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1. INTRODUCTION

Duvha Power Station currently has an existing hydrogen generating plant, however this plant has been out of service for more than 18 months as maintenance has become difficult / impossible due to the fact that most of the plant components have become obsolete. As a result of this, hydrogen gas is supplied by means of cylinders to meet the demand of the units. This exercise is very expensive and not cost effective for the station. In addition to this, the existing plant does not comply with Eskom Standards for Hydrogen generating plants hence posing a significant safety risk.

During the concept design, the following options were investigated as a solution to ensure continuous hydrogen supply to the station:

- Option 1: Bottle Supply
- Option 2: Installation of a new Electrolysis Plant

After investigating the above options in various categories, the most viable option for implementation was the design and installation of a new electrolysis plant. This report will therefore consist of all requirements and standards (Mechanical, Electrical, Structural and Control & Instrumentation) that must be adhered to by the designer of the system.

2. SUPPORTING CLAUSES

2.1 SCOPE

This document covers the mechanical, electrical, structural and control and instrumentation technical requirements for the hydrogen generating plant at Duvha Power Station.

2.1.1 Purpose

The purpose of this document is to provide the technical requirements for the design, supply, commissioning and handover of the hydrogen plant.

2.1.2 Applicability

This document shall apply to Duvha Power Station and Eskom Group Technology Engineering.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] ISO 9001 Quality Management Systems

[2] Occupational Health and Safety Act of 1993

[3] 240-53113685: Design Review Procedure

[4] 240-4332798: Engineering Policy

2.2.2 Informative

[5] 382-ECM-AABZ28-SP0008-2 Stakeholder Requirements Definition_Duvha Power Station Hydrogen Generating Plant Upgrade

[6] 382-ECM-AABB-D00138-19 Duvha Power Station Hydrogen Generating Plant Upgrade Concept Design Report

[7] 382-ECM-AABZ4-AS0000-2: Duvha PS Hydrogen Plant Fire Protection/Detection Assessment

[8] 240-4332798: Engineering Policy

[9] 240-53113685: Design Review Procedure

[10] 382-ECM-AABZ28-D00017-8: Duvha Power Station Hydrogen Generating Plant Upgrade Engineering Change Proposal

[11] 382-ECM-AABZ26-RP0000-31: Duvha Power Station Hydrogen Generating Plant Upgrade Engineering Change Proposal

2.2.3 Disclosure Classification

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

2.3 ABBREVIATIONS

Abbreviation	Description
C&I	Control and Instrumentation
CM	Configuration Management
CoE	Centre of Excellence
EDWL	Engineering Design Work Lead
EOD	Electrical Operating Desk
EMD	Electrical Maintenance Desk
FDS	Fire Detection System
FMECA	Failure Modes, Effects and Criticality Analysis
H_2	Hydrogen
HMI	Human Machine Interface
HAZLOC	Hazardous Location
HAZOP	Hazard and Operability
LDE	Lead Discipline Engineer
LOSS	Limit of Scope and Supply
LPS	Low Pressure Services
MCP	Multiple Cylinder Pack
OEM	Original Equipment Manufacturer
OHS	Occupational, Health and Safety
OPCR	Outside Plant Control Room
PECI	Production, Engineering, Integration and Coal
P&ID	Piping and Instrumentation Diagram
QCP	Quality Control Plan
RAM	Reliability, Availability and Maintainability
SANAS	South African Accreditation System
SCADA	Supervisory Control and Data Acquisition
VDSS	Vendor Document Submittal Schedule

2.4 ROLES AND RESPONSIBILITIES

Complier: The document compiler is responsible for ensuring that this document is up-to-date and that this document is not a duplication of an existing documentation, regarding the document's objectives and content.

Functional Responsibility: The Functional Responsible Person shall determine if the document is fit for purpose, before the document is submitted for authorisation.

Authoriser: The document authoriser is a duly delegated person with the responsibility to review the document for alignment to business strategy, policy, objectives and requirements. He/she shall authorise the release and application of the document.

Project EDWL: The Project EDWL is primarily accountable for the integrity of the overall engineering product during asset creation and/or modification. The EDWL co-ordinates the design work provided by the Lead Discipline Engineering roles and integrates this work into a final integrated design product.

Lead Discipline Engineer: Coordination, integration and interfacing of discipline specific design related activities and deliverables up to commissioning and handover for their discipline. Coordination may be required with other disciplines, Suppliers, Contractors, or Consultants. Ensure that the plant is built according to approved designs for their respective discipline.

CoE Manager: The CoE manager is the ultimate engineering authority for design work and is responsible for and is the custodian of technical knowledge within their engineering domain. The CoE manager ensures that his/her respective Design Review Committee/Team (DRC/DRC) is on place, properly constituted and representative of all relevant CoE stakeholders as required per End-of-Phase design review and ensure implementation and compliance to this procedure.

2.5 PROCESS FOR MONITORING

N/A

2.6 RELATED/SUPPORTING DOCUMENTS

N/A

3. SYSTEM DESCRIPTION

Hydrogen is produced, dried, analysed and compressed inside the plant building. The gas is stored in the storage vessels that are located on the outside of the building. The gas is then supplied to the unit skids at a constant pressure of 600kPa.

The plant also has a back-up system which is made up of multiple cylinder packs. These usually consist of 5 skids of 12 hydrogen filled cylinders. The pressure of the generated hydrogen gas is monitored at

the metering station. If for some reason the supply pressure drops below 6 bar, the metering station sends communication to an actuated valve which will activate the supply from the MCP's. This will assist with increasing the pressure back up to 600kPa.

Hydrogen purity analysis is carried out both at the generating plant and at the unit skids. If for some reason the purity of the hydrogen produced drops to 99.5%, this gas will not be allowed to enter the system. The generating plant will automatically blow off this gas and restart the generation process. Figure 1 below illustrates a process flow for the hydrogen plant:

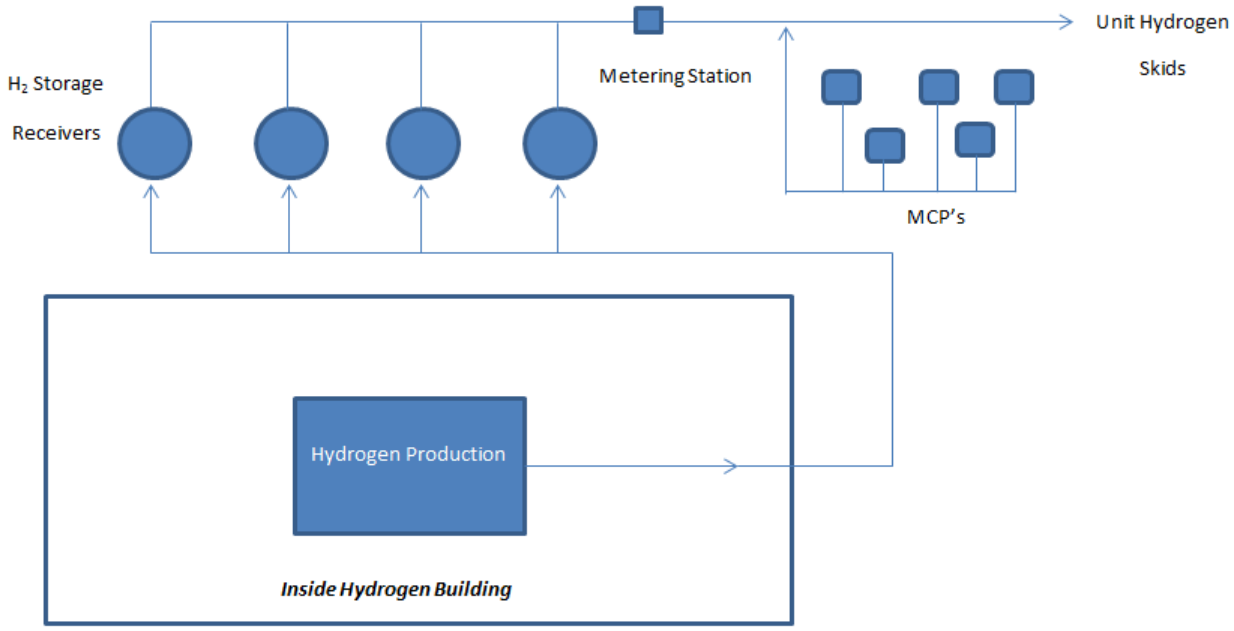

Figure 1: Hydrogen Generation Process Flow Diagram

4. OPERATING PHILOSOPHY

4.1 PLANT OPERATING PHILOSOPHY

The operation of the plant shall be fully automatic, with system start/stop initiated from the Local control station which is connected to the PLC of the generating plant and interface to the Employer's OPCR SCADA for monitoring and alarming. Local/remote selection shall be done at one location in the plant. The control system for receiver filling and that of the generating plant shall be integrated to optimise the life of the cell stack and to ensure safe plant operation.

The hydrogen generating plant shall vent produced hydrogen with purity below 99.5% and initiate a trip if the oxygen content is greater than 1%. Following the trip, the plant will depressurise and an automatic

nitrogen purge shall be initiated following a safety trip. In order to ensure safe plant operation of pressurised electrolysers it is required that at minimum production and maximum pressure all contamination must stabilise after approximately 30 minutes. Under no circumstances will it be allowed that the contamination on the Hydrogen and oxygen exceeds 1% measured directly after the cell stacks. This monitoring shall be repeated at maximum production and pressure. The Hydrogen generating plant shall comply with all requirements stated in 240-56227413: Hydrogen Systems Standard.

4.2 RECEIVER OPERATING PHILOSOPHY

The receivers shall be filled in the following sequence:

- Fill the first receiver when the hydrogen generating plant is at maximum capacity until receiver entirely full.
- Reduce generating capacity to 12Nm^3 then fill the next fullest receiver to capacity.
- Fill the third receiver at 8Nm^3
- The last receiver shall be filled at 6Nm^3

This filling philosophy is used in order to maximise the cell stack's life span, by minimising the stop/starts of the generating unit. When hydrogen is used from a receiver and the pressure gets to 500kPa, the outlet solenoid from the receiver shall be closed. If the pressure drops below 450 kPa, an alarm should be initiated in the control room.

5. DESCRIPTION OF WORKS

5.1 SCOPE OF WORK/BATTERY LIMITS

The scope of work for the mechanical design is as follows:

- Hydrogen generating plant equipment
- The multiple cylinder pack (MCP) and metering station system
- Hydrogen distribution piping from generating plant to storage vessels (including pipe supports)
- Hydrogen distribution piping from the storage vessels to the units skids (including pipe supports)

The unit skids and the storage vessels do not form part of the design scope. The existing storage receivers will be utilised for the system. A LOSS diagram will be provided for connection to the unit skids during the Works Information.

The marked up area in Figure 2 illustrates the scope:

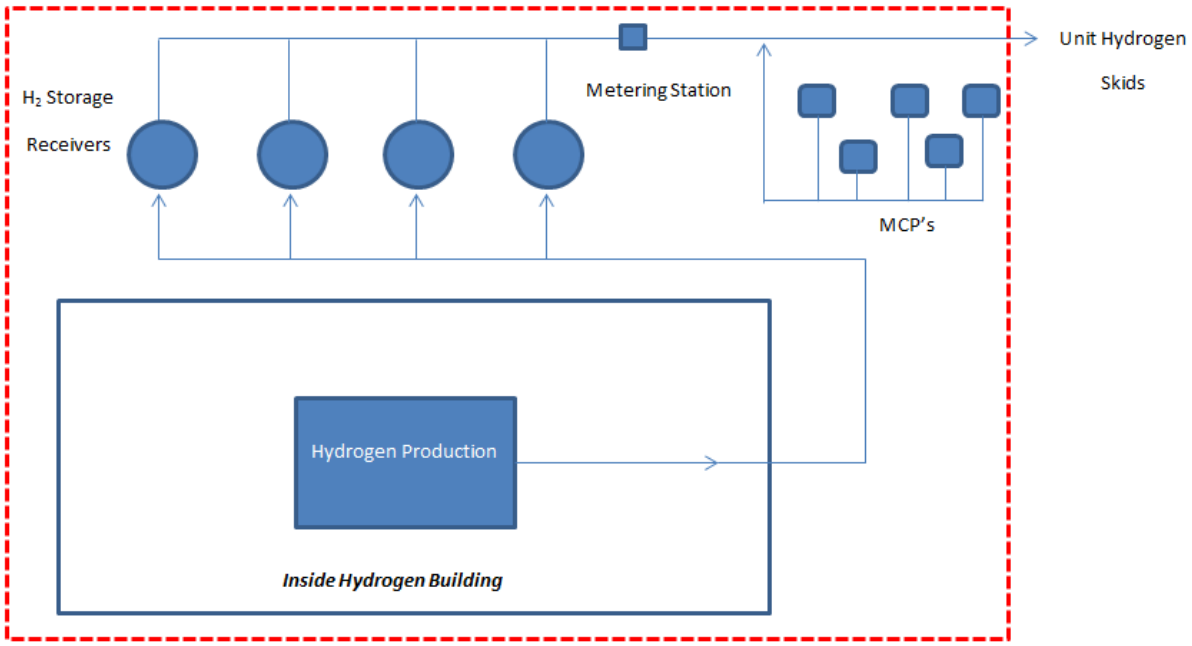

Figure 2: Scope of Work

5.2 MECHANICAL REQUIREMENTS

The Hydrogen generating plant shall be designed to produce 15 Nm^3/h at a pressure of 27 bar with no external compression. The Hydrogen purity shall be a minimum of 99.9 % by volume and the dew point of -50°C or better at 101.4 kPa. Four hydrogen storage vessels with each having a storage capacity of 20 m^3 currently exist on site and will be utilized for hydrogen storage. The Hydrogen should be supplied at a constant pressure of 600kPa to the unitized systems/skids within each unit.

The Hydrogen generating unit, metering station and the control system shall be located inside the existing plant building and it shall be equipped with hydrogen fire and leak detection devices. The dew point analysers, hydrogen and oxygen purity measuring devices shall be integrated into the hydrogen generating plant. Key design requirements for the hydrogen generating plant are:

- Safe operation shall be assured at all times.
- Simplicity and reliability.
- Measuring equipment and analysers must be installed to identify the production of a potentially explosive mixture and prevent it from being stored.
- An Automatic, unattended operation, insensitive to power interruptions. The plant shall revert to a safe condition, depressurised and purged with nitrogen in the event of a power interruption.
- The control system must be insensitive to power interruptions and after reboot will be able to continue with producing hydrogen without requiring the reinstallation of software.

- Data recording that is integrated to the plant with minimum of thirty days storage.

5.2.1 Functional Requirements

The hydrogen plant shall be capable of producing hydrogen gas at a rate of 15Nm^3/h for the sufficient supply of hydrogen gas to the power generating units, at a purity of 99.9% and a pressure of 600kPa. Hydrogen shall be stored in the receivers to provide sufficient quantity of seven days for normal consumption of all generators. The operation of the plant shall be fully automatic with the signals passed from the generating plant to the outside plant control room.

The equipment of the plant to be designed by the Contractor shall operate effectively for 22 years, which is the remaining life of the power station.

5.2.2 Fire System Requirements

A fire protection and detection assessment was carried out and it has been confirmed that the existing plant building is non-compliant in terms of the required fire protection and detection. The fire detection and protection must be implemented to ensure that the plant is complaint.

5.2.2.1 Fire Protection Requirements

The Contractor is to provide/do the following:

1) Supply and install “No Parking” signs in such a way that no stopping/parking of vehicles is allowed in a radius of 5m from the hydrogen plant.
2) Supply and install the required Safety Signs in accordance with SANS 1186.
3) Supply and install active fire protection over the hydrogen storage vessel to prevent flame impingement on the vessel in case of an exposure fire. The active fire protection is to be medium velocity deluge systems on the hydrogen storage vessels in accordance with NFPA 15 of 2017 (or the latest revision) and activates once a detection sprinkler breaks (automatic activation).
    - The minimum pressure and flow is to be as specified in NFPA 15 of 2017 (or the latest revision).
    - The available pressure in the line at the various possible tie-in points is assumed to be at 800kPa.
    - Please refer to Appendix A for the following:
        - A satellite photo of the possible tie in points identified.
        - The P&ID that highlights these tie-in points. The Contractor is to determine the shortest, and/or best route for tie-in point of the existing fire ring main.

- The fire protection system is to be pressure tested as described in NFPA 13 and commissioning is to be done as described in 240-56356376 On-Site Commissioning for Low Pressure Systems Standard.

4) At the 5 multi cylinder packs (this is used as a backup source for the H_2 generating plant that will be situated outside the power station in the fenced-off area). Each multi cylinder pack consists of 18 cylinders. The *Contractor* is to put these cylinder packs at a minimum distance of 6m away from the storage vessels, and at a distance of 1.5m from each other, assuming these cylinders packs have less than $11m^3$ storage capacity, if this cannot be achieved, then a passive fire protection system is to be installed between the cylinders and storage vessels and/or between the cylinders themselves. This barrier is to be 2 hour fire rated, and explosion proof.

5.2.2.2 Fire Detection Requirements

5.2.2.2.1 System Description

The main function of the FDS (Fire Detection System) is to detect fire and smoke and send the signal to the control panel for indication. The purpose of the fire detection system is to provide or to give an early warning of fire to enhance the safety of the occupants, equipment and property.

The Fire detection system provides 24-hour surveillance of the conditions and its own system integrity for unit 1-6, the admin building and outside plant. All the information relayed is available to the global repeaters panel located in EOD and EMD Workshop 2. With a reliable Fire Detection system in place major plant damage and more importantly injury to personnel can be mitigated.

5.2.2.2.2 Fire Detection Scope of Work

The scope of the works includes the following:

- Detail design, supply, installation, commissioning and testing of the fire detection equipment in the hydrogen plant (H_2 building and the H_2 equipment room).
- Install smoke detectors in the H_2 plant building and H_2 plant equipment room.
- Install siren/strobe units
- Install manual call points
- Install one Fire Detection Panel dedicated to the H_2 plant.
- Fire Detection Panel to be installed in the Outside Plant Control Room (OPCR) for 24-hour monitoring of the H_2 system.
- Interface the H_2 fire equipment to the fire panel via a PH30 or PH120 fire rated cable.

- Interface H_2 fire panel to the existing station wide Fire Detection System (panel located in the EOD) via a PH120 cable or wireless radio rink as per SANS 10139.
- Cabling (including termination) from the field devices to junction boxes and to the fire control panel.
- All field cabling complies with the Eskom Standard 240-56355815 Control & instrumentation Field Enclosures and Cable Termination Standard and 240-56355754 Field Instrument Installation Standard.

5.2.2.2.3 Interface to the Active Fire Protection (H_2 vessels) and Passive Fire Protection

The Contractor is to ensure that the pressure switch sends an alarm signal to the OPCR SCADA once the deluge system activates (refer to section 5.2.2.1, point 3).

5.2.2.2.4 Interface to HVAC

Not required.

5.2.2.2.5 Fire Detection Power Supply Requirements

FDS power supply to comply with the South African National Standard 10139: Fire detection and alarm systems for buildings - System design, installation and servicing.

5.2.2.2.6 Other Requirements

- Fire Detection System (FDS) for the H_2 plant building plant to comply with the Eskom standard: Fire Detection and Life Safety Design Standard (240-56737448) and SANS 10139 (this excludes Video Based Fire Detection for H_2 fires as it is better to prevent an H_2 fire by ensuring ventilation and H_2 leak detection is employed effectively).
- Fire alarms sounder and sirens shall comply with SANS 50054-3.
- Visual alarms to be provided in accordance with SANS 10139 and shall comply with SANS 50054-23.
- The Contractor is a member of the Fire Detection Installers Association (FDIA).
- The Contractor is South African Qualification and Certificate Committee (SAQCC) accredited.

5.2.3 Battery Limits

LOSS diagrams will be developed during the compilation of the Works Information to indicate the most practical tie-in point to the station’s existing fire system.

5.2.4 Heating, Ventilation and Air Conditioning (HVAC)

The new hydrogen generating plant technologies are fitted with close loop cooling systems. The appointed Contractor will be required to verify if any additional HVAC will be required. All work (if any) must be done in accordance to the Eskom HVAC standard.

5.2.5 Piping System Requirements

The piping systems shall comply with the requirements stated in Eskom standard.

5.2.6 Pressure Test Requirements

The H_2 supply piping shall be pressure tested to determine if there are any leaks. The following shall apply:

- Pressure test procedure shall be submitted to and approved by Employer before pressure tests take place. Pressure test procedures shall also be included in the data book.
- Two pressure gauges shall be used for the pressure test.
- All pressure gauges shall have valid calibration certificates prepared by a SANAS accredited pressure laboratory for all locally manufactured items. The maximum validity of the calibration certificates shall be 6 months.
- Proper venting shall take place and all air pockets shall be vented. Method statement shall be provided.
- The pressure inside the equipment under test shall be increased to a value of the specified test pressure as defined by the code. Thereafter, the pressure shall be increased in steps of approximately 10% per minute of the specified test pressure until the full test pressure is reached. The piping system shall be held at the test pressure for a period of at least 30 min.
- After the test has been completed a pressure test certificate shall be issued which shall be included in the data book.

5.2.7 Applicable Standards:

The Contractor must adhere to the latest revision of the following standards as a minimum:

- 240-56227413: Eskom Hydrogen Systems Standard
- 240-83539994: Standard for Non-Destructive Testing (NDT) on Eskom Plant
- 240-106628253: Standard for Welding Requirements on Eskom Plant
- 240-123801640: Standard for Low Pressure Pipelines

- 240-56356376 On-Site Commissioning for Low Pressure Systems Standard
- 240-56737448: Fire Detection and Life Safety Design Standard
- 240-56737450: Fire Protection and Life Safety Design Standard
- SANS 1186: Symbolic Safety Signs
- SANS 10139: Fire Detection and Alarm Systems for Buildings – System Design, Installation and Servicing
- SANS 50054-3: Fire Detection and Fire Alarm Systems: Fire Alarm Devices - Sounders
- NFPA 55: Compressed Gases and Cryogenic Fluids Code
- NFPA 13 (of 2016 or latest revision): Standard for the Installation of Sprinkler Systems
- NFPA 15 (of 2017 or latest revision): Standard for Water Spray Fixed Systems for Fire Protection
- 240-102547991: General Technical Specification for HVAC Systems Standard

5.3 CONTROL AND INSTRUMENTATION REQUIREMENTS

5.3.1 System Overview

The hydrogen plant is currently controlled, operated and monitored locally via the Siemens S5 PLC. Selected signals to be monitored from the outside plant control room.

Currently the HMI of the outside plant SCADA performs two main functions – that of displaying data relating to the operation of the outside plant equipment to the operators and an alarm system to alert the operator of any discrepancies or abnormal status, as well as the forwarding of this data to the station's historian. OPCR SCADA runs of iFix 2.4 and Historian is Visual Automation v4.5.

Central to the bus communication network, there is a Siemens S7 - 300 PLC referred to as the Marshalling PLC which communicates with all of the control equipment that forms part of the outside plant SCADA network, collecting data from each at regular intervals for monitoring purposes. The Siemens S7 – 300 PLC supports the following protocols:

- Profibus
- Profinet

See Figure 3 below "As Is" bus communication for the outside plant.

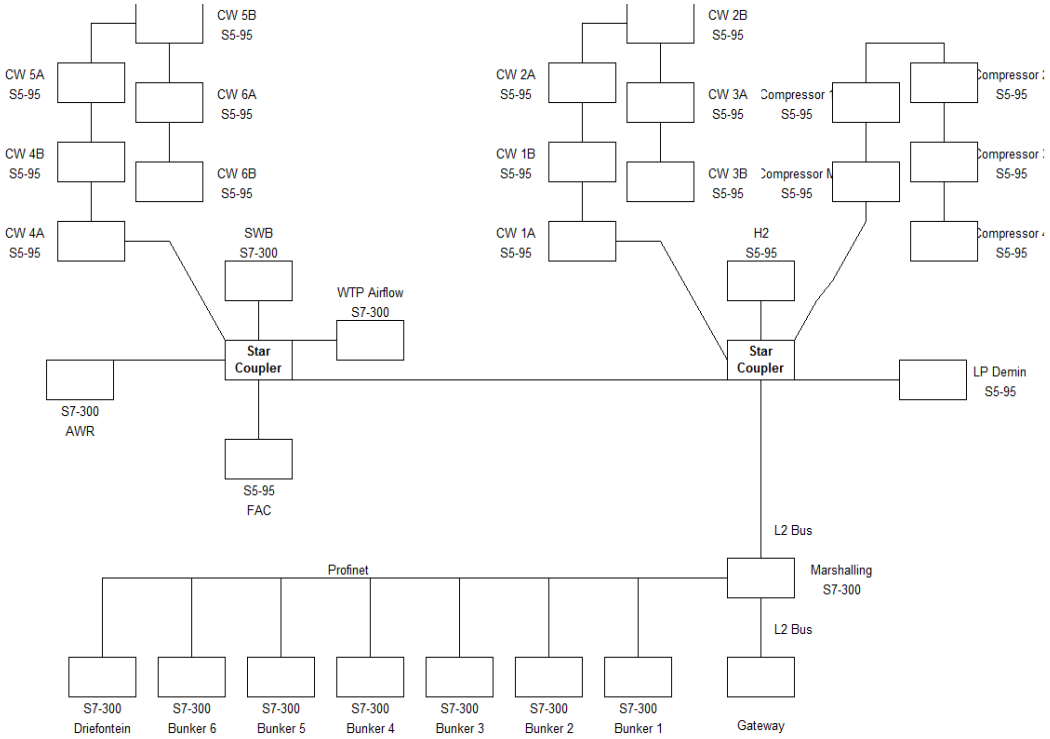

Figure 3"As Is" Bus Communication Network for the Outside Plant

5.3.2 Scope of Work

The scope of the works includes the following:

- Detail design, supply and installation, commissioning and testing of the control system and field equipment for the hydrogen plant.
- Updating of the HMI graphics, including the interfacing to the existing historian and the Employer's OPCR SCADA by interfacing to the existing Siemens S7 – 300 (Marshalling) PLC.
- Programming of the Marshalling PLC to cater for the new hydrogen plant PLC.
- System to meet the operating and control philosophy specified in Section 4.
- Documentation as specified in section 5.3.10
- All software and licences for the works.

5.3.3 Field Equipment Requirements

- Standardisation of all field equipment is required.
- All instrumentation shall be provided with a nametag/plate. The Contractor must comply with the Eskom Standard ETS0004: AKZX Plant Coding Standard and AKZX Plant Location Coding Standard ENS0002.
- Analogue instruments to utilise HART protocols for on-plant diagnostics and programming.

- All instrumentation must use either 24V for binary feedback or 4-20mA for analogue feedback.
- All additional signals to be trended on the station's historian.
- Listing of all the devices in the Control & Instrumentation Instrument Schedule 240-61379718 template and completing all the information required by the template.
- Listing of all the devices in the Drive and Actuator Schedule 240-61379755 template and completing all the information required by the template.
- Cabling (including termination) from the field devices to junction boxes and to PLC.
- Cable routing and racking.

5.3.4 Junction Box

Junction boxes shall be properly labelled with permanent labels that will not be effortlessly removed and to also have enclosure material of 3CR12 stainless steel grade or higher and will be powder coated using RAL7035. Junction boxes are rated IP 65. The Contractor to comply with standard 240-563555: Junction box and cable termination.

5.3.5 Cabling & Racking (Cable Installation and Routing)

All Cable Installation and instrumentation cables, shall be flame retardant low smoke type, and comply with 240-56227443: Requirements for Control and Power Cables for Power Stations Standard. Instrument cabling to be installed taking safety, reliability, access, maintenance, environmental conditions and best practices into consideration. All cabling must be suitably protected against mechanical damage, chemicals, dust build-up and heat.

5.3.6 Impulse Piping

All instrument piping connections must be welded, no connectors allowed. Non-destructive testing shall be conducted on all impulse piping welds. The results of all non-destructive testing on impulse piping welds must be accepted by the Employer's representative. All pipe work provided is inclusive of supports, transition pieces to primary isolating valves and drains to provide complete impulse, equalising and blow-down lines for all instruments. The drains impulse piping provided shall be 1.3 meters from the manifold with tips facing away from the transmitter face. The Contractor must comply with 240-89147446: Instrument Piping for Fossil and Hydro Power Plant Standard.

5.3.7 Control System Requirements

The Controllers provided by the Contractor must meet the following requirements:

- Processor to be capable of being replaced on-line with no effect on the operating plant.

- The PLC interfaces to the existing Employer's OPCR SCADA system network and historian for remote monitoring of the hydrogen plant.
- The design, engineering and installation of the PLC comply with the requirements specified in the PLC OEM programming, installation and operating manuals and equipment data sheets.
- The PLC is housed in a panel which is suitable for the environment, IP 65 as a minimum. The material of the panel is as per the requirements specified in 240-56355815: Junction Boxes and Cable Termination Standard.
- The panel wiring shall be as per the requirements specified in 240-56355815: Junction Boxes and Cable Termination Standard.
- Analogue input measurements from the field are based on two-wire 24 V DC, 4 - 20 mA signals.
- 10% spare I/O capacity at hand over.
- All analogue and digital signals used for operator information, control, calculations or plant history are continuously monitored for validity.

5.3.8 Life Expectancy

All control components shall be supported and maintainable for duration of at least 15 years from installation.

5.3.9 Power Supply Requirements

The Employer will provide the 24 V DC power distribution which consists of dual 380 V AC LV boards, battery chargers, battery banks and distribution boards. The 24 V DC power distribution is used to supply the hydrogen plant PLC, network switches and field instrumentation.

5.3.10 Documentation Requirements

The Employer provides the following documentation as input to the Contractor's design:

- Outside plant network configuration drawing
- SCADA graphic files
- SCADA database
- Existing fire detection system drawing

The drawings and documentation must comply with requirements stated in section 3.9 and section 3.10. The control and instrumentation documentation package include the following:

- Detail electrical hook-up drawings (including instrument loop drawings)
- Detailed mechanical hook-up drawings for instrumentation
- PLC functional specification

- Signal and alarm list
- PLC programme (software), licenses and warrantees
- Instrument schedule as per the Control & Instrumentation Schedule 240-61379718 template
- Drive schedule as per the Control & Instrumentation Drive & Actuator Schedule 240-61379755 template
- Equipment list
- Standard equipment operating manuals
- Equipment data sheets
- Maintenance manuals and procedures
- Updated SCADA graphic files
- Updated SCADA database
- Updated network configuration diagram
- PLC panel internal equipment layout, configuration and wiring
- Cable schedules and termination schedules
- Junction boxes GA and internal layout drawings
- FDS H_2 plant layout
- Programmed data or information on the H_2 fire detection panel
- Updated existing fire detection system drawing (reflecting new interface changes for the H_2 plant)
- Log book and log book holder (fire detection system)
- Field device calibration certificates
- Cold commissioning procedures and test reports
- SAT procedure and report

5.3.11 Requirements for Engineering, Installation, Commissioning and Testing

During the engineering phase the Contractor performs plant investigation to verify and clarify scope, documentation provided by the Employer and the location of equipment.

The installation of the relevant equipment does not begin until the design documentation has been accepted by the Project Manager. Quality inspections and tests are carried out by the Contractor and Employer's representative after installation to prove the compliance of the installation with the technical specification and the detailed engineering design documentation. The installation is only considered complete once the quality inspections and tests for the installation concerned have been accepted by the Project Manager.

The Contractor is required to perform cold commissioning activities which include field equipment loop checks, testing of the PLC functionality and SCADA interface.

Factory Acceptance Test (FAT) shall be performed at the Contractor's workshop to demonstrate that the control system meets the requirements of the technical specification and design documentation. The test includes full testing of the logic/program, mechanical and visual inspection of the equipment (including wiring in the panel), plant coding, signal descriptions, SCADA graphics, etc. The tests must be witnessed by the Employer's representative.

5.3.12 Applicable Standards

The Contractor must adhere to the latest revision of the following standards as a minimum:

- 240-56227443: Requirements for Control and Power Cables for Power Stations Standard
- 240-89147446: Instrument Piping for Fossil and Hydro Power Plant Standard
- 240-71432150: Plant Labelling and Equipment Description Standard
- 240-56356396: Earthing and Lightning Protection Standard
- 240-56355754: Field Equipment Installation Standard
- 240-56355843: Pressure Measurement System Installation Standard
- 240-56355888: Temperature Measurement System Installation Standard
- ENS0002: AKZX Plant Location Coding Standard
- ETS0004: AKZX Plant Location Labelling Standard
- 240-5635581: Junction Boxes and Cable Termination Standard

5.4 ELECTRICAL REQUIREMENTS

5.4.1 Electrical System Overview / Reticulation

The existing hydrogen plant and lighting Distribution Board is fed from the 380V Distribution Board 2, circuit 30, CFS Type-Fuse Isolator (300A Fuse, Fuse rating 400A), via a 185mm^2, 4 core, cable. The 400V Distribution Boards are fed from the 11kV Station Boards via 11/0.4kV, 1600kVA Distribution Board Transformers respectively, refer to drawing number: 0.57/55006, sheet 2, rev 4.

5.4.2 Electrical Scope of Work

The electrical scope is to provide the bulk power supply for the upgrade of the hydrogen plant. The upgrade of the hydrogen plant is limited to the maximum capacity of the upstream breaker (CFS Type-Fuse Isolator (300A Fuse, Fuse rating 400A)) from the 380V Distribution Board 2 and existing cabling (185mm^2, 4 core).

The Employer:

- Will provide bulk power supply (380V, 3 phase), including cabling from the 380V Distribution Board 2 to the termination point of the Distribution Board.
- Will review and accept electrical designs for the hydrogen plant.

The Contractor:

- Shall adhere to Generation Plant Safety Regulations for all Electrical Works.
- Shall be responsible for the designs, manufacturing, construction, testing and commissioning of the electrical reticulation for the hydrogen plant.
- Shall design, manufacture, construct, test, transport, deliver, install and commission the Distribution Board based on the total power requirements for the hydrogen plant including small power and lighting installation requirements. The Contractor shall provide the Certificate of Compliance for the installation. Lighting and small power designs shall be done in compliance with 240-56227413: Hydrogen Systems Standard.
- Shall terminate the bulk power supply cables from the 380V Distribution Board 2 to the Distribution Board for the hydrogen plant. Prior to termination, the Contractor shall assessment the capacity of the existing feeder cable and upstream breaker from the 380V Distribution Board 2 based on the total load required for the hydrogen plant upgrade, and replace if deemed necessary.

5.4.3 Applicable Standards

The Contractor must adhere to the latest revision of the following standards as a minimum:

- 240-56227443 Control and Power Cables for Power Stations Standard.
- 240-56356396: Earthing and Lightning Protection Standard.

5.5 CIVIL AND STRUCTURAL REQUIREMENTS

5.5.1 Civil and Structural Overview

Duvha Power Station has an existing building were the current (defunct) hydrogen generating plant is situated. The Contractor will make use of the existing building to house all required equipment for the new plant. Any and all modifications to the existing structure must be included in the Contractor's design and submitted to the Employer for approval before any work may commence.

5.5.2 Civil and Structural Scope of Work

The Civil and Structural scope of work is the provision of sufficient support for all new equipment that will be installed.

- Where existing plinths and foundations are available it may be used, provided the new equipment loading doesn't exceed the loading of the old equipment. If the loading from the new equipment exceeds the loading from the old equipment the Contractor need to either:
    - Demolish the existing plinths, and design and construct new plinths capable of supporting the new imposed loadings, or
    - Prove that the existing plinths are capable of supporting the new imposed loads by making use of Non-Destructive Tests (NDT).
- Current storage vessels' plinths are to be analysed by means of NDTs, to confirm their suitability.
- All existing plinths' and foundations' surface to be neatened with project specification grout.
- New plinths need to be designed to support the MCPs. The final position will be determined by the fire safety risk assessment.
- Where piping and cable racks are to be installed against the walls, care must be taken to not damage any rebar or existing imbedded services that may be present. The Contractor must determine the correct routing to avoid such damage.
- Any and all modifications to the existing structure must be included in the Contractor's design and submitted to the Employer for approval before any work may commence.
- Levelling of the floor where the old equipment is removed.
- Where new piping is installed underground the preferred construction methodology is trenching, since a single road will be crossed, but the Contractor may present an alternative methodology.
- Irrespective of methodology, the Contractor must submit full method statements to the Employer for approval before any work may commence.
    - The following precautions should be adhered to as a minimum:
        - Contractor to ensure no existing services will be damaged by the installation, by performing a survey such as ground penetrating radar or similar.
        - All piping to be at a minimum depth of 900mm

- All piping to be installed according to SANS 1200, as well as any other relevant SANS and Eskom standards.
- All backfill to be done to the specified densities (depending on location) as per the relevant SANS and TRH standards.
- If the road is to be closed, the station management will be consulted to ensure sufficient alternative routes will be available for traffic during the construction period.

5.5.3 Applicable Standards

The Contractor must adhere to the latest revision of the following standards as a minimum:

- SANS 1200 - Standardized specification for civil engineering construction
- SANS 10100 - The structural use of concrete
- SANS 10160 - Basis of structural design and actions for buildings and industrial structures
- TRH 14 – Guidelines for road construction materials
- TRH12 – Flexible Pavement Rehabilitation Design
- Construction Regulations
- 240-56364545: Structural Design and Engineering Standard

5.6 CONFIGURATION MANAGEMENT REQUIREMENTS

5.6.1 PLANT CODING AND LABELLING

5.6.1.1 Plant Coding

The Employer will only code the AKZX code defining Documentation listed above. The Employer will assign a coding practitioner who will interact with the Contractor in coding the plant as listed above. It may be required that the person be based at the Contractor's offices on a full time basis. The Contractor will then be required to include allocated codes to all other designs and related documentation. It is also the responsibility of the Contractor to consistently apply the AKZX codes throughout the rest of the technical documentation which shall include, but not limited to:

- Load schedules
- Board parts lists
- Cable block diagram

- Termination diagram
- Drive & actuator schedules
- Instrument schedules
- Alarm lists, loop diagrams
- Signal lists
- Schematic diagrams
- Termination diagrams
- Logic diagrams, etc.

The Contractor shall ensure that all documentation is coded (as per the codes assigned by the technician) prior to submission to Employer for review.

Plant Coding shall be undertaken by the Employer and as minimum the Contractor shall make available the following documentation to code:

5.6.1.1.1 Mechanical

- Piping and Instrumentation Diagrams (P&IDs)
- Interface list
- Process flow diagrams (PFDs)

5.6.1.1.2 Electrical

- Single line diagrams,
- Electrical board general arrangements (GA)
- Cable schedules

5.6.1.1.3 Civil

- Site layouts
- Cable rack & support

5.6.1.2 Plant Labelling

It is the responsibility of Contractor to manufacture and install labels according to station based labelling standard (Eskom to provide the labelling standard). The Coding Practitioner shall facilitate base-lining of all equipment lists from the Contractor, and only baseline equipment lists shall be used as a basis for the production of labels. The Abbreviation Standard for labelling of Plant at Power Stations (240-109607332) shall be provided to the Contractor as a reference for the creation of equipment lists.

Coding and labelling of components inside electrical and C&I panels shall be done by the Contractor.

5.6.2 Applicable Standards

The Contractor must adhere to the latest revision of the following standards as a minimum:

- 240-109607332: Eskom Plant Labelling Abbreviation Standard
- ENS0002: AKZX Plant Location Coding Standard

6. PERFORMANCE CRITERIA

The Contractor must ensure that the following plant performance, as a minimum, is demonstrated to the Employer:

- The plant is able to produce a flowrate of 15 Nm^3/h at a pressure of 27 bar with no external compression.
- The hydrogen purity is at a minimum of 99.9 % by volume
- A dew point of -50°C or better at 101.4 kPa

7. SPARES AND MAINTENANCE REQUIREMENTS

A detailed maintenance programmes for a 22 year life span shall be priced separately from the tender. It shall consist of the component list, model numbers and technical description including details of critical spares. The spare cell stack shall be supplied at the cost of the Contractor during the warranty period with the option of the purchase by the Employer at the end of the warranty period.

Routine maintenance of the plant equipment shall be required at 6 month intervals for minor maintenance and yearly for major maintenance interventions.

8. SAFETY REQUIREMENTS

The Contractor shall comply with the latest revision of the Eskom Generation Plant Safety Regulation as well as site specific procedures and stipulations of the Occupational Health and Safety Act.

9. TRAINING REQUIREMENTS

Training with associated training manuals (including special tools) for the operation and maintenance of the plant shall be provided by the Contractor for effective and efficient operations.

10. RELIABILITY, AVAILABILITY AND MAINTAINABILITY

Hydrogen Plant Works shall be designed and configured such that the availability of the individual sub-systems over its life in percentage of time is 99.99% or greater. The Contractor shall perform RAM (Reliability, Availability and Maintainability) studies on all major areas of Plant forming part of the Works. The RAM studies shall be done in accordance with the requirements as laid down in the Eskom RAM guideline. The objectives of these studies are to achieve the following:

- Predicting the Availability, Reliability and Throughput of each subsystem.
- Predicting the Availability, Reliability and Throughput of the complete System.
- Performing redundancy studies on the systems.
- Using the above studies to optimise the system spares holding.
- Essential to the above process is the construction of an ABD (Availability Block Diagram) of the system and shall form part of the RAM study. The ABD shall show the interconnections between equipment for each of the subsystems making up the plant. All redundancies must also be shown.

The VisualSPAR latest version reliability simulation software package shall be used in performing the RAM analysis. The Contractor shall supply the following:

- RAM Report as per the objectives listed above. The report must include all the models, model results, programming logic flow-charts, plant design down to equipment level.
- A presentation of the results.
- All RAM documentation including all assumptions, as well as the operating and maintenance philosophy for the complete system in the works.
- The Contractor shall present the RAM models and documentation, in draft format for comment, to the Employer two weeks prior to compiling the final RAM assessment and package.
- Detailed RAM models and programming logic flow-charts.
- Process description of the system and subsystems.
- Availability, Reliability and Throughput and Sensitivity analysis of the system and the subsystems derived from the model output.
- ABD’s (Availability Block Diagrams) of the complete system and subsystems in the works, in order to achieve the objectives described above. Each ABD shall show the interconnections between the equipment of the systems and subsystems concerned.
- Derive an Optimised Maintenance philosophy for the systems and equipment. Ageing of equipment must be taken into account. The “probabilistic ageing” feature of the VisualSPAR

model will be used and the process taken to arrive at the optimised maintenance philosophy must also be shown.

- The complete ABD model's software logic (All VisualSPAR Input files, Bubble logic files and Output files) – i.e. the actual ABD VisualSPAR latest version software models. The ABD models and software logic provided by the Contractor, as part of the works, must be supplied in their entirety and is sufficient in it for the Employer to replicate or re-create all the ABD calculations and models using only the VisualSPAR latest version software.
- MTTF (Mean Time to Failure) for each type of equipment provided as part of the works and the type of failure distribution i.e. Exponential or Weibull.
- MTTR (Mean Time to Repair) or MDT (Mean Down Time) for each type of equipment provided as part of the works.
- Optimised spares holding for the complete system using the VisualSPAR Optimizer (SPAROpt) tool to optimise the system spares holding.
- The Contractor shall train three Eskom employees as part of knowledge transfer during the development of the RAM studies.
- The Contractor shall demonstrate the attainment of the results as predicted by the RAM studies once the plant is in operation.
- The Contractor shall make a presentation of the RAM studies report to the Eskom team prior to handover of the signed report.

10.1 APPLICABLE STANDARDS:

The Contractor must adhere to the latest revision of the following standards as a minimum:

- 240-52844017: System Reliability, Availability and Maintainability Analysis Guideline

11. TECHNICAL RISK ASSESSMENTS

11.1 HAZARD AND OPERABILITY STUDY (HAZOP)

The Contractor shall carry out a formal Hazard and Operability Study. These studies shall be done in accordance with the requirements as laid down in the Eskom guideline. The HAZOP study shall be conducted with ESKOM Design, Operation and Maintenance team members.

11.1.1 Applicable Standards

The Contractor must adhere to the latest revision of the following standards as a minimum:

- 240-49230111: Hazard and Operability Analysis Guideline

11.2 FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS (FMECA)

The Contractor shall carry out formal Failure Mode Effects and Criticality Analysis. These studies shall be done in accordance with the requirements as laid down in the Eskom guideline. The Contractor shall make a presentation of the FMECA report to the Eskom team prior to handover of the signed report.

11.2.1 Applicable Standards

The Contractor must adhere to the latest revision of the following standards as a minimum:

- 240-49230046: Failure Mode and Effects Analysis Guideline

11.3 HAZARDOUS LOCATION STUDY (HAZLOC)

The Contractor shall carry out a formal HAZLOC Study according to the Eskom standard. The Contractor shall make a presentation of the HAZLOC report to the Eskom team prior to handover of the signed report.

11.3.1 Applicable Standards

The Contractor must adhere to the latest revision of the following standards as a minimum:

- 240-56536505: Hazardous Locations Standard

12. QUALITY REQUIREMENTS

No work will be done without a QCP that is approved by the Employer. A QCP must be submitted to the Employer for all that will be done 3 days before that part of the work is to be commenced.

QCP's and related documentation shall be subject to comment and approval by the Employer's Quality Control personnel as well as Engineering. QCP's will make provision for signatures for interventions by at least the Contractor's QC Representative, the Employers QC Representative, the Employer's Engineering Department and the site AIA representative.

Intervention points will be signed as the work progresses and no back-dating will be allowed.

Notification for hold and witness points shall be in writing and shall be done at least 24 hours in advance.

The following minimum hold points must be included for the Employer's Quality Control Department:

- Approval of QCP

- Approval of “As Required” arrangement and dimensional drawings
- Review of Welding Procedures
- Review of Visual Inspection and NDT Reports
- Final Sign off and Acceptance
- Final Data book Review

13. SYSTEM INTEGRATION REQUIREMENTS

13.1 DRAWINGS REQUIREMENTS

The creation and control of all Engineering Drawings shall be in accordance with the latest revision of 240-86973501: Engineering Drawing Standards – Common Requirements. The Contractor shall provide detailed “As Required” arrangement/dimensional drawings for each part of work to be done. No work will commence without approval of these drawings approved by the Engineering representative of the Employer.

After the works have been completed, detailed “As-built” drawings shall be provided by the Contractor. The “As-built” drawings are subject to the Employer’s Engineering representative comments and approval. All drawings shall indicate new installation/modified parts as well as adequate existing pipework to which the items are connected. This shall be done in sufficient detail to easily identify the location of the installation.

All drawings shall contain the following as a minimum:

- Description of component with AKZ number.
- Layout of the pipework with dimensions and angles.
- Bill of materials for all components traceable to the layout. BOM should include size, schedule, pressure rating or class, material, quantity etc.
- Design and operating pressures and temperatures.
- Proof Pressure Test requirements and pressures.
- Design Code.
- All drawing revisions must be provided as paper copies in original (in all cases at least A3) size as well as provided in .pdf format.

To aid in the production of the drawings, the Contractor may request copies of P&ID’s and the equipment’s original drawings from the Employer’s Library. The availability of current plant drawings cannot be guaranteed.

All required drawings shall be prepared in accordance with the requirements as specified in 240-86973501: Engineering Drawing Office and Engineering Drawing Standard. A drawing register (Master Document List, with document titles, document revision, status, transmittal details and project phase) which records the drawing's information shall be maintained by the Contractor.

Drawings to be prepared will include and not be limited to:

- Equipment drawings;
- Equipment lists;
- Isometric drawings and P&ID's;
- Original Equipment Manufacturer (OEM) manuals and part catalogues;
- Set point and parameter lists;
- Three dimensional drawings requirements- DGN model

13.2 DRAWING FORMAT AND LAYOUT

The creation, issuing and control of all Engineering Drawings will be in accordance with the latest revision of 240-86973501 Engineering Drawing Common Requirements Standard. Drawings issued to Eskom will be a minimum of one hardcopy and an electronic copy. All Contractors 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.

13.3 DOCUMENT MANAGEMENT

13.3.1 General Requirements

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-Contractors. It shall not apply to drawings developed by manufacturers for equipment and material such as valves, instruments, etc. Drawing numbers shall be assigned by the Employer as drawings are developed.

The project name shall be listed on all drawings, including manufacturers' drawings. A separate sheet may be attached to the submittal if needed to adequately list all tag numbers associated with the drawings such as valves or instruments which may have numerous tag numbers associated with it.

The language of all documentation shall be in the English language. The units of measure shall be metric. The Contractor retains project design calculations and information for the entire life cycle of the

plant and provides these to the Employer on prior written notice at any time notwithstanding the expiry or termination of the contract.

13.3.2 Documentation Requirements

All documents supplied by the Contractor shall be subject to Eskom's approval. Documents such as QCP's, Method Statements and other documents impacting the work shall be approved by the Employer at least 3 working days prior to commencement of the Works.

Each revision of a document or drawing shall be accompanied with a list of the comments made by the Employer on the previous revision if applicable and the response/corrective action taken by the *Contractor.* Changes shall be recorded in a revision table contained on/in each drawing/document.

Documents and drawings shall indicate the Employer's drawing number as allocated by the Employer. The Contractor may have his own internal document or drawing number on the document or drawing, but where reference is made among documents or drawings, the Employer's number shall be used.

The Contractor shall compile a complete data book for all work done during manufacturing, construction and commission containing the following as a minimum if applicable:

- Scope of work
- Approved "As built" drawings
- Design calculations
- Approved QCP / ITP
- Inspection reports
- Pipe ovality reports if applicable
- As built drawings (isometric drawings and P&IDs)
- Material summary that gives full traceability between components used, drawings and material certificates
- All material certificates for pipes, fittings and all components used.
- Pressure test certificate and the calibration certificates of the gauges used.
- Pressure test procedures
- The manufacturer's/repairer's certificate as defined in PER.
- All CAR's and corrective actions
- Operating Philosophy including all alarm and trip values
- BFP Charging Procedure
- Parts catalogue

- Maintenance manual
- Storage, packing and transportation instructions
- Apart from what is already mentioned in the list above, for fire protection the following is also required:
    - Node diagram (to be used with hydraulic calculations)
    - Hydraulic calculations (With fine design point & Without fine design point)
        - With fine design point – using the minimum requirement for pressure and flow at the furthest nozzle
        - Without fine design point – using the actual input of pumps on plant to determine the pressure, flow and velocities in the pipes
- Spray pattern drawings indicating that the whole hydrogen storage vessel is covered (4 tanks in total).

13.3.3 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 Eskom's drawing number in the drawing title block. This requirement only applies to design drawings developed by the Contractor and his Sub-Contractors. Drawing numbers will be assigned by the Employer as drawings are developed. All documentation shall be controlled and managed in accordance with Project/Plant Specific Technical Document and Records Management Procedure (240-53114186).

13.3.4 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 (240-65459834)
- Project Documentation Deliverable Requirement Specification (240-65459834).
- Technical Documentation Classification and Designation Standard (240-54179170).

13.3.5 SharePoint Transmittal

- The Contractor shall submit all documentation to the Eskom Representative as well as the Project's Documentation Centre in the following media:
- Electronic copies shall be submitted to Eskom Documentation Centre through SharePoint transmittal site that will be provided during contract award.
- Hard copies shall be submitted to the Eskom Representative accompanied by the Transmittal Note.

13.3.6 Email Subject

Electronic copies shall be submitted to the Eskom Representative email subject;Project Name_Discipline_Subject. Electronic copies that are too large for email will be delivered on 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 Eskom Representative.

13.3.7 Engineering Change Management

All Design change management shall be performed in accordance to the latest revision of the Eskom Project Engineering Change Management Procedure (240-53114026) and the Employer shall ensure that Contractor is provided with latest revisions of this procedure. Any uncertainty regarding this procedure should be clarified with the *Employer*. All design reviews will be conducted according to 240-53113685: Design Review Procedure.

14. AUTHORISATION

This document has been seen and accepted by:

Name & Surname	Designation
Anasen Pillay	LPS CoE Engineering Manager (Acting)
Christiaan Bekker	Structural Design CoE LDE
Conrad Henning	Turbine Plant CoE LDE
David Kunene	Electrical CoE LDE
Francisco De Freitas	Fire Detection Engineer: C&I CoE
Funeka Grootboom	Dams, Waterways and Hydro CoE Manager (Acting)
Manie Van Staden	PEI Senior Consultant (Turbine Auxiliaries and Hydrogen)
Mary Maunye	Senior Technologist: LPS CoE
Mershan Reddy	Project EDWL: LPS CoE
Mfanufikile Shange	Configuration Management Lead: Duvha Power Station
Nelisiwe Nhlapo	Plant EDWL: Duvha Power Station
Nhlanhla Ngcobo	System Engineer: Hydrogen Plant - Duvha Power Station
Nomfundo Mdlokovana	C&I CoE LDE
Peter Phochana	Eskom Reliability Engineer
Willem Erasmus	Fire Protection Engineer: LPS CoE
Zamaswazi Luswazi	LPS CoE Engineering Manager

15. REVISIONS

Date	Rev.	Compiler	Remarks
November 2017	0	M Reddy	First Issue
February 2018	1	M Reddy	Report updated after team review and input
February 2019	2	M Reddy	Report updated as per ECP (382-ECM-AABZ26-RP0000-31)
March 2019	3	M Reddy	Updated after CCCC review

Date	Rev.	Compiler	Remarks
June 2019	4	M Reddy	Additional Fire Protection and Detection scope added

16. DEVELOPMENT TEAM

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

- Mershan Reddy
- Mary Maunye
- Willem Erasmus
- Zamaswazi Luswazi
- Conrad Henning
- Nomfundo Mdlokovana
- Francisco De Freitas
- David Kunene
- Christiaan Bekker
- Manie Van Staden
- Nelisiwe Nhlapo
- Mfanufikile Shange
- Peter Phochana

17. ACKNOWLEDGEMENTS

- Mary Maunye
- Manie Van Staden

18. APPENDIX A: FIRE RING MAIN POSSIBLE TIE-IN POINTS

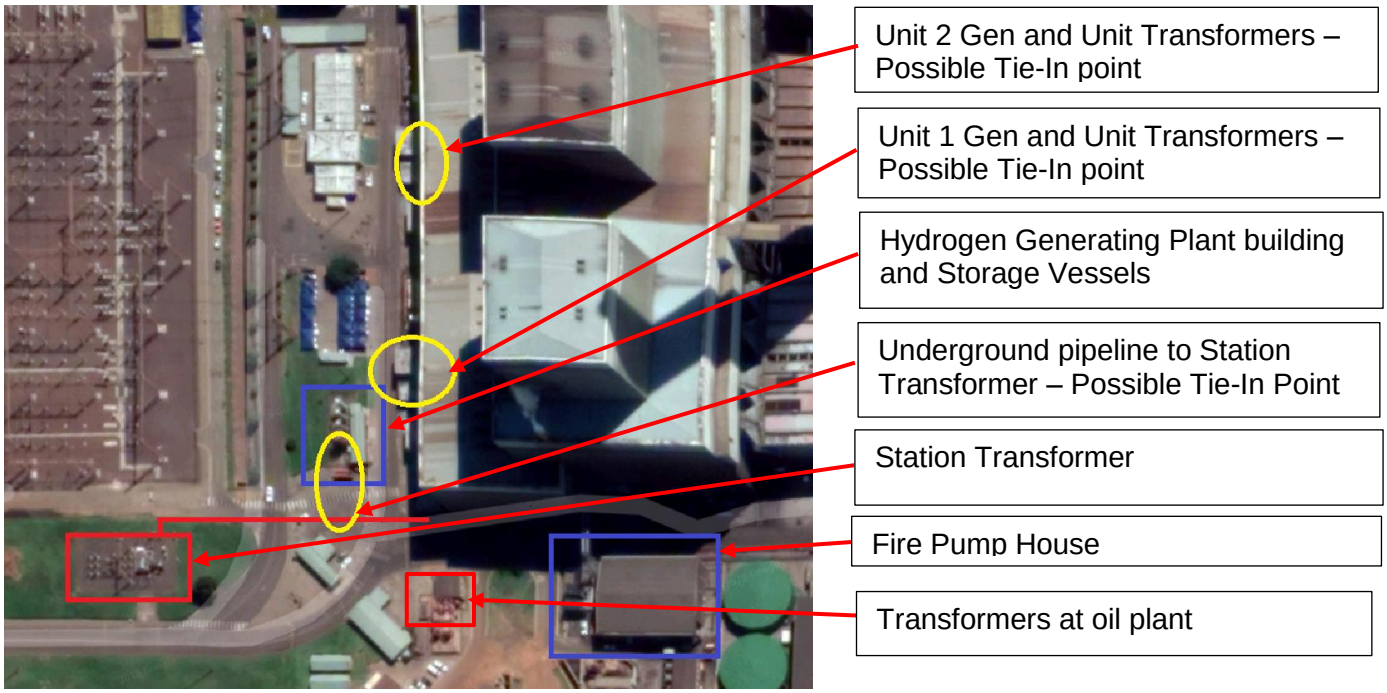

Figure 4: Satellite Photo - Possible Tie-In Points

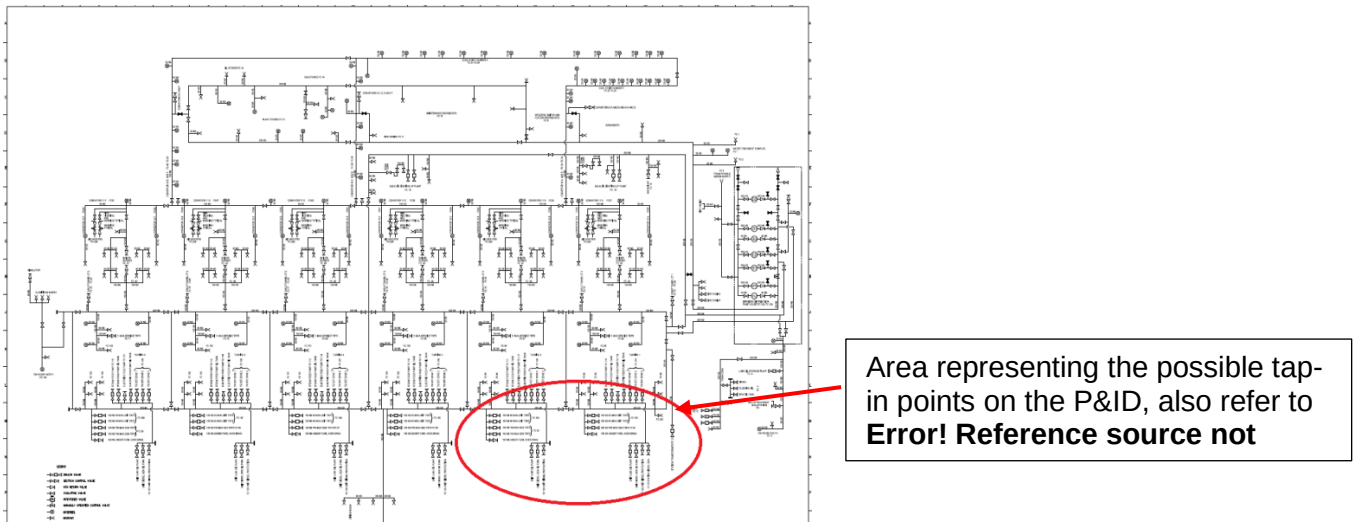

Figure 5: Duvha Power Station Schematic Diagram of Fire Control Systems and Associated Services Rev 04 SHT 00 – Drawing Number: 0.57/13640

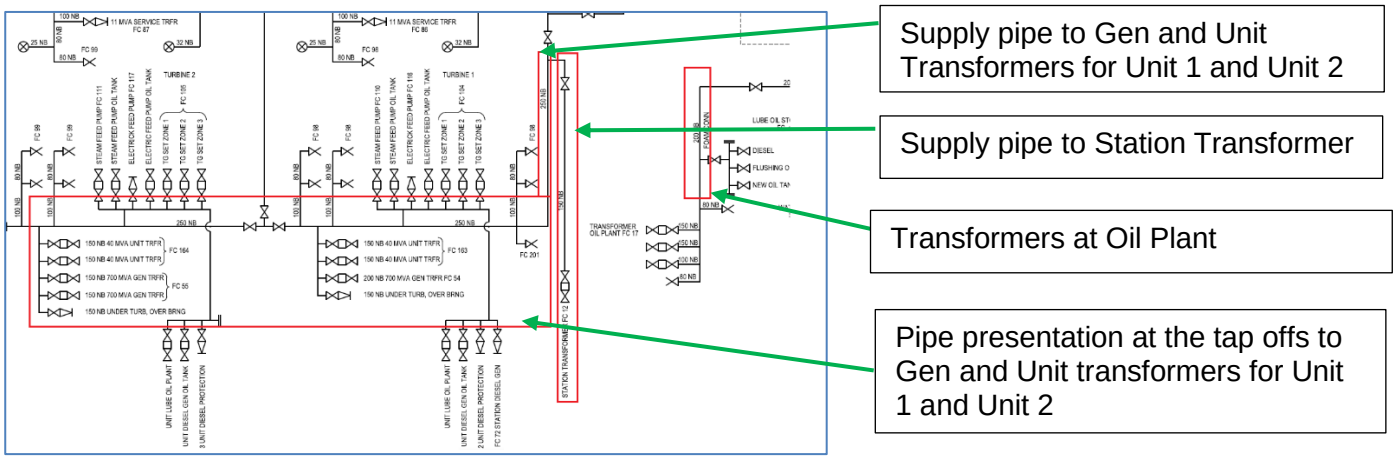

Figure 6: Enlargement of highlighted area in Figure 5

Summary of Appendix A:

The hydrogen storage vessels require fixed fire protection as stated earlier in the document. A few possible tie-in points have been identified as per the figures (Figure 4, Figure 5, and Figure 6). The tie-in points are:

1) Underground pipeline to Station transformer
    - This is the preferred option as it is the closest tap-in point to the tanks and will cause the least amount of interference on site. The issue is that the pipe is underground in a cable tunnel that needs to be broken through to connect the pipes.
2) Supply pipe to the units
    - This is the second closest point, but there are a lot of roads to cross in this option.
3) Pipes at area of Gen and Unit transformers at Unit 1
    - These are not preferred, but are listed as an option as it is also possible to tie-in here. The issue is that there is a lot of work to route the pipes from the tie-in point to the hydrogen storage vessels
4) Pipes at area of Gen and Unit transformers and Unit 2
    - Same as in point 3 above
5) Pipes at area of Oil Plant Transformers
    - Same as in point 3 above