SECTION V

EMPLOYER'S REQUIREMENT

Note to the Bidders:

This Employer's Requirements (ERQ) and the accompanying Bill of Quantities (BoQ) have been prepared by the Department of Energy (DoE) as guidance to prospective Bidders, based on preliminary assessments and assumptions. All systems, components, works and services described herein form part of the Scope of Works and shall not be omitted. Parameters specified as "minimum", "not less than" or "≥", including hydrogen production capacity, performance guarantees and safety requirements, are mandatory technical thresholds and shall be met or exceeded.

Parameters stated as "indicative", "approximately" or "subject to DoE approval" are not guaranteed. Bidders shall verify such values on the basis of their own proposed design, site visit and investigations, and shall state the values and quantities they have adopted in their bid, priced against the corresponding BoQ items. These values shall be finalised during the detailed engineering design, subject to DoE approval, and any resulting variation shall be deemed to be included in the Contract Price.

In the absence of specific Bhutanese standards/regulations for hydrogen facilities, the ERQ refers to internationally accepted standards. Bidders may propose equivalent or superior standards, subject to DoE approval, and shall comply with all applicable Bhutanese laws. Any error, omission or inconsistency in the ERQ or BoQ shall not relieve the Bidder of its responsibility to deliver a complete, safe and fully functional facility meeting the specified performance requirements.

Bidders shall notify the DoE in writing of any discrepancy before the bid clarification deadline.

PART A

ENGINEERING, PROCUREMENT, AND CONSTRUCTION OF A 250 kW GREEN HYDROGEN PLANT AT JAMJI, THIMPHU BHUTAN FOR MOBILITY APPLICATIONS

ABBREVIATIONS

Abbreviation	Full Form
AC	Alternating Current
ACB	Air Blast Circuit Breaker
AMC	Annual Maintenance Contract
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ATEX	Atmosphère Explosible
ATS	Automatic Transfer Switch
BASEEFA	British Approval Service for Electrical Equipment in Flammable Atmospheres
BMS	Battery Management System
BPV	Boiler Pressure Vessel
BS	British Standard
CBCT	Core Balancing Current Transformer
CCoE	Chief Controller of Explosives, PESO
CCTV	Closed Circuit Television
CEA	Central Electricity Authority
CENELEC	European Committee for Electrotechnical Standardization
CGA	Compressed Gas Association
CIMFR	Central Institute of Mining and Fuel Research
CPWD	Central Public Works Department
CSIR	Council of Scientific and Industrial Research
DC	Direct Current
DoE	Department of Energy
DCP	Dry Chemical Powder
DIN	Deutsches Institut für Normung
DM Water	Demineralised Water
DMP	Disaster Management Plan
DLP	Defect Liability Period
DMR	Double Modular Redundancy
EC	European Regulation
ECBC	Energy Conservation Building Code
EIGA	European Industrial Gases Association
ELCB	Earth Leakage Circuit Breaker
ELR	Earth Leakage Relay
EMC	Electromagnetic Compatibility
EMERA	Escape Muster and Emergency Response Analysis
EMS	Energy Management System
EN	European Norms
EPC	Engineering, Procurement, and Construction
ERTL	Electronics Regional Test Laboratory
ESD	Emergency Shutdown Device
ETP	Effluent Treatment Plant
EWS	Engineering Workstation
FBT	Fast Bus Transfer
FCEV	Fuel Cell Electric Vehicle

FFL	Finished Floor Level
FM	Factory Mutual Laboratories
FRLS	Fire Retardant and Low Smoke
GC	Gas Chromatograph
GUI	Graphical User Interface
H2	Hydrogen
HAC	Hazardous Area Classification
HART	Highway Addressable Remote Transducer
HAZOP	Hazard and Operability Study
HIRA	Hazard Identification and Risk Assessment
HMI	Human Machine Interface
HT	High Tension
HTFS	Heat Transfer Fluids
HTRI	Heat Transfer Research, Inc.
HVAC	Heating, Ventilation, and Air Conditioning
ICS	Integrated Control System
IEC	International Electrotechnical Commission
IECEx	IEC System for Certification to Standards Relating to Explosive Atmospheres
IEEE	Institute of Electrical and Electronics Engineers
NCHM	National Center for Hydrology and Meteorology
IP	Ingress Protection
IS	Indian Standard / Intrinsically Safe
ISA	International Society of Automation
ISO	International Organization for Standardization
LAN	Local Area Network
LCD	Liquid Crystal Display
LCIE	Laboratoire Central des Industries Électriques
LED	Light Emitting Diode
LEL	Lower Explosive Limit
LOTO	Lock Out Tag Out
LT	Low Tension
m	Meters
MCB	Miniature Circuit Breaker
MCC	Motor Control Center / Cubicle
MCCB	Moulded Case Circuit Breaker
MSDS	Material Safety Data Sheet
NBC	National Building Code
NDE	Non-Destructive Examination
NDT	Non-Destructive Testing
NFPA	National Fire Protection Association
NoA	Notification of Award
NTFO	Non-Thermal Forward Osmosis
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
OISD	Oil Industry Safety Directorate
OPC	Open Platform Communication / Ordinary Portland Cement
OPEX	Operational Expenditure

OWS	Operator Workstation
PAM	Personnel Area Monitor
PBG	Performance Bank Guarantee
PCC	Point of Common Coupling
PEB	Pre-Engineered Building
PESO	Petroleum and Explosives Safety Organisation
PG	Performance Guarantee
PLC	Programmable Logic Controller
PSA	Pressure Swing Adsorption
PSU	Power Supply Unit
PTR	Performance Track Record
PVT	Production Validation Test
PWHT	Post Weld Heat Treatment
QMR	Quadruple Modular Redundancy
QRA	Quantitative Risk Assessment
RE	Renewable Energy
RMU	Ring Main Unit
RO	Reverse Osmosis
RS	Raman Spectrometry
RTC	Round the Clock
SCADA	Supervisory Control and Data Acquisition
SCVS	Servo Controlled Voltage Stabilizer
SIL	Safety Integrity Level
SIS	Safety Instrumented System
SM	Spectrometry
SMART	Specific, Measurable, Achievable, Relevant, Time-bound
SMPV	Static and Mobile Pressure Vessel
SPD	Surge Protection Device
SS	Stainless Steel
SSD	Solid State Drive
TCP/IP	Transmission Control Protocol / Internet Protocol
TEMA	Tubular Exchanger Manufacturers Association
TMR	Triple Modular Redundancy
TMS	Thermal Management System
UL	Underwriters Laboratory
UPS	Uninterruptible Power Supply
VFD	Variable Frequency Drive
WL	Water Liters
XLPE	Cross-Linked Polyethylene
ZLD	Zero Liquid Discharge

A. PROJECT INFORMATION

1.1 Project Overview

The proposed project involves the development of a 250 kW green hydrogen production plant with an on-site hydrogen refuelling facility at Jamji, located below the upcoming Jamji Solar Power Plant. The project site lies between Thimphu and Paro, approximately 27 km from Thimphu. Owing to its strategic location along the Thimphu–Paro corridor, the facility will be easily accessible to Fuel Cell Electric Buses (FCEBs).

1.2 Project Location and Accessibility

The project site benefits from existing infrastructure and road connectivity. Expansion and black-topping of approximately 140 meters of road will be required. However, the nearby 33kV line is approximately 500 meters away from the proposed site. KMZ file is attached.

1.2.1 Land Area and Site Characteristics

The total land area allocated for the project is approximately 1 acres, with:

- Latitude: 27°19'23.45"N
- Longitude: 89°33'49.12"E
- Length: 110-120 meters
- Width: Approximately 30-32 metres

The available area is adequate to accommodate:

- Green hydrogen production equipment
- On-site hydrogen storage and refuelling infrastructure
- Site office and auxiliary facilities

The site elevation ranges between 2,180 and 2,182 metres above mean sea level. Due to a variation of approximately 2 metres in ground level, excavation and levelling works will be required as part of site preparation.

1.3 Water Requirement

1.3.1 Water Source

The water requirement for the green hydrogen plant will be met from a nearby river known as Wangchhu located close to the project site. Water will be abstracted and supplied to a distillation and storage facility for use in hydrogen production. The river is perennial throughout the year.

B. SCOPE OF WORK

2. Design Requirements

a. Facilitate inspection, cleaning, and maintenance with a strong focus on operational safety and personnel protection.

b. Minimize fire risk through appropriate design measures and material selection.

c. Ensure safety, reliability, and flexibility of service in all operating conditions.

d. Minimize turnaround time during maintenance and shutdown activities.

e. Provide adequate provisions for future expansion and modifications.

f. Maximize interchangeability and standardization of equipment.

g. Ensure an appropriate level of operator interface for coordinated, efficient, and fail-safe operation, including data logging and maintenance support.

h. Provide automatic and fail-safe protection for all mechanical and electrical equipment.

i. Ensure all equipment and machinery operate within defined design limits.

j. Design systems to suit applicable environmental and site-specific conditions.

k. Select equipment with adequate capacity to meet process and operational requirements.

l. Provide comprehensive control and indication systems for safe and efficient operation.

m. Use energy-efficient equipment, including motors and lighting fixtures.

n. Maintain required aesthetics in line with Bhutanese standards.

o. Incorporate required redundancy based on process and operational needs to ensure continuous full-capacity operation.

p. Design all equipment, systems, piping, and structures considering saline atmospheric conditions and implement measures to prevent corrosion and rust formation.

q. Follow ANSI/ISA 5.1-2024 or KKS coding system for identification and tagging of all equipment, including instrumentation and sub-packages.

3. Brief Scope of Work

3.1 The document defines the technical specifications for the complete Design, Engineering, Procurement, Supply, Installation, Integration, Testing, Commissioning, Performance Validation, and Handover of a ~250 kW (nominal) grid-connected Green Hydrogen Generation Plant at Jamji, Thimphu Bhutan based on Proton Exchange Membrane (PEM), with proven technologies with demonstrated commercial operation and proven reference installations.

3.2 The plant shall be designed as a fully automated, modular, skid-mounted or containerised system.

3.3 The Bidder shall design, engineer, construct, and commission the entire hydrogen facility, including all equipment, piping, cabling, and supporting structures, in a manner that ensures safe, fully functional, and visually organized installation. The overall plant layout, equipment arrangement, routing, identification, signage, color coding, and housekeeping shall comply with all applicable international standards, including but not limited to PESO, ISO 19880-1, NFPA 2, IEC 60079 series, API RP 500/505, ASME B31.12, and ISO 20560, as well as good engineering, safety, and industry practices.

3.4 The scope of equipment, systems, and documentation to be provided by the Bidder includes:

a. Supply of 250 kW Electrolyser system of Min. production of ~4.5 kg/hour.
b. Hydrogen compression system to compress hydrogen to 500 bar with a rated capacity of 5 kg/hr.
c. Hydrogen storage facility capable of storing an indicative minimum of 140 kg at 500 bar in H_2 cylinder cascades, sized by the Bidder to deliver two consecutive fills of minimum 20 kg each to FCEBs at 350 bar without any interval between fills, confirmed by fill simulation submitted for DoE approval.
d. Hydrogen dispenser system to fill hydrogen into FCEBs at 350 bar.
e. Nitrogen generation system of 5 Nm^3/hr for production of N_2 gas for purging operations.
f. Gas Chromatograph (GC) and/or spectrometry system for testing hydrogen gas samples entering FCEV buses.
g. Firefighting facilities and fire suppression system in H_2 areas and control buildings.
h. Water Treatment Facility for producing treated water for hydrogen generation.
i. Complete civil and electrical works, including integration of HT system, H_2 generation, compression, storage and dispenser system, and associated office cum switchgear building.
j. Unified Integrated Control System (ICS) including SCADA and EMS for control and monitoring of the entire plant.
k. Conducting safety studies, including HAZOP, SIL, HIRA, QRA, Hazardous Area Classification (HAC), Escape Muster and Emergency Response Analysis (EMERA), and Disaster Management Plan (DMP).
l. Wi-Fi and network connectivity as specified in Clause 4.4.3.
m. Effluent Treatment Plant (ETP) for the entire plant facilities, as specified in Clause 4.4.1.

3.5 The Bidder shall identify, include, and implement all components, systems, and provisions necessary for the safe, complete, and compliant operation of the Works, whether or not

explicitly specified under Clause 3.4. All such components shall conform to applicable international standards, industry best practices, and relevant codes and regulations. Any omission in Clause 3.4 shall not relieve the Bidder of its responsibility to deliver a fully functional and compliant facility.

3.6 The Bidder shall provide the detailed feasibility study of utilizing excess hydrogen generated for ammonia and synthetic fuels and oxygen generated from the 250 kW pilot plant for industrial and medical applications**.**

4. Detailed Scope of Work

4.1 The Bidder shall ensure that the Engineering Design Package is complete in all respects and suitable for execution, including process calculations, equipment sizing, electrical load and cable sizing calculations, control logic, and safety system design as per the site conditions specified in the Section A. Project Information. All design documents shall be subject to review and approval by the DoE prior to implementation. The detailed design of the project shall be completed within six months from the signing of the contract.

4.1.1 Compressed hydrogen refueling stations shall be designed, constructed, operated, and maintained in accordance with NFPA, CGA H-5, and ISO 19880.

4.2 The hydrogen fueling station comprises the following systems:

Sl. No.	Description	Quantity
1	Hydrogen generation system (Electrolyzer and its accessories)	1 Lot
2	Hydrogen Compression system with all accessories	1 Lot
3	Hydrogen Storage system	1 Lot
4	Hydrogen Dispensing system	1 Lot
5	Complete Civil and Electrical Works including firefighting system, office cum switchgear building, foundation etc.,	Lumpsum
6	Capacity Building and maintenance (Including capacity building training programs, preventive and breakdown maintenance assistance along with supply and replacement of spares, consumables, fulfilling statutory requirements etc.,)	

4.3 The completion of all facilities, along with the procurement of fuel cell buses, including commissioning of the hydrogen fuelling station, shall be completed within **18 months** after the completion of design works.

4.4 In addition to 4.3, the Bidder shall provide and ensure the following:

4.4.1 Effluent Treatment Plant (ETP) for the complete facilities, including the hydrogen generation area, treating RO/DM reject and regeneration water, bus-washing water and sanitary effluent. Treated water shall be reused for bus washing, landscaping and utilities as far as practicable, and any discharge shall meet the applicable National Environment Commission effluent standards.

4.4.2 Non-evaporative, closed-cycle type design for all heat exchangers.

4.4.3 Wireless network with managed secured internet gateway (firewall, switches, routers, access-points, etc.) for a minimum of 10 concurrent users, including leased line service of 10 Mbps bandwidth (1:1), for the office cum switchgear building (Wi-Fi) with an envelope of at least 20 m around the filling station. Separate Wi-Fi and LAN connectivity shall be provided for the office-cum-switchgear building.

4.4.4 Appropriate number of CCTV IP-based PoE cameras (minimum 8 MP high resolution, manual focus and digital focus with night color vision) for at least 15 days of data storage, covering the entire hydrogen fueling station. CCTV feed shall be available locally at the control room and security room, and remotely from any part of the country.

4.4.5 All buildings shall be reinforced cement concrete (RCC) framed structures designed as per IS 456 and IS 1893-1, **and constructed in accordance with the Bhutan Building Regulation 2018 and the Building Code of Bhutan 2018,** incorporating traditional Bhutanese architectural design (including rabsel windows, traditional roof and cornice details, and traditional colour schemes and motifs) **as per the Bhutanese Architectural Guidelines 2014.** The design and execution shall incorporate hydrogen-specific safety considerations, including appropriate hazardous area classification and zoning, adequate natural and mechanical ventilation, fire resistance, blast mitigation measures (where applicable), and proper segregation of hazardous and non-hazardous areas.

4.4.6 Complete drainage arrangement, including dewatering, site approach, and service roads, shall be provided for the entire plant, including the electrolyser system, with RCC gutters and heavy-grade grating.

4.4.7 Pavement for the complete facilities, including the electrolyser system.

4.4.8 Site grading, including slope protection, ground preparation, filling, leveling, and compaction of the identified area for the hydrogen station, covering the entire fuelling station including the hydrogen generation area.

4.4.9 Civil/Foundation works for the office cum switchgear complex, electrolyser, hydrogen storage, hydrogen compression unit, hydrogen dispenser, switchgear, electrical and SCADA panels, batteries, control room equipment, transformers, etc.

4.4.10 Interiors of all buildings (office cum switchgear and cabins) must be furnished with premium furniture, sanitary equipment, electrical and lighting fittings**.**

4.4.11 Necessary expansion and black-topping of approximately 140 meters of single-lane access road, with carriageway width, shoulders, drainage and pavement as per the Road

Design Standards of the Royal Government of Bhutan (Guidelines on Road Classification System, Annex-1 – Access Roads) and the requirements of the Department of Surface Transport, including one passing bay, for vehicular movement and sufficient space for staff and visitor parking. The station layout shall provide vehicle circulation enabling FCEBs (7–9 m) and fire tenders to enter, fuel and exit in the forward direction without reversing in the vicinity of hydrogen equipment, by means of a drive-through loop or turning area sized to the vehicle manufacturer's turning radius, subject to DoE approval.

4.4.12 Facilities for FCEV buses maintenance, including development of parking areas and an automatic water cleaning system for H_2 buses.

4.4.13 Providing & fixing G.I chain-link mesh including fixing of post or struts, G.I staples (inlcuding the cost of posts/struts, earthwork, concrete etc.) for 4mm (8 SWG) x 50mm (180m length & 2.5m height) with vehicular and pedestrian gates; wire mesh fencing for internal area segregation; including landscaping and façade.

4.4.14 Sanitary and plumbing works, including connection with existing service networks.

4.4.15 Crash guards to be suitably installed around the dispenser.

4.4.16 Display boards, billboards, LED/Neon signages.

4.4.17 Arrangement of drinking water coolers (150 L and 30 L capacity, 2 units each) and establishment of pantry facilities including purifier, heater, refrigerator, etc.

4.4.18 All architectural works shall reflect local culture and history for aesthetic appeal of the station.

4.4.19 All license fees, technology fees, customs clearance (including reconciliation with authorities), custom duty charges, port clearance, port charges, statutory requirements, and approvals, if any.

4.4.20 Shall be responsible for obtaining all necessary clearances, approvals, and permits required for the execution of the project, including but not limited to power clearance, environmental clearance, water clearance, land clearance, and any other approvals from relevant local authorities and statutory regulatory bodies. The DoE shall extend necessary facilitation and coordination support to the Bidder in securing such clearances.

4.4.21 Safety of the hydrogen fuelling station during total execution, commissioning, trial run, PG test.

4.4.22 Arrangement of construction power and construction water for setting up the project, including potable water for labour and other personnel at the worksite/colony.

4.4.23 Transportation, unloading, and storage of the complete hydrogen generation systems, including insurance for transportation from anywhere to the site location.

4.4.24 Safe disposal of all packing materials, hazardous components, chemicals, and civil scraps generated during project execution.

4.4.25 All incidental items not shown or specified but reasonably implied or necessary for completion and proper functioning of the hydrogen station, including revisions and amendments required during execution.

4.4.26 All equipment, materials, and services, whether explicitly stated or otherwise, necessary for satisfactory operation of different systems.

4.4.27 Temporary arrangements for works, testing lab, storage shed, accommodation for labour and staff, and site office.

C. MINIMUM TECHNICAL SPECIFICATIONS

1. Electrolyzer Generation

Sl. No.	Parameter	Requirement
1	Electrolyzer Technology	PEM
2	Rated Electrical Input	250 kW[1]
3	Hydrogen Production	Minimum 4.5 kg/h (≈ 50 Nm^3/h)
4	Annual Operating Hours	≥ 8,000 hours/year
5	Plant Availability	≥ 90% per year
6	Overall Stack Energy Consumption	≤ 55 kWh/kg H_2 (AC)
7	Stack Degradation Rate	0.5–1%
8	Stack Life (hours)	Minimum 60,000 hours
9	Outlet Pressure	Minimum 25 bar
10	Water consumption	≤ 10 Liters/Kg
11	Altitude	Should be operable at 2000-3000 meters above sea level
12	Technology Maturity	Minimum 5 years with completion certificates, client references, and proven installations

2. Hydrogen Compression System

Sl. No.	Parameter / Specification	Details
1	Type / Technology	Diaphragm or any relevant technologies
2	Number of Units	1 unit including cooling system
3	Output Capacity (Flow)	Minimum 5 kg/h
4	Inlet Pressure	20 bar
5	Outlet Pressure	450 / 500 bar

[1] The Bidder shall propose unit sizing of appropriate electrolyzer modules based on the existing bridge capacity for transportation and delivery.

Sl. No.	Parameter / Specification	Details
6	Outlet Temperature	Maximum 40°C
7	Standards	API 617 / API 618 (8th edition) / API 619 / ISO 14122 / ISO 4413 / IEC 6052 / EIGA DOC 244, 121, 102 and all applicable H_2 compressor standards
8	Approval Required	PESO (complete equipment)
9	Part Load Operation	Capable of operating at part load
10	Features	• Built-in sensor to detect oil traces in H_2 • Vibration monitoring system • All safety devices including health monitoring system • Operates based on electrolyser operation (flow and pressure control)

3. Hydrogen Storage Systems

Sl. No.	Parameter / Specification	Details
1	Type of H_2 Storage Cylinder / Tubes	Type 1 / Type 3 / Type 4
2	Storage Capacity (Usable)	Minimum 40 kg deliverable to FCEBs at 350 bar (two consecutive fills of 20 kg each without interval)
3	Storage Capacity (Total)	Indicative minimum 140 kg (500 bar), to be confirmed by the Bidder's fill simulation, with provision for future expansion
4	Storage Pressure	Type 1 or Type 4: 500 bar; Type 3: 450 bar
5	Standards to be Complied	ISO 12245 / ISO 11119 / ISO 10961 / EN 17533 / EN 17339 / BS EN 13769 / BS EN 13807 / IS 7285
6	Approval Required	PESO (complete set of equipment)
7	Cascade Structure	Designed to cater for all loads, forces, and explosion safety requirements. Diameter of hydrogen storage cylinders used for filling and storage of CHG shall not exceed 80 cm with approval PESO.

4. Hydrogen Dispensing System

Sl. No.	Parameter / Specification	Details
1	Type	H35 (T20) Dispenser
2	Fueling Protocol	Fast filling as per SAE J2601/2:2023 (heavy-duty fuelling protocol)
3	Communication Protocol	SAE J2799:2019 with IR communication

Sl. No.	Parameter / Specification	Details
4	Fueling Method	Single nozzle (with provision for a second nozzle) with minimum 2 kg/min average fuelling rate and minimum 3 meters hoze length.
5	Operation of Dispensing Fuel	Through priority panel (selection of storage system and fueling the FCEB)
6	Parameters Display	Pressure, flow rate, temperature of hydrogen during dispensing, with totalizer
7	Additional Safety Features	• Protective jacket over hoses • Safety controls during fueling: – Hose break detection – High hose pressure or abnormal ramp rates • Shrouded breakaway connectors (prevent hydrogen release) • Collision detector • All components compliant with Zone-1 requirements
8	Special Features	• Display of H_2 purity in dispenser (interfaced with Gas Chromatography and/or Spectrometry) • Provision for Automatic Payment System (digital transaction interface)
9	Approval Required	PESO (complete equipment) and compliance with IECEx requirements

5. Nitrogen Generation system

Sl. No.	Parameter / Specification	Details
1	Type	Pressure Swing Adsorption (PSA)
2	Generation Capacity	5 Nm^3/hr
3	Outlet Purity and Pressure	> 99.95% purity at 10 bar
4	Storage Capacity	Minimum 2 × 30 Nm^3 at 10 bar
5	Control Specifications	• Automatic operation • Interface with PLC and SCADA

6. Fire Suppression System

Sl. No.	Parameter / Specification	Details
1	Type	• Inert gas system for Control Room and SCADA Room • CO_2 flooding system for compressor, FCEV bus filling bay, Gas Chromatograph / Spectrometer • CO_2 flooding / water-based system for buffer tanks • Water sprinkler system for H_2 storage • Fire protection system for H_2 dispenser
2	Fire Rating Capacity	As per NFPA and relevant IS standards
3	Systems Covered	Electrolyzer, Compressor, Storage, Dispenser and others

Sl. No.	Parameter / Specification	Details
4	Control Specifications	• Automatic operation • Interface with PLC and SCADA

7. Gas Chromatograph/Mass or Raman Spectromenter

Sl. No.	Parameter / Specification	Details
1	Number of Connections (each equipment)	Minimum 3 points (Electrolyser outlet, Compressor outlet, Dispenser inlet)
2	Type	Primary and Secondary sampling
3	Gas Measurements	Minimum: Nitrogen, Oxygen, Moisture
4	Protection	• H_2 leak detection • Flame detection• Fire suppression
5	Control Specifications	• Automatic operation • Interface with PLC and SCADA

8. Air Compressor System

Sl. No.	Parameter / Specification	Details
1	System	Instrument Air (01 no) and Service Air (01 no)
2	Quantity	02 Nos., 7.5 HP each with noise enclosure
3	Type	Oil-free air compressor with dryer
4	Pressure and Purity	12 bar and particle size < 25 microns
5	Receiver	Each 1 m^3, vertical type
6	Instrumentation	• Dew point monitoring • Pressure and temperature transmitters and gauges
7	Control	• Automatic operation and auto draining • Interface with PLC and SCADA
8	Protection	• Over pressure and over temperature • High dew point • Pressure relief devices • Compressor cooling (level, temperature)
9	Standard	ISA-7.0.01-1996

9. Water Treatment System

Sl. No.	Parameter / Specification	Details
1	Technology	Deionization/Non-Thermal Forward Osmosis/Reverse Osmosis depending on the water quality test (Annexure I).
2	Generation Output Capacity	Should be sufficient for the 250 kW Electrolyzer and BoP.

Sl. No.	Parameter / Specification	Details
3	Overall Water Recovery	> 90%
4	Water Quality (mg/L)	TDS < 1
5	Conductivity (µS/cm)	< 1 for PEM and <5 for Alkaline
6	Subsystems	1. Feed Water Storage Tank (5 m^3) 2. Pre-treatment and filtration system
7	Control Specifications	• Automatic operation • Interface with PLC and SCADA

5. Detail System Requirements

5.1 Electrical

5.1.1 The Bidder shall be responsible for the complete system starting from drawl of AC power from Bhutan Power Corporation Limited to Switchgear MCC including stepdown transformer for integrating with hydrogen generation system and providing power to compression, storage, dispensing of hydrogen in FCEVs and other auxiliaries as per the statutory requirements of Bhutan.

5.1.2 Electrical Equipment

5.1.2.1 All electrical rotating equipment shall be of IE3 efficiency or better.

5.1.2.2 Equipment installed in the hazard zone shall be flameproof and explosion-proof. It shall also comply with NFPA, IEC, IS-5571 and IS-15142, etc. Ordinary industrial electrical appliances shall not be used in zone 2 areas.

5.1.2.3 Electrical equipment for hazardous areas shall be certified by testing authorities like CMRI / CIMFR / CPRI / ERTL or equivalent recognized independent test houses such as BASEEFA / LCIE / PTV / UL / FM / ATEX / IECEx / CENELEC / PTB, UL / FM. All equipment (indigenous and imported) shall also have valid statutory approval i.e., CCoE, PESO.

5.1.2.4 All electrical equipment shall be provided with a suitable canopy for weather protection.

5.1.2.5 All panels, distribution boards, and junction boxes installed in outdoor environments shall be of IP 67/68 protection. All bus bars shall be weatherproof IP55 with suitable seal and canopy.

5.1.2.6 Maximum surface temperature shall not exceed the ignition temperature of the gases as indicated by the T Class (T1–T6) of the apparatus as defined in IEC 60079 / IS 8239. The minimum temperature class to be considered is T3.

5.1.2.7 Critical loads, e.g., Fire Station supply, shall have two supplies from different power sources.

5.1.2.8 Design the power system to adapt and maintain the power quality parameters (harmonics and power factor, etc.) as per IEC 519, IEC 61000, IEC 62586, IEEE, CEA, Grid Code regulations.

5.1.2.9 Insulation coordination between the electrical equipment and the protective devices shall be done in line with IS 3716.

5.1.2.10 Control supply of local panels of critical loads, air compressors, shall be provided with UPS.

5.1.2.11 Electronic cards of systems like UPS, battery charger, VFD, SCADA, Heater, control system, and all third-party systems and packages such as PLC/SCADA, shall be ISA-G3 compliant as per Std. S.71.04 with conformal coating provided.

5.1.3 Switchgear

5.1.3.1 All HT and LT breakers shall have numerical relays for protection, remote operation, and monitoring with LOTO provisions.

5.1.3.2 HT breakers shall be provided for motor ratings above 120 kW. Motors rated above 55 kW and up to 120 kW shall be controlled through ACB and motor protection relay and shall be fed from PCC. (Not applicable to the 250 kW scope unless motors above 55 kW are proposed.)

5.1.3.3 The main LV board, MCCs and lighting distribution boards shall be single bus-section with a single incomer. Automatic changeover shall be provided only on the essential services board (BPC/DG) and through the fire pump transfer switch.

5.1.3.4 HT and LT breakers and LT modules shall be of metal-clad and draw-out type.

5.1.3.5 All HT and LT incomers shall have Tri-Vector Energy Meter and/or net metering with interfacing provision for metering purposes as per CEA/CERC guidelines.

5.1.3.6 The switchgear room floor shall have an electrical insulation coating of 33 kV and 415 V in accordance with IEC/ISO standards.

5.1.3.7 Bus-section feeder/circuit breakers shall have rating whichever is higher of the maximum connected load or bus-bar current rating.

5.1.3.8 Incomers of these switchgears shall be designed to cater to the complete load including 20% margin for future load growth.

5.1.3.9 Electrical running loads shall be uniformly distributed on each bus, and running and standby loads shall be fed from separate feeders.

5.1.3.10 HT Switchgear shall comply with IEC 62271-200, IEC 60470, and equivalent Indian standards.

5.1.3.11 Short circuit calculations shall be based on IEC 60909 / IS 13234.

5.1.3.12 All PTs shall be provided with additional Open Delta Tertiary winding with damping resistor.

5.1.3.13 Earth fault protection shall be provided with CBCT for providing sensitive E/F protection.

5.1.3.14 Each MCC shall be fed by a single incomer with a four-pole breaker.

5.1.3.15 Minimum 20% spare feeders or one no. of each rating and type on each side of the bus section whichever is more shall be provided.

5.1.3.16 All motors feeders rated above and including 15 kW and upto 55 kW shall be controlled through switch fuse unit, contactor, overload relay with CBCT, ELR for earth fault protection & shall be fed from MCC.

5.1.3.17 All TPN switch fuse feeders rated 250 A and above shall be provided with ammeter. All emergency / critical drives, irrespective of ratings, shall be provided with an ammeter.

5.1.3.18 All Bus incomer breakers up to the PCC level shall be provided with the Under Voltage Tripping protection with time graded for various voltage levels.

5.1.5 Bus Duct

5.1.5.1 HV bus duct shall be phase segregated type, and MV and LV bus duct shall be non-phase segregated type with support structure of galvanized iron.

5.1.5.2 Bus bar material shall be electrolytic aluminium / copper with flexible expansion joints.

5.1.5.3 Bus insulators shall be non-hygroscopic, non-inflammable, and flame-retarding type.

5.1.6 Motors

5.1.6.1 All motors shall have class F insulation with temperature rise limited to class B.

5.1.6.2 Microprocessor-based variable speed drives shall be communicable type and able to communicate with PLC / SCADA / DCS.

5.1.7 Transformers

5.1.7.1 Transformer rating shall suit 20% spare capacity (for power distribution and lighting). No standby transformer is required. For the 250 kW scope, one 33/0.415 kV distribution transformer of indicative rating 600-700 kVA shall be provided; the final rating shall be confirmed by the Bidder's load calculation.

5.1.7.2 Distribution transformers up to 2 MVA shall comply with IS 1180 part-1 minimum level 3.

5.1.7.3 Less than 1000 kVA: oil-filled hermetically sealed type or dry type (if indoor) and 1000 kVA & above: oil-filled conservator type.

5.1.7.4 Firewall shall be provided between the transformer and the DG set where the required separation distance cannot be achieved.

5.1.7.5 A diesel generator (DG) set shall be provided to supply the essential services board and the fire pump. It shall be sized by the Bidder, derated for site altitude (approximately 2,200 m) and ambient conditions, to (a) carry all essential loads continuously, and (b) start and run the fire pump with the essential loads connected, with voltage at the fire pump motor not less than 85% of rated voltage during starting, as per NFPA 20. Indicative rating: 125–160 kVA (prime rating). Fuel storage shall be sufficient for a minimum of 8 hours at full load. The DG set shall have an acoustic enclosure, comply with applicable emission norms, and be located outside hazardous areas with a bunded fuel tank and exhaust spark arrester. The electrolyser and hydrogen compressor shall not be connected to the DG set.

5.1.7.6 An essential services board shall be provided, fed from the main LV board and the DG set through an automatic mains failure (AMF) panel with automatic changeover and electrical and mechanical interlock to prevent parallel operation. The essential services board shall supply the UPS system, hydrogen dispenser, pre-cooling chiller, ventilation fans for enclosed hydrogen areas, and essential lighting.

5.1.8 Cables

5.1.8.1 Minimum size of high voltage cables shall be based on short circuit withstand capacity for a minimum time of 0.25 sec with backup protection in line.

5.1.8.2 Selection of cables shall comply with IS, NFPA, IEC standards and be suitable for hazardous areas. Fire protection for cables shall be provided as per IS 12459.

5.1.8.3 Only screened type signal cables are to be considered in VFD applications.

5.1.8.4 All HV cables shall be with stranded aluminium conductor, dry cured XLPE insulated, insulation screened, PVC inner sheathed, armoured, and FRLS PVC outer sheathed.

5.1.8.5 All LV power cables shall be with stranded aluminium / copper conductor, XLPE insulated, PVC inner sheathed, armoured, & FRLS PVC outer sheathed. Copper conductor shall be used for sizes up to and including 10 sq. mm, and for higher sizes aluminium conductor shall be used, except in hazardous areas and for motor and fire pump circuits, where copper conductors shall be used irrespective of size.

5.1.8.6 All control cables shall be XLPE, armoured type with copper conductors, FRLS PVC outer sheath, twisted pair, overall shielded type.

5.1.8.7 All control wiring in the panel shall be XLPE with copper conductors, FRLSH.

5.1.8.8 All power and control cables shall be in single continuous lengths without any splices or intermediate joints. In no case shall the joint be located in a hazardous area.

5.1.8.9 All incoming cables to switchgear/UPS/DC system/DBs and other equipment shall be sized with additional capacity of 10% and cable for capacitor banks shall be sized for 135% of the rated capacitor current.

5.1.8.10 Copper cables shall be used in UPS ACDB & ACDB to downstream distribution systems.

5.1.8.11 Cables installed in aboveground enclosed areas shall be fire retardant and have non-propagating, self-extinguishing characteristics in accordance with IEC 60332 and IS 10810 Part 61-64.

5.1.8.12 Separate cables shall be provided for AC and DC signal/control circuits.

5.1.8.13 All cables shall carry cable tag numbers for easy identification.

5.1.8.14 Signal cables (Instrument, communication, fire alarm, LAN, and data highway, etc.) shall preferably not be laid in the same trench/tray along with electrical cables. If laid in the same trench/tray, a clearance of minimum 300 mm from electrical cables shall be provided. GI earth strip of earthing grid shall run along the cable trays.

5.1.8.15 GI conduits shall be used between trenches and field equipment like motors, control stations, etc.

5.1.8.16 Lighting cables shall be run along the structures/cables, buried between cable rack and equipment using conduit.

5.1.8.17 All cables (HV and LV) shall be laid in concrete cable trenches with cable trays.

5.1.8.18 Fireproof coating shall be applied to cables passing through the electrical storeroom/battery bank room.

5.1.8.19 HT cable metallic screen SC rating shall be minimum 1 kA for 2 sec of individual core.

5.1.9 DC System

5.1.9.1 Independent DC power supply system shall be provided for the following (unless otherwise specified):
a. Electrical Switchgear controls.
b. DC critical lighting and DC critical drives.

5.1.9.2 Each DC power supply system shall include battery bank, charger-cum-rectifier, and DC distribution board. A single battery charger with charger-failure alarm to SCADA is acceptable. Alternatively, the 33 kV RMU may be provided with self-powered protection relays.

5.1.10 UPS System

5.1.10.1 Uninterrupted power supply system shall be provided for critical loads that cannot withstand a momentary interruption in voltage (e.g., critical instrumentation, control, Human Machine Interface (HMI) for numerical relays, fire alarm, LAN system, etc.) with a minimum battery backup of 30 minutes.

5.1.10.2 One UPS system of redundant configuration (2 × 100%) shall be provided, with static bypass, maintenance bypass and fault alarms to SCADA. The UPS rating shall be determined by the Bidder's load calculation, including a design margin, and submitted for DoE approval. Battery shall be Ni-Cd type (low-maintenance), with a design life of not less than 15 years, installed in a battery room with ventilation designed as per IEC 62485-2. The UPS shall supply, as a minimum, the following loads:

a. PLC, safety PLC/ESD system and associated I/O cabinets;

b. Gas leak, flame, smoke and heat detection and the fire alarm system, including control panels and field detectors;

c. ESD solenoid valves and field instrument power supplies;

d. SCADA servers, operator and engineering workstations, and the energy management system (EMS);

e. Electrolyser, compressor, dispenser and chiller package control systems (control electronics only);

f. Gas chromatograph / spectrometer;

g. Dispenser metering and control electronics;

h. Network equipment, firewalls, routers and GPS clock;

i. CCTV and access control systems;

j. Public address, telephone and emergency communication systems;

k. Emergency and escape lighting in the control room, switchgear room and escape routes.

Process and motor loads (electrolyser stack and rectifier, compressor motor, chiller compressor, pumps, fans and HVAC) shall not be connected to the UPS.

5.1.10.3 UPS system shall be provided with ACDB with 100% redundancy of feeders on each section.

5.1.10.4 Surge Protection Device (SPD) shall be provided in all outgoing feeders.

5.1.10.5 Bypass (SCVS) input supply of both UPS systems shall be from the common source so that 110 VAC output of both UPS systems remains synchronized, and synchronized (no-break) transfer (<4ms) can be achieved at downstream ATS in case of failure of running/preferred source of the ATS.

5.1.10.6 All incoming power supply sources to the UPS system (UPS-1 / UPS-2 / Bypass) shall not fall on the same power source.

5.1.10.7 UPS system shall be sized to have at least 20% additional capacity with 20% additional feeders.

5.1.11 Earthing and Lightning System

5.1.11.1 Design shall conform to IS:3043 2018 and lightning protection to IS/IEC: 62305, OISD-0180, and Code of Practice for Electrical Wiring Installations IS 732:2019.

5.1.11.2 All conductors of main grids should be strictly exothermic welded for better performance and there should be no porosity in joints. Exothermic welding to be as per IEE837 standard and should be UL Listed.

5.1.11.3 For copper strips, only exothermic welding is allowed; no brazing. For MS and GI strips, exothermic welding shall be carried out.

5.1.11.4 All electrical equipment operating above 110 volts shall have two separate and distinct connections to earth grids. A separate earthing grid shall be provided for instrument, control system, and electrical power. Separate earthing shall be provided for transformer neutral.

5.1.11.5 UPS, DCS, PLC, and other electronic instruments, including electronic relays, shall be provided with copper plate clean earth and kept galvanically isolated from the system and safety earthing.

5.1.11.6 Smart online earthing measurement system.

5.1.11.7 Lightning protection shall be designed according to the Lightning Protection Level-I (LPL-I), as per IS IEC-62305 and OISD-STD-180. All components shall be tested as per IEC 62561.

5.1.11.8 Tanks, piping, process vessels, and equipment containing flammable liquids or gas shall be earthed by a connection to the earth network, or by bonding to an earthed metal structure.

5.1.11.9 Surge protection shall be designed based on IEC 61643 with type-1 SPD.

5.1.11.10 Static electric discharge system shall be installed at all hydrogen locations (electrolyser, compressor, dispenser, storage cylinder, and control and equipment room). Static electric discharge system shall have a dedicated earthing system.

5.1.12 Air-conditioning System

5.1.12.1 Adequate air conditioning system shall be provided for the complete set-up including office, conference rooms, equipment rooms, switchgear.

5.1.13 Lighting System

5.1.13.1 Lighting levels throughout the plant shall comply with hazardous area working conditions of NFPA and IEC standards. It shall also comply with IS 3646:1992 or latest.

5.1.13.2 LED fixtures with anti-glare shall be provided for outdoor and indoor lighting. They shall comply with hazardous area requirements.

5.1.13.3 Separate emergency lighting shall be provided for the complete hydrogen fuelling station.

5.1.13.4 Exit light fixtures shall be provided in ingress pathways and exit doors of all locations with a dedicated power source.

5.1.13.5 Adequate number of self-contained portable hand lamps and battery-operated emergency lighting units shall be provided for immediate use in buildings where no DC supply is available.

5.1.13.6 Lighting system shall consist of lighting transformers, lighting distribution boards (LDBs), lighting and power panels, fixtures, junction boxes, etc. Outdoor lighting shall be operated based on synchronous timer/photoelectric cell with manual overriding.

5.1.13.7 Lighting distribution boards shall have a single incomer; emergency and escape lighting shall be fed from the UPS. A minimum of 20% MCB outgoing feeders shall be left as spare in all lighting and power panels.

5.1.13.8 Lighting and power panels shall be provided with MCB and ELCB as incomer, and Miniature Circuit Breakers (MCBs) for outgoing feeders control and protection of lighting circuits.

5.1.13.9 All DB/JB/fixtures for emergency lighting and critical lighting shall be colour-coded for distinct identification.

5.2 Mechanical Equipment

5.2.1 Mechanical Equipment

5.2.1.1 All piping along with structure and equipment shall be designed considering dynamic operation, wind loading, and seismic analysis.

5.2.1.2 Welding and brazing qualification shall be as per ASME BPV Sec. IX.

5.2.1.3 All couplings and exposed rotating parts shall be provided with adequate protection guards.

5.2.1.4 Noise level of running equipment shall not exceed 85 dBA at 1 m distance from the source unless otherwise specified.

5.2.1.5 Corrosion allowance for carbon steel vessels shall be minimum 3 mm unless otherwise specified.

5.2.1.6 All components and equipment shall meet the requirements of the respective hazardous area classification.

5.2.1.7 Compression system shall be mounted on the foundation in a closed enclosure (firewall) with proper noise insulation and well ventilated.

5.2.1.8 Hydrogen storage system shall be provided with a well-ventilated shed having a light roof with louvers with at least two sides open. Safe weather protection over gaseous hydrogen storage systems shall conform to CGA PS-46 provisions.

5.2.1.9 Container or closed civil infrastructure shall have both active and passive ventilation systems to avoid accumulation of hydrogen.

5.2.1.10 Hydrogen dispensing system shall be provided with a separate roof covering dispenser and FCEV buses on both sides.

5.2.1.11 All underground vessels, tanks, and piping shall be provided with galvanic/cathodic protection.

5.2.1.12 Non-Destructive Examination (NDE) shall be performed as per ASME BPV Sec. V.

5.2.1.13 Layouts for oil and gas installations and safety requirements shall be as per OISD-118.

5.2.1.14 All flange joints on piping systems, including flanges on equipment and manholes, shall be tightened using hydraulic bolt tensioners. Fastener bolting nuts shall be marked for tightness confirmation.

5.2.1.15 Hot and Cold Insulation

a. Materials shall be based on recommendations of standard specification for hot insulation of vessels, piping, and equipment of OEM.
b. When operating temperature is below 20 °C, pipes shall be wrapped with aluminium foil or SS foil (in case of SS lines) prior to applying insulating materials.
c. All pipes (except SS pipes) shall be coated with zinc silicate coatings (below 120 °C) or silicon aluminium (above 120 °C). No painting shall be done on SS lines.
d. Only aluminium cladding sheets shall be used for pipelines and equipment.

5.2.1.16 All items shall be marked (stamped/etched) in accordance with the applicable code/standard/specification along with the item code/tag number.

5.2.1.17 Compressed hydrogen storage cascade shall be designed such that cylinders are easily removed from the cascade for periodic testing.

5.2.1.18 All pipes shall have isolating valves at both ends for each system.

5.2.1.19 Piping schedule, route, and isometric drawings are to be provided well before the start of work.

5.2.2 Piping/Tubing

5.2.2.1 Piping/tubing in gaseous service and pipelines in gaseous hydrogen service shall comply with ASME B31.12:2019 standard with minimum stainless-steel material. It shall also conform to ISO 15649.

5.2.2.2 All piping/tubing must be labelled as per ANSI/ASME A13.1 standard. Associated items such as valves, check valves, and filters must be tagged legibly for quick identification.

5.2.2.3 Piping/tubing shall be cleaned as per ASTM G93/G93M-19 standard on the oxygen side before commissioning/service.

5.2.2.4 Flexible hoses used for hydrogen delivery shall conform to ISO 16964 and IECEx testing requirements.

5.2.2.5 All piping systems shall be hydro tested at 1.5 times the design pressure subject to Indian Boiler Regulation-1950, Regulation 374 or ASME B31.12:2019. For systems where hydro testing is impractical, tests as per ASME B31.1:2022 in lieu of hydro test shall be acceptable.

5.2.2.6 All fitting and component manufacturers shall comply with EC-79 / ISO 12619 / UN ECE R134 or equivalent standards.

5.2.2.7 Piping used for DM Plant and DM water shall be stainless steel with a minimum grade of 304.

5.2.2.8 All vents shall be routed to a safe area such that vented gas is blown away from the nearest building. Height of vent shall be minimum 5 m above ground level. Distance between vent and fence shall be minimum 5 m from at least three sides. Venting shall conform to CGA G 5.5 specification.

5.2.2.9 Separate venting systems shall be provided for electrolyser, compressor, storage, and dispenser. Flame arrestors with temperature transmitters shall be installed at all vent points. NFPA-2 Hydrogen technologies compliance shall be followed.

5.2.2.10 Piping shall be suitably supported to avoid vibrations and shall be designed so that forces and moments imposed on the compressor do not exceed OEM recommendations.

5.2.2.11 All carbon steel pipes and fittings with wall thickness ≥19 mm shall be post-weld heat treated (PWHT). Alloy steel (Cr-Mo) pipes/fittings shall be PWHT irrespective of weld type or thickness. All austenitic stainless-steel grades shall be solution annealed after welding. 100% radiography of welded joints shall be done before and after PWHT.

5.2.2.12 All hoses shall be clearly marked with service and working pressure at both ends. Hoses shall be resistant to ageing, abrasion, and suitable for outdoor installations. Complete hose assemblies shall be tested at two times the design pressure.

5.2.2.13 Use of adapters or unions shall be avoided. Where unavoidable, approval from DOE is required prior to installation. Length of high-pressure tubing/piping shall be maximized, and smaller tubing/piping fittings shall be avoided.

5.2.3 Valves and Tanks

5.2.3.1 All valve castings shall be of radiographic quality. Valves shall comply with ASME SEC-VIII, DIV.1, ASME SEC-V, and ASTM standards.

5.2.3.2 All solenoid valves, control valves, and critical manual valves shall have feedback mechanisms for status monitoring locally and remotely.

5.2.3.3 The system shall include necessary connections with proper isolation devices, valves, regulators, manifold piping, cylinders, trollies, and canopies to enable purging/flushing with nitrogen during commissioning and maintenance.

5.2.3.4 Supply and maintenance of adequate nitrogen gas for emergencies.

5.2.3.5 All storage tanks shall be designed based on API 620 and API 650. DM water tanks shall be stainless steel and suitable for saline atmosphere.

5.2.3.6 Nozzle flanges up to 600 NB shall be per ASME B16.5; above 600 NB, ASME B16.47 (Series B) shall be used.

5.2.3.7 Filter housings shall comply with ASME Section VIII, Div.1.

5.2.3.8 Vents connected to tanks storing liquid for heat transfer in hydrogen applications shall be provided with H2 leak detectors. H2 leak detectors shall be installed at all vents connected to secondary circuits of heat exchangers.

5.2.3.9 Firefighting system shall comply with NFPA standards. The fire water pumping system shall comprise one electric main fire pump and one electric jockey pump. The main fire pump shall be fed from the main LV board and the DG set through a listed fire pump controller with automatic transfer switch, using fire-survival cables, as per NFPA 20.

5.2.4 Platforms and Pipe Racks

5.2.4.1 Proper canopies and ramp protection shall be provided at appropriate locations.

5.2.4.2 Platforms, ladders, and stairways shall be consistent with access and safety requirements.

5.2.4.3 Platforms shall be provided with stair access for normal monitoring activities.

5.2.5 Rotating Equipment

5.2.5.1 Hydrogen compressors shall be located under a shed with provisions for top venting from compressor sheds.

5.2.5.2 Compressors shall comply with API 617 / 618 / 619. Mechanical run tests shall be performed at OEM works before dispatch, and reports submitted to DoE,MoENR.

5.2.5.3 Hydrogen compressor health monitoring system (vibration, temperature, etc.) shall be integrated into the PLC system.

5.2.5.4 Belts for equipment located in hazardous areas shall be static non-conducting type and suitably certified for the area classification.

5.2.5.5 Separate air compression facilities shall be provided for instrument air and service air for maintenance and FCEV requirements.

5.2.5.6 Air compression facilities shall include auto and manual drain systems.

5.2.5.7 Pumps for firewater applications shall be direct-coupled.

5.2.5.8 All reciprocating pumps in the water system shall comply with API 674/675. Pulsation suppression and dampeners shall be provided.

5.2.5.9 Positive displacement rotary pumps shall comply with API-676 and be suitable to run simultaneously at the pressure-limiting accumulation pressure and at trip speed without damage.

5.2.5.10 Pumps and fans serving critical duties shall have 100% standby, namely process cooling pumps for the electrolyser and compressor, and ventilation fans for enclosed hydrogen areas (compressor enclosure and electrolyser container). Other pumps and fans do not require standby.

5.2.6 Heat Exchangers

5.2.6.1 Thermal design shall be performed using HTRI or HTFS methods/software. Air-cooled heat exchangers shall comply with API 661.

5.2.6.2 All heat exchangers shall be hydrostatically tested and certified at OEM works in compliance with ASME Boiler and Pressure Vessel Code Section VIII and TEMA.

5.2.6.3 All plate-type heat exchangers shall be designed as per ASME Code Section VIII, Div. 1, and TEMA.

5.2.6.4 Air-cooled heat exchangers shall have minimum thickness as per API 661.

5.2.6.5 Fins of heat exchangers shall be coated to prevent rusting or atmospheric damage.

5.2.7 Safety Valves

5.2.7.1 CHG cylinders fitted with safety relief devices or pressure relief devices shall have such devices manufactured and maintained in accordance with IS: 5903, CGA S-1.1, CGA S-1.2, CGA S-1.3, and UN R-134 code.

5.2.7.2 All safety valves shall be ASME UV code stamped.

5.3 Instrumentation

5.3.1 Instrumentation System

5.3.1.1 Instrumentation system shall be designed based on Safety Instrumented System (SIS) requirements. Safety Integrity Level (SIL) assessment shall be performed on the complete instrumentation and control system of the project.

5.3.1.2 All instrumentation in safety/interlock loops shall comply with IEC 61508 and 61511 and meet SIL assessment requirements.

5.3.1.3 Instrumentation and control systems shall comply with API RP-551, 552, 554, 555 or EN 334, EN 14382, as applicable.

5.3.1.4 All transmitters/instruments shall be intrinsically safe and certified for use in the specified hazardous area classification by recognized authorities such as CMRS, FM, CENELEC, PTB, BASEEFA, etc.

5.3.1.5 PLC systems with redundant power supplies, CPU, and communication shall be SIL-2. Standalone ESD systems shall be SIL-3. Solenoid valves shall be IS type with 24 V DC operation and SIL-3 certified minimum.

5.3.1.6 All intrinsically safe and explosion-proof instruments, analyzers, and accessories shall be approved by CCoE and PESO.

5.3.1.7 Instrumentation shall be electronic type; only final control elements shall be pneumatic.

5.3.1.8 Performance Track Record (PTR) for all field instruments and for system/subsystem (including PLC/SCADA) shall be a minimum of 4000 hours.

5.3.1.9 All equipment shall meet ECR/EMC technical requirements of IEC 61000, IEC 61326, and IEEE C37.90.

5.3.1.10 Instrumentation system shall have two independent sources; instrument cubicles shall be dual-fed with redundant PSUs wired in hot standby mode.

5.3.1.11 2-out-of-3 (2-O-O-3) voting configuration shall be used for all input signals to ESD/SIS.

5.3.2 Environmental Protection

5.3.2.1 All instruments and equipment shall be suitable for the project's climatic conditions.

5.3.2.2 All instruments, junction boxes, pushbutton stations, control cabinets, panels, and field enclosures shall be intrinsically safe (IS) type, dustproof, weatherproof (IP65 or NEMA 4X), and secure against fumes, dampness, insects, and vermin.

5.3.2.3 All panels, distribution boards, junction boxes, pushbutton stations, control cabinets, and instruments in hazardous zones shall be flameproof and explosion-proof, compliant with ATEX and IECEx directives.

5.3.2.4 Field instruments (except for H2 service) shall be suitable for Zone-I, Gr. IIA/IIB, T3.

5.3.2.5 Field instruments for hydrogen service (compressor, storage, dispenser) shall be suitable for Zone-1, Gr. IIC, T3 minimum.

5.3.2.6 Analyser enclosures shall be suitable for Zone-1, Gr. IIC, T3 or as per individual hazardous area classification.

5.3.2.7 Instrument enclosures shall have dual compartments providing metallic isolation between electronics and terminal compartments.

5.3.2.8 All instrument wetted parts shall be SS 316 minimum. Electronic housings shall be epoxy-coated die-cast aluminum. For gas detectors or instruments in toxic/corrosive environments, SS housings shall be used.

5.3.3 Instruments

5.3.3.1 Dedicated online mass flow meters (Coriolis type) shall be provided in each stream of the compressor and dispenser.

5.3.3.2 For all hydrogen applications, transmitter diaphragms shall be gold-plated on SS 316L. Gold plating thickness shall comply with ASTM or process requirements, whichever is higher.

5.3.3.3 Pressure transmitters shall constantly monitor system pressure. If pressure exceeds limits, hydrogen production shall stop and the system shall be put in standby.

5.3.3.4 All transmitters shall be intrinsically safe, SMART type, with HART protocol, integral LCD indicator, test terminals, and bypass diode.

5.3.3.5 Field transmitters shall be used instead of switches; all PLC/SCADA inputs shall be via field transmitters.

5.3.3.6 Proper approaches or platforms shall be provided for all locally mounted gauges. Field-mounted instruments shall be close-coupled (post-mounted if close-coupling is not feasible).

5.3.3.7 Thermowells and orifice plates shall be made of SS 316 minimum. Standard type orifice plates shall comply with ISO 5167.

5.3.3.8 All remote-mounted instruments, including those connected to lines or vessels via flush or remote diaphragm seals (e.g., transmitters, switches), shall be SS 316 minimum unless process conditions require a more suitable material.

5.3.3.9 For dispensers, instruments shall have a feature for switching off pressure and temperature compensation.

5.3.3.10 For liquid level applications, remote diaphragm seal type smart level instruments shall be used with local indicators.

5.3.3.11 Double isolation type root valves shall be provided for hydrogen applications above 40 bar and for other applications above 60 bar.

5.3.3.12 Temperature transmitters shall be remote-mounted type, dual-channel, dual-sensor, dual-compartment, smart transmitters with HART bus protocol, integral output meter, burnout protection, and auto-changeover. These shall be used for all temperature measurements unless otherwise infeasible.

5.3.3.13 DM plant and all corrosive service shall use non-contact type level instruments.

5.3.3.14 All critical parameters such as pressure, temperature, flow, and levels shall have both local and remote indications. All critical parameters for operation and emergency shutdown of the station or individual equipment shall have 100% redundancy in instruments.

5.3.4 Control Valves

5.3.4.1 Control valves shall be sized as per IEC / ISA 75.01. Each valve trim shall be constructed from SS 316 unless stated otherwise.

5.3.4.2 All control valves shall meet predicted aerodynamic/hydrodynamic noise levels in compliance with IEC 534-8-3 and IEC 534-8-4.

5.3.4.3 All control valve actuators shall be provided with SMART positioners, complete with air sets with 5-micron filters and capable of transmitting full diagnostic and predictive maintenance data to PLC/SCADA.

5.3.4.4 All ESD and depressurizing valves shall be pneumatically operated and compatible with process material, temperature, and pressure. SIL 1/2 rated valves shall be provided.

5.3.4.5 All valves shall be subject to NDE/NDT in accordance with ASME B16.34.

5.3.5 Analyser, Gas Chromatograph (GC), and Spectrometry (SM)

5.3.5.1 Analyzer systems shall comply with IEC 61000. Certification from statutory authorities such as BASEEFA, FM, PTB, CENELEC for imported items, and from CMRI, ERTL for domestic items, shall be provided.

5.3.5.2 Complete assemblies shall be mounted on free-standing easel-type frames with overhead rain/sun protection and clearance.

5.3.5.3 Minimum sampling points shall be provided at the outlet of each electrolyser (H2 and O2), each compressor, and inlet to the dispenser.

5.3.5.4 GC and SM-based analyser systems are required for continuous display/recording of hydrogen purity, oxygen content (ppm), moisture content (ppm), nitrogen (ppm), argon (ppm), and other components as per SAE J2719 / ISO 14687.

5.3.5.5 Minimum detection limit of the analyser, GC, and SM shall be below the maximum admissible value specified in SAE J2719 / ISO 14687 with valid certification.

5.3.5.6 GC and SM systems shall include complete sets of analysers, sampling systems, sample-conditioning systems, internal power supplies, cabling, and inter-piping.

5.3.5.7 GC and SM systems shall have redundant power supply and communication to PLC/SCADA.

5.3.5.8 Moisture measurement technology shall use TDLAS.

5.3.6 Tubing and Fittings

5.3.6.1 All fittings shall comply with EC-79 or better latest standards.

5.3.6.2 Tubing shall be SS material, seamless, with minimum 2.5% molybdenum and carbon content <0.03%. Wall thickness tolerance ±10%. Testing shall follow DIN/NFA/ASTM/EN standards.

5.3.6.3 Fittings shall be SS with minimum 17% chromium, 12% nickel, and carbon content <0.05%. All components shall be of the same material and etched. Fittings shall have a two-ferrule grip design. Testing shall follow DIN/NFA/ASTM/EN standards.

5.3.6.4 Air distribution main header and all instrument air/N2 piping shall be SS304 minimum with tapping as per API standards.

5.3.7 Instrumentation Cable

5.3.7.1 All instrumentation cables shall be individually shielded, FRLSH, and armoured.

5.3.7.2 All cable glands shall be 304 SS, double compression type, flameproof with Ex(d) certification, and suitable for armoured cables with PVC shrouds.

5.4 Integrated Control System (ICS)

5.4.1 ICS shall comprise the following components at minimum:

5.4.1.1 Controllers capable of performing algorithms and logics for analogue control, sequences, and interlocks during startup, shutdown, and normal continuous operation.

5.4.1.2 HMIs for operators to monitor and perform control actions as required.

5.4.1.3 Servers facilitating access to real-time live data and processed/stored data for operations, maintenance, and corporate needs.

5.4.1.4 Network printers (colour, multi-function) compatible with A3 and A4 paper sizes.

5.4.1.5 Input/output cards with racks, communication processors, and power supplies interfacing with field devices.

5.4.1.6 Cabinets to house electronic components with accessories for power/signal conditioning (MCB/MCCB, distribution, converters, barriers, surge protection), and cable termination/dressing. Cabinets for ICS components shall be ex-proof/flame-proof.

5.4.1.7 Communication interfaces for field-level package systems and data exchange to the data layer.

5.4.1.8 Network infrastructure with firewall and cybersecurity complying with IEC 62443. Third-party certification shall be provided.

5.4.1.9 Software for performing control, monitoring, configuration, and maintenance functions.

5.4.1.10 Shutdown-related inputs shall be hardwired from the local emergency pushbuttons.

5.4.2 PLC and SCADA

5.4.2.1 All plant and equipment interlocks shall be executed through PLCs which shall communicate to SCADA/DCS through redundant direct bus connectivity (preferred) or Modbus protocol.

5.4.2.2 DMR SIL2 PLC system and architecture shall be used for each compressor, dispenser, and safety system for executing trips/interlocks.

5.4.2.3 DMR PLCs can also be used for chillers, cooling towers, utilities, etc.

5.4.2.4 Maximum loading of the processor shall not exceed 50%, including all installed spares.

5.4.2.5 PLC-based SCADA for overall control of the hydrogen fuelling station shall be provided. SCADA shall be able to acquire real-time data from identified equipment. The SCADA should have a historian and be capable of storing at least one year of data.

5.4.2.6 PLC and SCADA shall be integrated with an Energy Management System (EMS) to enable real-time monitoring, operation, control, and reliable, efficient performance of the hydrogen fuelling station.

5.4.2.7 EMS with PLC/SCADA shall provide facilities for scheduling electrolyser and compression system operations:
a. Auto start/stop based on scheduled generation/time of day (ToD) or both.
b. Ramp up/ramp down loading based on scheduled renewable energy generation or actual RE generation.
The required algorithm for the above provisions shall be finalized during the engineering stage.

5.4.2.8 Dedicated EMS shall monitor all electrical equipment status, energy flow, fault monitoring, and provide reporting features.

5.4.2.9 Selected data shall be made available to central offices located anywhere in Bhutan through secured web-based clients or other means with proper authentication.

5.4.2.10 PLC/SCADA system shall have provision for interfacing with the dedicated Server (Data Acquisition System). Provision for OPC (OLE for Process Control) protocol and facility is required for any third-party interface and for remote operation of the hydrogen fuelling system.

5.4.2.11 SCADA shall provide real-time reporting of alarms and statistical data via SMS and email. Dedicated internet connectivity shall be provided for the control system.

5.4.2.12 SCADA shall interface with Zone-1 for equipment outside hazardous zones, or Zone-0 if equipment is located near hydrogen sources.

5.4.3 Control System

5.4.3.1 The control room shall enable monitoring and control of the entire hydrogen fuelling station without manual intervention and include a Personnel Area Monitor (PAM) system to continuously measure O_2 and H_2 gas with alarm annunciation for low (19.5%) and enriched (23.5%) O_2 atmosphere.

5.4.3.2 All PLC/CPU shall have 100% redundancy along with power sources. The complete process, with all relevant parameters, shall be monitored and controlled by microprocessors with hot-standby CPU modules for seamless changeover.

5.4.3.3 Power system and control system equipment shall be designed and tested for cybersecurity as per National Cybersecurity-Strategy, GovTech 2025.

5.4.3.4 Control system shall be configured for remote monitoring with all required infrastructure, internet facilities, web interface portal with GUI, and secured access.

5.4.3.5 Bidder shall provide one industrial-grade laptop (minimum 15-inch display) with latest generation, including licensed PLC/SCADA software, relays, antivirus, firewall with latest patches.

5.4.3.6 In case of microprocessor malfunction or emergency, the unit shall shut down immediately. Safety devices protecting microprocessors from power disturbances shall be provided. The system shall withstand electrical surges and wide voltage variations.

5.5 Safety Systems and Studies

5.5.1 General Safety Systems

5.5.1.1 Adequate safety systems shall be installed for continuous monitoring and ensuring personnel and equipment safety. Certification/calibration dates shall be displayed on equipment.

5.5.1.2 Emergency pushbuttons shall be provided at key locations (HOS Room, Control Room, Switchgear MCC, Electrolyser, Compressor, Dispenser, Security, Transformer) for emergency isolation and system shutdown.

5.5.1.3 Temperature and humidity sensors along with air quality sensors (e.g., CO_2 loggers) shall be installed inside office-cum-switchgear building rooms.

5.5.1.4 The hydrogen station shall include protection systems to safely trip/shutdown the station locally and remotely (Area Isolation System-AIS) in emergencies. The AIS shall be hardwired to isolate the entire H_2 system.

5.5.1.5 Minimum two 65-inch LED screens shall be provided in the office-cum-switchgear building (Conference Room, Control Room) for real-time parameter display.

5.5.1.6 Safety devices with 100% redundancy for critical signals shall be provided for safe hydrogen release, pressure control, etc.

5.5.1.7 Hydrogen leak detectors (0–100% LEL), flame detectors, smoke detectors, heat sensors, and interlocks shall be provided with 100% redundancy. Alarms shall activate at 20% LEL, and equipment shutdown/interlock at 40% LEL.

5.5.1.8 The Bidder shall obtain all necessary regulatory approvals from PESO for equipment, components, storage, and hydrogen station layout**,** and the building permit from the local authorities**.** Any layout changes by the Bidder must be approved by the DoE before submission to PESO.

5.5.1.9 Hydrogen cylinders shall comply with Gas Cylinder Rules, 2016, amendments, and AIS 157:2020. All approvals for installed and operational systems shall be obtained by the Bidder within project timelines.

5.5.1.10 The following safety studies shall be carried out by the Bidder and others as mandated by statutory requirements.

5.5.1.11 Hazard and Operability Study (HAZOP) of the entire system (electrolyser, compressor, storage tubes, dispenser, etc.) prior to installation.

5.5.1.12 Fire and Gas mapping studies for gas, flame, and smoke detection devices per ISA standards.

5.5.1.13 Quantitative Risk Assessment (QRA), Hazardous Area Classification (HAC), Escape Muster, and Emergency Response Analysis (EMERA) as per ISO 14001 shall be carried out.

5.5.1.14 Hazard Identification Risk Assessment (HIRA) shall be conducted and submitted before trial operation completion.

5.5.1.15 The Bidder shall prepare, implement, and maintain a comprehensive Disaster Management Plan, including on-site and off-site emergency preparedness, drawings, and safety SOPs, for the entire facility during commissioning and operation, in compliance with all applicable laws and standards.

5.5.1.16 Proper operation of the hydrogen gas leak detection system (with 100% redundancy) shall be tested before starting trial operation using sample gas.

5.5.1.17 Gas leakage determination and ventilation shall comply with IEC/EN 60079 standards. Sensor response time shall be minimized.
a. Point detection and flame detection devices for confined spaces covering all operational areas (Compressor, Storage, Dispenser, GC/RS, etc.).
b. Ultrasonic leak detection devices for open spaces (Buffer Tank, Compressor, Storage, Dispenser, GC/RS, etc.).

5.5.1.18 Flame detection devices shall be installed at all locations (Buffer Tank, Compressor, Storage, Dispenser, GC/RS, etc.).

5.5.1.19 The Bidder shall provide portable ultrasonic hydrogen leak detectors with multiple cameras, LCD image display, and hazardous area compliance.

5.5.1.20 All high-pressure joints shall be welded and radiographed. Piping/tubing must maintain continuity to avoid static energy generation, with appropriate grounding/bonding provisions.

5.5.1.21 All major isolation and critical valves shall be installed to provide proper Lock-out/Tag-out (LOTO) provisions.

5.5.1.22 The complete system shall include all safety provisions required for safe hydrogen handling. The system shall be designed for safe operation with all control instruments, interlocks, alarms, etc., for normal and emergency start-up/shutdown. Any additional interlocks identified during design review, FAT, or SAT shall be incorporated.

5.5.1.23 All necessary instrumentation, isolation valves, and safety equipment (e.g., safety valves) shall be provided for safe pressure vessel operation.

5.5.1.24 Dedicated fire suppression devices (water sprinklers, hydrants, CO_2 flooding systems) shall be installed in compressor, storage, dispenser, and other H_2 service areas. Inert gas systems shall be provided in the control room and control equipment rooms, with automatic and manual operation.

5.5.1.25 Portable fire extinguishers (DCP, CO_2 cylinders, etc.) shall be installed at various locations as per PESO, IS, and NFPA guidelines.

5.5.1.26 The Bidder shall provide necessary safety gears, first-aid facilities for all employees, representatives, and workmen during project execution and for operation.

5.5.1.27 Safety signboards, evacuation routes, warnings, layouts, and MSDS instructions shall be displayed at appropriate locations.

5.5.1.28 Equipment shall be labeled with names, standard operating procedures, and emergency instructions.

5.6 Civil and Architectural Works

5.6.1 Design and Layout Consideration

5.6.1.1 Topographical survey and soil/geotechnical investigations shall be conducted at the site, and results used for civil works, building foundations, and layout design.

5.6.1.2 The hydrogen fuelling station complex shall have sufficient space, proper interior design, ventilation, lighting, temperature control, dust-free environment, and fire-fighting facilities.

5.6.1.3 All civil works shall comply with the Bhutan Building Regulation 2018, the Building Code of Bhutan 2018 and the Specifications for Building and Road Works of the Royal Government of Bhutan. RCC and steel structure design shall comply with IS 456 and IS 800, respectively, and seismic design with IS 1893 and IS 13920.

5.6.1.4 All RCC buildings and allied works shall meet NFPA, IEC, and relevant Bhutanese standards.

5.6.1.5 All the necessary meteorological data shall be collected from National Center for Hydrology and Meteorology, Bhutan for drainage and flood safety design.

5.6.1.6 Construct an RCC flood protection wall along the Wangchhu River bank with an approximate length of 160 meters and a height of 2.5 meters above the Reduced Bed Level (RBL), including a minimum scouring depth of 1.5 meters below ground level. The wall shall have a minimum thickness of 1.2 meters and shall be designed to withstand hydrological forces, erosion, and flood conditions. The wall shall be provided with four (4) railings for people to commute safely near the river.

5.6.1.7 Earthquake-resistant design shall comply with IS 1893-1 for foundations, structures, and facilities.

5.6.1.8 Basic wind speed provisions shall follow IS 875-3 for buildings and structures.

5.6.1.9 Corrosion protection painting shall comply with corrosive Category (C) as per ISO 12944-2.

5.6.1.10 RCC structures around storage cylinder cascades shall have 4-hour fire-resistant rating as per IS 1642 and comply with CCoE separation distances.

5.6.1.11 Excavation of foundation work, filling, and compaction shall be based on mother soil data.

5.6.1.12 Foundations for all equipment, buildings, and walls shall accommodate all loads, seismic, wind, and site conditions.

5.6.1.13 The entire fuelling station, including the hydrogen generation area, shall be paved with interlocking tiles with FGL of minimum 300 mm.

5.6.1.14 A 3D display board shall be provided at the top of the office building and main road. Billboard shall be provided at the main road.

5.6.2 Room-wise Requirements for RCC Building

5.6.2.1 Control room shall be designed for continuous operational use with ergonomic layout for operators, including space for control panels, SCADA systems, and monitoring equipment. It shall be air-conditioned with controlled temperature and humidity, provided with false ceiling, LED lighting, optional raised flooring for cabling, acoustic insulation, and provisions for data and communication systems. Fire detection and alarm system shall be installed. Indicative size: 5 m × 4 m (≈20 m²), subject to modification based on equipment layout and approval of DoE.

5.6.2.2 Switchgear room with UPS and electrical equipment shall accommodate switchgear panels, UPS systems, batteries, and associated electrical systems with adequate safety clearances. The room shall have heavy-duty anti-static and fire-resistant flooring, proper cable trenches and trays, forced ventilation or HVAC, dedicated battery area with ventilation for gas exhaust, earthing and lightning protection systems, and fire detection and suppression system. Access shall be restricted. Indicative size: 6 m × 5 m (≈30 m²), subject to revision based on equipment capacity and DoE approval.

5.6.2.3 Conference room shall be designed to accommodate 10–15 persons with adequate lighting, ventilation, and air-conditioning. It shall include acoustic treatment, provision for projector/display system, video conferencing facilities, and adequate power and data outlets. Indicative size: 6 m × 4 m (≈24 m²), subject to modification based on requirements and DoE approval.

5.6.2.4 Two toilets shall be provided with proper sanitation facilities including WC, wash basin, plumbing system for water supply and drainage, anti-skid flooring, water-resistant wall finishes, and exhaust ventilation. Provision for septic tank or sewer connection shall be included. Indicative size (each): 2 m × 1.5 m (≈3 m²), subject to revision based on design and DoE approval.

5.6.2.5 Kitchen shall be designed for basic pantry use with countertop, sink, storage cabinets, plumbing connections, electrical outlets for appliances, proper ventilation, and non-slip, easy-to-clean finishes. Indicative size: 3 m × 3 m (≈9 m²), subject to adjustment based on functional requirements and DoE approval.

5.6.2.6 Glazing Requirements for RCC Building

- Air-insulated (double) toughened glass shall be used in the RCC buildings as follows:
  a. All internal partitions of the office-cum-switchgear room shall be full glass partitions, except for switchgear and battery rooms.
  c. Fireproof glass suitable for shock resistance, radiation protection, and electrical safety shall be provided in switchgear rooms.

6. Testing, Commissioning and Acceptance Test

6.1 Scope

a) Covers Factory Acceptance Test (FAT), pre-commissioning, trial operation, and Performance Guarantee (PG) tests.
b) Applicable to the entire hydrogen fuelling station system from hydrogen generation to dispensing.
c) Includes electrolyzer system, hydrogen purification and drying system, compressor, buffer tank, storage system, sequential and priority panels, hydrogen dispensing system, nitrogen generation system, cooling systems, electrical systems, instrumentation, control systems, and all safety systems.
d) All the tests, including FAT, pre-commissioning checklist, trial operation and PG test must be recorded and verified by the Bidder and must be witnessed and approved by the DoE.

6.2 Objectives of Testing

a) To verify operational readiness and healthiness of all equipment in the hydrogen fuelling station.
b) To measure and validate guaranteed performance parameters as specified in the technical specifications.
c) To establish baseline operating parameters including pressure, temperature, flow rate, and power consumption for future reference.
d) To verify the performance of the electrolyzer system including hydrogen production rate, efficiency, and purity.
e) To ensure proper functioning of compressors, storage systems, and dispensing systems under operating conditions.
f) To validate operation of all safety systems including interlocks, alarms, emergency shutdown systems, and leak detection systems.
g) To ensure proper functioning of hydrogen purity measurement systems and analyzers.
h) To verify integrated operation of all subsystems under actual operating conditions.

6.3 Factory Acceptance Test (FAT), Pre-Commissioning, Trial Operation and Performance Guarantee Test

6.3.1 Factory Acceptance Test (FAT)

a) FAT shall be carried out for the complete hydrogen generation and fuelling system prior to dispatch from the manufacturer's works.
b) FAT shall be conducted in accordance with applicable international standards, codes, and guidelines including ISO, IEC, ASME, NFPA, CGA, and applicable national regulations.
c) FAT shall include inspection, functional testing, safety verification, and integrated system

testing.
d) Performance testing shall include continuous operation for 24 to 48 hours.

e) System-wise FAT requirements shall include but not limited to:

1. Electrolyzer System
i. Verification as per ISO 22734 and OEM specifications
ii. Hydrogen production rate, specific energy consumption, and efficiency
iii. Hydrogen purity verification using analyzers
iv. Start-up, shutdown, and load variation testing
v. Gas separation efficiency and oxygen venting verification
vi. Safety systems including leak detection, interlocks, and emergency shutdown
vii. Continuous operation test for minimum 24 hours

2. Hydrogen Compression System
i. Verification of compressor capacity, flow rate, and discharge pressure
ii. Measurement of power consumption and efficiency
iii. Verification of cooling system performance
iv. Functional testing of start/stop, load/unload, and interlocks
v. Safety testing including high-pressure and temperature trips
vi. Leak testing of high-pressure components
vii. Verification of vibration and noise levels

3. Hydrogen Storage System
i. Hydrostatic or pneumatic pressure testing
ii. Leak testing of cylinders, manifolds, and valves
iii. Verification of pressure relief devices including TPRDs
iv. Functional testing of isolation valves and instrumentation
v. Verification of cascade and priority panel logic

4. Hydrogen Dispensing System
i. Verification of flow rate, pressure control, and ramp rate
ii. Testing of pre-cooling system performance, demonstrating stable T20 delivery temperature at 2 kg/min
iii. Calibration and verification of mass flow meter accuracy
iv. Functional testing of dispenser control logic
v. Verification of nozzle, hose integrity, and breakaway coupling
vi. Safety testing including emergency stop and leak detection

5. Hydrogen Purification and Drying System
i. Verification of hydrogen purity as per specification
ii. Dryer performance including dew point measurement
iii. Analyzer calibration and accuracy verification

6. Nitrogen Generation System
i. Verification of capacity, pressure, and purity
ii. Functional testing of control system and alarms
iii. Continuous operation test for stability

7. Water Treatment System
i. Verification of output water quality as per electrolyzer requirements
ii. Measurement of conductivity and purity
iii. Verification of flow rate and recovery efficiency
iv. Functional testing of pumps and control systems

8.Electrical and Control System
i. PLC and SCADA logic verification
ii. Signal simulation and interlock testing
iii. Alarm and trip verification
iv. Verification of communication and system integration

9.Safety System
i. Gas leak detection system testing
ii. Fire detection and alarm system testing
iii. Emergency shutdown system verification
iv. Interlock and trip logic verification

6.3.2 Pre-Commissioning and Trial Operation

a) Pre-commissioning shall be carried out after installation and prior to trial operation.
b) Mechanical completion, alignment, and system integrity shall be verified.
c) Calibration of all instruments shall be completed using approved standards.
d) Electrical connections, earthing, and control wiring shall be verified.
e) Flushing, cleaning, and purging of pipelines using nitrogen shall be completed.
f) Functional testing of all equipment shall be carried out individually and in integrated mode.
g) All safety systems including interlocks, alarms, and emergency shutdown systems shall be tested.
h) Availability of utilities such as power supply, water systems, cooling systems, and instrument air shall be ensured.

6.3.2.1 Pre-Commissioning Checklist

a) A comprehensive system-wise checklist shall be completed prior to trial operation.
b) The checklist shall include verification of installation, instrumentation, safety systems, electrical systems, and utilities.
c) The checklist shall be jointly verified and signed by the EPC contractor and the owner.
d) Trial operation shall commence only after successful completion of the checklist.

e) Checklist of the system includes but not limited to:

Sl. No.	System	Checking Items	Status	Remarks	EPC Sign	DOE Sign
1	Safety Devices	a. Buffer Tank – H_2 Leak and Flame Detectors b. Compressor – H_2 Leak and Flame Detectors c. Storage Cylinders – H_2 Leak and Flame Detectors				

Sl. No.	System	Checking Items	Status	Remarks	EPC Sign	DOE Sign
		d. Dispenser – H_2 Leak and Flame Detectors e. Priority & Sequential Panels – H_2 Leak and Flame Detectors f. Nitrogen System – Safety Devices g. Cooling System – H_2 Leak Detectors h. Control Room – Smoke Detectors i. Gas Chromatograph – H_2 Leak Detectors j. PLC & SCADA – Smoke Detectors k. MCC Rooms – Smoke Detectors l. Battery Room – Smoke Detectors m. VFD Panel – Smoke Detectors				
2	Fire Fighting System	a. Pumps b. Portable Fire Extinguishers c. CO_2 Flooding System d. Hydrant/Sprinkler System				
3	Control System	a. UPS b. Batteries and Charger c. PLC and SCADA d. Operator & Engineering Workstations				
4	Consumables	a. N_2 Purging Gas b. GC/SM Carrier Gas c. Instrumentation Air d. DM/RO Water for Electrolyzer				
5	Power Source	a. HT Breaker b. LT Breaker and Modules c. Distribution Transformer d. Rectifier System for Electrolyzer				
6	H_2 Buses	a. H_2 Leak Detectors b. H_2 Flame Detectors				
7	Integration of H_2 Generation System	a. Buffer Tank b. Flame Arresters c. Hydrogen Dryer/Purifier d. Gas Separation System				
8	Electrolyzer System	a. Electrolyzer Stack Modules b. Stack Cooling System d. Electrolyte Circulation System (if applicable)				

Sl. No.	System	Checking Items	Status	Remarks	EPC Sign	DOE Sign
		e. Gas-Liquid Separator (if applicable) f. Hydrogen Dryer Unit g. Oxygen Venting System h. Rectifier & Power Supply Interface i. Hydrogen Purity Analyzer j. Pressure, Temperature & Flow Instruments k. PLC Panel & Control System Integration l. H_2 Leak Detection System n.Ventilation System o. Interlocks with Compressor & Storage				
9	Hydrogen Compression System	a. Cooling System b. Hydraulic Oil System c. PLC Panel & Motor Control Panel d. Flame Arresters				
10	Storage System	a. Cylinder Manifolds b. Flame Arresters c. Priority Panel d. TPRDs				
11	Dispensing System	a. Pre-cooler b. Dispenser Panel c. Hoses and Nozzle d. Flame Arresters e. Chiller System				
12	Sequential Panel	a. Piping System b. Instrumentation c. Isolation and Control Valves				
13	Priority Panel	a. Piping System b. Instrumentation c. Isolation and Control Valves				
14	Nitrogen Generation System	a. Nitrogen Generator Unit b. Purity Analyzer c. Pressure & Flow Instruments d. Control Panel				
15	Water Treatment System	a. RO System b. DM Plant c. Storage Tank d. Flow & Purity Monitoring Instruments				
16	Electrical	a. Earthing System				

Sl. No.	System	Checking Items	Status	Remarks	EPC Sign	DOE Sign
		b. Lightning Protection System c. Static Discharge System d. Lighting Arrangement				

6.3.3 Trial Operation

a) Trial operation shall be carried out under actual operating conditions.
b) Each equipment shall operate continuously for a minimum of eight hours without tripping.
c) Trial operation shall be conducted for two consecutive days.
d) Hydrogen dispenser shall demonstrate dispensing of minimum 40 kg hydrogen through two consecutive FCEB fills.
e) Operating parameters shall be recorded and validated.

6.3.4 Performance Guarantee (PG) Test

a) PG test shall be conducted after successful completion of trial operation.
b) PG test shall be carried out under defined operating conditions.
c) All parameters shall be recorded using calibrated instruments.
d) Acceptance shall be based on compliance with guaranteed performance parameters.
e) Any deviation shall require corrective action and re-testing.

f) System-wise PG verification shall include but not limited to:

1. Electrolyzer System
i. Hydrogen production rate meeting guaranteed capacity
ii. Specific energy consumption within specified limits
iii. Hydrogen purity, ramping rates as per contractual requirements
iv. Stable operation without alarms or trips

2. Hydrogen Compression System
i. Continuous operation at minimum 50% load for 100 hours
ii. Achievement of required discharge pressure (450–500 bar)
iii. Stable performance without abnormal vibration or trips

3. Hydrogen Storage System
i. Achievement of maximum allowable storage pressure
ii. Verification of system integrity without leakage

4. Hydrogen Dispensing System
i. Dispensing of minimum 20 kg hydrogen per bus at 350 bar
ii. Two consecutive bus fills of minimum 20 kg each (total minimum 40 kg hydrogen) without interval between fills
iii. Minimum average fuelling rate of 2 kg/min

5. Hydrogen Purification and Drying System
i. Hydrogen purity within specified limits
ii. Dryer performance meeting dew point requirements

6. Nitrogen Generation System
i. Capacity of 5 Nm^3/hr
ii. Pressure of 10 bar
iii. Purity greater than 99.9%
iv. Continuous operation for minimum 12 hours

7. Water Treatment System
i. Minimum 90% recovery efficiency
ii. Water purity meeting electrolyzer requirements
iii. Continuous operation for minimum 24 hours

8. Electrical and Control System
i. Stable PLC/SCADA operation without faults
ii. Verification of alarms, interlocks, and communication

9. Safety System
i. All safety systems operational without failure
ii. Successful operation of emergency shutdown system

6.3.5 The Bidder shall submit the following reports as part of the completion and commissioning documentation;

- FAT reports
- Pre-commissioning Checklist Reports
- Trial Operation Report.
- PG Test reports
- Calibration certificates
- Test data logs and performance curves

7. **Operation, Maintenance, Warranty and Spares**

7.1 The Bidder shall be responsible for ensuring reliable, safe, and efficient operation of the Green Hydrogen Plant through proper design, supply of spares, training, and long-term maintenance support.

7.2 The plant shall be designed for continuous operation of ≥8,000 hours per year with a minimum plant availability of 95% and provide the following:

- Detailed Operation & Maintenance (O&M) manuals
- Standard Operating Procedures (SOPs)
- Emergency and shutdown procedures

The system shall further support:

- Automated operation with minimal manual intervention
- Remote monitoring and diagnostics capability

7.3 The Bidder shall provide a complete list of all consumables required for the operation of the Plant and shall supply and replace such consumables at no additional cost during the Defect Liability Period of two (2) years from the date of commissioning. Thereafter, the

supply and replacement of consumables shall continue under a legally binding Annual Maintenance Contract (AMC), the consumables include but not limited to:

- Electrolyser-related consumables (electrolyte, membranes as applicable)
- Gas purification system consumables (catalysts, molecular sieve/drying media)
- Water treatment consumables (filters, resins)
- Compression system consumables (oil, seals, filters)

The Bidder shall clearly specify:

- Consumption rate of each consumable
- Replacement frequency
- Estimated annual consumption and cost

7.4 The Bidder shall provide a detailed stack life and replacement profile, including:

- Minimum electrolyser stack life shall be ≥60,000 operating hours.
- Stack degradation profile over time
- Expected replacement interval
- Cost of stack replacement
- Replacement procedure and expected downtime

7.5 The stack shall be modular and replaceable with minimal downtime and without requiring a complete system shutdown.

7.6 The Bidder shall provide a complete list of all spare parts required for the operation of the Plant and shall supply and replace such spare at no additional cost during the Defect Liability Period from the date of commissioning. Thereafter, the supply and replacement of spares will be carried out under a legally binding Annual Maintenance Contract (AMC).

7.7 The Bidder shall supply and maintain at site, on a consignment basis during the Defect Liability Period, a stock of mandatory critical spares for equipment whose failure stops hydrogen fuelling and whose spares have a delivery lead time exceeding two weeks. The stock shall include at minimum: (a) hydrogen compressor: diaphragm sets, valve kits and seals; (b) dispenser: hose assembly, nozzle, breakaway coupling and nozzle O-rings; (c) pre-cooling chiller: contactors and relays, expansion valve, condenser fan motor, controller board and one refrigerant charge; (d) electrolyser: critical sensors and consumables as recommended by the OEM; (e) fire pump: mechanical seal and controller spares. Spares consumed shall be replenished by the Bidder at no additional cost during the Defect Liability Period. At the end of the Defect Liability Period, the remaining stock shall be handed over to the DoE, and replenishment thereafter shall be covered under the AMC.

7.8 The Bidder shall deploy one qualified O&M plant expert, holding a Diploma or Bachelor's degree in Engineering with at least 3 years of experience in the operation of

hydrogen systems, as follows:
(a) resident full-time at site for the first 12 months after commissioning, to operate the plant together with the DoE operators and provide on-the-job training;
(b) for the remaining Defect Liability Period attendance at site within 48 hours of a breakdown and remote technical support shall be provided as per site situations.
Any replacement of the expert shall be subject to DoE approval. After the Defect Liability Period, the deployment of the O&M plant expert shall be covered under the Annual Maintenance Contract (AMC).

7.9 The entire plant shall be covered under a comprehensive warranty in accordance with the terms and duration specified by the respective manufacturers for all equipment and components. This warranty shall include the applicable manufacturer warranties, covering but not limited to:

a) Electrolyser system
b) Balance of Plant (BoP)
c) Electrical systems
d) Instrumentation and control systems

During the warranty period:

a. All defects arising from design, materials, or manufacturing shall be rectified at no additional cost to the Employer.
b. Repair or replacement of defective components or equipment shall be carried out in line with the applicable manufacturer warranty provisions.
c. The Bidder shall clearly define the maximum response time and resolution time for fault identification and rectification.

7.10 The Bidder shall provide an cost estimate for the Annual Maintenance Contract (AMC) for 3 years and extendable (based on performance and requirements) if required, The AMC shall include:

- Preventive maintenance
- Corrective maintenance
- Supply of spare parts and consumables
- Technical support
- Repairs attributable to the performance of the green hydrogen plant, excluding forced majeure events

7.11 In addition, the Bidder shall provide, on their expenses, a minimum of 2 weeks of hands-on training to both operators and maintenance personnel at the site identified byDoE, covering:

- Plant operation
- Maintenance procedures

- Safety systems and protocols
- Emergency handling
- Troubleshooting and fault diagnostics

D. DOCUMENTATION

The documents and drawings as listed below shall be submitted by the Bidder to the DoE, MoENR as part of the EPC contract unless specified otherwise. The list is indicative and not exhaustive, and the Bidder shall submit all additional documents required to ensure completeness, operability, safety, and reliability of the system.

a) Three sets of all necessary documentation in hardcopy (English) along with soft copies shall be submitted. This shall include user manuals, operation and maintenance manuals, vendor manuals, product catalogues, wiring diagrams, termination drawings, interconnection schematic diagrams, and all related documents for the complete system including electrolyzer, pressure vessels, compressor, storage cylinders, gas chromatograph, dispenser, chillers, and firefighting systems.

b) All civil, mechanical, electrical, and instrumentation design documents including simulation studies, field studies, design basis, and detailed calculations shall be submitted in both hard and soft copies.

c) All relevant drawings, specifications, datasheets, and supporting documents necessary to demonstrate operability, safety, and reliability of the complete system shall be provided.

d) Third-party inspection and certification documents shall be submitted for all critical components including electrolyzer, compressors, dispensers, and high-pressure storage vessels/tubes.

e) Safety and risk assessment studies including Safety Integrity Level (SIL), Hazardous Area Classification (HAC), Hazard and Operability Study (HAZOP), Quantitative Risk Assessment (QRA), Emergency Risk Assessment (EMERA), Disaster Management Plan (DMP), and Hazard Identification and Risk Assessment (HIRA) reports shall be submitted.

f) Certificates demonstrating compliance with Ingress Protection (IP) standards for all relevant equipment shall be provided.

g) Factory and laboratory calibration certificates for all instruments and devices shall be submitted.

h) All ownership and registration certificates for the installed systems and equipment shall be in the name of theDoE.

i) As-built drawings for all disciplines including mechanical, electrical, instrumentation, and civil works shall be submitted upon completion.

j) Design criteria and detailed drawings/documents for civil infrastructure including superstructure, substructure, foundations, and underground facilities shall be provided.

k) Architectural drawings required for construction and execution including detailed floor plans, elevations, sections, and finishing details shall be submitted. This shall include finish schedules (internal and external), colour schemes, door and window details, flooring layouts, false flooring, false ceilings, sanitary and plumbing details.

l) Reports demonstrating compliance with all statutory and regulatory requirements applicable to the facilities and systems shall be submitted.

Annexures

Annexure-I: Water Quality Parameters

Sl. No.	Parameters	unit	Observed Value		
			Max.	**Min.**	**Avg.**
1	pH value				
2	Calcium hardness	mg/l			
3	Magnesium hardness	mg/l			
4	Sodium / Potassium	mg/l			
5	Colour	Hazen			
6	EC	µs/cm			
7	Salinity	PSU			
8	Turbidity	NTU			
9	Total Hardness	mg/l			
10	TDS	mg/l			
11	Nitrate	mg/l			
12	Copper	mg/l			
13	Iron	mg/l			
14	Manganese	mg/L			
15	Total Coliform	MPN/100 ml			

Note:
The Bidder is requested to conduct a water quality parameter testing during their site visit or during the detailed engineering phase to proposed the most effective water treatment plant for the hydrogen refueling station at Jamji.

Annexure-II: Minimum Requirement of ICS System

A. Human Machine Interface

HMI software shall include:

1. Graphic (HMI) displays all process areas, showing equipment status (ready, not ready or running) and analog values for critical process variables.
2. There shall be multiple levels (types) of process graphics:
    a. Level 1 graphics are used for navigation between offsite locations, display KPIs (Key Performance Indicators), alarm summary, trends, and run reports.
    b. Level 2 graphics will mirror the PFDs (Process Flow Diagrams) for each offsite location for normal control operations.
    c. Level 3 graphics will mirror the PCIDs (Piping and Instrumentation Diagrams) for each offsite location for detailed control operations.
    d. Level 4 graphics will be provided as necessary for equipment specific integration screens and auxiliary information.
3. Alarm display and logs, showing the alarm tag number, title, date and time.
4. Trend displays with flexible time and process variable axes for any analog process variable.
5. Loop displays showing PID controller settings and trending of process variable, setpoint and output.
6. Password controlled multiple user access levels like Operator, Supervisor and Engineer.
7. Graphic panels shall be created to replicate process and equipment using ISA standard and/or custom build symbol library. The system shall support 3D representations with rich color combinations for static and dynamic indications.
8. Data refresh rate in graphics for hardwired IOs shall be 1-2 sec and through communication shall be 3-5 sec.
9. Reports shall support standard and custom developed allowing multiple report formats (shift-wise, daily…), scheduled and adhoc reporting.
10. Number of reports and graphics shall be based on operational needs and shall not limited by the number of licenses
11. Ability to configure and operate sequence and control functions in
    a. Auto and Manual modes
    b. Start-up Bypass and Overrides for interlocks
    c. Maintenance Modes
12. Ability to synchronize time
13. Alerts on critical alarms and/or data shall be send to key operation/maintenance personal over SMS and/or emails
14. Diagnostic details from various system components shall be presented as alarms in the system

B. SCADA Server

The SCADA Server (SCD) shall be PC based running SCADA/HMI software on Windows Server 2022 or the latest operating system. This server will collect raw data from the ICS Controller, Safety System, Fire and Gas System, and third-party PLCs to make it available to operator works stations. The SCADA servers shall be configurable as redundant pairs. The following hardware requirements apply, else virtual hardware should be assigned with similar capability.

Minimum specification for Server shall be:

- Intel I9 processor or better
- 32 GB RAM, Min. 1TB SSDs with Raid 3
- Dedicated Graphics Card, Network Card
- Single 32" Monitor, Keyboard and Mouse

C. Operator Workstation

Operator Workstation (OWS) shall be PC based running SCADA/HMI software on Windows 11 or latest operating system. Operator shall use this as a single window for the control and monitoring of the entire process and facility related input/outputs. It shall comply with ISO 9241-5, 9241-302 and 9241-303 and ISO 11064.

Minimum specification for OWS shall be:

- Intel I9 processor or better
- 16 GB RAM, Min. 1TB SSDs with Raid 3
- Dedicated Graphics Card, Network Card
- Single 32" Monitor, Keyboard and Mouse.

D. Engineering Workstation

Engineering Workstation (EWS) shall be PC based running SCADA/Programming software on Windows 11 or latest operating system. A single software platform that allows configuration of controllers and SCADA HMI is preferred. EWS shall include OWS software also.

Minimum specification for EWS shall be:

- Intel I9 processor or better
- 16 GB RAM, Min. 1TB SSDs with Raid 3
- Dedicated Graphics Card, Network Card
- Single 32" Monitor, Keyboard and Mouse.

EWS shall be based on IEC-61131-3 for programming of controllers and HMI.

E. ICS - Controller

Features and requirements of CPU stated below shall be met.

a. Be of robust design using reliable components with high availability. Be compact, stand-alone din rail mountable.

b. Not include moving ports whose failure results in failure or degradation of system performance. All the performances committed shall not deteriorate in the entire range of operating temperature.

c. Support redundancy for hot-standby operations

d. Possess redundant equalizing ports (no single point failure) to exchange diagnostic/failure details to perform switchover. Switch overtime shall be of the order of 300 mSec.

e. Support multiple scan times for digital processing (50 msec), critical analogue controls (500 msec) and 1 second for the rest.

f. Capable of solving application logic, storing the application program and having an OLED status display.

g. Be based on intel or compatible microprocessor operating at speeds no less than 1GHz as the main processing element, memory mounted on the board. A min of 32Mb of retentive user memory shall be on board for user configurable application data storage and documentation storage.

h. Possess dedicated ethernet ports with speeds of 10/100/1000mbps for IO communication.

i. Cyber secured control system environment with a certification which adheres to all parts of IEC 62443. Be cyber secure with a certification like Achilles 2 or equivalent. Additionally, it shall include provisions around password protection, encrypted communications, encrypted firmware updates. All devices, testing and processes shall be adhered to all parts of IEC 62443.

j. Be certified CE, UL, ATEX, C1D2, ATEX Zone 2, ABS, BV, DNV, GL for operating in harsh environment.

k. Support Modbus TCP/IP, HART Passthrough, Profinet, OPC UA, DNP3 protocols for devices and/or packaged system integration.

l. Optical Fiber Communications (OFC) shall be provided for all system and packages interconnections with ring and redundant network for the connectivity more than 60 m.

m. CAT 6e or 7 shall be provided for all system and packages interconnections with ring and redundant network for the connectivity less than 60 m. For above 60m, it is required to install ethernet switches/expander.

n. The control system should have the capability to interface to the cloud and send data, if required.

F. Networking

Firewalls shall be used as a method of protection between the ICS, any third-party equipment, and the cloud/internet if applicable. The firewalls used should provide deep

packet inspection of any industrial protocols used by third-party equipment. These firewalls shall operate in a redundant configuration.

Industrial Ethernet switches shall be used in the ICS cabinets that meet the environmental requirements of the site. These switches shall operate in a redundant configuration. The switches shall be L2 Managed type that supports

a. 24 VDC power input
b. 10/100 mbps copper port
c. 1000 mbps fiber port
d. The number and type of ports shall be decided based on the number of connections to the devices.
e. Industrial grade suitable for operating at 70 ^{O}C temperature

One router per site shall be installed in the ICS cabinets that meet the environmental requirements of the site. The router shall facilitate a wired WAN interface to connect to the local ISP's (internet service provider) modem and support a cellular interface as a backup. An outdoor antenna will be required for a strong cellular connection. These types of routers do not function as a redundant pair. Networking shall include LAN connectivity.

All networking devices, PLC system, service shall be in synchronization with 100% redundant external clock i.e. GPS.

G. ICS – Input / Output

ICS shall include dedicated remote IO racks installed in multiple locations and connected to the centralized CPUs. IO racks shall include power supplies, communication to CPU and various types of IO cards.

IO Cards in general possess/support the following features.

a. LED indicators for Power, Healthiness of card and status of digital signals
b. IO Module shall have Galvanic isolation between system and field to 1500 VAC
c. Analog IO module shall have Noise filters
d. Hot replacement i.e., removal and insertion with power on
e. IO modules shall be provided with Reverse polarity protection
f. Diagnostics to detect failures and send status updates to the controller/HMI.

There shall be a maximum of 1 model number used for each of the following I/O types in the ICS to minimize the amount of spare I/O cards the customer will need to keep on hand:

a. Discrete Inputs, Discrete Outputs
b. Analog (4-20 mA) Inputs and outputs
c. RTD/TC Inputs, Pulse Inputs

The maximum number of channels allowed for AIO cards is 16 and DIO cards is 32.

H. Data Historian

SCADA server shall be capable of storing raw, computed and aggregated data as defined in a structured database for extended periods of time (one year). Data from the historian shall be used for reporting, performing analytics and shared with Owner systems. Data communication to external systems shall be using OPC protocol. Any other protocol shall be with prior approval from Owner.

I. Web Clients

Using Web Clients, the system shall facilitate remote access to the data and/or graphical/report data for the purpose of monitoring. Mobile phones, tablets or PC connected through internet from a far location shall be allowed to access with proper user authentication. Also, it shall be able to use remote access in parallel to the local access in the control center.

J. ICS – Redundancy Requirements

Listed below are the guidelines identified for the redundancy requirements of this plant.

a. CPU, IO communication and power supplies shall be redundant
b. Critical IO(s) and communication links shall be redundant.
c. OWS shall be minimum two in numbers: 1 x OWS and 1 x OWS cum EWS.
d. EWS shall be minimum one in number: 1 x EWS (excluding of above)

Depending on the process operational needs additional OWS may be requested.

K. ICS – Spare Philosophy

Listed below are the minimum spare requirements.

a. IO cards shall include 10% of spare channels and shall be distributed evenly in multiple cards.
b. IO racks shall include 10% slots for installation of additional cards.
c. Power supplies shall have 20% excess capacity on top of what is required with all channels + installed spares.
d. Cabinets shall have 20% spare space to accommodate the additional installed spares/space.
e. Terminals and cable raceways shall have 20% spares on top of what is required with all channels + installed spares.
f. Accessories such as MCBs, signal conditioners, barriers and surge protectors – as applicable shall be per installed spares channel requirements.
g. Network ports shall include 20% spare ports.
h. Network loading shall not be more than 40% during normal operations.

i. CPU shall have an additional 25% capacity for future additions.

j. Licenses considered shall be on the based-on resources required for given IO with installed spares plus 25% for future expansion.

L. ICS – Single Window

The ICS shall be the single unified platform for monitoring and control the needs of the entire plant including process, utilities and facilities.

a. To the extent possible, all IO(s) from process and package equipment shall be wired to the ICS and controls implemented in it. Consider usage of package PLC(s) only for impossible cases with approval from the DOE.

b. Provide control and monitoring details for the ICSV to develop standardized operation and control philosophy. Key documents that ICSV need from Bidder or OEM, or its supplier are.

   i. PCID, IO list and Summary with alarm limits and priorities

   ii. CCE matrix, Sequence, Control narratives

   iii. Interlocks with bypass and overrides, Cable schedule

   iv. Entire control system shall be ordered and executed through a single entity of ICSV to ensure consistency in terms of hardware components, assembly and integration, software design with same look and feel.

Additional Information: List of Standards

The below list of standards to be followed for design, erection/installation/construction, commissioning testing, O&M of equipment, etc., for the entire project by the Bidder. List of standards which are detailed below, and it is not limited, latest and other standards for Hydrogen Application are also applicable.

S. No.	Standards	Description
1	ISO 14687: 2019	Hydrogen fuel quality — Product specification.
2	ISO 22734: 2019	Hydrogen Generators using water electrolysis – Industrial, Commercial C Residential Applications.
3	ISO 19880: 2020 Part 1 - 8	Gaseous Hydrogen Fuelling Station.
4	ISO/TR 15916:2015	Basic considerations for the safety of hydrogen systems
5	ISO 12944-2:2017	Paints and varnishes — Corrosion protection of steel structures by protective paint systems
6	NFPA 2	Hydrogen Technologies Code.
7	NFPA 10	Standard for Portable Fire Extinguishers.
8	NFPA 14	Standard for the installation of Standpipe and Hose System
9	NFPA 20	Standard for Installation of Stationary Pumps for Fire Protection
10	NFPA 22	Standard for Water Tanks for Private Fire Protection
11	NFPA 24	Standard for the Installation of Private Fire Service Water Mains
12	NFPA 70	National Electrical Code
13	NFPA 2001	Standard on Clean Agent Fire Extinguishing Systems.
14	SAE J2601-02:2014	Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles
15	SAE J 2799:2019	Hydrogen Surface Vehicle to Station Communications Hardware and Software
16	SAE J2601/3: 2014	Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles
17	SAE J 2719: 2020	Hydrogen Fuel Quality for Fuel Cell Vehicles
18	AIS 157:2020	Safety and Procedural Requirements for Type-Approval of Compressed Gaseous Hydrogen Fuel Cell Vehicles.

19	ANSI / ASME A13.1, (or) ASME A13.1: 2020	Scheme for the Identification of Piping Systems.
20	ASTM G93/G93M-19	Standard Guide for Cleanliness Levels and Cleaning Methods for Materials and Equipment Used in Oxygen- Enriched Environments.
21	IEC 60079	Electrical apparatus for explosive gas atmospheres
22	ASME B31.12:2019	Hydrogen Piping and Pipelines
23	ASME B31.1:2022	Power Piping
24	API-RP	American Petroleum Institute – Pipeline Recommended Practices
25	EC-79	European Regulations
26	ATEx and IECEx	International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres)

PART B:

TECHNICAL SPECIFICATIONS AND SCOPE OF WORK

SUPPLY AND MAINTENANCE OF FUEL CELL ELECTRIC BUSES

PART A

1. Introduction

The proposed 250 kW Hydrogen Pilot Project at Jamji will operate 7–9 m Fuel Cell Electric Buses (FCEBs). These FCEBs will be purchased, owned, and maintained by the DoE or designated authorities appointed by DoE, while leasing for operation on a specified route.

2. Abbreviations and References

Abbreviation	Meaning
FCEB	Fuel Cell Electric Bus
BCTA/DoST	Bhutan Construction Transport Authority/ Department of Surface Transport
COD	Commercial Operation Date – after registration of the FCEB and completion of acceptance test with the Authorities and Owner
DLP	Defect Liability Period
ECU/VCU	Electronic Control Unit/ Vehicle Control Unit
GVW	Gross Vehicle Weight
OWNER	DoE – the contract awarding authority

3. Scope of Supply and Services

a) Manufacture/procure and supply two FCEBs meeting technical specifications (Part B) and approved by the Owner. Conduct all routine and acceptance tests and provide necessary training.
b) Scope includes initial registration, permits, insurance, fitness fees, road taxes, etc., with expenses reimbursed by Owner upon submission of receipts. Any renewal of the above is also in scope of the Bidder.
c) All logistics and transportation arrangements to the delivery location shall be borne by the Bidder.
d) Supply shall include all items needed for safe, reliable, and trouble-free operation during the DLP, even if not specifically mentioned, without additional cost. Thereafter, cost will need to be incorporated in the AMC.
e) Equipment shall conform to high engineering standards, capable of continuous operation. Owner reserves the right to accept or reject any work/material failing to meet specifications. Deficiencies must be rectified by the Bidder; rejection DoEs not justify delays.
f) FCEBs must include a vehicle tracking system with real-time location access. On-board data acquisition system with access through ECU/VCU/control unit is required. Data shall be logged at a minimum frequency of 0.1 Hz, stored on Bidder's server, with access provided to Owner.

4. Training

a) Provide free training to personnel authorized by the Owner. Minimum 5 working days per bus at project location.
b) Training includes familiarization with basic operations, fault diagnostics, configuration (ITS), data download/transfer, and settings of FCEBs and accessories.
c) Travel, lodging, boarding, and instructor expenses are borne by the Bidder.

5. Final Acceptance

a) Each FCEB to undergo a 3-day trial run before acceptance. Daily operation of 204 km. All

tools, tackles, accessories, and manpower for trials are Bidder's responsibility.
b) Trials shall follow the acceptance criteria in Annexure II. Manufacturer must implement any modifications suggested by Owner free of charge.
c) FCEBs accepted after successful trial run and completion of registration formalities with respective BCTA/DoST.

6. Assured Annual Running
Each FCEB shall cover at least 74,460 km/year (204 km/day × 365 days).

7. Delivery Location
Jamji, Thimphu, Bhutan.

8. Bidding Clause
a) Components: Supply of FCEBs and AMC for 3 years.
b) AMC Quote: Provide yearly AMC cost for 3 years.

9. Defect Liability Period
2 years from final acceptance of each FCEB by Owner.

PART B

FCEB SPECIFICATION

1. Codes & Standards

1.1 The hydrogen storage, fuel cell systems, and associated safety components shall comply with internationally recognized standards, including:

Hydrogen Storage & Fuel Systems

- ISO 15869 – Gaseous hydrogen cylinders
- ISO 19881 – Hydrogen fuel tanks for vehicles
- ISO 14687 – Hydrogen fuel quality
- UNECE R134 – Hydrogen and fuel cell vehicle safety
- SAE J2579 – Hydrogen system safety

Fuel Cell Technologies

- IEC 62282 series – Fuel cell performance, safety, and testing

Hydrogen Refueling Interface

- ISO 17268 – Refueling connectors
- SAE J2601 – Fueling protocols

1.2 Homologated buses as per international guidelines are required to be provided.

2. General Design Features

a) The bus, complying with all acts/rules/regulations, shall be designed as per good engineering practices and to meet the following requirements:

1. Superior passenger comfort
2. High standards of passenger safety
3. Reliability of the product providing high standards of availability for safe and reliable operation
4. Ease of repair
5. Aesthetically designed interiors and exteriors
6. Ease of boarding and alighting for all passengers
7. Ergonomically designed driver's work area

b) The FCEBs shall comply with the following technical parameters and performance requirements:

S.No	Parameter	Value
1	Life	Min. 8 years
2	Length	7–9 m

S.No	Parameter	Value
3	Number of Seats	20–30 + 1 Driver
4	Number of Standees	No standees
5	Fuel Capacity	350 bar Hydrogen at 99.97%: min 30 kg
6	Fuel Filling Interface	Fast filling as per fueling protocol SAE J2601-2:2023 and communication protocol SAE J2799:2024 with T20 dispenser at maximum 350 bar pressure and IR communication. The Bidder shall submit the bus manufacturer's written confirmation that the FCEBs are approved for SAE J2601/2 fuelling with T20 pre-cooling at 2 kg/min
7	External Charging	No external electrical charging provision required; only hydrogen as primary energy
8	Ambient Temperature	0°C ~ (+)50°C
9	Altitude	2000–3000 MASL
10	Road Condition	Bhutanese road conditions
11	Route	Thimphu–Paro
12	Fuel Economy	Minimum 12 km/kg of H2
13	Range (GVW with HVAC on)	300–400 km
14	Maximum Speed at GVW Condition	As per applicable standard for intercity/intracity applications
15	Cold Start Ability	To start at 0°C
16	Motor Power to GVW Ratio	Shall be greater than 5 kW/ton
17	Suspension – Front	Air
18	Suspension – Rear	Air
19	Limping Range	20 km
20	Regenerative Braking System	Required
21	Seating Layout	2 × 2
21a	Seat Type	Pushback with Armrest and leg support required
22	Facilities for Passenger	a) USB Type C and laptop 5A charger in each seat; b) Water bottle holder; c) Magazine holder
23	HVAC Capability	Inside temperature 22–30°C, Relative Humidity 60%, AQI <50
24	ITS	a) Destination boards and route display boards, LED preferred; b) Speakers and Microphone for Driver announcement system; c)

S.No	Parameter	Value
		Cameras with cabin display for Interior Surveillance (CCTV) and reverse parking; d) Video Recorder for 30-day video footage storage
25	Interior Colour Scheme	Preferred lighter shades, finalized during production
26	Exterior Colour and Design Scheme	As per Owner requirement, finalized during production
27	Minimum No. of Service Doors	a) Driver side door – Right Hand Side (01 No.); b) Electro-pneumatically controlled on Left Hand Side – 01 No.
28	Interiors	a) Easily washable, proper drainage, sealed to prevent ingress of dust/gases/water; b) Windows with appropriate beadings to minimize vibration; c) Proper pictorial signage for emergency exits and seats for needy/specially-abled/senior citizens; d) All footsteps and exits anti-skid type; e) Stanchions, Handrails, and Handholds suitably designed and sufficient in number; f) Adjustable sun visor for driver; g) All lighting fixtures LED-based with smart dimming controls for passengers
29	Luggage Compartment	Decent luggage space to be provided

3. Additional Information

a) The Vehicle Health Monitoring and Diagnostic System shall record all alarms with time-stamping for retrieval for 30 days.

b) Bidder must ensure a suitable data acquisition system is installed to capture real-time data as indicated in Annexure I.

c) GPS-based tracking system along with On-Board Unit (OBU) for toll-based system.

d) Electric bells for stopping the buses.

e) The following documents should be provided at the end of bus supply:

S.No	Details of Literature/Drawings	Quantity
1	Service Manual(s)	1 No.
2	Part Catalogue	1 No.
3	Schematic of the bus body and aggregates	1 set
4	Lubricating chart along with specifications of oils/greases	1 set

ANNEXURE I
(REAL-TIME DATA OF THE OPERATIONAL PARAMETERS)

The vehicle shall be equipped with a vehicle tracking system with access to real-time vehicle location.

1. The Bidder shall provide a suitable on-board data acquisition system / access through on-board ECU/VCU/control unit for the following minimum data parameters:

   i. **Ambient Parameters:**

   - a) Temperature
   - b) Humidity
   - c) Barometric pressure

   ii. **Vehicle-Related Parameters:**

   - a) Vehicle speed
   - b) Distance travelled
   - c) GPS data: Longitude, Latitude, Altitude
   - d) Alarm / error, if any

2. Data shall be logged at a minimum frequency of 0.1 Hz and transmitted and stored on a server. Access shall be provided to Owner for monitoring vehicle movement status

ANNEXURE II
(Acceptance Tests)

1. Scope
The procedure shall cover the acceptance test as per technical specifications, to be conducted at site for the FCEBs (7–9 m) and/or provided by means of documentation from ARAI or such agencies.

2. Objective of the Test
a) To check availability of various equipment in the FCEB.
b) To measure necessary Guarantee parameters as mentioned in the existing tender document of FCEB specification.
c) To check the operation of all leak detection devices and interlocks for individual equipment and acceptance of the complete system.

3. Conditions of Test

3.1 Conductance of Acceptance Test
a) Acceptance tests shall be conducted during trial operation[1].
b) Acceptance test at site shall be conducted by representatives of the Bidder and witnessed by the Owner. The Bidder shall inspect the entire system in advance and make it ready for conducting the test with all safety clearances and compliances. The Bidder and its representative shall conduct all phases of the test and record all the data, events, alarms, etc., jointly with Owner representatives.
c) Any special manpower required during acceptance conductance shall be provided by Bidder free of cost.
d) In case of any failure of the system, the test shall be repeated under the same conditions.

3.2 Pre-Requisites to the Acceptance Test (to be ensured by Bidder)
a) Readiness of all protections, interlocks, and safety devices.
b) Availability of fire protection system / firefighting equipment.

3.3 Checklist of the System

S.N.	System	Checking Items	Status	Remarks
1	Safety Devices	Pressure Relief Device; Excess Flow Valve; Service Shut-off Valve; H_2 Leak Detection Sensors		
2	Fire Fighting System	Portable Fire Extinguishers		
3	Control System	EVCU (Electric Vehicle Control Unit) Hardware and Software		
4	Power Source	HV Battery SoC		

4. Tests / Procedures
(To be defined as per the trial plan and technical specifications.

S.N.	Description of Test	Acceptance Criteria	Document Check	Witness (Physical Check)	PGT Result
1	Vehicle health monitoring and diagnostics	Driver dashboard cluster and tell-tale indications			
2	Minimum grade-ability at GVW (Degree / %)				
3(a)	Minimum acceleration at GVW (m/s^2)	0.8 (0–30 kmph in 10.5 sec)			
3(b)	Energy utilization profile	Net energy efficiency ≥ 45%			
4(a)	Hydrogen consumption (km/kg of H_2)	> 12 km/kg			
4(b)	Storage capacity of H_2 cylinders				
5	Maximum speed at GVW (kmph)	70			
6	Cold start ability (°C)	0°C			
7	Motor power to GVW ratio (kW/ton)	> 5			
8(a)	Regenerative braking feature	Visual			
8(b)	Pneumatic braking system	Documented			
8(c)	Anti-lock braking system	Documented			
8(d)	Parking brakes	On rear wheels only			
9	Speed limiting device	Electronic, tamper-proof			
10	Hydrogen leakage detection system	Provided			
11	Front and rear suspension	Mechanical/Air suspension			
12	Windows (light transmittance)	≥ 50%	Documented		
13	HVAC system	1. Cabin temp: 20–30°C2. Proper ventilation			
14(a)	Driver panel instrumentation	Audio & visual alarms		Visual	
14(b)	Alarm recording system	Data storage for 30 days		Visual	

S.N.	Description of Test	Acceptance Criteria	Document Check	Witness (Physical Check)	PGT Result
15	Service doors	1. RHS driver door (1 no.)2. LHS electro-pneumatic door (1 no.)		Visual	
16	Minimum bus range (GVW + HVAC)				
17	Minimum limp home range	20 km (battery only, no H_2 supply)			
18	Real-time fuel cell data	Retrievable from system	Documented		
19	Trial operation completion	3 consecutive days run			
20	Safety certificates (H_2 cylinders)	Provided			
21	Safety certificates (H_2 supply system)	Provided			
22	Hydrogen leak detectors	1 sensor each in fuel cell & passenger area		Visual	
23	Manual cut-off switch (HV system)	Visual verification of detachment		Visual	
24	High voltage cable marking	Orange color (>24V DC/AC)			
25	Refuelling protection	Fuel cell shuts down when lid opens			
26	Activation during refuelling	Vehicle remains in refuelling mode			
27	Excess flow valve	Provided			
28	Thermal pressure relief device (TPRD)	Provided			
29	Hydrogen leak detection sensor	Provided			
30	Emergency switch	Located near driver for full shutdown			
31	Isolation resistance monitoring	Displayed in kΩ on cluster			
32	Solenoid valve	Provided			
33	Passenger information system	LED display with travel info			
34	Cameras	3 cameras			

ANNEXURE III: DOCUMENTATION

1.0 The Bidder shall provide the general schematic drawings, FCEBs layout, and front/rear and both side views of the offered FCEB designs during the detailed engineering stage.

2.0 The battery charging calculations, powertrain sizing, and hydrogen (H_2) consumption shall be provided.

3.0 In addition to the above, the following information shall also be provided regarding the offered bus:

S.No	Parameters	Details
1	Name of Manufacturer	
2	Vehicle Homologation Done (Date, Month and Year)	
3	Hydrogen Cylinder (Type)	
3(i)	Capacity of Each Cylinder	
3(ii)	Location (Top/Bottom/Front/Rear)	
3(iii)	Number of H_2 Cylinders	
3(iv)	Mounting Position of Cylinder	
3(v)	Receptacle Type	
4	Fuel Cell Stack	
4(i)	Module Capacity	
4(ii)	Total Capacity	
5	Battery Pack Rating (in kWh)	
6	Gross Vehicle Weight	
7	Motor kW Rating in Powertrain	
8	Acceleration Time (0–30 kmph)	Calculations and test report in support of data to be submitted

4.0 The Bidder shall provide at the time of detailed engineering:
a) Scaled drawings indicating all dimensions of front, top view, both sides, internal layout, and rear elevations of the bus.
b) Complete factory acceptance test reports.
c) Copies of tests carried out on the offered bus from regulatory bodies for meeting homologation requirements.
d) Routine checks and schedules along with a list of activities.