GAS TURBINE AND WIND TURBINE ENGINES FOR POWER STATIONS

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Contents

Summary

The basic concepts concerning gas turbine units and combined units with gas and steam turbines are given; the classification of numerous and various types of stationary power turbine units is presented. The review is given and the prospects of development of GTU are shown. The most expedient spheres of application of GTU in power production are determined. The thermodynamic cycles, kinematics and thermal schemes and basic parameters of created and perspective GTU and combined turbine units are considered. The evolution of gas turbine parameters in a direction of constant increase of inlet gas temperature in front of the turbine and increase of a pressure ratio in a

thermodynamic cycle at simultaneous complication of kinematics schemes of units is shown. Two basic directions of development of power GTU are specified: construction of units specially designed for work on power stations, and creation of GTU on the basis of aviation gas turbine engines. The basic directions of design and technological works are determined at creation of GTU on the basis of aviation engines. Perspectives of application of GTU in structure of combined gas-steam turbine units on power stations, in particular, for modernization of working steam turbine blocks is shown. At such combination it is possible to achieve rather high fuel efficiency, sharply to reduce emissions of harmful gases in an atmosphere in comparison with working steam turbine power stations. The real prospects of application of solid fuel first of all coal, in closed and semi-closed GTU, and also in combined gas-steam turbine units are shown. These prospects are based on positive experience received at operation of units on a number of power stations. The perspectives of application of air-accumulating GTU in powerful power systems are shown. The opportunities of application of GTU on a solar energy are shown. Among all directions of development the special place occupy GTU on nuclear fuel in a combination with high-temperature gas-cooled reactor. The working fluid of such installations simultaneously is cooling medium of nuclear reactor that appreciably simplifies an atomic power station and provides the greater safety of operation, than traditional atomic power stations. The problems of influence of power GTU and combined units on an environment are considered; the opportunities of reduction of noise level and toxicity of the exhausted gases are shown. The state with development of wind turbines in the world is considered, the main types of wind turbines are described, and the basic rules of their theory are stated. The analysis of possible harmful influences of wind turbines on an environment and measures ensuring decrease of such influences is given.

1. Introduction

The gas turbine units (or engines), and also combined units with gas turbines and steam turbines working on power stations of different types and with high capacity (from several tens up to several thousand of megawatt), are classified as *stationary turbine power units*. They provide customers with electrical energy and (sometimes) heat.

The stationary turbine power units form one of the special classes of gas turbine units. Based on its purposes, it is possible to divide these units as base, semi-peak, peak, emergency and auxiliary units. Such division of units is provisional one and is connected with distinguishing of appropriate zones in a production schedule of large power systems.

To peak, as a rule, attribute the units with a running time 500–1500 h in a year; the units with a running time 3500–4500 h in a year attribute to semi-peak units, and with running time 6000–8000 h – to base units which intended for performance of day-night base load.

The power units with gas turbines *on thermodynamic features* are divided on gas turbine units (GTU) which work on an open cycle, GTU of semi-closed cycle (SCGTU), GTU of closed cycle (CGTU), combined steam and gas (or gas and steam) units (STAG) of different kinds. Despite of all diversity of the possible units with gas turbines, the practical application is found very few of them: basically GTU of an open cycle and combined units with steam and gas turbines, working on liquid and (or) gaseous fuels.

During last 30 years, GTU have taken a sound place in power engineering of leading developed countries and also of developing countries with a noticeable part of oil and gas in their fuel balances. USA is on the first place on application of GTU among developed countries. The installed power of GTU in USA makes more than 60 million kW. Saudi Arabia with installed power about 20 million kW is on the first place among developing countries. In total above 13 thousand of stationary gas turbine power units with a total power about 200 million kW is exploited in the world. Considerable powers dispose Great Britain, Germany and other industrially developed countries. On some forecasts, in 1986–1995 in the world should be constructed about 8000 stationary gas turbine power units.

Advantages of GTU which ensure the expansion of their production are, specifically:

- short term of launching (2–3 years from a beginning of building),
- broad range of single powers (30–240 MW),
- capability of joining of several GTU in a unified power unit,
- feasibility of application of GTU in a structure of combined turbine power units, including units with gasification of solid fuel,
- low capital costs (according to the American specialists the costs make $225–375 per 1 kW),
- small harmful effect on environment,
- high enough fuel efficiency of perspective models,
- higher maneuverability (the possibility of quick start and reliable operation under cyclic conditions) as compared with steam turbine units,
- simplicity of automation,
- compactness,
- independence of water sources.

The power GTU find a use first of all as peak that is explained by a number of the causes. First reason is determined by that the part of electric power manufactured in peak operational mode in a general energy balance continuously increases. In these conditions GTU appear more preferential than steam turbine power plants. They react faster to change of load, are faster started up and shutdown; can work on two kinds of fuels; their initial cost is lower; they can be faster repaired etc. Rather lower efficiency of a GTU can be partly compensated by application of a heat recovery of exhausted gases in water heater or steam boilers. However power GTU have become popular for performance not only peak, but also base loads, and also as stand-by.

In spite of the fact that, as previously mentioned, the main fuels for a GTU and STAG are liquid fuel and gaseous fuel, the definite interest is displayed to application of solid fuel, first of all of coal, in them. The turbine installations on non-conventional power sources – Sun, wind, marine rising tides, on a temperature drop of water in ocean, on geothermal and petro-thermal heat sources, on a nuclear fuel etc are designed also. Naturally, the consideration of features of turbine units on so miscellaneous power sources in the article of a limited volume is impossible, therefore the most used and perspective of them are esteemed below. The kind of fuel in many cases renders decisive influence on selection of a thermodynamic cycle, parameters, thermal and structural schemes of unit, therefore further all turbine power units are considered depending on what fuel they work on.

Selection and estimation carry out on the strength of number of the requirements (or indicators) to designed installation. Orienting on these indicators it is possible to select rational thermodynamic and regime parameters of the designed installation, design of its assemblies etc.

The main requirements shown to stationary power units are their high economical efficiency, long operating life, high reliability, large single power, and high scale of automation and maneuverability.

2. Gas Turbine Units and Combined Units on Liquid and (or) Gaseous Fuels

2.1. Gas Turbine Units Working on an Open Thermodynamic Cycle

The main types of power units working on an open thermodynamic cycle on liquid and (or) gaseous fuels can be GTU and combined units with steam and gas turbines.

The installations of two types are produced: specially designed for operation as stationary power units (the units of an industrial type or heavy-duty GTU) (Table 1) and units which are built on the basis of the aviation jet engines.

Parameters	MS5001P	MS6001	MS7001E	MS9001E	MS9001FA
	General Electric (USA) and corporation of other countries under its licences				Nuovo Pignone (Italy) and corporation of other countries (on the licences of the company GE)
Year of a beginning of the output	1958	1978	1976	1979	1991
Nominal (peak) power at 15 °C and ~ 0.1 MPa), MW	25.89 (27.75)	37.5 (40.7)	78.4 (84.8)	111.4 (121)	226.5 (237.2)
Gas temperature at peak load, K:					
at turbine inlet	1270	1377	1377	1358	-
at turbine outlet	-	-	-	-	862
Air flow at compressor inlet, kg/s	122	138	279	401	602
Compressor pressure raqtio					

Ratio	10.2	11.5	11.5	11.4	15.0
Rated revolutions					
of output shaft,					
min^{-1}	5 105	5 105	3 600	3 000	3 000
Actual efficiency					
at nominal (peak)	28.1	31.0	32.4	32.1	35.7
power, %	(32.1)	(31.2)	(32.5)	(31.1)	(35.8)
Weight, t	172.5	190.7	267.9	295.1	-
External					
length	21.7	21.7	27.5	32.0	-
width	3.4	3.4	3.4	4.6	-
height	3.7	3.7	6.1	6.1	-

MS6001FA	MS9001EC	GT11N2	GT13E2	TG50D5S	V94.2	V94.2A	V94.3A	V84.3A
Nuovo Pignone (Italy) and corporation of other countries (on the licences of the company GE)		ABB (USA and other countries)		FIAT Avio (Italy and other countries)	Siemens KWU (Germany and other countries)			
1993	1994	1993	1993	1991	1981	1997	1995	1994
70.14	169.2	115.5	165.1	146.9	159.0	190.0	255.0	180.0
(73.57)	(177.5)	(123.3)	(176.9)	(-)	(167.0	(-)	(-)	(-)
- 870	- 831	- 797	- 797	- 795	- 787	- 800	- 914	- 850
197	499	375	533	470	514	527	641	445
15.0	14.2	15.0	14.6	14.0	11.1	14.0	17.0	17.0
5 247	3 000	3 600	3 000	3 000	3 000	3 000	3 000	3 600
34.2	35.0	34.9	35.7	34.2	34.5	36.4	38.5	38.5
(34.4)	(35.1)	(-)	(-)	(-)	(34.6)	(-)	(-)	(-)
-	-	190	330	170	295	320	330	235
		9.5	10.8	12.5	14.0	12.0	12.5	11.0
-	-	5.5	6.4	5.2	12.5	6.0	6.1	5.5
-	-	10.0	5.4	5.7	8.4	7.4	7.5	6.5

Table 1. The main characteristics of stationary power GTU of an industrial (heavy-duty) type with large capacity

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Biographical Sketch

Eduard A. Manushin – Candidate of sciences (Ph.D.) (Technics) – 1964; Doctor of Sciences (Technics) – 1978; Professor – 1980; Full Member of the Russian Academy of Education (former – Academy of Pedagogical Sciences of the USSR) – 1989.

Graduated from Moscow Higher Technical School (now Moscow State Technical University – MSTU) named after N. Bauman (1956), specialty – engineer-mechanic in turbine-building.

Engineer, lecturer, professor of MSTU (1956-1986). First vice-rector of MSTU (1986-1991). First vice-rector of the Russian Academy of Administration (1991-1994). General Director of the International System Research Center for Higher Education and Science (1995-1999). Academician-Secretary of the Higher Education Department of the Russian Academy of Education (1997-2002). Editor-in-Chief of the MAGISTER-PRESS Publishing House (1999 till now). Professor of MHTS (till now).

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He has 16 textbooks, more than 150 scientific articles. His recent publications include *Theory and designing of gas turbine and combined units* (textbook, 2000, with co-authors); *Heat-transfer apparatus and cooling systems of gas turbine and combined units* (textbook, 2003, with co-authors); *Education and 21st century: Information and communication technology* (with co-authors, 1999); *Thermotechnics* (with co-authors, 2003, forthcoming); *History of Humanity* (Russian edition of UNESCO Encyclopedia in 7 volumes – editor of 1-5 issued volumes).