC to the other satellites must be verified that they are valid before being used as commands or interlocks This is required to prevent problems in the case of bus failure
All signals sent for interlocking purposes should use positive logic. i.e. high signal for the enabling condition and a low signal for the blocked condition

Full details of all MV interlocking is contained in "KENDAL POWER STATION MV Switchgear Interlocking Rev.0 20 June 1995 "

GAS TURBINE BOARD INTERLOCKING



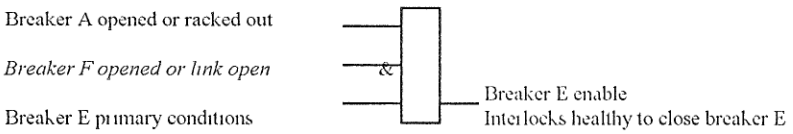
11.5kV GAS TURBINE BREAKER (A) INTERLOCK

Operator at station control room can only open the breaker from remote
Operator can not close breaker (A) from remote.

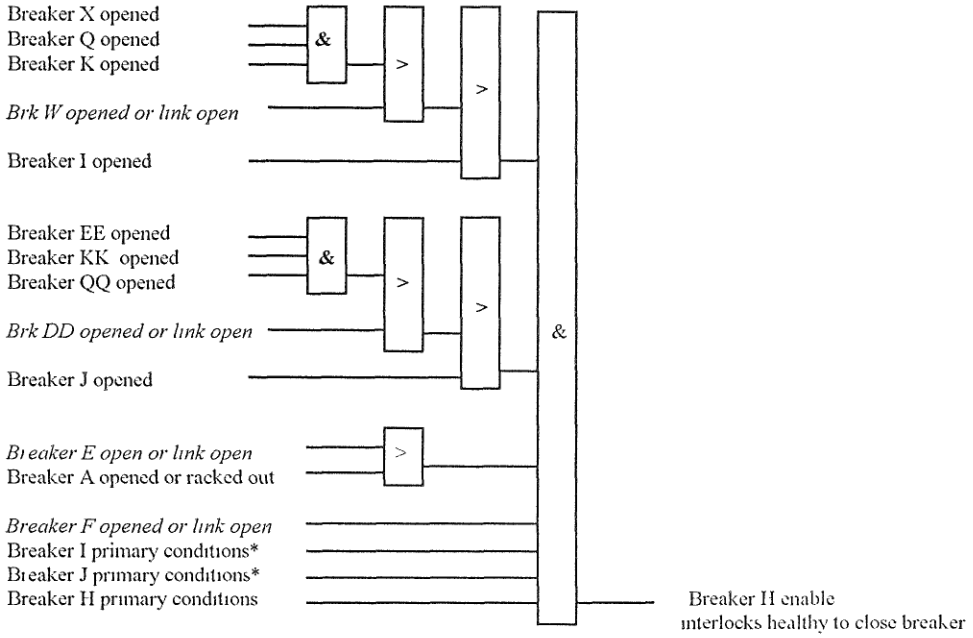
HARMONIC FILTER BREAKER (F) INTERLOCK

Operator at station control room can only open the breaker from remote
Operator can not close breaker (F) from remote.

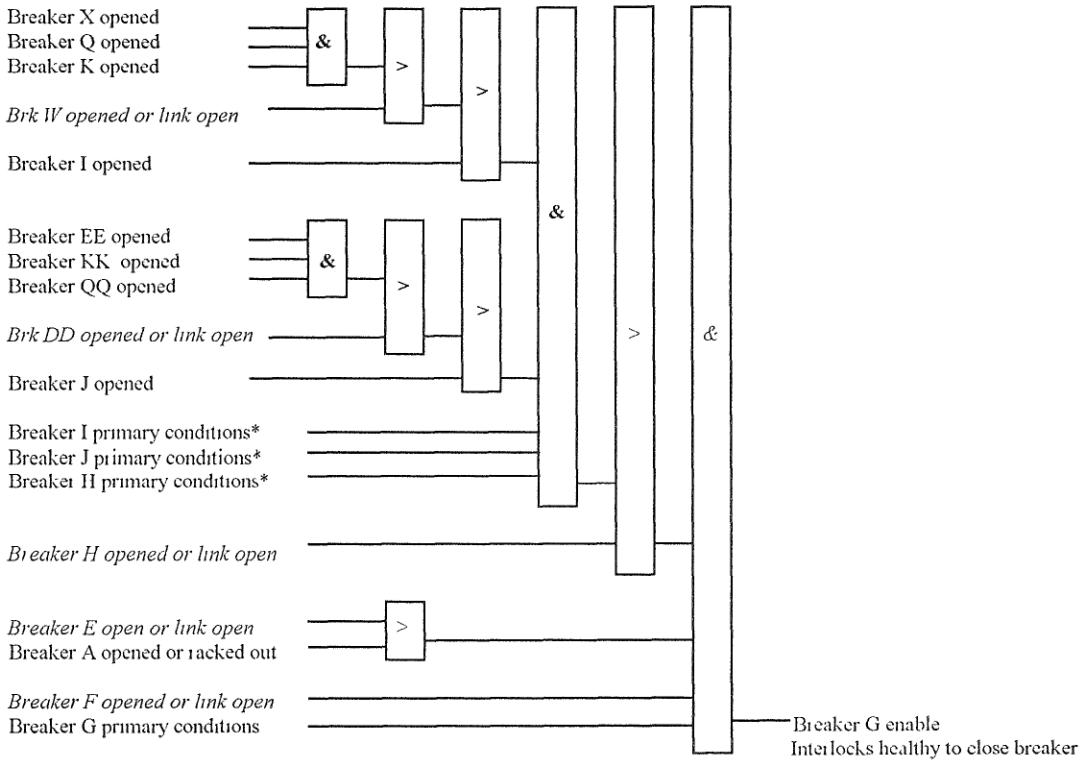
GT INCOMER (E) FROM 11.5KV GT BOARD INTERLOCK



GT FEEDER TO STATION BOARD 1 & 2 INTERLOCK



GT BOARD INCOMER FROM KHUTALA INTERLOCK



* Link Closed & E/S off

14.2. Interlocks during monthly start and black start

The interlocks for monthly start and black start are as per the sequence program. The interlocks for any step are based on the conditions of the previous transition being fulfilled. Interlocks in satellite PLCs other than the Gas Turbine PLC should be verified by that satellite before a command is given to the switchgear.

14.3. Sequence program

Under normal conditions, the following sequences will run automatically in the Gas Turbine PLC. If a manual start is required, then the operator should utilise the flowcharts and the C&I schedule to achive a manual start

14.3.1. Monthly start sequence

The monthly start sequence is initiated on the STN COROS station by selecting it using F8 on the Gas turbine mask During the sequence of the monthly start-up, the operator will be notified of the progress and the steps in the sequence via pop-up windows which appear on the COROS mask. PLC functions are indicated in yellow and operator functions in white.

If the PLC is unable to successfully perform a step within a pre-set time, then the sequence will halt and the operator will be prompted to abort or continue If he chooses to abort then the sequence program will be terminated and the operator will have to start again. (There are exceptions see flowchart for details). Should the operator choose to continue he should rectify the problem in the field and then press continue on the COROS. If all the conditions are satisfied the sequence will proceed. If the conditions are not met the operator will again be prompted to abort or continue.
If the monthly start sequence is in progress and the black start conditions are satisfied, the monthly start is aborted and the black start sequence begins
The monthly start flowchart is given in **fig. 15.**

14.3.2. Black Start Sequence

The black start is automatically initiated by the Gas Turbine PLC when it detects that there is undervoltage on both station boards and the Khutala incomer for a period of at least 30 seconds. During the sequence of the black start, the operator will be notified of the progress and the steps in the sequence via pop-up windows which appear on the COROS mask.

PLC functions are indicated in yellow and operator functions in white.

If the PLC is unable to successfully perform a step within a pre-set time, then the sequence will halt and the operator will be prompted to abort or continue. If he chooses to abort then the sequence program will be terminated and the operator will have to start again (There are exceptions see flowchart for details). Should the operator choose to continue he should rectify the problem in the field and then press continue on the COROS. If all the conditions are satisfied the sequence will proceed. If the conditions are not met the operator will again be prompted to abort or continue.
It should not be possible to select the monthly start program while the black start program is in progress
The Black start flow chart is given in **fig. 16**.

14.4. COROS functions

The control and monitoring functions of the Gas Turbine are performed primarily on the STN COROS system. In the event of hardware failure of either the STN COROS or the STN co-ordinator PLC then these functions will be available on the Unit COROS system

The alarms originating from the Gas Turbine PLC will be displayed on the Unit/STN COROS system. The control and monitoring functions of the Gas Turbine are split into three display pages, namely a reticulation overview screen (**fig. 3**), the status screen (**fig. 4**), and the interlock screen.

14.4.1. Gas Turbine Overview Screen.

The control and status of the switchgear as well as the most important analogue values (including the fuel consumption curve) are displayed on the overview screen

This screen displays the steps in the sequence program and a window showing the particular unit selected for black start, during the execution of sequence programs

The COROS shall follow the progress of any sequence program running in the Gas Turbine PLC and indicate the relevant step in the sequence, by means of text blocks describing the function being performed in that step. Details of the step displays are shown in **fig. 5a, 5b, and 5c.**

The step number consists of three digits The first digit indicates which sequence is running (0 - black start, 1 - unit 1, 2 - unit 2,

3 - unit 3, 4 - unit 4, 5 - unit 5, 6 - unit 6, 7 - monthly start). The second and third digits represent the step numbers, which correspond with the steps on the help figures (see sequence flowcharts for details).
A "help overlay" figure provides an aid to identifying the switchgear by the letter code given in **fig. 13**.

The overview screen has a two field status display. One field displays the status of the GT machine start-up sequence. The other field displays the status of the machine controls i.e. "local" or "remote".
The status of the start-up sequence is as follows.

READY- ready to start healthy, flame selection off, temp control off, control sequence not in progress, control sequence not complete, start pulse not active.
STARTING- ready to start unhealthy, flame selection off, temp control off, control sequence in progress, control sequence not complete, start pulse active, aux. running on.
FIRE- ready to start unhealthy, flame selection on, temp control off, control sequence in progress, control sequence not complete, start pulse active, aux. running on
WARMING- ready to start, flame selection on, temp control off, control sequence in progress, control sequence not complete, start pulse active, aux running on.
RUNNING - control sequence complete
RATCHETING- ready to start or flame selection off, temp control off, control sequence in progress, control sequence not complete, start pulse not active, aux running on.
STOPPED- flame selection off, temp control off, control sequence not in progress, control sequence not complete, start pulse not active.

14.4.2. Gas Turbine Status screen

The status screen is more closely associated with the functions of the Gas Turbine itself The status screen is the operator interface to the various modes and controls of the Gas Turbine machine and provides facilities to remotely control various devices and monitor their status.

The COROS should indicate the status of all digital inputs (designated "status") and the measured value of all analogue inputs (designated "measurement") described in the list of signals (**fig. 10**). It should provide the facility to operate the switchgear and Gas Turbine controls (designated "oper command" and "gen command") in the list of signals (**fig. 10**)

14.4.3. Gas Turbine Interlock Screen

The interlock screen should display the interlock logic diagrams which are included on pg. 9 and pg 10 of this document. The format should be similar to that used for other Station Control satellites. The completed interlock displays are shown in **fig. 20.**

14.4.4. Coros Function keys

The operation of the function keys for commands shall be in accordance with the general standards applicable to the station control system.

The operator will be prompted to make decisions at various stages in the sequence program He will exercise these decisions via the function keys. The function of these keys are described in more detail in the sequence flow charts

The operator will be prevented from remotely operating the Gas Turbine switchgear during the performance of a sequence program.

The gas turbine functions are described below.

HELP - This key appears on the overview screen and is used to toggle the swichgear alphabetic labels on and off

STATUSES - This key calls the Gas Turbine status screen.

INTERLOCKS - This key calls the Gas turbine interlock screen

SSB - This key calls the STN overview screen.

ACKNOWLEDGE - This key acknowledges a flashing status i.e. Operator acknowledges that a device has changed state without an operator command.

EMERGENCY STOP - This key is always active and will shut down the Gas Turbine

EMERGENCY STOP GAS TURBINE - This key appears after selecting "emergency stop", and confirms that the gas turbine will be stopped

CANCEL - This key is used to cancel any operation and return to the previous function key level.

MONTHLY START - This key on the status screen is used to initiate the monthly start sequence program.

START MONTHLY TEST SEQUENCE - This key appears after selecting "monthly start", and confirms that the monthly start sequence will begin.

CANCEL - This key is used to cancel any operation and return to the previous function key level.

GO BACK - This key will return you to the overview screen from the status screen

COMMAND MODE SELECT - This key appears on the overview screen when it is possible to control switchgear remotely i.e black start or monthly start not active. This key is always active on the status screen, and allows the operator to operate the synchroniser and the controls of the gas turbine The device to be operated is selected with the cursor. The options allowed will depend on the type of device to be operated.

OPEN - This key appears having selected command mode on the overview screen, and is used to open a breaker, or manually update the status of a link to open.

CLOSE - This key appears having selected command mode on the overview screen, and is used to close a breaker, or manually update the status of a link to close.

ON - This key appears having selected command mode on the overview screen and is used to manually update the status of an earth switch to earthed

OFF - This key appears having selected command mode on the overview screen and is used to manually update the status of an earth switch to not earthed.

RAISE - This key appears having selected command mode on the status screen and is used to raise the voltage or frequency of the gas turbine alternator.

LOWER - This key appears having selected command mode on the status screen and is used to lower the voltage or frequency of the gas turbine alternator.

START GAS TURBINE - This key appears having selected command mode on the status screen, and is used to start the gas turbine.

STOP GAS TURBINE - This key appears having selected command mode on the status screen, and is used to stop the gas turbine.

BASE - This key appears having selected command mode on the status screen, and is used to select base mode on the gas turbine.

PEAK - This key appears having selected command mode on the status screen, and is used to select peak mode on the gas turbine.

ISOCH - This key appears having selected command mode on the status screen, and is used to select isoch mode on the gas turbine.

DROOP - This key appears having selected command mode on the status screen, and is used to select droop mode on the gas turbine.

SYNCHRONISE GAS TURBINE WITH UNIT - This key appears having selected command mode on the status screen, and is used to enable the gas turbine to synchronise with a selected unit generator

SYNCHRONISE WITH STATION TRANSFORMER - This key appears having selected command mode on the status screen, and is used to enable the gas turbine to synchronise with the station transformer

CANCEL - This key is used to cancel any operation and return to the previous function key level

SELECT A UNIT - This key appears during the black start program when it is necessary for the operator to select a unit to black start.

UNIT 1, UNIT 2, UNIT 3, UNIT 4, UNIT 5, UNIT 6 - These keys appear after selecting "select a unit" during the black start sequence program These keys are used to bring up a selected unit overview on the gas turbine overview screen.

START SELECTED UNIT BLACK START PROGRAM - This key is used to confirm the selection of a unit to black start, once the unit overview appears on the gas turbine overview screen.

RE-SELECT A UNIT - This key returns the operator to the function key level "select a unit".

ABORT (EXIT PROGRAM) - This key appears during the sequence program when the sequence program halts at a defined hold point The operator has the option to abort execution of the sequence program at that point

CONTINUE (CONTINUE PROGRAM) - This key appears during the sequence program when the sequence program halts at a defined hold point. The operator has the option to continue execution of the sequence program whenever he is ready to continue

FAULT! - (INTERLOCK/TRC/LOR/DC/PLC OR HARDWARE PROBLEM) ABORT OR CONTINUE - These function keys appear during the sequence program when the sequence program halts for some reason The operator then has the choice to correct the fault manually and then continue or he may opt to abort that part of the sequence, in which case the sequence will restart at a predefined abort level. These abort levels can be clearly seen in the sequence flow diagrams.

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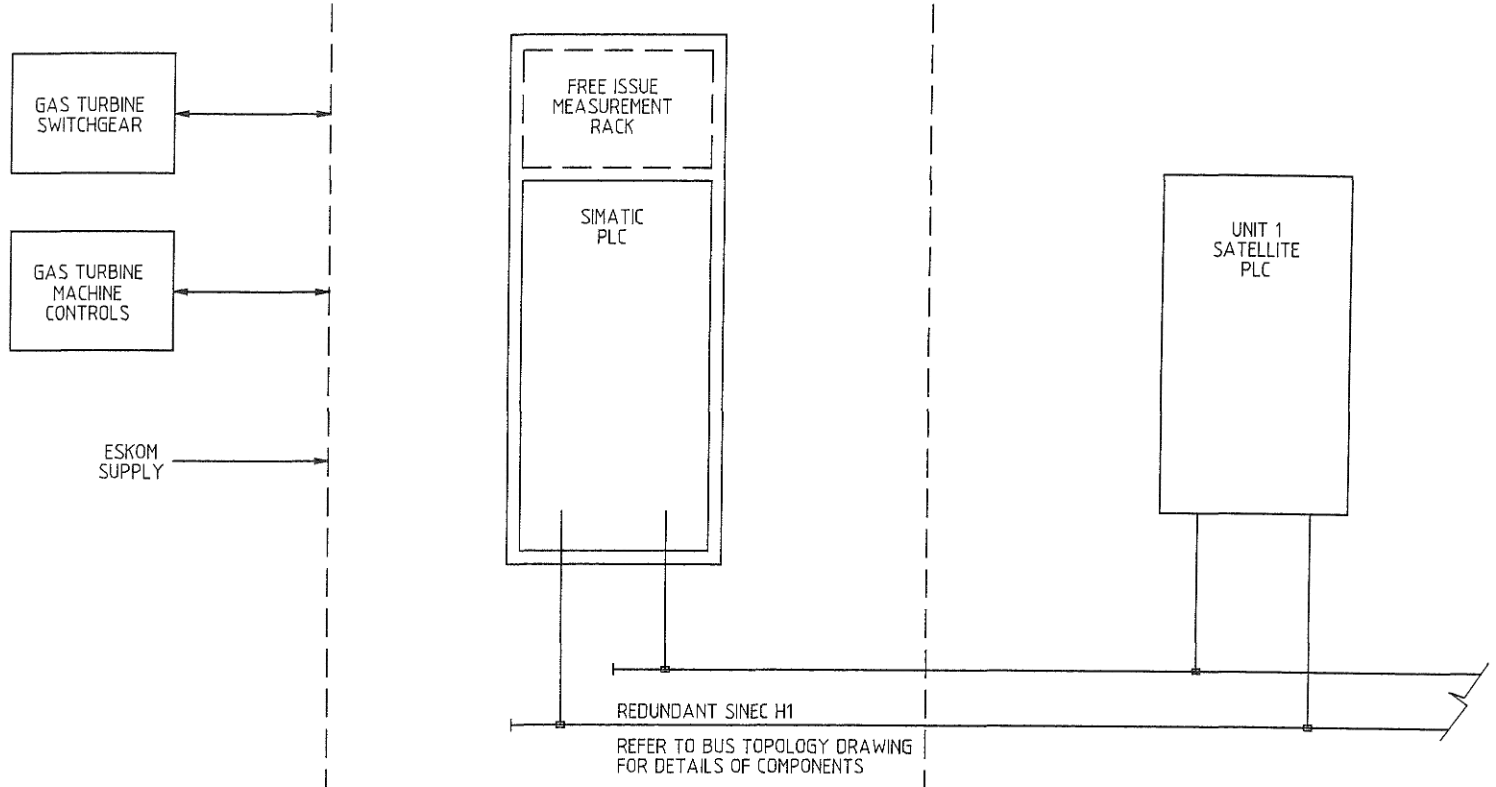


FIGURE 1

ACAD DIR NAME QUOTES95
ACAD FILE NAME 10402101

REV	REMARKS	DATE	SIGN	DEPT	KWU/TS
A	FOR APPROVAL	20 6 95	R.de.B	DATE	25 4.95
				CHECKED	R v E.
				DRAWN	CCA
				APPR	R d B.

KENDAL POWER STATION

BLACK START FACILITY

LIMITED
SOUTH AFRICA

REG No 01/07514/06

O No W No

GAS TURBINE

LIMITS OF SUPPLY

CUSTOMER DRG.No X.XX/XXXXX

REV

SHT 1

(3)G52006 – F 9104 – Y 021 – A

SHT 01

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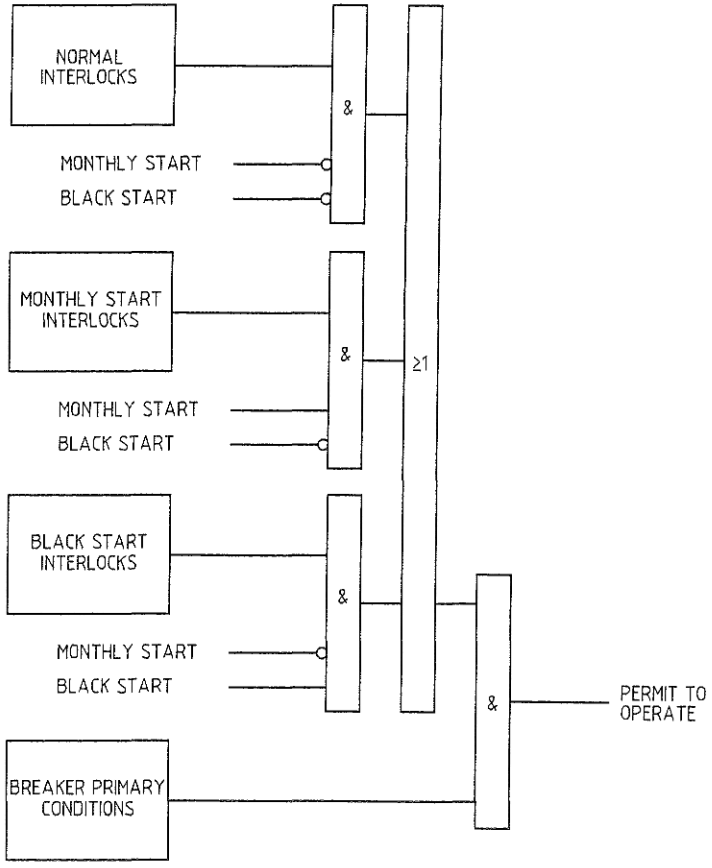


FIGURE 2

REV	REMARKS	DATE	SIGN		
				APPR.	R d.B
				CHECKED	R.v E
				DRAWN	CCA
A	FOR APPROVAL	20 6.95	R de B	DATE	2.5.95
				DEPT.	KWU/TS

KENDAL POWER STATION

BLACK START FACILITY

LIMITED
SOUTH AFRICA

REG No.01/07514/06

O No. W No

PRINCIPLE OF INTERLOCKING

CUSTOMER DRG No X.XX/XXXXX

REV

SHT 1

(3)G52006 - F 9106 - Y 021 - A SHT 01

ACAD DIR NAME QUOTES95
ACAD FILE NAME 10602101

KENDAL POWER STATION

BLACK START FACILITY

STATION CONTROL ROOM COROS DISPLAYS

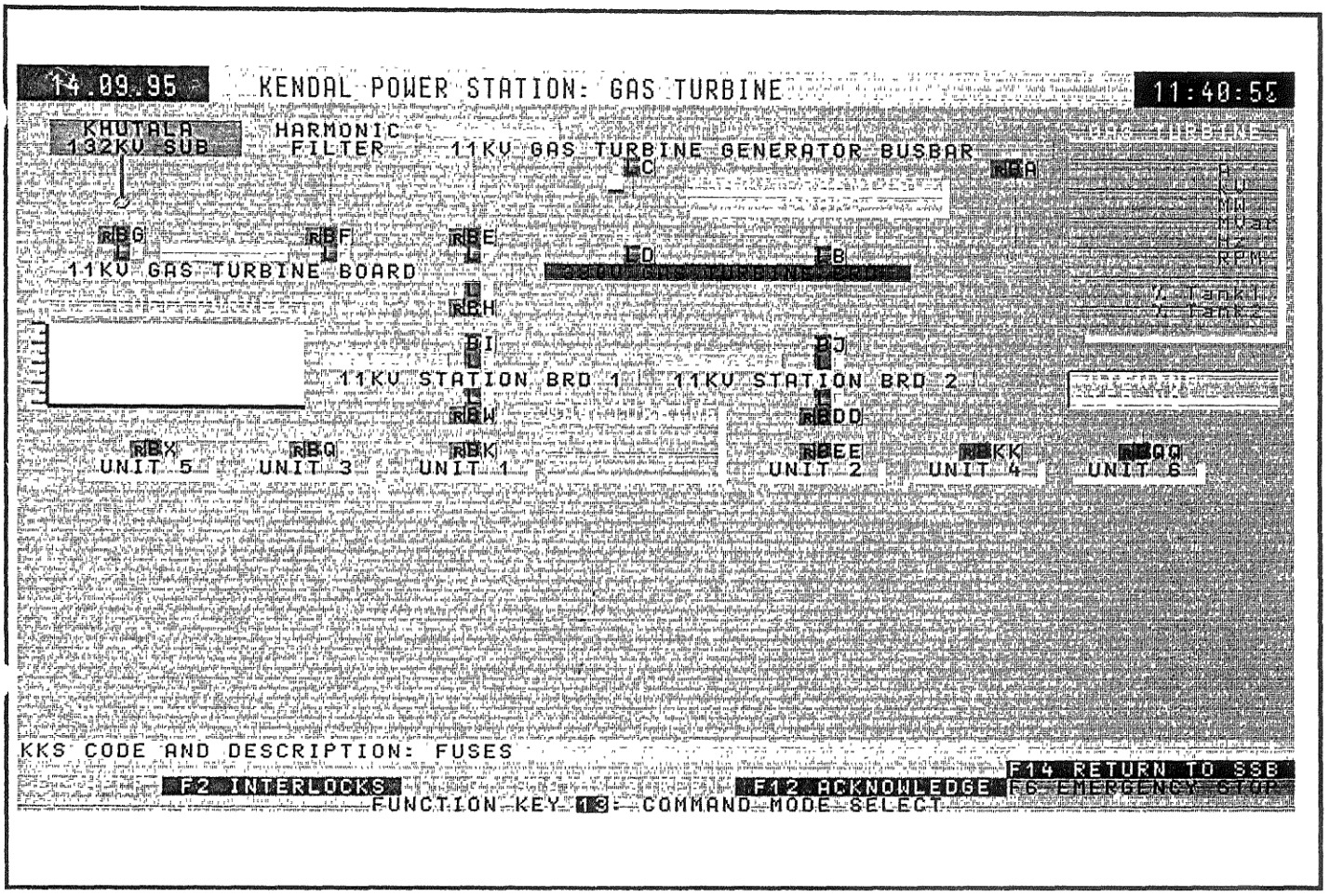


FIGURE 3: COROS DISPLAY - GAS TURBINE (OVERVIEW)

ISSUE STATUS: AS BUILT 9 NOVEMBER 1995