The Molokai Wind/Diesel Electric Hybrid Demonstration Project

December 22, 1990 - December 31, 1993

FINAL REPORT

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DRAFT REPORT

December 22, 1990 - December 31, 1993

Prepared for

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Molokai Wind/Diesel Report Outline

Table of Contents

Page

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES AND FIGURES

EXECUTIVE SUMMARY

Commercial-scale wind/diesel systems for pumping water should be promoted and developed in Hawaii. Wind energy is the State's most available and cost-effective renewable energy resource next to existing biomass systems. Semi-autonomous wind/diesel systems offer sufficient economic and efficient incentives to encourage the various Department of Water Supplies to purchase by contract the systems' power.

The Molokai wind/diesel system's reliability and system performance has exceeded projections. Projections in May 1990 were 744,600 kWhs/year from the wind/diesel system. Availability of the Molokai wind/diesel during the first year (February 1992 through February 1993) averaged above 98%. The annual capacity factor was 29.3% The system produced 768,756 kWhs for the first year with a 16.7 mph annual average wind speed. The diesel portion was 9,566 kWhs. Total production was 1,435,829 through November 30, 1993. Costs of installation were approximately $ 1,483/kW. Total project costs were $593,017, which includes 300 kW of wind, 100 kW diesel. Generally speaking, wind energy projects of the multi-megawatt size run around $ 1,200/kW in Hawaii and diesel projects of similar size run about $ 1,000 kW. The combination required extra construction, connection, controller, and auxiliary hook-ups. Costs for the project were also higher due to the project's small size and Molokai's remoteness and thus higher development costs. The project received a $ 0.0685 floor price, which exceeded the $ 0.063 annual average avoided cost price available from MECO/Molokai.

Fuel savings to MECO/Molokai were almost 60,000 gallons at MECO low price of $ 0.77 per gallon or $ 43,320.00.

The automatic controls and SCADA communication operated very effectively with no major problems encountered from the controller. There were some phone line problems that were due to the line being unshielded, as well as the failure of the cooling fan of the MECO dispatch computer.

Computer simulations, including actual economic and performance data, show great potential for commercial scale wind/diesel systems. All efforts should be made to evaluate, and perhaps develop, a wind/diesel project at Alealoa on Maui and Lalamilo on the Big Island.

Operating a remote wind/diesel system with automatic controls has successfully been accomplished by Zond on Molokai. Physical maintenance proved to be timely and costly. The size of the project does not warrant a full- or part-time employee, but rather requires intermittent maintenance if a problem arises that cannot be cured by remote control, i.e., soft fault, service maintenance was called on. The site being remote required a minimum 1.8 hours service charge. As example of higher maintenance efficiency, two full-time wind smith's can maintain 100 wind turbines. Building larger scale and multiple projects should help reduce these maintenance costs.

Wind/diesel systems have great technology transfer and adaptability to small scale island utilities. Other markets, including desalinization, wastewater pumping, or charging electric vehicles, should be studied further.

INTRODUCTION

Noting the significance of reducing our dependence of fossil fuels for pumping and processing water, the Thirteenth Legislature of the State of Hawaii, 1986, adopted Senate Resolution Number 187, S.D.I. The resolution requests that the Department of Business and Economic Development and the Department of Land and Natural Resources investigate the technical and economic feasibility of developing Hawaii's renewable energy resources in conjunction with the development of the state's water resources.

As growth continues at a rapid rate in Hawaii, the need to manage and plan for our water resources becomes even more predominant. One purpose of this project was to demonstrate the economic and technical feasibility of pumping water with wind-generated electricity. The other was to evaluate and demonstrate the automatic, multi-component, remote control system. In order to compete with conventional fossil fuel methods, we developed a wind/diesel electric hybrid system to offer a "semi-firm" dispatchable power source that maximizes our indigenous energy resources first.

It is necessary that the diesel component initially use fossil fuels, yet it is desirable, when commercially available, to utilize ethanol or methanol as the fuel source.

The trade wind resource that regularly passes over the Hawaiian Islands contains a vast amount of kinetic energy. It is very reliable and consistent, yet to date is underutilized. Although there are days of low or no trade winds, the consistent northeasterly "trades" are available more than 70% of the time (on an annual basis). When utilizing wind-generated electric energy, it's the intermittence of the resource which needs to be better understood and managed. More experience and application of wind energy will allow more ability to supply wind energy to the utility or other energy use customers.

Wind energy, as an electric power supplier by itself, is a relatively mature industry. Today there are thousands of wind energy conversion systems of various types and sizes worldwide. They operate commercially and most operate very reliably. Most wind energy developments sell their power production to utilities. Most utilities are large enough to absorb or accept the wind energy's fluctuating characteristics with no major problems.

Issues such as power curtailment and penetration limits have not been a problem on the mainland. If a utility were to receive too much wind energy on its system, it could "wheel" or transport excess power to adjacent utilities.

Hawaii's utilities on each island are not interconnected or intertied to each other or to any other utility grid, and have to operate autonomously. Therefore there are limits as to how much wind energy any separate island utility can accept. Theoretically, the utilities have established a 5% to 10% limit on wind penetration as set by turbine rated capacity. If penetration is too high, the utility may curtail purchases of wind energy based on "good engineering and safety practices." A priority ranking requires that the latest energy plant to sign on gets shut down first. High priority ranking is key to successfully financing any wind power project.

Purpose

The utilities in Hawaii are virtually totally dependent on fossil fuel for electric power generation. They purchase some renewable energies from a handful of independent power producers, the largest being the sugar companies that provide biomass and hydro power. The State of Hawaii would like to see larger use of alternative and renewable energy resources.

Water pumping in Hawaii is a major power consumer. The individual countries control the domestic water development, pumping, transmission and distribution. Fresh water is typically pumped from the basal lens that sits under each island. To obtain quality water, pump systems are located away from the coastal areas where salt and brackish water are predominant. Deep well pumps are thus situated at higher inland elevations, typically above the 800-foot level. Pumps will vary in size depending on the resource and demand. Most county water pumps for large volumes are 150 horsepower up to 750 horsepower. Depending on the bend, pipe size, and pipe length, these pumps can move 350 to 2,500 gpm. Utilizing wind energy to pump water is Hawaii's most viable alternative to fossil fuel pumping.

History

The Molokai Wind/Diesel Electric Hybrid System was developed as a progressive follow-up to two previous wind energy and water pumping studies. The first study verified the potential of pumping water in Maui County with wind energy. Various criteria were analyzed as well as certain theoretical assumptions proposed. This first study, *Wind Energy and Water Pumping for the County of Maui*, validated wind energy as a viable alternative for pumping water on Maui and throughout the state. The next actions required further study and implementation.

The follow-up study, *A Wind/Diesel Hybrid Electric System for Pumping Water*, examined the necessity of developing an electric hybrid to make economic viability of integrating intermittent wind energy and water pumping, which for Hawaii would require constant power or larger storage. Various hybrid configurations were noted and specific theoretical design characteristics were recommended to build an economically sound hybrid wind energy project.

For our purposes we would eliminate the complexity of electric storage which constitutes the major technical problem area of most wind/diesel hybrid electric systems. We would not be concerned with instantaneous variable load demands because demand and storage is in the form of water, therefore eliminating the complexity of electricity storage. The electricity it takes to pump water would be stored indirectly in a tank or reservoir in the form of elevated water storage.

The study concluded with the need to cooperatively finance a demonstration wind/diesel hybrid system. The State of Hawaii joined with Zond Pacific, Inc. and Zond Systems, Inc. to build and operate the system to prove long-term reliability and economic viability. Typically, private and public funds and resources must combine to accomplish the development of prototype projects into commercially usable and financible projects. In this case the project would demonstrate a reliable, renewable, cost-effective alternative for pumping water in a state that is over 90% dependent on fossil fuels for electricity. This would then attract Departments of Water Supply throughout the State of Hawaii to confidently sign on to using wind energy as a viable alternative to fossil fuel pumping water.

Objectives

The objectives of this project are as follows:

1. To examine the performance of the combination of commercially available wind turbines and a diesel electric generator for the potential of water pumping applications in Hawaii by simulating the dynamics of supplying required electricity to an actual water pumping system on Maui.

2. To demonstrate the long-term reliability of wind/diesel hybrid operation. To develop an automatic, remotely dispatched and monitored wind/diesel system that will allow for an economically-feasible and technically-viable alternative for pumping water in Hawaii.
3. To primarily examine the penetration effects of a wind/diesel power plant on a small utility, looking at penetration of off-peak utility demand and the effects of reactive power requirements.

Scope of Services

The scope of work consisted of the following services provided by Zond Pacific:

1. Plan, design, engineer, permit, construct, operate, and maintain a wind/diesel hybrid system consisting of three 100 kW V17 Vestas wind turbines and 80-foot towers, a hybrid controller, anemometer station, and a 100 kW diesel generator and accessories.
2. Provide expertise and training for assembly, installation, operation, and maintenance procedures.
3. Provide consultation and engineering for the hybrid controller and engineering for the hybrid controller and utility interface.
4. Select and obtain a site.
5. Gather wind data for the site.
6. Obtain a utility power purchase agreement.
7. Manage the project.
8. Operate the system for at least a one-year demonstration program, during which time system performance will be evaluated.
9. Submit a draft final report to DBEDT at least eight weeks prior to the completion date of the contract and submit five copies and a reproducible master of the final report incorporating DBEDT's comments and concerns four weeks after review comments have been received from DBEDT. This report should include, where applicable, estimates relating to: 1) cost per installed kilowatt (capital costs) and 2) operating costs per kilowatt hour.

Approach

Design and Installation

Reliability was a key consideration in the hybrid design and equipment selection process. Molokai's remoteness, salty atmosphere and strong winds provided a great challenge to building a successful wind/diesel power plant project. The hybrid project employs three 100-kilowatt, 17-meter, 56-foot diameter wind turbines, and one 100-kilowatt engine diesel-powered induction generator. Each turbine was modified by Zond's operations group to address the problems associated with Molokai's isolation. Zond provided its own Distributed Intelligence Control System (DICS) for each turbine and the diesel generator and installed stainless steel cabinets for their exposure protection. A 90-foot meteorological tower was included for wind speed and direction data. All of the wind plant operations and controls are performed primarily by the Supervisory Control and Data Acquisition

System (SCADA) specially designed and developed by Zond for this project. Due to the isolated nature of Molokai, the SCADA is the primary on-site maintenance and operation "technician," as on-site human operators are only employed when a major fault or break-down occurs.

The project received state approval in December 1990 and construction began in September 1991. Zond shipped to Molokai all the major project components. Prior to shipping the three wind turbines, all components were reconditioned, including the rotors. Salt conditions being a primary concern, all metal surfaces were checked for exposure and coated or protected. The new turbine controllers were assembled and built into new stainless steel cabinets. Each turbine was also modified with upgraded components to match the controllers' requirements. Zond then employed local shipping, construction, and material suppliers to assist in the construction.

Key Zond supervisory personnel were supplied to assist and oversee the project's installation, interconnection, start-up, and testing. Maui Electric — Molokai Division and Hawaiian Telephone (Molokai) assisted in the utility side interconnections.

Several delays were incurred due to Molokai's remoteness. The heavy crane required shipping from Oahu, and cement for the 60-cubic-yard monolith poured foundation was unavailable because the local Molokai supplier went out of business. The phone line, the main communication line, was old, unshielded, and provided unpredictable service.

The system's isolated site required high service charges from the time the appointed technician left the shop until he returned, and the project site was 16 miles from shop, with over six miles of rough, dirt road. Therefore a very reliable and sophisticated approach was designed into expectations of operation. The Zond engineers developed a remote wind/diesel hybrid that performed to above production estimates and over 98% availability for the test year and beyond. The test year ran from February 18, 1992 to February 18, 1993. The system is still operational.

ABOUT ZOND AND ZOND PACIFIC

Zond Systems, Inc. (Zond), headquartered in Tehachapi, California, was established in 1980 and was the first wind farm developer to obtain a utility power sales contract with Southern California Edison.

Zond Pacific Inc. (ZPAC) was incorporated in Hawaii in 1984 as a wholly owned subsidiary of Zond Systems. ZPAC over the last nine years has actively participated in many renewable energy initiatives and agendas for various counties and the state. In 1988 ZPAC helped sponsor the Enhancing Renewable Energy Development in Hawaii conference, which later gave birth to the Hawaii Energy Policy (HEP) and the creation of the Integrated Resource Plan (IRP) for Hawaiian utilities.

Zond's first decade started as a pioneering effort in commercial wind power generation and has advanced to the construction of "Sky River," a 77-megawatt state-of-the art wind power facility. Sky River became fully operational in late 1991, bringing Zond's total installed capacity to 260 MW. Zond produced 570 million kWhs in 1993. This is equivalent to the electricity needs of a residential population of 250,000 people, powered only by the wind.

Zond has dedicated itself to long-term ownership, operations, research, development, and management of wind power plants worldwide. In California Zond's facilities, including over 2,500 wind turbines, generated over 15% of all wind power in the state.

Zond's capabilities cover the full range of wind power requirements:

Engineering

Zond possesses in-house aerodynamic, civil, electrical, electronics, and mechanical engineering capabilities. These capabilities enable Zond to plan and construct facilities, manage all technical aspects of wind-power generation, and maintain a leadership position in wind power.

Siting

The foundation for a successful wind project is proper siting of the turbines, which begins with a wind-flow analysis of the proposed location. Zond's extensive capabilities include design and manufacturing of advanced wind-data recording devices, deployment and monitoring of instruments in the field, and acquisition and interpretation of the data to accurately determine optimum siting and reliable production estimates.

Construction

Having installed more than 2,500 wind turbines in topographically diverse locations, Zond is one of the most experienced wind power facility construction companies in the world. Zond has planned, engineered, and built five facilities valued in excess of $450 million with a combined generating capacity of 275 megawatts. Zond's wind power sites range from desert mesas to rocky mountain ridge lines. These installations include high-voltage transmission lines and substations together with all the related wind power facility infrastructure.

Plant Operations

The company provides operation and maintenance services for wind power stations with emphasis on maximizing electrical production while maintaining a balance between short- and long-term costs. This objective is achieved by constant plant surveillance to assure high turbine availability, thorough preventive and scheduled maintenance programs, and finally, careful quality control to ensure reliable operations. Zond's availability has averaged over 90% since 1982.

Within each site, a SCADA (Supervisory Control and Data Acquisition) system monitors turbine performance, records operational data, and automatically alerts and dispatches service crews in the event of a turbine fault. The SCADA system utilizes an HP1000 computer and proprietary software developed by Zond.

PROJECT DEVELOPMENT

Land Selection and Acquisition

Long-term land availability, with an adequate wind resource, is one of the major constraints to successful wind energy development in Hawaii. The island of Molokai was selected for the wind/diesel hybrid project for several reasons. (1) Molokai has some of the highest electric rates to the customer in the United States; (2) the utility exclusively uses diesel fired electric generation; and (3) wind energy's direct impact on such a system is the significant reduction in required fuel.

The wind/diesel hybrid was conceived to pump water in Hawaii. Most water pumps on county water systems are remotely situated. They also utilize electricity from fossil fuel-fired generating plants. In Hawaii water could be pumped by wind energy. Thus, Molokai was selected for its remoteness and its high (100%) dependence on fossil fuel for electricity.

Molokai's system average peak load is approximately 5,700 kW and its average minimum load is approximately 2,700 kW. The small electric grid allows for examination of variable wind turbine characteristics and utility penetration which has previously been examined in theory only.

Molokai was also selected because of its tremendous wind resources and the availability of leasable land.

In the early 1980's, two sites were monitored for wind speed and direction, at Ilio Point and the Momomi area. Although some data was lost, wind speed averages exceeded 20 mph at 100 feet over the life of the study. The site for the wind/diesel hybrid was very near the Momomi tower.

The land is owned by the Molokai Ranch Ltd. and is part of the 42,000± acres the ranch controls and operates for cattle husbandry.

Also in the early 1980's, a pioneering effort was undertaken by Molokai Energy Inc. to develop wind electric power at the selected site. Two early turbines, an ESI 52 and a Merkham, were erected and operated for a short time. After the operation of the early turbines ceased, the owners of Molokai energy continued to maintain a long-term "wind rights" ownership agreement. This wind rights concept is very unique in the industry and can be only compared to mineral rights ownership. The control of the wind energy rights would require two agreements to obtain the land necessary for the project development.

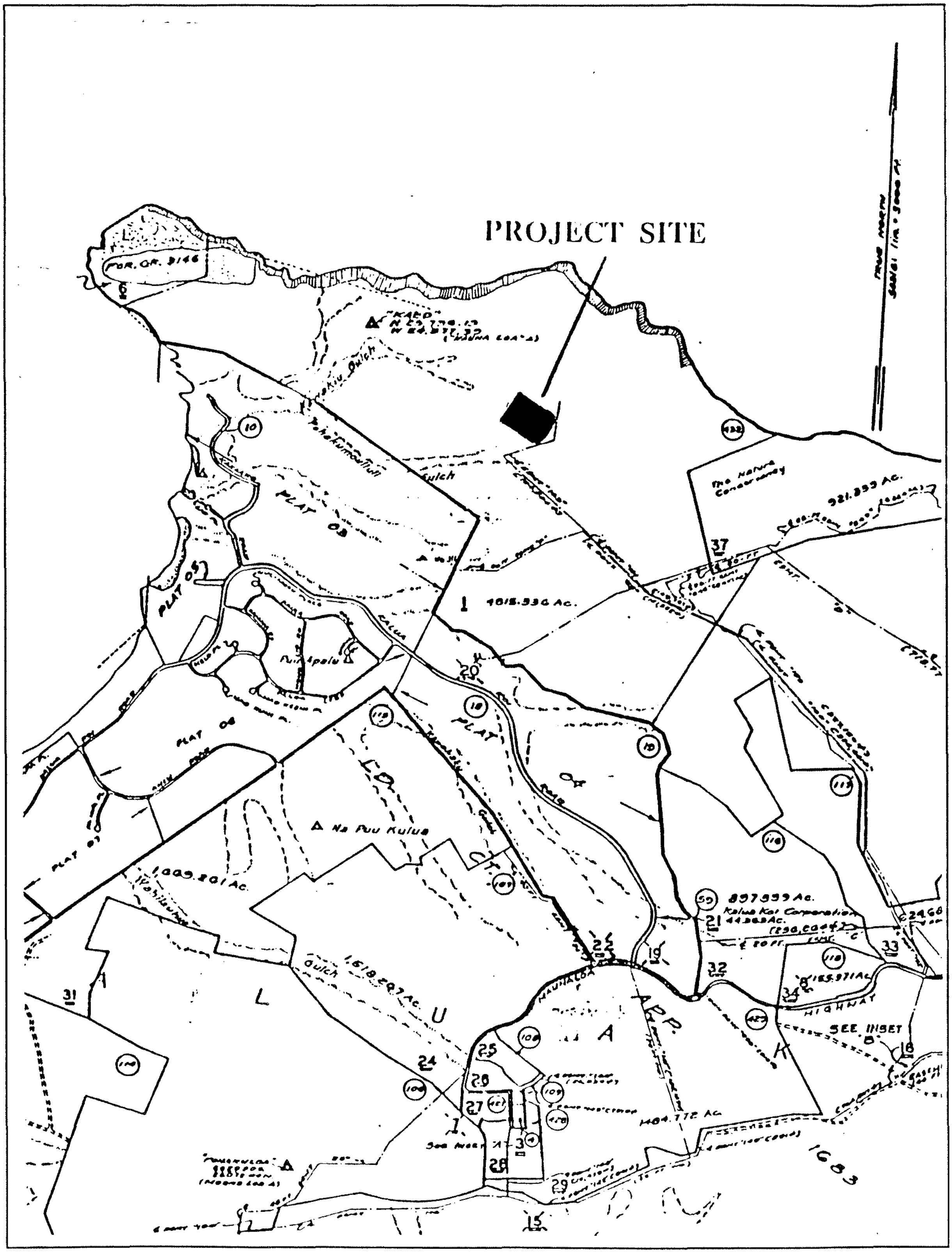


Figure 1: PROJECT SITE NW MOLOKAI

A 15-acre use area was selected and an easement royalty agreement was executed with Molokai Ranch under Molokai Energy's master lease contract. Simultaneously a sublicense agreement to use Molokai Energy's wind rights was concluded.

An important benefit to the site was the 12KV transmission line and telephone line already in place by Molokai Energy.

Power Purchase Contract

In 1978, Congress passed the Public Utilities Regulatory Policies Act (PURPA). The purpose was to stimulate renewable energy purchase power from utilities by giving renewable generated electricity a priority over fossil fuel generated power. This Act has allowed for the steady growth and increasing viability of renewable energy generation.

On May 24, 1991, Zond Pacific Inc. and Maui Electric Company Ltd. signed a one megawatt Purchase Power Contract for as-available energy from a qualifying facility. Zond Pacific simultaneously applied for, and received, Qualifying Facility (QF) status with the Federal Energy Regulatory Commission. In September 1991, the Hawaii Public Utilities Commission (HPUC) approved the contract allowing for the project's implementation. The contract represents the "standard" Hawaiian Electric Utility Purchase Contract particular to Maui Electric's unique characteristics.

The standard contract price is based on the avoided cost of oil as calculated by a pre-established formula approved by the HPUC. Definition of avoided cost, and what criteria go into the formula to establish this critical wholesale price of electricity, is a major stumbling block in the development of renewable energy electricity projects. Not typically included in the avoided costs are the so-called "external costs" attributed to the use of fossil fuels in today's societies.

Proponents of renewable energy have proposed that environmental and social costs of processing, transporting, protecting, and burning fossil fuels be included in the avoided cost. After many years of discussion on the methods of quantifying external costs, the range of value is still wide, yet there appears to be agreement that external costs exist and should somehow be incorporated into the contract pricing equation.

The Molokai Zond Pacific/MECO contract was signed without incorporation of societal or other terminology deemed necessary by some developers for a successful commercial wind plant development.

An avoided cost price minimum, or "floor price," was set upon contract approval by the HPUC at $.0685 kWh. The floor price is a lower end price that when established remains the lowest price the utility can pay for the Qualifying Facility (QF) power, regardless of the price of oil.

A low, flat-rate avoided cost (power purchase price) is not a desirable approach to financing agencies who would prefer an established (known) price schedule over 25 to 30 years. Wind energy development being especially capital intensive in the early years, requires an early higher avoided cost. The economic benefit of wind energy comes from the long-term operation. After capitalization, wind plant costs drop considerably (due to no fuel cost), thus offering greater benefits and alternatives to the rate payers over the long term.

In order to develop and demonstrate the Molokai wind/diesel project, the State of Hawaii Energy Division, the Federal Department of Energy and Zond Pacific cooperated in providing funding and expertise to finance the project. The contract also describes in detail the QF facilities, interconnection components and the importance of "good engineering operating procedures." The project has operated successfully from inception under the strict rules and guidelines of the Purchase Power Contract. The contract also was amended to allow for a 15-year term. The standard contracts are usually one year, so our contract was amended to 15 years to allow installation of additional turbines over time.

Funding and Permits

The Molokai hybrid demonstration project is a cooperative effort joining together public and private resources to accomplish a viable research and development project that benefits the general population. Typically the costs associated with a commercial demonstration project are relatively high, requiring government support of some kind.

The major companies and agencies involved in this projects are: 1) the U.S. Department of Energy, 2) the Department of Business, Economic Development & Tourism, Energy Division, Hawaii, 3) Zond Pacific Inc., Hawaii, and 4) Zond Systems Inc., California.

Zond Pacific and Zond Systems joined with the DBEDT Energy Division to develop the Molokai wind/diesel system. Zond provided 60% of the project development value through equipment, design, engineering, installation, administration, operation, and maintenance. The Energy Division supplied the capital at 40% of the project value to allow the system to be installed on Molokai.

Groups and individuals associated with the wind/diesel project on Molokai:

Zond Systems
Dept. of Business Economic Development and Tourism (DBEDT)
Department of Energy (DOE)
Zond Pacific — project coordination, system development, administration
Molokai Energy Task Force — local support
MECO, Maui — planning and installation, power contract
MECO, Molokai — planning and installation
HECO — power contract, negotiation support
HPUC — contract approval
County of Maui — building approval
Molokai Ranch — land lease
Molokai Energy — land and wind use agreements
ECM — Engineering
Friendly Isle Contracting & Equipment Inc.
Peterson Construction — trucking, concrete, heavy equipment
Molokai Supply — heavy equipment
Matson — shipping, California-Hawaii
Young Brothers — shipping, Oahu-Molokai
Mike Krochina Engineering — structural engineering
Cummins Diesel — diesel generator
Island Petroleum — fuel supply
Pacific Electric Mechanical — maintenance/operation

Permits

Wind energy conversion systems are acceptable in agricultural zones in Hawaii. The land parcel must be large enough to accommodate the tower and blades, so that if the tower fell, the structure would remain on the property. A determinant of building approval is the height limit imposed on the acceptability of the top of the windmill, set at 30 feet. Any structure above 30 feet requires a height variance. The County of Maui has the ability, under certain conditions, to allow a waiver of the height variance. Otherwise a public hearing is required. Because of the project's remoteness, lack of visual or neighbor impacts, a waiver was granted.

The project then required the typical County of Maui building permit application and process. The project received permits in November 1991 after an insurance indemnification contract with the County of Maui was confirmed. Construction commenced in early December 1991 and was completed in the early part of February 1991. After final system evaluation and testing, the hybrid began continuous operation February 18, 1991.

Construction, Operation and Maintenance

Although Molokai is centrally located in the Hawaiian Island chain, it is relatively remote and difficult to develop. This proved to be the case as Zond began the construction phase of the project. There always seemed to be delays for one reason or another, most pertaining to shipments and arrivals and the availability of supplies and equipment.

The wind turbines were tuned, retrofitted, and prepared for the Molokai environment by early November 1991 and shipped by barge from California to Oahu and then to Molokai, scheduled to arrive December 2, 1991. Most of the cargo arrived on schedule. Certain key components, including anchor bolts, came a week later, being misplaced on Oahu. By mid-December it was apparent that full construction wouldn't begin until after the end-of-the-year holidays.

Full construction began the second week in January and was completed by the first week of February. The machines went through troubleshoot testings and were commissioned on February 18, 1992.

Certain conditions prolonged the development besides the late arrival of equipment. Some of these conditions were:

1. Building permit approval delay.
2. Insurance indemnification authorization sign-off delayed.
3. Crane shipment delayed one week.
4. Cement company closes one week before equipment arrival.
5. Phone company refuses to upgrade single unshielded phone line. MECO wants two lines with one dedicated to Molokai dispatch. Hawaiian Telephone wants $50,000 for upgrade.
6. MECO requires more sophisticated interconnection. Some delays in design and in parts acquisition.
7. Diesel requires new Zond controller. Also arrives late. Cummins diesels all had synchronous generators; mistakenly thought one was induction.
8. Zond's main start-up technician gets blood poisoning, goes to hospital. Delays project two more weeks.

Actual construction, installation, execution, and start-up went rather well once all equipment and materials were on hand. Zond's team along with the local contractor and crew moved very effectively and timely through the installation.

The wind/diesel project was very well planned and conceived. Cost overruns were approximately 0.051%.

System Maintenance

Maintenance costs, including training, ran $ 14,102.00 in the first year of operation or approximately 30%. In partial year 1993, O & M ran approximately 12%.

In most cases, when the systems maintenance required a physical repair, Pacific Electro-Mechanical (PEM) of Molokai performed the service. Technicians from PEM were trained by Zond to perform all necessary maintenance work. Computer maintenance was performed by Perfect Micro Systems of Maui. Annual maintenance and repair was performed by specialized personnel sent from California. Due to the project's small size, maintenance cost was considerably higher. More time to repair was necessary due to the site's remoteness. A list of maintenance actions follows:

Date of Action	Total # of Hours	Action/Repair/Maintenance
09-Mar-92	7.0	Training on equipment
09-Mar-92	9.0	Troubleshoot generator controls
27-Mar-92	5.0	Troubleshoot shutdown of turbine #03
27-Mar-92	1.0	Hookup generator run signal to SCADA system
27-Mar-92	4.0	Troubleshoot telephone equipment
04-Apr-92	1.5	Read Meters/download data
13-Apr-92	3.0	Troubleshoot control system on diesel generator
13-Apr-92	2.5	Troubleshoot tracking problems turbines #01 and 02
14-Apr-92	1.8	Reset shunt trip
10-May-92	2.0	Fuel delivery
15-May-92	4.5	Troubleshoot cable overtwist turbine #03
19-May-92	2.0	Troubleshoot communication with site
25-May-92	3.5	Install updated programs/troubleshoot generator
16-Jun-92	4.0	Read Meters/download data/replace yellow box on turbine #03
25-Jun-92	12.5	Troubleshoot communications
02-Jul-92	2.0	Troubleshoot diesel generator overcrank
02-Jul-92	2.8	Troubleshoot SCADA system on turbine #01
05-Jul-92	1.0	Reset modem
05-Jul-92	1.0	Reset modem
01-Aug-92	2.5	Read Meters/download data/troubleshoot high water temp fault on diesel generator
03-Aug-92	2.5	Troubleshoot communications failure to computer, test systems
03-Aug-92	2.0	Read Meters/download data
04-Aug-92	6.0	Troubleshoot diesel generator overload
10-Aug-92	2.0	Troubleshoot SCADA system on turbine #01
14-Aug-92	2.5	Troubleshoot diesel generator
28-Aug-92	7.0	Troubleshoot diesel generator and computer
01-Sep-92	2.5	Read Meters/download data/troubleshoot high water temp fault on diesel generator
03-Sep-92	2.5	Troubleshoot communications failure
04-Sep-92	6.0	Troubleshoot loss of signal to diesel generator
29-Sep-92	7.0	Troubleshoot diesel generator GOL shutdown/cooling fan control/computer
02-Oct-92	1.5	Read Meters/download data
04-Oct-92	2.0	Read Meters/download data
08-Oct-92	4.0	Troubleshoot diesel genertor controls test/adjust
16-Oct-92	13.0	Preventative maintenance
27-Nov-92	2.0	Troubleshoot turbine #02 reset disconnect
01-Dec-92	2.0	Read Meters/download data
07-Dec-92	2.0	Troubleshoot turbine #02 no response
15-Dec-92	2.5	Service oil in diesel engine, troubleshoot LOP fault in turbine #01
18-Dec-92	3.0	Sample gear oil turbine #02
03-Jan-93	2.0	Read Meters/download data
10-Jan-93	2.0	Troubleshoot overspeed all turbines
19-Jan-93	3.0	Provide and install locks, remove external operators form disconnect swithces on turbines
07-Feb-93	2.0	Troubleshoot YOL turbine #01
09-Feb-93	2.0	Reset turbine #01/greased slew rings on all three
28-Feb-93	2.0	Read Meters/download data
09-Sep-93	3.5	Troubleshoot shutdown of turbine #01 Grease slew rings on all turbines
Total	161.0	

Table 1: MOLOKAI WIND/DIESEL MAINTENANCE ACTION

This list includes service calls and descriptions of work by Pacific Electric Mechanical of Molokai.

PROJECT COMPONENTS

The Wind Turbines

The V17 wind turbine is fabricated by Vestas-Danish Wind Technology A/S in Lem, Denmark. Vestas has been a leader in wind turbine, design, manufacturing, and quality development since 1978.

The V17 proved itself to be rugged and durable after its initial performance testing on Denmark's harsh North Sea coastline. The turbine is mounted on a 22.5-meter (73.8-foot) lattice type galvanized steel tower. All components are of the highest quality, with a life expectancy of 20 to 30 years with proper maintenance. Molokai's corrosive conditions could require higher and more preventive maintenance.

The V17 is a 17-meter (56-foot) diameter, three-blade, up-wind, stall-regulated, horizontal axis wind turbine employing 108-KVA, 6-pole, 480-volt, three-phase induction generator. The peak power output of the turbine just before high wind overspeed shutdown is about 130 kilowatts.

The turbine includes a three-caliper, low-speed shaft hydraulic braking system, an active yawing system, and an assortment of fault protection sensors. With a gear box ratio of 23.93 to 1, the hub will rotate at 50.15 rpm during generator synchronous operation of 1,200 rpm. Full power output occurs at a generator synchronous speed of 1235 rpm, corresponding to a hub speed of 51.61 rpm.

The Diesel Generator

A new Cummins model 6CT8.3-G Diesel, water-cooled induction generator set was employed for the hybrid project. The generator is rated 100 kW, 125 kva, 480 volts A-C, 3-phase, 3-wire, 60 Hz, 0.8 pf, 1800+ rpm. The system incorporates a unit mounted radiator, a blower fan with 1-hp, 3-phase electric motor, and a 24-vdc auto start/stop controls and battery set.

The generator panel is equipped with volt meter, amp meter, phase selector switch, engine instruments, engine control switch (auto-off-manual), safety shut-offs (low oil pressure, high water temperature, over-speed and over-crank). In addition, Zond provided a custom Distributed Intelligence Control (DIC) system and Zond's Supervisory Control and Data Acquisition System (SCADA) for the diesel/generator. During maximum operation of 125 kW the generator maintains 105°C (221°F), with the engine's rated at 207 bhp (154 bkW) spinning at 1800 rpm. The generator/diesel set is mounted on four spring-type vibration isolators. A residential exhaust silencer with stainless steel

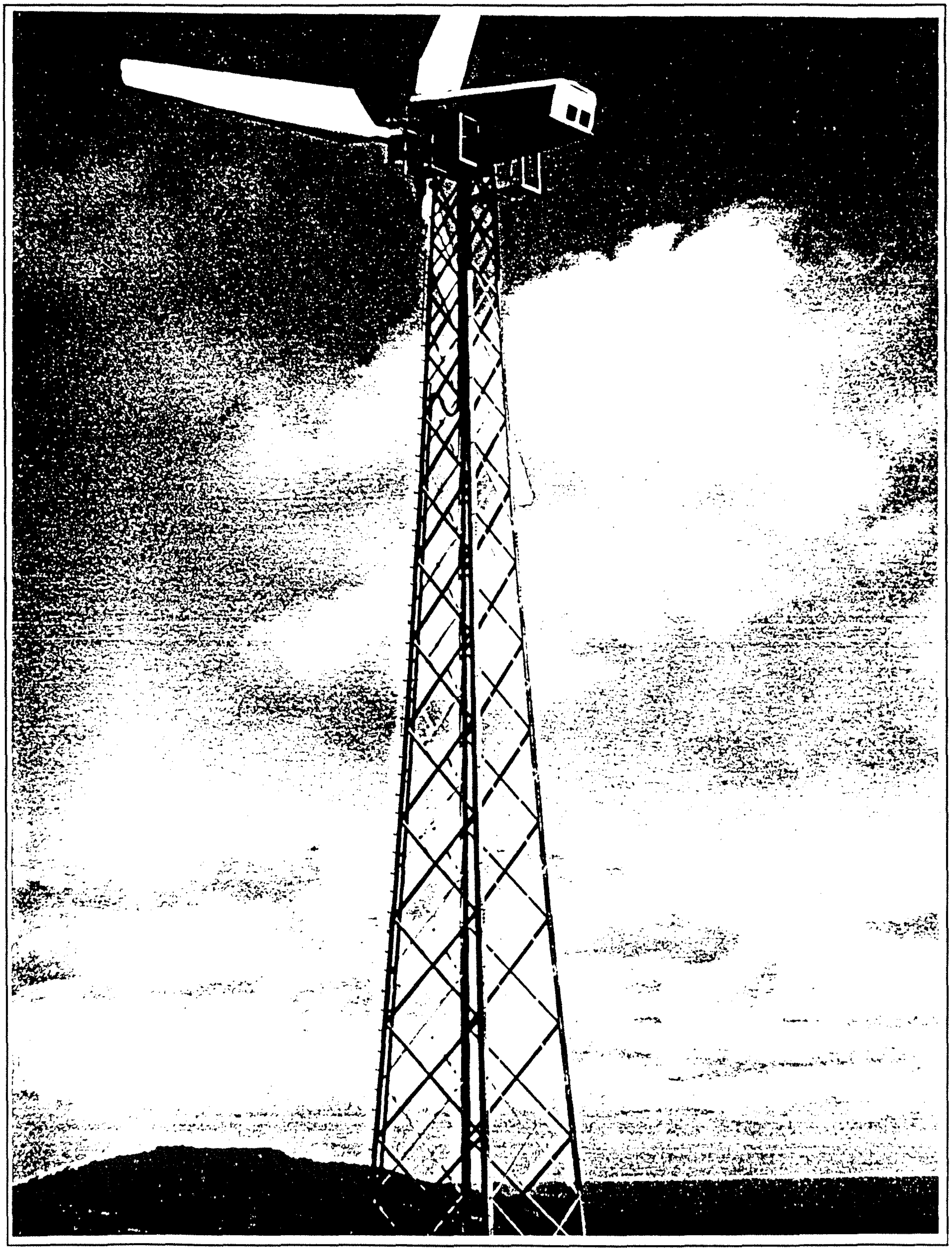


Figure 2: VESTAS V17 AT MOLOKAI SITE

loose flex connector exports all exhaust gases to the west side building exterior.

Fuel is supplied by a 50-gallon diesel fuel day tank, floor standing, with a 2 gpm auxiliary pump. The day tank is fed from a 350-gallon exterior above ground, steel, diesel fuel tank (single wall). The size of the storage capacity limited continuous long-term operation to approximately a 55-hour supply. Fuel is supplied by Island Petroleum Inc. of Kaunakakai, Molokai. Fuel was first delivered in December 17, 1991 with 396 net gallons at $1.289/gallon plus tax. Fuel type is diesel no. 2 #.9905, specific gravity of 380 loaded at 80°.

Approximately $2,045 or 1,587 gallons of fuel were used between February 18, 1992 and February 18, 1993. To minimize fuel costs and delivery, the diesel was automatically operated once a day for approximately one hour. Under a water pumping situation, the diesel needed to be available whenever the wind turbines' combined output was less than 95 kW. A command to automatically turn on and off the diesel daily proved the individual components could be operated by the system controller by power demand requirements. Only during the simulation period was the diesel turned on by automatic control when 95 kW was not achieved from the wind. The individual components operated very successfully in relation to each other and in this hybrid configuration.

The Master Controller/Control Communications

Zond has designed and manufactured over 3,000 electronic control systems and over 500 electronic data acquisition systems. These systems have been developed for the purpose of improving and monitoring the performance of wind turbines, wind turbine siting, upgrading older systems, and providing controls for advanced turbine designs.

The Molokai wind/diesel hybrid project employs the most sophisticated controls, communication, and data acquisition system available, all designed by Zond Systems' Electronic Research and Development Department.

V17 Control System Historical Development

To enhance reliability, based on Zond's extensive experience in wind turbine control system design, we have developed an entirely new controller. This controller employs six microcomputers packaged in small, easily removable modules. Such technology achieves distributed intelligence within the wind turbine control environment, creating a more reliable, easier to maintain controller.

By employing multiple microcomputers instead of a single microcomputer, we have developed a controller that requires only simple maintenance, small easy-to-debug

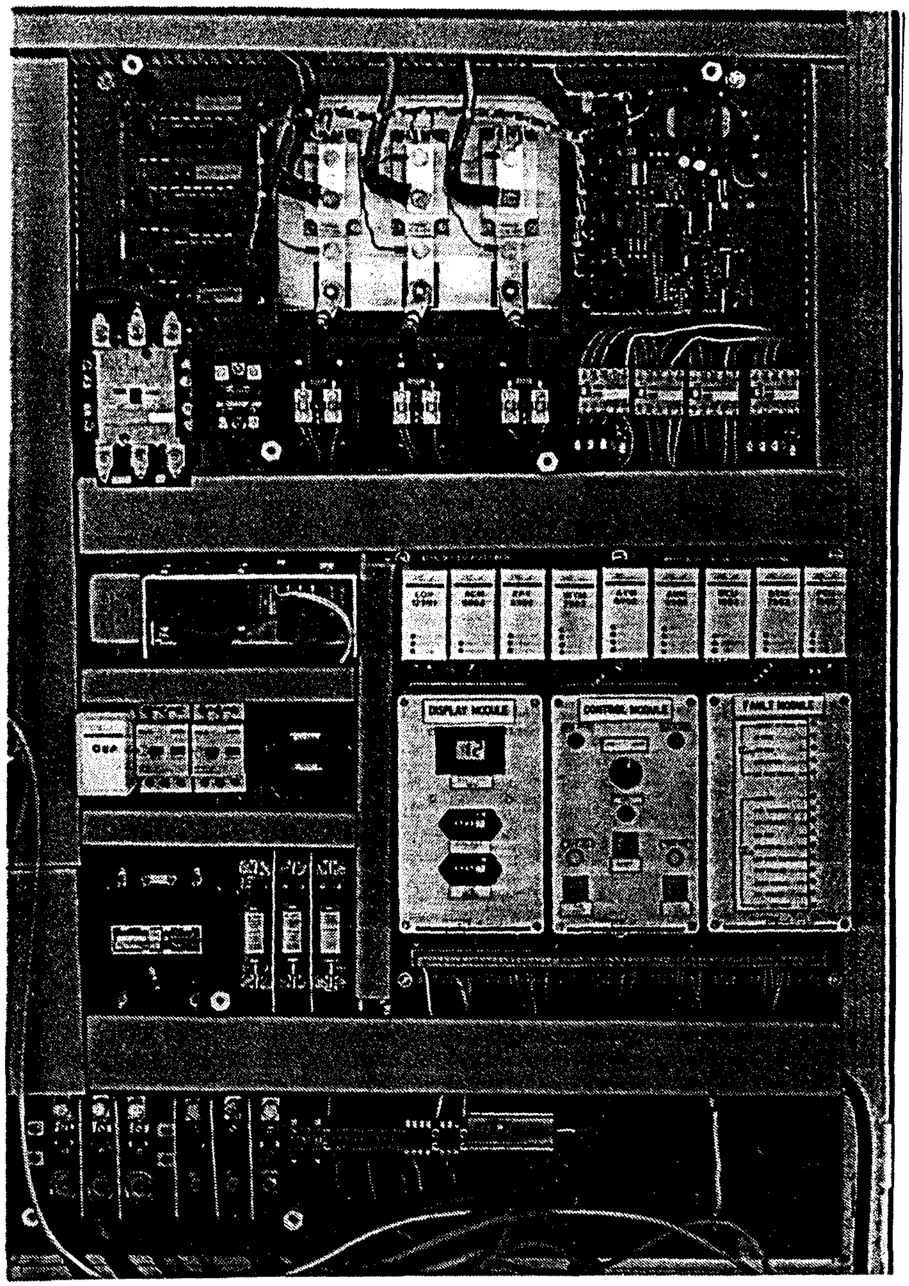


Figure 3: COMPLETE RETROFITTED CONTROL SYSTEM IN OPERATION

programs for fast development, increased overall system performance, and increased reliability. Due to the reduced cost of today's modern microcomputer technology, multiple chip designs offer increased performance without an increase in expenditures.

The new control system employs a highly efficient soft-start generator controller that eliminates problems with older solid state and contactor control systems including motoring against the brake.

Zond V17 Replacement Controller System Overview

Zond V17 replacement controller is a fully solid state system that does not use a main generator contactor or a bypass contactor. This has been accomplished by employing Silicon Controller Rectifiers (SCRs) along with a large heat sink. The SCR firing board system, called an Auto Synchronous Controller, or ASC, is manufactured by Enerpro Inc. of Goleta, California. This board controls the SCRs and commands all generator mains connection and disconnection automatically after a simple enable signal from the Distributed Intelligence Control System (DICS) motherboard's General Control Unit Module (GCU 1602). (See Appendix III.)

One advantage of the ASC system is its ability to extract more energy during light wind conditions than can be accomplished with a simple contactor. This helps eliminate the requirements for the second smaller generator that was employed on the original V17 turbines.

A second advantage of this system is its inability to allow the generator to be operated as a motor against the braking system. Once generator speed has dropped to near synchronous, the ASC allows the generator only small amounts of torque that can easily be overcome by the braking system. Even when fully enabled against the brake, only a small amount of current will flow and the brake system will hold the turbine stopped easily and without damage.

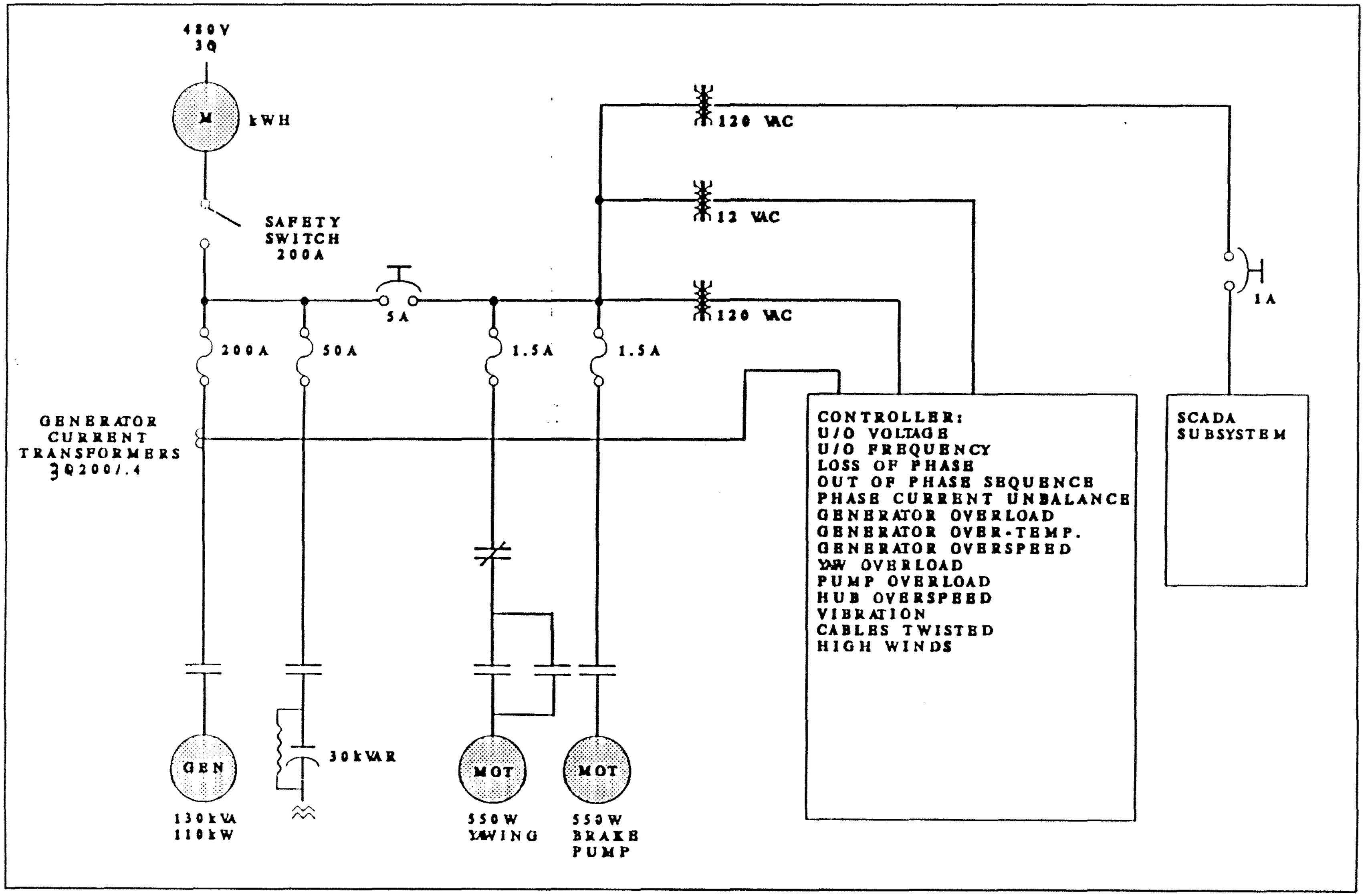


Figure 4: CONTROLLER SINGLE-LINE DIAGRAM

PROJECT PERFORMANCE

Reliability, System Performance

Since start-up on February 18, 1992 through February 18, 1993 (a survey period of 8,760 hours) the wind turbines have maintained a 29.3% plant capacity with the production, including the diesel, of 759,190 kWh. Overall gross availability for the wind turbines has been 98.3% for this same period with machine availability at 98.9%. Diesel generator production has been limited and averages about 800 kWh per month. The diesel is operated one hour per day when the wind is low to accomplish diesel fuel savings. This still allows for automatic operation, simulation and the demonstration of its feasibility.

Systems Description and Operation

Wind plant operations and control are performed primarily by the electronic Supervisory Control and Data Acquisition System designed and developed by Zond. This system allows operators at the wind park site and at remote sites to monitor and control each of the turbines and the diesel generator and to monitor meteorological data. Due to the remote nature of Molokai, the Supervisory Control and Data Acquisition System (SCADA) is the primary on-site maintenance and operation technician, as on-site human operators are not employed on a full-time basis.

The SCADA system consists of remote sub-system computers communicating to a central computer through a standard RS-422 serial interface. Each of the remote sub-system computers are used to communicate with their respective control systems, i.e., each individual wind turbine controller, the diesel generator controller, and the meteorological data recorder system. The central computer is used to gather data from all of the remote computers and to send control commands when required.

The SCADA system central computer and diesel generator are housed in a small building a few hundred feet from the wind turbines. This computer is a PC-based, rack mounted, industrial quality machine. An autonomous program, residing in this central SCADA computer, performs the main SCADA functions. This program is "self-booting" and will run upon a valid power-up condition. Therefore, power outages do not affect the operation of the SCADA system. After power has been returned, no human presence is required for resetting or restarting of the SCADA system program or the turbine control systems.

The SCADA system described above has several functions. First, it is designed to monitor each turbine, the diesel generator, and the meteorological tower. Data returned to the central computer consists of 10 different fault status points per turbine, two braking systems status points, available hours, line hours, kilowatt hours, and wind speed and direction. Second, the system is designed to deliver (from a central computer located on the wind turbine site) commands for stopping each turbine, the diesel generator, resetting each of the turbines' faults, yawing each turbine both left and right, and operating a sub-station primary circuit breaker. Third, the system performs automatic start-up of the diesel generator when the power output of the three wind turbines drops below a specified set-point. This set-point can be changed by a remote operator via the telephone modem or at the central SCADA computer. During the simulation, a preset of 95 kW was specified as the diesel automatic set-point. (See Appendix VI.)

An automatic dialing system originally planned and written into the software for this system has been defeated since initial start up of the site. The older existing phone line was a single-line and utility requirements of continuously monitoring via their remote computer system have prevented the main SCADA computer from dialing any other remote location. However, this feature was tested and allows automatic dial-up of Zond's main office followed by various other numbers should the main office number be inaccessible due to a busy signal or other problems.

Two remote PC-based computer systems are presently being employed with this SCADA system. One is operated by Zond from Tehachapi, California, and a second from the utility dispatch in Palaau, Molokai. Control system integration via these systems is controlled by three levels of passwords. Utility operations and monitoring occurs at the lowest level. Wind turbine monitoring by operations and maintenance technicians at the mid-level and overall control, monitoring and database recovery is accomplished at the third (or highest) level of security.

Utility operations consist of the ability to bring the turbines and diesel generator to a stop. Furthermore, the utility also has the ability to trip a main system circuit breaker if required. They also monitor the performance of the turbines to determine the effects of grid penetration into the small Molokai island load, which may require curtailment. If Molokai's electric system is jeopardized by high wind energy penetration, the control room dispatcher may shut off one or more turbines. Zond is then called, and when operational conditions allow, Zond may reinstate the turbines to operation.

Operations and monitoring available from the remaining two security levels are discussed below.

Visualization Software for Real-time Tele-robotic Operations

The overall SCADA system connected to each turbine, diesel generator, and the main computer employs a total of six microprocessors. Each turbine control system also employs six microprocessors. Counting the diesel generator controller and meteorological tower controller, a total of 26 computer (micro-processor and micro-controller) chips are employed to effect automatic control, supervisory control, data acquisition, and dial-up site monitoring capabilities. Although complex, this highly distributed system is simple in its operation and extremely intelligent without human intervention.

The success of this project is due in no small part to the quality of the turbines' controls and the SCADA system. SCADA system functions and operations are very much enhanced due to the use of visualization software and audio synthesized sound.

Visualization software was employed to create an accurate graphical moving picture of the overall wind turbine plant in real time operation. In addition, this same software was employed to generate an accurate graphical representation of each turbine's control system as it would look to an operator in the field. The diesel generator control system is treated in much the same fashion as the meteorological tower and its displays.

Employing such graphics greatly simplifies the operator interface. It allows operators to monitor and control the park with a minimum of training and supervision. Operators normally employed to operate turbines in a field environment can easily be trained to operate this system. Their experience with field operations can be applied directly with little computer knowledge.

Figure 1 shows the main graphical screen of the SCADA system. Each of the three wind turbines are represented by a graphical drawing on the computer screen. When the wind is blowing, the turbines will rotate on the screen as long as they are rotating in Hawaii. In the event that one or more of the turbines is down and not operating, that turbine will be depicted as stopped on the screen of the graphic display. This graphical picture is normally included with sound. A "swishing" sound is synthesized and occurs when the turbines are operating. The overall effect of this picture is to produce a two-dimensional virtual reality scene. The scene displayed on the screen of the computer represents what is occurring in the field at the wind park.

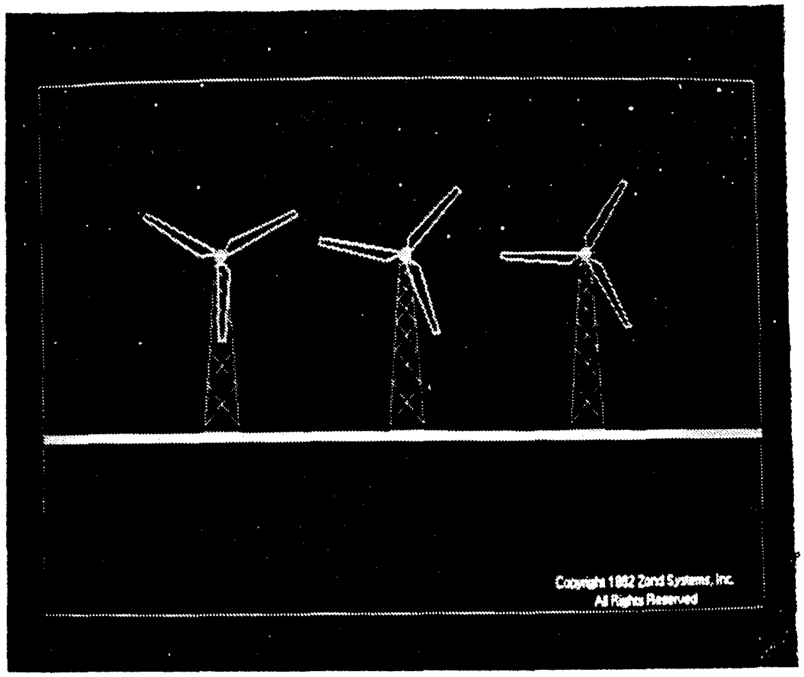


Figure 5: COMPUTER IMAGE OF MOLOKAI TURBINES

The scenes shown in Figure 5 and Figure 6 occur once communication is established between the central SCADA computer and a remote PC-based computer. Establishing communication is accomplished by running a simple menu-driven program which allows the operator to select a password for security level entry.

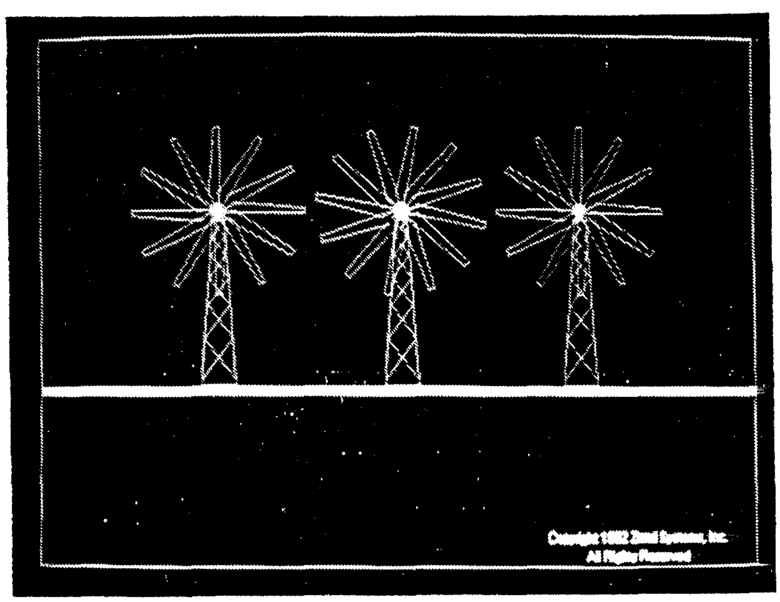


Figure 6: COMPUTER IMAGE OF TURBINES IN OPERATION

Once displayed, other graphics can be selected that include the control systems of the individual wind turbines. By highlighting the control system at the base of the tower, an operator can select the turbine he wishes to observe. The process of selecting the particular controller is accomplished by employing the Tab key on the computer keyboard. Alternately, a computer mouse could also be employed for "point and click" ability.

Figure 7 shows the turbine control system screen. This graphic represents the main modules of the turbine's Distributed Intelligence Control System. System parameters such as wind speed, turbine power output and availability are shown in the Display Module. Fault information is displayed in the Fault Module (actually a nonvolatile fault data recorder). Turbine control and overall status is shown in the Control Module. All buttons shown on this display are functional and operate in the same fashion as the actual controller. The yaw buttons, reset buttons, and external stop button can be accessed using the Tab key. Once highlighted, these buttons can be "depressed" by pressing the remote computer's Enter button.

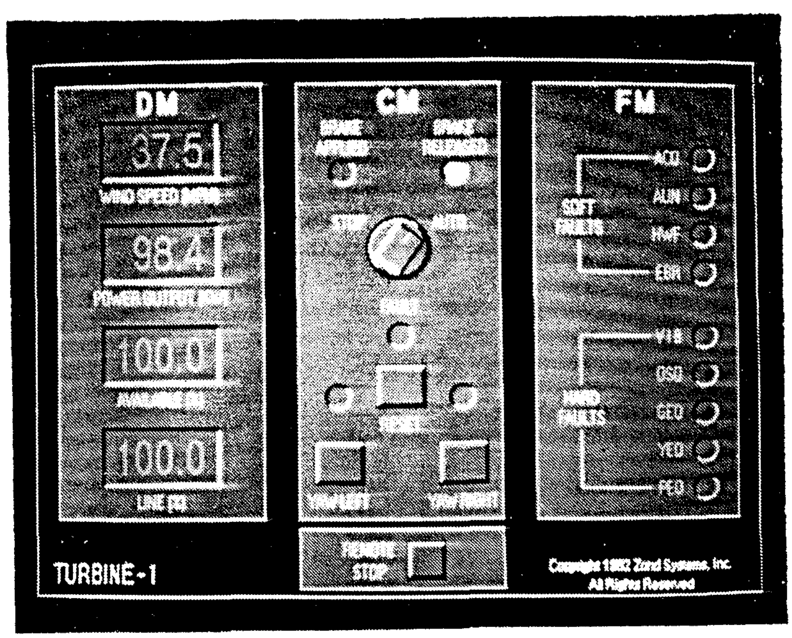


Figure 7: TURBINE CONTROL SCREEN

Once the required button has been selected and "depressed," the turbine selected will respond accordingly. The lamps represented on the graphical display will light as on the actual controller. The time lag between turbine response and graphical display response is only two to three seconds In the original version of this software. A newer version of this software will have a marked decrease in this response time, to about one second or less. However, for most purposes even a three-second response is very close to a "real time" approximation.

Figure 8 shows the Diesel Generator Control panel. Two switches are provided for easy start-up of the generator. Once activated, the diesel engine can be observed running by the flashing of its output shaft. This gives an excellent illusion of a rotating shaft using only two dimensions. Control lamps tell the operator when the engine is running and when the generator is producing.

Highlighting the generator's control enclosure and pressing the Enter button will result in a display of the diesel/generator's control system. See Figure 9 for details.

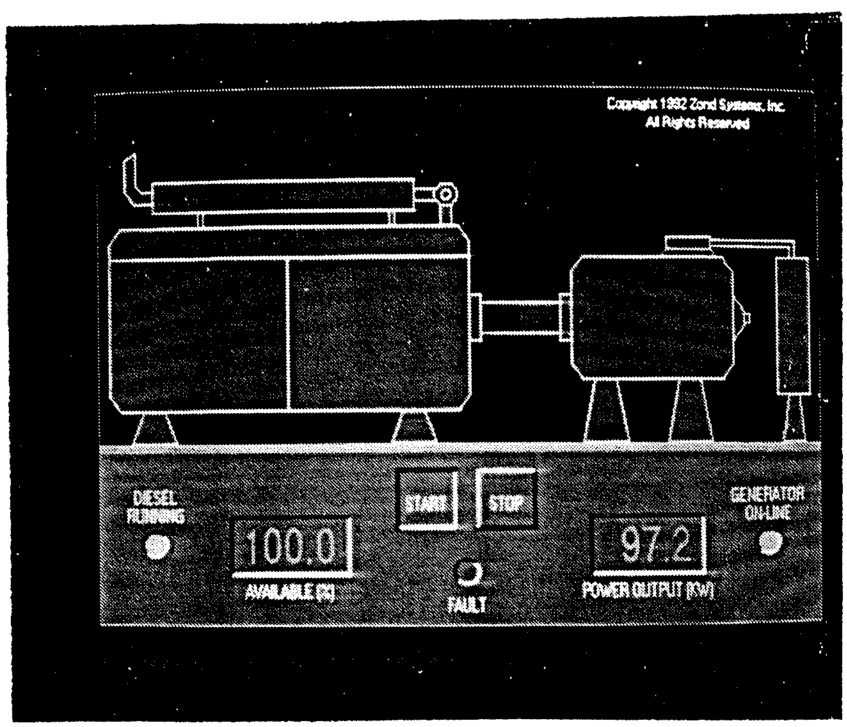


Figure 8: DIESEL CONTROL PANEL

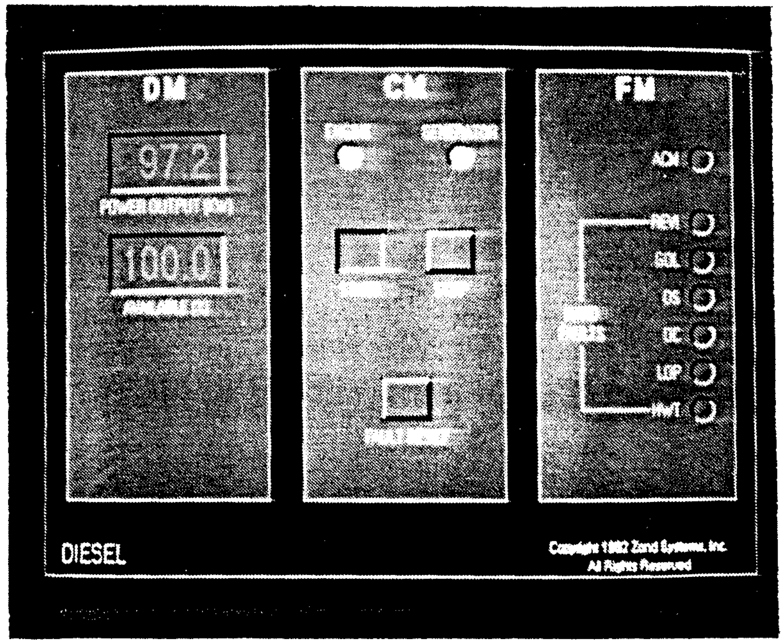


Figure 9: DIESEL CONTROL PANEL

Finally, the meteorological tower is represented by a view looking down upon the wind vane and anemometer (Figure 10). During wind speeds that will cause the anemometer cup to rotate, it will rotate on the screen of the graphical display. Similarly, the wind vane will change positions slightly in response to changing wind conditions. The speed of these changes is not tied directly to changing wind speeds but rather to average wind speed and direction changes. However, the effect is very similar to what can be viewed from the field by a technician or turbine operator. Actual wind speed and direction values (five-minute averages) are also displayed for operator convenience. A secondary screen for the meteorological tower is shown in Figure 11.

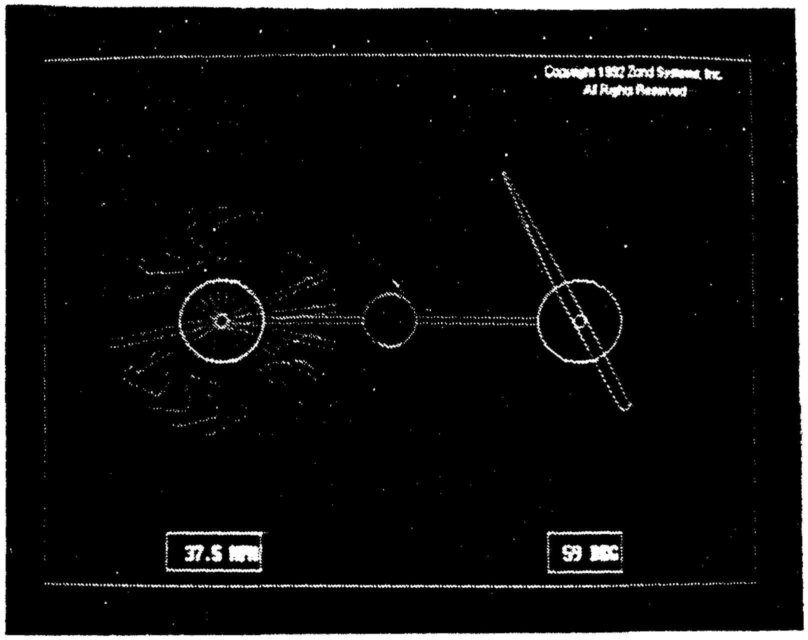


Figure 10: VANE AND ANEMOMETER SCREEN

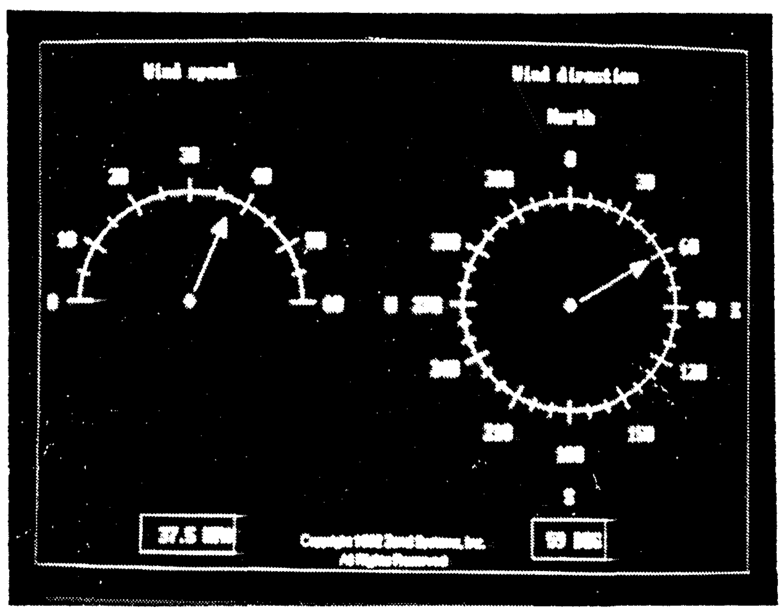


Figure 11: WIND SPEED AND DIRECTION SCREEN

Due to the advancement of computer technology, this type of system can be installed for remote wind park operations at a minimum of expense compared to what was required as little as three years ago. The operation of this type of system is intuitive and requires little operator training, aside from the normal wind turbine technician training level. Operator confusion when faced with a large array of tabular data is no longer a problem. The amount of data shown and displayed on this system is easily "captured" and understood by the computer operator. This leads to an increase in wind turbine performance due to increased availability.

UTILITY PENETRATION

An Independent Power Producer (IPP) will have various effects on the utility's power and distribution system when it connects in parallel. There are various criteria on both sides of the line that will change, depending on the power resource, where the connection is made, and the amount of power the IPP plans to produce.

Zond Pacific has a one-megawatt power purchase contract with Maui Electric Company on Molokai. Because Molokai's system load is small, certain limitations exist regarding how much wind energy can be accepted by Molokai's grid at any particular time.

Molokai's Systems

The MECO power plant on Molokai is located at Palaau. It is composed of four Cummins one-megawatt diesel/generator sets, individually housed, and two 1,200 kW Caterpillar diesel generators. There is also a 2.3 MW gas turbine that operated in conjunction with a now extinct biomass plant. The gas turbine is operated in emergencies and as back-up during maintenance, but its efficiency is low.

Total generating capacity is approximately 8.7 MW. Annual peak load is almost 6 MW, while average minimum load was 2.7 MW. The lowest minimum load was 1.32 MW. A projected peak load of 6.5 MW is anticipated by 1995. The Molokai Power System is manually dispatched on a 24-hour basis.

Wind Diesel System Design and Interconnection

In early 1991, Zond engineers and local electrical engineering consultant ECM, Inc. negotiated the design criteria and characteristics of the wind/diesel hybrid interconnection and associated hardware and software. It was determined that MECO would provide and install the overhead metering pole, the underground riser pole, and associated fixtures and equipment. MECO would also provide, install, and terminate the underground cable from the riser pole to Zond's transformer in accordance with its single line drawing. This would be paid for by the project and turned over to MECO/Molokai.

The interconnection point would occur at the strain insulator on the line side of the primary cross-arm of the metering pole. Upon interconnection completion, Zond retained responsibility for the maintenance of the interconnecting facilities.

Zond provided the high voltage transformer rated 12.47 kV and 480-V/277-V 450-KVA delta Y configuration. A metering package (including all PT's and CT's) was positioned on the 480 V customer side to monitor kWh/kW and KVARH. A 400-amp, 15-kV shunt trip recloser, SCADA-controlled, from Palaau Power Plant, with reclose feature disabled, was provided on the 480-V side by MECO and paid for by Zond. An under voltage device was also included on the Zond side of the recloser to allow closing on a dead bus condition only.

An enable/disable switch at Palaau Dispatch allows MECO Molokai Division to disconnect the system from the line instantaneously during emergency conditions. Molokai Dispatch was equipped with a dedicated personal computer and appropriate software and modem to monitor all the operational characteristics of the system 24 hours a day.

The phone line connection was a weak link in the project's communication system. The phone line installed in the early 1980's was an unshielded, 3-wire single-circuit line. Only one entity could communicate with the system at any one time. MECO required 24-hour observation, thus requiring Zond to call Dispatch to log off the system enabling Zond to log on and run through its daily system check. Although tedious in the beginning, the system proved to be extremely reliable, and early multiple daily checks by Zond were soon reduced to an early morning once-a-day surveillance.

Penetration

Zond's purchase power contract is for one megawatt, yet only 300 kW of wind energy capacity were installed. Limits on the project size reflected the ability of the Molokai division to absorb wind energy effectively into its system. Allowing maximum penetration with minimal curtailment is highly desirable. To have the system and the wind resource available and unable to sell power to the utility constitutes an uncontrolled loss of revenue. Any loss of potential revenue is undesirable. With a curtailment clause in the purchase power contract, financial institutions balk at an undefined ability to not sell power. Any instantaneous system shutdown by a utility switch, especially if repeated regularly, creates excess fatigue on components.

The concerns and criteria revolving around curtailment and penetration are guided by daily load requirements, site-specific Transmission and Distribution (T & D), capacity of the system relative to wind capacity, site geographical location relative to the utility generation plant, and the location and demand of the system loads throughout the utility system.

An understanding of the Molokai wind/diesel limits requires the evaluation of power (kW and KVAR) flows in the T & D system and the generation system during peak and off-peak load conditions, and during various line, transformer, and generation or load outage conditions. Wind energy is an intermittent or unscheduled source of power to the utility. Typical unconstrained kilowatt output of wind energy will vary as a function of variable wind speed. Under certain theoretical operating conditions, a penetration limit has been determined to be between 5% to 10% of the Hawaii utility systems. Cumulative wind penetration up to 5% of the annual utility system peak load should operate unconstrained. Economic viability and system stability are the concerns above 5% penetration. In most cases the curtailment penetration issue focuses on the minute to minute coincident wind farm kilowatt output fluctuations during normal everyday operating conditions, and nighttime off-peak low load periods when penetration may more than double, that occurring during the day or on peak loads. Molokai off-peak period is between 8:00 p.m. and 6:00 a.m. Lowest loads begin after 10:00 p.m. Over the year test period, using hourly averages, the Molokai wind/diesel produced over 200 kW or more continuous output 201 times, or 2.3% of the year's time. The 200 kW hourly average was selected for nighttime low load comparison. The 200 kW reflect the ratio of 7% to the average nighttime load of 2,700 kW, which represents the medium percentage of theoretical load penetration. At any of these 201 times, actual penetration limits varied from 4.6% to 10.7%. (See Appendix VIII.)

According to Maui Electric/Molokai, during the one-year test period, no instances occurred where high wind energy penetration required wind plant curtailment. (See Figure 13, Utility Penetration graph.)

The wind/diesel system occasionally reached an unconstrained penetration greater than 10%. Ten percent was achieved once in the year, December 4, 1992, and off-peak penetration averaged 6.8% for the nighttime low-peak period when the turbines were producing more than 200 kW.

The dynamics of the induction-type wind turbine dictate its requirement to follow frequency and phase as provided by the quality of power by the utility. Frequency excursions above .2 Hz may cause false tripping on the utility side. Frequency excursions from the normal 60 Hz are the result of short-term mismatches between generation and load. False tripping has not been experienced during systems operation. In most cases, a load fluctuation is followed by appropriate governor action so that generation again balances load. Molokai's system has handled a 1,300 kW load loss on the island's east end. Response time to full recovery was 1/2 second. The power plant adds and drops a 500 hp water pump two times a day with no problem.

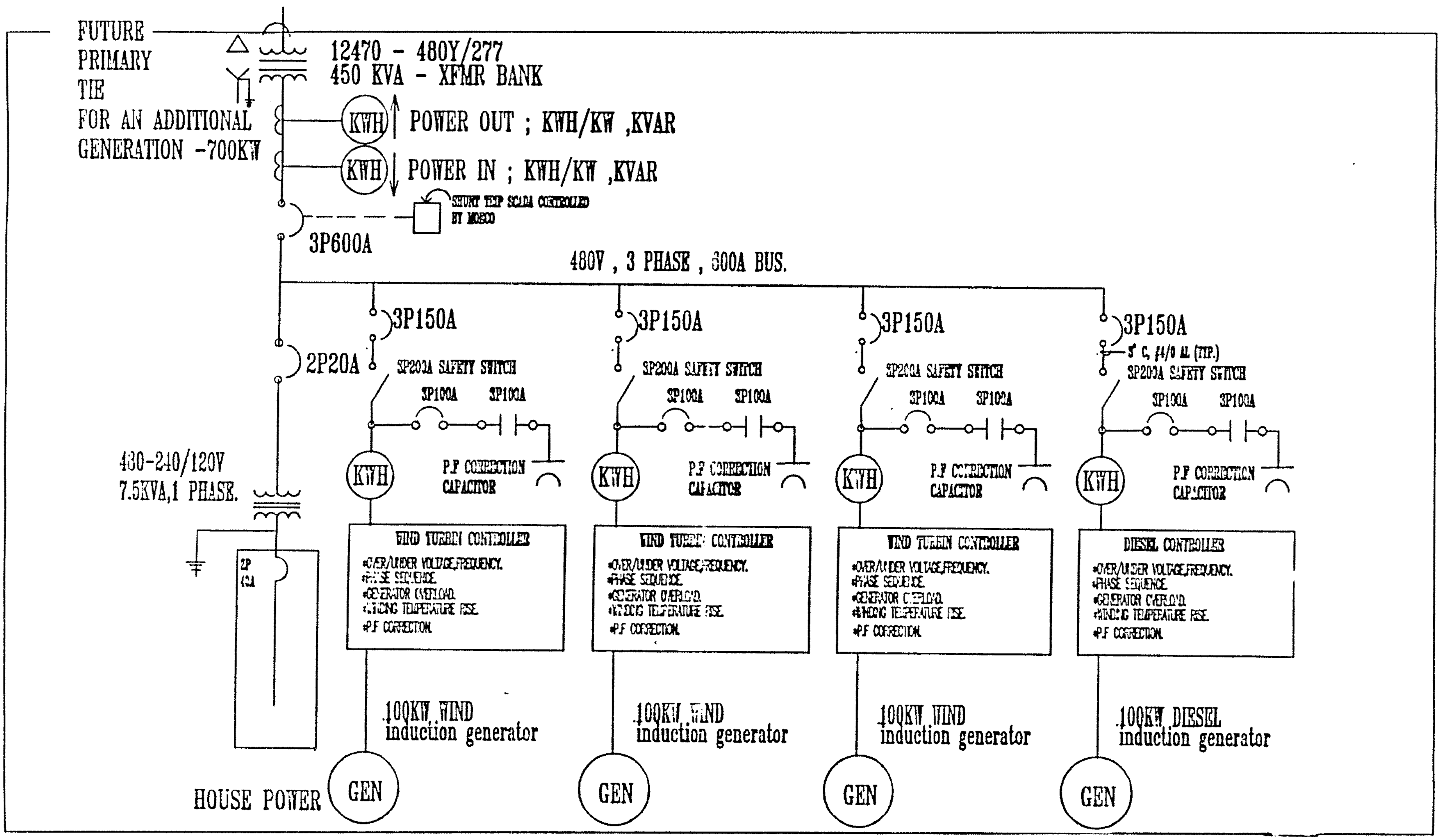


Figure 12: PRELIMINARY SINGLE-LINE DIAGRAM

The Cummins diesels at Palaau are fairly new and can respond very quickly to various load changes and the system has not been adversely affected by frequency excursions or out of phase situations.

To enhance penetration of intermittent resources into Hawaiian utility systems, the utility will need to take a more active and cooperative operational role. The utility, because of non-ownership and liability concerns, will not dispatch the wind plant. They will shut down the system, but will not switch back on. A more cooperative relationship of dispatching banks or multiple wind turbines could allow higher penetration. Outer island utilities, including Molokai, are all manually dispatched. Automatic generation controls (AGC) are commonly used throughout large and small utilities worldwide. Cost for the addition of an AGC is high, and who pays for the system is the concern. The utility feels that if an independent power producer (IPP) benefits by selling more power to the utility (increased penetration), they should pay for the AGC. The IPPs feel that any utility of Hawaii's size should already have an AGC, allowing for higher operation efficiency, system control reliability, and lower equipment fatigue.

Higher wind plant power penetrations can also occur by operating MECO/Molokai diesels that have droop controls, enhancing the system's ability to handle ramping fluctuations. This operational change will have economic penalties based on the hourly system fuel cost increases resulting from altering the economic dispatch of different generation. The question is then, who pays for the cost differences if the IPP power penetration into the utility is significantly increased.

Due to Hawaiian utility isolation, penetration will always be a considerable factor in determining the quantity of any unscheduled power resource which can be effectively absorbed into the utility system. A priority methodology has been established to rank unscheduled IPPs. Priority to sell power is determined by the effective start dates of power purchase agreements. The most recently approved contract is the first to be taken off line if penetration becomes a problem.

System Curtailment Not Due to Penetration

Three separate curtailment occurrences have occurred during the operation of the wind/diesel plant. The first was the loss of the phone line by Hawaiian Telephone due to storm damage to the island's west side system. Service was unavailable for over one week, causing Molokai Dispatch to disconnect. The turbines were able to provide power, but Dispatch, being unable to monitor the wind/diesel, desired the disconnect. The second curtailment occurred for a few hours on July 22, 1993 after the official one-year test period was over. The winds were very high and the wind/diesel was producing over 330 kW. The capacitors on the individual turbines are designed with a nominal pre-set range of approximately 95 KVAR. As the power output of the turbines increased, the capacitor's ability to meet power correction requirements was lagging and the system required more reactive power from the utility. According to MECO/Molokai, the utility's normal power factor is 95% to 96%, and at this particular time period power factor was lowered to 92% to 93%. Zond designed a nominal power factor to be approximately 95%.

The third curtailment occurred for a two-week period between August 30, 1993 and September 15, 1993, also after official test period. The fan on the computer power supply failed, causing the system to overheat, losing visual monitoring of the wind/diesel plant. Here again, the turbines were available but the communication link was down. The system was completely repaired and serviced and is again back on-line.

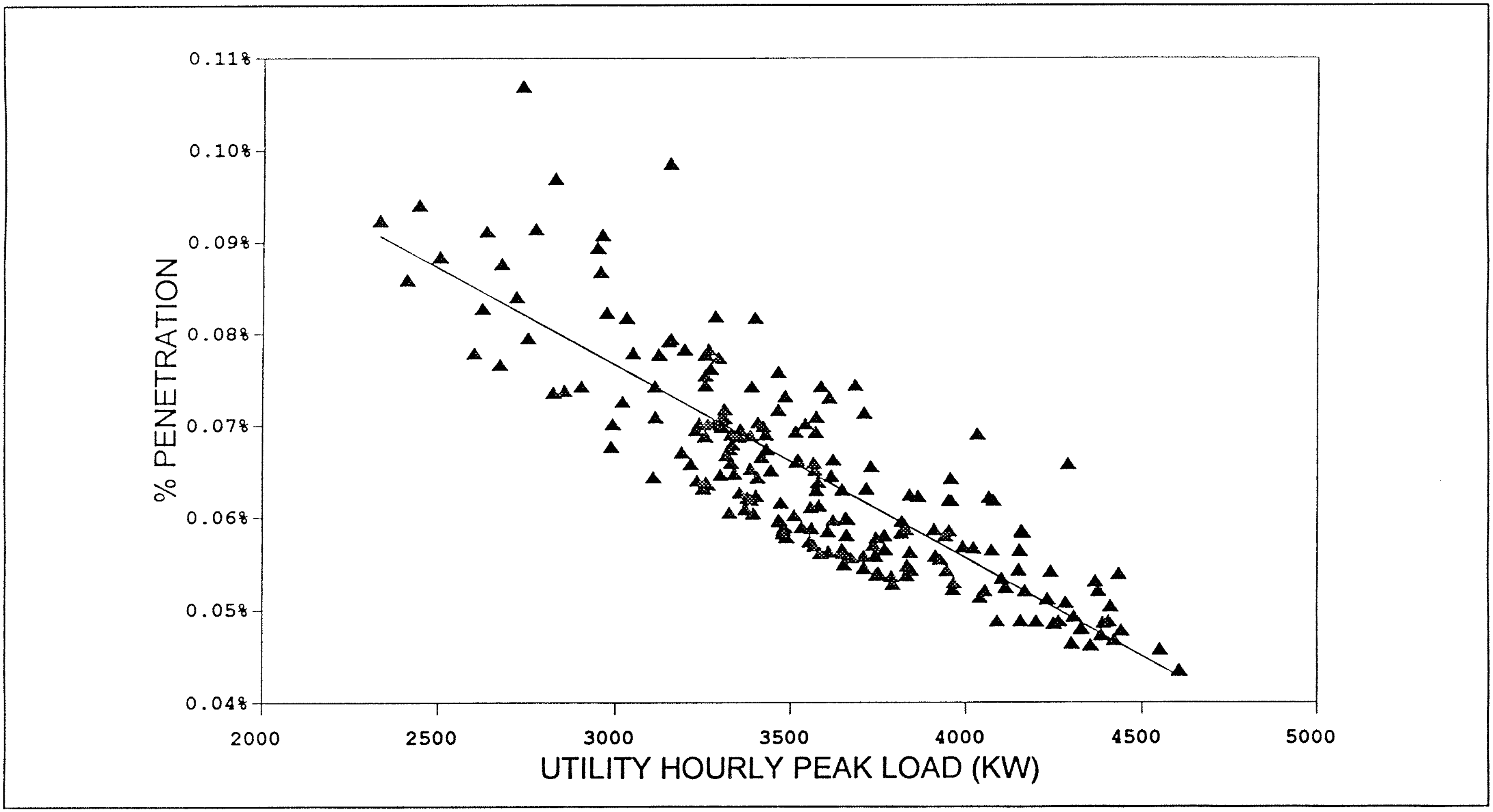


Figure 13: NIGHTTIME HIGH AVERAGE UTILITY PENETRATION

Each pyramid figure represents a system hourly average occurrence of 200 kW during off-peak hours. Penetration above 5% and up to 10% occurred several times without adverse effects to MECO such as instability or false tripping. Higher penetration may thus be acceptable.

PROJECT ECONOMICS

Development Costs

Many excruciating hours are spent on attempting to establish a project's overall development cost. Besides the actual attributable development costs, there are always pre- and post-development costs associated with the project. Sometimes costs are assigned to a general development fund as one project of many to be developed in a particular system area.

The Molokai wind/diesel project is a project that required several years of project studying, feasibility analysis, and applying for grants before the project broke ground. Zond Pacific Inc. over several more years and expenses established itself as a renewable energy developer in the state. Years of negotiations were required to acquire land, negotiate purchase power contracts and become part of Hawaii's Independent Power Producers community. The costs associated with visibility in the industry marketplace are generally not reflected in project development costs.

Zond has listed its actual development costs attributed solely to the Molokai wind/diesel project development. (See Appendix VII.)

With the unique problems associated with Molokai's remoteness, Zond completed the project at 5.6% over budget on a $592,000 estimate of cost. It is interesting to note that several variations of cost category occurred where some costs were much more than estimated while other costs were less than predicted.

Project cost per kilowatt installed came to $1,483. When supervisory project management, administration, construction consulting and support, attorneys' fees, and project travel, costs exceed $628,017, or $1,570 per installed kilowatt. These costs reflect the project's remoteness, size, the diesel component and research and development. Costs per kilowatt will vary with the size of the system. The diesel component ran about $600 kW, while the wind turbines installed cost were approximately $1,775 kW. Future commercial-size wind/diesel should reduce costs to approximately $1,200 kW.

In 1992, the wind/diesel system produced more than 760,000 kWh, saving 59,561 gallons of Diesel #2 at $0.77/gallon or $43,320. These are utility fuel prices. Zond's fuel price is $1.30/gallon. Fuel only avoided costs from MECO, Molokai division were $0.057 kWh.

Revenue Accounts

Upon PUC approval of the wind/diesel Power Purchase Contract, a "floor price" of $.0685 kWh was established, reflecting the avoided cost as calculated for that quarter. During the system's operation, the actual avoided cost for Maui Electric/Molokai was $.063 kWh. Thus the price paid by MECO/Molokai was $.0055 kWh higher than avoided cost.

A revenue account was established to receive utility power purchase payments. All system charges, including maintenance and operations, were paid from this account. Table 1 shows typical maintenance activity, action, and date. Pacific Electro-Mechanical provided all maintenance service during the project's operation.

The revenue account is divided by DBED's participation portion of $242,000 and ZPAC participation of $351,000. With total project costs at $593,000, DBED's pro-rata portion is equal to 40.8%, while ZPAC's portion equals 59.2%. These percentage portions were utilized to allocate costs and revenues.

Yearly income statements for 1992 and 1993 are shown on Tables 3 and 4. These tables show kilowatt hours produced (combined) as well as revenues less costs and expenses.

Figures 14 and 15 graph monthly kilowatt hour production.

Table 2: 1992-1993 CASH FLOW STATEMENT OF REVENUE ACCOUNT

	1991	1992	1993	1994	All Years	Allocation of Operations State of Hawaii	Allocation of Operations Zond Systems
Bank Account - Beginning	1,000	3,248	21,267	50,442	1,000	41%	59%
OPERATIONS:							
Wind Turbine Electric Revenue-net of usage	0	31,715	51,593	1,396	87,704	34,567	50,136
Maintenance and repair	0	8,095	16,052	4,384	28,532	11,641	16,891
Generator fuel	0	1,651	259	0	1,910	779	1,131
Interconnect - Elec usage				1,096	1,096	447	649
Total Operations and Maintenance	0	9,746	16,311	5,480	31,537	12,867	18,671
Royalty to Molokai Energy	0	1,435	4,353	565	6,353	2,592	3,761
Bank services Fees			154		154	63	91
Total costs and expenses	0	11,181	20,818	6,045	38,044	15,522	22,523
Net Income (Loss)	0	20,534	30,775	(4,649)	46,660	19,046	22,614
INFLOW: State of Hawaii advances	175,906	53,894	0	0	229,800		
Outstanding Total				(12,200)	(12,200)		

Table 3: 1992 MONTHLY INCOME STATEMENT

ZOND PACIFIC
Molokai Turbine Program
Statement of Income
10/06/93 ZP-STMT3 JLH

	1992 BY MONTH											1992	1993		One Full
	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC	YTD	JAN	FEB 18	Year @ 02/18/93
KWHS- STMT - Turbines	4,800	56,800	38,400	41,200	76,400	84,462	114,050	79,010	34,833	82,848	70,416	683,219	40,131	35,840	759,190
- Diesel						1,538	750	990	767	752	2,784	7,581	1,469	516	9,566
AVERAGE RATE PER KWH-net of usage	0.059	0.064	0.058	0.061	0.065	0.065	0.065	0.063	0.059	0.063	0.063	0.063	0.059	0.057	0.063
REVENUES:															
Wind Turbine Electricity-net of usage	283	3,628	2,220	2,501	4,931	5,572	7,501	5,079	2,097	5,304	4,581	43,697	2,464	2,064	48,225
Total Revenue	283	3,628	2,220	2,501	4,931	5,572	7,501	5,079	2,097	5,304	4,581	43,697	2,464	2,064	48,225
COSTS AND EXPENSES:															
Download data	0	100	102	540	135	135	135	0	102	135	135	1,519	135	0	1,655
Diesel Generator maintenance & repair	0	677	203	508	0	135	169	988	0	271	354	3,306	0	0	3,306
Maintenance & repair - other	0	609	288	440	136	1,033	135	203	1,928	1,016	339	6,127	394	237	6,758
Generator Fuel	540	0	585	0	0	0	0	0	526	0	259	1,910	0	0	1,910
Training - personnel	0	474	0	0	0	0	0	0	0	0	0	474	0	0	474
Total Operations & Maintenance	540	1,860	1,178	1,488	271	1,303	440	1,191	2,555	1,422	1,087	13,336	529	237	14,102
Royalty to Molokai Energy	0	0	0	0	293	0	0	1,142	0	0	943	2,379	0	0	2,379
Admin costs	0	15	800	0	0	0	0	0	0	0	0	815	0	0	815
Total costs and expenses	540	1,875	1,978	1,488	564	1,303	440	2,333	2,555	1,422	2,031	16,529	529	237	17,296
Net Income (Loss)	(256)	1,753	242	1,013	4,367	4,269	7,061	2,746	(459)	3,882	2,550	27,168	1,935	1,827	30,929

Table 4: 1993 MONTHLY INCOME STATEMENT

ZOND PACIFIC
Molokai Turbine Program
Statement of Income
10/06/93 ZP-STMT4 JLH

	1993 BY MONTH												
	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC	YTD
KWHS- STMT - Turbines	40,131	44,155	65,292	95,600	81,598	54,367	92,000	65,599	0	0	0	0	538,742
- Diesel	1,469	645	708	0	2	33	0	1	0	0	0	0	2,858
AVERAGE RATE PER KWH-net of usage	0.059	0.058	0.063	0.063	0.064	0.058	0.063	0.062	0.000	0.000	0.000	0.000	0.062
REVENUES:													
Wind Turbine Electricity-net of usage	2,464	2,581	4,183	6,048	5,204	3,128	5,805	4,064	0	0	0	0	33,476
Total Revenue	2,464	2,581	4,183	6,048	5,204	3,128	5,805	4,064	0	0	0	0	33,476
COSTS AND EXPENSES:													
Download data	135	135	135	135	135	135	135	0	0	0	0	0	946
Diesel Generator maintenance & repair	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance & repair - other	394	237	136	1,456	745	339	0	0	0	0	0	0	3,307
Generator Fuel	0	0	0	0	0	0	0	0	0	0	0	0	0
Training - personnel	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Operations & Maintenance	529	372	271	1,591	880	474	135	0	0	0	0	0	4,253
Royalty to Molokai Energy			1,083			507							1,590
Admin costs				800									800
Total costs and expenses	529	372	1,355	2,391	880	981	135	0	0	0	0	0	6,643
Net Income (Loss)	1,935	2,209	2,828	3,657	4,324	2,147	5,670	4,064	0	0	0	0	26,833

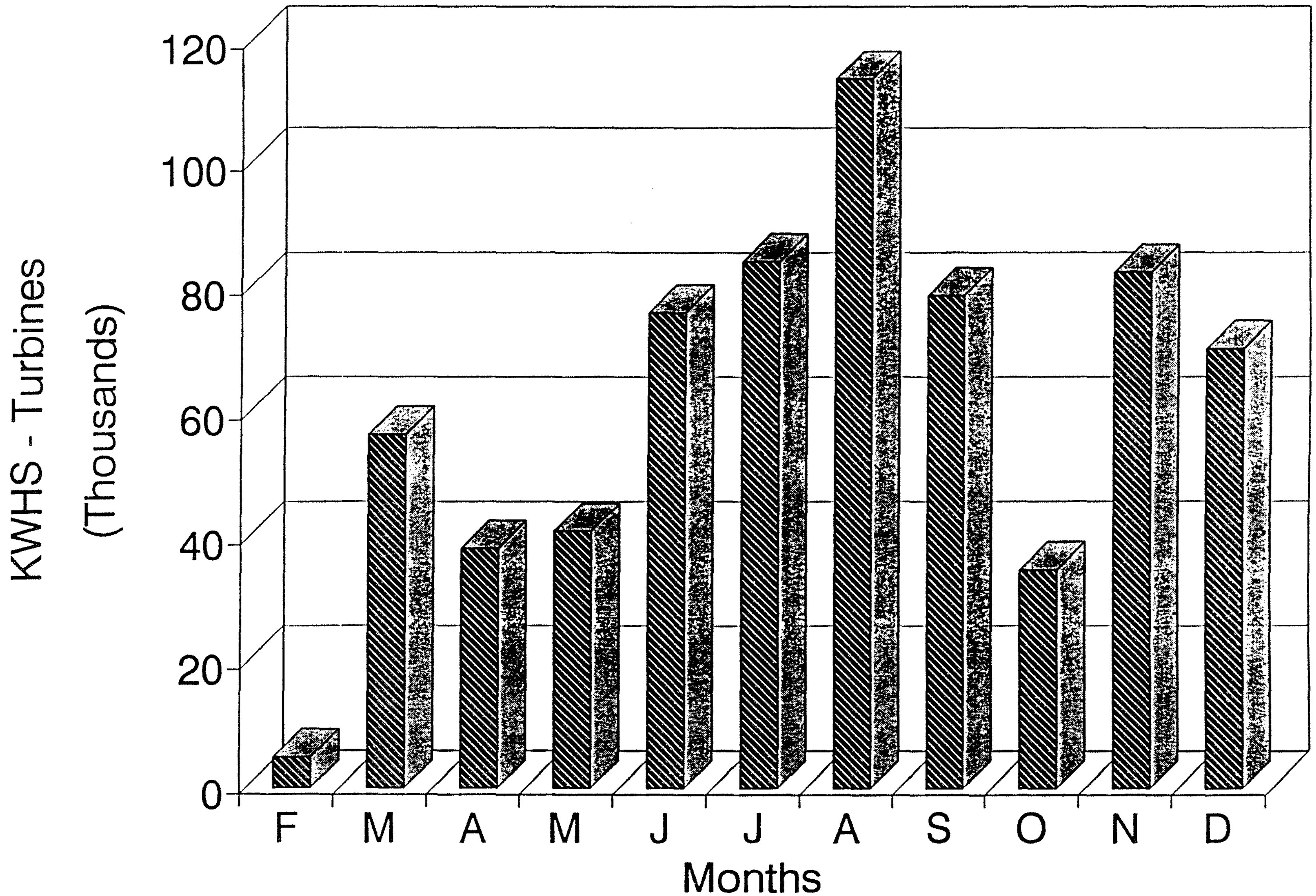


Figure 14: Monthly kWh Production - 1992

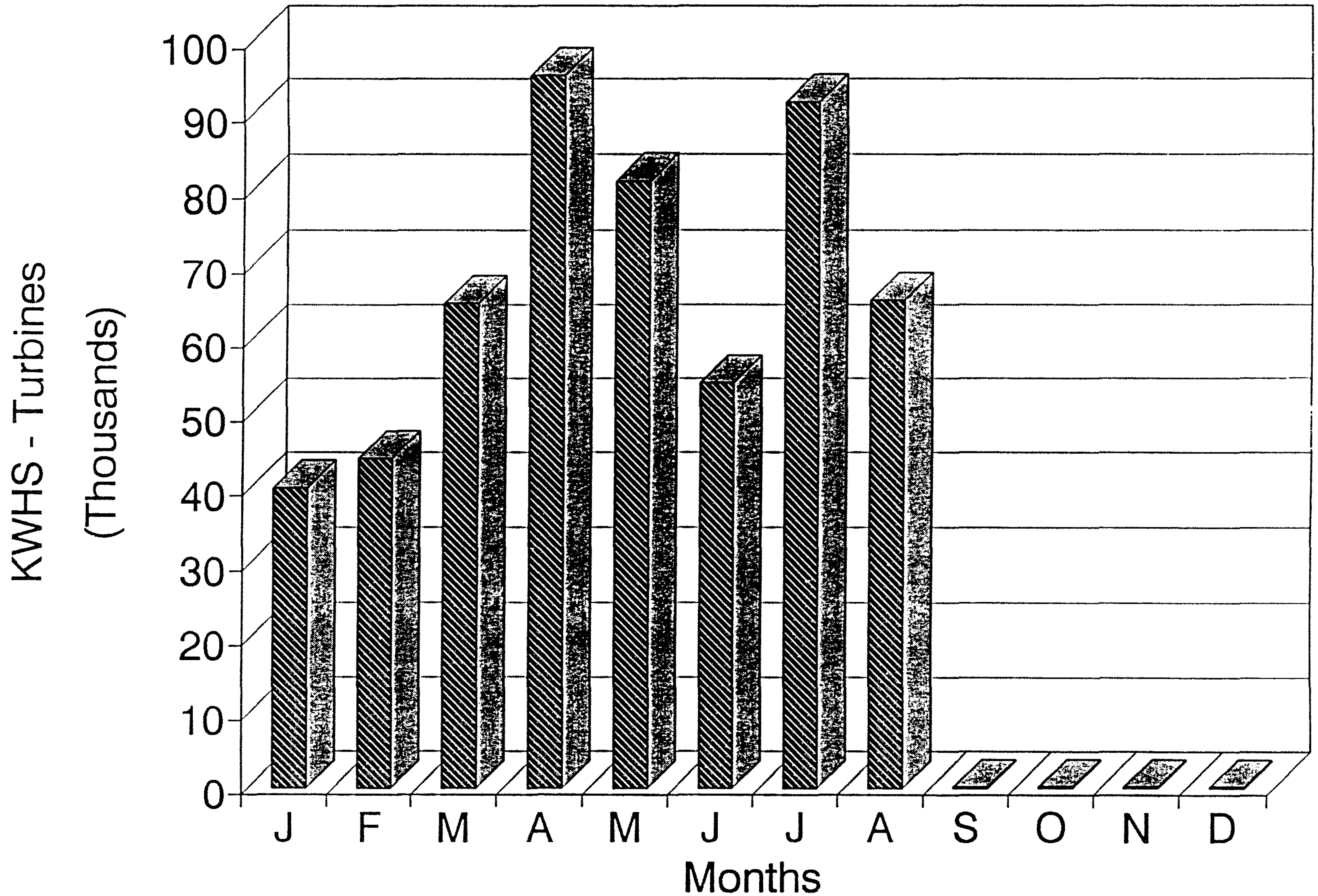


Figure 15: Monthly kWh Production - 1993

WATER PUMPING SIMULATION

The Molokai wind/diesel performed up to all expectations. Zond believes the success of the Molokai wind/diesel project's operation and performance signifies the potential to develop a commercial scale wind/diesel project in Hawaii. The wind/diesel system's availability at 98.7 percent should enhance the desire to build a wind/diesel system in cooperation with the different counties' Department of Water Supply and the utilities.

Previous wind energy and water pumping studies have designated the Alealoa Water System above Napili in the West Maui Mountains as a very favorable wind/diesel hybrid project site. It is at this site with its five water pumps that we will be simulating water pumping characteristics.

Maui Land and Pineapple Company owns all the land surrounding the county's water pump stations in the Alealoa area. Of the five pump stations, two have adjacent 100,000-gallon, ferrous cement, above-ground water storage tanks. The other three pumps stand alone. All the pumps have an electric control and maintenance shed adjacent to the pumps.

Zond Pacific has a long-term lease on approximately 250 acres of pasture land ideal for wind farm development just about 3,000 lineal feet above the various pumping stations.

Negotiating Power Purchase Contracts (PPC) with the Maui DWS and an excess PPC with MECO, a commercial wind/diesel project could be developed. The system will provide an alternative to just fossil fuel water pumping and will provide long term economic and security benefits to the water consumers of Hawaii.

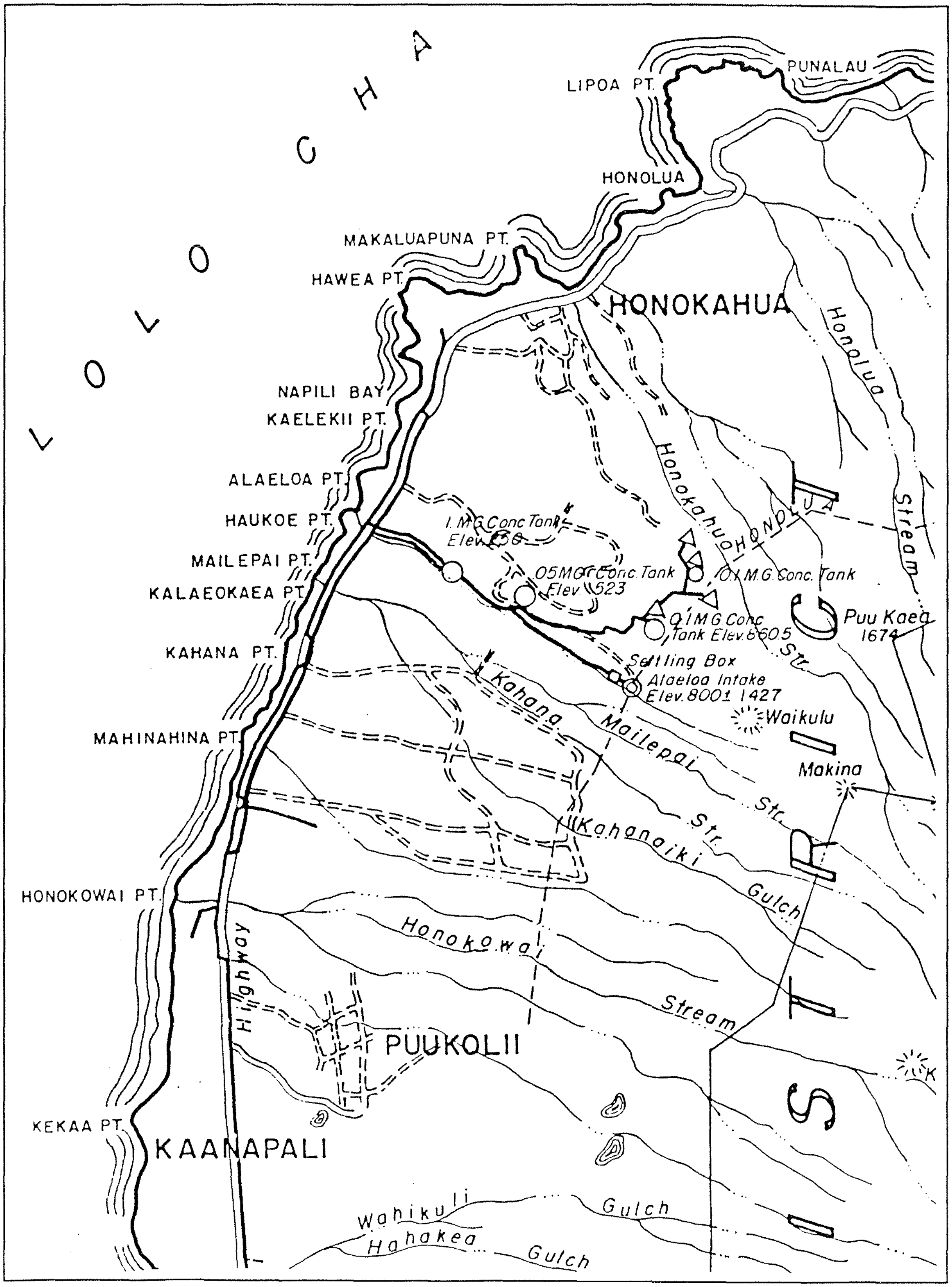


Figure 16: ALEALOA WATER SYSTEM, MAUI

Table 5:

County of Maui Board of Water Supply Monthly Source Record

for Alealoa Pump Stations

Water Pumped in Thousands of Gallons (000) 1992

Pump Name	Napili A	Napili B	Napili C	Honokahua A	Honokahua B
January	10,458	7,392	33,360	0	0
February	28,644	4,158	25,260	0	0
March	20,958	16,758	39,240	0	0
April	19,110	23,604	41,700	0	0
May	30,912	13,062	31,140	0	10,490
June	29,862	27,804	30,660	0	30,024
July	27,248	13,188	37,393	0	31,120
August	8,270	33,345	44,427	0	31,470
September	13,283	17,145	41,115	0	30,025
October	7,785	21,538	44,400	0	31,353
November	11,042	20,590	42,424	0	29,981
December	1,328	15,148	42,542	0	30,472
Year to Date	208,900	213,732	453,661	0	224,935
Same Time Last Year	18,018	9,996	29,280	0	0
Total Last 12 Months	208,900	213,732	453,661	0	224,935

Table 6:

County of Maui Board of Water Supply Monthly Source Record

for Alealoa Pump Stations

Water Pumped in Thousands of Gallons (000) 1993

Pump Name	Napili A	Napili B	Napili C	Honokahua A	Honokahua B
January	7,742	9,259	45,046	0	32,040
February	181	14,610	40,008	0	26,680
March	805	17,447	44,340	0	31,405
April	0	19,683	42,386	0	29,957
May	0	15,907	44,220	0	31,015
June	0	22,019	42,180	0	30,581
July	0	23,906	45,500	0	30,980
August	0	24,031	40,626	0	30,173
September	0	15,477	43,140	0	30,125
October					
November					
December					
This Year to Date	8,738	162,310	387,455	0	274,966
Same Time Last Year	13,283	17,145	41,115	0	30,025
Total Last 12 Months	28,804	219,585	586,821	0	306,772

The Alealoa Water System and Napili Pumps

The Alealoa water system is located in the Napili area of the West Maui Mountains. Two water resources are incorporated in the system. The first is a surface flow from the Honokahua area, and the second resource is via deep well Napili pumps.

The Alealoa intake and settling box receives its surface water from the Honokahua ditch. The ditch services Maui Land and Pineapple Plantation, the County of Maui, as well as Pioneer Sugar Plantation. The county of Maui's portion equals approximately 1,000 to 1,100 gallons per minute (gpm). The intake, with a turbidity meter, that automatically shuts off the water flow if turbidity is too high, is located at 800 feet above mean sea level (msl). During heavy rains the surface water becomes very silty, causing the shutdown of the ditch service. At this time additional deep well pumping is automatically added to satisfy water demand. From the intake an 8-inch, cast iron, cement lined transmission pipe travels around 4,000 feet to a 50,000-gallon mixing tank at 523 feet above msl. Flows are continuous at about 1.5 million gallons per day unless turbidity shuts the flow off.

The Napili pump station is just north of the Alealoa intake and constitutes the pumped ground water resource. There are five Floway vertical line shaft, oil lubricated, single speed, deep well centrifugal pumps.

Pump head varies between 800 feet above msl to 900 feet above msl.

All the pump motors are 480 V, 3-phase, four-wire induction motors transformed to the 1247 KV utility power lines.

Method of Operation

Two pumps, Napili B and C, run 24 hours continuously. During high turbidity when the surface water intake is closed down, or during high peak demand, a third pump, Honokahua B, will run simultaneously or as a substitution for Napili B or C. Napili A pump was always the lead pump station until recently, when the pesticide DBCP was discovered at higher than acceptable ratios. The Napili A station will remain off-line indefinitely. Honokahua pump A has been off-line for repairs for quite some time and re-entry to the system is unscheduled at this time.

Both Napili A and C have 100,000-gallon concrete storage tanks located at 860 feet above msl and 910 feet above msl, respectively. This Alealoa system supplies more than one billion gallons of water per year through 6,000 feet of 12-inch ductile iron pipe to the 50,000-gallon mixing tank at the 523 foot above msl elevation. The surface water transmission line and the Napili pump system line both meet at the mixing tank before flowing to the Alealoa one million gallon concrete holding tank.

Table 7:

System Component Characteristics

of Alealoa Pump Stations

Pump Name	Napili A	Napili B	Napili C	Honokahua A	Honokahua B
Pump No.	569	570	571	572	573
Tank No.	105	--	111	--	--
Tank Type	Conc.	--	Conc.	--	--
Elevation AMSL	860	800	900	800	760
Pump Brand	Floway	Floway	Floway	Floway	Floway
Motor	GE	GE	GE	GE	GE
Pump Size H.P.	250	250	350	250	250
Voltage	480	480	480	480	480
GPM	700	700	1,000	500	700
Start Amp	287	288	403	288	403
Operation Amp					
RPM	1,800	1,800	1,800	1,800	1,800

The Alealoa one million gallon ferrous cement tank at 270 feet above msl receives its water source via a 16-inch ductile iron, cement lined pipe traveling 3,000 feet from the upper mixing tank. At the mixing tank and again at the one million gallon tank, there will be various combinations of flow from the Napili pumped ground water and the Alealoa intake surface water, depending on turbidity, demand, and pump availability. Various flow combinations reflect the ability to utilize different combinations of adding more wind energy, water storage, or both to help reduce utility power participation as it relates to PURPA and demand. Listed in the following table are some possible flow combinations.

Table 8: VARIOUS FLOW COMBINATIONS FROM THE ALEALOA WATER SYSTEM (IN GPM)

500	1,500	2,100
700	1,700	2,300
1,000	1,100	2,400
1,400	1,800	2,800

The entire system is designed to backfill tanks starting with the one million gallon tank to shut down the pump and/or surface flows. When the one million gallon tank fills, only at night, if ever, then backfilling to the 50,000 tank occurs. When the 50,000 tank is full, backfilling to the Napili A tank fills and the Napili A or B pump shuts off, and similarly with Napili C tank shutting off Napili C pumps or the Honokahua pumps. Because of high demands on the system, backfilling has not been occurring, causing pumps to work on a 24-hour operation with pumps operating according to continuous demand. There are five pumps on the system, one of which is typically out of service. If more storage and larger wind energy capacity were incorporated, the backfilling process could be utilized effectively. Storage tanks would be filled and backfilled faster, shutting down pumps and maximizing storage. Water storage is less expensive and more cost controllable than purchasing fossil fuel power. Economic analysis would be required to find the ultimate combination of wind power and storage.

Diesel hybrid addition incorporates self-reliance and the ability to remove utility demand charges while provided wholesale power for system start-up and operation when wind is unavailable.

The Molokai Wind/Diesel Simulation for Water Pumping

The essence of the Zond designed Molokai wind/diesel system was to ensure reliability through a sophisticated, remote, and automatic control system. The wind portion of the system's availability at above 98% proves the automatic remote operation potential of the wind/diesel system.

Economic considerations, as seen at Lalamilo, Hawaii and, which would be similar to any wind only water pumping station, express the requirement for a dedicated diesel component. Because of high utility demand and/or standby charges, the costs are too high to the customer. A dedicated diesel removes the demand charges. Demand charges are those charges the larger customer pays for the utility to maintain the supply necessary to provide power to the customer's highest demand for any 15-minute period during the year. Whatever the highest demand is, the customer pays a fixed rate above $6.50/kW/month as an additional demand charge. A single pump with demand of 185 kW will be charged approximately $1,202/month. Utility intertie is still necessary to sell any excess power from the system, which is oversized due to the wind's intermittent nature.

Zond was unable to identify any small water pumps, below 100 H.P., with land available and in a good wind regime in the State that could have been used for the wind/diesel demonstration. Therefore, it was necessary to simulate the actual water pumping requirements and characteristics. The Alealoa water system was selected due to its location and twenty-four (24) hour pumping demand. It was also chosen because of its potential for actual commercial project development and implementation. The simulation used is the wind turbines' actual production. (See Appendix VI.)

Zond selected a one-month operational time in which the goal was to maintain a constant 95 kW. The output came from either the wind turbines alone, the diesel alone, or a combination of both. The electric motors that drive the pumps require constant power. Thus, whatever the pump/motor requires, the diesel must be capable of producing that demand, plus and a little more for start up. At any time the wind turbines alone, or the combination of the wind and the diesel, could be producing more than the 95 kW required by the pump. All excess power is sold to the utility at avoided cost or at a "floor price," whichever is higher, while the primary 95 kW would be sold to the Department of Water Supply at a pre-established price greater than the floor price or avoided cost. The system requires the wind turbines to have a capacity of three to four times the demand, as the annual capacity from the wind is about 30%. Excess sales of power are an integral part of the project's economics.

Data was collected on an hourly basis. The diesel would only operate for one hour at a time owing to the small, 350-gallon fuel tank capacity. In an actual wind/diesel hybrid, this would not be a limiting factor. A larger tank would be used. The computer would still show the diesel available and operating until the the proportion of wind energy exceeding combination of wind generation is over 95 kW and then the diesel would be shown to be switched off. In essence, it was already off; unless its running time was one hour or less. The month of June 1992 was selected because of good winds averaging at 20.54 mph.

The wind plant produced 96,990 kWh supported by 15,960 kWh from the diesel or 112,950 kWh total. Of the 112,950 kWhs, 44,550 went to the utility or 39.4%, as excess, exported for sale. The diesel produced 14% of the total kWhs and 23.3% of the simulated pump load. The wind plant produced 76.6% of the pump load and provided the rest to utility sales.

These percentages are important in that to remain a QF and fall within PURPA, the diesel or fossil fuel usage must not exceed 25%. If wind speeds average less, then either more wind turbines or larger water storage would be necessary or a biomass derived fuel could, and should, be incorporated. It would have been preferable to use a full year's operation for simulation since wind speeds vary. This would be more accurate to determine QF and economic status.

Appendix VI shows the hourly outputs of the system to produce the continuous 95 kW hourly average. It should be noted that this system does not require instantaneous diesel response when cold starting. The Alealoa system has enough storage for several hours. The diesel comes up to speed and full output in approximately one and a half minutes.

The following graphs show the typical (three separate days) wind/diesel hourly operational participation. The next table and two graphs represent monthly averages of component operational participation, including wind turbine production, the diesel and excess power performance. The simulation combined with the actual availability of the wind/diesel demonstrates that a wind/diesel system like Molokai's should be economically and technically successful at Alealoa The smallest Alealoa pump/motor would require 225 kW diesel with about 2,000 gallons of fuel storage and between 600 to 800 kW of wind energy. Alealoa already has 100,000 gallons of water storage, allowing sufficient time for diesel to cold start.

Appendix IX establishes a preliminary project economic evaluation using the Molokai wind/diesel's actual performance. To begin to show positive cash flow at least six V17's would be needed to operate one 185 kW demand pump. Alealoa (Napili) Pump "B" was modeled.

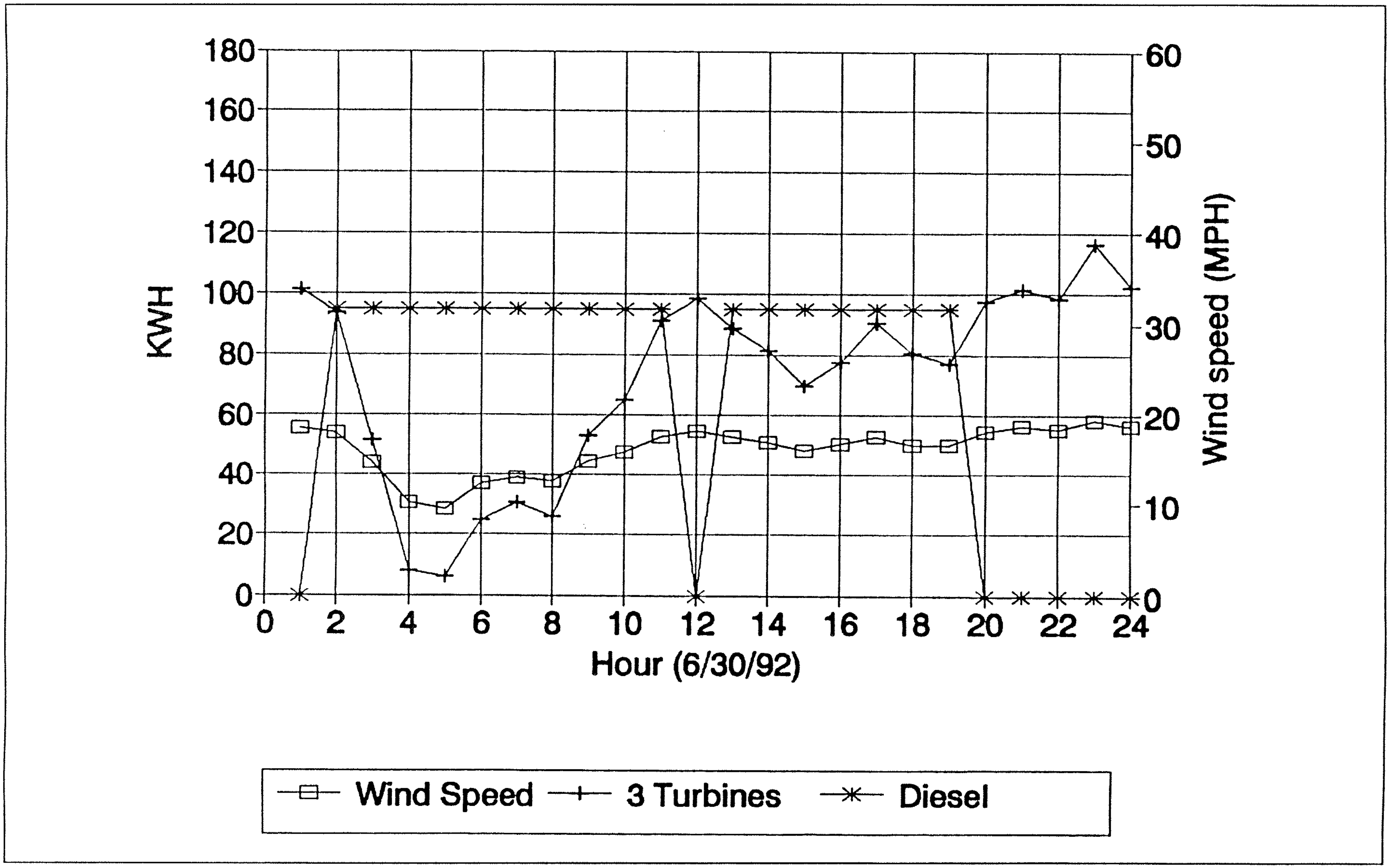


Figure 17: ONE-DAY WIND/DIESEL SIMULATION HOURLY PRODUCTION 6/30/92

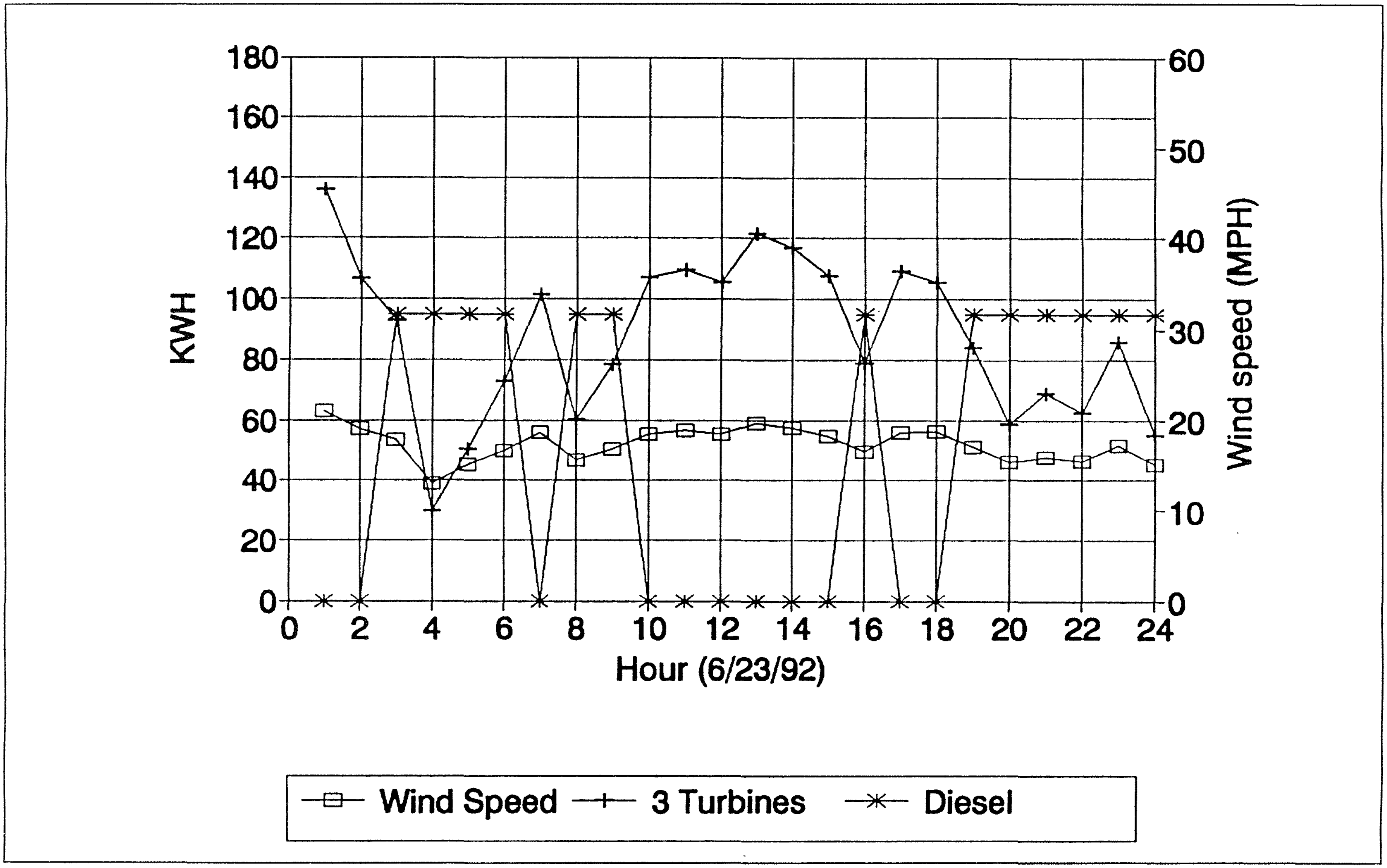


Figure 18: ONE-DAY WIND/DIESEL SIMULATION HOURLY PRODUCTION 6/23/92

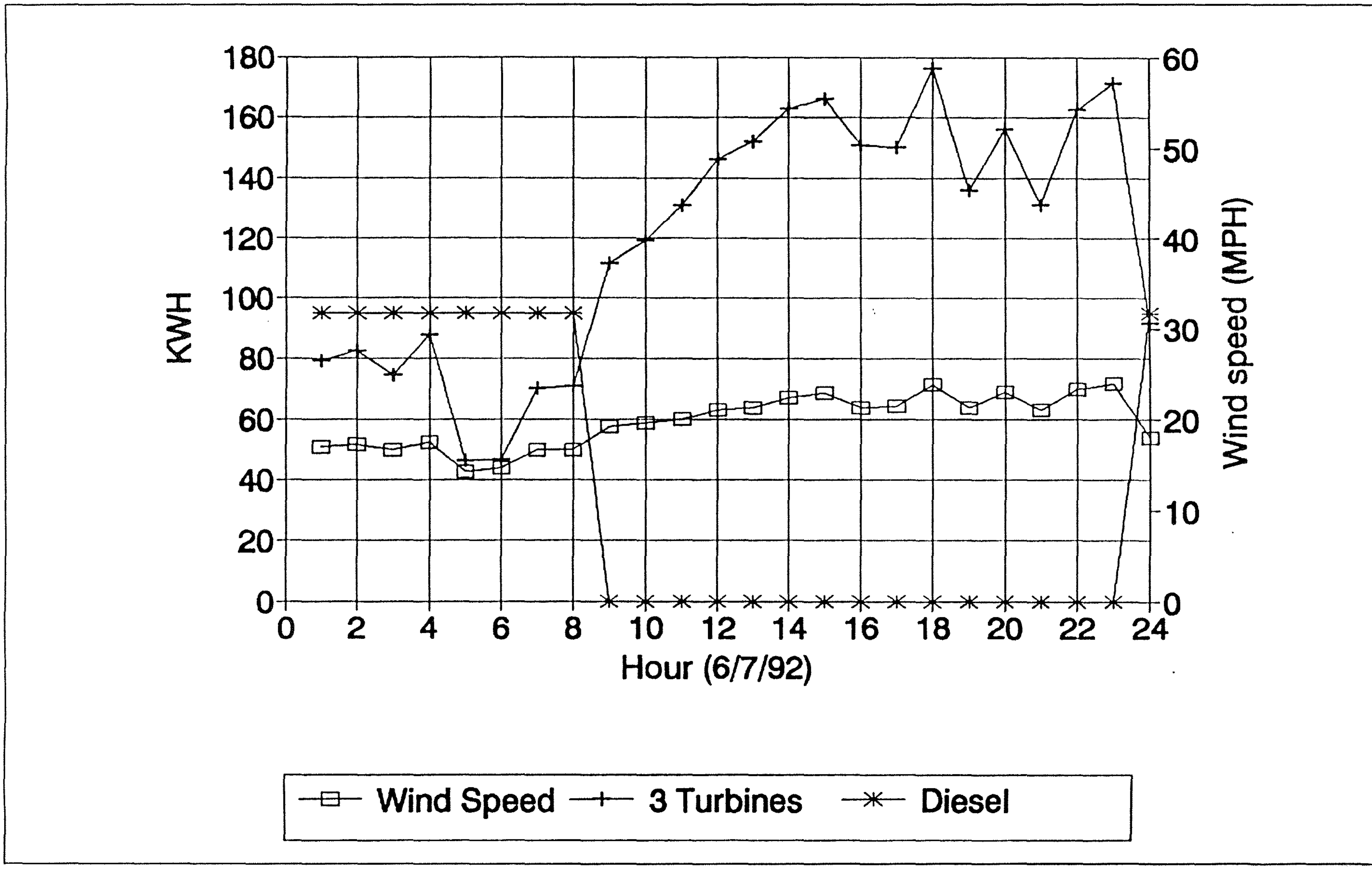


Figure 19: ONE-DAY WIND/DIESEL SIMULATION HOURLY PRODUCTION 6/7/92

Average Hour	MPH	3 Turbine Total KWH	Diesal KWH	Total KWH	Excess KWH
1	20.56	131.96	25.33	157.30	62.30
2	20.04	125.00	28.50	153.50	58.50
3	19.22	115.34	41.17	156.51	61.51
4	18.38	105.63	41.17	146.79	51.79
5	17.99	102.68	44.33	147.01	52.01
6	18.55	109.56	34.83	144.39	49.39
7	18.94	117.23	31.67	148.90	53.90
8	19.08	120.38	41.17	161.55	66.55
9	19.45	124.98	28.50	153.48	58.48
10	20.20	133.53	19.00	152.53	57.53
11	20.93	140.72	19.00	159.72	64.72
12	21.33	146.29	12.67	158.95	63.95
13	21.59	149.75	12.67	162.42	67.42
14	21.63	150.38	12.67	163.05	68.05
15	21.19	144.90	15.83	160.73	65.73
16	21.18	145.13	15.83	160.97	65.97
17	21.22	144.37	19.00	163.37	68.37
18	21.32	142.16	15.83	157.99	62.99
19	21.46	144.58	12.67	157.25	62.25
20	21.79	148.48	9.50	157.98	62.98
21	21.37	144.37	15.83	160.20	65.20
22	21.97	150.18	12.67	162.85	67.85
23	21.97	150.67	6.33	157.00	62.00
24	21.57	144.76	15.83	160.59	65.59
	======	=========	=========	==========	=========
Average day:	20.54	3, [illegible].03	532.00	3,765.03	1,485.03

Table 9: 24-HOUR AVERAGE POWER PRODUCTION FOR SYSTEM COMBINATION WIND/DIESEL

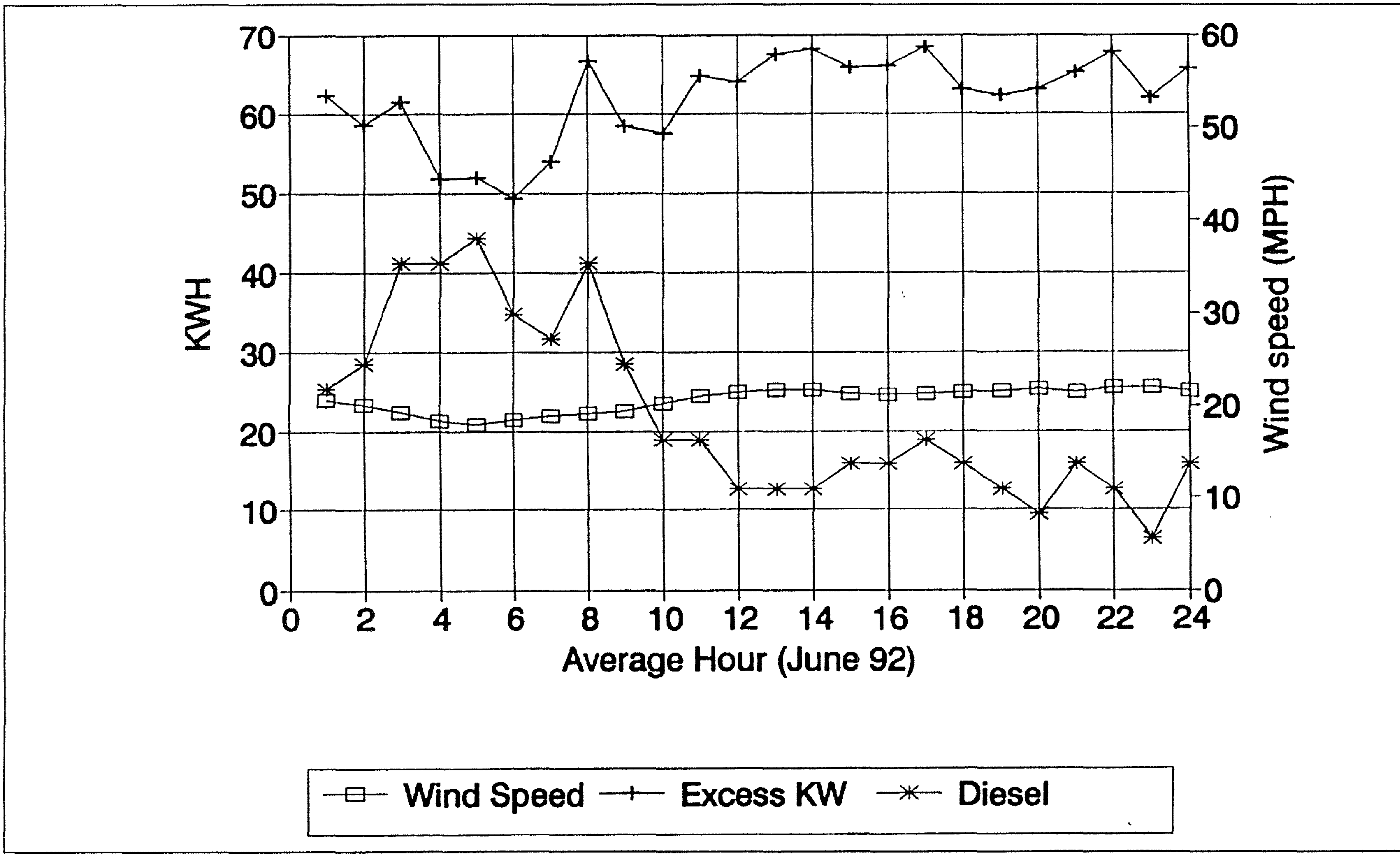


Figure 20: MONTHLY AVERAGE SYSTEM COMPONENT PARTICIPATION INCLUDING EXCESS

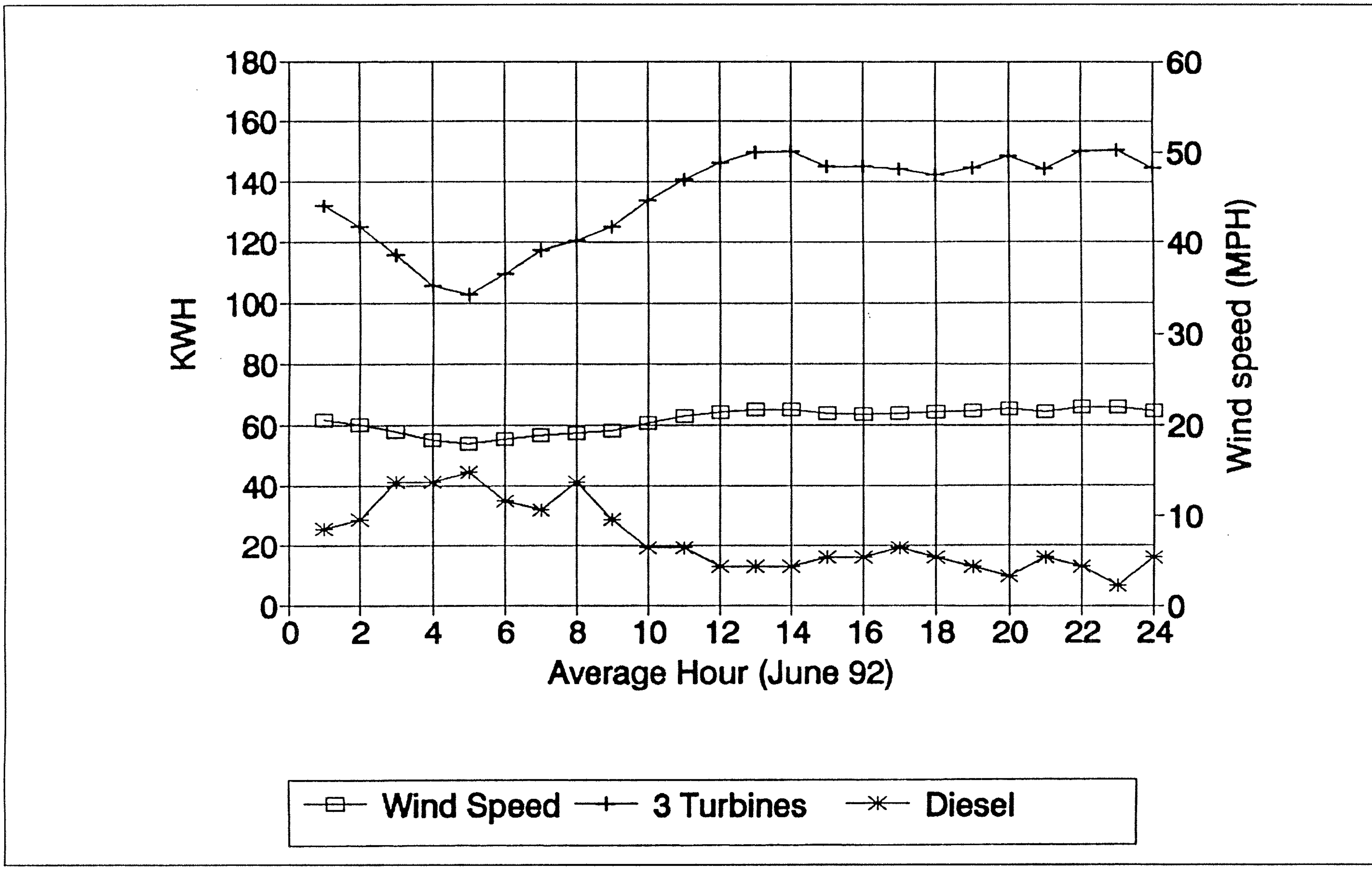


Figure 21: MONTHLY AVERAGE SYSTEM COMPONENT PARTICIPATION WITHOUT EXCESS

CONCLUSIONS AND RECOMMENDATIONS

The State's water resources are vital to Hawaii's daily livelihood. Each island on its own must locate or create its domestic, agricultural, and industrial water resources.

Similar to electrical transmission, each island is isolated and independent in transporting the water resource to its communities. There is no alternative, no borrowing in an emergency, or purchasing from another state, as on the mainland.

Hawaii's water resources come from rain only. The rain settles in surface catchments, aquifers in the mountains, and percolates to the basal lens under each island. A significant percentage of water is pumped from deep wells tapping the basal lens. These deep well pumps are all driven by electric motors. The majority receive power from the utility, and the utility primarily uses fossil fuels for their electricity generation.

Throughout the world wind energy has been used to pump water for hundreds of years. Early drawings of Honolulu show windmills being used.

The wind energy resource in Hawaii is larger than the utility's ability to absorb it into its system (5% to 10% of annual peak load, based on some calculations). Water pumping will enhance the use of larger amounts of wind energy in the State. Although the trade winds blow consistently throughout the island chain, certain areas on each island receive higher concentrations due to geography, topography, and the physical location of each island relative to its neighbor.

Several limiting factors will, and have, constrained the ability to develop wind energy even in the most remote areas. The islands have limits on land availability due to large land holdings, resorts, and urban sprawl. Visual impacts may be of more concern because view planes are narrower and more condensed.

Other considerations for wind energy and resource development are: system reliability and availability of power (intermittency), the cost of the power, including transmission and storage, and the institutional acceptability. The Molokai wind/diesel hybrid system has proven wind energy's suitability for providing power to water resource development.

A cooperative relationship between the state, counties, and a renewable energy developer is the key to the integration of wind energy and water resource development. Any project created between the Departments of Water and an IPP will require a land and easement agreement, transmission and distribution arrangement, and purchase power contracts between the Departments of Water, the IPP, and the utility. The utility is needed for purchasing excess power and emergency standby if all other systems fail.

All that has been learned from this demonstration now needs to be commercially developed. The Alealoa system on West Maui and the Lalamilo system on the big Island are perfect candidates for commercial wind and water pumping facilities.

Lalamilo already uses wind energy, but should incorporate a dedicated diesel and newer, more efficient wind turbines.

Based on water pumping requirements, the whole Alealoa system should incorporate approximately the equivalent of 500-kW rated diesel generators and two (2) or more MW of wind. The 500 kW-rated diesel(s) are required to operate two pumps at any time. The rated capacity of the wind turbines is approximately four times the demand due to annual capacity factors between 25 to 30 percent. All excess would be sold to the utility. To remain under the PURPA rules, the diesel energy use must be less than 25% of the total system output. This may be accomplished by additional wind turbines, larger water storage, or the use of an alternate non-petroleum-based fuel, like ethanol. In order to install the systems, land must be leased and purchase power contracts between the respective DWS's, Zond, and the utilities must be signed. As a result of this demonstration, a combined effort between state and county water resources and land agencies should move to developing wind/diesel hybrids on each island.

Conclusions

A great deal has been accomplished by the wind/diesel hybrid.

1. A commercial wind energy system has proven reliability.
2. Water pumping potential has been simulated and verified.
3. Penetration limits with little impact to the utility have been accomplished above 10%.
4. Remote and automatic control of the system has been demonstrated reliable and efficient.
5. Details of Hawaii's atmospheric conditions affecting wind turbine operation and life span have been observed, with further information to be learned.
6. Detailed wind data has been collected adding to Hawaii's wind resource data bank.

APPENDICES

APPENDIX I

HISTORICAL WIND DATA

Wind speed and directional data monitored and collected at project site. Data tower is an NRG 90-foot, tilt-up tower approximately 100 feet upwind from turbines.

MONTHLY AVERAGES MOLOKAI HAWAII NOV. 1993

AIR DENSITY: 1.225 Kg/m^3

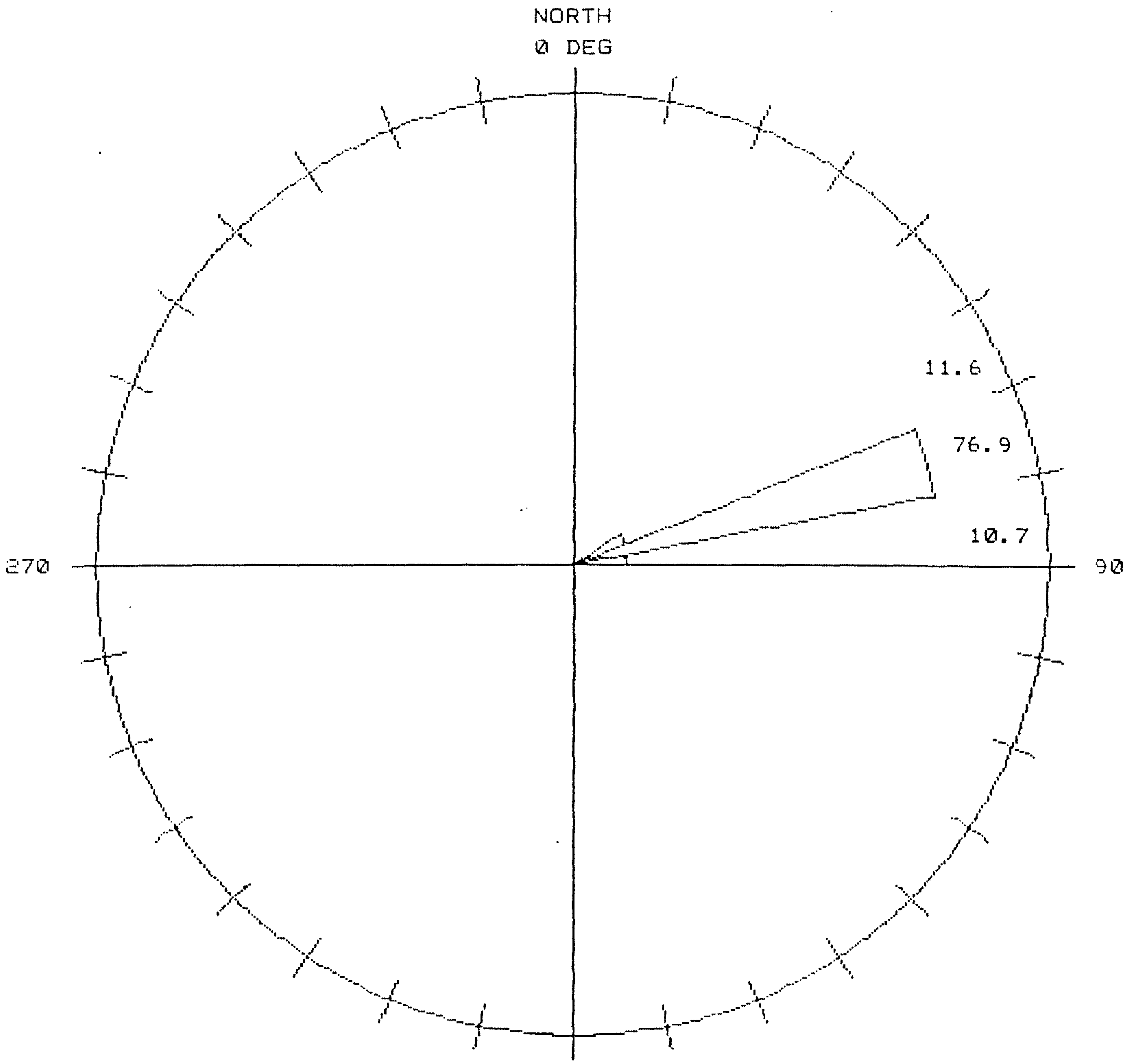
* INDICATES FILLED VALUE USING AVERAGES FROM OTHER YEARS

MR290 ANEMOMETER HEIGHT: 90 FT.

MONTH	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	AVERAGE	STD. DEV.	% WIND	POWER EST	% POWER
JAN											12.03*	12.03	12.03		5.87	95.22	2.67
FEB											15.78*	15.78	15.78		7.70	214.82	6.02
MAR											17.06	19.58	18.32	1.785	8.94	341.27	9.57
APR											12.00	20.31	16.16	5.875	7.89	276.47	7.75
MAY											12.08	19.17	15.62	5.011	7.63	240.75	6.75
JUN											20.54	19.88	20.21	0.466	9.87	451.90	12.67
JUL											20.43	19.78	20.10	0.462	9.81	444.72	12.47
AUG											22.87	18.52	20.69	3.077	10.10	500.70	14.04
SEP											17.34	14.13	15.74	2.269	7.68	219.95	6.17
OCT											15.18	15.60	15.39	0.299	7.51	199.53	5.59
NOV											17.27	18.85	18.06	1.116	8.82	324.10	9.09
DEC											16.75	16.75*	16.75		8.18	257.11	7.21
AVE:											16.61	17.53	17.07				
DEV:											3.514	2.647	2.512				

Table I-1: HISTORICAL WIND DATA

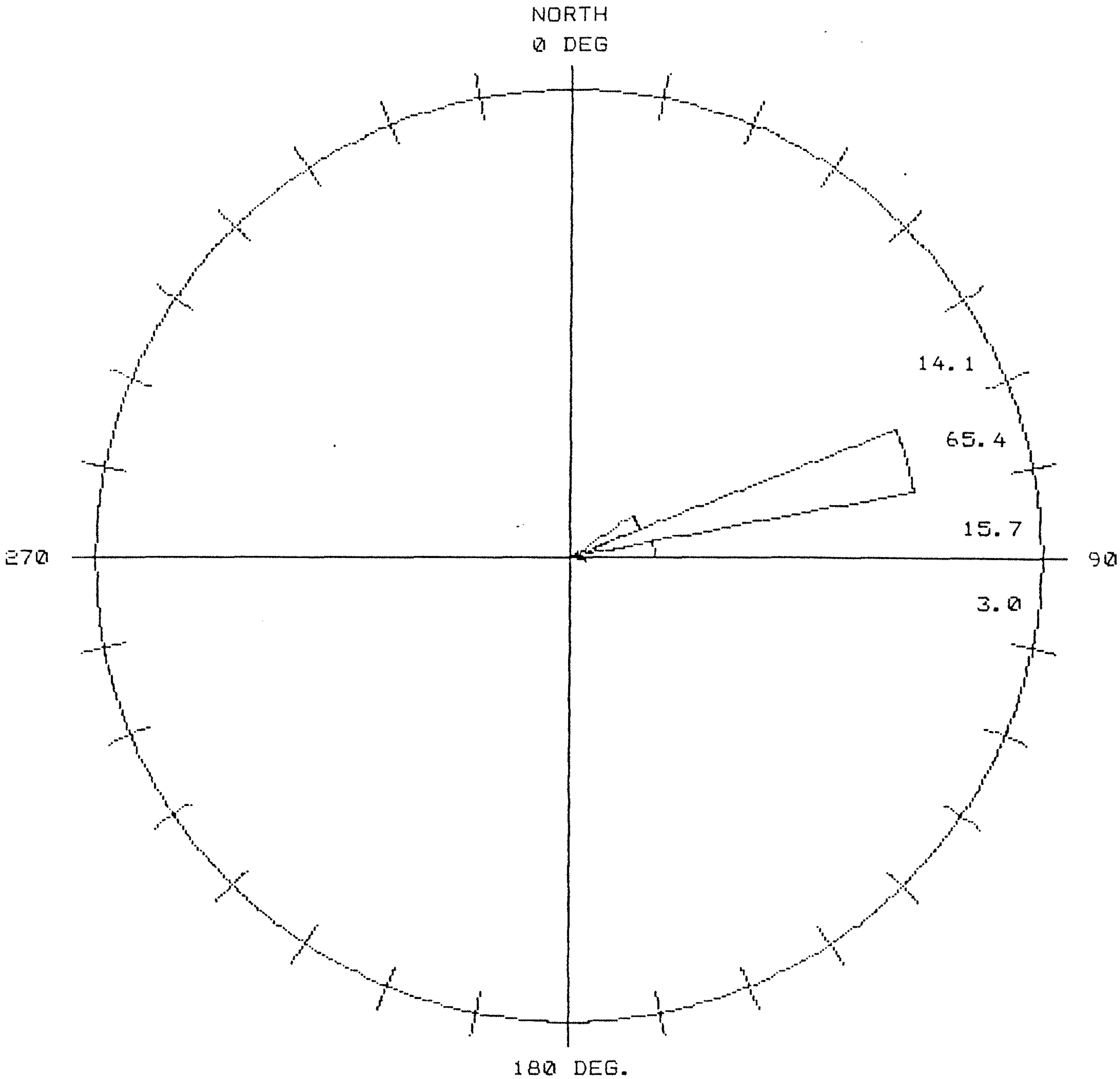
Figure I-1: PERCENT WIND POWER DIRECTION



Hawaii SCADA
JUN/92

NOTE : DATA SORTED INTO 11.25 DEGREE INTERVALS
NOTE : ONLY DATA VALUES 2% OR GREATER ARE PRINTED
NOTE : GRAPH SHOWS PERCENTAGE OF TOTAL WIND POWER

Figure I-2: WINDROSE



Hawaii SCADA
JUN/92

NOTE : DATA SORTED INTO 11.25 DEGREE INTERVALS
NOTE : ONLY DATA VALUES 2% OR GREATER ARE PRINTED
NOTE : GRAPH SHOWS PERCENTAGE OF TOTAL TIME

APPENDIX II

V17 POWER CURVE
AS FIELD TESTED
FEBRUARY 1992 - FEBRUARY 1993

Table II-1: TABLE OF ACTUAL V17 POWER CURVE

Molokai Hawaii Power curves
Feb. 92 - Feb. 93

Wind Speed (MPH)	Turbine-1 (KW)	Turbine-2 (KW)	Turbine-3 (KW)
0	0.00	0.00	0.00
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	0.00	0.00	0.00
4	0.00	0.00	0.00
5	0.00	0.00	0.00
6	0.01	0.01	0.00
7	0.02	0.01	0.02
8	0.13	0.06	0.11
9	0.65	0.30	0.71
10	1.93	1.46	2.22
11	4.13	4.06	4.77
12	6.80	6.73	7.45
13	10.06	10.23	10.71
14	13.72	13.69	14.39
15	17.89	17.71	18.54
16	22.18	21.95	22.91
17	26.57	26.45	27.73
18	31.06	31.00	32.36
19	35.90	35.89	37.37
20	40.43	40.69	42.56
21	44.68	45.17	47.21
22	49.22	50.11	52.52
23	53.52	54.85	57.24
24	57.91	59.25	61.72
25	61.59	63.42	65.95
26	65.06	67.23	69.72
27	68.44	70.60	72.94
28	71.58	73.85	76.42
29	74.69	77.00	79.61
30	76.81	79.72	82.18
31	79.67	82.54	85.12
32	82.11	85.05	87.87
33	84.36	87.63	90.20
34	86.97	90.12	92.36
35	88.67	92.21	94.89
36	90.66	93.83	96.70
37	93.62	95.93	98.96
38	94.73	97.79	100.00
39	97.72	100.11	103.28
40	97.11	99.56	102.67
41	99.60	103.90	107.30
42	0.00	0.00	0.00
43	0.00	0.00	0.00
44	0.00	0.00	0.00
45	0.00	0.00	0.00
46	0.00	0.00	0.00
47	0.00	0.00	0.00

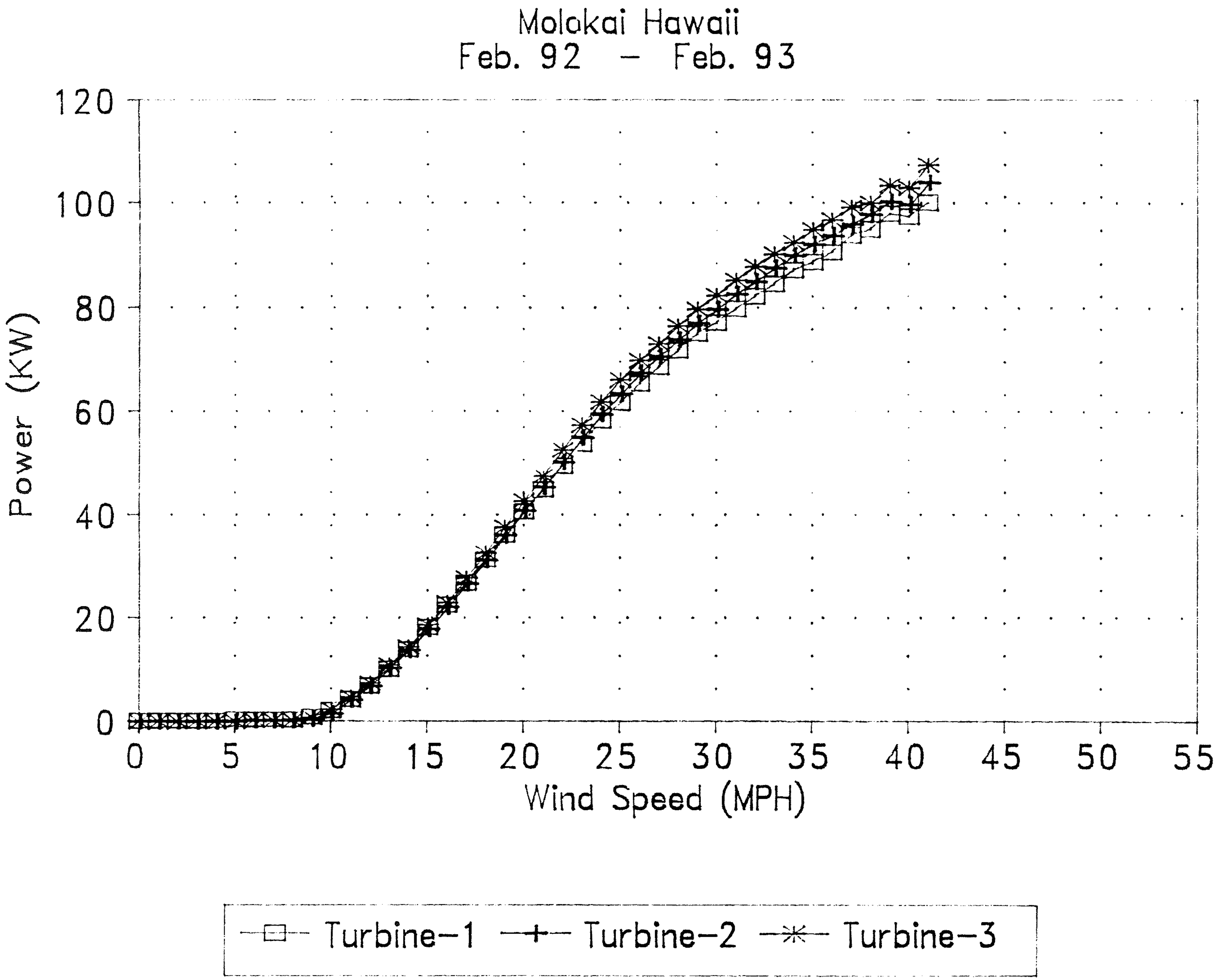


Figure II-1: GRAPH OF ACTUAL V17 POWER CURVE

APPENDIX III

TECHNICAL CONTROL DESCRIPTION

Including electronic description of:

Distributed Intelligence Controller (DICS)
Advanced Data Acquisition System (ADAS)
Supervisory Control and Data Acquisition System (SCADA)

Electronic Description, Distributed Intelligence Control System (DICS) for V17 Replacement Controller

With the exception of the generator main's connection and synchronization, all other fault, monitoring, and control requirements are handled by the Zond's Distributed Intelligence Control System (DICS) motherboard. This board contains 12 individual modules that make up its control and monitoring functions. Faults status, operational status, and manual control functions are available from these modules. A thirteenth module, the Out of Phase module, is located in the high voltage section of the controller. It generates a signal to the DICS motherboard upon an out-of-phase sequence fault.

The Distributed Intelligence Control System motherboard is comprised of 14 individual, easily-removable modules, and one motherboard. Nine mini-modules are located in a single row at the top, with the three larger modules located directly below them.

All connections between the motherboard and the remaining controller are handled through the three main terminal blocks (TB1, TB2, and TB3). All inter-module connections are etched into this circuit board, eliminating the need for hand wiring between modules. Shielded connections are run with "ground guards" on both sides of the etched trace between the terminal block and the module to which it is terminated.

Each motherboard is conformal coated with a military grade hard plastic conformal coating to protect it from moisture and humidity. This coating also decreases corrosion due to humidity or moisture.

A. Display Module Description

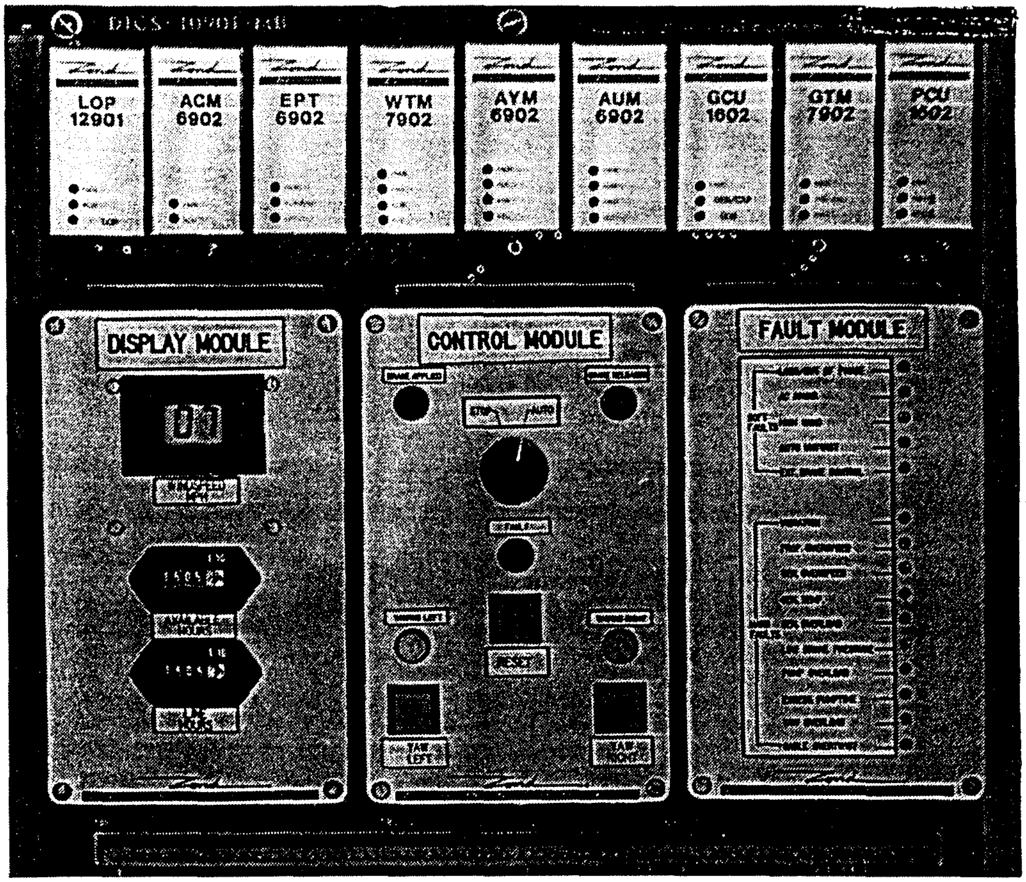
The Display Module is one of the three large modules located in the lower, left-hand portion of the DICS motherboard. The function of the Display Module (DM) is to provide display of wind speed, available hours accumulated, and base hours accumulated.

B. Control Module Description

The Control Module (CM) is located in the center bottom of the DICS motherboard. Its function is to provide manual control for the brake, the yaw motor, and to effect manual reset of faults. Five bright incandescent lamps provide indication of these parameters, including turbine yawing left, turbine yawing right, fault, brake released, and brake applied. The Control Module also includes snubbing diodes for the yaw contactor coils, K3 and K4, and for the brake solenoid.

The main manual control knob, located in the center of the module, is the brake function switch. It has two positions labeled "Stop" and "Auto." When there are no faults placing this switch in the Auto position releases the brake by applying the brake solenoid

Figure A-6: THE DISTRIBUTED INTELLIGENCE CONTROLLER (DICS)



with a supply voltage. Placing the switch in the Stop position sets the brake and brings the turbine to a stop. This position also removes power from the brake solenoid. Brake status is indicated by the green and red incandescent lamps with the red lamp indicating that the brake is applied and the turbine should be stopped. The green lamp indicates that the brake is released and the turbine is operational.

C. Fault Module Description

The Fault Module (FM) is located on the lower right-hand side of the DICS motherboard. The primary function of this module is to indicate fault conditions, remove power from the brake solenoids upon fault conditions, and memorize these fault conditions in case of power outages. A secondary function of this module is to create fault output signals for control of various functions within the controller.

Faults are defined as Hard or Soft. Soft faults will automatically be reset by the Fault Module when they are no longer present on the FM's input. Hard faults will remain in the faulted condition until an operator or a remote system effects a Reset function. The auto reset period for soft faults is pre-set within the Fault Module at 60 seconds.

D. Loss of Phase Module Description

The Loss of Phase Module, or LOP, is one of the nine mini-modules located in the upper left-hand corner of the DICS motherboard. The primary function of this module is to monitor the generator current and provide a fault output for a loss of phase current situation. Current signals are provided by CTA, CTB, and CTC located between the output of the Enerpro ASC unit and the MECO line input. These are the original Vestas current transformers with a current ratio of 200 to .4. They are terminated in 1 ohm resistors, and therefore have a RMS voltage across them of 400 millivolts at a generator current of 200 amperes.

E. AC Mains Module Description

The AC Module, or ACM, is one of nine mini-modules located in the upper left-hand portion of the DICS motherboard. The function of this module is to measure the line voltage and frequency, and signal the Fault Module during out of tolerance conditions. It employs a single 8-bit micro controller, one 8-bit analog to digital converter, and a dual op-amp to complete its circuitry. The entire circuit is contained on a single 2.5 x 2.85-inch circuit board. Signal input is obtained from the transformer.

The ACM module is designed to measure both under and over AC mains line voltage. It is also designed to measure both under and over AC mains line frequency. The parameters set for the V17 turbine are: 1) + or - 1 hertz of frequency variation for 16 cycles, and 2) + or - 10% line voltage variation for 1/2 second. Either of these faults will cause the ACM LED to light. Furthermore, the ACM will signal the Fault Module, which will set a latching soft fault indicated by the AC mains LED. A second LED on the AC mains module is used to indicate that power is applied to that module.

An AC mains fault generated by the ACM module is considered a soft fault. Sixty seconds after the AC mains voltage and frequency conditions return to their nominal values, this fault will automatically reset, returning the turbine to operational condition. This reset timer is located in the Fault Module as described in paragraph C.

F. Excess Pumping Time Module Description

The Excess Pumping Time module, or EPT, is one of the nine mini-modules mounted on the motherboard in the upper left-hand portion. The function of the module is to time the brake pump contactor and provide a fault if this time exceeds a pre-set amount. The EPT module employs a dip switch for selection pumping times between 5 seconds and 8 minutes. Brake pump motor function is monitored by the module and displayed on a single LED noted as PUMP on the outside of the module. Immediately following a pumping time that exceeds the pre-set time, a second LED labeled "EPT" will also be displayed. A third LED is used to indicate that power is applied to the module.

The EPT module's fault output (EPT) is connected to the Fault Module so that during an EPT fault, the Fault Module will remove the operating power to the brake pump contactor and cause the pump motor to stop pumping.

G. Wind Trigger Module Description

The Wind Trigger Module (WTM) is located among the nine mini-modules near the middle of the top of the motherboard. The Wind trigger module performs nearly the same functions as the older Zond Wind Trigger used on all Vestas V15 and V17 turbines. The primary functions of the Wind Trigger are to provide high wind over speed fault signaling, provide medium wind speed signaling to the auto-untwist system for disabling the auto untwisting, and finally to provide low wind speed signaling to enable the auto yaw system. A secondary purpose is to provide a signal for the Control Module wind speed meter.

The Wind trigger Module, OR WTM, employs a single 8-bit micro-controller and a simple anemometer amplifier to monitor the wind speed signals originating from the maximum type 40 cup anemometer. This cup anemometer provides a low frequency sine wave signal that is directly and linearly proportional to wind speed.

H. Auto Yaw Module Description

The Auto Yaw Module, or AYM, is one of the nine mini-modules located in the center of the top of the motherboard. The function of this module is to generate yawing signals for the controller upon error signals generated by the wind vane. The secondary function of the AYM is to effect a 90° out-of-the-wind yawing function during any fault condition. This is accomplished by selecting a second pair of wires from the wind vane that generates the 90° out-of-wind yawing.

The Auto Yaw Module outputs, Auto Yaw Left (AYL) and Auto Yaw Right (AYR), are passed on to the Auto Untwist Module. During normal conditions, when the cable is not over-twisted, these signals are simply sent to the yaw motor contactors to effect yaw motor action in the appropriate direction. The Auto Untwist Module will inhibit the function of these signals during conditions requiring an untwisting of the turbine's cables.

The Auto Yaw Module is enabled by the Wind Trigger Module. When the wind speed has been above 7 miles per hour for one minute, the AYE, or Auto Yaw Enable, signal will enable auto yaw in the Auto Yaw Module. Once enabled, the Auto Yaw Module will monitor signals from the sensors mounted inside the wind vane. These sensors tell the AYM when the nacelle is out of position with the wind direction. The AYM will activate either an AYL or AYR output signal when one of the wind vane error signals (Yaw Left or Yaw Right) has been present for six seconds. Once selected (either AYL or AYR), these signals will remain for a minimum of 3 seconds even if there is no corresponding signal from the wind vane. The purpose of this algorithm is to help the wind turbine track and stay into the wind without undue operation of the yawing motor and associated contactors.

The Auto Yaw Module functions in the same manner as the original V15 and V17 VHA4 module with Zond's modification applied.

The wind vane is manufactured by NRG system in Vermont to Zond specifications. This vane is fully compatible with older Vestas V15 and V17 wind vanes and can be used as a direct replacement. The wind vane has many improvements over the Vestas' design, including transient over-voltage protection, reverse voltage protection, and increased damping to its yawing response. The Auto Yaw Module provides all of the supply voltages for the wind vane.

I. Auto Untwist Module Description

The Auto Untwist Module, or AUM, is one of the nine mini-modules located in the top center of the DICS motherboard. The function of this module is to monitor cable twist signals from the cable twist sensor and untwist the cable by control of the yaw motor when the cable is over twisted. The secondary function of this module is to monitor the automatic yawing signals originating from the Auto Yaw Module and allow or disallow them to be used for control of the yaw motor contactors.

The AUM consists of a single 8-bit Motorola micro-controller. This computer monitors three cable twist signals originating from the nacelle mounted cable twist sensor. These signals are: 1) "3 Turns twisted Right" (3TR), 2) "3 Turns twisted Left" (3TL), and 3) "Turns Count signal" (TC). The function of the module is to cause the yaw motor, through the yaw motor contactors, to yaw and untwist the cable once it has become twisted. The 3TR and 3TL signals tell the module which way the cable is twisted and how much it has been twisted. This function of the Auto Untwist Module is disabled during wind speed above 20 miles per hour by a signal appearing on the AUD line originating from the Wind Trigger.

During the time when the wind speed is above 20 miles per hour and the untwist function of this module is disabled, the turbine can continue to twist. To prevent excess cable twist, the module monitors the turns counter signal which provides a signal every 1/2 turn. Therefore, once the wind speed drops to below 20 miles per hour, the micro-controller will untwist either left or right three turns plus the number of 1/2 turns accumulated.

The Auto Untwist Module signals the Fault Module via the Auto Untwist (AUN) line when it has begun an automatic cable untwisting sequence. This is a soft fault condition and once the Auto Untwist Module has completed the untwisting, the AUN line will again go high, signaling the Fault Module that there is no longer a fault. One minute later the Fault Module will reset this fault and the turbine will be allowed to operate in its normal fashion.

J. Generator Control Unit Module Description

The Generator Control Unit (GCU) is one of the nine mini-modules located in the upper right-hand corner of the DICS motherboard. The function of the GCU is to enable the Enerpro soft start ASC system control the power factor correction capacitor contactor, generate a fault output in case of a generator over-speed, and finally, generate a fault output in case of a failed tachometer sensor.

The GCU employs an 8-bit micro-controller which very accurately measures the rpm or rotational speed of the generator. A standard Electromatic DU-10 "Horseshoe Sensor" is used coupled to a steel bar which rotates along with the rotor of the turbine's 110-kilowatt generator. The GCU measures the time required for each pulse and determines the operating speed of the generator. At 1150 rpm the GCU signals both the Enerpro ASC unit and the capacitor contactor to activate. This is indicated by a LED

The GTM module is a highly accurate temperature compensated instrument. Total accuracy is + or - 1°C over the entire operating temperature range of the module, -25° to +85°C. It is designed to operate with 100 ohm PTC sensors. These sensors have a resistance that varies with temperature such that any increase in temperature will cause an increase in resistance. The resistance at 134°C (273.2°F) will = 149 ohms.

L. Propeller Control Unit Module Description

The Propeller Control Unit module, or PCU, is one of the nine mini-modules located in the upper right-hand corner of the DICS motherboard. The function of the module is to monitor the rotational speed wind turbines hub (slow speed shaft) and provide fault outputs in case of over speed conditions. A second function of the module is to provide a brake solenoid supply output voltage in case of an over speed condition that continues to accelerate even though the brake has been applied or in the case where the application of the brake does not slow the rotor down. During these conditions the module will re-supply the brake solenoid with power so that the brake will re-release and the turbine's tip flaps can be actuated, thereby slowing the rotor to below an over speed condition. A third function of the module is to provide a fault output condition in case of a failed DU-10 low speed shaft tack sensor either open or shorted or internally failed.

Error Reduction in Wind Turbine Field Testing Using the Advanced Data Acquisition System

Zond's Advanced Data Acquisition System, or ADAS, is a distributed multi-source, synchronous, multi-channel data recorder. By employing remote multi-channel data acquisition modules, the ADAS records data at the source of the required measurement. These remote modules acquire time synchronized analog and digital data and communicate to a host computer over a hard wire or radio telemetry interface. The ADAS greatly reduces common data acquisition system errors through the use of innovative hardware, software, and digital signal processing.

The ADAS, employing high impedance instrumentation amplifiers, eliminates lead length resistance in sensor signal lines. By employing voltage sense leads, the ADAS eliminates voltage drops normally associated with the applied excitation voltage. Careful alias filter design and construction lead to low phase distortion, a common affliction of such filters. By employing high frequency integrating converters and high performance instrumentation amplifiers, most noise problems within the alias filter passband are reduced or eliminated entirely. Finally, the overall ADAS accuracy approaches its specified linearity (+/- .005% of Full Scale) through self calibration and linear regression.

Recording data from an operating wind turbine is no simple task, especially on Molokai. Stringent requirements are placed on the turbine's data acquisition system including: operation over a wide range of meteorological variables, in conjunction with an electrical noisy environment, and on moving or rotating equipment while subject to vibrations. Complicating these environmental and physical requirements are the obvious needs of accuracy, resolution, recording space and data integrity.

Despite the advances in PC-based data acquisition systems, most recorders suffer from cumulative errors (McNiff and Simms, 1992, Analog Devices Staff, 1986), that reduce their overall effectiveness. Many recorders are relatively precise but lack basic accuracy, especially when measured over the wide temperature range required by an operating wind turbine. Even those systems that maintain accuracy over an extended temperature range can suffer from errors due to the problems with Wheatstone bridge excitation and measurement, electrical noise, alias errors, and sensor lead length resistance.

Recently, the Advanced Data Acquisition System, or ADAS, (Simms and Cousineau, 1992) was introduced. This system finally satisfied the requirements for a relative inexpensive, environmental hardened, and highly accurate instrument with a large recording space. Using state-of-the-art 32-bit micro-controller technology, previous design approaches (Cousineau, 1989), and National Renewable Energy Laboratory specifications (Simms and Cousineau, 1992), the first ADAS units were manufactured and placed into service in the fall of 1992.

The ADAS does not compromise its accuracy and precision to achieve environmental specifications. It employs both hardware and software technology to achieve a significant error reduction over conventional data acquisition systems. Errors caused by lead length resistance, excitation voltage variations, span and offset calibration, aliases and common mode voltages are reduced and many times eliminated.

Supervisory Control and Data Acquisition System Description

The Zond/Molokai wind/diesel project, consisting of three Vestas V17 wind turbines and one diesel generator, is monitored via a Supervisory Control and Data Acquisition system (SCADA). This system allows operators at the wind park site and at remote sites to monitor and control each of the turbines and the meteorological tower from a computer keyboard. Remote monitoring and control is accomplished using standard IBM PC type computers communicating with an electronic modem over a standard telephone line.

System Hardware Description

Main SCADA Computer System

A rack mounted, industrial quality, 16 MHz 80286 Central Processing Unit (computer) is used for overall monitoring and control via two communication lines, a RS-422 to the sub-system computers and a telephone line to the remote computers. The main 80286 computer is housed in the project's diesel generator/control building.

This computer system employs a Texas Microsystems industrial quality main frame employing a passive PC bus type motherboard. Attached to the motherboard are the 16 MHz 80286 computer, a 520 kilobyte by 8 byte solid state disk drive, a Hayes compatible 1200 baud modem, and the required monitor, floppy and hard drive cards. The system employs a single 3 1/2 inch high density disk drive, and a fast 40 megabyte hard drive for data storage. The keyboard, computer, and monitor are all mounted inside a 6-foot industrial rack cabinet for protection.

The AC wiring of this cabinet includes a dedicated transformer and line transient protection through the use of Metal Oxide Varistors. This transformer along with the isolated communication adapter provide a degree of electrical isolation of this computer system from both the AC line and the SCADA sub-system computers and their associated control systems.

A program for operating, displaying and control of the SCADA system is written in Microsoft Quick Basic and compiled into a machine code program. This program will start up and run independent of any operator once power has been applied to the Texas Microsystem computer.

All wind turbine, diesel generator, and meteorological tower status and accumulator points are displayed on an easy-to-read overview screen. This screen is updated every five seconds for operator convenience and safety.

SCADA Communications

Communication to the SCADA sub-system computers at the turbines, diesel generator, and met tower is accomplished through COMM1 of the 80286's twin RS-232 serial ports. This port is connected to an electrically isolated Phoenix Contact RS-232 to RS-422 converter.

The output of the RS-232 to RS-422 converter is connected through standard direct burial communication cable. This cable consists of six twisted pairs with overall solid copper shield. Two pairs are used for communication with four pairs for spares or future expansions. RS-422 consists of individual transmit and receive lines, fully differential and therefore requiring twisted pairs for each.

Equipment protection against lightning and other transient events is accomplished by the installation of over-voltage protectors on the communication cable near each of their terminations. These protectors are installed in the 80286 computer rack, and one at each SCADA sub-system. An electrical wiring diagram of the communication systems shown in drawing 9007A.

Communications between the main SCADA computer and the SCADA Sub-system computers is completed every five seconds. Any commands received by the main SCADA computer (such as a command to shut down the park from one of the remote SCADA computers) will be acted upon within one second and received by the SCADA Sub-system computers within five seconds. Actual stopping time for a V17 turbine varies depending upon the wind velocity, but averages between three and five seconds, giving an overall response time of between nine and eleven seconds.

All status and accumulator points monitored by the SCADA Sub-system computers are also communicated to the main SCADA computer every five seconds. This allows rapid display of all pertinent data by system operators without waiting for five-minute values to be accumulated.

SCADA Sub-System Computers

A SCADA Sub-system computer is located at each of the five sites (three wind turbines, one diesel generator, and one meteorological tower). Each of these sub-systems consists of a Phoenix Contact Interbus-R Intelligent Serial I/O system with optically isolated inputs for fault, status and pulse type data monitoring, and relay outputs for control.

The Interbus R modules employ a 16-bit microprocessor (NEC V25) operating at an internal clock frequency of 8 MHz. This processor operates and controls the RS-422 communication, and communication with the external I/O modules. With exception of the meteorological tower, each SCADA Sub-system consists of one Interbus R module, one Interbus 16-channel optically isolated digital input module, and one Interbus 8-channel relay output module.

The meteorological tower SCADA Sub-system employs an Interbus R module and a single digital input module. No relay output module is required for data collection from this tower. See drawing 9005B.

Power for each of the Interbus R modules is provided by DC power supplies. In each turbine a single 5-volt DC supply is used for the R module power with the I/O module power being provided form the turbine's controller. In the met tower, two individual DC supplies are required, one for the I/O modules and Zond SCADA I/O board (see paragraph 1.4) and a second for the Interbus R module. The diesel generator SCADA Sub-system also requires two separate power supplies.

Sub-System Computer to Wind Turbine Controller Interface

Interconnection between the control systems and the SCADA Sub-system is all accomplished by wiring harnesses. Refer to the Zond Distributed Intelligence Control System Manual for more information concerning operation of the wind turbine control system.

SCADA Operations

Zond Distributed Intelligence Controller Interface

The Interbus R CPU module communicates to both a 16-channel digital input module and a multi-channel relay output module. The digital input module handles both status and accumulator inputs. Accumulator inputs are required for Available Hours (AVH), AC line hours (ACO), and kilowatt hours generator by the kilowatt hour meter pulse initiator Y and Z outputs. These accumulators store 5-minute pulse counts for the kilowatt hours and total seconds for the AVH and ACO. They are collected by the main SCADA computer every five minutes.

Status points are scanned every five seconds by the main SCADA computer. These status points are stored in the main SCADA computer for use in case of a turbine failure. Twenty-four hours of the last five-second values are stored for turbine failure analysis by Zond personnel. These values along with the five-minute values can be used to determine the sequences of a turbine failure. Such a sequence is required in order to determine if a RESET must be initiated or if an operator must visit the site for repair and/or maintenance. The status of both kilowatt hour pulses and ACO/AVH pulses are also recorded every five seconds. This allows the operators the chance to determine if the turbine is on-line without waiting for five-minute updates.

The standard computer display shows all of the status points and the accumulator's present status (high or low). The display of the accumulator's present status allows the operator the ability to determine the present operational status of the wind turbine, including whether or not it is producing power without waiting for the latest five-minutes values to change.

A relay out module allows remote or main computer users the ability to control a portion of the turbine's operations. Connections to these relays consist of control lines marked, EBR (External Brake Control), RST (fault ReSeT), YLC (Yaw Left Contactor Control), and YRC (Yaw Right Contactor Control). A signal sent from the main computer will activate any of these relays. Fault reset control allows remote operators the ability to clear any faults that might occur during operation of the turbine. Brake control of the turbine is provided by the EBR line, allowing remote operators the ability to start and stop turbine operations. Yaw control over the turbine's yaw system is also provided.

Meteorological Tower Interface

The Meteorological tower is located upwind by 1-1/3 rotor diameters of the number 2 wind turbine. This tower has wind speed and direction sensors that are interfaced through the SCADA system via a Zond Wind Data I/O board. Refer to drawing 9006C for interface and wiring details.

The Zond Wind DATA I/O board provides two KYZ outputs that have been converted from wind speed and wind direction. These outputs are read by the SCADA sub-system computer digital input module as shown in 9006C. The SCADA system counts these pulses for five minutes and is then downloaded into the SCADA main computer system for storage and display of these values.

The complete wind data interface system is located inside the diesel generator/control room on the site. A direct burial cable connects the meteorological tower to this enclosure.

Diesel Generator Interface

Drawing 9006B shows the wiring diagram for the diesel generator interface cabinet. As with the wind turbine interface, kilowatt hours are delivered to the SCADA sub-system computer via the kilowatt hour meter's pulse initiator. The SCADA sub-system computer's digital input module accumulates these pulses for a five-minute period for storage and display by the main computer or the remote computers.

Fault status for the diesel generator is provided as shown. Four fault status lines are used to monitor low oil pressure, high water temperature, motor/generator over-speed, and over-cranking. These status points are updated (along with the kilowatt hour pulses) every five seconds.

The SCADA sub-system computer also provides a relay output control for starting and stopping of the diesel generator. This line is activated on command from the main SCADA computer or any remote computer.

APPENDIX IV

DIESEL DESIGN AND SPECIFICATIONS

(No page number 88 in original file copy.)

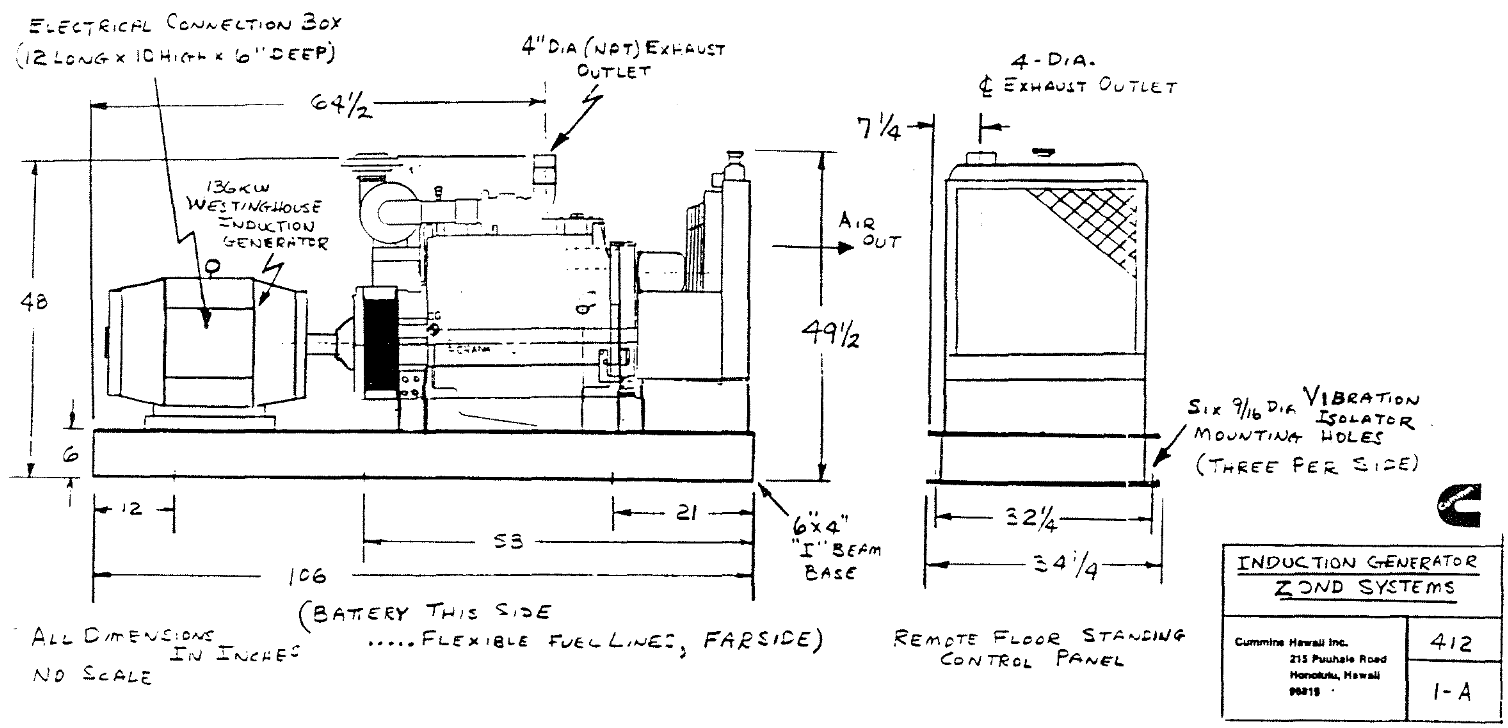


Figure IV-2: DIESEL DESIGN PLAN

CUMMINS ENGINE COMPANY, INC Columbus, Indiana 47201 ENGINE PERFORMANCE CURVE	Basic Engine Model: 6CTA-8.3 G		Curve Number: C-4501-C	
	Dry Exh.Manifold CPL: 0831	Wet Exh.Manifold CPL: N.A.	Date: 25Oct90	By: RMM

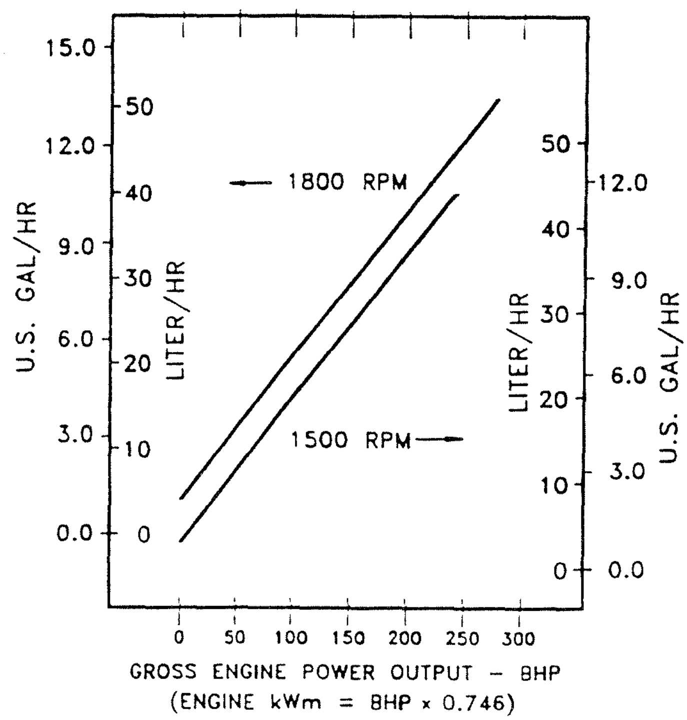
Displacement: 504.5 in.^{3} (8.3 liter) Aspiration: Turbocharged & Aftercooled Rating:
Bore: 4.49 in. (114 mm) Stroke: 5.32 in. (135 mm) No. of Cylinders: 6 277 HP (207 kWm) @ 1800 RPM

Power output curves are based on the engine operating with fuel system, water pump and lubricating oil pump; not included are battery charging alternator, fan, optional equipment and driven components.

Gross Engine Power Output

Engine Speed	Standby Power		Prime Power	
RPM	BHP	kWm	BHP	kWm
1800	277	207	252	188
1500	241	180	219	163

Fuel Consumption



OUTPUT POWER			FUEL CONSUMPTION	
%	BHP	kWm	U.S.Gal./HR	litre/h
		1800 RPM		
STANDBY POWER				
100	277	207	13.6	51
PRIME POWER				
100	252	188	12.2	46
75	189	141	9.0	34
50	126	94	6.2	23
25	63	47	3.6	14
0	0	0	1.1	4
		1500 RPM		
STANDBY POWER				
100	241	180	11.7	44
PRIME POWER				
100	219	163	10.6	40
75	164	122	7.8	30
50	110	82	5.3	20
25	55	41	2.9	11
0	0	0	0.8	3

Figure IV-3: ENGINE PERFORMANCE CURVE

Data shown above represent gross engine performance capabilities obtained and corrected in accordance with ISO-3046 conditions of 100 kPa (29.53. in. Hg.) barometric pressure [361 ft. (110 m) altitude], 77°F (25°C) air inlet temperature, and relative humidity of 30% with No. 2 diesel or a fuel corresponding to ASTM 2-D

See reverse side for application rating guidelines.

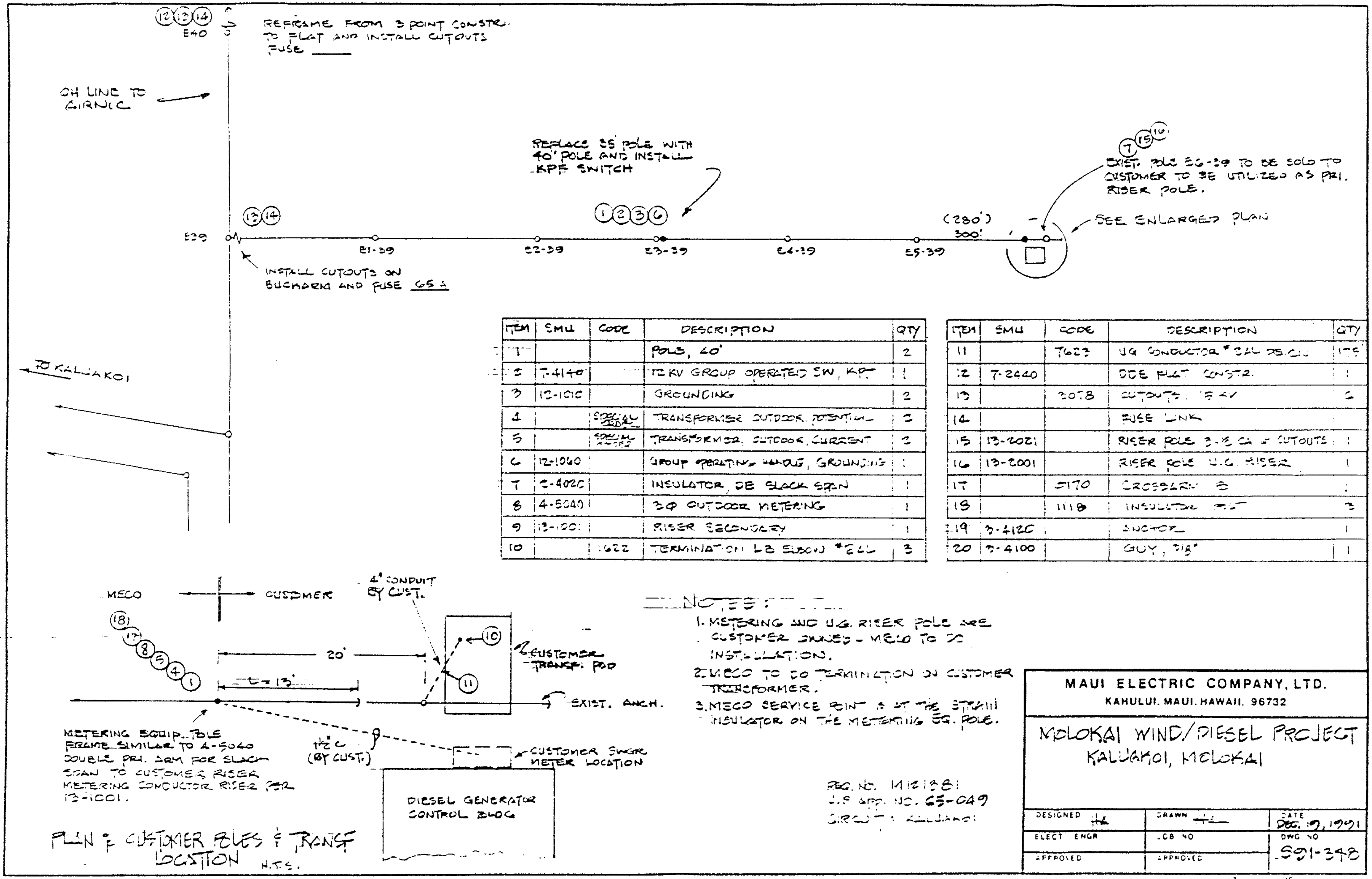
The fuel consumption data is based on No. 2 diesel fuel weight at 7.1 lbs./U.S. gal (0.85 kg/litre).

J. D. Kahlenbeck

TECHNICAL DATA DEPT. CERTIFIED WITHIN 5% CHIEF ENGINEER

APPENDIX V

MECO INTERCONNECTION



ITEM	SMU	CODE	DESCRIPTION	QTY
1			POLE, 40'	2
2	7-4140		12 KV GROUP OPERATED SW, KPF	1
3	12-1010		GROUNDING	2
4		SPECIAL ORDER	TRANSFORMER, OUTDOOR, POTENTIAL	2
5		SPECIAL ORDER	TRANSFORMER, OUTDOOR, CURRENT	2
6	12-1060		GROUP OPERATING HANDLE, GROUNDING	1
7	2-4020		INSULATOR, DE SLACK SPAN	1
8	4-5040		3Φ OUTDOOR METERING	1
9	13-1001		RISER SECONDARY	1
10		1622	TERMINATION LB ELBOW #2AL	3

ITEM	SMU	CODE	DESCRIPTION	QTY
11		7623	UG CONDUCTOR #2AL 25 CN	175
12	7-2440		DDE FLAT CONSTR.	1
13		3078	CUTOUTS, 15 KV	2
14			FUSE LINK	
15	13-2021		RISER POLE 3-Φ CA W CUTOUTS	1
16	13-2001		RISER POLE U.G. RISER	1
17		5170	CROSSARM 8'	1
18		1118	INSULATOR PIN	3
19	3-4120		ANCHOR	1
20	3-4100		GUY, 7/8"	1

Figure V-1: MECO-W/D CONNECTION - SINGLE LINE

APPENDIX VI

WIND/DIESEL SIMULATION

JUNE 1, 1992 - JUNE 30, 1992

For the month of June a simulation was run to show the automatic participation of the various system components. If the system output from the wind was less than 95 kW, the diesel would come on. The diesel would simulate operation until 95 kW or more was achieved by the wind turbines. In actuality, the diesel would only run one hour to save fuel, yet it was capable of continuous operation.

Table VI-1: WIND/DIESEL SIMULATION FOR JUNE 1992

Maintain 95 KW output

Date	Hour	MPH	Total 3 Turbine KWH	Diesal KWH	Total KWH	Excess KWH
06/01/92	1	10.97	16.83	95	111.83	16.83
06/01/92	2	12.21	23.33	95	118.33	23.33
06/01/92	3	12.38	24.08	95	119.08	24.08
06/01/92	4	10.31	7.08	95	102.08	7.08
06/01/92	5	10.68	9.08	95	104.08	9.08
06/01/92	6	10.30	9.17	95	104.17	9.17
06/01/92	7	8.93	1.58	95	96.58	1.58
06/01/92	8	6.63	0.17	95	95.17	0.17
06/01/92	9	2.88	0.00	95	95.00	0.00
06/01/92	10	6.83	2.00	95	97.00	2.00
06/01/92	11	11.30	15.75	95	110.75	15.75
06/01/92	12	14.06	45.75	95	140.75	45.75
06/01/92	13	16.65	79.58	95	174.58	79.58
06/01/92	14	17.73	94.33	95	189.33	94.33
06/01/92	15	16.35	73.67	95	168.67	73.67
06/01/92	16	16.02	70.58	95	165.58	70.58
06/01/92	17	15.59	64.50	95	159.50	64.50
06/01/92	18	14.86	34.58	95	129.58	34.58
06/01/92	19	13.01	29.08	95	124.08	29.08
06/01/92	20	14.93	56.50	95	151.50	56.50
06/01/92	21	10.18	18.58	95	113.58	18.58
06/01/92	22	9.85	8.00	95	103.00	8.00
06/01/92	23	11.22	17.17	95	112.17	17.17
06/01/92	24	12.46	27.17	95	122.17	27.17
06/02/92	1	14.29	47.92	95	142.92	47.92
06/02/92	2	13.55	39.17	95	134.17	39.17
06/02/92	3	8.62	1.42	95	96.42	1.42
06/02/92	4	8.80	0.17	95	95.17	0.17
06/02/92	5	6.43	0.00	95	95.00	0.00
06/02/92	6	5.11	0.00	95	95.00	0.00
06/02/92	7	4.84	0.00	95	95.00	0.00
06/02/92	8	7.18	0.33	95	95.33	0.33
06/02/92	9	9.84	6.33	95	101.33	6.33
06/02/92	10	13.39	36.00	95	131.00	36.00
06/02/92	11	12.82	34.58	95	129.58	34.58
06/02/92	12	13.19	35.50	95	130.50	35.50
06/02/92	13	16.40	72.92	95	167.92	72.92
06/02/92	14	16.64	81.67	95	176.67	81.67
06/02/92	15	17.47	85.92	95	180.92	85.92
06/02/92	16	16.87	79.17	95	174.17	79.17
06/02/92	17	16.06	73.58	95	168.58	73.58
06/02/92	18	17.22	86.08	95	181.08	86.08
06/02/92	19	18.61	106.17	0	106.17	11.17
06/02/92	20	18.83	104.58	0	104.58	9.58
06/02/92	21	16.48	72.50	95	167.50	72.50
06/02/92	22	18.29	97.75	0	97.75	2.75
06/02/92	23	19.14	108.50	0	108.50	13.50
06/02/92	24	19.28	110.83	0	110.83	15.83
06/03/92	1	18.78	102.08	0	102.08	7.08
06/03/92	2	14.89	51.58	95	146.58	51.58

06/03/92	3	14.38	50.75	95	145.75	50.75
06/03/92	4	12.57	28.42	95	123.42	28.42
06/03/92	5	7.17	0.17	95	95.17	0.17
06/03/92	6	7.37	0.00	95	95.00	0.00
06/03/92	7	2.65	0.00	95	95.00	0.00
06/03/92	8	0.31	0.00	95	95.00	0.00
06/03/92	9	3.43	0.00	95	95.00	0.00
06/03/92	10	6.55	0.00	95	95.00	0.00
06/03/92	11	8.05	0.33	95	95.33	0.33
06/03/92	12	7.16	0.83	95	95.83	0.83
06/03/92	13	9.26	6.00	95	101.00	6.00
06/03/92	14	9.38	11.17	95	106.17	11.17
06/03/92	15	5.71	0.00	95	95.00	0.00
06/03/92	16	5.88	0.25	95	95.25	0.25
06/03/92	17	9.65	3.33	95	98.33	3.33
06/03/92	18	12.73	31.00	95	126.00	31.00
06/03/92	19	11.46	19.00	95	114.00	19.00
06/03/92	20	6.81	1.00	95	96.00	1.00
06/03/92	21	5.86	0.00	95	95.00	0.00
06/03/92	22	9.44	7.42	95	102.42	7.42
06/03/92	23	18.30	95.25	0	95.25	0.25
06/03/92	24	13.82	40.67	95	135.67	40.67
06/04/92	1	11.77	18.92	95	113.92	18.92
06/04/92	2	11.88	20.08	95	115.08	20.08
06/04/92	3	9.21	5.00	95	100.00	5.00
06/04/92	4	11.53	21.08	95	116.08	21.08
06/04/92	5	12.66	26.50	95	121.50	26.50
06/04/92	6	13.72	41.83	95	136.83	41.83
06/04/92	7	13.20	39.17	95	134.17	39.17
06/04/92	8	11.21	21.42	95	116.42	21.42
06/04/92	9	15.59	62.75	95	157.75	62.75
06/04/92	10	18.78	107.58	0	107.58	12.58
06/04/92	11	17.49	86.58	95	181.58	86.58
06/04/92	12	18.90	106.75	0	106.75	11.75
06/04/92	13	20.16	124.33	0	124.33	29.33
06/04/92	14	19.58	118.00	0	118.00	23.00
06/04/92	15	18.03	96.67	0	96.67	1.67
06/04/92	16	17.68	96.42	0	96.42	1.42
06/04/92	17	17.37	86.00	95	181.00	86.00
06/04/92	18	17.43	90.00	95	185.00	90.00
06/04/92	19	19.59	117.83	0	117.83	22.83
06/04/92	20	20.32	125.33	0	125.33	30.33
06/04/92	21	20.75	127.58	0	127.58	32.58
06/04/92	22	19.07	107.92	0	107.92	12.92
06/04/92	23	22.03	145.58	0	145.58	50.58
06/04/92	24	22.56	154.67	0	154.67	59.67
06/05/92	1	21.93	145.75	0	145.75	50.75
06/05/92	2	18.53	96.75	0	96.75	1.75
06/05/92	3	16.59	72.50	95	167.50	72.50
06/05/92	4	15.11	56.42	95	151.42	56.42
06/05/92	5	18.13	93.67	95	188.67	93.67
06/05/92	6	20.64	127.92	0	127.92	32.92
06/05/92	7	18.44	100.58	0	100.58	5.58
06/05/92	8	17.16	81.67	95	176.67	81.67
06/05/92	9	17.25	83.17	95	178.17	83.17
06/05/92	10	15.79	70.67	95	165.67	70.67
06/05/92	11	21.31	145.75	0	145.75	50.75
06/05/92	12	19.23	121.58	0	121.58	26.58

06/05/92	13	20.16	134.75	0	134.75	39.75
06/05/92	14	20.98	137.83	0	137.83	42.83
06/05/92	15	16.24	73.92	95	168.92	73.92
06/05/92	16	19.48	124.25	0	124.25	29.25
06/05/92	17	20.76	141.92	0	141.92	46.92
06/05/92	18	20.38	134.00	0	134.00	39.00
06/05/92	19	20.06	130.08	0	130.08	35.08
06/05/92	20	23.16	171.25	0	171.25	76.25
06/05/92	21	21.95	154.50	0	154.50	59.50
06/05/92	22	22.12	154.25	0	154.25	59.25
06/05/92	23	20.44	129.00	0	129.00	34.00
06/05/92	24	19.73	121.25	0	121.25	26.25
06/06/92	1	19.28	115.75	0	115.75	20.75
06/06/92	2	25.98	202.50	0	202.50	107.50
06/06/92	3	25.27	189.92	0	189.92	94.92
06/06/92	4	22.98	168.25	0	168.25	73.25
06/06/92	5	22.77	167.25	0	167.25	72.25
06/06/92	6	22.45	164.50	0	164.50	69.50
06/06/92	7	24.61	192.17	0	192.17	97.17
06/06/92	8	25.68	206.17	0	206.17	111.17
06/06/92	9	24.08	189.67	0	189.67	94.67
06/06/92	10	24.38	187.50	0	187.50	92.50
06/06/92	11	26.70	214.00	0	214.00	119.00
06/06/92	12	24.37	187.17	0	187.17	92.17
06/06/92	13	24.03	183.50	0	183.50	88.50
06/06/92	14	24.53	190.83	0	190.83	95.83
06/06/92	15	21.45	154.42	0	154.42	59.42
06/06/92	16	21.97	157.75	0	157.75	62.75
06/06/92	17	21.79	154.25	0	154.25	59.25
06/06/92	18	20.98	143.08	0	143.08	48.08
06/06/92	19	21.74	149.75	0	149.75	54.75
06/06/92	20	21.76	149.50	0	149.50	54.50
06/06/92	21	20.47	134.58	0	134.58	39.58
06/06/92	22	21.87	156.25	0	156.25	61.25
06/06/92	23	20.48	131.08	0	131.08	36.08
06/06/92	24	19.23	110.00	0	110.00	15.00
06/07/92	1	16.96	79.17	95	174.17	79.17
06/07/92	2	17.11	82.17	95	177.17	82.17
06/07/92	3	16.65	74.33	95	169.33	74.33
06/07/92	4	17.43	87.67	95	182.67	87.67
06/07/92	5	14.22	46.25	95	141.25	46.25
06/07/92	6	14.73	46.92	95	141.92	46.92
06/07/92	7	16.60	70.25	95	165.25	70.25
06/07/92	8	16.61	70.75	95	165.75	70.75
06/07/92	9	19.16	111.42	0	111.42	16.42
06/07/92	10	19.60	118.92	0	118.92	23.92
06/07/92	11	19.88	130.75	0	130.75	35.75
06/07/92	12	20.94	146.33	0	146.33	51.33
06/07/92	13	21.30	152.17	0	152.17	57.17
06/07/92	14	22.29	162.83	0	162.83	67.83
06/07/92	15	22.78	165.83	0	165.83	70.83
06/07/92	16	21.28	151.00	0	151.00	56.00
06/07/92	17	21.41	150.17	0	150.17	55.17
06/07/92	18	23.81	176.42	0	176.42	81.42
06/07/92	19	21.24	135.92	0	135.92	40.92
06/07/92	20	23.02	156.17	0	156.17	61.17
06/07/92	21	20.93	131.17	0	131.17	36.17
06/07/92	22	23.18	162.50	0	162.50	67.50

06/07/92	23	23.83	171.00	0	171.00	76.00
06/07/92	24	17.93	91.67	95	186.67	91.67
06/08/92	1	22.87	165.17	0	165.17	70.17
06/08/92	2	24.00	182.67	0	182.67	87.67
06/08/92	3	15.30	59.08	95	154.08	59.08
06/08/92	4	19.91	123.17	0	123.17	28.17
06/08/92	5	22.07	157.25	0	157.25	62.25
06/08/92	6	21.48	144.58	0	144.58	49.58
06/08/92	7	24.21	184.33	0	184.33	89.33
06/08/92	8	27.83	224.33	0	224.33	129.33
06/08/92	9	25.71	200.92	0	200.92	105.92
06/08/92	10	24.81	193.25	0	193.25	98.25
06/08/92	11	22.79	169.00	0	169.00	74.00
06/08/92	12	21.88	157.92	0	157.92	62.92
06/08/92	13	21.37	151.17	0	151.17	56.17
06/08/92	14	21.25	152.00	0	152.00	57.00
06/08/92	15	23.85	180.75	0	180.75	85.75
06/08/92	16	24.33	186.00	0	186.00	91.00
06/08/92	17	24.18	183.50	0	183.50	88.50
06/08/92	18	25.37	197.08	0	197.08	102.08
06/08/92	19	24.52	186.42	0	186.42	91.42
06/08/92	20	27.04	210.92	0	210.92	115.92
06/08/92	21	28.60	227.25	0	227.25	132.25
06/08/92	22	28.88	230.25	0	230.25	135.25
06/08/92	23	25.68	201.67	0	201.67	106.67
06/08/92	24	24.38	187.33	0	187.33	92.33
06/09/92	1	23.94	180.00	0	180.00	85.00
06/09/92	2	24.20	179.08	0	179.08	84.08
06/09/92	3	22.14	153.25	0	153.25	58.25
06/09/92	4	20.18	127.25	0	127.25	32.25
06/09/92	5	21.26	139.50	0	139.50	44.50
06/09/92	6	20.66	134.08	0	134.08	39.08
06/09/92	7	19.68	120.58	0	120.58	25.58
06/09/92	8	22.06	156.00	0	156.00	61.00
06/09/92	9	23.46	176.92	0	176.92	81.92
06/09/92	10	24.13	183.17	0	183.17	88.17
06/09/92	11	23.49	175.58	0	175.58	80.58
06/09/92	12	24.08	180.08	0	180.08	85.08
06/09/92	13	23.98	177.50	0	177.50	82.50
06/09/92	14	25.03	191.92	0	191.92	96.92
06/09/92	15	24.28	180.50	0	180.50	85.50
06/09/92	16	23.39	176.67	0	176.67	81.67
06/09/92	17	22.42	164.08	0	164.08	69.08
06/09/92	18	20.54	131.08	0	131.08	36.08
06/09/92	19	21.61	153.83	0	153.83	58.83
06/09/92	20	20.68	139.00	0	139.00	44.00
06/09/92	21	18.16	100.50	0	100.50	5.50
06/09/92	22	24.74	178.50	0	178.50	83.50
06/09/92	23	18.83	105.67	0	105.67	10.67
06/09/92	24	21.18	136.92	0	136.92	41.92
06/10/92	1	14.79	53.92	95	148.92	53.92
06/10/92	2	19.08	105.25	0	105.25	10.25
06/10/92	3	21.94	149.67	0	149.67	54.67
06/10/92	4	21.38	143.42	0	143.42	48.42
06/10/92	5	21.28	140.67	0	140.67	45.67
06/10/92	6	23.75	172.17	0	172.17	77.17
06/10/92	7	22.18	152.42	0	152.42	57.42
06/10/92	8	23.48	171.25	0	171.25	76.25

06/10/92	9	24.61	184.83	0	184.83	89.83
06/10/92	10	24.03	179.08	0	179.08	84.08
06/10/92	11	22.58	159.58	0	159.58	64.58
06/10/92	12	22.27	157.00	0	157.00	62.00
06/10/92	13	22.93	166.75	0	166.75	71.75
06/10/92	14	21.10	143.67	0	143.67	48.67
06/10/92	15	21.76	146.50	0	146.50	51.50
06/10/92	16	21.73	149.92	0	149.92	54.92
06/10/92	17	21.15	140.08	0	140.08	45.08
06/10/92	18	20.33	128.50	0	128.50	33.50
06/10/92	19	20.18	123.75	0	123.75	28.75
06/10/92	20	20.23	123.92	0	123.92	28.92
06/10/92	21	21.48	144.17	0	144.17	49.17
06/10/92	22	23.37	167.50	0	167.50	72.50
06/10/92	23	23.02	164.42	0	164.42	69.42
06/10/92	24	22.24	154.25	0	154.25	59.25
06/11/92	1	19.90	119.33	0	119.33	24.33
06/11/92	2	18.73	100.50	0	100.50	5.50
06/11/92	3	20.71	131.08	0	131.08	36.08
06/11/92	4	20.81	133.25	0	133.25	38.25
06/11/92	5	20.52	129.83	0	129.83	34.83
06/11/92	6	21.10	136.25	0	136.25	41.25
06/11/92	7	21.53	146.83	0	146.83	51.83
06/11/92	8	20.46	133.50	0	133.50	38.50
06/11/92	9	21.68	148.33	0	148.33	53.33
06/11/92	10	24.33	183.83	0	183.83	88.83
06/11/92	11	24.88	186.92	0	186.92	91.92
06/11/92	12	23.97	184.83	0	184.83	89.83
06/11/92	13	24.09	182.50	0	182.50	87.50
06/11/92	14	24.73	185.17	0	185.17	90.17
06/11/92	15	23.93	178.08	0	178.08	83.08
06/11/92	16	23.62	178.08	0	178.08	83.08
06/11/92	17	23.40	177.50	0	177.50	82.50
06/11/92	18	23.29	169.58	0	169.58	74.58
06/11/92	19	24.26	185.50	0	185.50	90.50
06/11/92	20	26.43	206.17	0	206.17	111.17
06/11/92	21	26.32	208.33	0	208.33	113.33
06/11/92	22	27.38	218.42	0	218.42	123.42
06/11/92	23	26.75	212.67	0	212.67	117.67
06/11/92	24	27.59	211.42	0	211.42	116.42
06/12/92	1	24.98	182.00	0	182.00	87.00
06/12/92	2	21.17	138.92	0	138.92	43.92
06/12/92	3	23.67	177.08	0	177.08	82.08
06/12/92	4	23.68	178.33	0	178.33	83.33
06/12/92	5	24.53	183.17	0	183.17	88.17
06/12/92	6	25.03	184.17	0	184.17	89.17
06/12/92	7	23.92	176.50	0	176.50	81.50
06/12/92	8	24.43	179.08	0	179.08	84.08
06/12/92	9	21.27	141.33	0	141.33	46.33
06/12/92	10	22.30	159.92	0	159.92	64.92
06/12/92	11	27.16	216.08	0	216.08	121.08
06/12/92	12	28.75	231.83	0	231.83	136.83
06/12/92	13	27.43	223.00	0	223.00	128.00
06/12/92	14	28.10	226.75	0	226.75	131.75
06/12/92	15	28.93	237.92	0	237.92	142.92
06/12/92	16	29.58	241.00	0	241.00	146.00
06/12/92	17	29.82	239.58	0	239.58	144.58
06/12/92	18	28.53	228.92	0	228.92	133.92

06/12/92	19	27.44	216.00	0	216.00	121.00
06/12/92	20	28.54	231.25	0	231.25	136.25
06/12/92	21	29.15	237.67	0	237.67	142.67
06/12/92	22	29.10	235.83	0	235.83	140.83
06/12/92	23	27.64	222.75	0	222.75	127.75
06/12/92	24	29.49	243.67	0	243.67	148.67
06/13/92	1	29.85	244.75	0	244.75	149.75
06/13/92	2	29.05	239.92	0	239.92	144.92
06/13/92	3	27.59	224.50	0	224.50	129.50
06/13/92	4	28.94	236.92	0	236.92	141.92
06/13/92	5	28.12	227.67	0	227.67	132.67
06/13/92	6	28.32	230.08	0	230.08	135.08
06/13/92	7	29.53	242.42	0	242.42	147.42
06/13/92	8	27.52	221.08	0	221.08	126.08
06/13/92	9	23.91	183.67	0	183.67	88.67
06/13/92	10	22.98	173.83	0	173.83	78.83
06/13/92	11	24.12	184.00	0	184.00	89.00
06/13/92	12	26.31	210.17	0	210.17	115.17
06/13/92	13	24.15	187.33	0	187.33	92.33
06/13/92	14	26.03	207.58	0	207.58	112.58
06/13/92	15	27.16	218.83	0	218.83	123.83
06/13/92	16	29.43	239.42	0	239.42	144.42
06/13/92	17	27.72	224.42	0	224.42	129.42
06/13/92	18	27.33	221.75	0	221.75	126.75
06/13/92	19	26.57	213.33	0	213.33	118.33
06/13/92	20	29.04	237.25	0	237.25	142.25
06/13/92	21	27.74	227.33	0	227.33	132.33
06/13/92	22	27.04	216.08	0	216.08	121.08
06/13/92	23	28.31	229.92	0	229.92	134.92
06/13/92	24	28.33	231.67	0	231.67	136.67
06/14/92	1	27.09	216.50	0	216.50	121.50
06/14/92	2	28.93	236.17	0	236.17	141.17
06/14/92	3	26.19	211.92	0	211.92	116.92
06/14/92	4	24.45	185.50	0	185.50	90.50
06/14/92	5	25.83	207.33	0	207.33	112.33
06/14/92	6	25.36	202.08	0	202.08	107.08
06/14/92	7	25.39	199.50	0	199.50	104.50
06/14/92	8	25.83	204.75	0	204.75	109.75
06/14/92	9	25.58	204.83	0	204.83	109.83
06/14/92	10	26.63	217.00	0	217.00	122.00
06/14/92	11	26.09	212.42	0	212.42	117.42
06/14/92	12	26.18	211.17	0	211.17	116.17
06/14/92	13	27.55	224.92	0	224.92	129.92
06/14/92	14	26.07	211.42	0	211.42	116.42
06/14/92	15	24.21	192.25	0	192.25	97.25
06/14/92	16	24.98	198.83	0	198.83	103.83
06/14/92	17	23.54	184.75	0	184.75	89.75
06/14/92	18	23.82	180.25	0	180.25	85.25
06/14/92	19	26.05	209.58	0	209.58	114.58
06/14/92	20	24.72	192.00	0	192.00	97.00
06/14/92	21	24.05	183.67	0	183.67	88.67
06/14/92	22	22.78	166.58	0	166.58	71.58
06/14/92	23	27.17	217.00	0	217.00	122.00
06/14/92	24	26.48	214.33	0	214.33	119.33
06/15/92	1	26.39	213.25	0	213.25	118.25
06/15/92	2	23.48	177.58	0	177.58	82.58
06/15/92	3	25.15	196.17	0	196.17	101.17
06/15/92	4	24.34	188.58	0	188.58	93.58

06/15/92	5	24.19	189.08	0	189.08	94.08
06/15/92	6	24.19	188.42	0	188.42	93.42
06/15/92	7	24.21	191.50	0	191.50	96.50
06/15/92	8	24.13	186.08	0	186.08	91.08
06/15/92	9	25.72	207.33	0	207.33	112.33
06/15/92	10	24.76	195.08	0	195.08	100.08
06/15/92	11	24.01	185.00	0	185.00	90.00
06/15/92	12	23.93	187.33	0	187.33	92.33
06/15/92	13	23.30	178.25	0	178.25	83.25
06/15/92	14	23.83	183.75	0	183.75	88.75
06/15/92	15	24.60	190.92	0	190.92	95.92
06/15/92	16	22.79	170.50	0	170.50	75.50
06/15/92	17	24.00	186.42	0	186.42	91.42
06/15/92	18	24.38	187.33	0	187.33	92.33
06/15/92	19	25.67	206.25	0	206.25	111.25
06/15/92	20	26.73	213.42	0	213.42	118.42
06/15/92	21	26.92	216.58	0	216.58	121.58
06/15/92	22	27.09	217.67	0	217.67	122.67
06/15/92	23	26.12	205.17	0	205.17	110.17
06/15/92	24	28.25	229.75	0	229.75	134.75
06/16/92	1	26.35	209.92	0	209.92	114.92
06/16/92	2	22.92	168.25	0	168.25	73.25
06/16/92	3	21.40	143.92	0	143.92	48.92
06/16/92	4	21.63	148.83	0	148.83	53.83
06/16/92	5	23.87	181.00	0	181.00	86.00
06/16/92	6	23.73	182.00	0	182.00	87.00
06/16/92	7	20.59	140.08	0	140.08	45.08
06/16/92	8	22.78	165.83	0	165.83	70.83
06/16/92	9	17.95	104.50	0	104.50	9.50
06/16/92	10	20.04	136.75	0	136.75	41.75
06/16/92	11	22.49	165.92	0	165.92	70.92
06/16/92	12	24.22	182.17	0	182.17	87.17
06/16/92	13	21.83	159.50	0	159.50	64.50
06/16/92	14	19.63	123.92	0	123.92	28.92
06/16/92	15	19.46	120.50	0	120.50	25.50
06/16/92	16	23.37	173.42	0	173.42	78.42
06/16/92	17	20.84	145.58	0	145.58	50.58
06/16/92	18	24.64	175.75	0	175.75	80.75
06/16/92	19	25.56	181.42	0	181.42	86.42
06/16/92	20	24.02	175.75	0	175.75	80.75
06/16/92	21	21.47	141.08	0	141.08	46.08
06/16/92	22	21.63	148.17	0	148.17	53.17
06/16/92	23	21.04	139.67	0	139.67	44.67
06/16/92	24	21.74	151.17	0	151.17	56.17
06/17/92	1	18.98	114.75	0	114.75	19.75
06/17/92	2	22.65	159.58	0	159.58	64.58
06/17/92	3	22.33	160.67	0	160.67	65.67
06/17/92	4	19.10	115.92	0	115.92	20.92
06/17/92	5	22.37	157.58	0	157.58	62.58
06/17/92	6	24.60	187.75	0	187.75	92.75
06/17/92	7	22.92	159.75	0	159.75	64.75
06/17/92	8	23.04	172.17	0	172.17	77.17
06/17/92	9	23.56	174.08	0	174.08	79.08
06/17/92	10	23.94	178.00	0	178.00	83.00
06/17/92	11	23.54	175.33	0	175.33	80.33
06/17/92	12	23.99	182.33	0	182.33	87.33
06/17/92	13	24.23	178.50	0	178.50	83.50
06/17/92	14	22.52	163.92	0	163.92	68.92

Table VI-1: WIND/DIESEL SIMULATION FOR JUNE 1992 (continued)

06/17/92	15	22.58	165.42	0	165.42	70.42
06/17/92	16	21.61	148.17	0	148.17	53.17
06/17/92	17	25.03	191.00	0	191.00	96.00
06/17/92	18	21.98	155.00	0	155.00	60.00
06/17/92	19	20.86	137.83	0	137.83	42.83
06/17/92	20	21.23	142.50	0	142.50	47.50
06/17/92	21	23.58	176.17	0	176.17	81.17
06/17/92	22	24.58	187.25	0	187.25	92.25
06/17/92	23	19.99	130.67	0	130.67	35.67
06/17/92	24	21.31	144.92	0	144.92	49.92
06/18/92	1	22.69	160.08	0	160.08	65.08
06/18/92	2	22.72	165.50	0	165.50	70.50
06/18/92	3	23.55	173.17	0	173.17	78.17
06/18/92	4	24.15	179.92	0	179.92	84.92
06/18/92	5	17.98	96.92	0	96.92	1.92
06/18/92	6	20.56	123.33	0	123.33	28.33
06/18/92	7	22.78	158.58	0	158.58	63.58
06/18/92	8	22.12	151.75	0	151.75	56.75
06/18/92	9	20.90	134.83	0	134.83	39.83
06/18/92	10	20.46	135.25	0	135.25	40.25
06/18/92	11	23.23	167.83	0	167.83	72.83
06/18/92	12	23.55	177.50	0	177.50	82.50
06/18/92	13	23.87	182.92	0	182.92	87.92
06/18/92	14	24.34	191.50	0	191.50	96.50
06/18/92	15	23.41	179.42	0	179.42	84.42
06/18/92	16	21.90	158.33	0	158.33	63.33
06/18/92	17	22.51	167.92	0	167.92	72.92
06/18/92	18	22.65	165.75	0	165.75	70.75
06/18/92	19	20.89	138.67	0	138.67	43.67
06/18/92	20	20.49	134.25	0	134.25	39.25
06/18/92	21	22.51	161.42	0	161.42	66.42
06/18/92	22	22.09	152.42	0	152.42	57.42
06/18/92	23	23.38	176.67	0	176.67	81.67
06/18/92	24	22.41	156.17	0	156.17	61.17
06/19/92	1	22.78	169.08	0	169.08	74.08
06/19/92	2	22.16	156.42	0	156.42	61.42
06/19/92	3	22.36	160.08	0	160.08	65.08
06/19/92	4	21.28	143.08	0	143.08	48.08
06/19/92	5	16.28	69.83	95	164.83	69.83
06/19/92	6	18.59	103.67	0	103.67	8.67
06/19/92	7	22.34	156.50	0	156.50	61.50
06/19/92	8	24.36	180.08	0	180.08	85.08
06/19/92	9	22.25	155.83	0	155.83	60.83
06/19/92	10	22.93	171.67	0	171.67	76.67
06/19/92	11	22.94	169.25	0	169.25	74.25
06/19/92	12	23.91	184.42	0	184.42	89.42
06/19/92	13	22.83	166.58	0	166.58	71.58
06/19/92	14	20.17	123.83	0	123.83	28.83
06/19/92	15	22.18	153.50	0	153.50	58.50
06/19/92	16	21.51	139.00	0	139.00	44.00
06/19/92	17	20.81	135.50	0	135.50	40.50
06/19/92	18	21.35	139.08	0	139.08	44.08
06/19/92	19	22.25	154.92	0	154.92	59.92
06/19/92	20	24.33	176.33	0	176.33	81.33
06/19/92	21	24.94	183.25	0	183.25	88.25
06/19/92	22	26.61	202.92	0	202.92	107.92
06/19/92	23	24.31	181.58	0	181.58	86.58
06/19/92	24	23.78	169.25	0	169.25	74.25

06/20/92	1	24.87	185.50	0	185.50	90.50
06/20/92	2	22.54	156.25	0	156.25	61.25
06/20/92	3	22.71	156.83	0	156.83	61.83
06/20/92	4	17.84	89.33	95	184.33	89.33
06/20/92	5	16.67	77.92	95	172.92	77.92
06/20/92	6	18.58	98.33	0	98.33	3.33
06/20/92	7	18.23	96.92	0	96.92	1.92
06/20/92	8	19.06	110.42	0	110.42	15.42
06/20/92	9	19.88	122.33	0	122.33	27.33
06/20/92	10	19.38	116.75	0	116.75	21.75
06/20/92	11	20.05	123.67	0	123.67	28.67
06/20/92	12	20.27	127.75	0	127.75	32.75
06/20/92	13	20.84	133.75	0	133.75	38.75
06/20/92	14	19.40	116.92	0	116.92	21.92
06/20/92	15	18.73	105.42	0	105.42	10.42
06/20/92	16	19.93	125.00	0	125.00	30.00
06/20/92	17	19.23	115.75	0	115.75	20.75
06/20/92	18	20.01	121.75	0	121.75	26.75
06/20/92	19	21.88	149.50	0	149.50	54.50
06/20/92	20	22.36	154.92	0	154.92	59.92
06/20/92	21	19.23	112.92	0	112.92	17.92
06/20/92	22	21.51	147.25	0	147.25	52.25
06/20/92	23	20.45	127.58	0	127.58	32.58
06/20/92	24	22.03	153.50	0	153.50	58.50
06/21/92	1	16.39	72.58	95	167.58	72.58
06/21/92	2	11.48	19.67	95	114.67	19.67
06/21/92	3	17.87	87.92	95	182.92	87.92
06/21/92	4	17.50	88.33	95	183.33	88.33
06/21/92	5	16.98	81.42	95	176.42	81.42
06/21/92	6	18.70	103.00	0	103.00	8.00
06/21/92	7	23.94	174.08	0	174.08	79.08
06/21/92	8	25.98	199.83	0	199.83	104.83
06/21/92	9	25.00	189.50	0	189.50	94.50
06/21/92	10	23.23	170.08	0	170.08	75.08
06/21/92	11	21.20	146.67	0	146.67	51.67
06/21/92	12	22.36	157.50	0	157.50	62.50
06/21/92	13	21.89	150.42	0	150.42	55.42
06/21/92	14	21.93	150.83	0	150.83	55.83
06/21/92	15	21.77	148.00	0	148.00	53.00
06/21/92	16	22.00	151.17	0	151.17	56.17
06/21/92	17	21.65	151.25	0	151.25	56.25
06/21/92	18	23.13	162.75	0	162.75	67.75
06/21/92	19	23.08	167.17	0	167.17	72.17
06/21/92	20	22.53	158.83	0	158.83	63.83
06/21/92	21	20.76	134.67	0	134.67	39.67
06/21/92	22	22.13	150.08	0	150.08	55.08
06/21/92	23	20.18	125.67	0	125.67	30.67
06/21/92	24	11.22	17.08	95	112.08	17.08
06/22/92	1	14.52	51.08	95	146.08	51.08
06/22/92	2	17.26	80.33	95	175.33	80.33
06/22/92	3	16.12	68.42	95	163.42	68.42
06/22/92	4	10.48	9.75	95	104.75	9.75
06/22/92	5	10.88	12.08	95	107.08	12.08
06/22/92	6	12.77	29.75	95	124.75	29.75
06/22/92	7	15.08	52.50	95	147.50	52.50
06/22/92	8	15.38	58.83	95	153.83	58.83
06/22/92	9	15.28	56.92	95	151.92	56.92
06/22/92	10	16.13	68.42	95	163.42	68.42

06/22/92	11	17.71	91.00	95	186.00	91.00
06/22/92	12	17.88	94.25	95	189.25	94.25
06/22/92	13	18.42	103.33	0	103.33	8.33
06/22/92	14	18.38	106.42	0	106.42	11.42
06/22/92	15	18.29	105.83	0	105.83	10.83
06/22/92	16	18.59	109.83	0	109.83	14.83
06/22/92	17	17.16	91.17	95	186.17	91.17
06/22/92	18	18.40	102.25	0	102.25	7.25
06/22/92	19	20.24	124.33	0	124.33	29.33
06/22/92	20	20.98	141.08	0	141.08	46.08
06/22/92	21	22.58	153.58	0	153.58	58.58
06/22/92	22	16.31	73.25	95	168.25	73.25
06/22/92	23	21.34	138.08	0	138.08	43.08
06/22/92	24	23.20	168.25	0	168.25	73.25
06/23/92	1	20.93	135.83	0	135.83	40.83
06/23/92	2	18.97	106.58	0	106.58	11.58
06/23/92	3	17.82	92.92	95	187.92	92.92
06/23/92	4	12.93	30.00	95	125.00	30.00
06/23/92	5	15.09	50.42	95	145.42	50.42
06/23/92	6	16.65	72.67	95	167.67	72.67
06/23/92	7	18.67	101.50	0	101.50	6.50
06/23/92	8	15.57	60.17	95	155.17	60.17
06/23/92	9	16.74	78.25	95	173.25	78.25
06/23/92	10	18.55	107.25	0	107.25	12.25
06/23/92	11	18.85	109.67	0	109.67	14.67
06/23/92	12	18.52	105.50	0	105.50	10.50
06/23/92	13	19.73	121.42	0	121.42	26.42
06/23/92	14	19.20	116.83	0	116.83	21.83
06/23/92	15	18.28	107.42	0	107.42	12.42
06/23/92	16	16.45	78.67	95	173.67	78.67
06/23/92	17	18.63	109.25	0	109.25	14.25
06/23/92	18	18.70	105.67	0	105.67	10.67
06/23/92	19	16.98	83.75	95	178.75	83.75
06/23/92	20	15.34	58.75	95	153.75	58.75
06/23/92	21	15.89	68.75	95	163.75	68.75
06/23/92	22	15.53	62.58	95	157.58	62.58
06/23/92	23	17.18	86.00	95	181.00	86.00
06/23/92	24	15.07	55.00	95	150.00	55.00
06/24/92	1	14.64	50.83	95	145.83	50.83
06/24/92	2	11.41	15.92	95	110.92	15.92
06/24/92	3	12.62	29.75	95	124.75	29.75
06/24/92	4	14.58	47.75	95	142.75	47.75
06/24/92	5	13.97	43.33	95	138.33	43.33
06/24/92	6	11.48	19.00	95	114.00	19.00
06/24/92	7	14.44	50.42	95	145.42	50.42
06/24/92	8	17.32	81.92	95	176.92	81.92
06/24/92	9	20.03	112.92	0	112.92	17.92
06/24/92	10	20.31	131.00	0	131.00	36.00
06/24/92	11	18.44	103.42	0	103.42	8.42
06/24/92	12	19.72	117.67	0	117.67	22.67
06/24/92	13	21.78	159.67	0	159.67	64.67
06/24/92	14	25.58	202.75	0	202.75	107.75
06/24/92	15	23.09	171.25	0	171.25	76.25
06/24/92	16	22.03	161.25	0	161.25	66.25
06/24/92	17	20.97	144.58	0	144.58	49.58
06/24/92	18	20.78	137.17	0	137.17	42.17
06/24/92	19	21.25	144.83	0	144.83	49.83
06/24/92	20	19.70	115.50	0	115.50	20.50

06/24/92	21	17.46	89.50	95	184.50	89.50
06/24/92	22	19.00	111.17	0	111.17	16.17
06/24/92	23	19.76	128.92	0	128.92	33.92
06/24/92	24	21.76	154.75	0	154.75	59.75
06/25/92	1	20.87	139.17	0	139.17	44.17
06/25/92	2	20.86	137.58	0	137.58	42.58
06/25/92	3	20.12	128.08	0	128.08	33.08
06/25/92	4	19.44	117.42	0	117.42	22.42
06/25/92	5	19.44	117.42	0	117.42	22.42
06/25/92	6	19.04	110.25	0	110.25	15.25
06/25/92	7	17.13	81.25	95	176.25	81.25
06/25/92	8	16.18	72.25	95	167.25	72.25
06/25/92	9	16.95	84.67	95	179.67	84.67
06/25/92	10	20.17	131.42	0	131.42	36.42
06/25/92	11	20.72	138.33	0	138.33	43.33
06/25/92	12	22.48	162.92	0	162.92	67.92
06/25/92	13	23.50	180.00	0	180.00	85.00
06/25/92	14	22.31	168.42	0	168.42	73.42
06/25/92	15	23.58	179.50	0	179.50	84.50
06/25/92	16	23.42	171.92	0	171.92	76.92
06/25/92	17	23.67	178.17	0	178.17	83.17
06/25/92	18	22.77	170.92	0	170.92	75.92
06/25/92	19	24.88	193.75	0	193.75	98.75
06/25/92	20	22.48	160.92	0	160.92	65.92
06/25/92	21	22.83	166.33	0	166.33	71.33
06/25/92	22	23.95	180.00	0	180.00	85.00
06/25/92	23	25.16	193.08	0	193.08	98.08
06/25/92	24	24.43	188.33	0	188.33	93.33
06/26/92	1	22.80	166.75	0	166.75	71.75
06/26/92	2	23.42	173.83	0	173.83	78.83
06/26/92	3	22.56	161.00	0	161.00	66.00
06/26/92	4	23.36	169.33	0	169.33	74.33
06/26/92	5	23.88	175.58	0	175.58	80.58
06/26/92	6	23.97	177.75	0	177.75	82.75
06/26/92	7	23.99	176.58	0	176.58	81.58
06/26/92	8	22.86	170.50	0	170.50	75.50
06/26/92	9	22.43	158.17	0	158.17	63.17
06/26/92	10	22.97	170.92	0	170.92	75.92
06/26/92	11	23.09	169.67	0	169.67	74.67
06/26/92	12	22.04	159.42	0	159.42	64.42
06/26/92	13	20.51	137.00	0	137.00	42.00
06/26/92	14	20.70	144.17	0	144.17	49.17
06/26/92	15	21.32	157.42	0	157.42	62.42
06/26/92	16	20.06	138.92	0	138.92	43.92
06/26/92	17	21.03	143.83	0	143.83	48.83
06/26/92	18	21.04	140.83	0	140.83	45.83
06/26/92	19	19.28	116.42	0	116.42	21.42
06/26/92	20	20.08	119.67	0	119.67	24.67
06/26/92	21	20.13	123.67	0	123.67	28.67
06/26/92	22	19.43	117.67	0	117.67	22.67
06/26/92	23	19.27	116.92	0	116.92	21.92
06/26/92	24	20.87	136.75	0	136.75	41.75
06/27/92	1	20.38	130.67	0	130.67	35.67
06/27/92	2	18.08	99.33	0	99.33	4.33
06/27/92	3	15.21	56.67	95	151.67	56.67
06/27/92	4	18.18	103.92	0	103.92	8.92
06/27/92	5	18.39	102.75	0	102.75	7.75
06/27/92	6	17.74	92.92	95	187.92	92.92

Table VI-1: WIND/DIESEL SIMULATION FOR JUNE 1992 (continued)

06/27/92	7	19.68	123.25	0	123.25	28.25
06/27/92	8	17.41	86.25	95	181.25	86.25
06/27/92	9	22.30	160.42	0	160.42	65.42
06/27/92	10	20.63	140.58	0	140.58	45.58
06/27/92	11	22.73	168.67	0	168.67	73.67
06/27/92	12	24.48	187.58	0	187.58	92.58
06/27/92	13	25.20	196.17	0	196.17	101.17
06/27/92	14	26.03	205.33	0	205.33	110.33
06/27/92	15	25.93	203.58	0	203.58	108.58
06/27/92	16	25.23	198.75	0	198.75	103.75
06/27/92	17	25.13	192.42	0	192.42	97.42
06/27/92	18	24.34	185.00	0	185.00	90.00
06/27/92	19	23.39	173.08	0	173.08	78.08
06/27/92	20	23.91	175.25	0	175.25	80.25
06/27/92	21	23.08	169.92	0	169.92	74.92
06/27/92	22	24.48	182.08	0	182.08	87.08
06/27/92	23	23.15	172.75	0	172.75	77.75
06/27/92	24	22.86	162.58	0	162.58	67.58
06/28/92	1	23.08	170.58	0	170.58	75.58
06/28/92	2	24.34	189.58	0	189.58	94.58
06/28/92	3	22.88	166.50	0	166.50	71.50
06/28/92	4	24.45	186.42	0	186.42	91.42
06/28/92	5	22.68	167.75	0	167.75	72.75
06/28/92	6	22.76	166.25	0	166.25	71.25
06/28/92	7	24.33	183.67	0	183.67	88.67
06/28/92	8	22.76	166.83	0	166.83	71.83
06/28/92	9	21.68	151.25	0	151.25	56.25
06/28/92	10	21.49	149.42	0	149.42	54.42
06/28/92	11	22.59	164.92	0	164.92	69.92
06/28/92	12	22.82	168.08	0	168.08	73.08
06/28/92	13	22.83	168.67	0	168.67	73.67
06/28/92	14	24.74	190.67	0	190.67	95.67
06/28/92	15	24.18	178.83	0	178.83	83.83
06/28/92	16	23.28	173.25	0	173.25	78.25
06/28/92	17	24.08	180.08	0	180.08	85.08
06/28/92	18	23.61	174.67	0	174.67	79.67
06/28/92	19	23.27	170.17	0	170.17	75.17
06/28/92	20	24.08	176.83	0	176.83	81.83
06/28/92	21	26.98	214.83	0	214.83	119.83
06/28/92	22	27.82	222.00	0	222.00	127.00
06/28/92	23	25.31	199.83	0	199.83	104.83
06/28/92	24	24.97	195.75	0	195.75	100.75
06/29/92	1	25.42	199.50	0	199.50	104.50
06/29/92	2	21.63	151.58	0	151.58	56.58
06/29/92	3	18.73	101.83	0	101.83	6.83
06/29/92	4	14.03	45.17	95	140.17	45.17
06/29/92	5	12.13	22.92	95	117.92	22.92
06/29/92	6	10.78	13.25	95	108.25	13.25
06/29/92	7	11.24	13.58	95	108.58	13.58
06/29/92	8	14.59	52.08	95	147.08	52.08
06/29/92	9	19.47	111.25	0	111.25	16.25
06/29/92	10	20.42	125.75	0	125.75	30.75
06/29/92	11	20.13	119.50	0	119.50	24.50
06/29/92	12	20.16	118.83	0	118.83	23.83
06/29/92	13	19.83	121.33	0	121.33	26.33
06/29/92	14	19.94	125.42	0	125.42	30.42
06/29/92	15	20.19	124.92	0	124.92	29.92
06/29/92	16	20.17	129.08	0	129.08	34.08

Table VI-1: WIND/DIESEL SIMULATION FOR JUNE 1992 (continued)

Date	Hour	MPH	Total 3 Turbine KWH	Diesal KWH	Total KWH	Excess KWH
06/29/92	17	19.46	120.00	0	120.00	25.00
06/29/92	18	18.53	108.00	0	108.00	13.00
06/29/92	19	21.18	141.92	0	141.92	46.92
06/29/92	20	21.85	147.75	0	147.75	52.75
06/29/92	21	21.81	148.92	0	148.92	53.92
06/29/92	22	21.42	145.42	0	145.42	50.42
06/29/92	23	20.27	129.58	0	129.58	34.58
06/29/92	24	19.87	121.33	0	121.33	26.33
06/30/92	1	18.46	101.25	0	101.25	6.25
06/30/92	2	17.91	93.83	95	188.83	93.83
06/30/92	3	14.68	51.67	95	146.67	51.67
06/30/92	4	10.16	8.08	95	103.08	8.08
06/30/92	5	9.42	6.00	95	101.00	6.00
06/30/92	6	12.37	24.75	95	119.75	24.75
06/30/92	7	12.93	30.42	95	125.42	30.42
06/30/92	8	12.54	25.92	95	120.92	25.92
06/30/92	9	14.86	52.92	95	147.92	52.92
06/30/92	10	15.92	64.92	95	159.92	64.92
06/30/92	11	17.63	91.33	95	186.33	91.33
06/30/92	12	18.25	98.42	0	98.42	3.42
06/30/92	13	17.52	88.58	95	183.58	88.58
06/30/92	14	16.87	81.67	95	176.67	81.67
06/30/92	15	15.96	69.83	95	164.83	69.83
06/30/92	16	16.83	77.42	95	172.42	77.42
06/30/92	17	17.62	90.58	95	185.58	90.58
06/30/92	18	16.59	80.58	95	175.58	80.58
06/30/92	19	16.69	77.17	95	172.17	77.17
06/30/92	20	18.03	97.83	0	97.83	2.83
06/30/92	21	18.81	101.58	0	101.58	6.58
06/30/92	22	18.42	98.33	0	98.33	3.33
06/30/92	23	19.47	116.25	0	116.25	21.25
06/30/92	24	18.77	102.25	0	102.25	7.25
		======	=========	=========	==========	=========
		20.54	96,990.75	15,960.00	112,950.75	44,550.75

APPENDIX VII

WIND/DIESEL BUDGET
VS.
ACTUAL COSTS

Table VII-1: WIND/DIESEL PROJECT COSTS

PROJECT #060 MOLOKAI WIND/DIESEL
WEEK ENDED 08-Oct-92

ACTIVITY	FINAL $ ACTUAL	PROJECT BUDGET	ACTUAL TO BUDGET VARIANCE $	ACTUAL TO BUDGET VARIANCE %
SYSTEM PREP & RENOVATION				
LABOR/EQUIP	19,988	49,010	29,022	59.2%
MATERIAL	44,544	47,850	3,306	6.9%
SHIPPING	17,729	16,500	(1,229)	-7.4%
SUBTOTAL SYSTEM PREP	82,261	113,360	31,099	27.4%
ELECTRICAL/AUXILARY				
LABOR/EQUIP	22,183	14,000	(8,183)	-58.5%
DIESEL INSTALLATION	11,943	10,400	(1,543)	-14.8%
MATERIAL/EQUIP	59,189	79,034	19,845	25.1%
SUBTOTAL ELECTRICAL	93,315	103,434	10,119	9.8%
GRADING				
SUBCONTRACTOR	1,170	5,040	3,870	76.8%
TOTAL GRADING	1,170	5,040	3,870	76.8%
FOUNDATIONS				
DRILLING	0	3,150	3,150	100.0%
REBAR	991	1,350	359	26.6%
CONCRETE	26,674	8,910	(17,764)	-199.4%
LABOR	7,071	3,000	(4,071)	-135.7%
EQUIPMENT	4,676	4,500	(176)	-3.9%
MISC. MATERIALS	265	600	335	55.8%
TOTAL FOUNDATIONS	39,677	21,510	(18,167)	-84.5%
MECHANICAL				
EQUIPMENT	29,992	21,736	(8,256)	-38.0%
LABOR	751	7,400	6,649	89.9%
MATERIALS	10,464	3,900	(6,564)	-168.3%
V17'S & TOWERS	258,500	258,500	0	0.0%
TOTAL MECHANICAL	299,707	291,536	(8,171)	-2.8%

Table VII-1: WIND/DIESEL PROJECT COSTS (continued)

PERMITS				
GRADING PERMITS	0	785	785	100.0%
STRUCTURAL PERMITS	0	1,130	1,130	100.0%
TOTAL PERMITS		1,915	1,915	100.0%
ENGINEERING				
CIVIL ENGINEERING	24,369	2,260	(22,109)	-978.3%
STRUCTURAL ENGINEERING	6,123	5,000	(1,123)	-22.5%
ELECTRICAL / SCADA	16,523	8,900	(7,623)	-85.7%
WIND RESOURCE		0	0	0.0%
TOTAL ENGINEERING	47,015	16,160	(30,855)	-190.9%
SUPERVISION/CONTINGENCY				
SUPERVISION	29,872	15,000	(14,872)	-99.1%
CONST SUPPORT		4,800	4,800	100.0%
TOTAL SUPRV/CONT.	29,872	19,800	(10,072)	-50.9%
GRAND TOTAL PROJECT COST	593,017	572,755	(20,262)	-3.5%

Table VII-2: WIND/DIESEL LINE ITEM PRE-CONSTRUCTION BUDGET VS. ACTUAL COSTS

FILE: 60_0425
MOLOKAI WIND/DIESEL PROJECT

BUDGET ITEM	ACCT NO.	AMOUNT	ACTUAL COST	REMARKS
CIVIL				
FIELD STAKING	1260	1,260		
GRADING PLAN	1260	1,000		
ELECTRICAL				
SINGLE LINE DESIGN	1262	1,400		
UTILITY INTERFACE	1262	1,500	24,369	
CONST DRAWING	1262	4,000	16,523	
INSPECTION	1262	2,000	1,042	
STRUCTURAL				
SOILS	1261	1,500	6,123	
CONST PLANS	1261	3,000		
INSPECTION	1261	500		
SYS PREP & RENOVATION				
LABOR & EQUIP	1286	49,010	19,988	
MATERIALS				
YAW GEAR	1286	3,600		
YAW PADS & L BRKT	1286	1,950	5,090	
TURN CABLE TWIST COUNTER	1286	750		
BRAKE SYSTEM	1286	3,750	6,001	
ENAPRO SYS SINGLE GENERATO	1286	4,500		
NEW ZOND CONTROLLER	1286	6,000	16,205	
SUPERVISOR COMPUTER & CABL	1286	14,000		
SOFTWARE	1286	2,000		
SCADA	1286	7,500	17,248	
SPARE PARTS	1286	1,800		
ENVIRONMENTAL CONROLLED RM	1286	2,000		
STANDBY COMPUTER POWER	1286	0		
SHIPPING	1286	16,500	17,729	
GRADING				
SITE PREP	1276	5,040	1,170	
FOUNDATIONS				
DRILLING	1280	3,150		
REBAR	1280	1,350	991	
CONCRETE	1280	8,910	26,674	
LABOR	1280	3,000	7,071	
EQUIP	1280	4,500	4,676	
MISC. MATERIAL				
STAKES	1280	600	265	

Table VII-2: WIND/DIESEL LINE ITEM PRE-CONSTRUCTION BUDGET VS. ACTUAL COSTS (continued)

MECHANICAL			
EQUIPMENT	1287	21,736	29,992
LABOR	1287	7,400	751
MATERIALS			
ANCHOR BOLTS	1287	2,400	
TWR STL & FASTENERS	1287	1,500	10,464
V17 & TOWERS	1287	258,500	258,500
ELECTRICAL			
LABOR & EQUIP	1290	14,000	21,141
DIESEL INSTALLATION	1291	10,400	11,943
MATERIALS			33,591
DIESEL/GENERATOR 100 KW	1291	27,879	25,598
TRANSF/BRKR PKG/CONN/CABLE	1291	26,005	
TYPE ES RECLOSER	1291	13,000	
CT/PT	1291	8,000	
ARRESTORS	1291	2,100	
BREAKER 400AMP, 15KV	1291	2,050	
PERMITS			
GRADING	1246	785	
STRUCTURAL	1247	1,130	
SUPERVISOR			
PROJECT MANAGER	1285	15,000	29,872
CONST CONSULTANT	1285	0	
CONST SUPPORT			
PHONE	1253	0	
ELECT	1253	4,500	
PHONE INTERTIE	1253	300	
TOTAL PROJECT BUDGET		572,755	593,017

APPENDIX VIII

OFF-PEAK UTILITY PENETRATION BY WIND/DIESEL MARCH 1992 - JANUARY 1993

Between the hours of 10:00 p.m. and 6:00 a.m. utility reaches minimum loads. This table reflects all hourly average times. The three wind turbines were producing 200 kW or more during off-peak time.

Table VIII-1: OFF-PEAK UTILITY PENETRATION BY WIND/DIESEL

3/92 - 1/93

DAY	TIME	Wind Speed (MPH)	Direction (DEG)	TRB-1 (KWH)	TRB-2 (KWH)	TRB-3 (KWH)	TOTAL (KWH)	Hourly Peak (KW)	% OF LOAD
03/20/92	02:00	25.38	69.17	68.08	65.75	68.67	202.50	2,988	0.068%
03/20/92	03:00	26.60	70.05	73.58	70.42	75.58	219.58	3,019	0.073%
03/20/92	04:00	26.21	64.02	74.42	70.58	72.25	217.25	2,621	0.083%
03/20/92	05:00	26.90	66.93	72.17	72.42	74.50	219.09	2,750	0.080%
03/20/92	23:00	25.93	76.41	67.92	68.33	70.92	207.17	3,963	0.052%
04/03/92	01:00	27.78	79.41	76.17	73.92	74.25	224.33	3,256	0.069%
05/05/92	23:00	27.23	56.48	68.25	73.00	77.33	218.58	3,913	0.056%
05/05/92	00:00	26.49	54.53	66.67	71.00	75.08	212.75	3,661	0.058%
05/06/92	01:00	26.60	60.01	67.67	70.58	71.92	210.17	2,991	0.070%
05/06/92	23:00	26.08	64.78	68.92	67.33	70.92	207.17	3,709	0.056%
05/06/92	00:00	28.33	64.49	73.92	74.92	77.92	226.75	3,333	0.068%
05/07/92	05:00	26.37	47.85	75.25	68.58	69.67	213.50	3,299	0.065%
06/06/92	02:00	25.98	78.03	66.42	67.58	68.50	202.50	3,711	0.055%
06/08/92	23:00	25.68	68.35	67.75	63.67	70.25	201.67	4,355	0.046%
06/11/92	23:00	26.75	72.96	69.67	68.92	74.08	212.67	4,308	0.049%
06/11/92	00:00	27.59	76.57	65.67	70.67	75.08	211.42	4,055	0.052%
06/12/92	23:00	27.64	75.15	73.00	73.42	76.33	222.75	4,411	0.050%
06/12/92	00:00	29.49	75.35	80.67	79.58	83.42	243.67	4,158	0.059%
06/13/92	01:00	29.85	74.73	81.58	80.42	82.75	244.75	3,728	0.066%
06/13/92	02:00	29.05	75.05	78.42	78.25	83.25	239.92	3,406	0.070%
06/13/92	03:00	27.59	76.06	72.75	73.75	78.00	224.50	3,325	0.068%
06/13/92	04:00	28.94	75.98	76.83	77.58	82.50	236.92	3,428	0.069%
06/13/92	05:00	28.12	76.80	72.83	75.83	79.00	227.67	3,416	0.067%
06/13/92	06:00	28.32	74.84	74.17	75.92	80.00	230.08	3,647	0.063%
06/13/92	23:00	28.31	74.05	74.33	75.92	79.67	229.92	4,241	0.054%
06/13/92	00:00	28.33	77.94	75.83	75.67	80.17	231.67	3,952	0.059%
06/14/92	01:00	27.09	82.12	75.00	72.08	69.42	216.50	3,339	0.065%
06/14/92	02:00	28.93	77.31	77.83	78.90	81.44	238.17	3,310	0.072%
06/14/92	03:00	26.19	75.97	69.58	70.00	72.33	211.92	3,216	0.066%
06/14/92	05:00	25.83	74.93	66.17	68.83	72.33	207.33	3,235	0.064%
06/14/92	06:00	25.36	75.63	66.17	66.67	69.80	202.08	3,488	0.058%
06/14/92	23:00	27.17	78.27	70.50	73.08	73.42	217.00	4,233	0.051%
06/14/92	00:00	26.48	73.98	71.00	70.42	72.92	214.33	3,945	0.054%
06/15/92	01:00	26.39	77.76	69.75	70.25	73.25	213.25	3,770	0.057%
06/15/92	23:00	26.12	76.35	64.58	68.75	71.83	205.17	4,200	0.049%
06/15/92	00:00	28.25	78.28	75.50	76.58	77.67	229.75	3,911	0.059%
06/16/92	01:00	26.35	77.02	68.83	70.00	71.08	209.92	3,376	0.062%
07/09/92	02:00	25.99	74.17	69.83	65.67	69.08	204.58	3,673	0.056%
07/09/92	04:00	27.62	72.18	71.75	70.17	75.58	217.50	3,556	0.061%
07/09/92	05:00	29.24	72.50	76.33	75.17	81.93	233.42	3,616	0.065%
07/09/92	06:00	28.58	72.20	76.08	72.92	78.08	227.08	3,992	0.057%

DAY	TIME	Wind Speed (MPH)	Direction (DEG)	TRB-1 (KWH)	TRB-2 (KWH)	TRB-3 (KWH)	TOTAL (KWH)	Hourly Peak (KW)	% OF LOAD
07/17/92	23:00	27.09	73.94	67.92	70.83	74.00	212.75	4,442	0.048%
07/17/92	00:00	27.28	73.89	70.17	70.50	76.67	217.33	4,169	0.052%
07/18/92	01:00	28.08	70.56	72.58	72.55	74.42	219.58	3,580	0.061%
07/18/92	02:00	26.28	67.86	71.42	64.67	70.25	206.33	3,647	0.057%
07/18/92	03:00	26.49	72.08	68.83	67.50	69.08	205.42	3,394	0.061%
07/18/92	06:00	26.63	75.57	66.75	69.75	72.42	208.92	3,844	0.054%
07/18/92	23:00	27.38	74.00	0.00	0.00	0.00			
07/18/92	00:00	27.53	71.26	71.33	70.50	77.50	219.33	4,102	0.053%
07/20/92	02:00	26.17	69.93	69.17	66.17	71.17	206.50	3,466	0.060%
07/24/92	23:00	30.33	65.16	86.17	80.58	86.25	253.00	4,065	0.062%
07/24/92	00:00	29.77	67.56	81.17	79.75	83.75	244.67	3,950	0.062%
07/25/92	01:00	31.11	70.96	81.83	82.92	89.83	254.58	3,957	0.064%
07/25/92	02:00	30.41	68.94	80.83	79.92	87.08	247.83	3,571	0.069%
07/25/92	03:00	30.97	67.93	83.50	81.42	87.08	252.00	3,388	0.074%
07/25/92	04:00	31.18	69.63	82.00	83.42	90.00	255.42	3,485	0.073%
07/25/92	05:00	30.27	68.37	84.00	79.92	86.67	250.58	3,197	0.078%
07/25/92	06:00	30.55	66.88	84.75	80.83	85.75	251.33	3,159	0.080%
07/25/92	23:00	25.78	62.34	74.75	65.08	68.17	208.00	4,328	0.048%
07/25/92	00:00	25.53	64.51	72.58	65.92	68.33	206.83	4,250	0.049%
07/26/92	01:00	25.28	66.05	71.08	63.08	69.17	203.33	3,568	0.057%
07/26/92	02:00	26.64	70.36	68.67	69.92	75.25	213.83	4,390	0.049%
07/30/92	05:00	26.18	75.45	66.25	68.42	70.42	205.00	3,650	0.056%
08/01/92	23:00	29.01	77.51	75.50	76.25	80.33	232.08	4,368	0.053%
08/01/92	00:00	29.18	78.68	77.75	77.17	79.75	234.67	4,153	0.057%
08/02/92	00:00	27.36	76.25	71.17	70.83	75.92	217.92	4,285	0.051%
08/03/92	01:00	25.89	74.95	66.17	65.17	71.33	202.67	3,751	0.054%
08/03/92	23:00	26.45	76.87	66.93	68.75	71.50	207.17	4,422	0.047%
08/03/92	00:00	25.93	77.31	66.50	67.92	17.58	206.00	3,830	0.054%
08/08/92	23:00	25.36	75.46	66.75	64.17	69.83	200.75	4,606	0.044%
08/12/92	23:00	25.79	76.55	62.33	67.70	70.67	200.17	4,301	0.047%
08/17/92	06:00	26.23	77.43	71.50	65.67	68.33	205.50	3,482	0.059%
08/17/92	23:00	27.76	76.34	63.33	70.92	73.58	207.83	4,385	0.047%
08/17/92	00:00	27.38	74.84	62.17	69.33	71.92	203.42	3,788	0.054%
08/18/92	01:00	28.84	74.21	70.50	73.50	75.67	219.67	3,659	0.060%
08/18/92	02:00	30.23	74.43	73.75	78.25	81.50	233.50	3,521	0.066%
08/18/92	03:00	27.89	73.92	66.42	70.58	71.58	208.58	3,533	0.059%
08/18/92	04:00	30.64	75.80	70.00	79.33	83.17	232.50	3,516	0.066%
08/18/92	05:00	28.02	73.93	64.92	70.33	74.33	209.58	3,561	0.059%
08/18/92	06:00	28.36	73.20	67.50	71.25	75.33	214.08	3,471	0.062%
08/18/92	23:00	28.51	78.24	64.33	73.58	77.33	215.25	4,407	0.049%
08/19/92	01:00	27.58	77.79	64.92	71.58	72.42	208.92	3,742	0.056%

Table VIII-1: OFF-PEAK UTILITY PENETRATION BY WIND/DIESEL
3/92 - 1/93 (continued)

DAY	TIME	Wind Speed (MPH)	Direction (DEG)	TRB-1 (KWH)	TRB-2 (KWH)	TRB-3 (KWH)	TOTAL (KWH)	Hourly Peak (KW)	% OF LOAD
08/19/92	03:00	27.08	77.09	62.08	69.25	71.83	203.17	3,608	0.056%
08/19/92	04:00	27.43	75.28	65.08	69.42	72.58	207.67	3,263	0.064%
08/19/92	05:00	28.24	75.23	69.00	72.33	75.17	216.50	3,622	0.060%
08/19/92	06:00	28.74	75.56	69.92	74.17	77.17	221.25	3,385	0.065%
08/20/92	02:00	28.09	74.78	68.42	76.00	74.83	219.25	3,404	0.064%
08/20/92	03:00	26.69	76.25	62.50	71.33	71.67	205.50	3,250	0.063%
08/24/92	23:00	28.09	75.25	73.00	75.83	79.33	228.17	4,377	0.052%
08/24/92	00:00	29.48	75.33	76.25	79.75	83.92	239.92	3,839	0.062%
08/25/92	01:00	28.43	72.85	71.75	78.42	79.67	227.83	3,818	0.060%
08/25/92	02:00	28.63	73.00	74.33	76.92	80.25	231.50	3,431	0.067%
08/26/92	23:00	26.19	74.21	66.42	70.25	72.00	208.67	4,266	0.049%
08/29/92	04:00	26.56	76.67	66.75	71.00	73.33	211.08	3,607	0.059%
08/29/92	05:00	26.02	76.88	62.92	69.50	71.83	204.25	3,478	0.059%
09/05/92	05:00	25.68	69.38	62.83	68.08	73.17	204.08	3,554	0.057%
09/11/92	23:00	27.93	201.12	65.92	70.83	71.83	208.58	4,550	0.046%
09/14/92	23:00	26.44	74.24	66.67	70.83	72.67	210.17	3,965	0.053%
10/23/92	23:00	27.57	69.82	68.33	74.42	75.33	218.08	3,927	0.056%
10/23/92	03:00	26.11	72.33	60.83	69.25	70.83	200.92	3,653	0.055%
10/23/92	23:00	28.55	77.68	76.58	76.25	77.42	230.25	4,073	0.057%
10/23/92	00:00	28.64	77.26	75.67	76.08	76.42	228.17	4,022	0.057%
10/24/92	01:00	28.95	76.16	75.67	77.50	80.50	233.67	3,385	0.069%
10/24/92	02:00	30.83	75.47	82.00	82.33	85.42	249.75	3,150	0.079%
10/24/92	03:00	26.83	75.93	67.50	69.67	73.42	210.58	3,354	0.063%
10/24/92	04:00	26.15	76.30	64.17	67.08	70.24	201.50	3,325	0.061%
10/24/92	05:00	27.71	78.50	73.58	73.50	75.67	222.75	3,816	0.058%
10/24/92	23:00	31.00	77.28	82.75	83.58	86.25	252.58	4,078	0.062%
10/24/92	00:00	30.43	78.32	79.50	81.83	83.50	244.83	3,958	0.062%
10/25/92	01:00	28.22	76.22	76.08	75.33	79.50	230.92	3,302	0.070%
10/25/92	02:00	27.91	76.53	73.67	74.58	77.00	225.25	3,574	0.063%
10/27/92	03:00	28.78	76.52	77.42	76.33	76.67	230.42	3,280	0.070%
10/27/92	04:00	27.89	76.83	75.08	74.33	78.50	227.92	3,240	0.070%
10/27/92	05:00	28.53	75.20	75.92	75.50	78.75	230.17	2,444	0.094%
10/27/92	23:00	26.03	75.46	64.33	68.42	70.50	203.25	4,156	0.049%
10/27/92	00:00	27.70	75.23	69.83	73.67	75.33	218.83	3,767	0.058%
10/28/92	01:00	29.17	77.61	73.67	77.58	80.17	231.42	3,112	0.074%
10/28/92	02:00	32.08	76.90	82.25	86.00	88.58	256.83	2,957	0.087%
10/28/92	03:00	32.62	75.80	84.17	87.42	92.17	263.75	2,947	0.089%
10/28/92	04:00	30.30	76.51	79.08	81.17	85.00	245.25	2,974	0.082%
10/28/92	05:00	27.42	80.94	70.67	72.25	71.25	214.17	3,189	0.067%
10/28/92	23:00	28.29	73.43	75.25	74.00	75.67	224.92	3,829	0.059%
10/28/92	00:00	26.34	71.29	69.17	66.92	71.17	207.25	3,466	0.060%

Table VIII-1: OFF-PEAK UTILITY PENETRATION BY WIND/DIESEL
3/92 - 1/93 (continued)

DAY	TIME	Wind Speed (MPH)	Direction (DEG)	TRB-1 (KWH)	TRB-2 (KWH)	TRB-3 (KWH)	TOTAL (KWH)	Hourly Peak (KW)	% OF LOAD
10/29/92	01:00	26.32	70.00	71.08	66.75	72.08	209.92	3,387	0.062%
10/29/92	02:00	27.73	68.38	75.08	70.50	74.08	219.67	3,328	0.066%
10/29/92	03:00	29.13	71.23	80.58	76.26	78.00	234.83	3,311	0.071%
10/29/92	04:00	27.87	72.30	71.17	72.92	77.67	221.75	3,316	0.067%
10/29/92	05:00	32.60	74.12	85.33	87.08	90.67	263.08	3,464	0.076%
10/29/92	06:00	30.31	78.30	78.75	81.17	84.08	244.00	3,514	0.069%
10/29/92	23:00	26.01	81.06	64.25	67.25	68.58	200.08	4,089	0.049%
11/06/92	23:00	29.97	77.25	77.17	78.83	83.25	239.25	4,434	0.054%
11/06/92	00:00	30.48	76.98	78.92	80.08	81.83	240.83	3,863	0.062%
11/07/92	01:00	29.66	73.98	76.50	76.67	81.58	234.75	3,715	0.063%
11/07/92	02:00	26.26	74.23	66.75	66.58	68.00	201.33	3,586	0.056%
11/07/92	23:00	30.01	77.51	76.75	80.75	82.67	243.17	4,162	0.058%
11/07/92	00:00	28.45	74.68	73.83	75.08	80.08	229.00	3,942	0.058%
11/08/92	01:00	29.08	74.29	74.92	77.25	80.75	232.92	3,570	0.065%
11/08/92	02:00	27.18	74.56	71.75	71.83	75.58	219.17	3,662	0.060%
11/08/92	05:00	27.76	75.27	71.67	72.83	76.75	221.25	3,114	0.071%
11/08/92	06:00	29.03	76.96	76.25	77.33	80.42	234.00	3,356	0.070%
11/08/92	23:00	28.58	73.39	73.08	74.58	77.92	225.58	4,150	0.054%
11/08/92	00:00	26.88	72.01	69.67	68.92	71.67	210.25	3,832	0.055%
11/09/92	06:00	29.85	70.32	79.33	78.67	82.33	240.33	3,622	0.066%
11/09/92	23:00	26.17	77.12	67.83	68.58	71.50	207.92	4,039	0.051%
11/10/92	03:00	25.36	71.60	68.17	64.92	69.83	202.92	3,478	0.058%
11/15/92	01:00	26.12	76.58	61.67	68.58	71.33	201.58	3,745	0.054%
11/25/92	01:00	28.39	52.08	72.17	76.25	76.08	224.50	3,444	0.065%
11/25/92	02:00	28.85	57.60	75.00	79.00	76.75	230.75	3,351	0.069%
11/25/92	03:00	27.38	61.38	65.92	71.25	68.33	205.50	3,370	0.061%
11/25/92	04:00	26.93	63.07	67.75	70.08	70.42	208.25	3,258	0.064%
11/25/92	05:00	30.94	58.54	81.25	84.33	84.00	249.58	3,272	0.076%
11/25/92	06:00	31.38	58.93	82.75	85.17	87.25	255.17	3,294	0.077%
11/27/92	06:00	35.12	79.73	88.75	91.08	89.33	269.17	2,960	0.091%
12/04/92	01:00	26.90	75.37	70.17	65.50	72.50	208.17	2,824	0.074%
12/04/92	03:00	29.67	76.35	78.00	75.42	81.33	234.75	2,675	0.088%
12/04/92	04:00	27.77	76.58	72.67	69.58	73.42	215.67	2,332	0.092%
12/04/92	23:00	39.80	75.05	101.25	103.00	107.08	311.33	3,154	0.099%
12/04/92	00:00	36.71	75.47	93.67	96.50	102.33	292.50	2,734	0.107%
12/05/92	01:00	35.09	74.58	89.17	91.75	97.25	278.17	3,398	0.082%
12/05/92	02:00	33.27	74.61	86.42	87.33	91.67	265.42	3,711	0.072%
12/05/92	03:00	33.87	75.67	87.17	89.00	93.33	269.50	3,285	0.082%
12/05/92	04:00	33.25	75.23	88.17	87.42	91.25	266.83	3,587	0.074%
12/05/92	05:00	34.72	76.86	88.83	91.50	94.33	274.67	3,685	0.075%
12/05/92	06:00	33.40	76.51	84.67	87.67	91.83	264.17	3,611	0.073%

Table VIII-1: OFF-PEAK UTILITY PENETRATION BY WIND/DIESEL
3/92 - 1/93 (continued)

DAY	TIME	Wind Speed (MPH)	Direction (DEG)	TRB-1 (KWH)	TRB-2 (KWH)	TRB-3 (KWH)	TOTAL (KWH)	Hourly Peak (KW)	% OF LOAD
12/05/92	23:00	35.59	75.84	90.67	93.58	98.50	282.75	4,290	0.066%
12/05/92	00:00	34.15	75.89	89.83	92.42	96.75	279.00	4,033	0.069%
12/06/92	01:00	31.80	75.03	80.83	83.08	89.58	253.50	3,257	0.078%
12/06/92	02:00	31.98	75.45	82.33	83.33	90.33	256.00	3,266	0.078%
12/06/92	03:00	29.98	77.38	77.42	78.08	82.42	237.92	3,049	0.078%
12/07/92	05:00	27.01	75.61	65.33	71.42	68.25	205.00	2,672	0.077%
12/08/92	00:00	26.69	62.72	68.42	71.50	71.83	211.75	3,511	0.060%
12/09/92	01:00	29.02	58.43	75.58	78.58	81.17	235.33	3,566	0.066%
12/09/92	02:00	29.74	58.39	77.25	79.83	82.58	239.67	3,422	0.070%
12/09/92	03:00	29.13	68.12	69.58	78.75	80.92	229.25	3,263	0.070%
12/09/92	04:00	30.68	61.38	84.00	84.17	85.58	253.75	3,573	0.071%
12/09/92	05:00	30.60	63.89	80.17	83.17	85.58	248.92	3,541	0.070%
12/09/92	06:00	30.87	64.33	78.33	84.08	85.92	248.83	3,464	0.072%
12/09/92	23:00	28.10	76.04	65.75	74.92	75.25	215.92	4,113	0.052%
12/09/92	00:00	29.53	74.93	68.33	79.42	81.00	228.75	3,579	0.064%
12/10/92	01:00	31.28	74.24	72.92	84.25	85.42	242.58	3,257	0.074%
12/10/92	02:00	31.56	74.13	74.83	85.00	86.33	246.17	3,257	0.076%
12/10/92	03:00	32.82	74.02	77.58	87.50	88.58	253.67	2,771	0.092%
12/10/92	04:00	35.05	73.73	84.50	94.67	95.17	274.33	2,826	0.097%
12/10/92	05:00	31.16	77.60	74.33	84.92	83.83	243.08	3,123	0.078%
12/10/92	06:00	29.66	79.79	69.92	78.92	76.08	224.92	3,230	0.070%
12/10/92	23:00	27.88	86.73	66.92	73.92	75.67	216.50	3,743	0.058%
12/10/92	00:00	27.03	77.33	69.92	70.25	72.00	212.17	3,400	0.062%
12/11/92	01:00	29.08	75.88	74.92	75.92	79.42	230.25	3,331	0.069%
12/11/92	02:00	31.18	76.84	80.17	82.67	85.33	248.17	3,030	0.082%
12/11/92	03:00	29.73	77.36	74.83	78.67	80.25	233.75	3,300	0.071%
12/11/92	04:00	30.35	76.59	77.08	80.25	83.00	240.33	2,632	0.091%
12/11/92	05:00	29.34	79.49	74.92	76.92	76.83	228.67	2,717	0.084%
12/11/92	06:00	27.67	83.21	70.33	70.42	68.58	200.50	3,109	0.064%
01/15/93	23:00	25.52	59.03	63.67	68.00	68.83	200.50	3,792	0.053%
01/16/93	23:00	26.93	65.83	70.25	70.67	75.25	216.17	3,842	0.056%
01/16/93	00:00	26.85	68.48	66.25	71.25	75.75	213.25	3,737	0.057%
01/17/93	01:00	26.73	71.68	64.33	71.33	75.33	211.00	2,854	0.074%
01/17/93	02:00	27.31	72.01	66.75	73.58	75.50	215.83	2,902	0.074%
01/17/93	04:00	26.07	72.82	61.83	69.17	71.75	202.75	2,599	0.078%
01/17/93	05:00	26.42	70.15	64.00	69.92	73.42	207.33	2,410	0.086%
01/17/93	06:00	28.08	68.16	69.58	74.67	77.17	221.42	2,502	0.088%

APPENDIX IX

SYSTEMS ECONOMICS FOR PUMPING WATER AT ALEALOA, MAUI

SYSTEMS ECONOMICS FOR PUMPING WATER AT ALEALOA, MAUI

It is the intent of the Molokai wind/diesel to establish a rate schedule for the DWS that supplies the utility service reliability while offering a true savings to the DWS over a long term. The wind/diesel also will maximize a renewable energy resource first offering a long-term alternative to fossil fuel dependence for pumping water while maximizing real dollars savings to the DWS customers.

An economic and performance model was created for the wind/diesel project. Actual performance of the wind/diesel system and the Alealoa Pump "B" power requirements were incorporated into the performance. Noting 98.3% availability and the 35% capacity factor, an accurate performance record is established. The diesel availability and fuel consumption are also reflected in the model. The model allows the addition of V17 wind turbines mirroring the three existing turbines' actual production.

The Alealoa Pump "B" is rated at 225 H.P. Demand is 185 kW, requiring a 225 kW diesel generator for start up and continuous operation. A 3,000-gallon fuel tank will allow long- term continuous operation during no wind periods, approximately 150 hours at 9 kWh/gal.

The performance summary includes weekly wind energy and backup diesel production. When demand is met by the wind and excess power is being produced, that excess shows up as sale power. Fuel used is a function of diesel requirements. Various pricing assumptions can be utilized until an optimum project is economically acceptable.

In the case of the Alealoa Pump "B", six V17's were used along with the 225 kW diesel.

Table IX-1: PERFORMANCE ASSUMPTIONS

```
 ame:                 Alealoa  Pumps
Run:                  Three
Comments:             Pump "B"
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PERFORMANCE ASSUMPTIONS
=======================

----------------- Site Information -------------------------

Yearly Average Air Density .................   1.184 kg/m^3
Day Time Vertical Shear Exponent ...........   0.146
Night Time Vertical Shear Exponent .........   0.146
Measured Wind Speed Height .................      80 ft.

Pumping Rate       .........................     700 gpm
Pumping Demand .............................     185 kW
Water Storage Capacity .....................  100,000 gal.
Inital   Storage Level .....................    5,000 gal.

----------------- Diesel Generator Information -------------

Number of Diesels (1 or 2) .................       1
Single or Largest Diesel Type (1 to 5)......       2
Smallest Diesel Type (1 to 5)..............        0
Minimum Run Time for Large or Single Diesel.      60 min.
 inimum Run Time for Small Diesel..........        0 min.

DIESEL TYPES:
  Cummins Generator Sets / G-Drive
--------------------------------------------------------------
| 1 = 6BT5.9 G/GC-1 (73 kW)    2 = NT-855 G/GC-3 (225 kW)    |
| 3 = NTA-855 G/GC-1 (250 kW) 4 = NTTA-855 G/GC-2 (315 kW)   |
--------------------------------------------------------------
           5 =   Not Listed   Generator Set

Rated Diesel Power for Not Listed ..........        0 kW
Fuel Consumption for Not Listed ............      0.0 gal/hr
```

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CASH FLOW STATEMENT [,000]   Alealoa "B"   Run: one   Page One

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
REVENUE												
Energy Production (MWh)	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8
Excess Generation (MWh)	434.5	434.5	434.5	434.5	434.5	434.5	434.5	434.5	434.5	434.5	434.5	434.5
Power Rate (mls/kWh)	95.0	98.8	102.8	106.9	111.1	115.6	120.2	125.0	130.0	135.2	140.6	146.2
Excess Pwr. Rate (mls/kW	50.3	52.8	55.5	58.2	61.1	64.2	67.4	70.8	74.3	78.0	81.9	86.0
Gross Revenue	204.3	212.7	221.5	230.6	240.0	249.9	260.2	270.9	282.0	293.6	305.7	318.3
Interest on Reserve	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Reserve Fund Credit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL REVENUE	204.8	213.2	221.9	231.0	240.5	250.4	260.6	271.3	282.5	294.1	306.2	318.7
EXPENSE												
Outstanding Principle	811.4	769.9	724.9	676.0	623.0	565.5	503.1	435.4	361.9	282.2	195.7	101.8
Interest Payment	69.0	65.4	61.6	57.5	53.0	48.1	42.8	37.0	30.8	24.0	16.6	8.7
Principle Payment	41.5	45.0	48.9	53.0	57.5	62.4	67.7	73.5	79.7	86.5	93.8	101.8
Debt Service	110.5	110.5	110.5	110.5	110.5	110.5	110.5	110.5	110.5	110.5	110.5	110.5
Management Fee	10.2	10.6	11.1	11.5	12.0	12.5	13.0	13.5	14.1	14.7	15.3	15.9
Insurance Cost	12.6	13.1	13.6	14.2	14.7	15.3	15.9	16.6	17.2	17.9	18.6	19.4
Property Taxes	5.2	5.5	5.7	5.9	6.1	6.4	6.6	6.9	7.2	7.5	7.8	8.1
Fuel Cost	28.8	30.5	32.4	34.3	36.4	38.5	40.9	43.3	45.9	48.7	51.6	54.7
O & M	17.8	18.6	19.3	20.1	20.9	21.7	22.6	23.5	24.4	25.4	26.4	27.5
Rent (% Gross Rev.)	6.1	6.4	6.6	6.9	7.2	7.5	15.6	16.3	16.9	17.6	18.3	19.1
TOTAL EXPENSES	191.3	195.1	199.2	203.4	207.8	212.4	225.1	230.5	236.2	242.2	248.5	255.1
CASH FLOW	13.5	18.0	22.8	27.6	32.7	37.9	35.5	40.8	46.2	51.8	57.7	63.6
Rent (% of Net Rev.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure IX-1: 20-YEAR MODEL CASH FLOW FOR ALEALOHA PUMPS

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2007	2008	2009	2010	2011	2012	2013	2014
1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8
434.5	434.5	434.5	434.5	434.5	434.5	434.5	434.5
152.1	158.2	164.5	171.1	177.9	185.1	192.5	200.2
90.3	94.8	99.6	104.6	109.8	115.3	121.1	127.1
331.4	345.0	359.3	374.1	389.5	405.5	422.3	439.7
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
341.4	345.0	359.3	374.1	389.5	405.5	422.3	439.7
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.6	17.3	18.0	18.7	19.5	20.3	21.1	22.0
20.2	21.0	21.8	22.7	23.6	24.5	25.5	26.5
8.4	8.7	9.1	9.5	9.8	10.2	10.6	11.1
58.0	61.4	65.1	69.0	73.2	77.6	82.2	87.1
28.6	29.7	30.9	32.1	33.4	34.8	36.1	37.6
19.9	20.7	21.6	22.4	23.4	24.3	25.3	26.4
151.5	158.8	166.4	174.4	182.8	191.7	200.9	210.7
189.9	186.2	192.8	199.6	206.6	213.9	221.3	229.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure IX-1: 20-YEAR MODEL CASH FLOW FOR ALEALOHA PUMPS (continued)

189.9	186.2	192.8	199.6	206.6	213.9	221.3	229.0
======	======	======	======	======	======	======	======
64.3	67.4	70.7	74.1	77.6	81.4	85.3	89.5
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
2007	2008	2009	2010	2011	2012	2013	2014
341.4	345.0	359.3	374.1	389.5	405.5	422.3	439.7
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.2	21.0	21.8	22.7	23.6	24.5	25.5	26.5
8.4	8.7	9.1	9.5	9.8	10.2	10.6	11.1
58.0	61.4	65.1	69.0	73.2	77.6	82.2	87.1
16.6	17.3	18.0	18.7	19.5	20.3	21.1	22.0
28.6	29.7	30.9	32.1	33.4	34.8	36.1	37.6
19.9	20.7	21.6	22.4	23.4	24.3	25.3	26.4
151.5	158.8	166.4	174.4	182.8	191.7	200.9	210.7
======	======	======	======	======	======	======	======
189.9	186.2	192.8	199.6	206.6	213.9	221.3	229.0
(94.9)	(93.1)	(96.4)	(99.8)	(103.3)	(106.9)	(110.7)	(114.5)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
189.9	186.2	192.8	199.6	206.6	213.9	221.3	229.0
94.9	93.1	96.4	99.8	103.3	106.9	110.7	114.5
======	======	======	======	======	======	======	======
94.9	93.1	96.4	99.8	103.3	106.9	110.7	114.5

Figure IX-1: 20-YEAR MODEL CASH FLOW FOR ALEALOHA PUMPS (continued)

CASH FLOW STATEMENT [,000]   Alealoa "B"   Run: one   Page Two

	2006	2007	2008	2009	2010	2011	2012	2013	2014
REVENUE									
Energy Production (MWh)	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8	1920.8
Excess Generation (MWh)	434.5	434.5	434.5	434.5	434.5	434.5	434.5	434.5	434.5
Power Rate (mls/kWh)	146.2	152.1	158.2	164.5	171.1	177.9	185.1	192.5	200.2
Excess Pwr. Rate (mls/kWh)	86.0	90.3	94.8	99.6	104.6	109.8	115.3	121.1	127.1
Gross Revenue	318.3	331.4	345.0	359.3	374.1	389.5	405.5	422.3	439.7
Interest on Reserve	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reserve Fund Credit	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL REVENUE	318.7	341.4	345.0	359.3	374.1	389.5	405.5	422.3	439.7
EXPENSE									
Outstanding Principle	101.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Interest Payment	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Principle Payment	101.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Debt Service	110.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Management Fee	15.9	16.6	17.3	18.0	18.7	19.5	20.3	21.1	22.0
Insurance Cost	19.4	20.2	21.0	21.8	22.7	23.6	24.5	25.5	26.5
Property Taxes	8.1	8.4	8.7	9.1	9.5	9.8	10.2	10.6	11.1
Fuel Cost	54.7	58.0	61.4	65.1	69.0	73.2	77.6	82.2	87.1
O & M	27.5	28.6	29.7	30.9	32.1	33.4	34.8	36.1	37.6
Rent (% Gross Rev.)	19.1	19.9	20.7	21.6	22.4	23.4	24.3	25.3	26.4
TOTAL EXPENSES	255.1	151.5	158.8	166.4	174.4	182.8	191.7	200.9	210.7
CASH FLOW	63.6	189.9	186.2	192.8	199.6	206.6	213.9	221.3	229.0
Rent (% of Net Rev.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure IX-1: 20-YEAR MODEL CASH FLOW FOR ALEALOHA PUMPS (continued)

NET CASH FLOW	63.6	189.9	186.2	192.8	199.6	206.6	213.9	221.3	229.0
Cost of Energy (mls/kwh)	108.3	64.3	67.4	70.7	74.1	77.6	81.4	85.3	89.5
Coverage Ratio	1.58	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

INCOME STATEMENT [,000] Alealoa "B" Run: one Page Two

	2006	2007	2008	2009	2010	2011	2012	2013	2014
TOTAL REVENUE	318.7	341.4	345.0	359.3	374.1	389.5	405.5	422.3	439.7
OPERATING EXPENSE									
Interest Payment	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Depreciation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Insurance Cost	19.4	20.2	21.0	21.8	22.7	23.6	24.5	25.5	26.5
Property Taxes	8.1	8.4	8.7	9.1	9.5	9.8	10.2	10.6	11.1
Fuel Cost	54.7	58.0	61.4	65.1	69.0	73.2	77.6	82.2	87.1
Management Fee	15.9	16.6	17.3	18.0	18.7	19.5	20.3	21.1	22.0
O & M	27.5	28.6	29.7	30.9	32.1	33.4	34.8	36.1	37.6
Rent (% Gross)	19.1	19.9	20.7	21.6	22.4	23.4	24.3	25.3	26.4
OPERATING EXPENSE	153.3	151.5	158.8	166.4	174.4	182.8	191.7	200.9	210.7
PRETAX-INCOME	165.5	189.9	186.2	192.8	199.6	206.6	213.9	221.3	229.0
Taxes Saved (pd)	(82.7)	(94.9)	(93.1)	(96.4)	(99.8)	(103.3)	(106.9)	(110.7)	(114.5)
Tax Credits	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Cash Flow	63.6	189.9	186.2	192.8	199.6	206.6	213.9	221.3	229.0
AFTER TAX BENEFITS	(19.1)	94.9	93.1	96.4	99.8	103.3	106.9	110.7	114.5
RETURN TO EQUITY AFTER TAX	(19.1)	94.9	93.1	96.4	99.8	103.3	106.9	110.7	114.5

Figure IX-1: 20-YEAR MODEL CASH FLOW FOR ALEALOHA PUMPS (continued)

APPENDIX X

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Barrel (of oil) 42 U.S. gallons, or 6 million BTUs.

DBEDT Department of Business Economic Development and Tourism.

DICS Distributed Intelligence Control System.

DLNR Department of Land and Natural Resources.

DOE Department of Energy.

Curtailment Shedding of power supplied by a QF or IPP.

False Tripping Reflects to high voltage circuit breakers designed to trip out at pre-set over and under frequency limits. Frequency excursions above or below the pre-set limit will cause false tripping and disrupt service.

Gross Availability Time the system is completely operational.

HEP Hawaii Integrated Energy Policy.

HPUC Hawaii Public Utilities Commission.

IPP Independent Power Producer.

Kilowatt (kW) One thousand watts.

Kilowatt Hour (kWh) One thousand watt hours.

KV Kilovolt

KVA Kilovolt ampere

Machine Availability Time the individual turbine is operational.

MECO Maui Electric Company.

MECO/Molokai Maui Electric Company, Molokai Division.

Megawatt (MW) One million watts.

Megawatt Hours (MWh) One million watt hours.

Net of Usage The system turbines, being induction generators, require reactive power. The computer required AC power and the room required air conditioning. This power consumed is retail metered, thus the price expressed as "average rate per kWh — net of usage" and reflects the subtraction of MECO billing kWh price, after which payment received for kWhs at the floor price is averaged with the retail cost. Thus the lower than floor price net payment. If less power is produced, this rate will go lower.

Penetration Providing power to the utility in significant amount to the point where the utility is concerned with potential system instabilities.

PURPA Public Utilities Regulatory Policies Act.

QF Qualifying Facility under PURPA.

SCADA Supervisory Control and Data Acquisition

Windrose Second-by-second data averaged hourly and plotted. Plotting represents direction of percentage wind power.

% Power As used in Table A-1, p. 66, refers to the "average yearly total power estimate" divided by the "monthly power estimate."

% Power Est(imate) = watts/square meter equation.

% Wind As used in Table A-1, p. 66, refers to the hourly average amount of time per month the winds were equal to the monthly wind speed average.