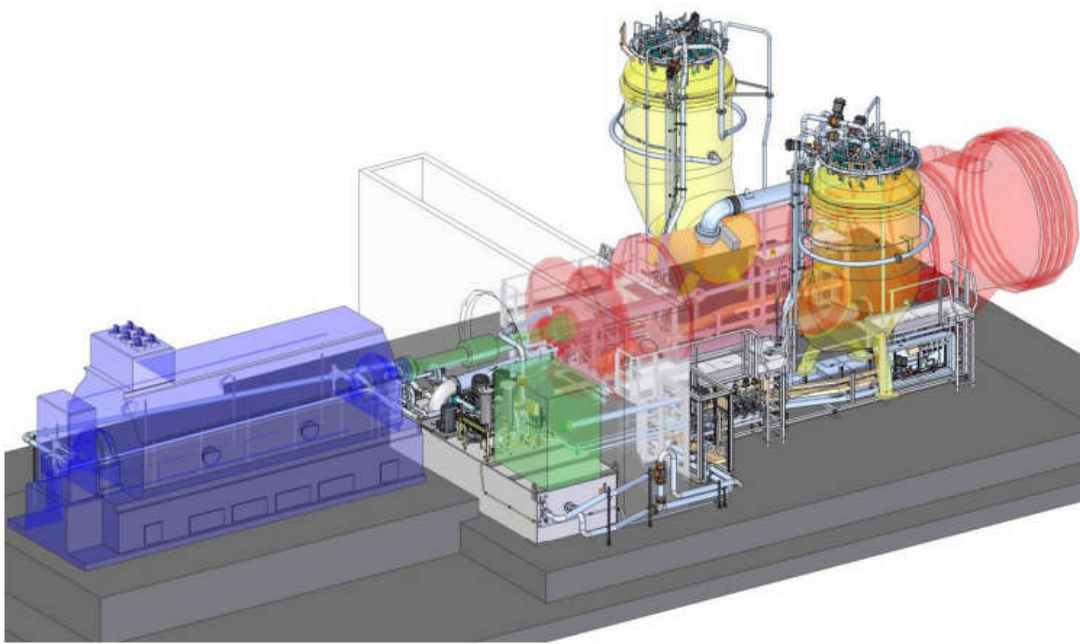


AE94.2 GAS TURBINE

TECHNICAL DESCRIPTION



上海电气燃气轮机有限公司

Shanghai Electric Gas Turbine Co., Ltd

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1. GAS TURBINE

1.1 Description

The AE94.2 gas turbine is a single shaft, cold end drive, silo type combustors, heavy duty gas turbine designed for 50 Hz operation.

The mono shaft arrangement allows the gas turbine to drive directly its air compressor and the separate electrical generator. The fuel combustion takes place in the two symmetrical multi-burner combustion chambers, vertically mounted on both sides of the turbine. Each combustion chamber is equipped with 8 burners.

Ambient air enters the compressor through the intake duct, where filters and silencer are installed. The compressed air is then directed to the burners located at the top of each combustion chamber. The hot gas of combustion flows through the turbine where its enthalpy is converted into mechanical power. The electrical generator is coupled to the compressor side of the gas turbine rotor through an intermediate shaft.

The exhaust gas is discharged at atmospheric pressure through an axial diffuser and it can be either discharged to the atmosphere through a vertical stack or used to generate steam in an external boiler connected to the diffuser. The steam can be employed either for district heating purposes or for industrial processes or to operate a separate steam turbine.

- Machine body

The AE94.2 gas turbine is based on a single shaft design: it includes a sixteen (16) stages axial compressor and a four (4) stages axial turbine having a common rotor.

The rotor consists of a front shaft section, sixteen (16) compressor blade disks, a central hollow shaft section, four (4) turbine blade disks and a rear shaft section, all held together by a single central tie bolt with a clamping nut at the turbine end.

Each disk of the rotor has radial Hirth teeth on both sides; the Hirth serrations provide radial alignment between the rotor sections, ensuring torque transmission and allowing free relative radial expansion and contraction.

The rotor resulting from such a construction is a self supporting drum with low weight and high stiffness; therefore it can be supported by only two bearings, one at the front shaft section and one at the rear shaft section. The bearing at

the compressor end is a combined journal and thrust bearing designed to accommodate the axial thrust of the rotor. The two bearings are located outside the pressurized region of the gas turbine, providing the basis for constant good alignment and excellent running qualities.

- Combustion Chambers

The AE94.2 gas turbine is equipped with two combustion chambers, vertically mounted on the sides of the gas turbine and connected to lateral flanges of the gas turbine outer casing. This combustion chamber arrangement offers good accessibility of all components for inspections and, when required, easy assembly and disassembly.

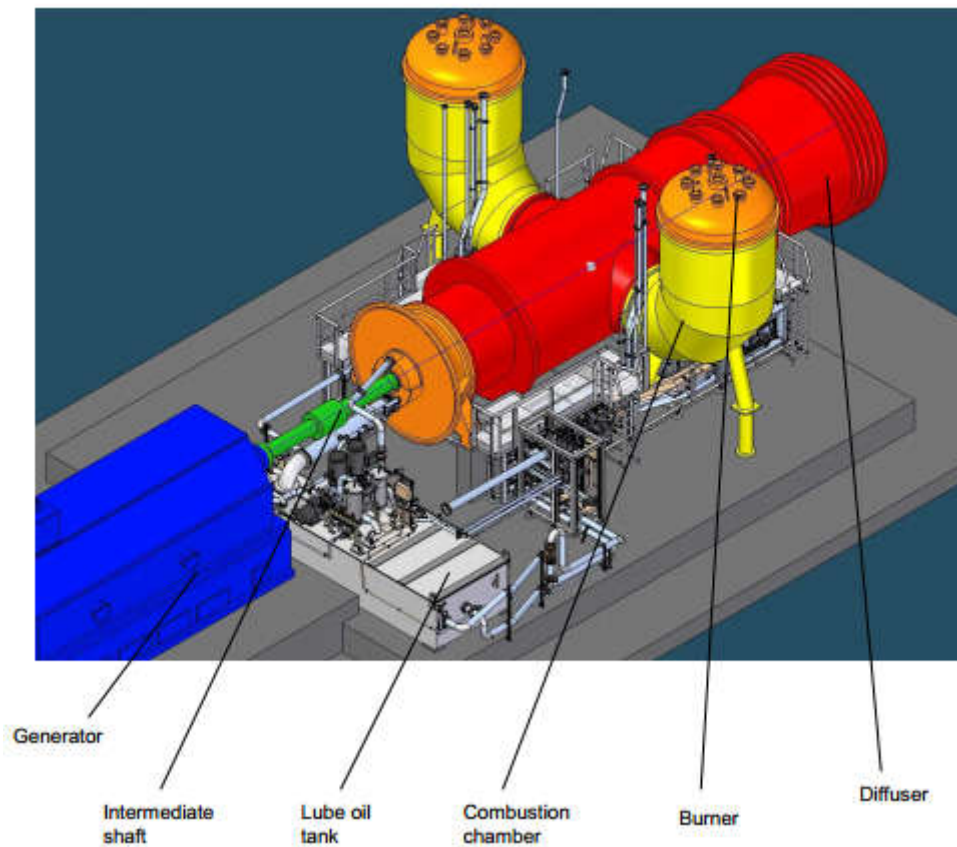


Fig1 – Gas Turbine AE94.2

1.2 Data Sheet

Compressor

| | |
|---|--|
| Number of stage | 16 |
| Type of rotor construction | Multi-disc with Hirth serration and central tie rod |
| Number of stages of variable inlet guide vanes | 1 |
| Blow-off valves | n° 2 at stage 5 n° 1 at stage 10 |
| Compressor pressure ratio | 12 |

Combustion Chamber

| | |
|--------------------------------------|--------------------------|
| Number of combustion chambers | 2 |
| Number of flame tubes | 2 |
| Flame tube protection | Ceramic tiles |
| Number of burners | 16 (8 per comb. chamber) |
| Type of igniters | Spark plugs |
| Numbers igniters | 1 per burner |
| Type of flame supervisory elements | Flame sensors |
| Number of flame supervisory elements | 4 (2 per comb. chamber) |

Turbine

| | |
|----------------------------|---------------------------------|
| Number of stages | 4 |
| Type of rotor construction | Multi-disc with Hirth serration |

Gas turbine speed

| | |
|--------------------------------|-----------------|
| Nominal speed | 3000 rpm(50 Hz) |
| Range of allowed speed | 47.5-51.5 Hz |
| Overspeed protection threshold | 3240 rpm |

Duration of start-up and loading

| | |
|---|--|
| Time to reach full speed no load condition from standstill | 5 min * |
| Load jump after synchronization | 15 MW (reference value) |
| Normal loading / unloading gradient | 11 MW/min |
| Fast loading / unloading gradient | 30 MW/min |
| Time to reach base load from full speed no load condition (excluding synchronization time): | ca. 23 min (reference value at ISO condition, by nominal gradient) ca. 8 min (reference value at ISO condition, by fast gradient) |

* Time due to boiler purging are not included, they shall be added when necessary.

Governor

| | |
|------|------------------------|
| Type | Digital Control System |
|------|------------------------|

Turning gear

| | |
|------|----------------------------|
| Type | Hydraulic turbine (Pelton) |
|------|----------------------------|

| | |
|----------------------------|------------|
| Speed in turning operation | 85-110 rpm |
|----------------------------|------------|

| | |
|--|-----|
| Operating period required after shutdown | 24h |
|--|-----|

| | |
|-------------------------------|-----|
| Facilities for manual barring | Yes |
|-------------------------------|-----|

Starting system

| | |
|------|------------------|
| Type | Static converter |
|------|------------------|

| | |
|---------------|--------|
| Nominal power | 2900KW |
|---------------|--------|

| | |
|-------|--------------------|
| Speed | from 0 to 2100 rpm |
|-------|--------------------|

Bearings

| | |
|---------------|---|
| Type / number | 1 journal (turbine side) 1 combined journal/thrust (compressor side) |
|---------------|---|

| | |
|-------------------|----------|
| Supplied oil type | ISO VG46 |
|-------------------|----------|

| | |
|----------------------------|-----------------------------|
| Lube oil inlet temperature | 48 - 54°C (reference value) |
|----------------------------|-----------------------------|

| | |
|-------------|---------------------------------|
| Alarm value | 100 °C (on bearing white metal) |
|-------------|---------------------------------|

| | |
|------------|---------------------------------|
| Trip value | 120 °C (on bearing white metal) |
|------------|---------------------------------|

Other conditions

| | |
|--|-----------------------------------|
| Temperature on the outside of the insulation | $\leq 60\text{ }^{\circ}\text{C}$ |
| Design temp range for indoor equipment | [+5 - +45°C] |

2. GAS TURBINE AUXILIARIES

2.1 Air Intake System

The air intake system has the purpose of conveying the combustion air to the compressor inlet. It is arranged on one side or three sides and consist of the following items:

- weather hoods
- vane-type weather louver
- prefilters
- fine filters
- filter house
- transition duct to silencer
- silencer and silencer housing
- bend
- vertical duct with plenum (including piping for compressor cleaning), and connection to the compressor inlet

Air enters the filter, then the plenum, the bend, the inlet silencer, and the horizontal duct till the compressor inlet. Air is compressed and then it enters the combustion chamber to take part to the combustion process and to the following expansion in the turbine.

The weather hoods protection prevents rain from passing into the stages of the filtration system. The filtration section consists of prefilters (according to EN779 class G4) and fine filters (according to EN779 class F9).

Prefilters and fine filters will be either wall type or cartridge type. The filter section consists of completely pre-fabricated modules, designed for assembly at site. The filter house, ducts, silencer housing and plenum are made of carbon steel stiffened and suitably painted panels for bolted and/or welded assembly at site.

2.2 Exhaust System

The exhaust gas system has the purpose of conveying the exhaust gas at the turbine outlet towards the exhaust stack or towards the boiler.

The exhaust gas system consists of the following main components:

- expansion joint between gas turbine and exhaust diffuser;

-exhaust diffuser manufactured with internal insulation technique.

The system is equipped with tapping points for temperature and pressure measurements (to be used, for instance, during the performance test execution).

2.3 Blow Off System

The axial compressor of the gas turbine is designed to run at the rated speed of the turbine generator. Since during start-up and shut-down the speed is below the allowed speed range, air must be extracted from selected compressor location in order to prevent compressor surge.

Two blow off lines are connected to compressor stage 5, and one to compressor stage 10. The blow off lines open into the exhaust gas duct downstream of the gas turbine.

During start-up the blow off valves are closed according to the speed. At nominal speed all the blow off valves are closed. During shut down or when trip occurs, all blow off valves open at nominal speed, at the same time when closing the fuel stop valve.

The blow off valves have a pneumatic actuator. The compressed air used as working medium for the blow off actuators is taken from the compressed air system.

2.4 Gas Turbine Monitoring

The gas turbine unit is equipped with the following control devices:

- Speed monitoring: six speed transmitters give a “2 out of 3” signal to the overspeed protection and to the turbine controller for the speed dependent operation.
- Bearing temperature measurement: a series of thermocouples are arranged in the turbine and compressor bearings and in the generator bearings.
- Vibration measurement: casing and shaft vibrations near the turbine, compressor and generator bearings are monitored using vibration transmitters.

- Turbine outlet temperature control: the turbine outlet temperature is measured by 6 thermocouples. Their values is used either as a media, in relation with the compressor inlet temperature to calculate the “corrected exhaust temperature”, and separately to check the radial temperature distribution in the exhaust duct.
- Compressor temperature and pressure control: the temperature and pressure of air at the compressor inlet are measured by resistance thermometers (it is required for calculating the correct exhaust temperature), a pressure control is required for surge detection and protection.
- Compressor stationary blade adjustment: the stagger angle of the first compressor stage blades (also called “stage 0” or “IGV” = inlet guide vanes) can be adjusted by an actuator between a minimum and a maximum value to change the amount of the air flow according to the different load conditions.
- Air dryer: during long period of standstill (> 2 hours from turning operation) the air at the compressor inlet must be dried in order to prevent corrosion on the compressor blading due to humidity.

2.5 Compressor Washing Skid

The compressor cleaning system is a portable unit (generally close to the intake system and consisting of a tank (500 liters), a centrifugal pump, a strainer, a connection hose.

The system is used to remove deposits from compressor blading. Deposits reduce the gas turbine power output and efficiency.

Jet nozzles (2) and spray nozzles (20) are uniformly distributed around the circumference of the compressor inlet guide vanes.

2.6 Gas Turbine On Board Drainage System

The drainage system discharges the water after off line compressor cleaning operation.

For this purpose, manual drain valves are provided. They must be opened only during off-line compressor cleaning. During gas turbine operation they must be in the closed position.

2.7 Lube And Lifting Oil System (Incl. RDS)

The lube oil system supplies oil to the compressor and turbine bearings of the gas turbine and to the generator bearings. The supplied oil performs several functions: firstly, it forms a film which prevents metal-to-metal contact between shaft journals and bearing shells, thus reducing friction.

Secondly, the flow of oil removes heat from the bearing areas. Lube oil is also used to drive the turning gear. In addition it provides jacking action to lift the shaft at low speed.

Besides, it supply oil to the RDS (Rotor Displacement System) system.

The oil tank is used for collection, extraction and deaeration of the lube and jacking oil. The lubricating oil is filled into the tank via a strainer.

Two oil vapor extraction fans are mounted on the tank and they remove oil vapor from the tank and create a slight sub-atmospheric pressure also in the return lines of the entire lube oil system.

The oil separator prevents oil vapor release in the environment.

Several pumps are provided to ensure supply of lube oil to bearings at the required pressure.

The main lube oil pump supplies the lube oil system during normal operation. The system is also equipped with an auxiliary oil pump and an emergency oil pump. All these are vertical centrifugal pumps, single-stage design. The main and auxiliary oil pumps are driven by three-phase motors, the emergency oil pump is driven by a DC motor.

Downstream of the main and auxiliary lubricating oil pumps, the lube oil enters a cooler (2x100% capacity) in order to dissipate the heat.

A constant temperature at the inlet bearings is achieved controlling a part of lube oil which bypasses the cooler by a thermostatic valve.

Downstream of the cooler, a duplex filter is located and it holds back any foreign material. One filter only is in operation, whereas the other is in stand by.

The lube oil is supplied to the bearings via orifices. The lube oil flows from the bearings back into the lube oil tank through return lines.

To protect the bearings, the bearing metal temperatures are measured directly and monitored.

In order to lift the rotor at low speed and to avoid metal-to-metal contact, a lifting oil pump is provided. The lifting oil pump is vane pump driven by a three-phase motor.

The hydraulic motor for turning operation is actuated by a dedicated turning gear pump, AC driven.

The turning gear is a hydraulic motor which is connected to the gas turbine shaft by a mechanical overrunning clutch. It is actuated by oil from the turning gear pump by a solenoid valve and a pressure control valve. After every shut-down the shaft must be cooled down for 24 hours by means of the turning gear. Thereafter, the turning gear is operated for 2 minutes every 6 hours to prevent the shaft from bowing. The turning speed is 85-110 rpm. The turning gear is not required for gas turbine start up.

In addition a barring gear is provided for manually turning the turbine shaft, during maintenance or in case of emergency.

RDS (Rotor Displacement System)

A gain in efficiency and an increase in power output can be obtained from Gas Turbines when the rotor is shifted against the direction of flow. Through this action the gaps between turbine blades and the casing become narrower, and the gaps in the compressor are increased accordingly but the sum of the two effects produce an increased GT efficiency and power output.

The medium for actuating the RDS is lube oil taken from the lube oil tank and

boosted to the required pressure by a dedicated pump(s) or by the same lifting oil pumps(s) (according to the system configuration) and then, by accumulators, solenoid valves and distributor pipes, supplied to the compressor bearing housing.

On the bearing housing two analogic position transmitters are used to measure the axial rotor position and the shaft shift due to the RDS.

2.8 Hydraulic Oil System

The hydraulic oil system has the purpose of positioning the fuel gas control valves according to the fuel controller requirements, opening or closing the fuel emergency stop valves when the gas turbine is started or stopped. In addition, the system immediately closes the emergency stop valve in case of faults which demand immediate gas turbine shut down (trip).

The control device which adjusts the hydraulic oil supply to the actuator is directly mounted on the valve actuators so that each valve is a very compact unit. Two accumulators serve the purpose of ensuring that sufficient hydraulic oil quantities are made available anytime.

2.9 Fuel Gas Skid

The fuel gas system supplies the burners with clean and filtered fuel gas and controls the amount which flows into the combustion chamber corresponding to the demand of start-up, operation and shut-down.

The fuel gas must be supplied in dry and clean condition at the fuel gas skid inlet. A coarse filter inside the skid prevents large particles from damaging the downstream components only in case of failure of the upstream components. It has no filtering function. The first shut off valve is the emergency stop valve. Its function is to enable or disenable the flow of fuel gas to the combustion chamber on start-up and shutdown of the gas turbine. It is closed during disturbances when immediate interruption of the gas turbine operation is

required (GT trip).

Downstream of the emergency stop valve, the fuel line divides in two branches: the first one, in which the fuel gas control valve is placed, supplies the diffusion and the premix burners, the second one supplies the pilot gas burners. In this secondary line the pilot gas control valve is located.

The three lines are isolated at each combustion chamber by means of ball valves (diffusion, premix and pilot gas ball valves), electrically actuated.

When the gas turbine is in fuel gas diffusion configuration, the diffusion ball valves on the combustion chambers are opened and the fuel gas enters the burners to be burnt in diffusion mode.

When the gas turbine is in fuel gas premix operation, the premix and the pilot ball valves are opened, the pilot gas control valve adjusts the quantity of pilot gas to stabilise the premix flame.

Gas turbine start up occurs in diffusion mode. The diffusion mode can be maintained in the whole load range of gas turbine operation. The premix mode is allowed only in the upper load range: at approx. 45% of base load the control system automatically switches from diffusion to premix mode and the fuel gas flows through the premix burners. The premix flame is also sustained by the pilot flame coming from the pilot gas burners.

In case of load rejection during the premix mode, a fast switch over for diffusion mode occurs, the pilot control valve opens a little more in order to ensure flame stability during the transient phase. Strainer, stop and control valves are arranged in compact form (fuel gas skid).

2.10 Fuel Gas Final Filtration Skid

The function of the system is to supply the gas turbine with gaseous fuel in accordance with the specified requirements. The fuel gas is processed in this module and be fed to the inlet flange of the gas turbine fuel gas skid with required characteristics at this location.

At the point of connection to the main gas supply system, an insulating flange electrically isolates the fuel gas front module from the main supply system. Equipment for measuring actual fuel-gas consumption during gas turbine operation is provided after the insulating flange, without redundancy or bypass provisions.

Vertical Dust-and-Liquid Separators with redundancy are provided in the system. Two vertical, combined dust-and-liquid separators for each gas turbine are installed outside the gas turbine building to protect the turbine. The filters remove corrosion products from the system as well as any moisture remained. The separator is designed as a two-stage filter unit. The first stage (baffle type) serves to remove moisture and solid particles, while the second stage (cellulose cartridges) provides for mechanical filtration. Because the amount of liquid collecting at the bottom of the separator is very small only, it is equipped with a manual condensate drain.

Installed downstream of the Final Filter is the pneumatic driven block valve which can be used to isolate the gas turbine from the fuel gas supply system. The block valve is designed as an ESD ball valve. The instrument air is about 8 bar. To produce a buffer volume to enable one opening procedure without taking gas volume from the main instrument air pipeline the system is equipped with the pressure vessel.

Most of the constructive elements is arranged in compact form in the so called fuel gas final filter skid. The fuel gas is then distributed to fuel gas skid for further process.

2.14 Gas Turbine Enclosure

The gas turbine generator set is a complete set of power generation equipment with high intensity noise level and multi noise source. Under the premise of ensuring the normal operation of the gas turbine, set the gas turbine casing and its auxiliary system to reduce the influence of the noise of the gas turbine on the external environment.

For the gas turbine enclosure and its auxiliary system (ventilation system, lighting system), mainly acoustic performance, fire performance, fire performance and maintenance performance requirements.

- GT Enclosure

The noise level should meet the requirements. The enclosure shall be designed in an indoor manner to absorb the noise generated by the GT so that the noise is limited to less than 85 dB (A) at a noise level of 1.2 m from the operating platform at a distance of 1.2 m from the operating platform.

The enclosure should be rigid frame, and each compartment have a removable top and side wall. The sidewalls should be designed so that they are accessible during routine maintenance, observation, and operation adjustments.

Pipes or cable ducts should not pass through removable top and wall. Ducts, fire protection systems, gas detection, etc. should not be fixed at the bottom of the top or side wall to be opened for maintenance.

2.15 Fire Fighting system

The firefighting system will be designed to:

- Quickly detects fires inside the protected buildings and areas;
- Quickly detects gas leakage (CH₄) inside the Gas Turbine and Skid gas enclosure. A signal will be shown on the Local Alarm Panel and the signal will be sent to the GTCMPS for tripping the Gas Turbine;
- Extinguishing fires Gas Turbine and Skid gas enclosure with CO₂ total flooding fixed installations.

The firefighting protection system will include the following system: Carbon dioxide extinguishing system; Fire and Gas detection system; Fire and Gas alarm system.

3. GAS TURBINE PERFORMANCE THE GAS TURBINE CONTROL , MONITORING AND PROTECTION SYSTEM

The AE94.2 Reference Gas Turbine Control、Monitoring and Protection System (hereafter indicated as **GTCMPS**) is the electronic equipment specifically dedicated to perform the Control, Protection and Supervisory functions of SEC AE94.2 Gas Turbine Generator Set.

The GTCMPS is usually designed with the ABB SYMPHONY PLUS system platform

The GTCMPS can be engineered for single or multi shaft configurations in open or combined cycle plants and sharing with the steam turbine control system(hereafter indicated as DEH), if supplied by SEC, the same data highway, operator station and engineering work station.

SEC can provide for the customers with the whole integrated plant system, which means the GTCMPS, DEH and DCS(the whole control system) use the same hardware and software, achieve data sharing, safe and redundant data communication, and spare parts sharing. So that the GTCMPS system and DEH are operated and controlled at the DCS operator station.

The GTCMPS performs the control, monitoring and protection functions of the systems and components included in SEC AE94.2 Gas Turbine Generator Set during all operating modes.

Control Functions

The Control Functions are the continuous and discontinuous actions aimed at keeping the process variables at the relevant suitable levels

Monitoring Functions

The Monitoring Functions allow the operator to manually initiate the Control Functions, to follow the ongoing automatic actions and provide the operator with the information related to the alarms and status of the process and equipment.

Protection Functions

The Protection Functions are the actions aimed at avoiding hazardous situations and at safeguarding the integrity of the process and equipment