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INTERNATIONAL STANDARD

Solar thermal electric plants –
Part 4-1: General requirements for the design of solar power tower plants

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FOREWORD

IEC 62862-4-1 has been prepared by IEC technical committee 117: Solar thermal electric plants. It is an International Standard.

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

Draft	Report on voting
117/166/FDIS	117/169/RVD

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/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- withdrawn,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 4-1: General requirements for the design of solar power tower plants

1 Scope

This part of IEC 62862 specifies the general requirements for the design of solar power tower plants and covers the electric power system requirements, the solar resource assessment, the site selection, the overall planning, the layout of the heliostat field and the receiver tower, the layout of the power block, the collector system, the heat transfer, the thermal energy storage and steam generation system, the steam turbine system, the water treatment system, the information system, instrumentation and control, the electrical equipment and system, occupational safety and occupational health.

This document is applicable to the design requirements of newly built, expanded or rebuilt solar power tower plants employing steam turbines with molten salt or water-steam as heat transfer fluid. If other heat transfer fluids are employed, it is possible that the provisions set out in this document will need to be adapted.

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 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-3, *Rotating electrical machines – Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines and for synchronous compensators*

IEC 60034-16 (all parts), *Rotating electrical machines – Part 16: Excitation systems for synchronous machines*

IEC 60038, *IEC standard voltages*

IEC 60045-1, *Steam turbines – Part 1: Specifications*

IEC 60076-1, *Power transformers – Part 1: General*

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

IEC 60076-3, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-4, *Power transformers – Part 4: Guide to the lightning impulse and switching impulse testing – Power transformers and reactors*

IEC 60076-5, *Power transformers – Part 5: Ability to withstand short circuit*

IEC 60076-7, *Power transformers – Part 7: Loading guide for mineral-oil-immersed power transformers*

IEC 60086-1, *Primary batteries – Part 1: General*

IEC 60183, *Guidance for the selection of high-voltage A.C. cable systems*

IEC 60255 (all parts), *Measuring relays and protection equipment*

IEC 60479 (all parts), *Effects of current on human beings and livestock*

IEC TS 60815 (all parts), *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

IEC 60839-11-2, *Alarm and electronic security systems – Part 11-2: Electronic access control systems – Application guidelines*

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

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61511 (all parts), *Functional safety – Safety instrumented systems for the process industry sector*

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

IEC 62040-1, *Uninterruptible power systems (UPS) – Part 1: Safety requirements*

IEC 62052-11, *Electricity metering equipment – General requirements, tests and test conditions – Part 11: Metering equipment*

IEC 62053 (all parts), *Electricity metering equipment – Particular requirements*

IEC 62053-21, *Electricity metering equipment – Particular requirements – Part 21: Static meters for AC active energy (classes 0,5, 1 and 2)*

IEC 62053-41, *Electricity metering equipment – Particular requirements – Part 41: Static meters for DC energy (classes 0,5 and 1)*

IEC 62271 (all parts), *High-voltage switchgear and controlgear*

IEC 62305-1, *Protection against lightning – Part 1: General principles*

IEC 62642-1, *Alarm systems – Intrusion and hold-up systems – Part 1: System requirements*

IEC 62676-1-1, *Video surveillance systems for use in security applications – Part 1-1: System requirements – General*

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 81346 (all parts), *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations*

ISO/IEC 11801-3, *Information technology – Generic cabling for customer premises – Part 3: Industrial premises*

ISO 8995-1, *Lighting of workplaces – Part 1: Indoor*

ISO/CIE 8995-3, *Lighting of workplaces – Part 3: Lighting requirements for safety and security of outdoor workplaces*

ISO 11064-3, *Ergonomic design of control centres – Part 3: Control room layout*

ISO 11064-6, *Ergonomic design of control centres – Part 6: Environmental requirements for control centres*

ISO 12100, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO/TR 14121-2, *Safety of machinery – Risk assessment – Part 2: Practical guidance and examples of methods*

ISO 45001, *Occupational health and safety management systems – Requirements with guidance for use*

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 http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
receiver tower
tall structure which supports the receiver and auxiliary systems

3.2
solar power tower plant
solar thermal power plant consisting of a point-focus solar system that is composed of heliostats, a receiver system, and a receiver tower

3.3
heliostat field
area on which the heliostats are installed to concentrate the solar radiation onto the receiver

3.4
molten salt
inorganic salt in the liquid phase, usually composed of mixtures of alkali nitrates, carbonates or chlorides

3.5
annual efficiency of collector system
ratio of the thermal energy transferred to the heat transfer fluid from collector system to the total direct normal irradiation multiplied by the heliostat field aperture area over a year

3.6
shading loss
energy loss due to the reduction in the effective aperture of the heliostat caused by shadows cast by other heliostats or the tower

3.7
blocking loss
energy loss due to reflected rays being blocked by adjacent heliostats

3.8
capacity factor
ratio of the number of equivalent operating hours to the total number of hours in a year (8 760)
ratio of equivalent full-load operating hours to the total hours in a year

3.9
heliostat field efficiency
ratio of the solar radiant power incident in the receiver aperture from the heliostat field to the available radiant solar power over a given period (hourly, daily, weekly, etc.)

3.10
receiver efficiency
ratio of the thermal power transferred to the heat transfer fluid to the solar radiant power incident in the receiver aperture from the heliostat field over a given period

3.11
cosine loss
energy loss due to the incident direction of sunlight being not parallel to the normal direction of the mirror surface

3.12
atmospheric attenuation
energy loss due to the reflected rays from the heliostats being absorbed and scattered by the air before reaching the receiver

3.13
receiver spillage
energy that is reflected from the heliostats but fails to reach the receiver, after deduction of the blocking loss and the atmospheric attenuation

4 Basic requirements

4.1 For the design of a solar power tower plant, the 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 power block capacity, the storage capacity and the operation modes of solar power tower plants are determined by a techno-economic evaluation on the basis that the electric power system requirements are satisfied.

4.3 For the system capacity matching of solar power tower plants, the following provisions apply.

a) The overall optimization should be performed between the heliostat field, the receiver capacity, the steam generator capacity, the steam turbine capacity and the storage capacity.
b) The maximum continuous flow rate of the steam generation system shall match the maximum turbine inlet steam flow rate.
c) The maximum continuous capacity of the generator shall match the maximum continuous output of the steam turbine.

4.4 The annual electricity output may be estimated as specified in Annex A.

4.5 The design lifetime for solar power tower plants shall meet customer requirements.

4.6 A uniform identification system should be employed for the plant design and the uniform identification system employed shall meet the requirements of the IEC 81346 series.

4.7 All computer-based systems shall meet the local information technology requirements for security protection.

5 Electric power system requirements

5.1 General requirements

The main transformers, circuit breakers and other electric equipment connected to the power grid shall meet the frequent start-up/shutdown requirement for the plant.

5.2 Requirements for grid-connection

5.2.1 The grid-connection scheme for solar power tower plants shall meet the local grid-connection requirements.

5.2.2 The voltage class for grid-connection should be selected according to the power plant capacity, and there should be one or two voltage classes.

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

5.2.4 The rated power factor of the generating units of the 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 requirements of IEC TS 62749.

5.3 Relay protection and automatic safety device

5.3.1 The relay protection and the automatic safety device shall meet the requirements of IEC 60870-5 (all parts).

5.3.2 The configuration of the line protection shall meet the local grid requirements.

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 prediction system should be installed at the power plants. The solar power prediction system should also have the function of upload the data on predicted power, the direct normal irradiance, the capacity of the thermal energy storage system and other real-time information to the dispatch.

5.5 Electric power system communication

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

5.6 Electric energy metering

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

6 Solar resource assessment

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

7 Site selection

7.1 When selecting a site for a plant, the following factors should be considered: the power grid structure and the electric power system planning, the auxiliary energy supply, the water source, the traffic and large equipment transportation, the environmental impact assessment, the outgoing line corridor, the landform, geology, the seismicity, the hydrology, the meteorology, the construction, the effect of surrounding companies on the solar power tower plant, etc.

7.2 When the site of a solar power tower plant is selected, the following provisions for the water supply apply.

a) The water source should be stable and reliable. The water supply should meet requirements of the long-term water consumption of the power station.

b) 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.

c) If underground water is used as water source, a hydro-geological investigation report shall be completed, and it can be subject to local requirements.

7.3 The following provisions for the site's natural conditions apply.

a) The proposed site should be selected in areas with abundant and stable direct normal irradiance.

b) The site should not be set in a dangerous rock, landslide, karst development, mudslide section, seismogenic fault or goaf zone. If a geological disaster-prone area cannot be avoided, in the site selection stage, a geological disaster risk assessment should be conducted and comprehensively assessed.

c) In the site selection, suspended particulate matter, airport runways and routes, high wind speed areas, and surroundings with tall and wide trees, mountains, buildings and other factors should be taken into consideration.

d) Bird habitats and migration routes should be avoided.

e) The proposed site should be located in a flat region.

f) The buildings (structures) inside and outside the power plant should not cast shadow on the collector during the majority of daytime hours.

g) The proposed site should be away from important, protected cultural relics. The site should not be located in an open mineral resources area or underground shallow layer mining area with exploitation value.

7.4 During the site selection process, essential data on the geological conditions in the site area should be obtained, to determine the foundation design scheme of buildings (structures) in the site.

7.5 The seismic fortification intensity of the site should be determined based on the local seismic fortification intensity or design ground motion parameters.

8 Overall planning

8.1 General requirements

8.1.1 According to the environmental conditions of sites and the environmental conditions in the vicinity of sites, an overall planning for the land use, sites and construction area, water source, water supply and drainage pipelines, auxiliary fuel pipelines, transportation, and outgoing line corridor, etc. shall be considered in the overall planning.

8.1.2 The overall planning shall minimize the land use to the extent possible. Buildings in the plant should be grouped into a complex. Construction land shall make full use of interspaces between plants and the reserved land.

8.2 Off-site planning

8.2.1 The off-site planning shall be based on site location and the main plant processes, considering the transportation, water supply and drainage, auxiliary energy supply and the outgoing line corridor according to the plant design capacity and the environmental conditions.

8.2.2 For the transportation planning, the following provisions apply.

a) The transportation planning of the power plant shall be consistent with the environmental conditions and with the layout design. Local legal requirements can also apply.
b) The access roads shall connect to the existing roads. Access roads should be short and easy for driving. The access road shall be negotiable for the maximal size and weight of the equipment supplied.
c) The existing roads should be used for maintenance and inspections of the off-site water supply and the drainage facility.

8.2.3 The overall planning of the water supply and drainage shall be done according to the design capacity of the power plant, construction capacity of the current stage, water source, landform, geology, and environmental protection, etc. The following provisions apply.

a) The feedwater pump rooms, and the feedwater pipelines of the off-site feedwater system shall be located in reasonably close proximity to the water source. Space should be reserved for future expansion.
b) The supply and the drainage pipelines should be arranged alongside the existing roads or planned roads.

8.2.4 The outgoing line corridor of the power plant shall be planned according to the design capacity of the power plant and the construction capacity of the current stage. The urban and rural general planning, transmission line directions, voltage classes and loop numbers shall also be considered.

8.2.5 The auxiliary fuel supply, if required, shall be reliable and stable. And the transportation method of any such auxiliary fuel supply should be determined after a techno-economic evaluation of nearby transportation and coordination conditions. The auxiliary fuel pipelines should be reasonably planned according to the local fuel supply, transportation, and environmental protection requirements.

8.3 On-site planning

8.3.1 The solar power tower plant site shall be divided into the heliostat field and the receiver tower; the power block, including the thermal energy storage; and other facilities according to different process demands. For the general planning, the following provisions apply.

a) Layout design of the heliostat field shall meet the requirements of the site location, solar energy resource, landform, equipment features, operation modes, and construction and inspection.

b) The power block should be concentrated around the receiver tower.

c) The receiver tower, turbine house, thermal energy storage, direct air-cooling platform, and cooling tower should be built in areas with high ground bearing capacity.

d) The auxiliary fuel, if required, shall be stored separately and the storage area shall be arranged separately. Local safety regulations for fuel storage can apply.

e) Temporary salt storage areas should be provided.

8.3.2 For the corridor planning of incoming and outgoing power lines in the plant, a uniform planning should be carried out according to the system requirements and outgoing line direction; crossing of power lines should be avoided.

8.3.3 Local regulations on flood control can apply. When the site elevation is lower than the high water level in the design, the following provisions apply for flood prevention measures.

a) Local regulations regarding the apron elevation of the turbine house and receiver tower can apply.

b) The site elevation of the heliostat field shall be determined to meet the requirement that electric control equipment is not to be submerged by flood.

c) When other flood control measures are taken, the site elevation may be slightly lower than the high water level in the design.

8.3.4 The power plant vertical arrangement shall be considered taking into account hydrological and meteorological conditions, flood control (water logging prevention), engineering geology, production process, etc. The following provisions apply.

a) Landform should be utilized to reduce earthwork quantity.

b) The heliostat field should maintain the original landform. On rugged landform, a wide range of site formation can apply.

c) The vertical arrangement of power block and other facilities areas may adopt a plane layout or a step layout.

d) The elevation of buildings (structures) should meet the requirements of production and maintenance and ensure smooth drainage. The design elevation of the indoor floor should be determined according to the building function, transportation, drainage and geology conditions. Local regulations regarding the design elevation of the indoor floor can apply.

e) The minimum gradient and direction shall be designed to drain surface water and match gutters of the buildings, roads, and site.

8.3.5 The drainage of power plant shall be designed according to landform, hydrometeorology, engineering geology, underground water level and off-site gutters, etc. The following provisions apply.

a) The power block may drain water through natural method, road gutters, field gutters or open trench according to specific conditions.

b) The heliostat field shall employ a natural drainage system, draining water through natural method or open trench in different zones.

8.3.6 The site pipelines may be laid out employing burying laying, trench laying and overhead laying. The pipeline layout shall be planned according to the design capacity, site layout, vertical arrangement, pipeline features and safety. The following provisions apply.

a) A comprehensive pipe frame may be employed for the power block.

b) The flammable and explosive pipelines shall not cross buildings when unnecessary or cross other items such as production equipment, auxiliary workshops, storage facilities and tanks, etc.

8.3.7 Local standards and regulations can apply in terms of road design in the power plant. In addition, the following provisions apply.

a) Local fire protection requirements regarding the fire lane can apply. Annular fire lanes should be provided for power block and inflammable explosive areas. Turning radius, width and clear height of the fire lane shall meet access requirements of fire trucks.

b) The annular fire lanes in the power block and access roads to the power block should be made of cement concrete or bituminous concrete. The heliostat field should be divided into different zones. The road width between zones and annular lanes around the heliostat field should meet the requirements of maintenance and cleaning.

c) The inspection and maintenance roads should be built inside the heliostat field.

8.3.8 Local requirements regarding the enclosure walls can apply.

9 Layout of heliostat field and receiver tower

9.1 General requirements

9.1.1 The layout of the heliostat field and the receiver tower shall be designed and optimized in accordance with the local conditions such as latitude, topography, and geomorphology.

9.1.2 The annual efficiency of the collector system, location, environmental conditions, field shape, land utilization ratio, demand curve and shape, time-dependent tariff and atmospheric attenuation shall be considered for the receiver tower height, distance between heliostats and receiver tower, and distance between heliostats.

9.1.3 The layout of heliostat field and the receiver tower shall satisfy requirements of both power block layout and outgoing line.

9.1.4 The heliostat field shall reserve clearance space for inspections and meet the access requirements for vehicles of installation, inspections and maintenance.

9.2 Layout of heliostat field

9.2.1 Typically, the heliostat field is set out in radial staggered pattern or in unified array pattern.

9.2.2 The heliostats should be so arranged as to reduce shadowing and blocking losses utilizing landform.

9.2.3 The aim point strategies of heliostats should establish a radiation flux required by the receiver at the design point and not exceed the receiver's flux or temperature limits.

9.3 Layout of receiver tower

9.3.1 The location of the receiver tower should be determined by efficiency optimization calculations for the full TMY (typical meteorological year).

9.3.2 The equipment in the receiver tower and the facilities layout shall be determined according to process flow and plant overall plan.

9.3.3 The platform's arrangement in the receiver tower shall meet the space requirements for process, structure, electrics, and fire control.

9.3.4 Stairs shall be installed in the receiver tower and laid out to meet the requirements of safety and clearance.

9.3.5 The elevator should be installed in the receiver tower, and arranged to meet the requirements of safety, maintenance, and inspections.

9.3.6 The equipment, facilities and channels in the receiver tower shall satisfy the requirements of space for pipe installation and heat expansion, to keep a safe distance from the pipes.

9.3.7 External walls of the receiver tower should have a calibration area.

9.4 Safety protection facilities

9.4.1 A risk assessment shall be carried out to meet the requirements of ISO 12100 and ISO 14121.

9.4.2 The tower roof shall have an aerial beacon.

9.4.3 The heliostat field should be equipped with devices to drive birds away according to the environmental impact assessment.

9.4.4 Protections shall be provided for the equipment near the receiver to avoid damage from solar radiation concentrated by the heliostat field.

9.4.5 The receiver tower and the heliostat field shall be equipped with lightning protection and grounding devices. The receiver tower and the heliostat field shall meet the requirements of IEC 62305-1.

9.5 Maintenance and inspection facilities

9.5.1 The inspection area in the heliostat field should meet the needs of the inspection vehicle, parking of lifting equipment and temporary storage.

9.5.2 The roads in the heliostat field and distances between heliostats shall meet the requirements for inspection and maintenance equipment.

9.5.3 Devices in the receiver tower, valves and instruments shall be arranged so as to be easy to maintain and inspect. Platforms and stairs should be built for areas requiring maintenance and inspection.

9.5.4 The receiver tower should be equipped with a hoist for overhaul.

10 Layout of power block

10.1 General requirements

10.1.1 The power block layout scheme shall be adapted to the production process, installation, operation, and overhaul. Equipment arrangement and organization should be reasonable and compact. Pipe and wire connections shall be short, neat and with few crossings.

10.1.2 The power block should adopt centralized or combined arrangement so that functional zones are clear and system connections are simple. The turbine area and feedwater heaters including the deaerator area should be arranged compactly. Heat transfer, thermal energy storage and auxiliary heating areas should be arranged compactly and close to the turbine house so that the steam pipelines are short.

10.1.3 The equipment should be installed outdoors or semi-outdoors if the process and environmental conditions are appropriate.

10.1.4 The power block layout shall be convenient for operation and maintenance, and adapt to fire protection. The power block shall be explosion-proof, damp-proof, dust-proof, and have corrosion control, anti-freezing, etc. Areas in which operation and maintenance personnel gather should be located away from vibration and noise sources while also ensuring that process requirements are met.

10.1.5 The air cooling system for steam turbine exhaust shall be located to coordinate with the turbine house and receiver tower so that the turbine house and receiver tower have the least effect on the air-cooling facility.

10.1.6 Buildings for auxiliary production in the power block shall be divided into different zones, including the thermal energy storage zone, the steam turbine zone, and the balance of plant zone, or auxiliary facility zone, in accordance with their functions and combined into a complex.

10.2 Layout of thermal energy storage area

10.2.1 The thermal energy storage tanks area shall be located separately from the steam turbine area and also separately from other areas. Local fire protection requirements can apply regarding the thermal energy storage tanks area and the steam turbine area.

10.2.2 When molten salt is used as the thermal energy sensible heat storage medium, the cold and hot tanks should be placed outside.

10.2.3 The molten salt tanks shall be surrounded by a protective non-inflammable physical embankment. The effective volume within the protection embankment shall not be less than the maximum volume of any single tank.

10.2.4 The molten salt circulation pumps should be a vertical wet pit type, and should be mounted on top of the tanks with independent pump support separated from the tank. However, the pump support can be integrated with another support or structure, such as the platform where the heat exchangers of steam generation system are located.

10.3 Layout of steam generation system area

10.3.1 The molten salt steam generation system can be situated near the thermal energy storage tanks so that the molten salt drainage location can be shared, and so that the molten salt pipes between the tanks and the exchangers are short. But also, the molten salt steam generation system can be arranged near the steam turbine so that the water and steam pipes are short.

10.3.2 The steam generation system should be situated in outdoor or semi-outdoor locations. For areas with severe cold, sandstorm or other special climate, indoor arrangement is also recommended.

10.3.3 The arrangement of the heat exchangers in the steam generation system shall adapt to the process flow, drainage, operation and maintenance needs.

10.3.4 If there are molten salt drain pumps and tanks, they should be installed in such a position that is lower than the molten salt pipes and easy for operation. Indoor arrangement is preferred in severe cold or sandstorm areas.

10.3.5 Periodic and continuous blow down flash tanks for the molten salt steam generation system should be installed near the steam generator.

10.4 Layout of steam turbine house

10.4.1 The steam turbine should be placed indoors.

10.4.2 The deaerator and other regenerative heaters should be installed on an independent support, or on a structure integrated with the steam turbine house.

10.5 Layout of auxiliary heating area

10.5.1 If there is a start-up boiler for steam turbine daily start- up, it should be close to the turbine so that the steam pipes to the turbine system are short.

10.5.2 The storage facilities for auxiliary fuel shall be situated in a separate area. If indoor storage facilities are used, pressure-relief components shall be avoided towards personnel gathering areas or main roads.

10.5.3 Local regulations and standards regarding the layout of the auxiliary heating area can apply, including fire and explosions protection regulations.

10.6 Maintenance facilities

Maintenance and overhaul spaces shall be reserved for molten salt recirculation pumps and steam generator.

11 Collector system

11.1 General requirements

11.1.1 The solar thermal collector shall be set up taking into account information as regards meteorological and environmental data, the turbine capacity, the rated storage capacity and the operation mode.

11.1.2 The selection of components and systems shall adapt to local circumstances, including temperature range, ultra-violet radiation level, chemical aggressivity of atmosphere, etc.

11.1.3 The total aperture area of the heliostat field should meet the requirements of technical economic optimization.

11.1.4 Fire protection, explosion proofing, damp proofing, dust proofing, corrosion control and anti-freezing measures shall be taken for the heliostat field as required.

11.2 Heliostats

11.2.1 The reflectors, the frames and the drives of the heliostats shall meet the requirements of the heliostat performance, including optical reflection and spot quality. The heliostats shall meet the energy and safety requirements of the collector system.

11.2.2 The local climate conditions shall be considered for operation wind load of the heliostats.

11.2.3 The heliostats shall be designed to withstand windy weather. They should survive the maximum wind speed with a period of recurrence of 50 years at stow position.

11.2.4 The heliostats shall be designed to survive in snowy weather. They should survive the maximum snow pressure with a period of recurrence of 50 years at stow position.

11.2.5 For the heliostats, the following provisions apply.

a) The mirror shape error shall be considered and shall meet the requirements of the overall performance of the heliostat field.
b) The mirror reflectance shall be considered and shall meet the requirements of optical and radiation energy performance of the entire heliostat field.
c) The strength of the heliostat mirrors shall meet the requirements to resist wind and hail impact.

11.2.6 For the heliostat support structure, the following provisions apply.

a) The support structure strength shall be considered and shall meet structural safety requirements under extreme conditions.
b) The support structure stiffness shall be considered and shall meet the requirements of optical performance, and of the resistance to bending and torsional deformation caused by gravity and wind pressure during the whole operation process.
c) The support structure should be subject to anti-corrosion treatment for a lifetime based upon environmental climate conditions of the site.

11.2.7 The drive equipment of the heliostat may select slewing reducer, actuator, hydraulic cylinder, spiral elevator or any other devices. The accuracy shall meet the requirements of optical and thermal performance of the entire heliostat field.

11.3 Receiver

11.3.1 The total aperture area of all mirrors of a heliostat field shall be considered taking into account rated power capacity, site landform, environmental and climate conditions, receiver tower layout, size of receiver heating surface area, allowable receiver flux, mirror quality, drives of the heliostats and so on.

11.3.2 Molten salt or water-steam are preferably employed as the heat transfer fluid. The use of molten salt or steam as heat transfer fluid is covered by this document. If other heat transfer fluids are employed, reference may be made to the provisions laid out in this document for molten salt and water-steam.

11.3.3 For molten salt receivers, the following provisions apply.

a) Receiver thermal output may be determined based on synchronized provision of thermal power to run the turbine under design-conditions and to charge the storage system.
b) The outlet temperature and pressure of molten salt from the receiver should match the design parameters of the steam generation system. The rated outlet temperature of molten salt from the receiver should be in the range of ±5 K of the rated value.
c) The receiver thermal power should be operated in such a way that allows an adjustable range to keep the system safe and stable. The receiver thermal power may operate in a range of 20 % to 110 % of receiver nominal net thermal power conditions.
d) The electric heat tracing system shall be applied to the molten salt pipe and vessels. The power used for the heating system should meet requirements of preheating and anti-freezing.

e) The molten salt receiver should be provided with an independent air compressor which provides high pressure compressed air for the receiver accumulator which is used when the molten salt pump loses power and then the air compressor provides power to drive the molten salt.

11.3.4 For water-steam receivers, the following provisions apply.

a) The thermal power output from the receiver shall not be less than the rated thermal power of the steam turbine at design point.
b) The receiver outlet temperature of superheated steam should be higher than the rated inlet temperature of the turbine to offset the heat loss from receiver to turbine. It should be at least 3 K higher than the rated inlet temperature of the turbine.
c) The receiver outlet temperature of reheated steam should be higher than the rated inlet temperature of the pressure cylinder of the turbine to offset the heat loss from receiver to turbine. The receiver outlet temperature of the reheated steam should be at least 2 K higher than the rated inlet temperature of the pressure cylinder of the turbine.
d) The pressure drop from the outlet of the superheater of the receiver to the inlet of the steam turbine should be considered to avoid too much heat loss. This pressure drop should not exceed 5 % of the rated inlet pressure of the steam turbine.
e) The receiver may employ natural or forced circulation based upon the design parameters and system requirements.

11.4 Heliostat cleaning

11.4.1 The cleaning equipment for heliostats shall be designed according to the local environmental conditions, area, and number of overall heliostats, and shall meet the requirements of mirror cleanness. Additional local environmental regulations can apply.

11.4.2 Water based cleaning of heliostat mirrors is preferred and is covered by this document. Waterless mirror cleaning may be employed in areas that are short of water or severely cold in winter. Cleaning methods other than water based methods may be used if they ensure that the requirements are met.

12 Heat transfer, thermal energy storage and steam generation system

12.1 General requirements

12.1.1 The rated capacity of the thermal energy storage system should be determined after economic comparisons have been carried out taking into account the configuration of the heliostats and the receiver system, the steam turbine capacity, and the operation mode.

12.1.2 For the water receiver tower plant, steam thermal energy storage or other storage medium may be adopted after economic analysis. The rated capacity of the thermal energy storage system should be determined according to characteristics of the thermal energy storage system.

12.1.3 If molten salt is chosen as the heat transfer fluid and storage medium, the thermal energy storage system should employ cold and hot two-tank sensible heat storage technology, and the number of tanks should not be limited to an even number.

12.1.4 If molten salt is chosen as the heat transfer fluid and storage medium, the selection of molten salt material type shall be considered with the freezing point temperature at least according to the requirements of heat transfer and storage.

12.1.5 The maximum thermal load of the steam generator shall be consistent with the maximum capability load. For detailed information on the maximum capability load, see IEC 60045.

12.2 Heat transfer system

12.2.1 If molten salt or water-steam is chosen as the heat transfer fluid, the outlet flow rate and the head of heat transfer fluid circulation pumps of the receiver shall be determined according to the receiver maximum net thermal power and the heat transfer fluid parameters at the inlet and outlet of the receiver.

12.2.2 If molten salt or water-steam is chosen as the heat transfer fluid, the configuration of the heat transfer fluid circulation pumps for the receiver shall be chosen according to the receiver maximum net thermal power and pump reliability. The number of pumps shall not be less than two with one backup. When any one of the pumps is out of service, the others shall meet the total capacity.

12.2.3 If molten salt or water-steam is chosen as the heat transfer fluid, a variable speed pump shall be employed as the receiver heat transfer fluid circulation pump.

12.2.4 If molten salt or water-steam is chosen as the heat transfer fluid, the head of the receiver heat transfer fluid circulation pump shall be determined by the flow rate at receiver maximum net thermal power conditions, including the pressure losses of molten salt pipes, the valves and other equipment.

12.2.5 The pipelines from the outlet of the receiver molten salt circulation pumps to the inlet of the receiver, and the pipelines from the outlet of the receiver to the inlet of hot tanks should be designed with 1 × 100 % capacity.

12.3 Thermal energy storage system

12.3.1 The thermal energy storage system shall meet the requirements of IEC TS 62862-2-1.

12.3.2 For the thermal energy storage medium, the following provisions apply.

a) If using a heat transfer fluid as the thermal energy storage medium is more economical and the system is proved to be reliable, it is preferable that the heat transfer fluid be the same as the thermal energy storage medium.

b) The physical and chemical properties of the medium shall be stable.

c) When molten salt is used as the heat transfer fluid, it should also be used as the thermal energy storage medium. When water-steam is used as the heat transfer fluid, water should not be the thermal energy storage medium in the thermal energy storage system with high capacity.

d) The impurity content should be controlled within an acceptable range.

12.3.3 For the selection of the thermal energy storage equipment, the following provisions apply.

a) When molten salt is employed as the medium for sensible heat thermal energy storage, either a single tank with thermocline solution or a two-tank solution should be adopted. When molten salt is employed as the medium for latent heat thermal energy storage, a single tank should be adopted.

b) Welded steel tanks shall be used for molten salt sensible heat thermal energy storage. A fixed roof of the tank is preferred rather than other floating roofs due to the fact that the freezing of molten salt can stop the floating roof movement and there is less volatilization of the fluid in the tank.

c) When water-steam is used as the heat transfer fluid, and molten salt is used for sensible heat thermal energy storage, a set of molten salt charging heat exchangers shall be installed.

d) If the two-tank sensible heat thermal energy storage system is selected, when one tank is out of service, the other tank shall have capacity enough to contain the full inventory of molten salts.

12.3.4 Materials of tanks and pipes shall meet the requirements of the allowable stress within the operating temperature range and gradients, and the protection against corrosion of the molten salt.

12.4 Steam generation system

12.4.1 The steam generator should have one train with 100 % capacity or two trains, in which case each train should have 50 % capacity.

12.4.2 When molten salt is used for thermal energy storage, temperature drop, and pressure drop from the outlet of the steam generator to the inlet of the steam turbine should be determined based upon the relative position of steam generator and turbine.

12.4.3 When molten salt sensible heat thermal energy storage is employed, the steam generator may adopt one of the following types of boiler: once-through boiler, kettle boiler, natural circulation with steam drum or other proved type.

12.4.4 When water-steam is chosen as the heat transfer fluid and molten salt is chosen as the sensible heat thermal energy storage, the capacity of the charging heat exchanger shall match the design of the receiver system, rated capacity of thermal energy storage system and process features.

12.4.5 The outlet flow rate of molten salt recirculation pumps shall be designed in accordance with the maximum design thermal load of the steam generator.

12.4.6 The configuration of steam generator molten salt recirculation pumps shall be consistent with the configuration of feedwater pumps. The number of pumps shall not be less than two with one backup. Variable speed pumps shall be employed.

12.4.7 The head of the molten salt recirculation pumps of the steam generation system shall be determined by the pressure losses of molten salt pipes, valves, and other equipment under condition of maximum flow rate of molten salt.

12.4.8 The flow rate of attemperation pumps shall ensure that the molten salt inlet temperature of all heat exchangers shall not exceed the design temperature, and the outlet temperature of the superheater and reheater shall not exceed the allowable inlet temperature of the steam turbine.

12.4.9 The head calculation of attemperation pumps shall be the same as the calculation method of the head of molten salt recirculation pumps.

12.5 Auxiliary system

12.5.1 Fuel heating or electrical heating may be adopted by salt melting equipment, which shall be designed according to the molten salt volume and allowable initial melting time.

12.5.2 Where molten salt freezing may occur, electrical heat tracing devices shall be installed onto the molten salt pipelines and molten salt heat exchanger shells.

12.5.3 The molten salt drain system shall be arranged with molten salt drain tanks, whose capacity shall be determined by the volumes of pipes and equipment which should be drained.

12.5.4 Immersion electrical heaters installed near the bottom of the molten salt tanks are preferred as a measure of anti-freeze protection.

12.5.5 The steam generator and auxiliary system shall be provided with anti-freeze protection. A low-load preheater and external water circulation pumps (which mix the hot water from the steam drum with the feedwater upstream of the economizer) can be used to ensure that the feedwater temperature at the inlet of the economizer is not lower than the molten salt freezing point.

12.5.6 When drum type or kettle boiler steam generators are employed, the water-steam side shall be equipped with a flash tank to recover the water and steam.

12.5.7 When the steam generator employs forced circulation, the steam generator should be equipped with at least two forced circulation pumps (variable speed pumps shall be used) with one of them serving as backup.

12.5.8 The steam generator shall be equipped with a start-up electrical heater when there is no external steam source that meets the heating requirements of start-up. The capacity of the start-up electrical heater shall be designed according to the cold start-up time and the total preheating thermal energy requirement of pipelines and equipment in the steam generator and turbine system.

13 Steam turbine system

13.1.1 The steam turbine system shall meet the requirements of IEC 60045-1.

13.1.2 The steam temperature of the turbine shall be determined according to the design temperature of the heat transfer fluid and the thermal energy storage process.

13.1.3 The capacity of the steam turbine units should be consistent with the capacity of the heliostat field and the thermal energy storage system.

14 Water treatment system

14.1 Water quality and pretreatment

The water treatment system shall be designed according to all the available water quality analyses for the water source of recent years.

14.2 Water pre-desalination

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

14.3 Demineralized water treatment system

The demineralization system shall be designed considering factors such as influent water quality, water and steam quality criterion of the thermodynamic system, water rate of units, equipment and chemicals supply conditions, as well as requirements for environmental protection.

14.4 Heliostat cleaning water treatment

14.4.1 The heliostat cleaning water should be softened water or demineralized water.

14.4.2 When reverse osmosis water or demineralized water is used for heliostat cleaning, the cleaning water treatment system and demineralization water treatment system should be combined. Then the capacity of relevant demineralized water treatment system equipment shall meet the following requirements.

a) The increased output of the demineralization water treatment system should meet the water consumption of a batch of heliostat cleaning.

b) The increased water tank volume shall be sufficient to meet the cleaning water consumption for one batch of heliostats.

14.5 Wastewater treatment

The wastewater treatment system shall be considered taking into account such factors as the wastewater types, properties, water volume, reutilized conditions and the requirements of discharge water quality. After being treated, the wastewater shall be reutilized or discharged. Local discharge requirements can apply.

15 Information system

15.1 Security and protection system

15.1.1 The security and protection system may include an intrusion alarm system, video monitoring system and access control system.

15.1.2 The security and protection system should cover all the important areas of plant, such as the entrance and exit of the heliostat field, molten salt storage area, central control room, etc.

15.1.3 The intrusion alarm system shall meet the requirements of IEC 62642-1. Video monitoring systems shall meet the requirements of IEC 62676-1-1. The access control system shall meet the requirements of IEC 60839-11-2.

15.2 Video monitoring system for production

The video monitoring system for production should cover the heliostat field, receiver tower, storage area, steam generator area, steam turbine house, booster station, electronic equipment room, distribution room and unmanned auxiliary workshop.

15.3 Information system cabling

Information system cabling shall meet the requirements of ISO/IEC 11801-3.

15.4 Information security

Security protection measures shall be taken for the hardware, network operating system, database, application service, terminals, and interface in the information system.

16 Instrumentation and control

16.1 Automation level

The automation level of the collector system, heat transfer system, thermal energy storage system, steam generation system, steam turbine system and other auxiliary systems shall be compatible with each other. All systems are designed such that the operator station in the central control room may achieve complete start-up and shutdown, monitor and adjust the operation and handle any failures with the help of patrol inspection and local operations.

16.2 Control mode and control room

16.2.1 The operator stations of a collector system, heat transfer system, thermal energy storage system, steam generation system, and steam turbine system shall be located in the central control room, and all these systems will be centrally controlled by an operator.

16.2.2 The operator stations of auxiliary system shall be located in the central control room, and the auxiliary system will be centrally controlled by the operator. Local terminals of auxiliary system can be set for system commissioning, initial start-up and operation, fault detection, and inspection.

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

16.3 Measurements and instrumentation

For the collector system, heat transfer system, thermal energy storage system and steam generation system, the following parameters shall be measured.

a) Direct normal irradiance, wind speed, wind direction, temperature and other environmental parameters.
b) The actual tracking position and other operation state parameters of each heliostat, for example "in track", "in stow" or "in standby".
c) Temperature, pressure, flow rate, fluid levels and other operation parameters of the receiver.
d) Pressure, temperature, and flow rate of heat transfer system, state of the receiver heat transfer fluid circulation pump and operation parameters.
e) Pressure, temperature, molten salt level and other operation parameters of the thermal energy storage system.
f) Pressure, temperature, flow rate of the steam generation system, and molten salt circulation pump state and operation parameters.

16.4 Alarms

The main alarm items of the collector system, heat transfer system, thermal energy storage system and steam generation system shall include the following contents:

a) Wind speed and cloud abnormal alarm.
b) Alarm for abnormal surface temperature and abnormal medium temperature of the receiver.
c) Alarm for abnormal parameters of the heat transfer system such as outlet pressure of molten salt pump, etc.
d) Alarm for abnormal parameters of the thermal energy storage system such as wall temperature of the molten salt storage tank, molten salt temperature and molten salt flow, etc.
e) Alarm for abnormal parameters of the steam generation system such as drum wall temperature, drum pressure, drum water level parameter of drum type steam generator, etc.
f) Alarm for communication and power failure of control systems.
g) Other basic alarm items.

16.5 Protection

16.5.1 The protection system may use an electronic logic system or a hard logic relay system. The system shall use a certified SIL3 level safety related system. The safety related system shall meet the requirements of the IEC 61508 series and the IEC 61511 series.

16.5.2 The heliostat field shall have a back-up operation procedure in case of loss of communication and/or power supply. The back-up operation procedure should drive heliostats to standby or stow position in the event of loss of communication and/or power supply.

16.5.3 The main protection items for the receiver and heliostat shall include:

a) Over-temperature protection of the receiver surface.
b) Cut-off protection of the heat transfer fluid.
c) Low pressure protection of compressed air for receiver inlet tank.
d) High heat transfer level and low heat transfer level protection of receiver inlet tank and receiver outlet tank.
e) Communication and power fault protection of heliostat field control system.
f) Communication and power fault protection of heliostat local control device.
g) High wind speed and hail protection.
h) Other protections required by the receiver and heliostat.

16.5.4 The main protection items for the thermal energy storage and steam generation system shall include:

a) High water level and low water level protection of steam drum.
b) Low thermal storage medium level protection of hot tank.
c) Water or steam leakage protection of heat exchangers in steam generation system.
d) High temperature molten salt circulation pump full shutdown protection.
e) Low feedwater temperature protection of the low-load preheater outlet.

16.6 Analogue control

16.6.1 The analogue control system shall meet the requirements of system operation. The control loop shall be designed with priority given to practicality and reliability. It is necessary to achieve safe and economic operation during the system start-up and operation under various loads. In addition, corresponding interlocked protection measures of the system under accident and abnormal conditions shall be considered in this regard.

16.6.2 The following items should be provided for analogue control:

a) Heat collection system tracking control system.
b) Temperature control system for heat transfer fluid of the receiver.
c) Flow control system for thermal energy storage medium.
d) Level control system of the receiver inlet and outlet tanks.
e) High pressure compressed air pressure control system.
f) Heat transfer fluid temperature control system for steam generation system.

16.7 Control system

16.7.1 The control system of the power plant shall be designed according to the principle of centralized control. The main control system should be a distributed control system. A field-bus-based distributed control system may be employed if proved by a technical and economical evaluation. It is allowed to adopt field bus technology on the field instruments and equipment layers. The distributed control system is provided with data acquisition and processing, analogue control, and sequential control.

16.7.2 The monitoring and control of the receiver system, heat transfer system, thermal energy storage system and steam generation system shall be incorporated into the main control system.

16.7.3 The heliostat control system should be incorporated into the main control system. If a separate heliostat control system has been employed, it shall be able to communicate with the main control system.