News From Japan

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New Frequency Converter Station Starts Operation in Japan

The history of the use of electricity in Japan began as telecommunication, which started in 1869, one year after the Meiji Restoration. The first electric arc lamp shone in Ginza, Tokyo, in 1882, the same year as the start of operation of Edison's Pearl Street Power Plant in New York. Only four years later (1886), Tokyo Electric Light Company, one of the predecessors of Tokyo Electric Power Company Holdings, started its business as the first electric power company in Japan. Many similar companies started their businesses in the following several years. In these early days, electric power companies in eastern Japan imported 50-Hz generators from Allgemeine Elektricitäts-Gesellschaft (AEG) in Germany, and those in western Japan imported 60-Hz generators from General Electric Company in the United States. From this historical background, AC 50 Hz is still used in eastern Japan and 60 Hz in western Japan.

If one country has two frequencies of AC electricity, it is a big problem for the power grids in that country. The idea to interconnect the two regions with the two frequencies started around 1960. After earnest technical and economic consideration and difficult construction work, the Sakuma Frequency Converter Station (FC) was constructed near the Sakuma Hydroelectric Power Station and the Sakuma Dam in October 1965, as the first facility to convert frequencies in Japan. The reason for the selection of this site was that the Sakuma Power Station was Japan's largest power plant at that time and that 50-Hz and 60-Hz 275-kV transmission lines extended respectively to the east and west. The frequency converting devices adopted were initially mercury arc rectifiers and later changed to thyristor switches. The interconnection capacity of the Sakuma FC was 300 MW and remains at this initial value.

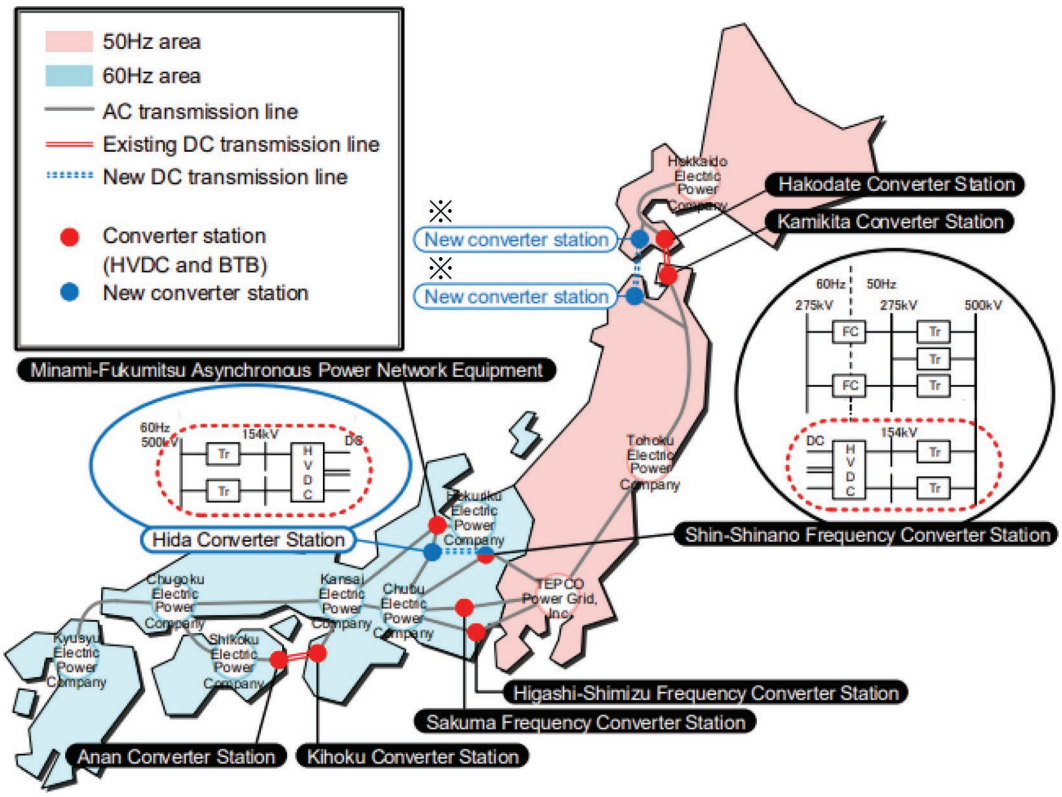

Figure 1. Locations of the Hida-Shinano HVDC link and other frequency converter stations (FCs) and converter stations (CSs). The pink and blue areas indicate the 50-Hz and 60-Hz power areas, respectively. ※ The new Hokkaido-Honshu link via a railway tunnel was opened in March 2019 [2].

Japanese power utility companies continued to construct new FCs with the help of the Japanese government. The second facility, the Shin-Shinano FC, started its operation in 1977 with an initial interconnection capacity of 300 MW, which was increased to 600 MW in 1992. In 2006 the Higashi-Shimizu FC started its operation as the country's third FC facility, with an initial interconnection capacity of 100 MW. Here, the combined capacity of the three facilities was about 1 GW.

The Great East Japan earthquake occurred on March 11, 2011. It caused disastrous tsunamis with the wave height of more than 10 m and the maximum run-up height of 40.1 m [1]. Quite a lot of power generating plants in the eastern Japan area stopped operating due to this earthquake and the tsunamis, including the Tokyo Electric Power Company's Fukushima Daiichi (= first) and Daini (= second) Nuclear Power Plants and the company's many other thermal and hydroelectric power plants.

The Japanese government and power utility companies tried to transmit the electricity from the western 60-Hz area to the eastern 50-Hz region as much as possible. However, they realized that the interconnection capacity of 1 GW was too small. This poor ability to transfer electric power beyond the border between the 50- and 60-Hz regions caused a severe shortage of electricity over a wide area in eastern Japan for quite a long period. To improve on this situation, the interconnection capacity of the Higashi-Shimizu FC was raised to 135 MW immediately after the earthquake, namely in May 2011, as an emergency measure. It was then increased to 300 MW in February 2013.

Although the above enhancement of facilities increased the total interconnection capacity between the 60-Hz and 50-Hz areas to 1.2 GW, it would not be sufficient if we take account of the total electricity demand in Japan and the soaring expansion of renewable energies into the power grids. Therefore, the construction of a new facility, the Hida-Shinano high voltage (HV) DC link, was approved. Excluding Okinawa Electric Power Company, which is an electric power utility in the Ryukyu Islands isolated completely from mainland Japan, all the other nine general electric power companies funded this project. Figure 1 shows the location of this HVDC link, together with those of the Sakuma, Shin-Shinano, and Higashi-Shimizu FCs. The pink and blue areas indicate the 50-Hz and 60-Hz power areas, respectively. The Minami-Fukumitsu Converter Station (CS), also on the map, is a back-to-back station to interconnect the power grids of two power utilities with the same operating frequency of 60 Hz and not for the power transfer between the areas of different frequencies. In addition to the above CS, Japan has six more CSs: four for two power links in the 50-Hz area and two for one power link in the 60-Hz area. Each of the three links connects two power utilities located across a strait with one underground part and two overhead parts [2]–[6].

The Hida-Shinano power link is the first facility in Japan that connects power grids with different frequencies via an overhead HVDC line. Table 1 shows its major system specifications. The interconnection capacity of the Hida-Shinano power link is 900 MW. Whereas the CS on the eastern 50-Hz side was built on the site of the Shin-Shinano FC, the one on the western 60-Hz side, called the Hida CS, was built on a new site. The distance between the two sites is about 90 km. Regarding this, the power link has one circuit of ±200 kV DC bi-pole about 90 km long of overhead transmission line. Each pole has a dedicated return conductor, which is grounded at the 60-Hz side and isolated at the 50-Hz side. The master control station is on the 50-Hz side.

Table 1. Major system specifications of the Hida-Shinano HVDC power link

Item	Specification
Configuration (pole number)	2 poles (one bi-pole)
Rated active power	900 MW (450 MW × 2)
DC voltage	DC 200 kV
DC transmission line	Overhead line (all sections: approximately 90 km)
Method of the return path	Dedicated metallic return
AC system voltage	AC 500 kV (both the 50 Hz and 60 Hz sides)
AC converter system voltage	AC 154 kV (both the 50 Hz and 60 Hz sides)

The construction work on the Hida CS site began in October 2015. Because the site is in a mountainous area at an altitude of 1,085 m, its climate is very severe. The outside air temperature went down to −30°C, and the snowfall reached 2 meters in winter. Therefore, the construction was limited to the other three seasons. In addition, the above climate conditions are out of the scheme that various related industrial standards such as those determined by the Japanese Electrotechnical Committee assume. In this regard, manufacturers of various pieces of power equipment, such as Hitachi and Hitachi ABB Power Grids, which is now Hitachi Energy, had to check whether their products could withstand such severe conditions by doing many tests.

Figure 2 is a photo of the whole view of the Hida CS site, showing the arrangements of various pieces of major equipment as listed in Table 2. The frequency converting system adopted is the line-commutated current-sourced conversion

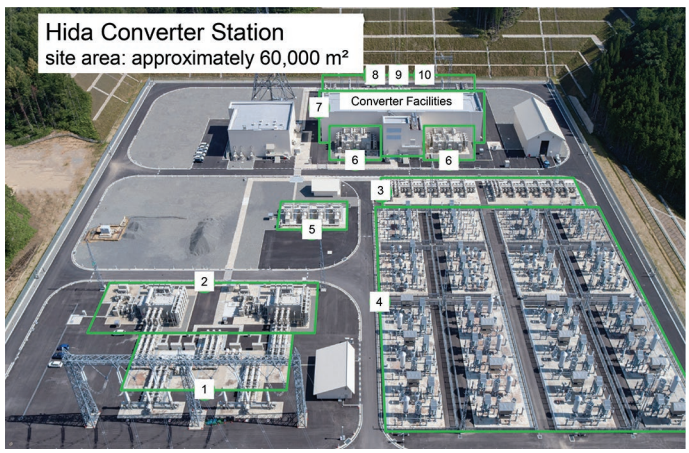

Figure 2. Photo of the whole view of the Hida CS site, showing major equipment. Refer to Table 2 for the numbered equipment.

Table 2. Major frequency converting equipment in the Hida CS

	Facility name	Frequency (Hz)	Rated voltage (kV)	Rated power	Quantity
1	Gas-insulated switchgear	60	500	—	5 units
2	Step-down transformers	60	500/154/77	500 MVA	2
3	Gas-insulated switchgear	60	154	—	16 units
4	AC filters	60	154	—	16 units
5	Reactive power suppliers	60	77	80 MVA	4
6	Converter transformers	60	154/86	548 MVA	2
7	Thyristor switches (in the building)	60	200	450 MW	2
8	DC reactors	DC	200	—	2
9	DC filters	DC	200	—	2
10	DC gas-insulated switchgear	DC	200, 10	—	4 units

Figure 3. Converter transformer at the Hida CS.

Figure 4. Thyristor switches to convert AC to DC or inversely.

(LCC) method using thyristor switches. As three examples of typical important power apparatus, photos of a converter transformer, thyristor switches, and AC filters are shown in Figures 3 to 5, respectively. Here, the converter transformer is to change the AC voltage from 154 kV of the external transmission line to 86 kV for the operation of thyristor switches that are rectifiers to convert AC to DC or inversely.

Figure 5. AC filters with covers and triangular roofs for protection against possible snow damage.

The Hida-Shinano power link started its operation on March 31, 2021. By the inauguration of this power link, the total interconnection capacity had reached 2.1 GW in Japan. More detailed information on the Hida-Shinano power link can be found in [7]. In the future, the interconnection capacity of the east–west power links will be increased further by 900 MW, which will make the total capacity in Japan 3.0 GW [8].

This article was completed in cooperation with Yusuke Kikuchi and Hiroyuki Tanaka of Chubu Electric Power Grid Co. Ltd.

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