Characteristics of the US Aero-Derivative Gas Turbine Market and Prospects for Market Expansion in Japan

TAKAMURA Kaoru : Chief Engineer, Energy & Plant Operations

A variety of discussions on how energy should be supplied in Japan have been continuing since last year's Great East Japan Earthquake and resulting tsunami. A quick review of the optimal energy mix is needed, based on the principle that energy should not be wasted. In the USA, there has been an expansion in power generation making use of the specific features of aero-derivative gas turbines. This paper gives an overview of the US aero-derivative gas turbine market and considers the prospects for the expansion of this market in Japan.

1. Introduction

Japan's energy mix is heading towards a new era in which a larger variety of power generation systems are efficiently integrated. The number of Power Producers and Suppliers (PPS) has been on the rise since the amendment of the Electricity Business Act in 2000. Since the 1980s, IHI has been launching power generation systems that apply aero-derivative gas turbines as prime movers in both the domestic and overseas markets. Still, the advantages of aero-derivative gas turbines have not yet gained broad recognition, despite the features including rapid start and stop, fast response, unlimited cycling, low emission, low fuel cost, and an improved power factor achieved by reactive power supply. One of the reasons for the low level of recognition is the low adoption rate of aero-derivative gas turbines for power generation in Japan. In contrast, the United States is experiencing rapid expansion of the power network stabilization market that employs aero-derivative gas turbines. This paper gives an overview of the US aero-derivative gas turbine market and discusses the prospects for the expansion of this market in Japan.

2. Power networks in the United States

The United States' national electrical grid is divided into three distinct regions that are not synchronized with one another, as shown in **Fig. 1**.[1] These three regions are the Eastern Interconnection, Western Interconnection, and the Texas Interconnection. Within each interconnection region, the power can flow freely limited only by the capacity and voltages of the transmission system. But, the power cannot flow across different interconnections as they cannot be synchronized with one another. Seen from an electrical standpoint, it is as if they are three completely different countries. For instance, the Texas Interconnection often experiences surplus power during the winter months, but this excess power cannot be utilized to benefit the high power demand of the Eastern Interconnection on cold days. The Eastern Interconnection and the Western Interconnections are further subdivided into control areas. An Independent System Operator (ISO) in each control area manages the generation and transmission of electricity. Each ISO monitors the demand and supply of electricity in its control area and decides when to turn on, ramp up, ramp down, and turn off generating plants.

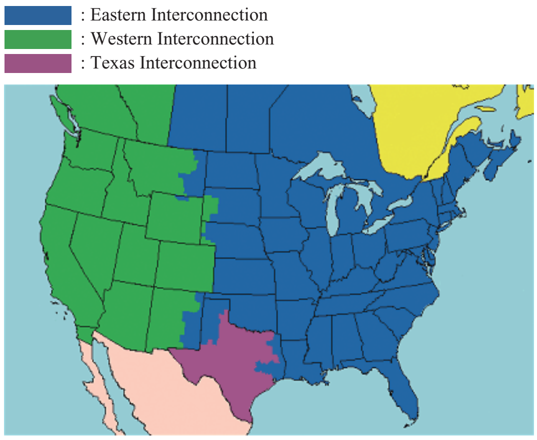


Fig. 1 North American power grid[1]

3. Essential role of peaking power plants

Let's look at an example of peaking power generation in the Texas Interconnection in the United States. Peaking power generation literally refers to the power generated in response to the peak power demand, usually occurring during the peak demand hours according to the characteristic curve (profile) of daily power demand. In a broader sense, peaking power generation may include recovery of the power lost as a result of natural disasters or backup of unstable power generation by renewable energy. The ISO called Electric Reliability Council of Texas (ERCOT) manages the network in the Texas Interconnection. ERCOT supplies electric power to 21 million households, which accounts for 85% of the state's electric power demand and 75% of the geographic area of Texas. The transmission line extending from over

550 generating plants has a total length of 64 800 km. On hot summer days, the power demand reaches 63 000 MW. As shown in **Fig. 2**,(2) the peak during normal weekdays occurs around 5:00 PM when people return home and turn on their air-conditioners, stoves, TVs, and other electric equipment. The demand starts to drop past 7:00 PM and the profile further draws a downward curve to a level below 30 000 MW around 3:00 AM.

The state of Texas has an abundance of natural gas, so thermal power generation fueled by natural gas accounts for more than 50% of the total generating capacity. Most of the gas-fired power generation is from combined cycle power plants with typical capacities from 500 to 1 000 MW (combined cycle is a form of power generation achieving high efficiency by combining gas turbine power generation and steam turbine power generation, wherein steam is generated with the exhaust heat from the gas turbine to spin the steam turbine. Meanwhile, simple cycle is a form of power generation using only gas turbines). What is notable in the Texas Interconnection is that a large number of simple cycle gas turbines are registered as peaking power plants in addition to the combined cycle power plants. In the United States, there are more than 400 LM6000 units operating in power plants. Over 75% of these units are used as simple cycle peaking power plants. An LM6000 is a gas turbine manufactured by General Electric (USA), which is derived from the CF6-80C2 engine for aircraft such as the Boeing 747 (Boeing: USA). IHI has been authorized by General Electric to supply LM6000s as an Original Equipment Manufacturer (OEM). ISOs usually request these peaking power plants to turn on to supply electricity from around 3:00 PM in preparation for the possible peak demand at 5:00 PM in the summer based on the daily profile. ISOs estimate the demand rate by considering weather factors in addition to the statistic demand profile in order to give detailed and accurate dispatch instructions to the most economic peaking power plant in an as geographically efficient manner as possible for the minimum amount of time. For this reason, a peaking power plant must first be able to start and stop quickly in response to the sudden dispatch instructions from an ISO, and aero-derivative gas turbines meeting such requirements are increasingly dominating the peaking power market. The LM6000 has a capacity of 50 MW which it can achieve within 10 minutes, therefore it is much easier to use as a power generation unit than the numerous heavy duty gas turbines (developed for use on land and on vessels assuming continuous operation for a long period of time) or boiler turbines produced from 1970 to 1990 and this is the reason why LM6000s are the first peaking unit called into service by ISOs.

4. Spinning reserve market

Peaking power generation as discussed in **Chapter 3** is also known as spinning reserve operation, the objective of which is reserve capacity. Stable power supply and an appropriate network frequency must be maintained even during a sudden shortfall in the supply capacity as a result of rapid demand increases due to sudden weather changes or unexpected emergency shutdown of generators. In such an event, all possible measures must be taken to increase the supply capacity, but it all depends on how soon the power can be delivered to the network. This is known as reserve capacity and generally, the supply shortfall must be supplemented within about 10 minutes. Examples of the reserve capacity include the margin output of part power generators, standby hydroelectric generators or gas turbine generators. The required reserve capacity is normally 3% or more of the demand and is determined by the probability of accidents, expected demand error, frequency adjustment, and many other factors.

In the United States, there are seven major ISOs as listed

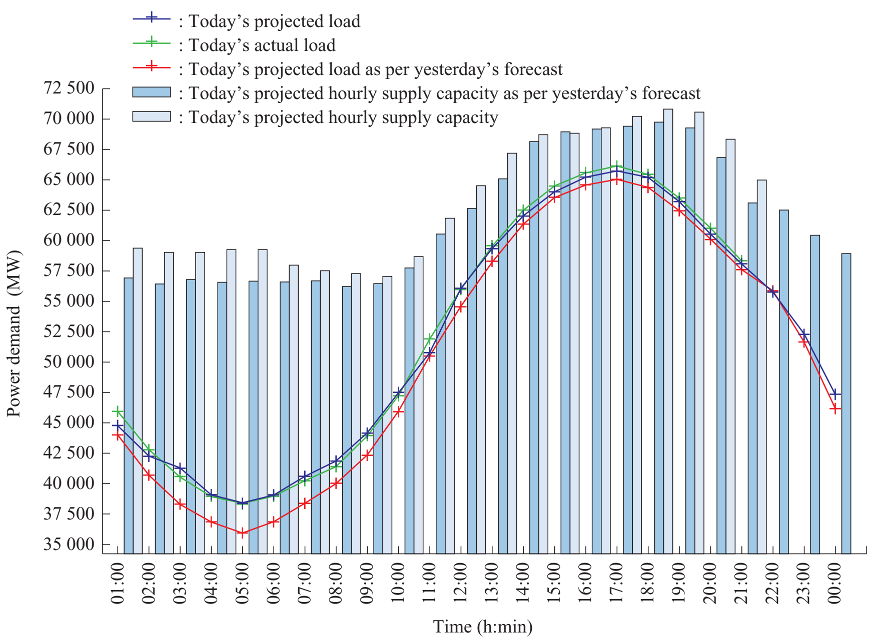


Fig. 2 Typical summer weekday electrical demand profile for Texas, USA(2)

below, which also function as Regional Transmission Organizations (RTOs).

- New England RTO
- New York ISO
- Midwest ISO (MISO)
- Pennsylvania-Jersey-Maryland (PJM) ISO
- Southwest Power Pool RTO (SPP)
- Electric Reliability Council of Texas (ERCOT)
- California ISO (CALISO)

The main task of these ISOs is to monitor the electricity demand which changes day by day from minute to minute and procure just the necessary amount of spinning reserve power based on the estimated change of power demand. Naturally, spinning reserve power producers must achieve a fast and reliable power supply in order to win the dispatch request from ISOs. This is the reason why aero-derivative gas turbines, particularly the LM6000, are the most preferred option. To further shorten the startup time by a minute or even a second, the clutch-coupled configuration as presented in **Fig. 3** is increasingly being used in the reserve market. This method can shorten the time to maximum output by 5 minutes as shown in **Fig. 4**, but it can also supply leading reactive power to improve the power factor, by spinning un-coupled generators as a synchronous motor, which contributes to the prevention of transmission loss and stabilization of the voltage of the network.

Since the LM6000 has the characteristics of an aircraft jet engine, it is capable of rapid output changes of more than ±50 MW/min, so the technology for achieving rapid startup and rapid generation from stand still to max within 5 minutes will become a reality in the near future.

Though not mentioned in detail in this paper, large scale wind-power businesses are thriving in the United States, encouraged by increasing global demand for renewable sources of energy, and accordingly the market for backup power generation by aero-derivative gas turbines is rapidly growing in order to overcome the need to quickly make up for the power shortfall associated with weather changes.

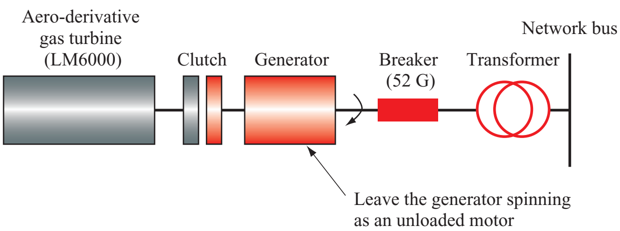
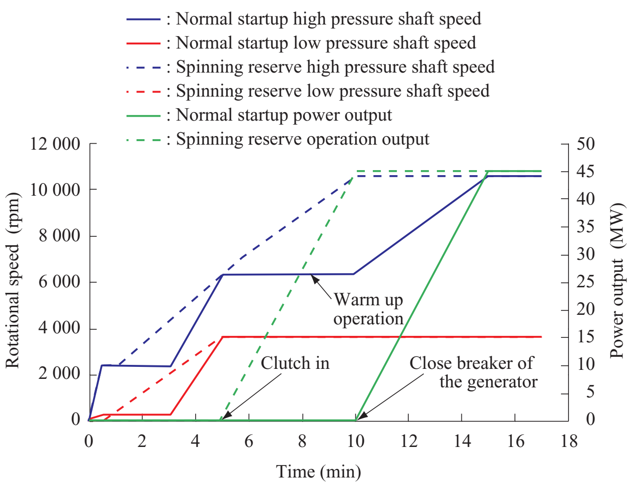


Fig. 3 Clutch-coupled configuration of spinning reserve



(Note) Subject : LM6000

Fig. 4 Fast start and fast loading employing clutch-coupled spinning reserve

5. Prospects in Japan

The history of power generation with LM gas turbines in Japan dates back to 1988. Initially it was introduced as a standby generator, then in the early 1990s, the power generation industry began laboratory studies of their suitability for commercial units. In particular, they were evaluated for their performance in peaking operation in the summer and winter. Since the beginning of the 2000s, LM gas turbines have become a popular source of energy for manufacturing plants needing electricity and heat, and they have been introduced to utility companies contracted by PPS's, as a result of the expansion of retail market liberalization after the amendment of the Electricity Business Act in 2000. All of these cases demonstrate the advantages of the useful features of aero-derivative gas turbines, such as rapid start and stop, unlimited number of startups, and fast ramp up and down.

After the Great East Japan Earthquake on March 11, 2011, Japan has faced a decisive turning point in the very concept of energy. The future of nuclear power plants, which were previously greatly favored as solutions for curbing global warming and reducing costs, is still uncertain and unless these nuclear power plants can resume operation, a large portion of baseload power will remain lost. The lost baseload power must be supplemented by alternative power sources or we will be forced to depend on careful saving, storage, or creation of energy. Taking these power saving effects into account, it won't be necessary to supplement the lost baseload power by alternative sources in its entirety, but the problem is the dynamic nature of the power saving effect and alternative power sources. It is unlikely that power saving measures alone will yield a stable and constant amount of saved power. As alternative power sources, renewable energies are categorized as baseload power, but since they are extremely dependent on natural events, they are hardly stable sources of power. Therefore, these alternative sources of power that supplement the lost baseload power as a result of the shutdown of nuclear power plants (including power saving effects) are considered extremely unstable in nature. In order to replenish this lost power with more stable power sources after the earthquake disaster, many of the closed large scale thermal power plants have been restored and restarted. However, operation of these thermal power plants may not be easy considering the fuel cost and green-house gas regulations, which disqualify them as a stable source of power. We must therefore come to the conclusion that the alternative sources of power that make up for the lost baseload power from nuclear power plants are essentially unstable, and therefore we need another source of power to compensate for such an unstable and changing power in a timely manner. The increasing popularity of peaking power generation or spinning reserve operation in the United States demonstrates advantages that compel Japan to incorporate them in its own future power supply system. Our company intends to continue proposing power supply systems that make the most of the agility of aero-derivative gas turbines.

6. Conclusion

Japan is now being challenged to restructure its power supply system not in the distant future, but indeed even tomorrow. The country must envision an energy structure with a variety of options. It is easy to imagine that the future system will consist of mixed sources of power with relatively small tolerance for imbalance between supply and demand, wherein the exact amount of power needed is efficiently supplied only when necessary. Given the gap left by nuclear power plants in the form of major decreases in stable sources of power, the power network will be increasingly unstable in the midst of the rapid deployment of distributed power sources and renewable energy. We expect spinning reserve operation with aero-derivative gas turbines to go mainstream.

REFERENCES

(1) Mark Axford : Characteristics of Gas Turbine Peaking Market in USA (2010. 10)

(2) < http://www.ercot.com/gridinfo/ > (2012-06-27)