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Ministry of MSME, Govt. of India

CONCENTRATED SOLAR THERMAL (CST) Installation, Commissioning, Operation and Maintenance Package



Under
UNIDO-GEF-MoMSME Project:
Promoting Business Models for Increasing
Penetration and Scaling Up of Solar Energy



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solutions



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01

Occupational Health and Safety (OHS)

1. Introduction

Concentrated Solar Thermal (CST) systems are used to convert solar radiation into useful thermal energy for applications including industrial process heat, hot water generation, steam generation and other thermal processes. CST installations comprise solar collectors, receiver systems, thermal-fluid circuits, pumps, heat exchangers, valves, storage systems where applicable, electrical and control systems, tracking mechanisms and associated civil and structural infrastructure.

The operation and maintenance of CST systems involve a combination of occupational hazards associated with solar radiation, elevated temperatures, thermal fluids, pressure, mechanical movement, electrical equipment, work at height, lifting operations, chemical handling and industrial process equipment. These hazards may arise independently or simultaneously during installation, commissioning, operation, inspection, maintenance and repair activities.

Occupational Health and Safety (OHS) measures are therefore required throughout the lifecycle of a CST installation to prevent occupational injuries and ill health, protect personnel and equipment, and ensure safe and reliable system operation.

The OHS provisions presented in this section provide a practical framework for MSMEs implementing or operating CST systems. They are intended to complement applicable statutory requirements, equipment manufacturer's instructions, site-specific risk assessments and relevant technical standards.

The applicable requirements of Indian occupational safety and labour legislation, including the Occupational Safety, Health and Working Conditions Code, 2020 and applicable rules/regulations, shall be considered in conjunction with the requirements presented in this section.

1.1. Objective and Scope

The objective of the CST OHS framework are to:

- identify occupational hazards associated with CST systems
- assess and control risks arising during installation, commissioning, operation and maintenance
- establish safe working procedures for high-risk CST activities
- define minimum inspection and monitoring requirements
- establish requirements for emergency preparedness and response
- ensure appropriate training and competency of personnel
- provide a systematic mechanism for recording and closing corrective actions
- promote continual improvement in workplace safety performance.

The framework applies to:

- CST system installation and construction activities
- mechanical and electrical installation
- system commissioning and testing

- routine operation
- preventive maintenance
- corrective maintenance and troubleshooting
- cleaning and inspection
- replacement of components
- contractor and visitor activities within the CST installation
- emergency response and recovery activities.

2. OHS Specific to CST Systems

CST installations require particular attention because solar energy is concentrated through optical components to generate useful heat. Consequently, the installation combines hazards that are characteristic of both solar-energy systems and conventional industrial thermal systems.

2.1. Principal CST-specific hazard sources

The principal hazard sources include:

- concentrated solar radiation and high-intensity reflected radiation;
- high-temperature receivers and thermal surfaces;
- hot water, steam and/or heat-transfer fluids;
- pressurised thermal-fluid circuits;
- thermal expansion and stored energy;
- moving collectors, tracking mechanisms and actuators;
- pumps, motors and rotating equipment;
- electrical distribution, control and instrumentation systems;
- elevated structures, roof-mounted equipment and access platforms;
- lifting and material-handling operations;
- welding, cutting and grinding;
- cleaning agents, lubricants and thermal fluids;
- fire and overheating;
- outdoor environmental exposure and heat stress.

The presence and severity of individual hazards will depend on the CST technology, operating temperature and pressure, collector configuration, thermal-fluid arrangement, process integration and site conditions.

2.2. OHS Requirements by Project Stage

Project stage	Main activities / condition	Principal OHS hazards & checks	Key OHS requirement
Installation & Construction	Civil works, foundations, structural erection, collector assembly, piping, electrical/instrumentation installation, lifting and welding.	• Work at height; lifting/suspended loads; manual handling; vehicles/equipment; • electrical work; • welding/hot work; excavation; • sharp/fragile components; unstable structures; • solar-radiation exposure.	Use task-specific risk assessment and work procedures. High-risk work only by trained, competent personnel under suitable supervision.
Commissioning	Transition from non-operational to energized and thermally active condition; controlled energisation and start-up.	• Verify collector/structural integrity; • piping/connections; pressure & temperature limits; • valves/safety devices; electrical protection/earthing; • instrumentation/controls; tracking/actuators; • emergency shutdown; • alarms/interlocks; • stow/defocus where applicable; • leakage/abnormal conditions.	Follow approved commissioning procedure. Carry out controlled energisation and start-up.
Operation & Maintenance	Routine operation, inspection, cleaning, servicing and corrective maintenance.	• Hot surfaces; hot water/steam/heat-transfer fluids; • residual pressure; • collector movement; • electrical energy; • automatic/remote operation; • rotating equipment; • work at height; cleaning; chemicals; • unexpected start-up.	Make equipment safe and isolate relevant energy sources before maintenance.

3. Identification and Control of Hazards

The following infographic summarises key OHS requirements. Detailed procedures shall be followed as per project OHS plan, applicable laws and equipment manufacturer's instructions.

1 SOLAR RADIATION AND OPTICAL HAZARDS



 Hazard Source	Concentration and reflection of solar radiation by CST collectors
 Applicable Activities	Collector operation, alignment, commissioning, inspection, cleaning and maintenance
 Potential Consequences	Eye injury, thermal burns, heat exposure and ignition of combustible materials
 Primary Controls	Controlled access; safe collector position; defocus/stow function where applicable; interlocks; exclusion zones; warning signage
 Administrative Controls	Restricted access; authorised personnel; defined procedures for collector-field entry
 PPE	Task-specific eye, face and skin protection where required by risk assessment
 Do not access areas with concentrated radiation hazards until the collector system is in the designated safe condition as per the manufacturer's operating procedure.	

2 THERMAL HAZARDS



 Hazard Source	Receiver, thermal-fluid piping, valves, heat exchangers and other hot surfaces
 Potential Consequences	Burns, scalding, heat stress and fire
 Primary Controls	Insulation, guarding and temperature control
 Administrative Controls	Warning signage, restricted access, cooling and isolation procedures
 PPE	Heat-resistant gloves, suitable protective clothing and eye/face protection where required
 Accessible hot surfaces shall be suitably insulated or guarded where practicable. Maintenance shall be undertaken only after the equipment has cooled to a safe condition.	

3 HOT WATER, STEAM AND HEAT-TRANSFER FLUID

 Hazard Source	Hot thermal fluids and steam under operating conditions
 Potential Consequences	Burns, scalding, exposure to hot fluid and pressure-related injury
 Controls	Insulation; pressure/temperature monitoring; appropriate valves; isolation; controlled depressurisation; drainage
 Maintenance Requirement	System shall be isolated, depressurised, cooled and verified before opening
 PPE	Gloves, eye/face protection and task-specific protective clothing

4 PRESSURE HAZARDS



Pressure-containing equipment and piping shall be designed, operated, inspected and maintained within the applicable design parameters.

Controls shall include:

- ✓ Appropriately rated equipment and piping
- ✓ Pressure indication
- ✓ Pressure relief arrangements
- ✓ Inspection of pressure-containing components
- ✓ Controlled isolation
- ✓ Depressurisation before maintenance
- ✓ Prevention of unauthorised modification or bypass of safety devices

 No pressure-containing component shall be opened until safe isolation and pressure release have been verified.

5

MECHANICAL AND MOVING EQUIPMENT HAZARDS

Equipment	Principal Hazard	Key Controls
Tracking mechanism	Crushing / pinching	Guarding, exclusion zones, isolation
Actuators	Unexpected movement	Isolation and control-system lockout
Pumps	Rotating components	Guards, isolation and maintenance procedure
Motors	Rotating / electrical hazards	Guards and electrical isolation
Valves	Stored pressure / mechanical energy	Isolation and controlled operation

Machinery shall be maintained with appropriate guards, interlocks and safe systems of work. Isolate machinery before maintenance or removal of blockages. (ILO Recommendation)

6

ELECTRICAL HAZARDS

Electrical hazards may arise from switchboards, control panels, motors, pumps, actuators, instrumentation, cables and associated electrical infrastructure.

Controls shall include:

- ✓ Appropriate electrical design and protection
- ✓ Effective earthing/bonding
- ✓ Suitable isolation devices
- ✓ Lockout/tagout
- ✓ Verification of de-energisation
- ✓ Protection of cables from mechanical damage
- ✓ Inspection of electrical equipment
- ✓ Restricted access to electrical panels
- ✓ Competent personnel for electrical work

Electrical equipment shall be suitable for the environmental conditions in which it is installed and maintained.

7

WORK AT HEIGHT

Work at height may occur during collector installation, elevated piping, installation, structural inspection, receiver maintenance and roof-mounted CST applications.

Controls shall include:

- ✓ Suitable access and egress
- ✓ Stable platforms
- ✓ Guardrails
- ✓ Inspected scaffolding
- ✓ Appropriate fall-protection systems
- ✓ Suitable anchor points
- ✓ Secured tools and materials
- ✓ Protection against falling objects
- ✓ Emergency rescue arrangements

8

LIFTING AND MATERIAL HANDLING

CST installation may require lifting of collector assemblies, structural components, piping, pumps and other equipment.

Controls shall include:

- ✓ Approved lifting equipment and accessories
- ✓ Competent and trained lifting personnel
- ✓ Lift plan for critical lifts
- ✓ Pre-use inspection of lifting equipment
- ✓ Safe routes and clear communication
- ✓ Exclusion zones under suspended loads
- ✓ Proper rigging and load securing

Never stand or work under suspended loads. Do not exceed rated load capacity of equipment.

4. Safety during O&M Activities

1 COLLECTOR-FIELD ACCESS

Before Access:

- 1 Confirm the purpose and scope of work.
- 2 Check collector operating status.
- 3 Place collectors in the manufacturer's designated safe position.
- 4 Disable or isolate tracking as required.
- 5 Prevent automatic or remote restart.
- 6 Establish access restrictions / exclusion zones.
- 7 Verify the safe condition.
- 8 Commence work only after authorisation.

2 MAINTENANCE OF HOT OR PRESSURISED SYSTEMS

The following sequence shall be followed:

SHUTDOWN → ISOLATE → LOCK/TAG → DEPRESSURISE → COOL → DRAIN

VERIFY → MAINTENANCE → INSPECTION → RESTORE → CONTROLLED RESTART

! The exact sequence shall be adapted to the CST technology and thermal-fluid configuration.

3 ELECTRICAL MAINTENANCE

The following sequence shall be followed:

IDENTIFY → ISOLATE → LOCK/TAG → VERIFY DE-ENERGISATION → PERFORM WORK → INSPECT → RESTORE

i Verification of absence of electrical energy shall be undertaken using appropriate equipment and by competent personnel.

4 WORK AT HEIGHT

Work-at-height activities shall be planned before commencement. The selected access system shall be appropriate to the height, duration, task and site conditions.

Controls:

- ✓ Suitable access and stable platforms
- ✓ Guardrails and inspected scaffolding
- ✓ Appropriate fall-protection system (harness)
- ✓ Suitable anchorage points
- ✓ Secured tools and materials
- ✓ Protection from falling objects
- ✓ Emergency/rescue plan where fall protection is required

The ILO recommends that work at height be properly planned, supervised and carried out by competent persons using suitable equipment.

5 COLLECTOR CLEANING

Cleaning procedures shall consider:

- ✓ Collector operating condition
- ✓ Safe collector positioning
- ✓ Electrical isolation where required
- ✓ Hot-surface exposure
- ✓ Broken reflector/glass
- ✓ Access and fall hazards
- ✓ Water exposure to electrical equipment
- ✓ Approved cleaning materials

! Cleaning shall not be undertaken while the collector is in a hazardous operating configuration.

6 PERSONAL PROTECTIVE EQUIPMENT (PPE)

PPE shall be selected based on the task-specific risk assessment.

Activity	Typical PPE
General CST work	Safety helmet, safety footwear, appropriate work clothing
Mechanical maintenance	Safety glasses and suitable gloves
Electrical work	Task-specific electrical PPE
Work at height	Full-body harness / fall protection where required
Welding	Welding helmet, gloves and protective clothing
Cutting / grinding	Eye/face protection, gloves and hearing protection where required
Chemical handling	Chemical-resistant gloves and eye/face protection
Hot-fluid work	Heat-resistant gloves and appropriate eye/face protection
Collector cleaning	Gloves, safety footwear and eye protection as required

! PPE shall be inspected, maintained, correctly fitted and replaced when damaged or no longer suitable.

5. Emergency Preparedness and Response

Each CST installation shall maintain an emergency response arrangement appropriate to the system's hazards and site conditions. The emergency arrangements shall address all potential hazards and safety risks. Emergency arrangements shall identify all emergency that may arise from accidents and unexpected events and must ensure immediate response to mitigate and minimise loss during such events. Emergency procedures shall be communicated to workers and periodically reviewed.

A structured inspection programme shall be maintained to verify that OHS controls remain effective throughout the operating life of the CST system

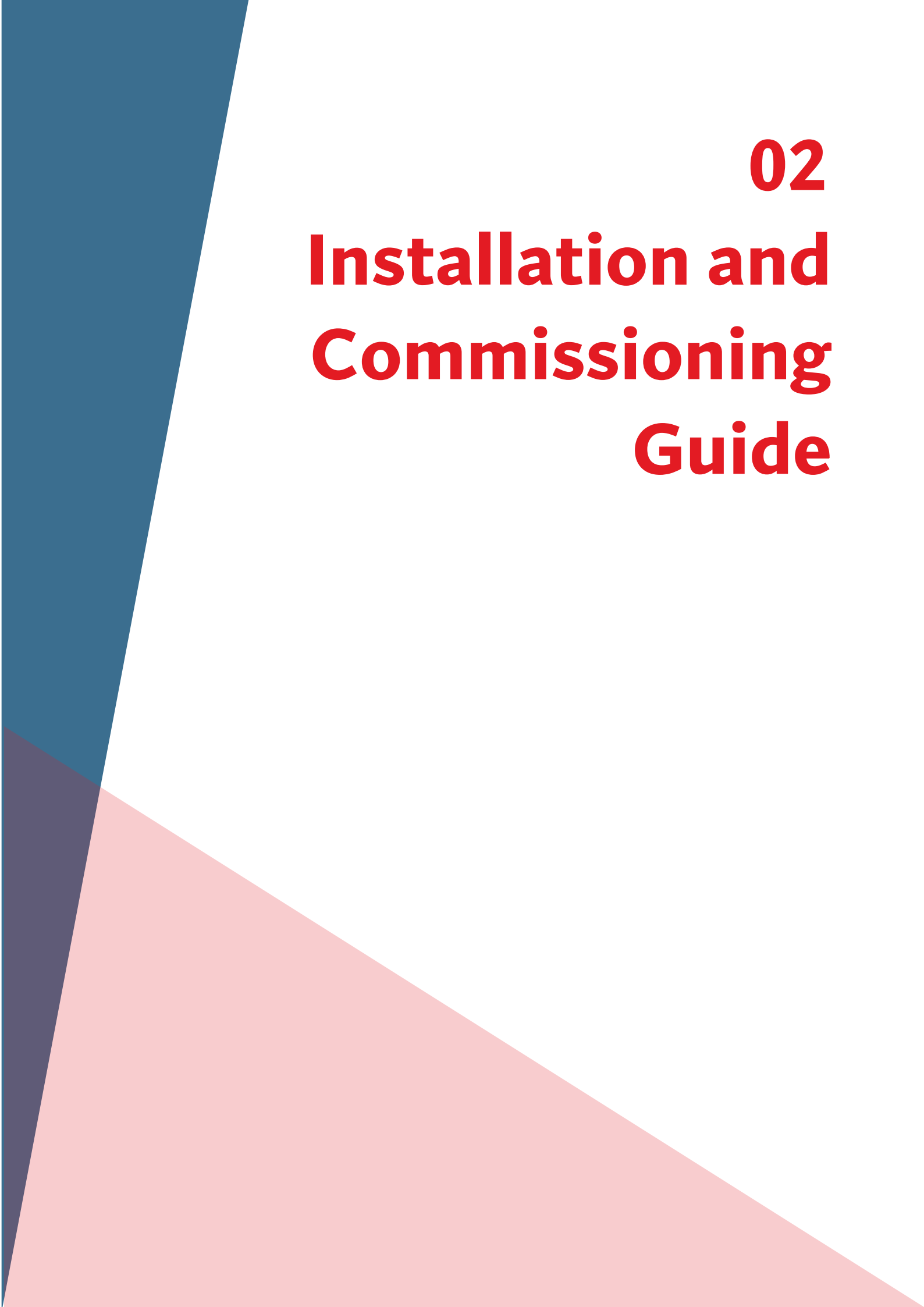
The inspection frequency should be based on the risk associated with the equipment and activity and may be increased where operating conditions or incident history indicate a need.

The minimum framework should comprise:

Frequency	Primary purpose	Typical responsibility
Daily	Identify immediate unsafe conditions before work/operation	Operator/Technician
Weekly	Verify condition of routine safety controls	Maintenance/Operations Supervisor
Monthly	Review equipment, safety systems and OHS records	O&M Supervisor/Responsible Person
Annual	Comprehensive review of installation, safety systems and statutory/technical requirements	Competent Person/Responsible Management

Safety inspection checklist:

Sl. No.	Safety Inspection Parameter	Inspection Interval
1	Access routes	Weekly
2	Collector field	Weekly
3	Thermal-fluid piping	Weekly
4	Electrical items, cables, panels, earthing	Monthly
5	Pumps, motors, piping network and fittings	Monthly
6	Fire equipment, Fire extinguishers	Monthly
7	PPE, First-aid provisions, Warning signage	Monthly
8	Collector structure, Tracking system	Monthly
9	Thermal insulation	Monthly
10	Emergency shutdown access	Monthly
11	Pressure protection, Pressure indicators	Monthly
12	Temperature protection	Monthly



02

Installation and Commissioning Guide

1. Introduction

Concentrating Solar Thermal (CST) systems can provide renewable heat for industrial processes and reduce dependence on conventional fuels such as coal, biomass, diesel, furnace oil, LPG and natural gas. This section of the document provides practical guidance for the installation, commissioning, operation and maintenance (O&M) of industrial CST systems. It focuses on safe installation practices, system commissioning, routine operation, preventive and corrective maintenance, cleaning, troubleshooting, performance monitoring, safety and handover. The guidance is intended to support reliable integration of CST with existing industrial process-heat systems while maintaining process continuity through appropriate conventional backup. System sizing, detailed engineering/design and procurement are outside the scope of this document and have been addressed through separate project documents.

2. Pre-Installation Requirements

2.1. Pre-installation Checks

1. Confirm latest approved drawings/specifications are available at site.
2. Confirm foundations, structural supports, access routes and equipment pads are ready.
3. Inspect delivered equipment for damage, completeness and identification.
4. Verify storage, lifting and handling arrangements.
5. Confirm installation method statements, inspection/test plans and HSE arrangements.
6. Confirm interfaces with existing boiler, furnace, hot-water, steam or process systems.

2.2. Site Readiness Checklist

Item	Requirement
Civil works	Foundations and pedestals completed and cured
Access roads	Cleared and suitable for heavy equipment delivery
Power supply	Temporary construction power available on site
Water supply	Available for HTF flushing, hydrotesting, and cleaning
Storage area	Secure laydown area for collectors, receivers, and cabling
Survey & alignment markers	Benchmarks established for solar field layout

3. Installation Procedures

3.1. Civil & Foundation Works

Complete foundation casting for collector pylons, receiver support structures, thermal energy storage (TES) tanks, and power block per approved civil drawings. Verify curing time before mechanical loading.

3.2. Mechanical Installation

1. Install collector structures, reflectors/receivers and tracking components to approved drawings.
2. Install HTF, water, steam or other heat-transfer piping with correct supports, slopes and expansion provisions.
3. Install pumps, valves, strainers, heat exchangers, steam generators and thermal storage where applicable.
4. Complete insulation and weather protection after testing and inspection.
5. Provide safe access for inspection, cleaning and maintenance.

3.3. Electrical, instrumentation and controls

1. Install power supply, distribution, cabling, earthing and lightning protection.
2. Install temperature, pressure, flow, level, irradiance and other required sensors.
3. Complete PLC/SCADA, communications, alarms and data logging.
4. Verify instrument ranges and locations against approved drawings.
5. Provide safe isolation and emergency shutdown arrangements.

3.4. Process integration

1. Connect the CST system at the approved process integration point.
2. Verify isolation, bypass and non-return arrangements.
3. Verify control interface with existing process/boiler/furnace.
4. Confirm conventional backup remains available during low-solar periods and peak loads.
5. Verify process quality and continuity requirements are maintained.

3.5. Thermal Storage System Installation

1. Erect hot and cold TES tanks and verify foundation levelness
2. Install tank insulation, heating trace, and level instrumentation
3. Hydro-test tanks per design pressure before commissioning

4. Commissioning and Acceptance

4.1. Commissioning Sequence

Step-by-step procedure from completion to operational handover of CST system is illustrated below:



4.2. Pre-Commissioning Checks

1. Confirm mechanical completion and close installation punch-list items.
2. Complete piping pressure/leak testing as applicable.
3. Flush and clean process/HTF circuits as required.
4. Verify pump rotation, valve operation and equipment lubrication.
5. Calibrate instruments and verify signals at the control system.
6. Test electrical protection, earthing and emergency shutdown circuits.

4.3. Functional Testing

1. Test manual and automatic modes.
2. Test pumps, valves and tracking drives.
3. Test alarms, trips, permissives and interlocks.
4. Test high-temperature, low-flow and protective functions.
5. Test emergency shutdown and safe collector stow where applicable.
6. Verify data logging and remote monitoring.

4.4. Solar-field and process commissioning

1. Verify collector alignment and tracking operation.
2. Establish controlled thermal-fluid circulation.
3. Verify operating temperature, pressure and flow ranges.
4. Introduce solar heat gradually and verify stable process operation.
5. Demonstrate transition between solar and conventional heat supply.
6. Confirm process conditions remain within approved limits.

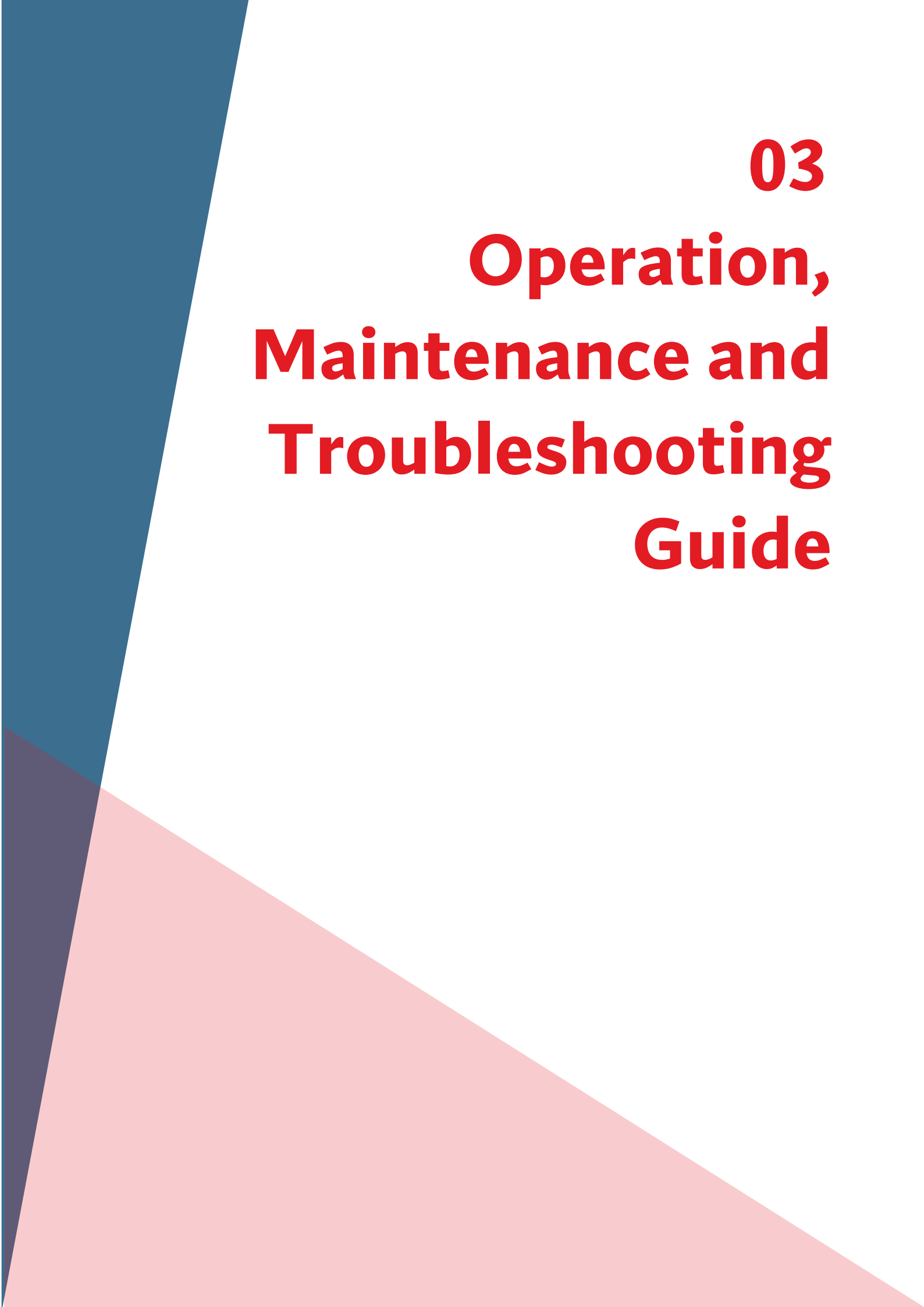
4.5. Performance acceptance

Acceptance should follow the approved project test protocol and contractual guarantees. As applicable, verify:

1. Useful thermal energy delivered at the agreed measurement boundary.
2. Operating temperature and pressure.
3. Flow rate and system availability.
4. Control and safety-system functionality.
5. Auxiliary electricity consumption.
6. Stable process integration.
7. Performance guarantee under defined test conditions.

4.6. Documentation and Handover

1. As-built drawings and P&IDs
2. Factory and Site Acceptance Test (FAT/SAT) reports
3. Equipment warranty certificates and OEM manuals
4. Commissioning test records and punch-list closure
5. Operator training records
6. Formal handover certificate signed by contractor and client



03

**Operation,
Maintenance and
Troubleshooting
Guide**

1. Introduction

Operation and Maintenance (O&M) is essential for ensuring the safe, reliable and efficient long-term performance of an industrial Concentrating Solar Thermal (CST) system. This chapter provides practical guidance for routine operation, inspection, cleaning, preventive and corrective maintenance, troubleshooting, safety during maintenance activities, performance monitoring and record keeping. O&M activities should ensure that the collector field, heat-transfer system, pumps, heat exchangers, controls, instrumentation and process interfaces remain in good operating condition while maintaining process continuity through appropriate use of the conventional backup system. All maintenance work should be planned and carried out by competent and authorised personnel, following approved procedures, equipment manufacturer's instructions, task-specific risk assessments and appropriate isolation and safety practices.

2. Operation and Monitoring

2.1. Normal Operation

A CST system requires continuous monitoring during its operation to ensure that the plant:

1. Operate within approved temperature, pressure and flow limits.
2. Prioritise solar heat when solar resource and process conditions permit.
3. Use conventional backup during low-solar periods, peak loads or system faults.
4. Maintain process temperature/pressure within approved limits.
5. Record daily operating data and abnormal events.

The key parameters of normal operation are presented in the table below:

Parameter	Typical monitoring requirement
Solar irradiance / DNI	Continuous or high-frequency where available
Collector inlet/outlet temperature	Continuous
HTF/process flow	Continuous
Process temperature and pressure	Continuous or process-specific
Pump status	Continuous
Tracking status	Continuous
Thermal storage temperature	Where applicable
Alarms/faults	Continuous event logging
Useful heat delivered	Daily/monthly reporting
Fuel consumption/displacement	Daily/monthly reporting

2.2. Abnormal Operating Conditions

1. Follow approved procedures for low solar radiation, high temperature, low flow, pump failure, tracking failure, leakage, power failure and control faults.
2. Keep conventional backup available whenever process continuity requires it.
3. Do not bypass safety interlocks except under an approved controlled maintenance procedure.
4. Record abnormal events and corrective actions.

2.3. Measurement Records

1. Record the agreed measurement boundary and meter locations.
2. Maintain calibration certificates for critical meters and sensors.
3. Keep consistent operating records so solar heat and fuel displacement can be compared over time.
4. Document changes in production, operating hours or conventional-fuel use that may affect reported performance.

3. Preventive Maintenance

The following maintenance principles should be followed:

- Follow manufacturer's intervals where more stringent.
- Use lock-out/tag-out and permit-to-work procedures.
- Record maintenance, defects, parts replaced and downtime.
- Trend recurring faults and address root causes.

General preventive maintenance to be carried out as per the schedule below:

Frequency	Typical activities
Daily	Check alarms, temperatures, pressure, flow, pump status, tracking and visible leakage.
Weekly	Visual inspection of collectors/reflectors, piping, valves, pumps and equipment condition.
Monthly	Inspect tracking system, instrumentation, insulation, controls and performance trends.
Quarterly	Detailed mechanical inspection and assessment of collector cleanliness/soiling.
Half-yearly	Check instrumentation, electrical systems, pumps, valves and safety systems.
Annually	Comprehensive inspection, calibration, performance assessment and major preventive maintenance.

A detailed preventive maintenance schedule checklist for CST system is presented in the table below:

Equipment	Daily	Weekly	Monthly	Seasonal/ Quarterly	Annual
Focus/Collectors	✓				
Receiver Tubes	✓				
Nitrogen Pressure	✓				
Pump Suction Valve	✓				
Pump Discharge	✓				
Vent Valve	✓				
Drain Valve	✓				
Reflector & Receiver		✓			
Y Strainer		✓			
Strainer Fed Pump Suction		✓			
All the Valves, NRVs, Safety Valves, blow down valve		✓			
Safety Valve			✓		
Gauge Glass & Protector Glass			✓		
Rotating Part			✓		
Electrical Control Panel				✓	
Level Controller				✓	
Boiler					✓
All the Valves, NRVs, Safety Valves, blow down valve					✓
Pressure Gauge					✓
Temperature Indicators & Controllers					✓
Feedwater Tank					✓
Bolts and fasteners					✓

Cleaning of Collectors:

- Inspect collector/reflector cleanliness regularly, especially after dust events or dry periods.
- Define cleaning frequency based on site conditions and measured performance impact.
- Use approved cleaning methods/materials to avoid optical or surface damage.
- Confirm water availability and quality for wet cleaning.
- Provide safe access and controls for manual or automated cleaning.

- Record cleaning dates, method, water use where relevant and observed performance improvement.

4. Corrective Maintenance and Troubleshooting

The table below summarises common problems/observations, possible causes and what initial action to be taken.

Observation	Possible cause	Initial action
Low thermal output	Soiling, low solar resource, low flow, control issue	Check irradiance, cleanliness, flow and alarms.
Low outlet temperature	Insufficient circulation or control problem	Check pump, flow, valves and controls.
Collector not tracking	Sensor, drive or control fault	Check tracking status, power supply and alarms.
High temperature	Low flow or control failure	Check circulation, valves and protective controls.
Pump trips	Electrical or mechanical fault	Check pump alarms, motor, power supply and system conditions.
Unstable process temperature	Control-loop or integration problem	Check process control, heat exchanger and solar/conventional changeover.
Frequent shutdowns	Alarm/interlock or equipment fault	Review event history and identify root cause before reset.
HTF/water leakage	Joint, valve, seal or equipment defect	Isolate safely, depressurise as required and repair before restart.

4.1. Corrective maintenance procedure

The following infographic illustrates corrective maintenance procedure of CST systems.



4.2. Emergency conditions

1. Follow the approved emergency shutdown sequence.
2. Move collectors to the safe position where applicable.
3. Isolate pumps and heat-transfer circuits as required.
4. Isolate the process interface if required.
5. Prevent personnel exposure to hot fluid, steam, concentrated radiation or electrical hazards.
6. Record and investigate incidents before restart.

5. Spare Parts and Consumables

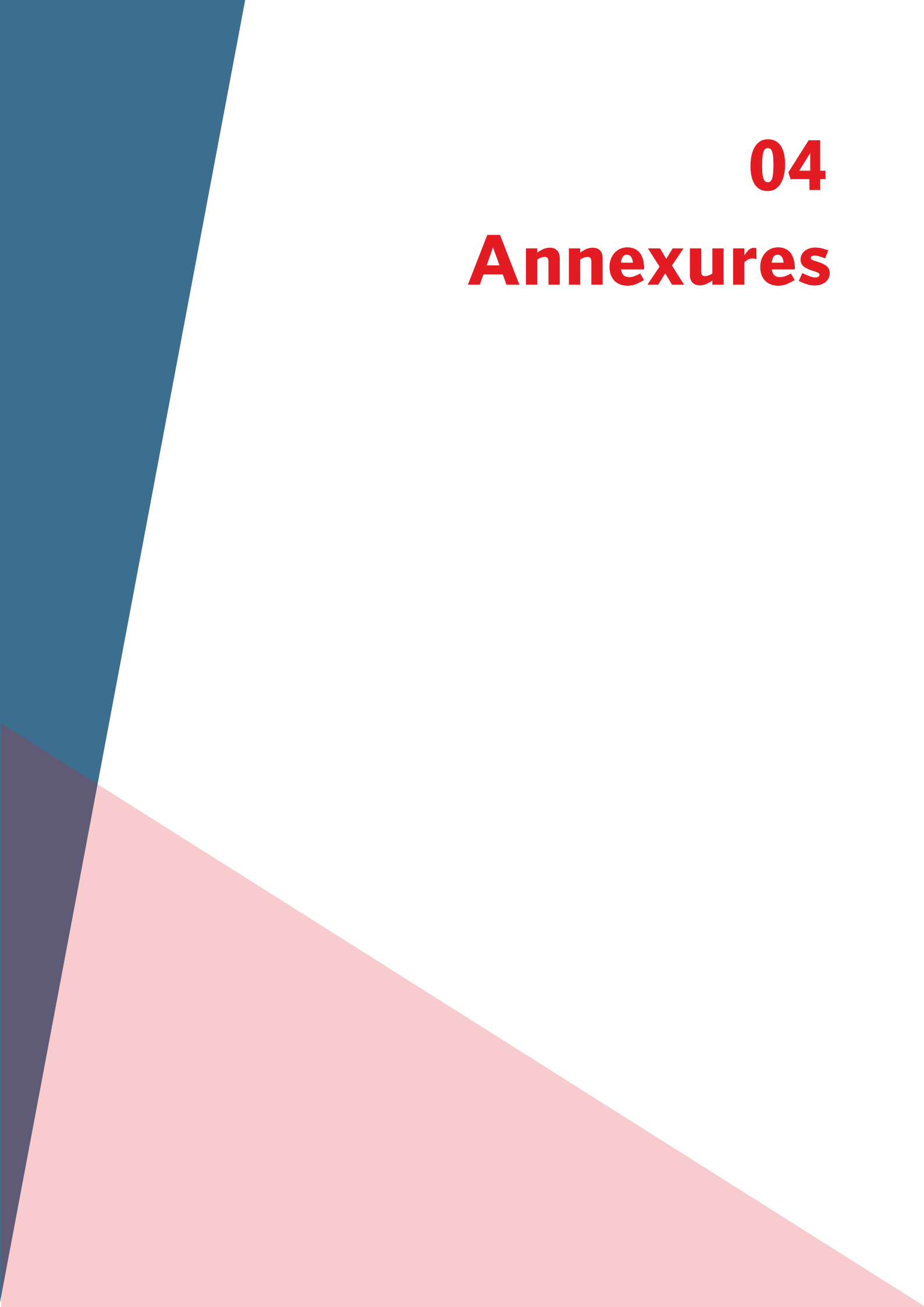
- Maintain critical spare parts needed to avoid prolonged shutdown.
- Maintain routine consumables such as filters, seals, lubricants and cleaning materials as applicable.
- Identify stock levels, replacement intervals and lead times.
- Store spares according to manufacturer requirements.
- Review inventory at least annually and after major failures.

Category	Examples
Critical spares	Tracking-drive components, critical sensors, pump components, control-system components
Routine consumables	Filters, seals, lubricants, cleaning materials
Instrumentation	Temperature, pressure and flow sensors/transmitters
Electrical/control	Fuses, relays, communication/control components

6. Performance Monitoring and Measurement & Verification

Performance monitoring should focus on useful solar heat actually delivered to the industrial process at the agreed measurement boundary. Collector output alone is not sufficient to demonstrate process benefit.

Key Performance Indicators (KPI)	Recommended reporting frequency
Useful solar heat delivered	Daily / monthly
Solar system availability	Monthly
Collector/field operating hours	Daily / monthly
Fuel displaced	Monthly
Auxiliary electricity consumption	Monthly
Major faults and downtime	Monthly
Cleaning frequency	Monthly
O&M expenditure	Monthly / annual
GHG reduction	Monthly / annual



04

Annexures

Annex A. Installation Checklist

Check	Status / remarks
Approved drawings/specifications available	
Site and foundations ready	
Equipment received and inspected	
Collector structures installed	
Collectors/receivers/tracking installed	
Piping installed and supported	
Pumps/valves/heat exchangers installed	
Insulation completed	
Electrical/earthing completed	
Instrumentation installed	
PLC/SCADA and communications completed	
Process interface completed	
Safety systems installed	
Installation punch list closed	

Annex B. Pre-Commissioning and Commissioning Checklist

Check	Status / remarks
Mechanical completion confirmed	
Pressure/leak testing completed	
Flushing/cleaning completed	
Instrument calibration completed	
Pump/valve operation verified	
Electrical tests completed	
Controls and communications tested	
Alarms/interlocks tested	
Emergency shutdown tested	
Tracking/stow operation verified	
Thermal circulation established	
Process integration tested	
Solar/conventional changeover tested	
Performance test completed	
Operator training completed	
Handover documentation complete	

Annex C. Performance Monitoring Log

Date	Solar resource	Useful heat	Fuel use/displacement	Availability	Faults/remarks

Annex D. Handover Checklist

Item	Status / remarks
As-built drawings	
P&IDs	
Electrical/control drawings	
Equipment manuals	
Commissioning reports	
Calibration certificates	
O&M schedule	
Spare-parts register	
Warranty documents	
Training records	
Emergency procedures	
Performance baseline	
Punch-list closure	
Final acceptance/handover certificate	

