

Gas-Turbine Power Stations on Associated Gas by Motor Sich OJSC

P. A. Gorbachev^a and V. G. Mikhailutsa^b

^a Ground-Based Gas-Turbine Stations, Borisfen Avia LLC

^b International Programs, Motor Sich OJSC, ul. 2-ya Peschanaya 5, Moscow, 125252 Russia
phone: +7(495)4115111
e-mail: gorbachev@motorsich.ru

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Abstract—Wide introduction of gas-turbine power stations working on associated oil gas is topical for Russia. Designing and operational characteristics of PAES-2500 (2.5 MW) and EG-6000 (6.0 MW) gas-turbine power stations on associated oil gas manufactured by Motor Sich Company are presented.

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At present many well-known manufacturers of aviation gas-turbine engines are actively exploring a prospective market of ground-based gas-turbine power stations. One of the oldest and largest producers of aviation engines in the post-Soviet space, Motor Sich OJSC (Zaporozhye), is among them. Together with its core activities, including production of engines for aircrafts, helicopters, and cruise missiles, Motor Sich has been implementing its own power energy strategy for about half a century. This strategy is based on clear evaluation of the constantly increasing demands of different sectors of the national economy for new power generating capacities, supported by knowledge of major trends of the scientific and technological progress. That was the reason for the company to get involved into the implementation of a large-scale electrification plan for the Soviet Union and the neighboring countries as early as the 1950s.

Since the start of production till present Motor Sich has produced about 3000 high-grade power stations installed by the specialists of the enterprise in different parts of the world, from oil-and-gas districts of the Russian Far North to equatorial Brazil. The total capacity of the produced equipment significantly exceeds the capacity of the first robin of spring of the Soviet great construction epoch, the famous Dnieper Hydro-Power Station.

Consumers, who have used gas-turbine power stations produced in Zaporozhye for quite a number of

years, have aptly tagged them as “unkillable” with regard to their operational lifetime and have described their capabilities as unlimited. The original technical characteristics of these units make it possible to operate them at temperatures ranging from -50° to $+45^{\circ}$. Gas-turbine power stations manufactured by Motor Sich are unique systems adaptable to any networks with a wide range of alternating loads. The capabilities of these units produced in Zaporozhye to adapt to peak capacity loads (e.g. during passage of trains) are justly considered one of the best in the world.

At present power stations with the capacity of 1, 2, 5, 6, and 8 MW manufactured by Motor Sich are in operation in Russia and other countries, and it is by no means the limit. EG-1000 modular transportable gas-turbine power station produced by Motor Sich is designed to supply electricity and heat to industrial and household consumers in the basic and other operating modes. It is characterized by high cost effectiveness and can be completed with equipment ensuring self-containment. The container-type structure of these power stations requires no additional conditions (buildings, constructions, or ground works) during installation and operation. The modules can be also installed at flat cars.

PAES-2500 and EG-2500T with the capacity of 2.5 MW are intended to supply electricity to industrial and household objects, compensate for shortcomings

of electricity and heat at peak loads, and work in the electricity backup mode. Consumers appreciate these power stations for simplicity of control and operation, high mobility, and increased reliability.

EG-6000 and EG-8000 power stations by Motor Sich are designed to supply electricity and heat to industrial and household users. They work on gaseous or liquid fuels. The gas-turbine drive can be started both from the control panel and remotely.

Today, technical complexity of the units, which is the company's special know-how, and their high reliability, which has been proved by many years of operation in various climatic zones, are serious arguments for the customers in favor of Motor Sich power stations. Power stations form the main component of heat and power complexes and make it possible to produce heat and electricity at fuel combustion efficiency of 85% and higher.

Special attention is attracted by the experience gained by Motor Sich OJSC in designing, engineering, manufacturing, testing, and putting into operation of gas-turbine power stations working on associated oil gas. The gas-turbine power station of the Igol'sko-Talovoye deposit (Tomsk oblast) commissioned in 2004 can serve as an example of gas-turbine power stations working on associated oil gas. The station, consisting of 4 gas-turbine units with the capacity of 6 MW each, is fired with associated gas containing almost 30% of C_{2+} hydrocarbons (see the table). By now more than 500 mln. kWh of electricity has been generated at this object. The initial costs of the power station amounting to \$24 mln. were paid back in 2 years of operation even without taking into account the heat produced by 2 units working together with waste-heat boilers and generating heat to cover the needs of the rotation village.

The first experience in operation of Motor Sich gas-turbine power stations on associated oil gas was received as early as 1978. Since 1978 PAES-2500 power stations on associated oil gas have been installed at the following objects: Glavtyumen'-neftegaz, 6 items; Uzbekgazprom, 12 items; Lenaneftegaz, 13 items; Turkmengazprom, 19 items (after 1980); Komigazprom, 11 items (after 1984); Yamalneftegazgeologiya, 9 items etc.

At present there are 167 PAES-2500 (2.5 MW) and 4 EG-6000 (6.0 MW) power stations that are in operation and work on associated oil gas. The total number of power stations that are in operation includes

Composition of associated oil gas from Igol'sko-Talovoye deposit

Parameter	Value
Gas composition, vol % (in compliance with GOST 23781-87 All-Union State Standard)	
methane	67.45
ethane	7.31
propane	12.1
isobutane	2.38
butane	4.83
isopentane	0.91
pentane	0.98
hexane	0.18
carbon dioxide	1.78
nitrogen	2.05
oxygen	0.01
C_4 Hydrocarbons and higher hydrocarbons, $g\ m^{-3}$	465.95
C_5 Hydrocarbons and higher hydrocarbons, $g\ m^{-3}$	63.88
Physicochemical parameters at 20°C and 0.1 MPa	
Molecular weight, $g\ mol^{-1}$	25.59
Absolute density, $kg\ m^{-3}$	1.07
Relative density, $kg\ m^{-3}$	0.89
Heating value in compliance with GOST 27667-82 All-Union State Standard, $kcal\ m^{-3}$	
lower	11618
higher	12745
Wobbe index, $kcal\ m^{-3}$	
lower	12316
higher	13511

783 PAES-2500 (2.5 MW) and 6 EG-6000 (6.0 MW) power stations, as well as more than 100 gas-turbine drives of D-336 series with the capacity ranging from 6 to 8 MW as part of gas compressor units.

In recent years 20 PAES-2500 power stations working on associated oil gas were put into operation as follows: Novy Urengoy, Sibneftegaz, 4 items in 2001–2002 and 2 items in 2007; Yurkharovneftegaz, 5 items in 2007; MRK-Engineering LLC and Severneft' Oil Company LLC, 6 items in 2007; Tomskgazprom OJSC and Kazanskoye oil-and-gas condensate deposit, 3 items in 2009. Four EG-6000 (GTE-6/6.3M1UKhL1)



Fig. 1. Liquid fraction in gas-supply line.



Fig. 2. Burners with buildups.

power stations were also commissioned at Igol'skaya Gas-Turbine Power Station and Tomskneft' OJSC under VNK (Eastern Oil Company) in 2004.

With regard to chemical properties, associated oil gas is different from natural gas (Table 1) and, therefore, requires corresponding preparation before it can be used as a fuel for gas-turbine drives. The operational experience has demonstrated that the fuel equipment of PAES-2500 power stations is the least capricious with respect to associated oil gas. The use of 6-MW gas-turbine drives (Igol'skaya Gas-Turbine Power Station) with associated oil gas as a fuel requires obligatory compliance with certain gas preparation requirements; non-compliance can result in early breakdown of the fuel equipment. Formation of combustion product buildups at burners results in

change of direction and non-uniformity of the heat flow in the combustion chamber, as well as in oscillating combustion behavior (resulting from unstable physicochemical properties of associated oil gas). All of this results in off-design behavior of the gas-turbine drive and subsequent breakages (Figs. 1–3).

In order to ensure reliable operation of EG-6000 power stations working on associated oil gas, characterized by unstable density and heating value, in the presence of liquid fractions in the gas composition, Motor Sich introduced improvements into the fuel equipment of the gas-turbine drive. One of them was development and production of the gas burner and the combustion chamber allowing the flame tube to withstand stresses resulting from flickering of flame during operation of the gas-turbine drive on fuel with



Fig. 3. External appearance of the gas-turbine drive compressor after entry of associated gas liquid fraction into the combustion chamber.

unstable parameters. A fuel-gas filter-separator, ensuring additional gas cleaning and removal of liquid fractions from the gas directly before supplying the gas to the power station fuel equipment, was also proposed for completion of the equipment.

Implementation of the measures related to the power station fuel equipment and activities performed by the operating company at the object made it possible to minimize failures in operation of power stations working on associated oil gas.

As of 08.11.2009, the non-failure operating time of the Igol'skaya Gas-Turbine Power Station units amounted to: GTU-1 (Gas-Turbine Unit 1) 37 724 h, GTU-2 34 925 h, GTU-3 37 506 h, and GTU-4 36 248 h.

The total non-failure operating time of 4 units reached 146 403 h, including 90 262 h during the last 3 years.

The electricity production cost is 1.37 rubles/kWh (excluding VAT); the heat production cost is 364 rubles/Gcal (excluding VAT).

The total combined output of gas-turbine power stations manufactured by Motor Sich OJSC amounts to many billions of kWh. It is necessary to note that large-scale application of PAES power stations manufactured by Motor Sich is becoming more and more topical for Russia in connection with the requirement to significantly reduce harmful emissions in oil-and-gas districts of the country.