Generator/electric storage: **100kW binary generators compete over low cost, high reliability**

Yoichiro Hata, Smart Japan (ITmedia)
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Binary generation enables power generation from heat sources that are as cool as 100 degrees Celsius. It is characteristic in that it can use heat sources not available in steam turbines. Low-temperature heat sources are huge in total amount, but they are distributed in many places. Users' business scale tends to be small. For these reasons, small and cheap products are required.

Binary generation is a method of generating power by producing "steam" from low-temperature heat sources and driving a turbine *1). It is characteristic in that it generates power by receiving heat from heat sources without using a specific fuel as in the case of thermal power generation. Binary generation does not require high-temperature heat sources, which is another factor that makes it easy to use this solution.

*1) Unlike thermal and geothermal generation, binary generation does not drive a turbine directly by using water vapor. The heat from water vapor or other sources is passed to a working fluid with a low boiling point, and power is generated by using steam of the working fluid. This method is called "binary" because it uses two media, water and a working fluid. Its advantage over steam turbines is that it can use low-temperature heat sources. Steam turbines use high-temperature steam, at 600 degrees Celsius for example, while binary generation can use water at 100 degrees Celsius or lower.

The lower the temperature of unused heat sources—whose heat is released in the air—is, the larger they become both in total volume and number of sources. But it is more difficult to use lower-temperature heat, and even when it is used for power generation, it is inevitably less efficient than high-temperature heat sources. Unless cheaper generators are available at lower installation costs, binary generation is unlikely to be adopted on a large scale.

At N-EXPO 2013 TOKYO (May 21 – 24, 2013), binary generators that embrace this idea were showcased.

ANEST IWATA, a manufacturer of compressors and vacuum pumps, showcased a small binary generator that it has been testing in the field (Fig. 1). It delivers an output of 5.5kW and generates power using water at 90 degrees Celsius or higher. "For hot springs, which we mainly target as users, what is more important is to obtain power from waste heat with low investment rather than obtaining large power. Therefore, we aim for a price range of around 6 million yen for the system alone." Its 6% heat efficiency is not very high, but the company has put emphasis on making it easier for users to implement it. Including installation costs, it would cost around 10 million yen, the company said.

For the generator, the company has employed a scroll expander, a mechanism often used for air conditioning systems. As a working fluid for binary generation, HFC245fa *2) is used. The company started a proving test in Beppu, Oita Prefecture in January 2013, and it plans to test-market it starting fall 2013. "We are currently developing an 11kW product, which we plan to start shipping in or after 2014," said ANEST IWATA.

*2) HFC245fa is characteristic in that a boiling point under ordinary pressure is as low as 15.3 degrees Celsius. Because it does not contain chlorine (Cl) ($CF_3CH_2CF_2H$), it has zero ozone depletion potential, unlike CFCs. It is also used for centrifugal chillers and as foaming gas for urethane.

The 5.5kW product runs with 11.4 tons/h of water (at 90 degrees Celsius).

Fig. 1 Binary generator with an output of 5.5kW. 1.3m×1.3m×1.64m in size.

ANEST IWATA also showcased a system configuration combining the generator with a source from a hot spring. The system lets water vapor and other sources from a hot spring run through a turbine generator (yukemuri (vapor from hot spring) generator, Fig. 2), and additional power is obtained through binary generation. A yukemuri generator produces an output of 20 – 50kW.

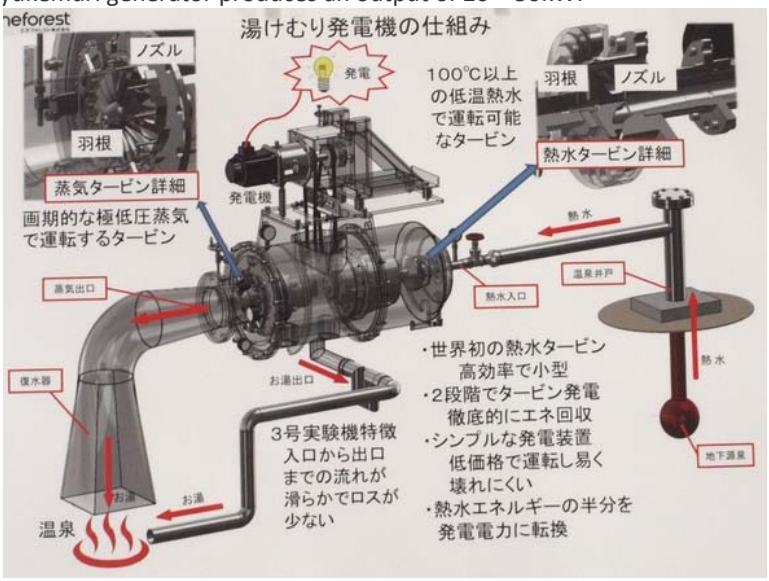


Fig. 2 Mechanism of yukemuri power generation

Aiming for cost reduction through mass production

"We standardized a small binary generator to facilitate mass production. We offer it as a module and in a package. It is easy to install the system. We have already sold 20MW in the world." (Vatche Artinian, Chairman, President, and CEO, Access Energy)

Photovoltaic and wind power generation systems have been standardized to enable mass production. They need to be designed and installed in accordance with requirements at each location, but a great majority of units that obtain electricity are based on standardized design instead of custom design. By enabling mass production of the

same products, volume efficiency can be attained, which leads to lower prices. This also reduces rejection rates during production.

However, binary generators are not in line with this trend, Artinian said. Especially, systems that directly deal with geothermal heat are huge, and design varies depending on users, which makes it difficult to lower costs, he pointed out.

Access Energy's Thermapower 125MT (Fig. 3) delivers an output of 125kW (electricity) with a heat source at 135 degrees Celsius. The unit is as small as 285×117×200cm. Users can simply bring it on the site and connect it with a heat source using pipes, etc. "We installed Thermapower 125MT that we purchased from Access Energy at a user's incineration facility in Fuefuki, Yamanashi Prefecture, to conduct a proving test. Because it is as light as 2.6 tons, we installed it by lifting it to the height equivalent to the third floor with a crane, and started operation by completing piping and other work in about three months [*3)]." (Daiichi Jitsugyo)

*3) Daiichi Jitsugyo started negotiation with Access Energy in July 2012, and completed installation in October 2012. "It can be quickly installed if the factory has it in stock. But we need about three months to obtain approval relating to purchase of the total amount of power. We also need to submit a construction plan to relevant government offices one month prior to the beginning of construction." (Daiichi Jitsugyo)

Fig. 3 Binary generator "Thermapower 125MT"

The green part in the top left of Fig. 3 is a turbine generator. The part in the lower center is an economizer, in which low-pressure steam of a working fluid that ran through a turbine passes heat to a liquefied working fluid returned from a condenser. On the backside of the equipment, it has a receiver tank that stores a working fluid returned from a condenser, controller that controls magnetic bearings, AC-to-DC converter, and so on.

In order to run this system, a user needs to have multiple peripheral devices such as an evaporator, which evaporates a working fluid by receiving heat from a heat source, and a condenser and cooling tower to liquefy a working fluid. They are all large-scale devices. Sometimes existing equipment can be used, but not in many cases. In addition, piping work is required (Fig. 4). "Therefore, the cost to implement Thermapower ranges between 60 to 70 million yen." (Susumu Igarashi, manager of energy project, energy petro chemistry, Daiichi Jitsugyo) [*4)]

*4) Thermapower can be introduced at a low cost relative to its high output. Access Energy claims that a user can recoup investment within 48 months depending on an installation condition.

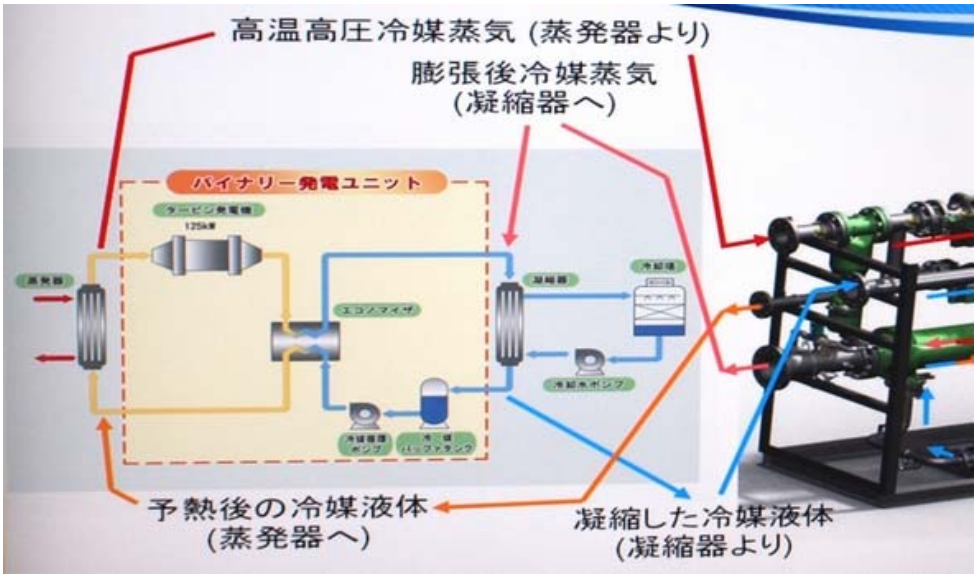


Fig. 4 Relation between Thermapower and peripheral devices – Source: Daiichi Jitsugyo

In Fig. 4, Thermapower is shown from the opposite direction from Fig. 3. The part indicated in light yellow in the drawing shows the internal mechanism of Thermapower, and the area outside the box shows peripheral devices. Peripheral devices are, from left, evaporator, condenser, cooling water pump, and cooling tower.

Market for incinerators in Japan

Access Energy's system can be used in various applications. It can be used for co-production using hot water, a by-product in the oil and gas industry and also in combination with various devices including compressors that produce heat by compressing air and gas, impurity removal systems for natural gas (amine treatment), systems for gas combustion during petroleum refinery, water jackets around cylinders in marine engines, geothermal and photovoltaic generation systems, and engine turbochargers, the company said.

Currently, its main customer is the energy division of US-based General Electric[*5)]. GE uses the system with reciprocating engines, biomass boilers, and gas turbines and steam pressure turbines for power generation. US-based Capstone Turbine has employed it in combination with a microturbine.

*5) Access Energy has offered an exclusive license in a device for internal combustion engines to General Electric. In 2010, it sold to General Electric a plant where it had manufactured the device for internal combustion engines.

In Japan, Daiichi Jitsugyo has started marketing the device for incinerators. It has already signed a contract with an OEM vendor in Japan regarding employment in water jackets of marine engines. The company is also in talks with customers about possible employment in geothermal generation systems and use of industrial waste heat.

Following the verification test in Yamanashi, Daiichi Jitsugyo signed three contracts with its customers[*6)]. "They are all for incineration facilities. We expect accepting orders of 15 systems, including fixed projects, in FY2013 combining orders at incineration facilities and geothermal generation plants." (Igarashi, Daiichi Jitsugyo)

*6) They are projects funded by the Agency for Natural Resources and Energy's program to urgently implement facilities using next-generation heat. The company submitted an application for three systems in two projects in March 2013.

Access Energy's technology is favorably accepted in three markets, incineration facilities, hot springs, and industrial waste heat, he said.

According to the Ministry of the Environment's research, there are 1,414 industrial waste incineration facilities in Japan, among which 69% do not use waste heat. Another 23% do not generate power although they use waste heat in some way. Only 7% use waste heat to produce energy (106 facilities). Likewise, most municipal waste incineration facilities do not use surplus heat. Among 1,269 facilities, 33% do not use waste heat, 43% use waste heat but do not generate power, and only 24% generate power.

"We believe our system supports both types of facilities. In the U.S., waste is land-filled. We see one of the biggest waste incineration markets in Japan, which is important to us." (Herman Artinian, Managing Director, Access Energy)

The company anticipates that geothermal generating capacity that can be developed in Japan is 3,700MW. Among this capacity, 33MW has heat sources at 120 degrees Celsius or higher, which Thermapower technology can handle. 850MW has heat sources at 55 – 120 degrees Celsius, among which 50% can be covered by the technology, the company expects. In addition, the technology can be applied to 5% of the remaining 2,817MW.

In the market for industrial waste heat, industrial boilers account for a significant part. The company expects good demand in cement factories as well.

Magnetic bearing is key to achieving reliability

It is easy to understand one of the points that the company makes about Thermapower's advantages, which is the design that allows mass production and easy installation. Access Energy also mentions high reliability as another strength of the system. What is high reliability?

"What reduce the reliability of generators of this kind are gears, lubricant, and seal materials. None of these are used in Thermapower. The key factor of this system is the design of the turbine in the power generating part (Carefree Integrated Power Module: IPM) (Fig. 5). The rotating part in the IPM is held by magnetic bearings, enabling rotation without friction. This enhances reliability. It reaches 26,000 rpm within a few minutes after starting the system. It starts as easily as a consumer device." (Daiichi Jitsugyo)

The disk-like parts to the right and left sides of the generator in Fig. 5 are magnetic bearings.

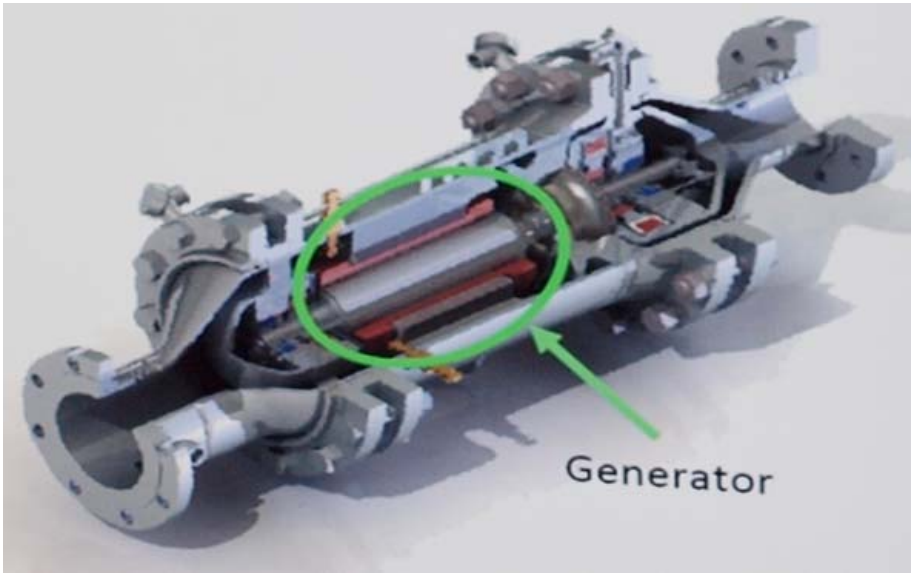
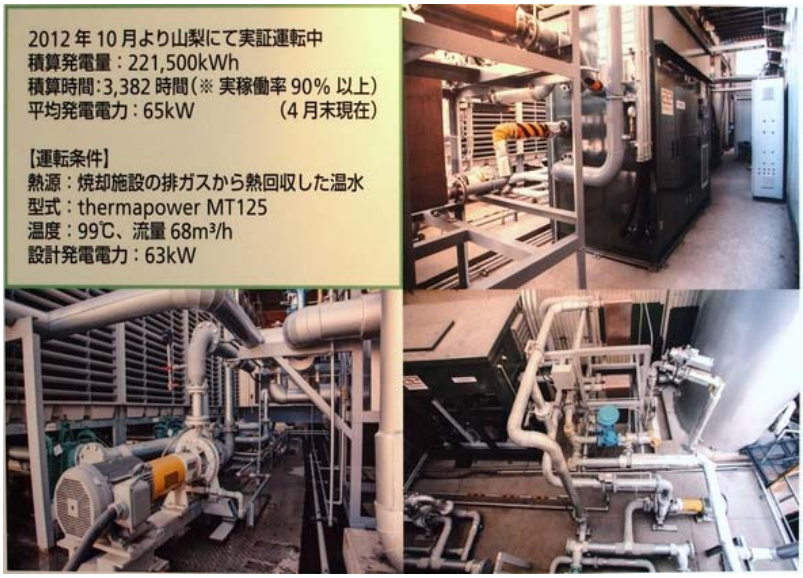


Fig. 5 Structure of IPM – Source: Daiichi Jitsugyo

Access Energy's parent company Calnetix Technologies has a technology relating to magnetic bearings, which seems to have been employed in the system. The company's magnetic bearing technology is based on dynamic

control. A sensor measures the position of the component rotating in the turbine, and changes magnetic strength in real time according to the measured data to maintain stable rotation.

In the proving test in Yamanashi Prefecture, which has been mentioned above, the cumulative power generated after installation has reached 221,500 kWh (Fig. 6). It has run for a total of 3,382 hours with an actual operation rate of over 90% and average generation capacity of 65kW. It uses 68 m^3 of hot water per hour.



(English translation of Japanese in Fig.6)
[Verification test being conducted in Yamanashi since October 2012
Cumulative generated power: 221,500 kWh
Cumulative hour: 3,382 hours (*actual operation rate of over 90%)
Average power generated: 65kW (as of end of April)

[Operation conditions]
Heat source: hot water obtained with heat recovered from exhaust gas at incineration facility
Model: Thermapower MT125
Temperature: 99 degrees Celsius, flow:68 ㎥/h
Designed generating capacity: 63kW]

Fig. 6 Results of verification test in Yamanashi, on-site photos – Source: Daiichi Jitsugyo

Why does the actual operation rate remain 90% while the company claims high reliability? “The system has been installed at a waste incineration plant, where there is a lot of air-borne dust. The dust is sucked up by a cooling tower in the facility. Therefore it is indispensable to clean the cooling tower. Because they need to stop Thermapower during cleaning, the operating rate is not 100%. We don’t think Thermapower’s operating rate is lowered due to factors caused by Thermapower.” (Daiichi Jitsugyo)

Support for low temperature is most desired

Thermapower delivers an output of 125kW, according to the company. Then, why is the output of the system in Yamanashi as low as 65kW? “In binary generation, higher output can be obtained with higher-temperature heat sources. In Yamanashi’s case, the system uses hot water at 99 degrees Celsius produced by heat recovered from exhaust gas at an incineration facility. Even if peripheral systems are improved, 70kW would be the highest output it could achieve. To obtain Thermapower’s rated output of 125kW, steam at 135 degrees Celsius is required.” (Daiichi Jitsugyo)

The lower the temperature is, the more the number of users is. There is a strong need for binary generation that supports low temperature. Access Energy is developing products that support an optimal heat source temperature of 95 degrees and even 80 degrees Celsius, while maintaining its policy of providing them as modules to enable mass production[*7)]. Both of them deliver an output of 125kW.

*7) According to the company, a working fluid hasn't been changed. Instead, they support lower temperatures by circulating a working fluid at high speed and increasing the amount of circulation, and also by optimizing the turbine part.

The company will start shipping Thermapower 125XLT supporting 95 degrees Celsius and Thermapower 125ULT supporting 80 degrees Celsius in the third quarter of 2013 and the second quarter of 2014, respectively. "In the proving test in Yamanashi, we will replace the system with the one supporting lower temperature in around September 2013 to verify the effect." (Daiichi Jitsugyo)