HAWAII'S GEOTHERMAL AND DEEP WATER CABLE PROGRAMS

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ABSTRACT

Hawaii's dependence on imported fuel oil for over 90 percent of its energy needs can be minimized by exploitation of the State's abundant indigenous energy resources. Geothermal power offers the best prospect for providing a significant baseload alternate to oil-fired electrical energy. However, the largest resource is on the Island of Hawaii which is separated by a substantial distance and extreme ocean depths from the State's load center on Oahu. No high voltage direct current electrical transmission cable has ever been installed under these conditions. This paper presents an overview of geothermal development in Hawaii and some details of the ongoing Hawaii deep water cable feasibility program to provide the necessary energy bridge.

INTRODUCTION

A major goal of the State of Hawaii is to wean itself from its dependence on imported petroleum, which accounts for over 90 percent of its energy needs. Over \$1.3 billion...almost 10 percent of the Gross State Product...leaves the state for petroleum purchases. Electrical energy self-sufficiency is attainable. Geothermal offers the earliest, major baseload potential for reducing Hawaii's dependence on petroleum. The Island of Hawaii conservatively has a 1,000 MW geothermal resource, far in excess of that island's projected long-term demand. However, this is not located near Oahu (the center of demand); hence requiring that the State consider an inter-island electrical connection.

In 1981, the Hawaii Deep Water Cable Program was initiated by Hawaii to address the technical and non-technical issues which must be resolved before an inter-island transmission system can be constructed. The U.S. Department of Energy entered the program in 1982.

Geothermal Development in Hawaii

The 3,218 kilometer (2,000 mile) Hawaiian Archipelago is of volcanic origin which continues to expand in a southeasterly direction. The Island of Hawaii at the southeast end of the chain is the youngest and most volcanically active island. The Kilauea Lower East Rift on the Island of Hawaii has been estimated to contain at least 7,500 megawatt-years of electrical energy.

Serious geothermal exploration began in 1976 with the drilling of Hawaii Geothermal Project - Abbott (HGP-A), the hottest well in the United States, having a bottom hole temperature of 358°C (676°F) at a depth of 1,951 meters (5,400 feet). This well is capable of producing over 45,000 kg/hr of steam (55%) and water (45%). A 3-megawatt geothermal wellhead generating plant was constructed at this site through the cooperative efforts of the U.S. Department of Energy, the State of Hawaii's Department of Planning and Economic Development, the County of Hawaii and the University of Hawaii. Built at a cost of about \$10 million (\$3,000/kw), the plant began producing electricity in early 1982. Thus, Hawaii became the second state in the United States to have a geothermal generating plant. That plant is continuing to demonstrate successfully the technical and economic viability of the geothermal resource in the Kilauea East Rift.

Three private geothermal resource development organizations subsequently responded to the Hawaii Electric Light Company (HELCO), the Big Island's utility, Request-for-Proposals (RFP) for a 25 to 50 megawatt geothermal electric power development project. Two of the respondents have drilled a total of seven deep exploratory wells to confirm the resource in the Kilauea Lower Rift. The third organization has been constrained in their plans to acquire the permits, leases and other approvals necessary to undertake a major geothermal project on land zoned for

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conservation district purposes. That third organization has also undertaken initial exploratory work in Hakeakala's Southwest Rift in response to an RFP issued by Maui Electric Company for supporting geothermal electrical energy smaller in quantity than that issued by HELCO.

Present forecasts indicate that the Island of Hawaii cannot accept more than 40 to 50 megawatts of additional power over the next 30 to 40 years. The largest load center for the Island of Hawaii's geothermal resource is the Island of Oahu, which consumed over 5 billion kWh of electricity in 1983.

Hawaii needs a means of transporting large quantities of energy to Oahu from the rich geothermal fields of the Big Island. While more advanced energy bridges involving the on-site production and shipment of gaseous and liquid hydrogen, liquid methanol and ammonia or fuel cells are possible, electrical transmission systems have generally been accepted as the most feasible in the near term.

State-Funded Portion of the Hawaii Deep Water Cable Program

The Hawaii Deep Water Cable (HDWC) Program is a research and development program directed towards extending knowledge in high voltage, direct current (HVDC) submarine cable design, manufacture, deployment, retrieval and repair. The State support began in 1981 with a contract award to Hawaiian Electric Company (HECO) assisted by Parsons Hawaii for the Phase I, Preliminary Definition Study. Work efforts include: a.) preliminary route survey analysis; b.) preliminary prototype cable design criteria development; c.) preliminary cable ship inventory; d.) preliminary study for integration of individual island grid systems into a unified HVDC system; and e.) a public information program including a narrated slide program describing the HDWC Program.

Phase II-A of the State portion of the program was completed in 1984 by HECO assisted by Parsons Hawaii, Power Technology, Inc., the Hawaii Natural Energy Institute and the Hawaii Institute of Geophysics. This phase included a preview of the environmental issues and permitting requirements for both the present HDWC Program at-sea test plan and the potential commercial cable system. The analysis concluded that direct environmental impacts of the demonstration program will be limited to short-term ship operations and temporary disruption of very small areas of marine benthic habitats. The U.S. DOE also evaluated potential impacts of the demonstration program in light of its responsibility under NEPA, and concluded that

where will be no significant environmental impacts and that a NEPA EIS is not required.

In contrast, implementation of a commercial inter-island cable system could have environmental impacts in a multitude of areas and it does appear that both a federal and a state Environmental Impact Statement (EIS) will be required before the commercial cable could be installed.

Phase II-A continued the electrical grid system integration studies, and the investigation of corrosion, abrasion and cathodic protection characteristics for metals which may be used as cable conductors, sheath or armor material. The grid system integration studies presented advanced conceptual plans to link Hawaii and Oahu with an HVDC cable system. These studies also provided conceptual system designs and capital costs for the HVDC submarine cable and HVAC terrestrial lines, and operational scenarios and costs. Preliminarily, it appears that a rectifier (ac to dc) site near the geothermal wellfield in the Southeast portion of the Island of Hawaii will be superior to one near or at the assumed submarine cable take-off point in the Northwest portion of the Island of Hawaii on technical, economic and environmental grounds.

The grid integration study estimated capital costs to vary between \$226 and \$409 million for a direct route between Hawaii and Maui, between \$226 and \$413 million for a route via Maui, and between \$189 and \$336 for a route via Maui and Molokai. Preliminarily, this study concluded that with or without a neutral cable the three-250 MW cable scheme is preferred over schemes such as four-125 MW. The study also indicated that the transmission of geothermal energy over a deep water cable system from Hawaii to Oahu is economically feasible when the price of fuel oil reaches \$67 per barrel.

Phase II-B of the State program will be completed about September 1985. It includes additional route survey analyses, materials corrosion testing, electrical grid system investigations, at-sea route surveys, environmental analysis, and a public information program as well as program management and technical support. The same tasks will be refined in a subsequent Phase II C which will start in the later half of 1985 and be completed in late 1986 or early 1987.

The State of Hawaii is in the second phase of legal, institutional and financial studies relating to a commercial cable system. The first phase revealed that there are no apparent legal or regulatory barriers to the system. The institutional framework for a cable system could include a public

entity such as a governmental agency or corporation, or a private entity such as a private corporation, a joint venture comprised of two or more private corporations or even a combination of private and public corporation, or a limited partnership. It could be owned publicly if, for example, the system were developed wholly by the State. It could be owned entirely by a private corporation or joint venture; or it could be owned by a combination of a public agency or corporation and one or more private corporations.

A cable system could be operated by an entity, whether a single corporation or joint venture, that is unrelated to the entity that owns the system. It can be reasonably assumed that the current phase of the institutional investigations will reveal that operation by a utility is probable, regardless of the entity that owns the system. The alternative financing approaches include: self-supported non-recourse or "true" project financing; credit-supported or recourse financing; or, and perhaps the most appropriate for a cable system, a combined or hybrid financing.

Federally-Funded Portion of the HDWC

The federally funded part of the program was started in September 1982 with a contract between U.S. DOE and HECO, and was originally scheduled for completion in July of 1985. Extensions to the schedule are currently in process.

The overall objective of the program (combined state and federal) is to determine the technical feasibility of deploying and operating a submarine power transmission cable between Kohala on the Island of Hawaii and the Makapuu area of Oahu over a service life of at least thirty years. The federally funded portion of the program is structured to provide technical information of benefit not only for the Hawaii application, but for other national and international applications and for the utility and cable industry in general.

To date, principal program accomplishments include:

- o Completion of power cable preliminary design
- o Completion of conceptual studies for cable-laying machinery and integrated control system
- o Completion of candidate-vessel survey
- o Completion of preliminary study of vessel motions and interactions with cable-laying operations in the Alenuihaha Channel

- o Completion of near-shore bottom surveys in the Alenuihaha Channel
- o Completion of development of the test plan for a structural-analysis computer-code validation effort (using a remnant piece of cable from the DOE OTEC Program)
- o Completion of preliminary development of a cable-laying computer program for a constant-slope bottom based on Zajac's two dimensional formulation.

The cable preliminary design has led to the selection of a candidate test cable which is described Figure 1. The cable has an overall diameter of 119.5 mm and weighs 36.4 kg/m in air and 25.8 kg/m in water.

FIGURE 1 - TYPICAL SCOF CABLE CROSS SECTION

Conceptual studies have identified the principal elements of equipment required for cable laying. These include a linear tensioner of greater capacity than exists on any cable-laying vessel (approximately 80 metric tons), a turntable of 10 meters in diameter, an overboarding sheave 12.3 meters in diameter, and a surge-slack control device. A conceptual arrangement for this equipment on a barge is shown in Figure 2.

FIGURE 2 - HAWAII DEEP WATER CABLE PROGRAM
CABLE VESSEL DECK LAYOUT CONCEPT

A survey of existing vessels has determined that no existing cable-laying vessel (and equipment) fully meets the requirements for installation of the HDWC program cable.

Preliminary studies of vessel motions indicate an expected dynamic amplification factor of thirty-five for the cable-laying tension. This estimate is based on the expected environmental conditions in the Alenuihaha Channel, and a 400-foot barge laying vessel.

The preferred cable route from the Island of Hawaii to the Island of Oahu is shown in Figure 3.

FIGURE 3 - CABLE ROUTE

Conclusion

It is unlikely that more than 50 megawatts of geothermal electrical power will be developed on the Island of Hawaii this century unless there is a means to transport

it to Oahu. The fabrication, installation and operation of high voltage direct current submarine cable between the two islands appears to be technically and environmentally feasible. Confirming investigations and tests are planned this decade. Although there is strong consensus that cable-transmitted geothermal energy cannot compete economically in Hawaii with oil-fired generating plants given current worldwide petroleum prices, it is fully anticipated that eventual oil price increases will support the application of this alternate energy technology.

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