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INTERNATIONAL STANDARD

Solar thermal electric plants –
Part 3-1: Systems and components – General requirements for the design of parabolic-trough solar thermal power plants

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INTERNATIONAL
ELECTROTECHNICAL
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SOLAR THERMAL ELECTRIC PLANTS –

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FOREWORD

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The text of this International Standard is based on the following documents:

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Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 62862 series, published under the general title *Solar thermal electric plants*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

SOLAR THERMAL ELECTRIC PLANTS –

Part 3-1: Systems and components – General requirements for the design of parabolic-trough solar thermal power plants

1 Scope

This part of IEC 62862 specifies the general requirements for the design of parabolic-trough solar thermal power plants. It includes requirements for the electric power system, solar resource assessment, site selection, overall planning, collector system, heat transfer system, thermal energy storage system, steam generation system, steam turbine system, layout of solar field, layout of power block, electrical equipment and system, water treatment system, instrumentation and control, auxiliary system and ancillary facilities, as well as considerations concerning health and safety.

This document is applicable to the design of new, expanded or rebuilt parabolic-trough solar thermal power plants using a steam turbine.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60076-2, *Power transformers – Part 2: Temperature rise for liquid-immersed transformers*

IEC 60870-5 (all parts), *Telecontrol equipment and systems – Part 5: Transmission protocols*

IEC 61850 (all parts), *Communication networks and systems for power utility automation*

IEC TS 62749, *Assessment of power quality – Characteristics of electricity supplied by public networks*

IEC TS 62862-1-1, *Solar thermal electric plants – Part 1-1: Terminology*

IEC TS 62862-2-1, *Solar thermal electric plants – Part 2-1: Thermal energy storage systems – Characterization of active, sensible systems for direct and indirect configurations*

IEC 62862-3-2, *Solar thermal electric plants – Part 3-2: Systems and components – General requirements and test methods for large-size parabolic-trough collectors*

IEC TS 62862-3-3, *Solar thermal electric plants – Part 3-3: Systems and components – General requirements and test methods for solar receivers*

ISO 9806, *Solar energy – Solar thermal collectors – Test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 62862-1-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
parabolic mirror
reflector with a parabolic cross section mounted on the supporting structure of a parabolic-trough collector

3.2
receiver efficiency
ratio of the thermal power transferred to the heat transfer fluid (HTF) to the radiant power at the receiver aperture

3.3
heat exchanger efficiency
ratio of the energy gained by the heat transfer fluid to the energy supplied to the heat exchanger in full-load discharge operation mode

3.4
thermal energy loss
<of thermal energy storage system> lost energy by the thermal energy storage system during the period of time considered, without involving any charge or discharge process and without any external energy supply

3.5
molten salt
inorganic salt in liquid state usually composed of mixtures of alkali nitrates, alkali nitrites, carbonates, chlorides, etc.

3.6
low-boiling-point substance
substance in heat transfer fluid whose distillation temperature is lower than the initial boiling point of the unused heat transfer fluid

3.7
high-boiling-point substance
substance whose distillation temperature is higher than the final boiling point of the unused heat transfer fluid, after heating testing similar to the distillation method

3.8
identification system
coding system allocating a unique identification tag to each physical object, in order to distinguish such an object from others

3.9
drought index
ratio of the annual evaporation to the annual rainfall in a region

3.10
turbine maximum continuous rating
TMCR
maximum continuous output of the steam turbine under the conditions of design steam intake, design live steam and reheat steam parameters, design exhaust pressure (4,9 kPa), and no make-up water

3.11
boiler maximum continuous rating
BMCR
maximum evaporation rate of the boiler when it can produce steam safely and continuously at design steam parameters and design make-up water temperature using the designed fuel

Note 1 to entry: The boiler maximum continuous rating condition corresponds to the inlet steam parameters when turbine valves are wide open.

3.12
regulating volume
difference between the total volume of the heat transfer system at operating temperature and the total volume of the heat transfer fluid at filling temperature

4 General requirements

4.1 For the design of a parabolic-trough solar thermal power plant, site resource conditions should be evaluated considering long-term meteorological conditions at the proposed location of the plant. As a minimum, the evaluation of average yearly direct normal irradiance (DNI) values (P50 and P90), typical meteorological year series (P50), ambient temperature, ambient pressure, wind speed, wind gust and relative humidity should be performed.

4.2 The steam turbine capacity, thermal storage system capacity, solar field size and operation modes of the plant should be determined through techno-economic evaluation and should meet the requirements of local electric power planning.

4.3 The design capacity of the plant should meet the following provisions:

a) The overall optimization should be done among the solar field aperture area, steam generator evaporation, steam turbine capacity, HTF-thermal storage medium heat exchanger charging power and thermal energy storage capacity.
b) The BMCR evaporation of the steam generation system should match the maximum inlet steam flow rate of the steam turbine.
c) The turbine-generator capacity should match the maximum continuous output of the steam turbine.

4.4 The design life time of the plant should meet the client's requirements.

4.5 A uniform identification system should be deployed in the plant design and should meet the relevant provisions of the IEC 81346 series.

5 Electric power system requirements

5.1 General

The main transformer, circuit breaker and other electric equipment in connection with the power grid should meet the requirements of frequent start-up/shutdown of the plant.

5.2 Grid-connection

5.2.1 The grid-connection scheme of the plant can be subject to regulations, provisions and requirements of the local grid.

5.2.2 The voltage class for grid-connection should be selected according to the power plant capacity.

5.2.3 Off-load tap-changing transformers should be selected as main transformers. On-load tap-changing transformers may be selected as main transformers if the voltage adjustment calculation is proved necessary.

5.2.4 The rated power factor of the generating units of a power plant should meet the local grid operation demands.

5.2.5 The power quality level at the point of common coupling shall meet the relevant requirements of IEC TS 62749.

5.3 Relay protection and automatic safety devices

5.3.1 Relay protection and automatic safety devices should be designed according to the IEC 60255 series, as well as the IEC 60870 series.

5.3.2 Configuration of line protection can be subject to requirements of the local grid.

5.4 Dispatching automation

5.4.1 Telecontrol information shall meet the requirements of the IEC 60870-5 series.

5.4.2 The solar power forecasting system may be installed in the plant, which forecasts solar resource and power production together with the plant performance model.

5.5 Electric power system communication

The electric power system communication shall meet the requirements of the IEC 61850 series.

5.6 Electric energy metering

The electric energy metering device should meet the relevant requirements of the IEC 62053 series.

6 Solar resource assessment

Solar resource at the site should be assessed according to IEC TS 62862-1-2 and IEC 62862-1-3.

7 Site selection

7.1 When selecting a site for a parabolic-trough solar thermal power plant, the following factors should be considered:

a) local grid structure and local electric power planning;
b) auxiliary fuel supply;
c) requirements of urban planning;
d) water source;
e) traffic and transportation for large equipment;
f) environmental impact assessment;
g) social impact assessment;
h) outgoing line corridor;
i) landform;
j) geology;

k) seismicity;
l) hydrology;
m) meteorology;
n) construction.

7.2 When selecting a site for a parabolic-trough solar thermal power plant, the water source should meet the following provisions:

a) If river water is used as water source, the water intake point should be located in the riverbed section which is stable all year around, so that the impact of mud, sand, vegetation, ice, drifting sundries and drained water backflow can be avoided.
b) If underground water is used as water source, a hydro-geological investigation report can be subject to local requirements.

7.3 When selecting a site for a parabolic-trough solar thermal power plant, the natural conditions should meet the following provisions:

a) The site should be selected in regions with abundant and stable DNI resources.
b) The site shall not be located in regions that include dangerous rocks, landslide, karst development, mudslide section, seismogenic fault and goaf zone.
c) If geological disaster prone region cannot be avoided, risk assessment should be done, and geological disaster risks should be comprehensively assessed.
d) Suspended particulate matter, airport runways and air routes, high wind speed regions, and surrounding obstacles such as tall and large trees, mountains, buildings should be taken into consideration.
e) The site should be located in a flat region.
f) Buildings or structures inside and outside the site should not shadow the solar field during most of the daylight hours.

7.4 When selecting a site for a parabolic-trough solar thermal power plant, essential data of the geological conditions of the site should be obtained, which will be used as the design basics for buildings and structures.

7.5 The seismic fortification intensity of the site shall be determined subject to the local provisions of seismic fortification intensity or seismic ground motion design parameters.

8 Overall planning

8.1 General

8.1.1 Overall planning of parabolic-trough solar thermal power plants should be done considering the following factors:

a) impact of DNI on the solar field layout;
b) requirements relating to construction and production of the plant;
c) natural conditions of the site;
d) construction schedule;
e) water supply and drainage facilities;
f) heat supply piping;
g) off-site traffic;
h) outgoing line corridor;
i) flood control and drainage;
j) current stage and long-term development of the site.

8.1.2 Planning for flood control and drainage should be done according to the natural conditions and safety requirements of the site. A flood bank, flood trench or floodwall may be used.

8.2 Off-site planning

8.2.1 Planning for off-site transportation can be subject to local laws and regulations.

8.2.2 Planning for off-site water supply and drainage facilities should be determined by comparing alternative options, considering plant capacity, water source, topographic conditions, environmental protection, soil and water conservation requirements, etc. Locations and piping for off-site water intake and drainage should be planned in a harmonized way.

8.2.3 Planning for an outgoing line corridor should be done according to the design capacity of the plant, construction scale of the current stage, planning of local electric power, as well as direction, voltage and circuit number of transmission lines.

8.2.4 Auxiliary fuel supply, if any, shall be reasonably planned according to local requirements of fuel supply, transportation and environmental protection.

8.3 On-site planning

8.3.1 On-site planning should meet the following provisions:

a) As per its different functions, the plant may be divided into solar field, power block and thermal storage system. The solar field may be subdivided into subfields according to different loop combinations.
b) Planning for corridors of incoming and outgoing power lines should be done according to system requirements and line directions, and line crossing should be avoided.
c) Location of entrances and exits of the plant should be convenient for transportation, and road specification can be subject to local requirements for production, living and fire protection.

8.3.2 Planning for solar field should meet the following provisions:

a) The solar field should be reasonably arranged according to topographic conditions, equipment specifications and construction requirements. The solar field should use the modularization arrangement in subfields.
b) The layout of the solar field should be comprehensively determined considering longitude, latitude, altitude and other geographical factors of the site, as well as site area and collector cost.
c) The installation height of the collector should be determined considering local flood levels and snow thickness.
d) For a site with high wind and dust, wind barriers and dust control facilities should be considered according to the wind direction and collector layout direction.
e) The layout of piping in the solar field should be planned in a harmonized way, and pipelines of HTF and cables should be laid along roadsides.

8.3.3 Planning for the power block should meet the following provisions:

a) The power block should be located in the centre of the plant.
b) Taking into account rational process flow, the planning for the subregion division and building layout in the power block should be done according to local sunlight direction, wind direction, topographical and geotechnical conditions.
c) Auxiliary and ancillary buildings with similar functions should be arranged side by side in the same subregion.

d) The layout of auxiliary fuel facilities (if any) may be determined according to the fuel type, supply and transportation conditions. If such facilities are located inside the power block, they should be arranged in a separated area.

e) Thermal energy storage facilities should be arranged in a separated area.

f) The location of collector assembly workshops should be considered.

8.3.4 Plant layout and site selection can be subject to local regulations on environment and safety for protection against flooding, earthquake and other natural disasters.

8.3.5 The flood protection standards of the plant can be subject to local codes and regulations, and mutually agreed with the client.

9 Collector system

9.1 General

9.1.1 The scale of the collector system should be determined through techno-economic evaluation considering plant capacity, annual equivalent operation hours, DNI conditions, thermal energy storage system capacity and collector specifications.

9.1.2 Collectors shall meet the provisions of IEC 62862-3-2.

9.1.3 The specifications of each collector component should match each other.

9.1.4 Collectors should meet the design requirements of the plant under normal operating conditions, considering exceptional situations such as extreme wind speed and extreme temperature.

9.2 Collectors

9.2.1 Collectors should meet the following provisions:

a) Collectors should be designed to survive at the maximum wind speed with a recurrence period of 50 years at stow position following the indications of local wind load codes and the technical specification of the plant.

b) Collectors should be designed to bear the reference snow pressure with a recurrent period of 50 years at stow position.

c) Collectors can be subject to other local meteorological conditions and applicable codes.

d) Loads to be applied to the collector structural models may be obtained from wind tunnel tests or computational fluid dynamics previously calibrated and tested with wind tunnel results.

9.2.2 Parabolic mirrors should be selected according to the following provisions:

a) Parabolic mirrors should be selected including but not limited to hot bending mirrors, toughened mirrors, laminated mirrors, or mirrors made from metals and polymer reflective materials.

b) Parabolic mirrors should satisfy the requirements of sand and hail impact on the basis of local climate conditions.

c) The reflectance and curvature accuracy of the parabolic mirrors should meet the performance requirements of the collectors.

d) Parabolic mirrors should have protective layer(s) to meet the durability requirements of anti-wear and anti-ageing.

9.2.3 In order to ensure performance of the solar field, the parabolic mirrors should have an average solar specular reflectance not lower than 93 % according to ISO 9050. Durability of the parabolic mirrors should be proven by accelerated ageing tests and should meet the design lifetime requirement of the plant.

9.2.4 Receivers should be selected according to the following provisions:

a) The material of receivers should meet the requirements of the HTF.

b) The design temperature and pressure of the receivers should match the operating temperature and pressure of the HTF.

c) The durability and technical performance parameters of solar receivers shall meet the provisions of IEC TS 62862-3-3.

9.2.5 Supporting structures should meet the following provisions:

a) Supporting structures should be designed following applicable codes, considering local ambient and climate conditions. The strength and stiffness of the supporting structure should meet the requirements of focusing and tracking accuracy.

b) The anti-corrosion design of the supporting structure should be determined according to local climatic conditions and design lifetime.

c) Supporting structures should be able to compensate the thermal expansion of the receivers and related parts during operation.

9.3 Driving and tracking system

9.3.1 The tracking accuracy of the driving and tracking system should be determined through techno-economic evaluation according to the collector overall performance.

9.3.2 Driving devices should be hydraulic or mechanical. Driving and tracking systems should be adapted to the outdoor environment.

9.3.3 Driving devices should be designed to be compatible within the complete rotation angle range, to prevent the collector from getting stuck and to drive the collector into stow position within the required time specified in the design.

9.3.4 Electrical and control equipment of the driving devices should meet the following provisions:

a) The protection level should not be lower than IP55.

b) The local controller should be placed on the drive pylon, and should match the drive pylon to facilitate operation and maintenance.

c) The local controller should have an automatic mode and a manual mode. The automatic mode should meet the requirements of normal operating conditions and emergency protection of the system. The manual mode should meet the needs of commissioning, maintenance and cleaning.

9.3.5 The driving device of the collector should be equipped with a shared or an individual reliable emergency power supply and/or energy accumulator, in order to safely defocus the collector in case of a power blackout to avoid overheating the HTF during operation. The emergency power supply configuration should meet the power supply requirement to drive the collector back to stow position in case of a power blackout.

9.3.6 The driving device should be able to hold the collector in any position under regular design conditions, and no free rotation of the collector should be possible.

10 Heat transfer system

10.1 General

10.1.1 The design flow rate of the heat transfer system should be determined through techo-economic evaluation considering the configuration of the collector system, design capacity of the steam turbine and operation modes of the plant.

10.1.2 For the selection of HTF, the following factors should be considered:

a) thermal expansion coefficient;
b) thermal and chemical stability;
c) specific heat capacity, thermal conductivity, kinematic viscosity;
d) operating temperature, freezing point;
e) flash point, corrosion-free properties;
f) environment friendly qualities.

10.1.3 The HTF could be thermal oil. If it makes sense technically and economically, molten salt, water or other heat transfer fluids could be used. This document mainly focuses on the regulations and requirements of thermal oil as a heat transfer fluid.

10.1.4 If the historical extreme minimum temperature of the site is lower than the freezing point of the HTF, anti-freezing measures should be considered in the plant design.

10.1.5 The flow rate and number of HTF main pumps should meet the following provisions:

a) The flow rate of the main pumps should meet the total flow rate requirement at the thermal load design point of the solar field, plus at least a 5 % margin.
b) The main pumps should comprise at least two sets including at least one redundant set, and should be equipped with variable frequency control devices. If one pump is out-of-service, the remaining pump(s) should meet the total flow rate requirement.
c) For the discharge head of the main pumps, the following factors should be considered:
   - pressure drop due to pipe flow friction and local fitting friction along all HTF pipeline calculated at design point flow rate;
   - the largest value among the following three sums calculated at design point flow rate: sum of solar field pressure drop and steam generation system pressure drop, sum of solar field pressure drop and thermal energy storage system pressure drop, and sum of thermal energy storage system pressure drop and steam generation system pressure drop in discharge operation mode;
   - static pressure due to different height between the highest point of HTF returning pipe and the minimum liquid level in the expansion tank;
   - at least 5 % margin.

10.1.6 Bypass filters should be installed in the system pipeline, depending on the specific properties of the HTF.

10.2 HTF storage and expansion system

10.2.1 If using thermal oil as HTF, the heat transfer system should include an expansion tank, overflow tank(s), overflow pump(s) and a nitrogen coverage system. A nitrogen coverage system shall be used if the HTF is easily flammable.

10.2.2 All venting pipes should be led to the expansion tank.

10.2.3 The regulating volume should be at least 1,3 times the total volume increase of the HTF from filling temperature to operating temperature.

10.2.4 The operating pressure of the expansion tank should not be less than the corresponding vapour pressure at the maximum temperature of the HTF under all working conditions, plus a margin of 30 kPa to 50 kPa.

10.2.5 Multiple overflow tanks may be used if the dimension of one single tank is too big and difficult for manufacture or transportation.

10.2.6 The design pressure of the overflow tank(s) should be the same as that of the expansion tank.

10.2.7 If it makes sense technically and economically, the volume of the expansion tank may be increased and usage of overflow tank(s) may be cancelled.

10.2.8 When using overflow tanks, two or more overflow pumps should be installed, including a redundant one.

10.2.9 The nitrogen coverage system should be connected to the expansion tank and the overflow tank(s) in order to keep pressure in all tanks within the set range.

10.3 HTF ullage system

10.3.1 When using thermal oil as HTF, a ullage system should be installed.

10.3.2 The ullage system can remove high-boiling-point substances and low-boiling-point substances generated during plant operation, and recover the thermal oil. The capacity of the ullage system should be determined as per the larger value between the vent gas amount of the expansion tank and the vent gas amount of the flash expander in the high-boiling-point substance treatment system.

10.3.3 Two-stage recovery tanks should be used in the ullage system for low-boiling-point substances. Air cooling condensers should be used at stage 1, and a sump oil tank should be installed downstream of the stage 2 recovery tank to accommodate low-boiling-point substances.

10.3.4 For the discharge head of the ullage pumps, the following factors should be considered:

a) total pressure drop due to pipeline friction from the stage 1 recovery tank to the expansion tank, and local fitting friction;
b) maximum operating pressure of the expansion tank;
c) static pressure due to different liquid levels between the stage 1 recovery tank and the expansion tank;
d) at least 5 % margin.

10.3.5 A flash expander should be installed in the high-boiling-point substance treatment system of the ullage system.

10.3.6 A sump oil tank should be installed in the ullage system.

10.4 HTF filling system

10.4.1 When using thermal oil as HTF, an HTF filling system should be installed to fill the HTF into the heat transfer system.

10.4.2 One or two self-priming pump(s) equipped with filter at their inlets should be used as filling pumps for the HTF filling system.

10.5 HTF anti-freezing system

10.5.1 When using thermal oil or molten salt as HTF, an anti-freezing system should be installed if the historical extreme minimum temperature of the site is lower than the freezing point of the HTF. The thermal power output of the anti-freezing system should be higher than the thermal losses of the whole heat transfer system at the historical extreme minimum temperature.

10.5.2 The anti-freezing facilities should comprise at least two sets including at least one redundant set. If one facility is out-of-service, the remaining facility(ies) should meet the thermal power requirement for anti-freezing. At least 5 % margin should be considered for the nominal power of each anti-freezing facility.

10.5.3 The anti-freezing pumps should not be less than two including one redundant pump. If one pump is out-of-service, the remaining pump(s) should meet 105 % of the anti-freezing flow rate. The anti-freezing flow rate should be calculated according to anti-freezing thermal power, HTF design parameters and design temperature difference.

10.5.4 For the discharge head of the anti-freezing pumps, the following factors should be considered:

a) pressure drop due to pipe flow friction and local fitting friction along the HTF pipeline;
b) equipment pressure drop in HTF-molten salt heat exchangers of the thermal energy storage system;
c) equipment pressure drop in the steam generation system;
d) pressure drop due to flow friction and local fitting friction along collectors;
e) equipment pressure drop in anti-freezing heaters;
f) at least 5 % margin.

11 Thermal energy storage system

11.1 General

11.1.1 The thermal energy storage system should meet the following provisions:

a) Molten salt sensible heat should be used for thermal storage.
b) Thermal insulation, anti-freezing facilities, thermal storage medium leakage protection facilities and drainage system should be used in the thermal energy storage system. When using thermal oil or any other flammable medium as HTF, inertial gas coverage shall be used.
c) The thermal energy storage system should be surrounded by a non-flammable barrier or should be located in a basin, which can accommodate the volume of thermal storage medium in case of tank collapse.

11.1.2 The characterization of a sensible thermal energy storage system shall meet the provisions of IEC TS 62862-2-1.

11.2 Storage system of thermal storage medium

11.2.1 The flow rate measurement shall be performed according to ISO 9806.

11.2.2 The thermal storage medium should be able to reach the maximum temperature required by the system process. The physical and chemical properties of the medium should be stable within the operating temperature range during the lifetime of the plant.

11.2.3 The total mass of the thermal storage medium should be determined according to the specific enthalpy and operating temperature range of the thermal storage medium, as well as the operation modes and energy losses of the thermal storage system.

11.2.4 Storage tank(s) should meet the following provisions:

a) For the total volume of the cold or hot tank(s) at the design liquid level, the whole molten salt volume at the corresponding maximum operating temperature of the tank(s) should be considered.

b) A vertical cylindrical tank with dome should be used.

c) The height-diameter ratio of the tank(s) should be determined according to the length of the salt pump(s).

d) The material of the tank(s) should meet the thermal storage medium characteristics, operating temperature and corrosion requirements.

e) The wall thickness of the tank(s) should be determined according to the design pressure, design temperature, design lifetime and corrosion rate.

f) Anti-freezing electric immersion heaters should be installed inside each tank.

g) At least two independent liquid level gauges should be installed in each tank. Each gauge shall be provided with upper limit alarm, lower limit alarm and shut-off device.

h) When using inertial gas coverage for each tank, molten salt draining pipes and safety valve(s) with proper thermal insulation shall be installed. If no inertial gas coverage is needed, the tank(s) can be vented to the atmosphere.

11.3 Heat transfer system of thermal storage medium

11.3.1 When using molten salt sensible heat for thermal storage, the following provisions should be met:

a) The flow rate of the hot salt pump(s) should be determined according to the design discharge power, inlet and outlet HTF temperature in the HTF-molten salt heat exchanger, heat exchanger efficiency, as well as design temperature of the hot salt and the cold salt.

b) The flow rate of the cold salt pump(s) should be determined according to the solar field thermal power, design charge power, inlet and outlet HTF temperature in the HTF-molten salt heat exchanger, heat exchanger efficiency, as well as design temperature of the hot salt and the cold salt.

11.3.2 The number of hot salt pumps or cold salt pumps should not be less than two including one redundant pump for each type of pump. If one pump is out-of-service, the remaining pump(s) should meet not less than 105 % of the total flow rate. The 5 % margin is for the pump degradation during lifetime, and the other margin value can be used if there are more reliable engineering practices.

11.3.3 In discharge mode, for the discharge head of hot salt pumps, the following factors should be considered:

a) static pressure due to different liquid levels between hot salt tank and cold salt tank when the hot salt tank is at minimum liquid level;

b) pressure drop due to pipe flow friction from the outlet of the hot salt pump(s) to the inlet of the HTF-molten salt heat exchanger(s);

c) equipment pressure drop in the HTF-molten salt heat exchanger(s);

d) pressure drop due to pipe flow friction from the outlet of the HTF-molten salt heat exchanger(s) to the inlet of the cold salt tank(s);

e) static pressure at the inlet of the cold salt tank(s);

f) at least 5 % margin.

11.3.4 In full power charge mode, for the discharge head of cold salt pumps, the following factors should be considered:

a) static pressure due to different liquid levels between hot salt tank and cold salt tank when the cold salt tank is at minimum liquid level;
b) pressure drop due to pipe flow friction from the outlet of the cold salt pump(s) to the inlet of the HTF-molten salt heat exchanger(s);
c) equipment pressure drop in the HTF-molten salt heat exchanger(s);
d) pressure drop due to pipe flow friction from the outlet of the HTF-molten salt heat exchanger(s) to the inlet of the hot salt tank(s);
e) static pressure at the inlet of the hot salt tank(s);
f) at least 5 % margin.

11.3.5 Vertical submerged pumps with variable frequency drives should be used as salt pumps.

11.3.6 Welding connection should be used for molten salt pipeline connection.

11.3.7 When selecting an HTF-molten salt heat exchanger, the following provisions should be met:

a) The flow direction of both media can be switched between forward and backward directions, in order to implement charge and discharge two-way heat transfer.
b) A tubular heat exchanger, header type heat exchanger or plate heat exchanger may be used.

11.3.8 Molten salt pipelines should meet the following provisions:

a) There should be bypassing pipelines, draining pipelines and corresponding shut-off valve(s).
b) A certain slope for molten salt pipelines should be designed to ensure drainage of the molten salt.
c) A heat tracing system and thermal insulation should be used in molten salt pipelines, drainage points, valves, and any other molten salt equipment.

11.4 Additional components

11.4.1 An inertial gas coverage system, if any, should meet the following provisions:

a) Balancing pipeline(s) for inertial gas should be used between the cold salt tank and hot salt tank.
b) An inertial gas buffer with pressure relief device should be installed in the thermal energy storage area.

11.4.2 An anti-freezing system should meet the following provisions:

a) Electric heaters or auxiliary combustion heaters may be used for anti-freezing purposes.
b) Anti-freezing facilities should be used in molten salt tank(s). Either an electric immersion heater, heat tracing inside the tank, or a circulation heater outside the tank can be acceptable.
c) Electric heat tracing and anti-freezing heaters should be connected with an emergency power supply.

11.4.3 The layout of molten salt pumps, pipelines and valves in the thermal energy storage tank area should be designed for easy inspection and operation. Supporting platforms, overhaul platforms and stairways should be installed in the heat exchanger area.

12 Steam generation system

12.1 General

12.1.1 For the design and model selection of the steam generation system, live steam temperature and make-up water temperature should be determined according to the specifications of the steam turbine, as well as the operating pressure and operating temperature of the HTF at the outlet and inlet of the heat transfer system.

12.1.2 The evaporation capacity of the steam generation system should match the demand of the steam turbine.

12.1.3 The steam generation system should be composed of preheater, steam generator, superheater, reheater (if any) and other auxiliary equipment.

12.1.4 When using thermal oil or molten salt as HTF, one or two train(s) of steam generation equipment should be used. If using two trains, evaporation of each train should be at least 50 % of the total design value.

12.1.5 Primary continuous blow-down expansion should be used in the continuous blow-down system that can be switched to periodical blow-down expansion using a bypass. Both blow-down systems should be installed on the water-steam side of the steam generation system.

12.1.6 The steam generation system should also have thermal insulation, HTF anti-freezing facility, and HTF leak protection and draining system.

12.2 Steam generation equipment

12.2.1 Two types of evaporators, i.e. kettle-type and steam drum type (tube-and-shell or header-and-coil), could be used for steam generation.

12.2.2 Pressure drop and temperature drop of the superheating and reheating system should meet the following provisions:

a) The pressure drop from the superheater outlet to the steam turbine inlet should not be 5 % higher than the design live steam pressure of the steam turbine.
b) The design steam temperature of the superheater outlet should be 3 °C higher than the design live steam temperature of the steam turbine, or follow good engineering practices.
c) The total pressure drop of the reheating system should be not more than 10 % of the exhaust pressure of the steam turbine high pressure cylinder at the design point.
d) The design steam temperature of the reheater outlet should be 2 °C higher than the design inlet steam temperature of the intermediate pressure cylinder of the steam turbine.

12.2.3 Preheaters, steam generators, superheaters and reheaters should be equipped with a sufficient number of safety valves on the steam-water sides of the steam generation system in accordance with the rules as set forth in ASME BPVC and EN 12952-3.

12.2.4 When using shut-off valve(s) at the outlet on the HTF side of the steam generation system, pressure relief bypass should be installed accordingly, and the blow-down HTF by pressure relief should be recycled.

13 Steam turbine system

13.1 Steam turbine

13.1.1 Specifications of steam turbine should meet the relevant provisions of IEC 60045-1. The steam temperature should be determined according to the design temperature of the HTF and the thermal energy storage process.

13.1.2 In accordance with requirements of power output, the steam turbine should be designed to work at different partial loads and to be compatible for frequent and quick start-up and shutdown.

13.1.3 The back pressure of the steam turbine should be determined through optimization calculation according to the hydrological and meteorological conditions of the site, as well as the cooling system solution of the plant.

13.1.4 The air-cooling steam turbine should be selected for water-deficient regions where the drought index is higher than 1,5.

13.1.5 The nominal capacity and other capacity of the steam turbine should meet the relevant provisions of IEC 60045-1.

13.1.6 The regenerative system should be designed according to the size of the solar field and specifications of the steam turbine generator unit.

13.2 Live steam, reheat and bypass system

13.2.1 The diameter and wall thickness of pipelines for the live steam and reheat steam should meet the pressure and flowrate requirements of the superheaters and reheaters.

13.2.2 For the design of the steam turbine bypass system, the following factors should be considered:

a) operation characteristics of the steam turbine and the steam generation system;
b) start-up models of the steam turbine.

13.3 Feedwater system and pump

13.3.1 Each steam turbine generator unit should have one feedwater piping system.

13.3.2 The number and flow rate of feedwater pumps should meet the following provisions:

a) The total number and flow rate of the feedwater pumps should ensure that if one pump is out-of-service, the remaining pump(s) can still meet the flow rate requirement of the steam generation system.
b) The number of feedwater pumps should be at least two including one redundant one.

13.3.3 For the discharge head of the feedwater pumps the following factors should be considered:

a) feedwater flow rate consideration at the BMCR condition of the steam generation system;
b) pressure drop due to feedwater flow friction from the outlet of the deaerator feedwater tank to the inlet of the steam generation system;
c) static pressure due to different water levels between the highest one of the steam generation system and the normal one of the deaerator feedwater tank;
d) pressure drop due to steam flow friction from the outlet of the steam generator to the inlet of the superheater;

e) steam pressure required at the outlet of the superheater;

f) design pressure of the deaerator (negative value);

g) equipment pressure drop in the steam generation system;

h) total pressure drop during start-up of the preheater(s), low pressure heater(s), high pressure heater(s) and other auxiliary equipments;

i) at least 5 % margin.

13.4 Deaerator and feedwater tank

13.4.1 Each steam turbine generator unit should have one deaerator. The output flow rate of the deaerator should be determined according to the feedwater consumption under the BMCR condition of the steam generation system.

13.4.2 The volume of the feedwater tank should be at least 10 min to 15 min of feedwater consumption under the BMCR condition of the steam generation system.

13.4.3 The elevation of the deaerator should be determined according to static pressure from the lowest water level of the deaerator feedwater tank to the centre line of the feedwater pump(s). The following factors should be considered:

a) difference between water vapour pressure at the inlet of the feedwater pump(s) and operating pressure of the deaerator;

b) net positive suction head of the feedwater pump(s);

c) pressure drop due to flow friction along the water inlet pipe of the feedwater pump(s);

d) margin of 3 kPa to 5 kPa required for the safe operation of the feedwater pump(s).

13.4.4 Safety valves and venting pipes should be used in the deaerator and the feedwater tank.

13.4.5 The design of the deaerator and the feedwater tank should meet the relevant specification requirements for boiler deaerators.

13.5 Condensate system and condensate pump

13.5.1 Each steam turbine generator unit should have one condensate system.

13.5.2 Each condensate system should have two condensate pumps. The flow rate of each pump should be 110 % of the maximum condensed water volume, and the speed of each pump should be adjustable.

13.5.3 For the discharge head of the condensate pumps, the following factors should be considered:

a) pressure drop due to flow friction along the condensed water pipeline from the condenser hotwell to the condensed water inlet of the deaerator;

b) static pressure due to water level difference from the condensed water inlet of the deaerator to the minimum water level of the condenser hotwell;

c) spray pressure required by spray nozzle at the condensed water inlet of the deaerator;

d) maximum operating pressure of the deaerator;

e) maximum vacuum pressure of the condenser;

f) equipment pressure drop of the condensate system.

13.6 Drain pumps of low pressure heater

13.6.1 The flow rate and number of drain pump(s) of low pressure heaters should meet the following provisions:

a) The flow rate of the drain pump should be determined according to the drainage water volume discharged to the pump under the TMCR condition of the steam turbine.

b) Only one drain pump of the low pressure heater should be used, without redundancy. However, the drain pump should have a bypass pipeline for backflow to the condenser.

13.6.2 For the discharge head of the drain pump of low pressure heaters, the following factors should be considered:

a) pressure drop due to flow friction from the low pressure heater to the condensed water inlet of the deaerator;

b) static pressure due to water level difference from the condensed water inlet of the deaerator to the minimum water level of the low pressure heaters;

c) spray pressure required by the spray nozzle at the condensed water inlet of the deaerator;

d) maximum operation pressure of the deaerator;

e) vacuum pressure of the low pressure heater under the maximum condensate condition. In case of positive pressure, a negative value should be used.

13.7 Steam turbine cooling system

13.7.1 A cooling system solution should be selected through techno-economic evaluation based on local meteorological conditions, general layout, specifications of the steam turbine generator unit, operation modes, height limit for buildings, as well as operation modes and operation strategy of the plant.

13.7.2 When using air cooling, the type of air cooling system should be selected through techno-economic evaluation based on local meteorological conditions, cooling facilities layout, anti-freezing and noise control measures. A direct air cooling system should be preferred for cold or severe cold regions.

13.7.3 When using wet cooling, the type of wet cooling tower should be determined through techno-economic evaluation based on quantity, temperature and quality of circulating water, as well as operation modes of the circulating water system. Besides, the following factors and actual conditions should be also considered:

a) natural conditions like landform, local meteorological conditions and geological conditions;

b) interacted influence between the cooling tower and its surrounding buildings or collectors;

c) supply and construction conditions for material and equipment.

13.7.4 The cooling system in cold or severe cold regions should have reliable anti-freezing measures according to the characteristics of the steam turbine generator unit and operation modes of the plant.

13.7.5 The main air inlet of the direct air cooling system will face predominant wind directions in summer and the impact of high-temperature gale occurrence frequency on the air cooling system should be analysed.

13.7.6 Equipment and buildings under the air cooling condenser should be arranged close to row A of the steam turbine hall, not exceeding 1/4 height of the air cooling condenser platform.

13.7.7 The plane arrangement of the supporting structure of the air cooling condenser should be regular and symmetrical.

13.8 Auxiliary equipment cooling water system

13.8.1 The cooling water system for auxiliary equipment should be determined according to the cooling water source and water quality for the condenser, as well as requirements on volume, temperature and quality of cooling water by various equipment.

13.8.2 For the cooling water of rotating machinery bearings, carbonate hardness should be less than 250 mg/l ($CaCO_3$) and the pH value should be between 6,5 to 9,5, and the suspended solids content should be less than 100 mg/l.

13.8.3 The cooling water system for auxiliary equipment should meet the following provisions:

a) When using fresh water without treatment as cooling water, an open cycle cooling water system should be used. When using fresh water with treatment as cooling water, an open cycle and closed cycle combined cooling water system should be used.

b) When using seawater as cooling water, for those auxiliary equipment which are not suitable for direct cooling by seawater, a closed cycle cooling water system by demineralized water should be used, and seawater should act as cooling water source for the heat exchangers of the closed cycle cooling water system, instead of direct cooling of the auxiliary equipment.

c) When using recycled water as cooling water, for those auxiliary equipment which are not suitable for direct cooling by recycled water, a closed cycle cooling water system by demineralized water should be used, and recycled water should act as cooling water source for the heat exchangers of the closed cycle cooling water system, instead of direct cooling of the auxiliary equipment.

d) Cooling water for the open cycle cooling water system of a wet cooling plant should be taken from the circulating cooling water system of the condenser. Cooling water for the open cycle cooling water system of an air-cooling plant should be taken from the cooling water system of the cooling tower. Cooling water for the closed cycle cooling water system should be demineralized water or condensed water.

13.8.4 The heat transfer area of the closed cycle cooling water heat exchanger should be calculated on the basis of maximum calculated cooling water temperature. Two heat exchangers should be installed, and each one should have 65 % of the total required heat transfer area. The material of the heat exchangers should be consistent with that of the condenser.

13.8.5 When using a closed cycle cooling water system, two cooling water pumps should be installed, and each one should be at least 110 % of the maximum required cooling water flow rate. The discharge head of the cooling water pumps should not be less than the total pressure drop due to pipe flow friction calculated at the maximum required cooling water flow rate, plus at least a 5 % margin.

13.8.6 When using an open cycle cooling water system, necessity of a booster water pump and its coverage range should be determined and calculated according to the detailed layout of the system. If required, two booster water pumps should be installed, and each one should be at least 110 % of the maximum cooling water to be boosted. The discharge head of the pump(s) should be calculated considering the following factors:

a) pressure drop due to pipe flow friction calculated at the maximum cooling water flow rate, plus at least 5 % margin;

b) static pressure due to water level difference from the highest point of cooling water usage to the centre line of the booster water pump(s);

c) static pressure due to water level difference between inlet and outlet of the circulating water pipelines (negative value).

13.8.7 When using a closed cycle cooling water system, an expansion facility and a make-up water system should be installed. The installation height of the expansion facility should not be lower than that of the highest cooling equipment in the system.

13.8.8 The operating pressure on the closed cycle side in the closed cycle cooling water heat exchanger should be greater than that on the open cycle side.

13.9 Condenser and auxiliary facilities

13.9.1 Configuration of the condenser washing device should consider and meet the following provisions:

a) In a through water supply system, if high sand content is contained in the water and the pipes are free of scaling or sedimentation, a rubber ball washing device should not be used.
b) If suspended sundries are contained in the cooling water and are prone to form one-way blocking, a back washing device should be used.
c) For a surface condenser of indirect air cooling system, a rubber ball washing device should not be used.

13.10 Regenerative system

13.10.1 Hybrid heaters should be used in the deaerator, while surface heaters should be used in other regenerative heaters.

13.10.2 For high pressure heaters and low pressure heaters, the decision on using overall bypass or individual bypass should be made according to the reliability of the heaters and operation economy of the steam turbine generator unit.

13.10.3 When calculating the heat transfer area for the high pressure heaters and low pressure heaters, the needs of the various operating conditions of the steam turbine should be considered.

14 Layout of solar field

14.1 General layout of solar field

14.1.1 The general layout of the solar field should minimize heat losses and hydraulic losses. Rectangular layout is preferrable. The topography of the site should also be considered.

14.1.2 The solar field should be arranged in subfields according to site shape, collector direction, loop quantity and type.

14.1.3 The solar field should use the flat slope layout. The slope of the site should meet the layout requirement of the collectors. In case of high natural slope, terrace arrangement can be used for solar field layout.

14.1.4 The vertical layout of the solar field should be designed considering process flow, engineering geology, hydrology, meteorology, civil work and foundation treatment, and the following provisions should be met:

a) The maximum slope and orientation of the collector loops shall meet the requirements of IEC 62862-3-2.
b) Road and site draining facilities should match the minimum slope and direction of the site, and should be determined according to local precipitation and soil characteristics on-site.

14.1.5 Outgoing line and pipe racks should be arranged overhead along the roadside, and their shading on the solar field should be considered.

14.1.6 Wires and cables inside the solar field may be laid overhead, by trench or by burying. Wires and cables should not be laid in the same trench with other pipelines.

14.1.7 HTF pipelines inside the solar field should be arranged overhead at a low elevation.

14.2 Layout of collectors and HTF pipelines

14.2.1 The layout of the collectors should meet the process requirement of the solar field. The orientation of the collectors should be optimized and determined based on geographical latitude, DNI resource and solar multiple.

14.2.2 The layout of the collector loops should consider interacted shading effects.

14.2.3 The spacing between the collector loops should be determined through techno-economic comparison considering site latitude, DNI, solar multiple, available land area, collector aperture and tracking angles.

14.2.4 The collector loop should be symmetrically arranged along the cold and hot header pipes of the HTF in each subfield. The maximum slope along the collector axis direction should meet the technical specifications of the collectors.

14.2.5 The layout of the HTF header pipes and the collector loops should meet the inspection, operation and maintenance requirements of the collectors.

14.3 Wind and sand protection

14.3.1 Wind and sand protection measures for the solar field should be determined through techno-economic evaluation based on the layout of the collectors and meteorological conditions of the site.

14.3.2 Fences for wind and sand protection should be anti-tearing and anti-dropping.

15 Layout of power block

15.1 General

15.1.1 The power block includes central control building (room), HTF tank area, thermal storage area, steam generator area, steam turbine hall, power distribution area, chemical water workshop, auxiliary boiler workshop, other auxiliary production facilities.

15.1.2 The general layout of the power block should follow the principle of reasonable process flow, overall planning and overall coordination. All production facilities and systems functions should be combined, with clear zoning, compact and reasonable layout according to local conditions, in order to meet the requirements for fire prevention, explosion protection, environmental protection, occupational health and safety. The layout of buildings or structures inside the power block should meet the following provisions:

a) The power block should be arranged in the proper position of the plant. When using direct air cooling, the impact of meteorological conditions on the air cooling condenser operation and the main workshop direction should be considered. Thermal storage area, steam turbine hall and steam generator area should be located in the region with even stratum and high bearing capacity for foundation.

b) The layout of the power distribution area should be convenient for incoming line and outgoing line, and should avoid interference as much as possible.

c) Except for transportation by pipelines, loading and unloading areas for auxiliary fuel should be properly designed according to the specific fuel type. The auxiliary fuel shall be stored in separate zones.

d) HTF expansion and ullage area, and natural gas storage facilities shall be located in the upstream side of minimum frequency wind direction all year round from the steam turbine hall in the power block, and pollution to off-site residential areas shall be avoided.

15.1.3 The layout of the cooling facilities should meet the following provisions:

a) When using a natural ventilation wet cooling tower or natural ventilation indirect air cooling tower, the cooling tower should be located close to the steam turbine hall considering topographical and geological conditions, and it should not cause shadow or shelter on the surrounding collectors.

b) When using an air cooling condenser, the orientation of the direct air cooling platform should be comprehensively determined according to area of the platform, predominant wind direction, wind speed and wind frequency on the top of the steam distribution pipe all year round, in summer and during high temperature windy days, as well as safe and economic operation of the steam turbine generator unit.

c) When using an air cooling condenser, the orientation of the exhaust steam pipe from the steam turbine should be considered during the layout design of the direct air cooling platform. The transformer, electric power distribution room and storage tank for transformer oil may be arranged under the platform, taking into account sufficient space for transformer transportation, installation, fire fighting and overhaul.

d) When using mechanical ventilation for indirect cooling tower, the air inlet of the one-side air intake tower should face predominant wind direction in summer, and the air inlet of the two-side air intake tower should be parallel to predominant wind direction in summer.

15.1.4 Vehicle roads, fire lanes and sidewalks shall be set between buildings in the power block, as per production, living and fire fighting purposes, and the following provisions should be met:

a) For steam turbine hall and steam generator area, HTF tank area, thermal storage area, fuel oil tank area, natural gas storage facility area and outdoor power distribution area, an annular fire lane should be used. If it is difficult to use the annular fire lane, a dead end fire lane may be used along the long side and a turning lane or turnaround yard should also be used. The turnaround area should be at least 12 m × 12 m, and should be at least 15 m × 15 m when it is for the use of large fire fighting vehicles.

b) The width of the fire lane in the power block should be at least 4 m. If the pipe support structure, trestle bridge and other obstacles are above the road, the headroom shall be at least 4 m.

c) The travel lane of the main road in the power block should be 6 m wide, and the secondary road shall be 3,5 m to 4 m wide. The width of the approach road to the building entrance should be in line with the width of the gate.

15.1.5 The vertical layout of the power block should be designed considering process flow, engineering geology, hydrology, meteorology, civil work and foundation treatment, and the following provisions should be met:

a) The determination of elevation for all buildings (structures) and roads should meet production requirements. The elevation of above ground and underground facility foundation, pipeline, pipe support structure, pipe ditch, tunnel and basement should be properly arranged to ensure reasonable intersection, smooth drainage of water, and convenience for expansion and maintenance.

b) The minimum slope and orientation of the power block should facilitate quick discharge of surface water. The location of gutter inlet in buildings, roads and site should be determined according to the local precipitation and soil conditions on-site.

c) If the power block has great variation in topography, taking into account meeting process requirements, a terrace layout may be used. HTF process requirements, transportation convenience and underground facility layout should be considered when dividing terraces. In the junction between two terraces, protection measures for slope stability should be fully considered according to local geological conditions.

d) The water draining system of the power block should be designed with comprehensive consideration of topography, geology, hydrology, meteorology, underground water level, etc.

15.1.6 The layout of power block pipelines should meet the following provisions:

a) Main pipe racks, pipelines and ditches in the power block should be planned in a harmonized way and arranged in a centralized manner, reserving a reasonable pipeline corridor.

b) The process flow is reasonable and convenient for construction, inspection and maintenance.

c) Pipeline malfunctions shall not incur secondary disaster. Neither waste water nor harmful and flammable gas shall penetrate living water pipelines, or permeat other ditches or basement.

d) Mechanical damage or corrosion should be avoided.

e) Freezing of liquid inside the pipelines should be avoided.

f) Surface water, underground water and water from other pipe ditches should be prevented from seeping into cable trenches or tunnels.

g) Cable trenches and tunnels should be equipped with reliable water collecting and draining facilities.

h) A firewall should be used at the location where cable trenches or cable tunnels enter into buildings, or at a proper distance or interval. A firewall in the cable tunnels should be provided with a fireproof door.

15.1.7 Pipeline laying methods in the power block should meet the following provisions:

a) In case of overhead laying, a comprehensive pipe rack should be used. In the region where it is unfavourable for underground pipe ditches because of high underground water level, corrosive soil or shallow bedrock burial depth, a comprehensive pipe rack is preferred.

b) The feedwater pipeline, rainwater and waste water drainage pipeline for production, living and fire fighting should be laid underground.

c) The compressed air pipeline, auxiliary fuel pipeline, natural gas pipeline, and steam pipeline should be laid overhead. An HTF pipeline should be laid overhead considering drainage requirements.

d) An acidic and alkaline liquid pipeline may be laid overhead or in a ditch. If there is a risk of deterioration of the disaster in case of failure, such pipelines should not be laid in the same ditch.

e) Depending on specific conditions, cables in the power block may be laid overhead, in trench, in tunnel, in duct or by burying. The cables should not be laid in the same ditch with other pipelines.

f) Pipe racks, pipelines and ditches should be arranged along the roadside. Underground pipelines and ditches should be laid outside the travel lanes of the road.

g) Flammable and explosive pipelines should not be laid on unrelated buildings.

15.1.8 Horizontal spacing between ditches, underground pipes, buildings, roads and other pipelines, and vertical spacing for pipe crossing should be determined on the basis of burying depth of the underground pipelines and ditches, building foundation structure and construction, as well as overhaul requirements.

15.2 Layout of heat transfer facilities

15.2.1 Heat transfer facilities include HTF main pumps, anti-freezing pumps, expansion tank, overflow tank(s), overflow pumps, buffer tank (if any), ullage system and HTF heaters.

15.2.2 Discharge head, flow rate and fireproof requirements should be comprehensively considered for the main pumps and anti-freezing pumps. The layout of such pumps should be centralized.

15.2.3 The expansion tank, overflow tank(s) and ullage system should be located in the same area. Buffer tank(s), if any, should be located near the steam generator. Land saving, short piping and easy operation and maintenance should be considered for the layout of expansion tank, overflow tank(s) and buffer tank(s).

15.2.4 For the layout of HTF heater(s), convenient piping for the auxiliary fuel and HTF should be considered. The HTF heater(s) should be located close to other HTF facilities.

15.3 Layout of thermal storage facilities

15.3.1 Thermal storage facilities include molten salt tanks, HTF-molten salt heat exchangers, molten salt pumps, pipelines and valves.

15.3.2 The HTF-molten salt heat exchanger should be installed at a height appropriate to its type, economy and simplicity, as well as with simple and feasible draining and discharging of the heat exchange media. The HTF-molten salt heat exchangers should be located between the cold salt tank and the hot salt tank.

15.3.3 The hot salt pumps and cold salt pumps should be located above the corresponding molten salt tanks and close to the HTF-molten salt heat exchangers, supported by an independent platform.

15.3.4 The molten salt tanks and HTF-molten salt heat exchangers should be located outdoors. In extreme climate regions, the HTF-molten salt heat exchangers may be located indoors based on technical and economic evaluation.

15.3.5 Overhaul platforms should be installed for valves and other places which require operation and maintenance.

15.3.6 In the molten salt tank area, barriers for leakage prevention should be installed.

15.4 Layout of steam generation facilities

15.4.1 The steam generation facilities should be arranged near the steam turbine hall.

15.4.2 The steam generation facilities may be arranged at different elevations, reserving sufficient space for overhaul.

15.4.3 Overhaul platforms should be installed for valves and other places which require operation and maintenance.

15.4.4 The HTF main pumps and anti-freezing pumps should be located close to the steam generation facilities.

15.5 Layout of steam turbine hall and central control building

15.5.1 For the layout of the steam turbine hall, process flow requirements should be considered. Equipment arrangements should be compact and logical, and the pipeline connection should be short and neat.

15.5.2 In extreme cold climate regions, steam turbine, regenerative heaters, feedwater pumps, condensate pumps and other auxiliary equipment may be located indoors. Protective measures against fire, explosion, corrosion, freezing and toxin should be considered for special equipment as required.

15.5.3 The layout of the steam turbine hall should be determined through techno-economic evaluation according to natural conditions, overall planning and main and auxiliary equipment features and construction site, expansion conditions and other factors.

15.5.4 The layout of the steam turbine hall should be determined according to process flow requirements in the plant area and within main workshops, as well as expanding potential of the plant capacity. At the initial stage of planning and construction, necessity and feasibility of the plant expanding potential should be fully demonstrated.

15.5.5 In the steam turbine hall, necessary overhaul hoisting facilities, overhaul area and transportation channel for overhauls should be considered.

15.5.6 If using axial or lateral direction for exhausting, the steam turbine should be installed at a low elevation. If using vertically downward direction for exhausting, the steam turbine should be installed at a high elevation.

15.5.7 The layout of auxiliary equipment should meet the following provisions:

a) The main lubricating oil tank, oil pump, oil cooler and other equipment of the steam turbine should be arranged at 0 m level in the steam turbine hall and should be far away from high temperature pipelines.
b) Fireproof measures should be considered for the main lubricating oil tank and oil system of the steam turbine. An emergency oil tank (pit) should be installed at a proper position outside the main workshop, and its installation elevation and piping design should meet the requirement of smooth drainage of the oil in case of emergency. The volume of the emergency oil tank (pit) should not be less than the oil volume for the largest steam turbine. The emergency oil drain valve should be arranged in a safe position convenient for quick operation, and should be accessible through two passages.
c) Deaerator feedwater tanks should be installed at an elevation to prevent the feedwater pumps from cavitation under various working conditions.
d) If applicable, condenser rubber ball washing devices should be arranged beside the wet cooling condenser.

15.5.8 There should be a central control room for the whole plant.

15.5.9 The central control room should be located in the central control building close to the steam turbine hall side, or in an independent central control building. The central control room, electronic equipment room, cable interlayer, air-conditioning equipment and other process and living facilities in the central control building should be arranged by section. Favourable air-conditioning, lighting, dust proof, anti-vibration and noise prevention measures should be considered.

15.5.10 There should be at least two entrances for the central control building and the central control room.

15.6 Layout of auxiliary fuel facilities

15.6.1 Auxiliary boiler(s) should be located near the steam turbine hall and the steam generation system.

15.6.2 The layout of facilities in the auxiliary boiler workshop should be determined according to auxiliary fuel type and boiler evaporation.

15.6.3 Favourable ventilation should be ensured for the diesel generator room. The diesel generator should not be affected by rainwater, snow and excessive high temperatures. Convenient electrical connection should be considered.

15.6.4 Anti-freezing heater(s) for the HTF should be located near the HTF area.

15.6.5 The melting system for the molten salt during the commissioning stage should be located close to the molten salt tank area.

15.7 Maintenance facilities

15.7.1 The overhaul area of the steam turbine should meet the following provisions:

a) The overhaul area in the steam turbine hall should have sufficient space to meet the overhaul requirement of the steam turbine generator unit.

b) When using a large platform for the operation floor of the steam turbine hall, at least one installation and overhaul area should be considered for every two steam turbines. Its size may be determined according to the requirements of large piece hoisting and steam turbine cylinder turnover.

c) When using island-type layout, at least one overhaul area should be considered for every two steam turbines. The size of installation and overhaul area and location for the equipment entrance should be properly planned and designed in a compact way.

15.7.2 The overhead crane in the steam turbine hall should meet the following provisions:

a) One electric overhead crane should be installed.

b) The hoisting capacity should be determined as per the heaviest piece to be hosted during overhaul, excluding generator stator.

c) The elevation of the crane rail top surface should meet the requirement of maximum hoisting height of the hoisted pieces.

d) The expanding restrictions of the steam turbine hall are not considered when determining hoisting capacity, rail top elevation and other specifications of the overhead crane.

15.7.3 Where the use of an overhead crane in the steam turbine hall is not possible, necessary overhaul hoisting facilities should be considered.

15.7.4 On the operation floor of the steam turbine hall, the necessary space for pulling out the generator rotor by the overhead crane should be reserved. On the ground floor, the necessary space for pulling out and installing the condenser cooling tubes should be reserved.

15.7.5 The necessary overhaul hoisting and maintenance should be considered in the molten salt pump area, HTF pump area and large parts area like filters. For large valves and other accessories of the steam turbine, the feasibility of overhaul hoisting should be considered, and the following provisions should be met:

a) For indoor equipment which weighs 1 t or more, and pipe fittings and valves which require overhaul, an overhaul hoisting facility should be installed.

b) For indoor equipment which is frequently used and weighs 3 t or more, an electric hoisting facility should be installed.

c) For indoor equipment which weighs 10 t or more, an electric hoisting facility shall be considered.

d) For outdoor equipment, a mobile or fixed hoisting facility may be considered according to the detailed conditions nearby.

16 Electrical equipment and system

16.1 Generator and main transformer

16.1.1 Generator and excitation systems should meet the requirements of IEC 60034-1 and of the IEC 60034-16 series.

16.1.2 When the transformer operates normally and transmits rated power continuously, the average temperature rise of the windings shall not exceed the value specified in IEC 60076-2.

16.2 Main wiring

16.2.1 One generator should be connected to one main transformer. Circuit breakers or load switches should be installed between the generator and the transformer.

16.2.2 The neutral grounding method of the generator can be non-grounding or grounding via high resistance or arc-suppressing coil.

16.2.3 The neutral grounding method of the main transformer should be determined according to rated voltage and requirements of the local grid. Isolators should be installed when using grounding or grounding via arc-suppressing coil.

16.3 AC auxiliary power system

16.3.1 The voltage classes of the auxiliary power should meet the relevant provisions of IEC 60038.

16.3.2 If one generator is connected to one main transformer, the high-voltage auxiliary power system should be connected to the low voltage side of the main transformer. When using a generator circuit breaker, auxiliary branches should be connected between the transformer and such breaker.

16.3.3 The plant should have an AC emergency power supply. The voltage and neutral grounding method of the AC emergency power supply should be consistent with the high-voltage or low-voltage AC auxiliary power system.

16.4 High-voltage distribution devices

High-voltage distribution devices should be designed to conform to IEC TS 60815-1.

16.5 DC system

16.5.1 Key components of DC systems should meet the relevant provisions of IEC 60086-1 and IEC 62040-1.

16.5.2 Batteries should be installed as a DC system to supply power for both DC control load and power load.

16.5.3 One steam turbine generator unit should have one DC system to supply power for both DC control load and power load. Depending on the capacity of the steam turbine and configuration of the control system, one unit may have two DC systems if necessary.

16.5.4 When distribution systems in the solar field are far away from the steam turbine hall but require DC power, a complete set of DC system should be installed to supply power for both DC control load and power load.

16.6 Electrical monitoring and control

16.6.1 The following equipment or elements shall be monitored and controlled on the distributed control system or programmable logic controller:

a) generator, main transformer or generator-transformer group;
b) excitation system of the generator;
c) high-voltage auxiliary power system, including high-voltage operating transformer and high-voltage start-up/standby transformer;
d) high-voltage auxiliary transmission line;

e) low-voltage auxiliary transformer and low-voltage bus section circuit breaker in the steam turbine hall;
f) low-voltage standby transformer and standby power supply in the steam turbine hall;
g) power supplies of the collector system and the thermal energy storage system;
h) fire-fighting pumps.

16.6.2 The following equipment or elements should be monitored on the distributed control system or programmable logic controller:

a) DC system;
b) AC uninterrupted power supply;
c) diesel or natural gas generator unit.

16.6.3 The following equipment or elements of the electrical switchgear should be monitored and controlled on the power grid monitoring system:

a) bus-tie breaker, bus section breaker and reactor;
b) high-voltage lines;
c) interconnecting transformer (if any).

16.7 Relay protection and safety automation devices

The relay protection of the generator, transformer as well as electrical equipment and elements of the high-voltage and low-voltage auxiliary power systems should conform to the relevant provisions of IEC 60255-1.

16.8 Lighting system

The lighting system should have separate power supplies for normal lighting and emergency lighting, and should meet the requirements of the ISO 8995 series.

16.9 Cable selection and cable laying

Cable selection and cable laying should meet the relevant provisions of IEC 60183.

16.10 Overvoltage protection and grounding system

16.10.1 Overvoltage protection devices should meet the relevant requirements of IEC 60071-1, IEC 60071-2 and IEC 62305-1.

16.10.2 AC grounding systems should meet the relevant provisions of the IEC 60479 series and IEC 62271-1.

16.10.3 A main grounding network may be used for all electrical equipment and facilities with different functions and different voltages in the plant. All types of grounding networks should be connected to the main grounding network.

17 Water treatment system

17.1 Water quality and pretreatment

The water treatment system should be designed according to all available water quality analyses of for the water source in recent years. Such analyses can be subject to local standards and requirements.

17.2 Water pre-desalination

The treatment process for the water pre-desalination should be designed according to the type of water source and the water quality.

17.3 Demineralized water treatment

17.3.1 The design of the demineralization water treatment system should consider quality of the incoming water, water and steam quality criteria and consumption rate of the steam cycle, supply conditions of the dosing equipment and chemicals, as well as requirements for environmental protection.

17.3.2 The capacity of the demineralized water treatment system should match the feedwater amount considering normal water and steam losses. Various types of normal water and steam losses should be selected according to Table 1.

Table 1 – Various types of normal water and steam losses for a parabolic-trough solar thermal power plant

No.	Type	Normal losses
1	Water and steam circulation loss	2 % to 3 % of BMCR evaporation
2	Blow down loss of steam generator	As per calculation or data from steam generator manufacturer, but at least 0,3 %. Blow down percentage should not exceed 1 % for power-generation-only steam turbine and 2 % for cogeneration steam turbine.
3	Hot water loss in closed cycle cooling water system	0,5 % to 1 % of circulating water flowrate, or as per specific engineering condition.
4	Recirculating cooling water loss of indirect air cooling system	Average loss 3 t/h
5	Collector cleaning water loss (optional)	Average 0,7 l/m^2 per cleaning

17.3.3 Ion-exchange, combination of pre-desalination and ion-exchange, or combination of pre-desalination and electro-deionization may be used for the demineralized water treatment. The treatment process should be determined through techno-economic evaluation according to specific local conditions. If acids and alkalis are in short supply, the treatment process is restricted by local environmental protection, or the plant is power generation only instead of cogeneration, a combination of pre-desalination and electro-deionization should be selected.

17.3.4 Design of the demineralization system and selection of the equipment can be subject to relevant local standards and requirements.

17.4 Condensed water fine treatment

17.4.1 The condensed water fine treatment system should be designed according to specifications, start-up frequency and cooling method of the steam turbine, and should meet the following provisions:

a) De-ironing equipment without redundant design should be installed for the steam turbine generator unit using wet cooling, direct air cooling or indirect air-cooling with surface condenser.
b) De-ironing and demineralization equipment should be installed for the steam turbine generator unit using indirect air cooling with combined condenser. Demineralization equipment should be designed with redundancy, while de-ironing equipment should not.

17.4.2 The capacity of the condensed water fine treatment system should match the maximum flow rate of condensate pumps. The design pressure of the condensed water fine treatment system should be determined as per the shut-off pressure of the condensate pumps.

17.4.3 Each steam turbine generator unit should have one condensed water fine treatment system. The resin of the condensed water fine treatment system should be regenerated by an external regeneration method. A set-up using two units sharing one set of regeneration device is preferred.

17.5 Chemical dosing and water and steam sampling

17.5.1 Chemical dosing facilities should be installed in the water treatment system for the steam cycle, according to the steam generator type, steam cycle parameters and hydro-chemical working conditions.

17.5.2 Central sampling devices and monitoring instruments for water and steam should be installed in the steam cycle.

17.6 Cooling water treatment

17.6.1 The cooling water treatment system should be determined through techno-economic evaluation according to the cooling method, water balance and cooling water quality of the plant. Water treatment technology should be selected considering water conservation, environmental protection, as well as prevention of fouling, corrosion, algal-bacterial and aquatic organism breeding.

17.6.2 The concentration ratio for the circulating water supply system should be determined based upon environmental protection requirements, water quantity balance, water quality balance and feedwater source. When using seawater as feedwater source, the concentration ratio should be at least 1,5 to 2. Otherwise, it should be at least 3,5.

17.7 Collector cleaning water treatment

17.7.1 Collector cleaning water should be softened water, reverse osmosis water or demineralized water.

17.7.2 When using reverse osmosis water or demineralized water as cleaning water, the collector cleaning water treatment system and the demineralized water treatment system should be combined. When combining, the capacity of the demineralized water treatment system should meet the following provisions:

a) The increased output of the water treatment system accumulated during the time interval between two collector cleaning batches should meet the water consumption requirement for one collector cleaning batch.
b) The increased volume of the demineralized water tank should meet the required water volume for one collector cleaning batch.

17.8 Waste water treatment

The waste water treatment system should be designed according to category, property, quantity, recycling conditions and discharge quality requirement of the waste water. After treatment, waste water can be recycled or discharged if meeting local discharge standards.

17.9 Chemical storage

17.9.1 The warehouse for storing chemicals for water treatment should be designed according to consumption, supply and transportation of the chemicals.

17.9.2 The arrangement of the chemical storage facilities should be convenient for transportation, loading and unloading. Safety protection and ventilation facilities with proper anti-corrosion measures should be installed inside the chemical warehouse.

18 Instrumentation and control

18.1 General

18.1.1 The instrumentation and control system should be designed to meet the requirements of safe and economic operation, as well as start-up/shutdown control of the plant.

18.1.2 The computer-based control system should take security measures against hackers, viruses, malicious codes and illegal operations.

18.2 Automation level

18.2.1 The automation level of the plant should be determined according to its position in the local grid, specifications of the steam turbine, as well as the expected operation management level of the plant.

18.2.2 Automation levels of the solar field, collector system, thermal energy storage system, heat exchange system and steam turbine generator unit should be consistent with each other. All systems should be designed to such an extent that operator stations in the central control room can monitor and control start-up, shutdown and normal operation of the plant, as well as handle any malfunctions with the help of patrol inspection and local operation.

18.3 Control mode and control room

18.3.1 The control mode should be determined on the basis of construction scale, automation level and actual operation management mode. Centralized control should be used. There should be a central control room for the whole plant.

18.3.2 The steam turbine generator unit and auxiliary systems should use a centralized control mode provided by a control system located in the central control room. Local terminals used for commissioning during start-up, malfunction and inspection may be installed in the auxiliary systems.

18.3.3 The central control room and electronic equipment room should meet the following provisions:

a) The central control room should be arranged on the basis of plant design capacity and number of steam turbine generator units.
b) The electronic equipment room may use a centralized or decentralized arrangement according to equipment needs.

18.3.4 The design of the central control room should meet the requirements of ISO 11064-6 and ISO 11064-3.

18.4 Measurement and instrumentation

18.4.1 Measurement devices and instrumentation should be designed in order to:

a) detect and display operation parameters and conditions of the process system;
b) coordinate with instrumentation supplied together with the main and auxiliary equipment, in order to avoid any repetition;
c) provide instrumentation with parameters under normal operation, start-up/shutdown, malfunction and emergency conditions;
d) provide remote instrumentation for parameters which are necessary to be monitored and controlled during plant operation;
e) provide local instrumentation for parameters which are necessary for patrol inspection and local operation;