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SUPPLY TO RAPIDLY GROWING CITIES AND AREAS

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SUMMARY

The use of geothermal power contributes significantly to environmental improvements on a national as well as a global scale.

The Leyte geothermal resources have the potential for providing low cost and highly reliable energy, much needed to meet the Philippines' growing power requirements.

The HVDC interconnection is beneficial to both industry and the inhabitants of the Manila area, not only through the added power influx, but also through the inherent stabilizing effect of an HVDC link on the AC network

KEYWORDS: HVDC - Converter - Electrodes - Cable terminal stations - OH transmission line - MACH.

1. BACKGROUND

The main objective of the Leyte-Luzon HVDC Power Transmission Project is to interconnect the power systems of Leyte and Luzon Islands with an HVDC transmission link. The project enables transmission of the electrical generating capacity of the geothermal reserves in Leyte to various load centers, and will interconnect two of the existing island grids of the Philippines as part of an overall plan to combine the existing Luzon, Visayas and Mindanao grids into a single national grid. See Fig. 1.

It will also facilitate the use of the geothermal generating capacity in the Leyte area. The project forms a vital link in Napocor´s Power Development Program since, through the interconnection of generating assets, it is possible to balance energy supply and demand requirements more efficiently.

With the normal power-flow direction from Leyte to Luzon, the Ormoc converter station will act as the rectifier and Naga converter station as the inverter. This means that from the geothermal fields of Tongonan in Leyte, power will be fed into the Luzon grid, thereby feeding the Manila area through the existing AC grid.

The converter, electrode and cable terminal stations were contracted to a consortium consisting of ABB Power Systems AB, Sweden; ABB Power Inc., Philippines and Marubeni Corporation, Japan.

Fig. 1. Leyte-Luzon HVDC transmission Philippines.

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2. FINANCING

The project was primarily funded by a USD 113 million loan from the World Bank, which also provided extended co-financing amounting to USD 100 million. Financial assistance was also extended by the Export Import Bank of Japan through a USD 56 million loan, as well as by the Swedish Board for Investment and Technical Support, and by the Global Environment Trust Fund through separate grants of USD 41 million and USD 15 million respectively. Local counterpart funding was raised by Napocor through internal cash generation.

3. MAIN SYSTEM COMPONENTS

The Leyte-Luzon HVDC monopolar system is composed of the following major components, as shown in Fig. 2.

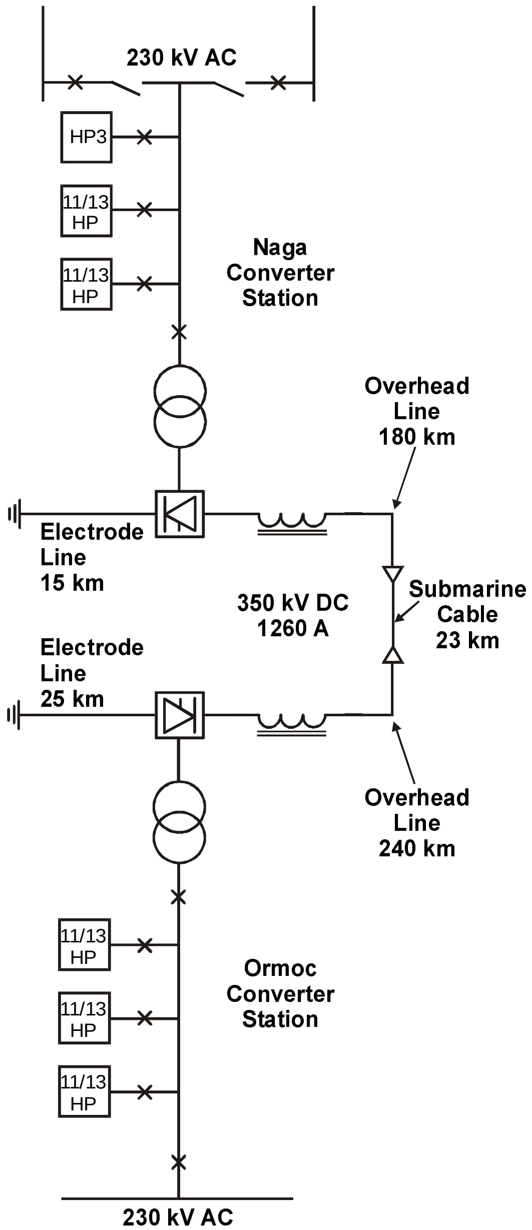

Fig. 2. Schematic of the HVDC interconnection.

- Converter stations located in Naga (Luzon) and Ormoc (Leyte)
- HVDC cables across the San Bernardino strait, 23 km (one cable is redundant).
- Cable terminal stations located in Cabacungan (Samar) and Sta Magdalena (Luzon)
- Shore electrodes located in Albuera (Leyte) and Calabanga (Luzon).
- Overhead bipolar transmission line in two sections of 180 km (Luzon) and 240 km (Leyte-Samar).
- Electrode lines, 15 km in Luzon and 25 km in Leyte.

4. CONVERTER STATIONS

The converter valves, smoothing reactors (240 mH) and converter transformers are of the same design at both stations for 440 MW at 350 kV direct voltage and 230 kV alternating voltage. The valves are suspended quadruple valves, air-insulated, water-cooled and the transformers are of a single-phase three-winding design.

At the converter station at Ormoc, there are three identical filter banks (35 MVAr each) on the AC side, each with an 11th/13th double-tuned branch and a high pass broadband branch.

The converter station in Naga is equipped with two filter banks (70 MVAr each) of similar design as in Ormoc, and one 3rd harmonic high pass filter bank (78 MVAr).

Each of the filter banks in both stations is connected to the converter station 230 kV AC bus via a power circuit breaker.

The use of overhead lines makes it necessary to filter harmonics from the outgoing direct current and of that reason a DC filter to shunt the harmonics is installed.

5. SHORE ELECTRODE

Leyte-Luzon, being a monopolar system, implies that low resistivity and economical current return path is required. Shore electrodes were considered as the most appropriate solution and have minimum impact on the environment. The electrodes located in Albuera (Leyte) and Calabanga (Luzon) are composed of 40 sub-electrodes each having two units for a total of 80 units per site. The sub-electrodes are installed in two parallel rows over a distance of about 200 m along the shores at depths varying from 10 to 13 m. Currents between sub-electrodes are balanced by mean of resistors located in the electrode building and connected in series with each sub-electrode cable. Electrode line equipment required for detecting faults on the line is also housed in the same building.

The access roads and facilities that have been used to build the electrodes are now much appreciated by fishermen and the local population. Beaches have been restored to their original condition and opened for public use. Measurements performed during commissioning have shown that no appreciable step and touch voltages can be detected. This proves that it is safe for all living creatures in the area. Additional monitoring continues and should demonstrate the proper operating behavior of the electrodes.

6. HVDC CABLES AND CABLE TERMINAL STATIONS

Two 350 kV 440 MW oil-filled cables were chosen for crossing the San Bernardino strait over a distance of 23 km between Sta Magdalena on Luzon Island and Cabacungan on Samar Island. The cables are buried from cable terminal stations out to a water depth of about 10 m. One cable is capable of carrying continuously rated current and overload current, which means that the other cable can be considered fully redundant. In normal operation, cables are paralleled, thus contributing to reduced system losses. A Japanese consortium consisting of the Nissho Iwai Corporation; Hitachi Cable, Ltd.; Fujikura Ltd. and the Kanematsu Corporation was awarded the contract for the design, manufacture, delivery and supervision of the installation of the cables, including cable terminations and protective arresters. Oil treatment plants and storing facilities for spare cable sections were also included in the scope of supply.

The cables were transported and laid in April 1996. Field tests were successfully performed in early 1997 and the cable terminal stations were completed later in the same year.

Even if the best route had been selected based on previous sea bottom surveys, it was not possible during cable laying to avoid all rocks, boulders, holes and dips in the seabed. Extensive use of remote operated cameras helped in avoiding major obstacles, but this was not sufficient. It had been contractually agreed that cable protection was needed for suspension lengths greater than 7 meters for sea current velocities above 3 knots, measured at 2 meter above the sea bottom. With the assistance of the remote video camera recorders, it was found that a number of suspension lengths exceeded the contractually agreed length. Various cable protection methods were evaluated. Rock dumping was found to be the most appropriate method, considering the very rough and uneven seabed. About 45 cable sections, totalling 1.5 km, were protected by rocks with average diameters ranging from 50 to 125 mm. A post-work survey has shown that so far, the method seems to be acceptable. No problem has been experienced with the cables since installation in April 1996.

The cable terminal stations contain the cable sealing ends, protective arresters, oil pump plant, monitoring equipment, telecommunications equipment, auxiliary supplies and all necessary disconnectors and ground switches for paralleling the two cables and the overhead transmission circuits.

7. HIGH VOLTAGE OVERHEAD TRANSMISSION AND ELECTRODE LINES

The HVDC overhead bipolar transmission line runs from Ormoc converter station, through Leyte and the Samar Islands, where it ends at the Cabacungan cable terminal station. From the Sta Magdalena cable terminal station on Luzon Island, the line runs all the way to the Naga converter station. More than half of the line's route is through mountainous terrain, very steep in places and with risks for landslides. Most of the other half of the line passes rice fields and other cultivation. Because of the various types of soils found along the line's route, different foundations were used as well as different tower designs. One of the most important aspects in the design of the line has been the capability to withstand wind velocities of up to 270 km per hour. This has resulted in a more stringent design criteria than that for seismic considerations.

Atmospheric pollution has been considered and adequate creepage distances have been included in the design. Because the Philippines is a tropical country, vegetation under the line grows very quickly and requires regular clearing. To assist in fault localization, a DC line fault locator has been incorporated in the converter station equipment.

The electrode lines run from the respective converter stations in Ormoc and Naga to the respective electrode stations in Albuera and Calabanga.

ABB SAE Sadelmi S.p.A., Italy was awarded the contract for the electrode and overhead transmission lines.

8. CONTROL SYSTEM

For HVDC (High Voltage Direct Current) applications, the control and protection system plays an essential part in the overall performance of the transmission system. The control and protection system MACH™ (Modular Advanced Control for HVDC), uses the latest technology from the fields of electronics and microprocessors. MACH is a fully computerized control and protection system.

The main characteristics of the MACH are the high degree of functional integration and the open systems interface approach. The open systems strategy is reflected both in the use of industrial standard serial and parallel communication buses, as well as in the use of standard formats for all collected data (such as events, alarms and disturbance data).

Integrated with the MACH control and protection equipment is the Station Control and Monitoring (SCM) system. Workstations (PCs) are interconnected by an Ethernet local area network. The distributed system for remote I/O, for control as well as for process interfacing with the SCM system, consists of a field bus network.

The HVDC transmission link can be remotely controlled from the dispatch center in Manila (Diliman), where all major alarm/indication functions are available.

The control system for Leyte-Luzon includes an Emergency Power Control mode and a Frequency Control mode in addition to the normal power control. The main purpose of the Emergency Power Control (EPC) is to quickly and automatically change the DC power when certain AC parameters deviate from their nominal values. This is done to perform fast power support in case of disturbances in the Luzon AC network. The EPC modulation is available in the Naga converter station and operates only during normal power direction and requires operational telecommunications.

The Frequency Control mode is active in Ormoc during normal power direction. The Frequency Control will hold the frequency of the Leyte (Visayas) AC network at 60 Hz, +/- a preset deadband. In the event of loss of one of the geothermal machines, or a trip of the Cebu cable, the frequency control will make a contribution to the Power Control in order to adjust the power transmitted on the DC link and keep the frequency within the deadband.

However, any action from the Emergency Power Control at Naga will override and disable the Frequency Control at Ormoc.

9. SYSTEM TESTS

This is the first time that an HVDC system is directly connected to a network almost solely supplied by geothermal power. The Leyte-Luzon HVDC power transmission system is the largest load for Leyte geothermal power generation. The second largest load comes from the islands of Cebu, Negros and Panay, partly fed by the 200 MW, 230 kV interconnection composed of overhead transmission lines and cables.

In order to accommodate the loads during the system tests, notice of approximately one day was necessary to allow for the preparation of an adequate number of steam wells and machines.

One important aspect to consider when relying on geothermal power is not only the necessary planning to pass from one power level to another, but also the consequences of load rejection for the plants and environment. Trips and blocks of the HVDC system result in steam being released to the outside environment. When power transmission is not quickly reestablished, wells have to be closed. By modulating its power, the HVDC system is capable of compensating for possible load/frequency variations on the Leyte-Cebu system. Loss of HVDC cannot be compensated by the Visayas network absorbing more power. In the same way, loss of the Visayas network load cannot be compensated by the HVDC if it is already operating at rated power. Consequently, under these operating conditions, the Leyte machines must be shut down.

The system test was completed on July 12,1998. After four weeks of trial operation, the HVDC link was taken into commercial operation on August 10,1998.

A separate paper regarding commissioning and system tests of the Leyte-Luzon HVDC Power Transmission Project will be proposed for Cigré 2000 in Paris.

10. OPERATING EXPERIENCES

Operational experiences since the fall of 1998 are very positive. High availability and reliability of the HVDC system is expected in the future.

During the system test period, and during the first part of the burn-in period, there were a few unexpected trips caused by various reasons.

11. ENVIRONMENTAL COMPLIANCE

The Leyte project assists in the development of critically needed energy in the Philippines and supports the use of an energy source that is both environmentally preferable and indigenous based. Furthermore, the project will have a meaningful impact on global warming emissions since an alternative coal-fired based plant would cause carbon dioxide (CO_2) emissions that were 15 to 20 times greater. The use of geothermal steam for power generation, followed by re-injection of exhaust liquids into the ground, offers considerable environmental advantages over fossil fuel energy sources in terms of reducing emissions of sulfites, NOX and particulates.

12. FUTURE EXTENSION

The project contains certain pre-investments for a future addition of a second pole. Such pre-investments include part of service building, spare parts for each station (including converter transformers and oil-filled smoothing reactors with foundations), design of equipment for future installation as well as site preparation for the bipolar system. Furthermore, the bipolar HVDC overhead transmission line and cables are already installed and commissioned, simplifying the conversion to a full bipolar system at a later stage.

In addition, about three-quarters of the bipolar AC filter configuration is already installed at the monopolar stage.

An HVDC interconnection between Leyte and Mindanao is under investigation that would complete the overall plan to interconnect the existing Luzon, Visayas and Mindanao grids into a single national grid.

13. CONCLUSION

With this first HVDC link between the islands of Leyte and Luzon, the first part of the overall plan to interconnect the existing grids on Luzon, Visayas and Mindanao has been achieved.

The Leyte geothermal resources have the potential for providing low cost and highly reliable energy much needed to meet the Philippines' growing power requirements. The development of geothermal resources implies the use of an environmentally preferable energy, avoiding coal and oil imports, and resulting in a more robust generating system. Furthermore, as the Leyte-Luzon project is a major step in the overall interconnection of the grid, it would offer potential long-term benefits associated with the better use of the country's energy resources in power generation, as well as the opportunity to improve the operation of the power system, to reduce reserve capacity, and provide more reliable service.