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Future View of Energy Supply & Role of Gas Turbine in Japan (View of Electric Power Company)

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ABSTRACT

Gas turbine generation has been developed in the characteristic in Japan such as imported energy source, large load change among seasons, daytime and nighttime. Now the combined cycle power generation using gas turbine has been the most affordable thermal power generation system.

Even there will be no big change in the total energy supply and consumption in Japan, the electricity demand is prospected to increase steadily.

Concerning demand prospect, global environment, electricity retail liberalization, gas turbine technologies should be improved in Cost Affordability (Cost Reduction), High Reliability, Fuel Flexibility, Output Variation, and Environmental Protection.

DEVELOPMENT OF GAS TURBINE GENERATION UP TO NOW

INTRODUCTION OF GAS TURBINE GENERATION

Recent electric utility service, the gas turbine has become the main force of thermal power generation. And the improvement of efficiency of thermal power generation largely due to progress of the gas turbine technology.

The introduction of gas turbine to electric utility was 30 years ago. At that time Japan was in rapid economic growth and the electricity demand was also increasing rapidly by stretch of an annual rate of 10% or more those days. Since it corresponded for extending, the simple cycle gas turbine power plant that can be built for a short period of time was built. TEPCO introduced 7 gas turbines in 1969 – 1970.

But, at that time the turbine inlet temperature (TIT) was about 800 degree-C. Output of TEPCO's gas turbines were 15MW to 30MW and the efficiency were low, about 24%(HHV).

INTRODUCTION OF COMBINED CYCLE SYSTEM

Material technology also progressed with progress of aircraft engine technology in the 1970s, and the reliability of gas turbine hot parts had also been improved.

1,100 degree-C class gas turbine that has 70-100MW outputs and efficiency 27% was developed. And combined cycle generation system that recover the energy of high temperature gas turbine exhaust gas to generate steam for steam turbine generation was also developed. These two technologies enabled large improvement of thermal efficiency.

In Japan, after the oil crisis, reduction of oil dependency became a big issue and fuel for thermal power was also greatly shifted from oil to LNG.

Moreover, the nuclear power as base load power supply was introduced and increased in the 1970s. The improvement in mobility of thermal power generation, such as high load adjustment capability and high efficiency in low load, was required for thermal power generation. But, there was a limit in the conventional boiler - steam turbine power generation.

From such a background, the combined cycle generation that uses the 1100 degree-C class was introduced.
Combined cycle generation was applied at Tohoku Electric Power's Higashi-Niigata Thermal Power Station Group 3 in 1984, and TEPCO's Futtsu Thermal Power Station Group 1 in 1985.
(Figure 1 : TEPCO Futtsu Thermal Power Station Group1&2)

Fig. 1 TEPCO Futtsu Thermal Power Station

DEVELOPMENT OF ACC SYSTEM

In the 1990s the 1300 degree-C class gas turbine was developed by progress of the hot parts material, blade cooling, thermal barrier coating on turbine blade or combustor and development of Dry Low NOx Combustor (DLNC).

And aiming at efficient and large-scale equipment, new combined cycle system, which adopted this new 1300 degree-C class gas turbine, was developed. TEPCO call this system ACC (Advanced Combined Cycle).

TEPCO's first ACC units Yokohama Gourp7,8 commissioned in 1996 and now 23 ACC units with total capacity 8,340MW are in commercial operation or commissioning. (Fig. 2 TEPCO

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Yokohama Group 7&8)

Fig. 2 TEPCO Yokohama ACC Plant

The performance of ACC units still is improving with progress of gas turbine technology.
Improvement of gas turbine cooling, sealing, thermal barrier coating technology resulted in improvement of thermal efficiency, and output.

At TEPCO, stage output 350MW, thermal efficiency 48.9%(HHV) in Yokohama 7&8 has been improved to 380MW, 50% in Futtsu 3 and Shinagawa 1.

Table 1 Improvement of TEPCO ACC units

	Yokohama 7,8	Chiba 1	Chiba 2	Futtsu 3	Shinagawa 1
Stage Output* MW	350	360	360	380	380
Thermal Efficiency %(HHV)	48.9	49	49	50	50
Number of Units	8	4	4	4	3
Type of GT	MS9001FA	M701F	MS9001FA	MS9001 FA+e	MS9001 FA+e

* Ambient temperature 5degree-C

There are following characteristics for electricity and power station location in Japan.

- Fuels depend on import
- Demands change widely among seasons, daytime and nighttime
- Strict environmental regulation
- Narrow space

Japan has almost no energy resources, so we have had to depend on import from other country. To save resources, we had to aim for high efficiency. And climate and life style of Japan results in much demand change among seasons, among daytime and nighttime. And Japan has had a much more strict environmental regulation than other countries. Gas turbine power generation plant has developed in such circumstance.

TEPCO IS NOT SIMPLY AN USER

TEPCO is not simply a gas turbine user but to give direction for the development of gas turbine or combined cycle system.
Such as

- Development of Dry Low NOx Combustor
- Life evaluation and extension of hot gas path parts
- Design of Advanced Combined Cycle System

And the results are the ACC system and extension of 9E gas turbine HGP life.
And TEPCO also had studied catalytic combustor for the purpose of environmental improvement.

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PROSPECT OF FUTURE ENERGY IN JAPAN

PRIMARY ENERGY SUPPLY & FINAL ENERGY CONSUMPTION

Fig.3 shows the prospect of primary energy supply in Japan. After the Oil Crisis, energy saving and restructuring of industry have progressed and oil dependency has been decreased.
Use of nuclear power and natural gas has been expanding and the energy source balance is expected to be more leveled in 2010.
Along this, TEPCO is preceding the new LNG projects such as Darwin (Australia), or Sakhalin 2(Russia).

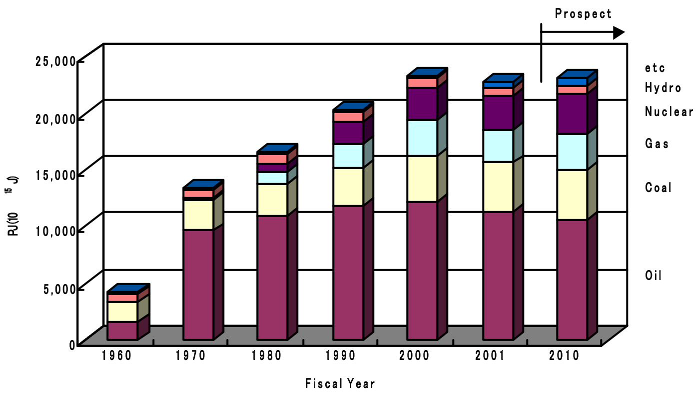

Fig. 3 Prospect of Primary Energy Supply
(Source: Overall Energy Statistics FY2001)

Final energy consumption by end user that had been mainly consumed by industry segment in the past has shifted to residential and transportation usage by the price reduction of petroleum and the change of life style.

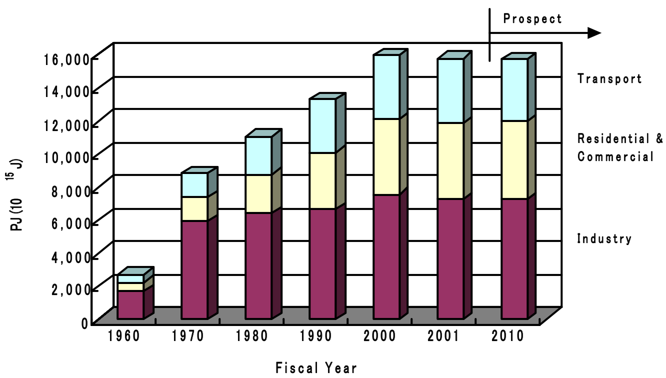

Fig. 4 Prospect of Final Energy Consumption
(Source:Overall Energy Statistics FY2001)

REDUCTION OF CO2 EMISSION

In 1997, COP3, the Conference of the Parties to the United Nations Framework Convention on Climate Change, Japan was obliged severe target to CO2 gas emission in 2008 – 2012 average to 6% lower than that of 1990 emission.
For this target electric utility companies' action is to expand use of LNG and non-fossil fuel such as nuclear, improve of thermal efficiency, and reduce transmission loss.

USE OF NEW ENRGY (RPS)

In Japan Special measures law concerning the use of new energy by electric utilities was enacted. In this law electricity retailers are obliged to use new energy such as solar, wind, biomass, geothermal, small-mid size hydro etc. This year the obliged energy amount is 9.87×10^{8}kWh to TEPCO, and 32.8×10^{8}kWh to total retailers in Japan. And the target amount in 2020 is 122×10^{8}kWh in Japan.

ELECTRICITY DEMAND

Electricity sales is expected to steadily increase even the rate will go down. Peak demand that highly related to utility companies' supply planning, is also expected to increase even the rate will decrease by economic condition or progress of load leveling in mainly residence and commercial section.

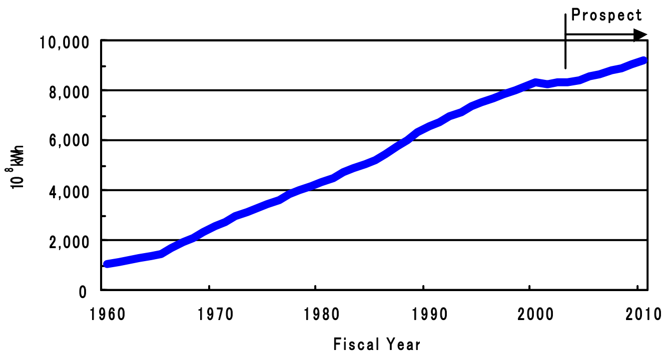

Fig. 5 Prospect of Electricity sales

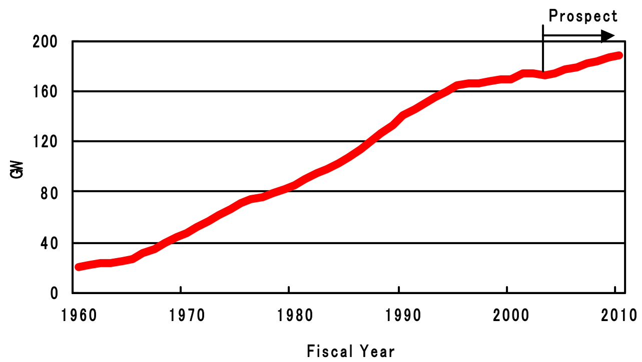

Fig. 6 Prospect of Peak demand

LIBERALIZATION OF ELCTRICITY RETAIL

Besides increase of electricity demand, retail liberalization also in progress and some part equivalent to 30% of total sales was already liberalized. Then by further retail liberalization equivalent to 60% of total sales will be the subject of liberalization in 2005 April.
More strategic and flexible investment in equipment is required for utility companies.

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FUTURE DEVELOPMENT OF GAS TURBINE

REQUIREMENT FOR THERMAL POWER PLANT

For such an energy circumstance, the following items are required for thermal power equipment.

- Cost Affordability (Cost Reduction)
- High Reliability
- Fuel Flexibility
- Output Variation
- Environmental Protection

REQUIREMENT FOR GAS TURIBNE

To solve these items, we expect 4 developments for gas turbine technologies.

The first one is to pursuit of scale merit by raise the firing temperature and pressure ratio. This method have been done and should be continued.

The second point that may have an inconsistency with previous point is to development mid or small size gas turbine. These gas turbines can be installed in a short term and deal with uncertain demand expectation. Micro gas turbines are also positioned in this category.

The third one is the improvement of existing gas turbine reliability. Especially gas turbine hot parts life extension is a big issue.

The last one is to expand fuel flexibility with efficiency, environment protection the development of IGCC technology that can use coal or heavy oil.

MACC SYSTEM

To pursuit of scale merit, TEPCO has developed and applied 1,500 degree-C class gas turbine combined cycle system. TEPCO calls this system "MACC (More Advanced Combined Cycle)".

To achieve high efficiency more than 53%(HHV) keeping reliable operation, development of reliability of gas turbine steam cooling system, hot parts life and reliability are required.
And for new hot parts material, its proper maintenance is important. Much more development and mature these new technologies is needed, and continue the development for further higher firing temperature in the next generation.
TEPCO has applied the MACC system for their Kawasaki Group 1 and Futtsu Group 4. The first unit is planned to commission in 2007.

If Futtsu Group 4 has commissioned, Futtsu thermal power station's total capacity reaches to 5,040 MW. That surpass Surgut 2 thermal power station in Russia, the current largest thermal power station in the world.

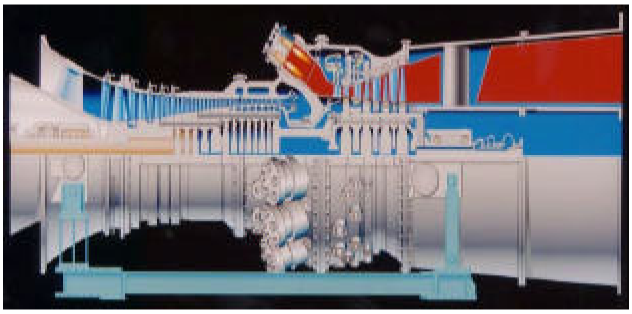

Fig. 7 1,500 degree-C class Gas Turbine

THE MID-SIZED GAS TURBINE WITH HIGH EFFICIENCY

Under recent uncertainty of electricity demand, electric utilities have to consider flexibility of new power plant construction besides keeping efficiency and economy,

Current gas turbines with around 100MW capacity have low efficiency and there is no mid-low sized high efficient gas turbine as product.

We can have flexibility of construction time and cost by operating only gas turbine first, and adding HRSG and Steam turbine at the proper timing that has often done in USA or Europe in large-size gas turbines.

There is high potential for mid-sized gas turbine with high efficiency equivalent with mid conventional plant, for replacement of old power plant or quick construction corresponding to electricity demand situation.

MICRO GAS TURBINE (MGT)

Micro gas turbine (MGT) has an excellent environmental performance. But its efficiency is below 30%, lower than competitor Diesel engines or Gas engines. Such economical subject make its quick spread in the market difficult.

But because of its environmental performance and simple structure, MGT has potential role as small size distributed power supply together with fuel cell. If they can improve its efficient and expand the variation of output MGT can compete with Diesel engines as distributed power supply.

IMPROVEMENT OF RELIABILITY

Combined cycle power plants have both high efficiency and load change capability. Combined cycle power plants have been operated mainly as base load for a while after commission because of their high efficiency. But its number of starts and stops increase as load adjusting power supply.

Such a severe operating condition could impact as low cycle fatigue to components of plant equipment, especially hot parts of gas turbine. To deal with such condition we have to improve the existing material for extension of life, and have to establish life diagnosis and evaluation technologies regarding life cycle costs.

Gas turbine dry low NOx combustor has a risk of high combustion dynamics that could be caused by the condition of air and fuel variety. It is needed to develop combustion test method or numerical analysis method with high accuracy to solve combustion dynamics problem.

FUEL FLEXIBILITY

Current gas turbine fuel for electric utilities is dominated by gas. Coal, crude, heavy oil have been used for conventional power plant fuel. For the viewpoint of energy security and efficiency, we have to expand the fuel variety for gas turbine. A solution for this subject keeping good environment is IGCC (Integrated Gasificated Combined Cycle) that can use coal as gas turbine fuel.

There are some IGCC commercial plants in USA or Europe. In Japan, it is continued to develop more efficiency IGCC system, and utility companies co-works are planning demonstrating plant in Ibaragi prefecture. The plant is planed to starts test in 2007.

IDEAL GAS TURBINE PLANT

The gas turbine ideal to electric company could be collected by keyword "PRAMO". PRAMO is often used word. On this paper I use this word for Performance, Reliability (availability), Affordability, Maintenancability, Operability.

Performance includes environment. High efficiency, specific output, low emission is basic requirements for gas turbine. And fuel flexibility enhances these performances.

Performance stands on reliability. Improvement of hot parts life or combustion dynamics result in improvement of availability.

Affordability is closely related to reliability. Less number and cost of components could realize higher reliability and affordability.

Maintainability means easy and safe to assemble / disassemble. For this, simple structure and accessories are required.

Operability, for more load adjustment capability. Especially in Japan, wide load band, quick load change and Daily Stop Start capability is required.

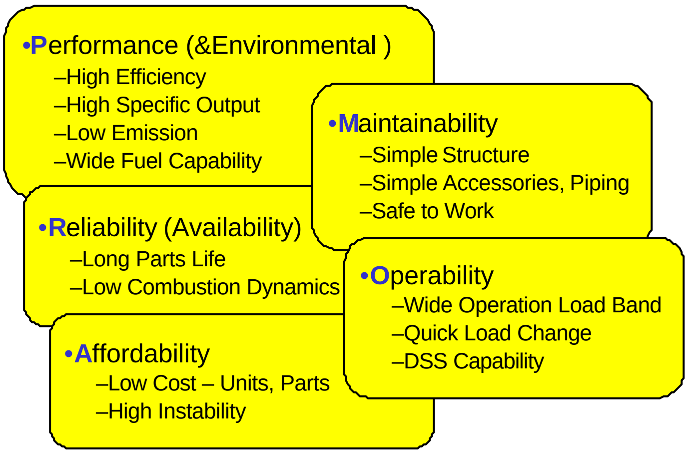

Fig.8 Gas turbine ideal to Electric utilities

CONCLUSION

Gas turbine technology has been improved rapidly and gas turbine generation has become the main force of thermal power generation and continues to expand its role in the future.

Concerning future energy condition in Japan and the world, gas turbine generation will be needed to be improved and extend its role.

As an electricity utility company, we hope the gas turbine technology will improve and contribute to economy and environment.